energy

[r]evolution

A SUSTAINABLE WORLD ENERGY OUTLOOK

EREC
EUROPEAN RENEWABLE
ENERGY COUNCIL

GREENPEACE

report 3rd edition 2010 world energy scenario

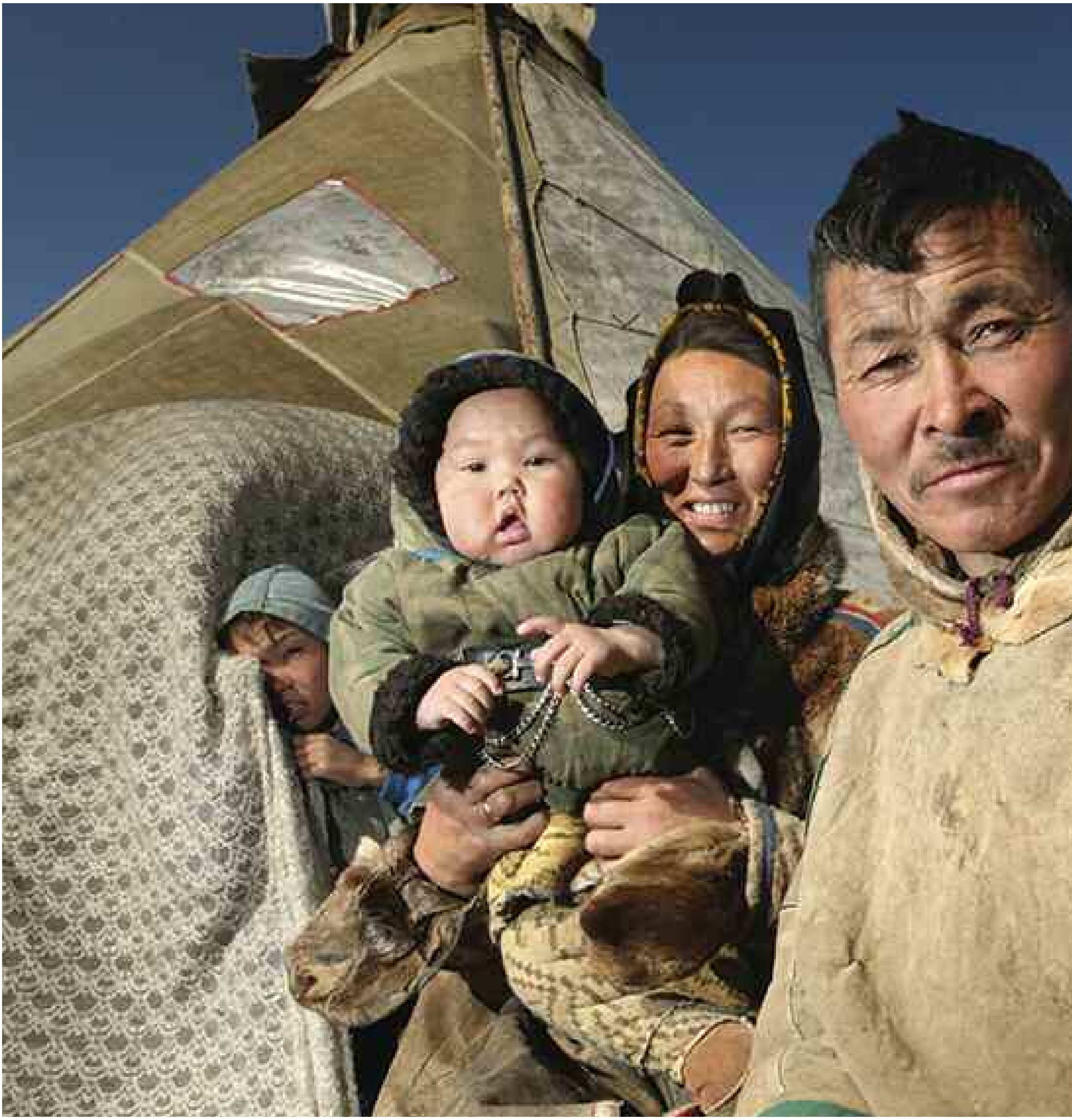

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image THE INDIGENOUS NENETS PEOPLE MOVE EVERY 3 OR 4 DAYS SO THAT THEIR REINDEER DO NOT OVER GRAZE THE GROUND AND THEY DO NOT OVER FISH THE LAKES. THE YAMAL PENINSULA IS UNDER HEAVY THREAT FROM GLOBAL WARMING AS TEMPERATURES INCREASE AND RUSSIA'S ANCIENT PERMAFROST MELTS.

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“will we look into the eyes of our children and confess

that we had the **opportunity**,
but lacked the **courage?**
that we had the **technology**,
but lacked the **vision?”**

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for further information about the global, regional and national scenarios please visit the energy [r]evolution website: **www.energyblueprint.info/**
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foreword

A global energy scenario paints a picture of our common future – the picture depicts how the future could unfold. Energy scenarios send important messages on alternative futures to decision makers in political, financial, industrial sectors as well as other stakeholders in the energy market. They paint a picture which can encourage and guide decision makers involved in shaping our energy future.

Based on assumptions, global scenarios provide information on the conditions necessary to harness existing renewable energy potential and allow for reasonable assessment of the factors of success.

If the assumptions are limited, they are likely to impede the dynamic development of renewable energy sources. Countries may not make important decisions, or decisions will be incorrect. If the assumptions are ambitious, they could encourage countries to reap the benefits that accompany the accelerated deployment of renewable energies. They can improve energy security, alleviate energy poverty and reduce carbon emissions.

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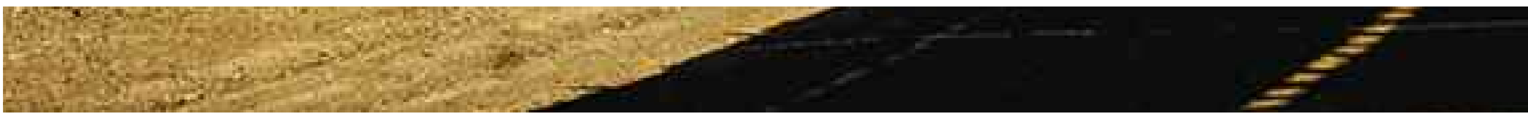

ANDASOL 1 SOLAR POWER STATION SUPPLIES UP TO 200,000 PEOPLE WITH CLIMATE-FRIENDLY ELECTRICITY AND SAVES ABOUT 149,000 TONNES OF CARBON DIOXIDE PER YEAR COMPARED WITH A MODERN COAL POWER PLANT.

It is clear that global scenarios have a critical role to play in the development of the global energy framework. To keep up with the fast paced development of renewable energy technologies, and to accurately convey current and possible future growth rates of renewable energy worldwide, global scenarios need to be kept up to date.

Due to the high relevance of energy scenarios in the global energy debate, the International Renewable Energy Agency, IRENA, will itself facilitate an open and transparent dialogue on renewable energy scenarios within the framework of its mandate. Its mandate does not include the issues of fossil or nuclear energy.

IRENA aims to ensure that assumptions about renewable energy reflect the rapid development that we can currently witness in renewable energy technologies and policies. In the long term, IRENA itself will play an active role in the development of Renewable Energy scenarios - in discussion with other organizations like the European Renewable Energy Council (EREC) and Greenpeace.

The energy [r]evolution series has become a reference publication for many over time. The third issue again displays all attributes of a good scenario: it accounts for progress in the field of technologies and policies, spells out the essential framework conditions, provides for solutions – like, in this case, a global financing model - and finally, visualizes positive benefits, like the impact of an accelerated deployment of renewable energies on the job sector.

Energy [r]evolution underlines once again the importance of renewable energy in the context of climate change mitigation. It demonstrates that renewable energies stand ready to make a significant contribution.

Hélène Pelosse
INTERIM DIRECTOR-GENERAL
IRENA - INTERNATIONAL RENEWABLE ENERGY AGENCY
JUNE 2010

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introduction

"FOR THE SAKE OF A SOUND ENVIRONMENT, POLITICAL STABILITY AND THRIVING ECONOMIES, NOW IS THE TIME TO COMMIT TO A TRULY SECURE AND SUSTAINABLE ENERGY FUTURE."

image A WORKER ENTERS A TURBINE TOWER FOR MAINTENANCE AT DABANCHENG WIND FARM. CHINA'S BEST WIND RESOURCES ARE MADE POSSIBLE BY THE NATURAL BREACH IN TIANSHAN (TIAN MOUNTAIN).

The energy debate has moved to the top of the agenda right across the social, political and economic spectrum. For governments this is because energy is the lifeblood of their economies, for scientists because of the threat of climate change to the dominance of fossil fuels, for NGOs because of the environmental and social impacts, for economists because of the business potential of a shift in the way our energy is produced, for engineers because they have the task of developing new technologies to supply and consume energy in a smarter way and last but not least for consumers as volatile energy prices have a direct impact on household budgets.

Access to sufficient energy is vital for making our economies work but at the same time one of the main sources of the greenhouse gas emissions that put our climate at risk. While the last climate change summit in Copenhagen was a failure, international negotiations to address the issue remain high on the political agenda. Highly volatile fossil fuel prices are creating more and more uncertainty for the global economy while at the same time giving an indirect incentive for investing in renewable energy technologies, which are now booming. Against that background this third edition of the Energy [R]evolution analysis takes a deep plunge into possible energy supply strategies for the future and how to develop a sustainable energy and climate policy.

Access to energy is of strategic importance for every country in the world. Over the past few years oil prices have gone up and down like a rollercoaster, jumping to a record high in July 2008 of $147.27 and then falling back again to $33.87 in December. Even so, over the whole of 2009 the average oil price was still between $60 and $80 per barrel. At the same time, with gas prices in Europe rising in line with the price of oil, the impact on both the heating and power sectors has been huge.

Security of energy supply is not only influenced by the cost of fuels, however, but by their long term physical availability. Countries without their own fossil fuel supplies have increasingly shown interest in renewable energy sources, not only because of the price stability this brings but because they are indigenous and locally produced.

Renewable energy technologies produce little or no greenhouse gases and rely on virtually inexhaustible natural elements for their 'fuel'. Some of these technologies are already competitive. The wind power industry, for example, has continued its explosive growth in the face of a global recession and a financial crisis and is a testament to the inherent attractiveness of renewable technology. In 2009 the total level of annual investment in clean energy was $145 billion, only a 6.5% drop from the record previous year, while the global wind power market grew by an annual 41.5%. The

image NORTH HOYLE WIND FARM, UK'S FIRST WIND FARM IN THE IRISH SEA WHICH WILL SUPPLY 50,000 HOMES WITH POWER.

© ANTHONY UPTON 2003

renewable energy industry now employs around two million people worldwide and has become a major feature of national industrial development plans. Meanwhile, the economics of renewables are expected to further improve as they develop technically, as the price of fossil fuels continues to rise and as their saving of carbon dioxide emissions is given a monetary value.

Despite the small drop in fossil fuel emissions in the industrialised world as a result of the economic crisis, globally the level of energy related carbon dioxide continues to grow. This means that a recovered economy will result in increasing CO_2 emissions once again, further contributing to the greenhouse gases which threaten our planet. A shift in energy policy is needed so that a growing economy and reduced CO_2 emissions can go hand in hand. The Energy [R]evolution analysis shows how this is possible.

Although the Copenhagen climate change conference at the end of 2009 was a huge disappointment, it should not lead to a feeling that nothing can happen. A change in energy policy has to be connected to a change of climate policy. The United Nations (UNFCCC) climate talks therefore still remain central to the survival of our planet and a global regime for CO_2 reduction. Placing a price on carbon, as well as a long term agreement on CO_2 reduction, are both of vital importance for the uptake of renewables and energy efficiency. A new 'fair, ambitious and legally binding' (FAB) deal will need to incorporate the existing Kyoto Protocol's architecture. This relies fundamentally on legally binding emissions reduction obligations, on common guidelines for accounting rules, on a compliance regime and on agreed carbon trading mechanisms.

energy [r]evolution 2010

This is the third edition of the global Energy [R]evolution scenario since the first one was published in January 2007, and the analysis has been constantly deepened. In the second edition we introduced specific research for the transport sector and an investigation of the pathway to future investment in renewable energies. Since than we have published country specific scenarios for over 30 countries and regions, added a study of the employment implications of the scenarios and a detailed examination of how the grid network needs to be improved and adapted.

This new edition has broken fresh ground again. The 2010 Energy [R]evolution not only includes the financial analysis and employment calculations in parallel with the basic projections, we have also added a second, more ambitious Energy [R]evolution scenario. This was considered vital because rapid improvements in climate science made it clear during 2009 that a global 50% reduction in energy related CO_2 emissions by 2050 might not be enough to keep the global mean temperature rise below +2°C. An even greater reduction is needed if runaway climate change is to be avoided.

The advanced Energy [R]evolution scenario has changed five parameters compared to the basic version. These mean that the economic lifetime of coal power stations has been reduced from 40 to 20 years, the growth rate of renewables has taken the advanced projections of the renewable industry into account, the use of electric drives in the transport sector will take off ten years earlier, the expansion of smart grids will happen quicker, and last but not least, the expansion of fossil fuel based energy will stop after 2015.

A drastic reduction in CO_2 levels and a share of over 80% renewables in the world energy supply are both possible goals by 2050. Of course this will be a technical challenge, but the main obstacle is political. We need to kick start the Energy [R]evolution with long lasting reliable policy decisions within the next few years. It took more than a decade to make politicians aware of the climate crisis; we do not have another decade to agree on the changes needed in the energy sector. Greenpeace and the renewables industry present the Energy [R]evolution scenario as a practical but ambitious blueprint. For the sake of a sound environment, political stability and thriving economies, now is the time to commit to a truly secure and sustainable energy future – a future built on energy efficiency and renewable energy, economic development and the creation of millions of new jobs for the next generation.

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SECRETARY GENERAL
EUROPEAN RENEWABLE
ENERGY COUNCIL (EREC)
JUNE 2010

Sven Teske
CLIMATE & ENERGY UNIT
GREENPEACE INTERNATIONAL

executive summary

"AT THE CORE OF THE ENERGY [R]EVOLUTION WILL BE A CHANGE IN THE WAY THAT ENERGY IS PRODUCED, DISTRIBUTED AND CONSUMED."

image THE PS10 CONCENTRATING SOLAR THERMAL POWER PLANT IN SEVILLA, SPAIN. THE 11 MEGAWATT SOLAR POWER TOWER PRODUCES ELECTRICITY WITH 624 LARGE MOVABLE MIRRORS CALLED HELIOSTATS. THE SOLAR RADIATION, MIRROR DESIGN PLANT IS CAPABLE OF PRODUCING 23 GWH OF ELECTRICITY WHICH IS ENOUGH TO SUPPLY POWER TO A POPULATION OF 10,000.

This third edition of the Energy [R]evolution is even more ambitious and visionary than the previous two editions. The report demonstrates how the world can get from where we are now, to where we need to be in terms of phasing out fossil fuels, cutting CO_2 while ensuring energy security. This phase-out of fossil fuels offers substantial benefits such as independence from world market fossil fuel prices as well as the creation of millions of new green jobs. It also means providing energy to the two billion people currently without power. Our future and the future of the planet is rooted in the investment in people and local communities in terms of installing and maintaining renewable energy sources, rather than further subsidising the dirty fossil fuels which are inherently finite. The following executive summary outlines in brief a practical blueprint of how to make this a reality.

environmental challenge:

The threat of climate change, caused by rising global temperatures, is the most significant environmental challenge facing the world at the beginning of the 21st century. It has major implications for the world's social and economic stability, its natural resources and in particular, the way we produce our energy.

The Copenhagen Accord, agreed at the climate change summit in December 2009, has the stated aim of keeping the increase in global temperatures to below 2°C, and then considering a 1.5°C limit by 2015. However, the national emissions reduction pledges submitted by various countries to the United Nations coordinating body, the UNFCCC, in the first half of 2010 are likely to lead to a world with global emissions of between 47.9 and 53.6 gigatonnes of carbon dioxide equivalents per year by 2020. This is about 10–20% higher than today's levels. In the worst case, the Copenhagen Accord pledges could even permit emission allowances to exceed a 'business as usual' projection.[1]

In order to avoid the most catastrophic impacts of climate change, the global temperature increase must be kept as far below 2°C as possible. This is still possible, but time is running out. To stay within this limit, global greenhouse gas emissions will need to peak by 2015 and decline rapidly after that, reaching as close to zero as possible by the middle of the 21st century.

a safe level of warming?

Keeping the global temperature increase to 2°C is often referred to as a 'safe level' of warming, but this does not reflect the reality of the latest science. This shows that a warming of 2°C above pre-industrial levels would pose unacceptable risks to many of the world's key natural and human systems.[2] Even with a 1.5°C warming, increases in

references
1 COPENHAGEN ACCORD PLEDGES ARE PALTRY-JOERI ROGELJ, MALTE MEINSHAUSEN, APRIL 2010.
2 W. L. HARE. A SAFE LANDING FOR THE CLIMATE. STATE OF THE WORLD. WORLDWATCH INSTITUTE. 2009.

image WELDER WORKING AT VESTAS WIND TURBINE FACTORY, CAMPBELLTOWN, SCOTLAND.


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drought, heatwaves and floods, along with other adverse impacts such as increased water stress for up to 1.7 billion people, wildfire frequency and flood risks, are projected in many regions. Neither does staying below 2°C rule out large scale disasters such as melting ice sheets. Partial de-glaciation of the Greenland ice sheet, and possibly the West Antarctic ice sheet, could even occur from additional warming within a range of 0.8 – 3.8°C above current levels.[3] If rising temperatures are to be kept within acceptable limits then we need to significantly reduce our greenhouse gas emissions. This makes both environmental and economic sense. The main greenhouse gas is carbon dioxide (CO_2) produced by using fossil fuels for energy and transport.

climate change and security of supply

Spurred by recent rapidly fluctuating oil prices, the issue of security of supply – both in terms of access to supplies and financial stability - is now at the top of the energy policy agenda. One reason for these price fluctuations is the fact that supplies of all proven resources of fossil fuels – oil, gas and coal – are becoming scarcer and more expensive to produce. So-called 'non-conventional' resources such as shale oil have even in some cases become economic, with devastating consequences for the local environment. What is certain is that the days of 'cheap oil and gas' are coming to an end. Uranium, the fuel for nuclear power, is also a finite resource. By contrast, the reserves of renewable energy that are technically accessible globally are large enough to provide about six times more power than the world currently consumes - forever.

Renewable energy technologies vary widely in their technical and economic maturity, but there are a range of sources which offer increasingly attractive options. These include wind, biomass, photovoltaics, solar thermal, geothermal, ocean and hydroelectric power. Their common feature is that they produce little or no greenhouse gases, and rely on virtually inexhaustible natural elements for their 'fuel'. Some of these technologies are already competitive. The wind power industry, for example, continued its explosive growth in the face of a global recession and a financial crisis in 2008 and 2009 and is a testament to the inherent attractiveness of renewable technology.

Last year (2009) Bloomberg New Energy Finance reported the total level of annual investment in clean energy as $145 billion, only a 6.5% drop from the record previous year. The global wind industry defied the economic downturn and saw its annual market grow by 41.5% over 2008, and total global wind power capacity increase by 31.7% to 158 GW at the end of 2009.[4] More grid-connected solar PV capacity was added worldwide than in the boom year of 2008. And the economics of renewables will further improve as they develop technically, as the price of fossil fuels continues to rise and as their saving of carbon dioxide emissions is given a monetary value.

At the same time there is enormous potential for reducing our consumption of energy, and still continuing to provide the same level of energy services. This study details a series of energy efficiency measures which together can substantially reduce demand across industry, homes, business and services.

Against these positive attractions, nuclear energy is a relatively minor industry with major problems. The average age of operating commercial nuclear reactors is 23 years, so more power stations are being shut down than started. In 2008, world nuclear production fell by 2% compared to 2006, and the number of operating reactors as of January 2010 was 436, eight less than at the historical peak of 2002. Although nuclear power produces little carbon dioxide, there are multiple threats to people and the environment from its operations. These include the risks and environmental damage from uranium mining, processing and transport, the risk of nuclear weapons proliferation, the unsolved problem of nuclear waste and the potential hazard of a serious accident. The nuclear option is therefore discounted in this analysis.

the energy [r]evolution

The climate change imperative demands nothing short of an energy revolution, a transformation that has already started as renewable energy markets continue to grow. In the first global edition of the Energy [R]evolution, published in January 2007, we projected a global installed renewable capacity of 156 GW by 2010. At the end of 2009, 158 GW has been installed. More needs to be done, however. At the core of this revolution will be a change in the way that energy is produced, distributed and consumed.

the five key principles behind this shift will be to:

- Implement renewable solutions, especially through decentralised energy systems
- Respect the natural limits of the environment
- Phase out dirty, unsustainable energy sources
- Create greater equity in the use of resources
- Decouple economic growth from the consumption of fossil fuels

Decentralised energy systems, where power and heat are produced close to the point of final use, will avoid the current waste of energy during conversion and distribution. Investments in 'climate infrastructure' such as smart interactive grids, as well as super grids to transport large quantities of offshore wind and concentrating solar power, are essential. Building up clusters of renewable micro grids, especially for people living in remote areas, will be a central tool in providing sustainable electricity to the almost two billion people around the world for whom access to electricity is presently denied.

greenhouse development rights

But although the Energy [R]evolution envisages a clear technological pathway, it is only likely to be turned into reality if its corresponding investment costs are shared fairly under some kind of global climate regime. To demonstrate one such possibility, we have utilised the Greenhouse Development Rights framework, designed by EcoEquity and the Stockholm Environment Institute, as a way of evening up the unequal ability of different countries to respond to the climate crisis in their energy polices.

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3 JOEL B. SMITH, STEPHEN H. SCHNEIDER, MICHAEL OPPENHEIMER, GARY W. YOHE, WILLIAM HARE, MICHAEL D. MASTRANDREA, ANAND PATWARDHAN, IAN BURTON, JAN CORFEE-MORLOT, CHRIS H. D. MAGADZA, HANS-MARTIN FÜSSEL, A. BARRIE PITTOCK, ATIQ RAHMAN, AVELINO SUAREZ, AND JEAN-PASCAL VAN YPERSELE: ASSESSING DANGEROUS CLIMATE CHANGE THROUGH AN UPDATE OF THE INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE (IPCC) "REASONS FOR CONCERN". PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES. PUBLISHED ONLINE BEFORE PRINT FEBRUARY 26, 2009, DOI: 10.1073/PNAS.0812355106. THE ARTICLE IS FREELY AVAILABLE AT: HTTP://WWW.PNAS.ORG/CONTENT/EARLY/2009/02/25/0812355106.FULL.PDF A COPY OF THE GRAPH CAN BE FOUND ON APPENDIX 1.
4 GLOBAL WIND 2009 REPORT, GWEC, MARCH 2010, S. SAWYER, A. ZERVOS.

"The long term scenario has been developed further towards a complete phasing out of fossil fuels in the second half of this century."

The Greenhouse Development Rights (GDR) framework calculates national shares of global greenhouse gas obligations based on a combination of responsibility (contribution to climate change) and capacity (ability to pay). Crucially, GDRs take inequality within countries into account and calculate national obligations on the basis of the estimated capacity and responsibility of individuals. Individuals with incomes below a 'development threshold' – specified in the default case as $7,500 per capita annual income, PPP adjusted – are exempted from climate-related obligations. Individuals with incomes above that level are expected to contribute to the costs of global climate policy in proportion to their capacity (amount of income over the threshold) and responsibility (cumulative CO_2 emissions).

The result of these calculations is that rich countries like the United States of America, which are also responsible for a large proportion of global greenhouse gas emissions, will contribute much more towards the costs of implementing global climate policies, such as increasing the proportion of renewables, than a country like India. Based on a 'Responsibility and Capacity Indicator', the USA, accounting for 36.8% of the world's responsibility for climate change, will in turn be responsible for funding 36.3% of the required global emissions reductions.

The GDR framework therefore represents a good mechanism for helping developing countries to leapfrog into a sustainable energy supply, with the help of industrialised countries, while maintaining economic growth and the need to satisfy their growing energy needs. Greenpeace has taken this concept on board as a means of achieving equity within the climate debate and as a practical solution to kick-starting the renewable energy market in developing countries.

methodology and assumptions

Three scenarios up to the year 2050 are outlined in this report: a Reference scenario, an Energy [R]evolution scenario with a target to reduce energy related CO_2 emissions by 50%, from their 1990 levels, and an advanced Energy [R]evolution version which envisages a fall of more than 80% in CO_2 by 2050.

The **Reference Scenario** is based on the reference scenario in the International Energy Agency's 2009 World Energy Outlook (WEO 2009) analysis, extrapolated forward from 2030. Compared to the previous (2007) IEA projections, WEO 2009 assumes a slightly lower average annual growth rate of world Gross Domestic Product (GDP) of 3.1%, instead of 3.6%, over the period 2007-2030. At the same time, it expects final energy consumption in 2030 to be 6% lower than in the WEO 2007 report. China and India are expected to grow faster than other regions, followed by the Other Developing Asia group of countries, Africa and the Transition Economies (mainly the former Soviet Union). The OECD share of global purchasing power parity (PPP) adjusted GDP will decrease from 55% in 2007 to 29% by 2050.

The **Energy [R]evolution Scenario** has a key target for the reduction of worldwide carbon dioxide emissions down to a level of around 10 Gigatonnes per year by 2050. A second objective is the global phasing out of nuclear energy. To achieve these goals the scenario is characterised by significant efforts to fully exploit the large potential for energy efficiency. At the same time, all cost-effective renewable energy sources are used for heat and electricity generation, as well as the production of bio fuels. The general framework parameters for population and GDP growth remain unchanged from the Reference scenario.

The **Advanced Energy [R]evolution Scenario** takes a much more radical approach to the climate crisis facing the world. In order to pull the emergency brake on global emissions it therefore assumes much shorter technical lifetimes for coal-fired power plants - 20 years instead of 40 years. This reduces global CO_2 emissions even faster and takes the latest evidence of greater climate sensitivity into account. To fill the resulting gap, the annual growth rates of renewable energy sources, especially solar photovoltaics, wind and concentrating solar power plants, have therefore been increased.

Apart from that, the advanced scenario takes on board all the general framework parameters of population and economic growth from the basic version, as well as most of the energy efficiency roadmap. In the transport sector, however, there is 15 to 20% lower final energy demand until 2050 due to a combination of simply less driving and instead increase use of public transport and a faster uptake of efficient combustion vehicles and – after 2025 – a larger share of electric vehicles.

Within the heating sector there is a faster expansion of CHP in the industry sector, more electricity for process heat and a faster growth of solar and geothermal heating systems. Combined with a larger share of electric drives in the transport sector, this results in a higher overall demand for power. Even so, the overall global electricity demand in the advanced Energy [R]evolution scenario is still lower than in the Reference scenario.

In the advanced scenario the latest market development projections of the renewable industry[5] have been calculated for all sectors (see Chapter 5, Table 5.13: Annual growth rates of renewable energy technologies). The speedier uptake of electric and hydrogen vehicles, combined with the faster implementation of smart grids and expanding super grids (about ten years ahead of the basic version) allows a higher share of fluctuating renewable power generation (photovoltaic and wind). The threshold of a 40% proportion of renewables in global primary energy supply is therefore passed just after 2030 (also ten years ahead). By contrast, the quantity of biomass and large hydro power remain the same in both Energy [R]evolution scenarios, for sustainability reasons.

towards a renewable future

Today, renewable energy sources account for 13% of the world's primary energy demand. Biomass, which is mostly used in the heat sector, is the main source. The share of renewable energies for electricity generation is 18%, while their contribution to heat supply is around 24%, to a large extent accounted for by traditional uses such as collected firewood. About 80% of the primary energy supply today still comes from fossil fuels. Both Energy [R]evolution scenarios describe development pathways which turn the present situation into a sustainable energy supply, with the advanced version achieving the urgently needed CO_2 reduction target more than a decade earlier than the basic scenario.

The following summary shows the results of the advanced Energy [R]evolution scenario, which will be achieved through the following measures:

- Exploitation of existing large energy efficiency potentials will ensure that final energy demand increases only slightly - from the current 305,095 PJ/a (2007) to 340,933 PJ/a in 2050, compared to 531,485 PJ/a in the Reference scenario.

references
5 SEE EREC, RE-THINKING 2050, GWEC, EPIA *ET AL.*

image THOUSANDS OF FISH DIE AT THE DRY RIVER BED OF MANAQUIRI LAKE, 150 KILOMETERS FROM AMAZONAS STATE CAPITOL MANAUS, BRAZIL.

This dramatic reduction is a crucial prerequisite for achieving a significant share of renewable energy sources in the overall energy supply system, compensating for the phasing out of nuclear energy and reducing the consumption of fossil fuels.

- More electric drives are used in the transport sector and hydrogen produced by electrolysis from excess renewable electricity plays a much bigger role in the advanced than in the basic scenario. After 2020, the final energy share of electric vehicles on the road increases to 4% and by 2050 to over 50%. More public transport systems also use electricity, as well as there being a greater shift in transporting freight from road to rail.
- The increased use of combined heat and power generation (CHP) also improves the supply system's energy conversion efficiency, increasingly using natural gas and biomass. In the long term, the decreasing demand for heat and the large potential for producing heat directly from renewable energy sources limits the further expansion of CHP.
- The electricity sector will be the pioneer of renewable energy utilisation. By 2050, around 95% of electricity will be produced from renewable sources. A capacity of 14,045 GW will produce 43,922 TWh/a renewable electricity in 2050. A significant share of the fluctuating power generation from wind and solar photovoltaic will be used to supply electricity to vehicle batteries and produce hydrogen as a secondary fuel in transport and industry. By using load management strategies, excess electricity generation will be reduced and more balancing power made available.
- In the heat supply sector, the contribution of renewables will increase to 91% by 2050. Fossil fuels will be increasingly replaced by more efficient modern technologies, in particular biomass, solar collectors and geothermal. Geothermal heat pumps and, in the world's sunbelt regions, concentrating solar power, will play a growing part in industrial heat production.
- In the transport sector the existing large efficiency potentials will be exploited by a modal shift from road to rail and by using much lighter and smaller vehicles. As biomass is mainly committed to stationary applications, the production of bio fuels is limited by the availability of sustainable raw materials. Electric vehicles, powered by renewable energy sources, will play an increasingly important role from 2020 onwards.
- By 2050, 80% of primary energy demand will be covered by renewable energy sources.

To achieve an economically attractive growth of renewable energy sources, a balanced and timely mobilisation of all technologies is of great importance. Such mobilisation depends on technical potentials, actual costs, cost reduction potentials and technical maturity. Climate infrastructure, such as district heating systems, smart grids and supergrids for renewable power generation, as well as more R&D into storage technologies for electricity, are all vital if this scenario is to be turned into reality. The successful implementation of smart grids is vital for the advanced Energy [R]evolution from 2020 onwards.

It is also important to highlight that in the advanced Energy [R]evolution scenario the majority of remaining coal power plants – which will be replaced 20 years before the end of their technical lifetime – are in China and India. This means that in practice all coal power plants built between 2005 and 2020 will be replaced by renewable energy sources from 2040 onwards. To support the building of capacity in developing countries significant new public financing, especially from industrialised countries, will be needed. It is vital that specific funding mechanisms such as the "Greenhouse Development Rights" (GDR) and "Feed-in tariff" schemes (see chapter 2) are developed under the international climate negotiations that can assist the transfer of financial support to climate change mitigation, including technology transfer.

future costs

Renewable energy will initially cost more to implement than existing fuels. The slightly higher electricity generation costs under the advanced Energy [R]evolution scenario will be compensated for, however, by reduced demand for fuels in other sectors such as heating and transport. Assuming average costs of 3 cents/kWh for implementing energy efficiency measures, the additional cost for electricity supply under the advanced Energy [R]evolution scenario will amount to a maximum of $31 billion/a in 2020. These additional costs, which represent society's investment in an environmentally benign, safe and economic energy supply, continue to decrease after 2020. By 2050 the annual costs of electricity supply will be $2,700 billion/a below those in the Reference scenario.

It is assumed that average crude oil prices will increase from $97 per barrel in 2008 to $130 per barrel in 2020, and continue to rise to $150 per barrel in 2050. Natural gas import prices are expected to increase by a factor of four between 2008 and 2050, while coal prices will continue to rise, reaching $172 per tonne in 2050. A CO_2 'price adder' is applied, which rises from $20 per tonne of CO_2 in 2020 to $50 per tonne in 2050.

future investment

It would require until 2030 $17.9 trillion in global investment for the advanced Energy [R]evolution scenario to become reality - approximately 60% higher than in the Reference scenario ($11.2 trillion). Under the Reference version, the levels of investment in renewable energy and fossil fuels are almost equal - about $5 trillion each - up to 2030. Under the advanced scenario, however, the world shifts about 80% of investment towards renewables; by 2030 the fossil fuel share of power sector investment would be focused mainly on combined heat and power and efficient gas-fired power plants. The average annual investment in the power sector under the advanced Energy [R]evolution scenario between 2007 and 2030 would be approximately $782 billion.

Because renewable energy has no fuel costs, however, the fuel cost savings in the advanced Energy [R]evolution scenario reach a total of $6.5 trillion, or $282 billion per year until 2030 and a total of $41.5 trillion, or an average of $964 billion per year until 2050.

"Worldwide we would see more direct jobs created in the energy sector if we shift to either of the Energy [R]evolution scenarios than if we continue business as usual."

future global employment

Worldwide, we would see more direct jobs created in the energy sector if we shifted to either of the Energy [R]evolution scenarios.

- By 2015 global power supply sector jobs in the Energy [R]evolution scenario are estimated to reach about 11.1 million, 3.1 million more than in the Reference scenario. The advanced version will lead to 12.5 million jobs by 2015.
- By 2020 over 6.5 million jobs in the renewables sector would be created due a much faster uptake of renewables, three-times more than today. The advanced version will lead to about one million jobs more than the basic Energy [R]evolution, due a much faster uptake of renewables.
- By 2030 the Energy [R]evolution scenario achieves about 10.6 million jobs, about two million more than the Reference scenario. Approximately 2 million new jobs are created between 2020 and 2030, twice as much as in the Reference case. The advanced scenario will lead to 12 million jobs, that is 8.5 million in the renewables sector alone. Without this fast growth in the renewable sector global power jobs will be a mere 2.4 million. Thus by implementing the E[R] there will be 3.2 million or over 33% more jobs by 2030 in the global power supply sector.

development of CO_2 emissions

While CO_2 emissions worldwide will increase by more than 60% under the Reference scenario up to 2050, and are thus far removed from a sustainable development path, under the advanced Energy [R]evolution scenario they will decrease from 28,400 million tonnes in 2007 (including international bunkers) to 3,700 in 2050, 82% below 1990 levels. Annual per capita emissions will drop from 4.1 tonnes/capita to 0.4 t/capita. In spite of the phasing out of nuclear energy and a growing electricity demand, CO_2 emissions will decrease enormously in the electricity sector. In the long run efficiency gains and the increased use of renewable electric vehicles, as well as a sharp expansion in public transport, will even reduce CO_2 emissions in the transport sector. With a share of 42% of total emissions in 2050, the transport sector will reduce significantly but remain the largest source of CO_2 emissions - followed by industry and power generation.

policy changes

To make the Energy [R]evolution real and to avoid dangerous climate change, Greenpeace and EREC demand that the following policies and actions are implemented in the energy sector:

1. Phase out all subsidies for fossil fuels and nuclear energy.
2. Internalise the external (social and environmental) costs of energy production through 'cap and trade' emissions trading.
3. Mandate strict efficiency standards for all energy consuming appliances, buildings and vehicles.
4. Establish legally binding targets for renewable energy and combined heat and power generation.
5. Reform the electricity markets by guaranteeing priority access to the grid for renewable power generators.
6. Provide defined and stable returns for investors, for example by feed-in tariff programmes.
7. Implement better labelling and disclosure mechanisms to provide more environmental product information.
8. Increase research and development budgets for renewable energy and energy efficiency.

figure 0.1: global: development of primary energy consumption under the three scenarios

('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)

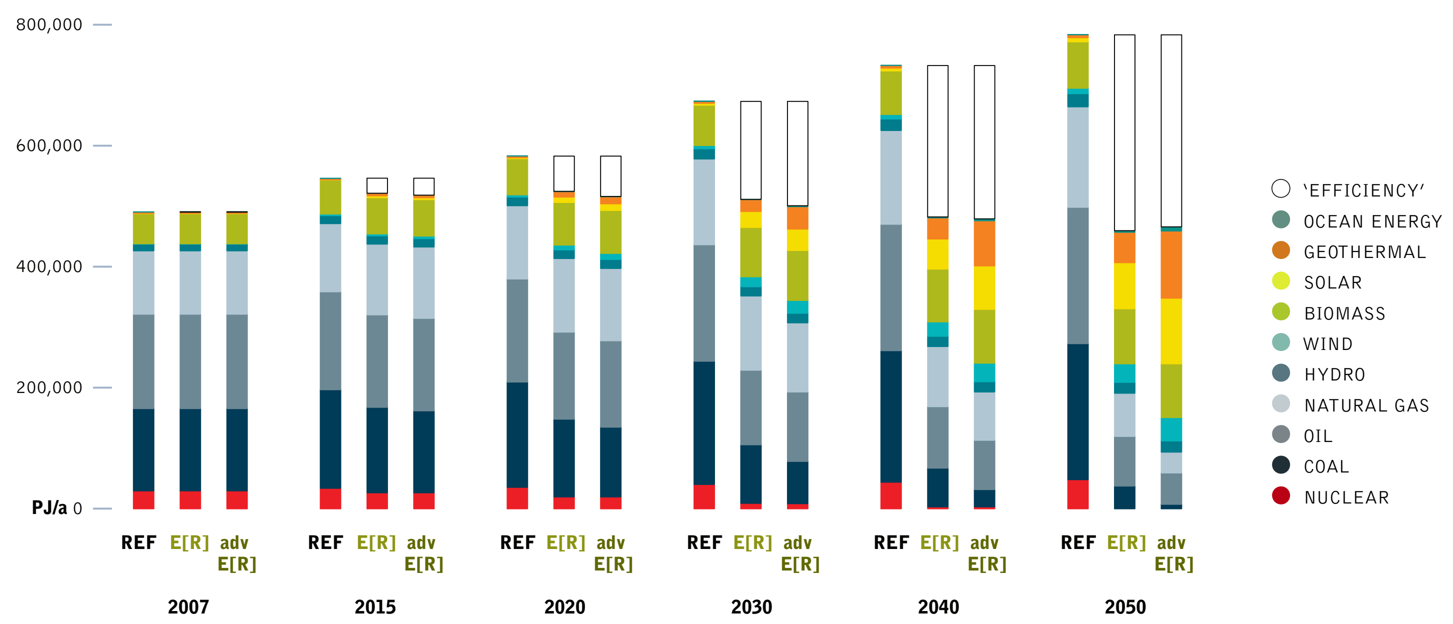

image CONSTRUCTION OF THE OFFSHORE WINDFARM AT MIDDELGRUNDEN NEAR COPENHAGEN, DENMARK.

table 0.1: energy [r]evolution: summary for policy makers

	POLICY	WHO	2010	2015	2020	2025	2030	2035	2040	2045	2050
	Climate										
targets	• Peak global temperature rise well below 2°C	UNFCCC									
	• Reduce ghg emissions by 40% by 2020 (as compared to 1990) in developed countries	UNFCCC									
	• Reduce ghg emissions by 15 to 30% of projected growth by 2020 in developing countries	UNFCCC									
	• Achieve zero deforestation globally by 2020	UNFCCC									
	• Agree a legally binding global climate deal as soon as possible	UNFCCC									
	Energy										
targets	• EU27: binding target of at least 20% renewable energy in primary energy consumption by 2020	EU									
	• G8: min 20% renewable energy by 2020	G8									
	• No new construction permits for new coal power plants in Annex 1 countries by 2012	G8									
	• Priority access to the grid for renewables	G8									
	• Establish efficiency targets and strict standards for electric applications	National Governments									
	• Strict efficiency target for vehicles: 80g CO_2/km by 2020	National Governments									
	• Build regulations with mandatory renewable energy shares (e.g. solar collectors)	National Governments									
	• Co-generation law for industry and district heating support program	National Governments									
	Finance										
mechanisms	• Phase-out subsidies for fossil and nuclear fuels	G20									
	• Put in place a Climate Fund under the auspices of the UNFCCC	UNFCCC									
	• Provide at least 140 billion USD/year to the Climate Fund by 2020	UNFCCC									
	• Ensure priority acces to the fund for vulnerable countries and communities	UNFCCC									
	• Establish feed-in law for renewable power generation in Annex 1 countries	National Governments									
	• Establish feed-in law with funding from Annex 1 countries for dev. countries	G8 + G77									
	ENERGY [R]EVOLUTION RESULTS										
	Renewables & Supply										
power	Global Renewable Power Generation										
	• Shares (max = adv. ER - Min = ER): **30%** / **50%** / **75%** / over **90%**	Utilities & RE Industry									
	• Implementation of Smart Grids (**Policy**/**Planning**/**Construction**)	National Governments									
	• Smart Grids interconnection to Super Grids (**Policy**/**Planning**/**Construction**)	Gov & Grid Operator									
	• Renewables cost competive (max = worst case - min = best case)	RE - Industry									
	• Phase out of coal power plants in OECD countries	Utilities									
	• Phase out of nuclear power plants in OECD countries	Utilities									
heating	Global Renewable Heat supply shares										
	• Shares (max = adv. ER - Min = ER): **30%** / **50%** / **75%** / over **90%**	RE Industry									
	• Implementation of district heating (**Policy**/**Planning**/**Construction**)	National Governments									
	• Renewables cost competive (max = worst case - min = best case)	RE Industry									
final energy	Global Renewable Final Energy shares										
	• Shares (max = adv. ER - Min = ER): **30%** / **50%** / **75%** / over **90%**										
	• Consumer and business (Other Sectors)										
	• Industry										
	• Transport										
	• Total Final Energy										
	Efficiency & Demand										
consumer	Global Statonary Energy Use										
	• Efficiency standards reduce OECD household demand to 550 kWh/a per person	Cusumer Product Dev.									
	• Power demand for IT equipment stablized and start to decrease	IT Industry									
	• National energy intensity drops to 3 MJ/$GDP (Japan's level today)	Industry + Gov.									
transport	Global Transport Development										
	• Shift fright from road to rail and where possible from aviation to ships	Gov. + Logistic Industry									
	• Shift towards more public transport	Regional Governments									
	• Efficient cars become mainstream	Car-Industry									
emissions	**Energy Related CO_2 Emissions**										
	• Global CO_2 reductions (min = adv. ER - Max = ER): **Emission peak** / **-30%** / **-50%** / **-80%**										
	• Annex 1 CO_2 reductions (min = adv. ER - Max = ER): **Emission peak** / **-30%** / **-50%** / **-80%**										
	• Non Annex 1 CO_2 reductions (min = adv. ER - Max = ER): **Emission peak** / **-30%** / **-50%** / **-80%**										

climate protection and energy policy

GLOBAL

THE KYOTO PROTOCOL
INTERNATIONAL ENERGY POLICY

RENEWABLE ENERGY TARGETS
DEMANDS FOR THE ENERGY SECTOR

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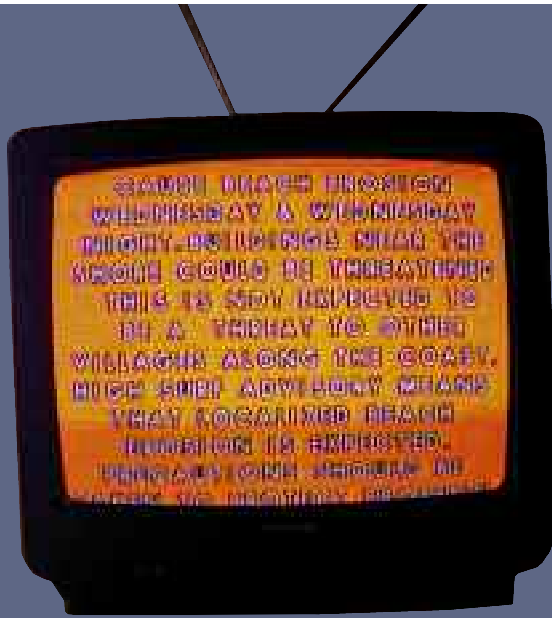

image THE LOCAL ALASKAN TELEVISION STATION BROADCASTS A WARNING FOR HIGH TIDES AND EROSION ALONG THE SEASIDE DURING A 2006 OCTOBER STORM WHICH IMPACTS ON THE VILLAGE OF SHISHMAREF. © GP/ROBERT KNOTH

“never before has humanity been forced to grapple with such an immense environmental crisis.”

GREENPEACE INTERNATIONAL
CLIMATE CAMPAIGN

image WANG WAN YI, AGE 76, ADJUSTS THE SUNLIGHT POINT ON A SOLAR DEVICE USED TO BOIL HIS KETTLE. HE LIVES WITH HIS WIFE IN ONE ROOM CARVED OUT OF THE SANDSTONE, A TYPICAL DWELLING FOR LOCAL PEOPLE IN THE REGION. DROUGHT IS ONE OF THE MOST HARMFUL NATURAL HAZARDS IN NORTHWEST CHINA. CLIMATE CHANGE HAS A SIGNIFICANT IMPACT ON CHINA'S ENVIRONMENT AND ECONOMY.

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The greenhouse effect is the process by which the atmosphere traps some of the sun's energy, warming the earth and moderating our climate. A human-driven increase in 'greenhouse gases' has enhanced this effect artificially, raising global temperatures and disrupting our climate. These greenhouse gases include carbon dioxide, produced by burning fossil fuels and through deforestation, methane, released from agriculture, animals and landfill sites, and nitrous oxide, resulting from agricultural production, plus a variety of industrial chemicals.

Every day we damage our climate by using fossil fuels (oil, coal and gas) for energy and transport. As a result, climate change is already impacting on our lives, and is expected to destroy the livelihoods of many people in the developing world, as well as ecosystems and species, in the coming decades. We therefore need to significantly reduce our greenhouse gas emissions. This makes both environmental and economic sense.

According to the Intergovernmental Panel on Climate Change, the United Nations forum for established scientific opinionon climate change, the world's temperature could potentially increase over the next hundred years by up to 6.4° Celsius. This is much faster than anything experienced so far in human history. The goal of climate policy should be to avoid dangerous climate change, which is being translated in limiting global mean temperature rise, as compared to pre-industrial levels, well below 2°C above, or even below 1.5°C. Above these tresholds, we will reach dangerous tipping points and damage to ecosystems and disruption to the climate system increases dramatically. We have very little time within which we can change our energy system to meet these targets. This means that global emissions will have to peak and start to decline by 2015.

Climate change is already harming people and ecosystems. Its reality can be seen in disintegrating polar ice, thawing permafrost, dying coral reefs, rising sea levels and fatal heat waves. It is not only scientists that are witnessing these changes. From the Inuit in the far north to islanders near the Equator, people are already struggling with the impacts of climate change. An average global warming of 1.5°C threatens millions of people with an increased risk of hunger, malaria, flooding and water shortages. Never before has humanity been forced to grapple with such an immense environmental crisis. If we do not take urgent and immediate action to stop global warming, the damage could become irreversible. This can only happen through a rapid reduction in the emission of greenhouse gases into the atmosphere.

This is a summary of some likely effects if we allow current trends to continue:

Likely effects of small to moderate warming

- Sea level rise due to melting glaciers and the thermal expansion of the oceans as global temperature increases. Massive releases of greenhouse gases from melting permafrost and dying forests.
- A greater risk of more extreme weather events such as heatwaves, droughts and floods. Already, the global incidence of drought has doubled over the past 30 years.
- Severe regional impacts. In Europe, river flooding will increase, as well as coastal flooding, erosion and wetland loss. Flooding will also severely affect low-lying areas in developing countries such as Bangladesh and South China.
- Natural systems, including glaciers, coral reefs, mangroves, alpine ecosystems, boreal forests, tropical forests, prairie wetlands and native grasslands will be severely threatened.
- Increased risk of species extinction and biodiversity loss.

The greatest impacts will be on poorer countries in sub-Saharan Africa, South Asia, Southeast Asia and Andean South America as well as small islands least able to protect themselves from increasing droughts, rising sea levels, the spread of disease and decline in agricultural production.

longer term catastrophic effects Warming from emissions may trigger the irreversible meltdown of the Greenland ice sheet, adding up to seven metres of sea level rise over several centuries. New evidence shows that the rate of ice discharge from parts of the Antarctic mean it is also at risk of meltdown. Slowing, shifting or shutting down of the Atlantic Gulf Stream current will have dramatic effects in Europe, and disrupt the global ocean circulation system. Large releases of methane from melting permafrost and from the oceans will lead to rapid increases of the gas in the atmosphere, and consequent warming.

"climate change has moved from being a predominantly physical phenomenon to being a social one" (hulme, 2009)."

the kyoto protocol

Recognising these threats, the signatories to the 1992 UN Framework Convention on Climate Change (UNFCCC) agreed the Kyoto Protocol in 1997. The Protocol finally entered into force in early 2005 and its 190 member countries meet annually to negotiate further refinement and development of the agreement. Only one major industrialised nation, the United States, has not ratified Kyoto.

The Kyoto Protocol commits the signatories from developed countries to reduce their greenhouse gas emissions by 5.2% from their 1990 level by the target period of 2008-2012. This has in turn resulted in the adoption of a series of regional and national reduction targets. In the European Union, for instance, the commitment is to an overall reduction of 8%. In order to help reach this target, the EU has also agreed a target to increase its proportion of renewable energy from 6% to 12% by 2010.

At present, the 193 members of the UNFCCC are negotiating a new climate change agreement that should enable all countries to continue contributing to ambitious and fair emission reductions. Unfortunately the ambition to reach such an agreement in Copenhagen failed and governments will continue negotiating in 2010 and possibly beyond to reach a new fair, ambitous and legally binding deal. Such a deal will need to ensure industrialized countries reduce their emissions on average by at least 40% by 2020, as compared to 1990 emissions. They will further need to provide at least $US 140 billion a year to developing countries to enable them to adapt to climate change, to protect their forests and to achieve the energy revolution. Developing countries should reduce their greenhouse gas emissions by 15 to 30% as compared to the projected growth of their emissions by 2020.

This new FAB deal will need to incoporate the Kyoto Protocol's architecture. This relies fundamentally on legally binding emissions reduction obligations. To achieve these targets, carbon is turned into a commodity which can be traded. The aim is to encourage the most economically efficient emissions reductions, in turn leveraging the necessary investment in clean technology from the private sector to drive a revolution in energy supply.

After Copenhagen, governments need to increase their ambitions to reduce emissions and need to even more invest in making the energy revolution happening. Greenpeace believes that it is feasible to reach a FAB deal in Cancun at the end of this year, if their would be sufficient political will to conclude such an agreement. That political will seems to be absent at the moment, but even if a FAB deal could not be finalised in COP16, due to lack of ambition and commitment of some countries, major parts of the deal must be put in place in Cancun, specifically those related to long term finance commitments, forest protection and overall ambition of emission reductions, so that by the Environment and Development Summit in Brazil in 2012 we can celebrate a deal that keeps the world well below 2 degrees warming with good certainty.

international energy policy

At present, renewable energy generators have to compete with old nuclear and fossil fuel power stations which produce electricity at marginal costs because consumers and taxpayers have already paid the interest and depreciation on the original investments. Political action is needed to overcome these distortions and create a level playing field for renewable energy technologies to compete.

At a time when governments around the world are in the process of liberalising their electricity markets, the increasing competitiveness of renewable energy should lead to higher demand. Without political support, however, renewable energy remains at a disadvantage, marginalised by distortions in the world's electricity markets created by decades of massive financial, political and structural support to conventional technologies. Developing renewables will therefore require strong political and economic efforts, especially through laws that guarantee stable tariffs over a period of up to 20 years. Renewable energy will also contribute to sustainable economic growth, high quality jobs, technology development, global competitiveness and industrial and research leadership.

renewable energy targets

In recent years, in order to reduce greenhouse emissions as well as increase energy security, a growing number of countries have established targets for renewable energy. These are either expressed in terms of installed capacity or as a percentage of energy consumption. These targets have served as important catalysts for increasing the share of renewable energy throughout the world.

A time period of just a few years is not long enough in the electricity sector, however, where the investment horizon can be up to 40 years. Renewable energy targets therefore need to have short, medium and long term steps and must be legally binding in order to be effective. They should also be supported by mechanisms such as feed-in tariffs for renewable electricity generation. In order for the proportion of renewable energy to increase significantly, targets must be set in accordance with the local potential for each technology (wind, solar, biomass etc) and be complemented by policies that develop the skills and manufacturing bases to deliver the agreed quantity of renewable energy.

In recent years the wind and solar power industries have shown that it is possible to maintain a growth rate of 30 to 35% in the renewables sector. In conjunction with the European Photovoltaic Industry Association[6], the European Solar Thermal Power Industry Association[7] and the Global Wind Energy Council[8], the European Renewable Energy Council and Greenpeace have documented the development of those industries from 1990 onwards and outlined a prognosis for growth up to 2020 and 2040.

references
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7 GLOBAL CONCENTRATED SOLAR POWER OUTLOOK – WHY RENEWABLES ARE HOT! MAY, 2009.
8 'GLOBAL WIND ENERGY OUTLOOK 2008', OCTOBER 2008.

image A PRAWN SEED FARM ON MAINLAND INDIA'S SUNDARBANS COAST LIES FLOODED AFTER CYCLONE AILA. INUNDATING AND DESTROYING NEARBY ROADS AND HOUSES WITH SALT WATER.

demands for the energy sector

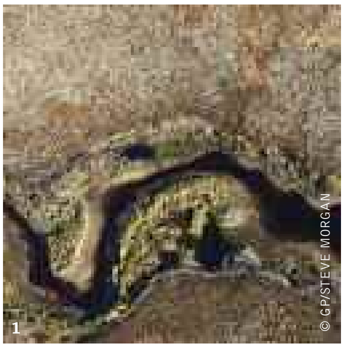
Greenpeace and the renewables industry have a clear agenda for the policy changes which need to be made to encourage a shift to renewable sources.

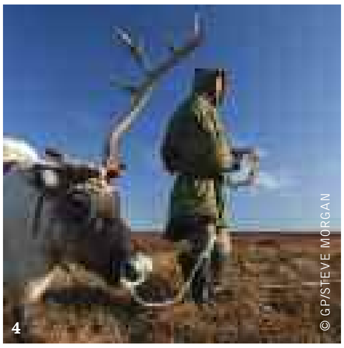
The main demands are:

1. Phase out all subsidies for fossil fuels and nuclear energy.
2. Internalise external (social and environmental) costs through 'cap and trade' emissions trading.
3. Mandate strict efficiency standards for all energy consuming appliances, buildings and vehicles.
4. Establish legally binding targets for renewable energy and combined heat and power generation.
5. Reform the electricity markets by guaranteeing priority access to the grid for renewable power generators.
6. Provide defined and stable returns for investors, for example through feed-in tariff payments.
7. Implement better labelling and disclosure mechanisms to provide more environmental product information.
8. Increase research and development budgets for renewable energy and energy efficiency

Conventional energy sources receive an estimated $250-300 billion[9] in subsidies per year worldwide, resulting in heavily distorted markets. Subsidies artificially reduce the price of power, keep renewable energy out of the market place and prop up non-competitive technologies and fuels. Eliminating direct and indirect subsidies to fossil fuels and nuclear power would help move us towards a level playing field across the energy sector. Renewable energy would not need special provisions if markets factored in the cost of climate damage from greenhouse gas pollution. Subsidies to polluting technologies are perverse in that they are economically as well as environmentally detrimental. Removing subsidies from conventional electricity would not only save taxpayers' money. It would also dramatically reduce the need for renewable energy support.

> "If we do not take urgent and immediate action to protect the climate the damage could become irreversible."





images 1. AN AERIAL VIEW OF PERMAFROST TUNDRA IN THE YAMAL PENINSULA. THE ENTIRE REGION IS UNDER HEAVY THREAT FROM GLOBAL WARMING AS TEMPERATURES INCREASE AND RUSSIA'S ANCIENT PERMAFROST MELTS. **2.** SOVARANI KOYAL LIVES IN SATJELLIA ISLAND AND IS ONE OF THE MANY PEOPLE AFFECTED BY SEA LEVEL RISE: "NOWADAYS, HEAVY FLOODS ARE GOING ON HERE. THE WATER LEVEL IS INCREASING AND THE TEMPERATURE TOO. WE CANNOT LIVE HERE, THE HEAT IS BECOMING UNBEARABLE. WE HAVE RECEIVED A PLASTIC SHEET AND HAVE COVERED OUR HOME WITH IT. DURING THE COMING MONSOON WE SHALL WRAP OUR BODIES IN THE PLASTIC TO STAY DRY. WE HAVE ONLY A FEW GOATS BUT WE DO NOT KNOW WHERE THEY ARE. WE ALSO HAVE TWO CHILDREN AND WE CANNOT MANAGE TO FEED THEM." **3.** WANG WAN YI, AGE 76, SITS INSIDE HIS HOME WHERE HE LIVES WITH HIS WIFE IN ONE ROOM CARVED OUT OF THE SANDSTONE, A TYPICAL DWELLING FOR LOCAL PEOPLE IN THE REGION. DROUGHT IS ONE OF THE MOST HARMFUL NATURAL HAZARDS IN NORTHWEST CHINA. CLIMATE CHANGE HAS A SIGNIFICANT IMPACT ON CHINA'S ENVIRONMENT AND ECONOMY. **4.** INDIGENOUS NENETS PEOPLE WITH THEIR REINDEER. THE NENETS PEOPLE MOVE EVERY 3 OR 4 DAYS SO THAT THEIR HERDS DO NOT OVER GRAZE THE GROUND. THE ENTIRE REGION AND ITS INHABITANTS ARE UNDER HEAVY THREAT FROM GLOBAL WARMING AS TEMPERATURES INCREASE AND RUSSIA'S ANCIENT PERMAFROST MELTS. **5.** A BOY HOLDS HIS MOTHER'S HANDS WHILST IN A QUEUE FOR EMERGENCY RELIEF SUPPLY. SCIENTISTS ESTIMATE THAT OVER 70,000 PEOPLE, LIVING EFFECTIVELY ON THE FRONT LINE OF CLIMATE CHANGE, WILL BE DISPLACED FROM THE SUNDARBANS DUE TO SEA LEVEL RISE BY THE YEAR 2030.

references

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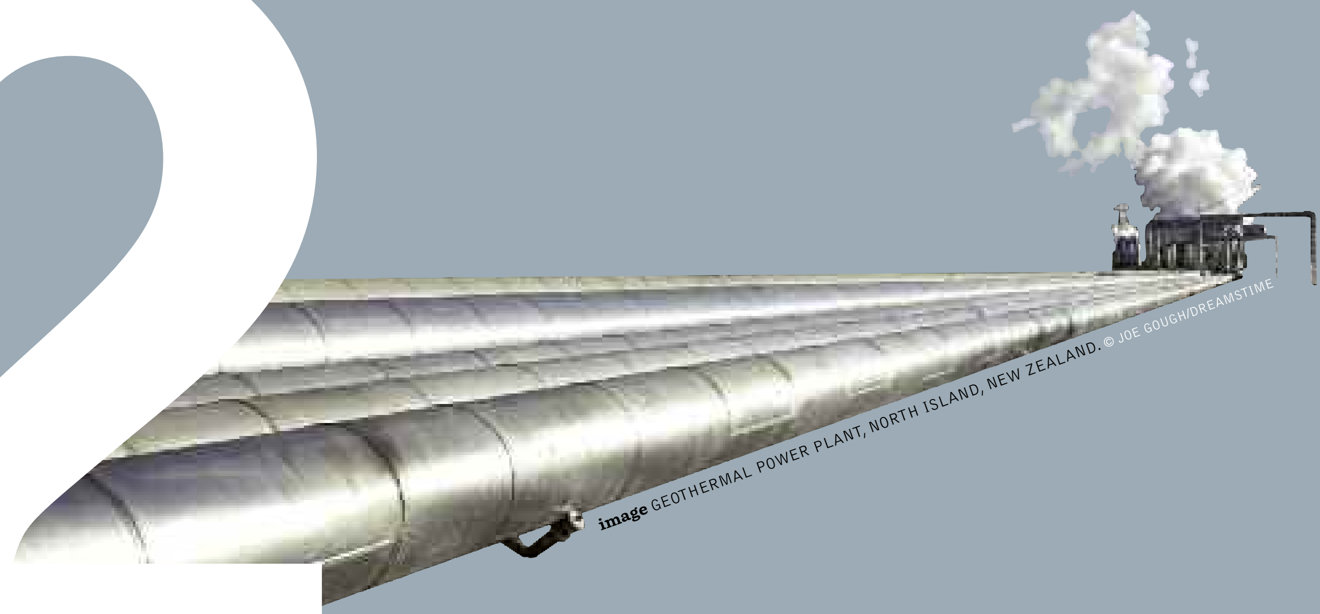

image GEOTHERMAL POWER PLANT, NORTH ISLAND, NEW ZEALAND. © JOE GOUGH/DREAMSTIME

“bridging the gap.”

GREENPEACE INTERNATIONAL
CLIMATE CAMPAIGN

image A WORKER ASSEMBLES WIND TURBINE ROTORS AT GANSU JINFENG WIND POWER EQUIPMENT CO. LTD. IN JIUQUAN, GANSU PROVINCE, CHINA.

This chapter starts "cost curve" calculations on which our projections for future investment in a dramatic shift towards renewable energy will be based. Based on these cost calculations two different innovative international mechanisms which will enable the Energy [R]evolution scenarios to be implemented are presented. The first is the concept of Greenhouse Development Rights, an attempt to even up on a global basis the unequal ability of different countries to respond in their energy polices to the climate crisis. The second is a proposal for a Feed-in Tariff Support Mechanism which would enable the expansion of new renewable energy projects to take place in the developing world both faster and with secure financial support.

2.1 cost curves: defining the priorities for investment

While energy scenarios play an increasing role within the global, regional and national energy and climate debate, the different ways of setting up scenarios are under discussion. In principle there are 2 different types of scenarios: "Top-down" and "Bottom up" calculated energy scenarios.

Top-down scenarios are mostly cost driven, the cost projections for each technology, fuel costs and CO_2 costs have a huge influence for the projected energy mix in the future as the model usually optimizes the mix in the basis of cheapest energy generation. A low cost projection for e.g. nuclear energy or the coal price will result in a large share of nuclear and coal power plants in the electricity generation of the future. However those models are often not very technology specific and in same cases there is not even a distinction between two very different solar electricity technologies to concentrated solar power (CSP) and photovoltaic (pv) as both technologies have very different capacities factors, costs and technical parameters. While "bottom up" scenario are technology driven and have therefore a very detailed breakdown of different technologies and can model energy system more exact. On the downside those models are not cost specific and they do not optimize the economic side of a future energy system. In the past years, both models are moving towards each other. While "top-down" scenarios have a greater level of technical details, bottom up scenarios include more and more economic parameters.

The IEA World Energy Outlook – which is the reference scenario for both energy [r]evolution scenarios are in principle bottom up models, but with a greater level of cost assumptions. The section provides an overview about the resulting cost curves of all three scenarios. As "cost curves" do play an increasing role in the energy and climate debate Greenpeace and EREC decided to include those in the new Energy [R]evolution edition.

concept and methodology

The concept of supply curves of carbon abatement and energy all rest on the same foundation. They are curves consisting typically of discreet steps, each step relating the energy generation/conservation or abatement potential related to the abatement measure/energy generation technology or measure to conserve energy to its marginal cost; and rank these steps according to their cost. As a result, a curve is obtained that can be interpreted similarly to the concept of supply curves in traditional economics.

The concept of abatement and energy supply curves has common and specific limitations. One of the most commonly cited ones is that in certain cases there are options to come to "negative costs". The existence of untapped "profitable" (i.e. negative cost) potentials themselves represents a realm of debates ongoing for decades between different schools of thought . Those accepting negative cost potentials argue, among others, that certain barriers prevent those investments from taking place on a purely market basis, but policy interventions can remove these barriers and unlock these profitable potentials. Therefore the barriers prevailing in renewable energy markets such as insufficient information, limited access to capital, uncertainty about future fuel prices (for example in the case of fossil fuels or biomass) or misplaced incentives (e.g. fossil fuel subsidies for social or other reasons) hindering a higher rate of investments into renewable energy technologies as well, but even more importantly for untapped energy efficiency measures, potentially resulting in negative cost options. A further concern about supply curves is that the methodology simplifies reality as the curves do not reflect the real choices of actors, who accordingly do not always implement the available options in the order suggested by the curve.

Perhaps one of the key shortcomings of the cost curves is that they consider and compare mitigation options apply individually, whereas typically a package of measures are applied together, therefore potentially missing synergistic and integrational opportunities. Optimised, strategic packages of measures may have lower average costs than the average of the individual measures applied using a piecemeal approach. In particular the missing dynamic system perspective considering relevant interactions with the overall system behaviour can be problematic, although cost curves applying advanced methods are dynamic rather than static. Also so called "low hanging fruits" – such as efficiency measures - appear in these graphs first and e.g. offshore wind in 10 years time. While in reality, the policy must do both at the same time. As efficiency measure are relatively easy to achieve via e.g. technical standards and codes, offshore wind takes several year of preparation. So a policy change in efficiency shows results fairly quickly, while a policy towards offshore wind will deliver the first electricity years later, due to longer planning and construction time. Besides that, strategic planning of the energy mix of the future required infrastructure – such as smart grids, offshore grids or district heating pipelines – which again need several years to implement. In particular this is true for GHG mitigation cost curves where the question of substituted energy options plays a major role for the calculation of the mitigated CO_2-emissions.

references

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global renewable electricity supply curves

Figure 2.1 shows the global renewable electricity supply curve for 4 scenarios: IEA WEO (2009), ETP (2010), Greenpeace Energy [R]evolution and Greenpeace Advanced Energy [R]evolution. Note that the only investment cost data were available for IEA scenarios, therefore the other cost components, such as fixed and variable capital and generation costs, including OM, have been taken from the Energy [R]evolution data. For the Energy [R]evolution and Advanced Energy [R]evolution scenarios potentials are projected both for 2030 and 2050, while unfortunately no such forecasts were available for the IEA scenarios for 2050.

The figures attest the importance of long-term frameworks for renewable energy. Potentials at the same costs more than double between 2030 and 2050 (please note that presently existing capacity is included in these potentials, with hydropower separated into "new hydro" and "existing hydro"). The IEA scenarios find significantly lower potentials at equal cost levels than the Energy [R]evolution ones. Both IEA and the Energy [R]evolution scenarios find wind as having a large potential at very competitive costs. In the Energy [R]evolution scenarios this is followed by biomass and then PV in 2030, while PV becomes cheaper by 2050 than biomass. IEA scenarios project very low costs for CSP, lower than for wind, however, this technology is not expected to add a significant power production capacity to global electricity generaion. Similarly, they also project approximately half the cost for geothermal power for 2030 as the Energy [R]evolution scenarios, however, they see very little potential for this technology; while Energy [R]evolution scenarios project fairly large potentials at the highest (Energy [R]evolution) or second highest (Advanced Energy [R]evolution) cost levels from among the technologies. Ocean energy is expected to play a small role, except in the Advanced Energy [R]evolution scenario, even if its costs are projected to be under that of several renewable electricity generation technologies.

figure 2.1: renewable energy supply curves for the energy [r]evolution scenario

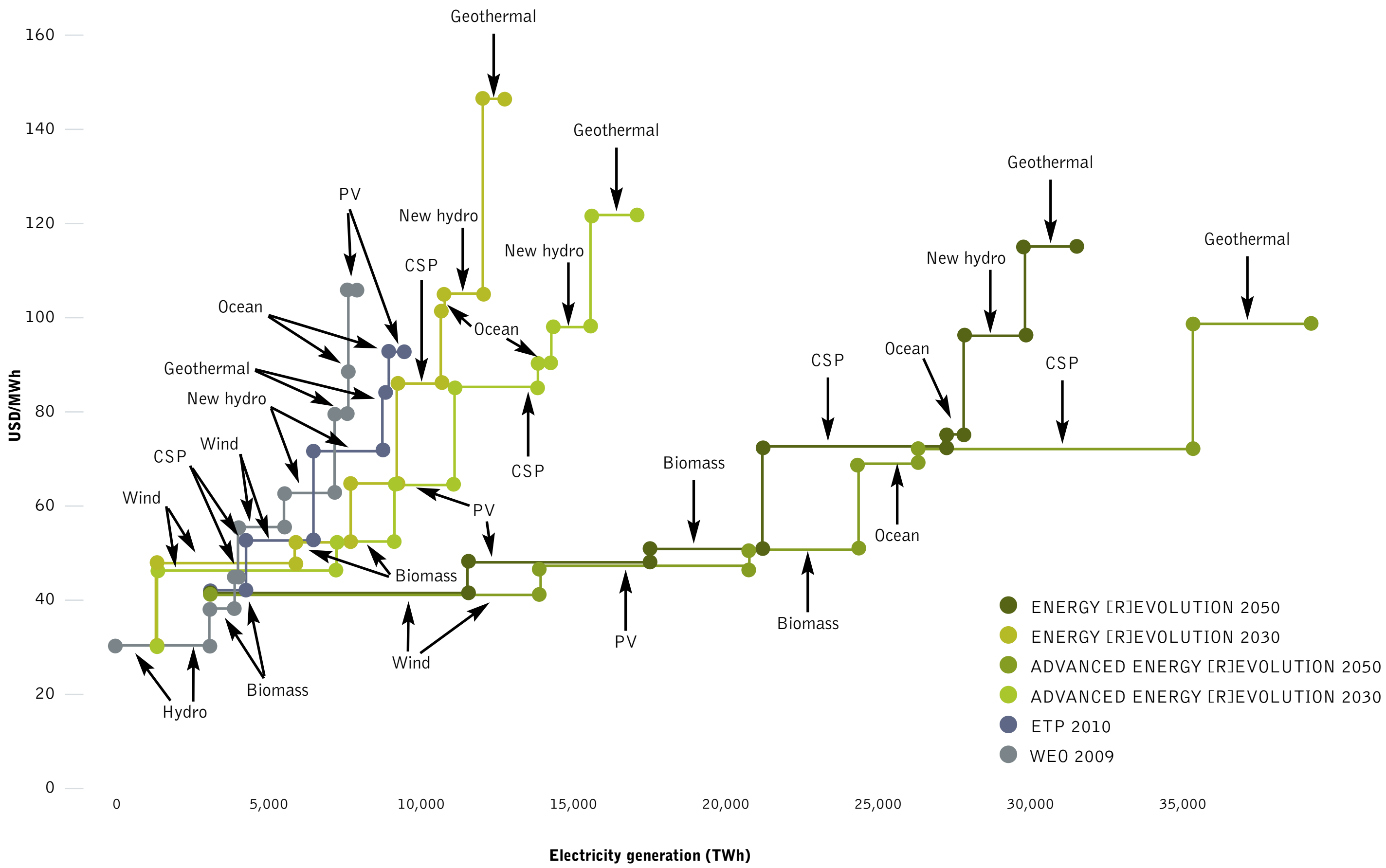

image A MAINTENANCE WORKER MARKS A BLADE OF A WINDMILL AT GUAZHOU WIND FARM NEAR YUMEN IN GANSU PROVINCE, CHINA.

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2.2 ftsm: a support scheme for renewable power in developing countries

This section outlines a Greenpeace proposal for a feed-in tariff system in developing countries whose additional costs would be financed by developed nations. The financial resources for this could come from a combination of innovative sources, could be managed by the Copenhagen Green Climate Fund (that still needs to be established), and the level of contributions should be set through the GDR framework (see 2.3).

Both Energy [R]evolution scenarios show that renewable electricity generation has huge environmental and economic benefits. However its investment and generation costs, especially in developing countries, will remain higher than those of existing coal or gas-fired power stations for the next five to ten years. To bridge this cost gap a specific support mechanism for the power sector is needed. The **Feed-in Tariff Support Mechanism (FTSM)** is a concept conceived by Greenpeace International.[11] The aim is the rapid expansion of renewable energy in developing countries with financial support from industrialised nations.

Since the FTSM concept was first presented in 2008, the idea has received considerable support from a variety of different stakeholders. The Deutsche Bank Group´s Climate Change Advisors, for example, have developed a proposal based on FTSM called "GET FiT". Announced in April 2010, this took on board major aspects of the Greenpeace concept.

bankable renewable energy support schemes

Since the early development of renewable energies within the power sector, there has been an ongoing debate about the best and most effective type of support scheme. The European Commission published a survey in December 2005 which provided a good overview of the experience so far. This concluded that feed-in tariffs are by far the most efficient and successful mechanism. A more recent update of this report, presented in March 2010 at the IEA Renewable Energy Workshop by the Fraunhofer Institute[12], underscores this conclusion. The Stern Review on the Economics of Climate Change also concluded that feed-in tariffs "achieve larger deployment at lower costs". Globally more than 40 countries have adopted some version of the system.

Although the organisational form of these tariffs differs from country to country, there are certain clear criteria which emerge as essential for creating a successful renewable energy policy. At the heart of these is a reliable, bankable support scheme for renewable projects which provides long term stability and certainty[13]. Bankable support schemes result in lower cost projects because they lower the risk for both investors and equipment suppliers. The cost of wind-powered electricity in Germany is up to 40% cheaper than in the United Kingdom[14], for example, because the support system is more secure and reliable.

experience of feed-in tariffs

- Feed-in tariffs are seen as the best way forward, especially in developing countries. By 2009 this system had incentivised 75% of PV capacity worldwide and 45% of wind capacity.
- Based on experience, feed-in tariffs are the most effective mechanism to create a stable framework to build a domestic market for renewables. They have the lowest investment risk, highest technology diversity, lowest windfall profits for mature technologies and attract a broad spectrum of investors.[15]
- The main argument against them is the increase in electricity prices for households and industry, as the extra costs are shared across all customers. This is particularly difficult for developing countries, where many people can't afford to spend more money for electricity services.

For developing countries, feed-in laws would be an ideal mechanism to support the implementation of new renewable energies. The extra costs, however, which are usually covered in Europe, for example, by a very minor increase in the overall electricity price for consumers, are still seen as an obstacle. In order to enable technology transfer from Annex 1 countries to developing countries, a mix of a feed-in law, international finance and emissions trading could be used to establish a locally based renewable energy infrastructure and industry with the assistance of OECD countries.

Finance for renewable energy projects is one of the main obstacles in developing countries. While large scale projects have fewer funding problems, there are difficulties for small, community based projects, even though they have a high degree of public support. The experiences from micro credits for small hydro projects in Bangladesh, for example, as well as wind farms in Denmark and Germany, show how both strong local participation and acceptance can be achieved. The main reasons for this are the economic benefits flowing to the local community and careful project planning based on good local knowledge and understanding. When the community identifies the project rather than the project identifying the community, the result is generally faster bottom-up growth of the renewables sector.

The four main elements for successful renewable energy support schemes are therefore:

- A clear, bankable pricing system.
- Priority access to the grid with clear identification of who is responsible for the connection, and how it is incentivised.
- Clear, simple administrative and planning permission procedures.
- Public acceptance/support.

The first is fundamentally important, but it is no good if you don't have the other three elements as well.

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12 EFFECTIVE AND EFFICIENT LONG-TERM ORIENTED RE SUPPORT POLICIES, MARIO RAGWITZ, MARCH 2010.
13 'THE SUPPORT OF ELECTRICITY FROM RENEWABLE ENERGY SOURCES', EUROPEAN COMMISSION, 2005.
14 SEE ABOVE REPORT, P. 27, FIGURE 4.
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the feed-in tariff support mechanism

The basic aim of the FTSM is to facilitate the introduction of feed-in laws in developing countries by providing additional financial resources on a scale appropriate to the circumstances of each country. For those countries with higher levels of potential renewable capacity, the creation of a new sectoral no-lose mechanism generating emission reduction credits for sale to Annex I countries, with the proceeds being used to offset part of the additional cost of the feed-in tariff system, could be appropriate. For others there would need to be a more directly funded approach to paying for the additional costs to consumers of the tariff. The ultimate objective would be to provide bankable and long term stable support for the development of a local renewable energy market. The tariffs would bridge the gap between conventional power generation costs and those of renewable generation.

the key parameters for feed in tariffs under FTSM are:

- Variable tariffs for different renewable energy technologies, depending on their costs and technology maturity, paid for 20 years.
- Payments based on actual generation in order to achieve properly maintained projects with high performance ratios.
- Payment of the 'additional costs' for renewable generation based on the German system, where the fixed tariff is paid minus the wholesale electricity price which all generators receive.
- Payment could include an element for infrastructure costs such as grid connection, grid re-enforcement or the development of a smart grid. A specific regulation needs to define when the payments for infrastructure costs are needed in order to achieve a timely market expansion of renewable power generation.

A developing country which wants to take part in the FTSM would need to establish clear regulations for the following:

- Guaranteed access to the electricity grid for renewable electricity projects.
- Establishment of a feed-in law based on successful examples.
- Transparent access to all data needed to establish the feed-in tariff, including full records of generated electricity.
- Clear planning and licensing procedures.

The average additional costs for introducing the FTSM between 2010 and 2020 under the Energy [R]evolution scenario are estimated to be between 5 and 3 cents/kWh and 5 and 2 cents/kWh under the advanced version. The cost per tonne of CO_2 avoided would therefore be around US$25.

The design of the FTSM would need to ensure that there were stable flows of funds to renewable energy suppliers. There may therefore need to be a buffer between fluctuating CO_2 emission prices and stable long term feed-in tariffs. This would be possible through the proposed Greenhouse Development Rights scheme, which would create a stable income for non-OECD countries (see Chapter 2.3, Table 2.7 and 2.8). The FTSM will need to secure payment of the required feed-in tariffs over the whole lifetime (about 20 years) of each project.

In order to be eligible, all renewable energy projects must have a clear set of environmental criteria which are part of the national licensing procedure in the country where the project will generate electricity. Those criteria will have to meet a minimum environmental standard defined by an independent monitoring group. If there are already acceptable criteria developed these should be adopted rather than reinventing the wheel. The members of the monitoring group would include NGOs, energy and finance experts as well as members of the governments involved. Funding will not be made available for speculative investments, only as soft loans for FTSM projects.

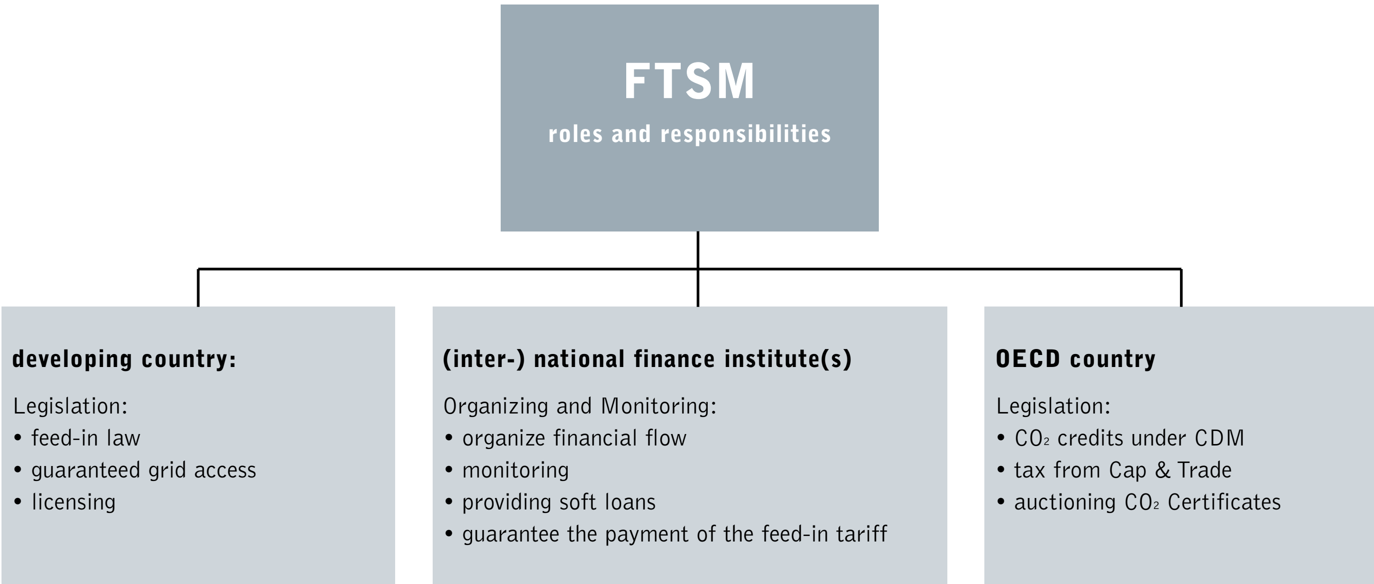
The FTSM would also seek to create the conditions for private sector actors, such as local banks and energy service companies, to gain experience in technology development, project development, project financing and operation and maintenance in order to develop track records which would help reduce barriers to further renewable energy development.

the key parameters for the FTSM fund will be:

- The mechanism will guarantee payment of the feed-in tariffs over a period of 20 years as long as the project is operated properly.
- The mechanism will receive annual income from emissions trading or from direct funding.
- The mechanism will pay feed-in tariffs annually only on the basis of generated electricity.
- Every FTSM project must have a professional maintenance company to ensure high availability.
- The grid operator must do its own monitoring and send generation data to the FTSM fund. Data from the project managers and grid operators will be compared regularly to check consistency.

image A WOMAN STUDIES SOLAR POWER SYSTEMS AT THE BAREFOOT COLLEGE. THE COLLEGE SPECIALISES IN SUSTAINABLE DEVELOPMENT AND PROVIDES A SPACE WHERE STUDENTS FROM ALL OVER THE WORLD CAN LEARN TO UTILISE RENEWABLE ENERGY. THE STUDENTS TAKE THEIR NEW SKILLS HOME AND GIVE THEIR VILLAGES CLEAN ENERGY.

figure 2.4: **ftsm scheme**



financing the energy [r]evolution with FTSM

Based on both Energy [R]evolution Scenarios for developing (non-OECD) countries, a calculation has been done to estimate the costs and benefits of an FTSM programme using the following assumptions:

power generation costs The average level of feed-in tariffs, excluding solar, has been calculated on the assumption that the majority of renewable energy sources require support payments of between 7 and 15 cents per kilowatt-hour. While wind and bio energy power generation can operate on tariffs of below 10 cents per kWh, other technologies, such as geothermal and concentrated solar power, will need slightly more. Exact tariffs should be calculated on the basis of specific market prices within each country. The feed-in tariff for solar photovoltaic projects reflects current market price projections. The average conventional power generation costs are based on new coal and gas power plants without direct or indirect subsidies.

specific CO_2 reduction per kWh The assumed CO_2 reduction per kWh from switching to renewables is crucial for calculating the specific cost per tonne of CO_2 saved. In non-OECD countries the current level of CO_2 emissions for power generation averages 871 gCO_2/kWh, and will reduce to 857 gCO_2/kWh by 2030 (see Reference scenario Chapter 6). The average level of CO_2 emissions over the period from 2010 to 2020 is therefore 864 gCO_2/kWh.

table 2.1: **assumptions for ftsm calculations**

KEY PARAMETER	AVERAGE FEED-IN TARIFF EXCL. SOLAR PV (ct/kWh)	AVERAGE FEED-IN TARIFF FOR SOLAR PV (ct/kWh)
2010	12	20
2020	11	15
2030	10	10

financial parameters From the beginning of the financial crisis in mid-2008 it became clear that inflation rates and capital costs were likely to change very fast. The cost calculations in this programme do not take into account changes in interest rates, capital costs or inflation; all cost parameters are nominal based on 2009 levels.

key results The FTSM programme would cover 624TWh by 2015 and 4,960 TWh by 2030 of new renewable electricity generation and save 77.6 $GtCO_2$ between 2010 and 2030. This works out at 3.8 $GtCO_2$ per year under the basic Energy [R]evolution scenario and 82 $GtCO_2$ or 4.1 $GtCO_2$ per year under the advanced version. With an average CO_2 price of US$23.1 per tonne, the total programme would cost US$1.62 trillion. This works out at US$ 76.3 billion annually under the basic version and US$ 1.29 trillion or US$ 61.4 billion annually under the advanced scenario.

Under the GDR scheme, this would mean that the EU-27 countries would need to cover 22.4% (US$ billion 289) of these costs, or US$14.4 annually. The costs for the USA would amount to US$24.9 billion each year. India, on the other hand, would receive US$13 billion per year between 2010 and 2030 to finance the domestic uptake of renewable power generation.

The FTSM will bridge the gap between now and 2030, when electricity generation costs for all renewable energy technologies are projected to be lower than conventional coal and gas power plants. However, this case study has calculated even lower generation costs for conventional power generation than we have assumed in our price projections for the Energy [R]evolution scenario (see Chapter 5, page 52, Table 5.3.). This is because we have excluded CO_2 emission costs. If these are taken into account coal power plants would have generation costs of 10.8 $cents/kWh by 2020 and 12.5 cents/kWh by 2030, as against the FTSM assumption of 10 cents/kWh over the same timescale. However, the advanced Energy [R]evolution case takes those higher costs into account and reaches economies of scale for renewable power generation around 5 years earlier. Therefore, in the second period in the advanced case, the annual costs of the FTSM programm drop significantly under the basic version even with much higher renewable electricity volume.

As the difference between renewable and coal electricity generation costs are projected to decrease, more renewable electricity can be financed with roughly the same amount of money.

for developing countries

Overall, the FTSM for non-OECD countries will bring more than 1,700 GW (2,300 GW in the advanced version) of new renewable energy power plants on line, creating about 5 million jobs with an annual cost of under US$15,000 per job per year.

more than 1700 GW renewables

figure 2.5: feed-in tariffs versus conventional power generation

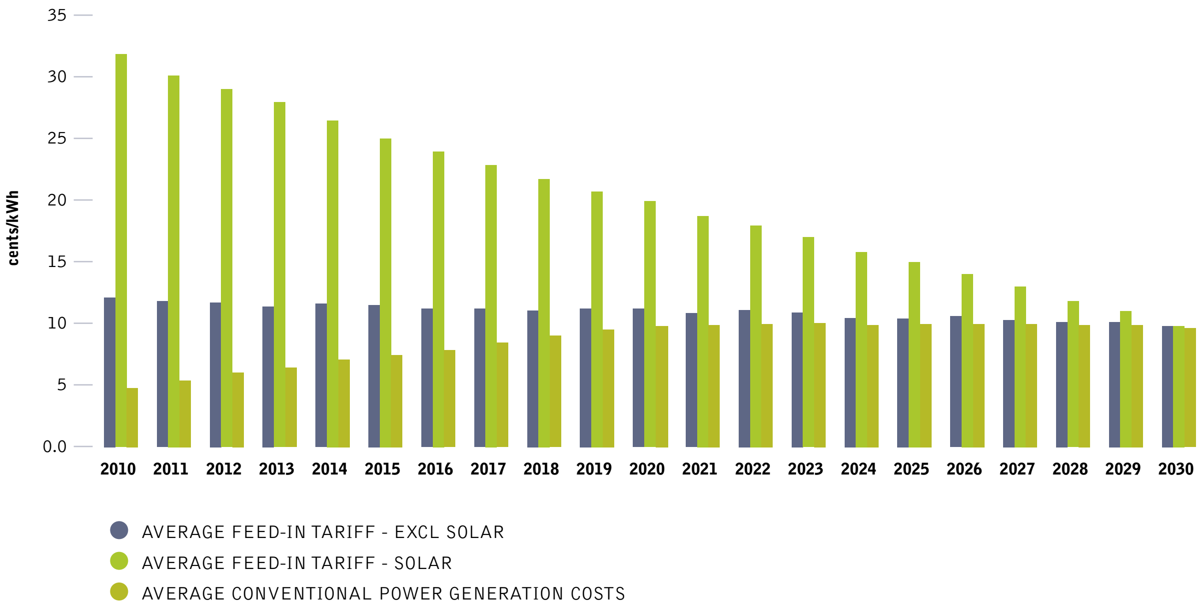


table 2.2: ftsm key parameters - Energy [R]evolution

KEY PARAMETER	CONVENTIONAL POWER GENERATION COSTS (ct/kWh)	INTEREST RATES (%)	SPECIFIC REDUCTION PER KWH (gCO_2/kWh)
2010	7	4	0.7
2020	10	4	0.7
2030	10	4	0.7

table 2.3: ftsm key parameters - adv Energy [R]evolution

KEY PARAMETER	CONVENTIONAL POWER GENERATION COSTS (ct/kWh)	INTEREST RATES (%)	SPECIFIC REDUCTION PER KWH (gCO_2/kWh)
2010	7	4	0.7
2020	11	4	0.7
2030	12.5	4	0.7

table 2.4: ftsm programme

KEY RESULTS TOTAL NON-OECD	YEAR	AVERAGE CO_2 COST PER TONNE [$/ TCO_2]	AVERAGE ANNUAL CO_2 EMISSION CREDITS (MILLION T CO_2)	TOTAL ANNUAL COSTS (BILLION US$)	TOTAL CO_2 CERTIFICATES PER PERIODE (MILLION T CO_2)	TOTAL COSTS PER PERIOD (BILLION $)
Period 1 E[R]	2010-2019	27.8	2,080.4	57.9	20,804	579.3
Period 1 adv E[R]	2010-2019	26.3	2,199.3	57.9	21,993	579.3
Period 2 E[R]	2020-2030	18.3	5,165.8	94.7	56,824	1041.6
Period 2 adv E[R]	2020-2030	11.9	5,461.0	64.8	60,071	712.7
Period 1+2 E[R]	2010-2030	23.1	3,623.1	76.3	77,628	1,621
Period 1+2 adv E[R]	2010-2030	19.1	3,830.1	61.4	82,064	1,292

image CHECKING THE SOLAR PANELS ON TOP OF THE GREENPEACE POSITIVE ENERGY TRUCK IN BRAZIL.

table 2.5: renewable power for non-oecd countries under ftsm programme

ELECTRICITY GENERATION (TWh/a)	2007	2015	2020	2030	INSTALLED CAPACITY (GW)	2007	2015	2020	2030
Wind E[R]	23.6	307.0	854.5	2,238.0	Wind E[R]	15	138	347	865
PV E[R]	0.2	22.0	105.4	673.0	PV E[R]	0	14	59	383
Biomass E[R]	41.2	218.0	488.5	950.0	Biomass E[R]	7	44	100	173
Geothermal E[R]	21.6	50.5	111.0	251.0	Geothermal E[R]	4	9	19	44
Solar Thermal E[R]	0.0	21.7	112.1	798.0	Solar Thermal E[R]	0	9	36	130
Ocean Energy E[R]	0.0	4.6	27.4	48.5	Ocean Energy E[R]	0	1	8	14
Total - new RE E[R]	**86.7**	**623.8**	**1,699.0**	**4,958.5**	**Total - new RE E[R]**	**26.2**	**214.1**	**570.7**	**1,610.3**
Wind adv E[R]	23.6	312.0	1,092.0	2,949.0	Wind adv E[R]	15	140	443	1,142
PV adv E[R]	0.2	22.0	204.0	998.0	PV adv E[R]	0	14	114	560
Biomass adv E[R]	41.2	218.0	487.0	946.0	Biomass adv E[R]	7	44	100	173
Geothermal adv E[R]	21.6	55.4	164.0	715.0	Geothermal adv E[R]	4	10	28	117
Solar Thermal adv E[R]	0.0	24.7	281.0	1,550.0	Solar Thermal adv E[R]	0	10	91	255
Ocean Energy adv E[R]	0.0	4.6	67.0	237.0	Ocean Energy adv E[R]	0	1	20	70
Total - new RE adv E[R]	**86.7**	**636.7**	**2,295.0**	**7,395.0**	**Total - new RE adv E[R]**	**26.2**	**218.1**	**795.1**	**2,316.2**

2.3 greenhouse development rights

The Energy [R]evolution scenarios present a range of pathways towards a future based on an increasing proportion of renewable energy, but such routes are only likely to be followed if their corresponding investment costs are shared fairly under some form of global climate regime. To demonstrate how this would be possible we have used the Greenhouse Development Rights framework, designed by EcoEquity and the Stockholm Environment Institute, as a potential basis for implementing the Energy [R]evolution .

Greenpeace advocates for industrialized countries, as a group, to reduce their emissions by at least 40% by 2020 (as compared to 1990 emissions) and for developing countries, as a group, to reduce their emissions by at least 15% by 2020 as compared to their projected growth in emissions. On top of these commitments Greenpeace urges industrialized countries to provide financial resources of at least $US140 billion per year to fund the cost of climate change mitigation and adaptation in developing countries. The Greenhouse Development Rights framework provides a tool for distributing both this emission reduction and finance target equally amongst countries. Below we show how this will work for implementing the Energy [R]evolution scenarios.

the greenhouse development rights framework

The **Greenhouse Development Rights (GDR)** framework calculates national shares of global greenhouse gas obligations based on a combination of responsibility (contribution to climate change) and capacity (ability to pay). Crucially, GDRs take inequality within countries into account and calculate national obligations on the basis of the estimated capacity and responsibility of individuals. Individuals with incomes below a 'development threshold' – specified in the default case as $7,500 per capita annual income, PPP adjusted – are exempted from climate-related obligations. Individuals with incomes above that level are expected to contribute to the costs of global climate policy in proportion to their capacity (amount of income over the threshold) and responsibility (cumulative CO_2 emissions since 1990, excluding emissions corresponding to consumption below the threshold).

The calculations of capacity and responsibility are then combined into a joint **Responsibility and Capacity Indicator (RCI)** by taking the average of the two values. Thus, for example, as shown in Table 2.6 below, the United States of America, with 4.5% of the world's population, has 35.8% of the world's capacity in 2010, 36.8% of the world's responsibility and 36.3% of the calculated RCI. This means that in 2010, the USA would be responsible for 36.3% of the costs of global climate policy.

Because the system calculates obligations based on the characteristics of individuals, and all countries have at least some individuals with incomes over the development threshold, GDRs would eliminate the overarching formal distinction in the Kyoto Protocol between Annex I and non-Annex I countries. There would of course still be key differences between rich and poor countries, as rich countries would be expected to pay for reductions made in other countries as well as making steep domestic emissions reductions, while poor countries could expect the majority of the incremental costs for emissions reductions required within their borders to be paid for by wealthier countries. Similarly, the national obligations calculated through GDRs could be used to allocate contributions to a global adaptation fund; again, even poor countries would have some positive obligations to contribute, but they would expect to be net recipients of adaptation funds, while rich countries would be net contributors.

table 2.6: population, income, capacity, responsibility and RCI calculated for 2010 for IEA regions and selected countries, plus projected 2020 and 2030 RCI.

REGION/COUNTRY	POPULATION (2010)	INCOME USD /A (2010)	CAPACITY (2010)	RESPONSIBILITY (2010)	RCI (2010)	RCI (2020)	RCI (2030)
OECD	**17.6%**	**32,413**	**86.6%**	**75.3%**	**80.9%**	**72.8%**	**63.7%**
North America	6.6%	37,128	39.8%	41.5%	40.6%	36.9%	32.9%
United States	4.5%	45,640	35.8%	36.8%	36.3%	32.7%	28.9%
Mexico	1.6%	12,408	1.3%	1.6%	1.5%	1.5%	1.5%
Canada	0.5%	38,472	2.6%	3.1%	2.9%	2.7%	2.5%
Europe	8.0%	29,035	29.3%	22.2%	25.8%	23.2%	20.1%
Pacific	3.0%	30,961	17.5%	11.5%	14.5%	12.7%	10.7%
Japan	1.9%	33,422	14.3%	7.3%	10.8%	9.2%	7.4%
Non-OECD	**82.4%**	**5,137**	**13.4%**	**24.7%**	**19.1%**	**27.2%**	**36.3%**
E.Europe/Eurasia	4.9%	11,089	1.5%	7.8%	4.7%	5.2%	5.7%
Russia	2.0%	15,031	0.9%	5.9%	3.4%	3.5%	3.8%
Asia	52.5%	4,424	5.6%	7.2%	6.4%	12.7%	20.1%
China	19.7%	5,899	2.9%	4.3%	3.6%	8.3%	13.6%
India	17.2%	2,818	0.1%	0.1%	0.1%	0.5%	1.3%
Middle East	14.9%	2,617	0.8%	2.0%	1.4%	1.7%	2.0%
Africa	3.1%	12,098	2.4%	4.8%	3.6%	4.3%	4.8%
Latin America	7.0%	8,645	3.1%	2.9%	3.0%	3.3%	3.6%
Brazil	2.9%	9,442	1.5%	1.1%	1.3%	1.4%	1.4%
World	**100.0%**	**9,929**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
European Union	**7.3%**	**30,471**	**28.1%**	**21.8%**	**25.0%**	**22.6%**	**19.6%**

A more detailed description of the GDR framework can be found in "The Greenhouse Development Right Framework" published in November 2008.[16] For this study, the standard GDR framework has been slightly modified to account for the most recent IEA World Energy Outlook 2009 baseline emissions and economic growth scenario up to 2030, and for the target pathways defined by the Energy [R]evolution and advanced Energy [R]evolution scenarios (for more details see Chapter 6). Because the GDR framework calculates the share of global climate obligation for each country, it can therefore be used to calculate (against a baseline) the amount of reductions required for each country to meet an international target. In Figure 2.6 we show the global obligation required to move from the IEA baseline to the emissions pathway in the Energy [R]evolution scenario (declining to 25 $GtCO_2$ in 2020 and 21 $GtCO_2$ in 2030), with the reduction divided into "wedges" proportional to each country's share.

Figure 2.7 shows the global emissions reductions required under the advanced Energy [R]evolution scenario, also divided into "wedges" proportional to each country or region's Responsibility and Capacity Indicator. Note that the size of each wedge in percentage terms changes over time, consistent with Table 2.6. The largest share is for the US, followed by Europe, while the wedges for India and China increase over time. Africa and Developing Asia have the smallest wedges.

figure 2.6: energy [r]evolution wedges

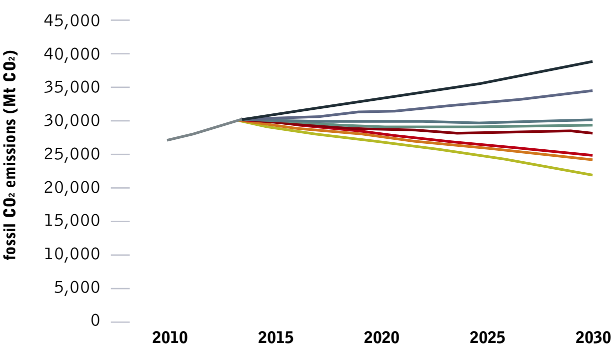
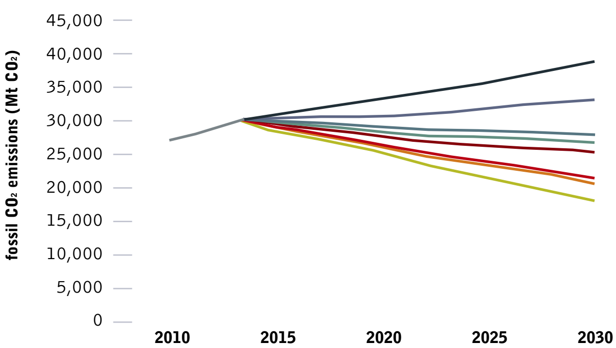


figure 2.7: advanced energy [r]evolution wedges



- BAU
- UNITED STATES
- OECD EUROPE
- OTHER OECD
- EITs
- CHINA
- INDIA
- OTHER NON-OECD

references
16 THE GREENHOUSE DEVELOPMENT RIGHT FRAMEWORK" PUBLISHED IN NOVEMBER 2008, BAER ET AL. 2008

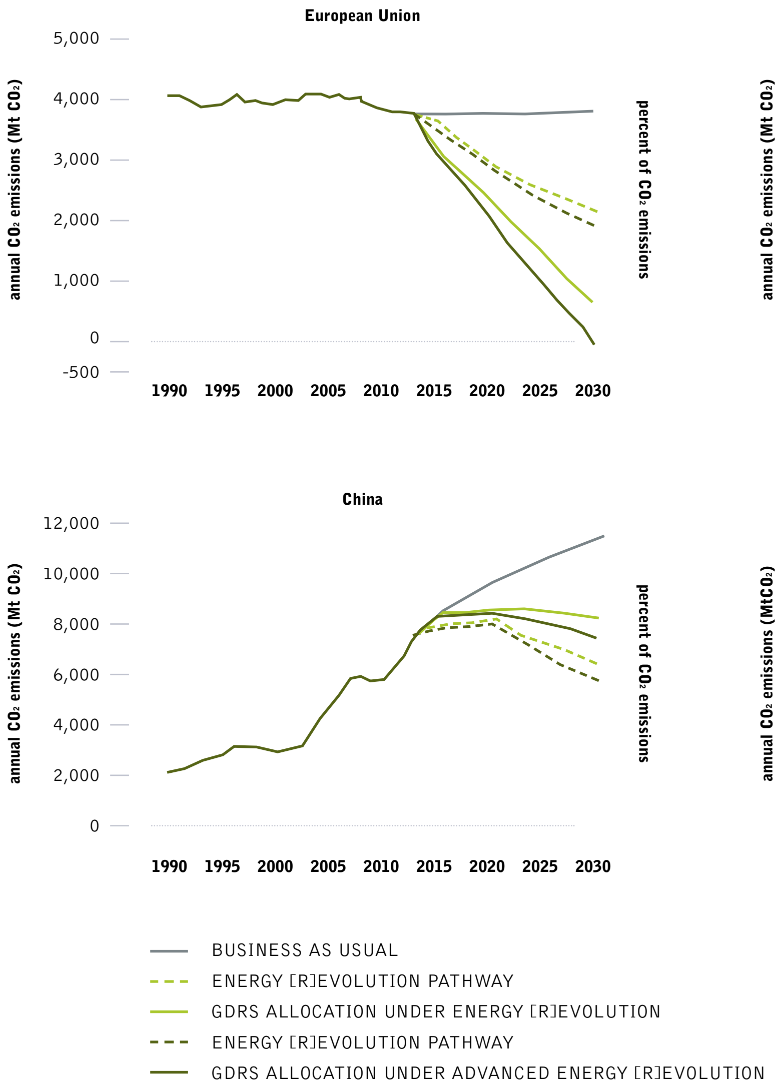
image WIND TURBINES AT THE NAN WIND FARM IN NAN'AO. GUANGDONG PROVINCE HAS ONE OF THE BEST WIND RESOURCES IN CHINA AND IS ALREADY HOME TO SEVERAL INDUSTRIAL SCALE WIND FARMS.

The charts in Figure 2.8 show for the US, EU, India and China, the relationship between domestic emissions reductions under the Energy [R]evolution scenarios and the allocation of responsibility through the GDR framework. For the EU and the US, the allocations (solid blue and green lines) are well below the estimated emissions (dotted blue and green lines), with the difference resulting from an international obligation to fund reductions in other countries. In India and China, by contrast, the allocation of permits is greater than the estimated emissions, indicating that other countries will need to support a reduction from the level indicated by the allocation (solid lines) and projected emissions (dashed lines).

Because the forward calculation of the Responsibility and Capacity Indicator (RCI) depends on the budget that is allocated, the percentage reductions of different countries and regions are slightly different under the Energy [R]evolution and advanced Energy [R]evolution pathways. Nevertheless, because neither capacity nor responsibility from 1990-2010 vary in the two scenarios, the RCIs for specific countries are still quite similar, and thus the actual allocations going forward differ between the two scenarios primarily because of the stricter targets in the advanced scenario.

It is also important to note that because GDRs allocate obligations as a percentage of the global commitment, measured in $MtCO_2$ in this example, a country with lower per capita emissions will appear to have a more stringent reduction target, when their target is stated in terms of a percentage of 1990 emissions by 2020 or 2030. However, it should be borne in mind that the GDR calculation does not specify the split between domestic and internationally supported reductions. Since we assume that emissions trading or a similar mechanism will lead to a rough equalisation of the marginal cost of reductions, it is in essence the "per capita tonnes of reductions", and thus per capita costs, which are made comparable (not equal) through the calculation of the RCI. With this in mind, we can see under the Energy [R]evolution scenario that the OECD nations have a global responsibility equal to a reduction to 45% below 1990 levels in 2020 and 2% of 1990 levels in 2030.

figure 2.8: annual ghg emissions and reduction pathways allocated under the GDR system for the USA, Europe, China and India



Based on the Energy [R]evolution pathway for the three OECD regions the total domestic emissions would add up to 9.9 $GtCO_2$ by 2020 and 7.2 $GtCO_2$ by 2030

Under the GDR scheme the OECD regions would have an emissions budget of 8.14 $GtCO_2$ by 2020 and 2.9 $GtCO_2$ by 2030. Therefore the richer nations have to finance the saving of 1.7 $GtCO_2$ by 2020 and 4.3 $GtCO_2$ by 2030 in non-OECD countries.

The non-OECD countries would in aggregate see their emissions allocation rise from 195% of 1990 levels in 2020 to 200% in 2030. In $MtCO_2$, China's emissions allocation would rise from about 8,200 in 2015 to about 8,500 in 2020 and grow only slightly more by 2030. India by contrast would see its allocation rise from 1,600 $MtCO_2$ today to about 2,000 by 2020 and 2,800 $MtCO_2$ in 2030. Within the OECD, the US allocation would fall to 52% of 1990 levels by 2020 and 2% by 2030, while the EU's allocation would fall from 84% today to 33% of 1990 levels in 2020 and -3% of 1990 levels by 2030. (A negative emissions allocation is simply a requirement to buy a larger quantity of emission permits/support a larger amount of mitigation internationally.)

Under the advanced Energy [R]evolution scenario, which has global emissions falling to 25 $GtCO_2$ in 2020, instead of 27 $GtCO_2$ in the basic version, and then to 18 $GtCO_2$ instead of 22 $GtCO_2$ in 2030, reductions are correspondingly steeper. The OECD countries' allocation of emissions falls to 19% of 1990 levels in 2020 and -22% in 2030, with the US share being 20% and -24% respectively and the EU's share 12% and -22%. China's emissions allocation peaks at 8,300 $MtCO_2$ (instead of 8,500 under the basic scenario) and falls to 7,300 $MtCO_2$ by 2030; India, however, changes little from its allowances under the less stringent global pathway.

For an interesting comparison in terms of relatively wealthy "developing" countries, which are currently completely excluded from binding targets under the Kyoto protocol, consider Brazil and Mexico; both see their allocation falling immediately below their 2010 levels. In the Energy [R]evolution scenario, the drop is about a 15% reduction below 2010 levels by 2020; in the advanced scenario, the drop is about a 30% reduction below 2010 levels.

Table 2.7 presents an overview of the CO_2 emission allocations by country and/or region based on the global Energy [R]evolution pathway towards a level of 27 $GtCO_2$ in 2020 and 21.9 $GtCO_2$ in 2030. The advanced version shown in Table 2.8 has a stricter reduction pathway, falling to 18.3 $GtCO_2$ by 2030, a bit more than ten years ahead of the basic scenario. The GDR system allocates the same emission allocations for each country under the advanced Energy [R]evolution pathway, but this scenario also results in a faster uptake of renewable energy, enabling developing countries to leapfrog from conventional to renewables faster. This pathway might also reduce stranded investments resulting from closed fossil fuel power stations, as developing countries will be able to build up the energy infrastructure with new technologies from the very beginning.

In total, all the OECD countries will have cumulative emissions allocations between 1990 and 2030 of 8.14 $GtCO_2$ and 7.35 $GtCO_2$ under the advanced Energy [R]evolution scenario. The scenarios show that 21% (basic version) or 27% (advanced) of those emission reductions will have to come from international actions, as domestic emissions are still too high. In summary, the OECD countries will have to finance a saving of 45 $GtCO_2$ for non-OECD countries. A possible mechanism to support the introduction of renewable power generation in those countries - crucial to the Energy [R]evolution scenarios - would be the feed-in tariff support system described below.

applying GDR to the energy [r]evolution

It is obvious that, given the huge responsibility and large capacity of industrialised countries, they have a high RCI. Their responsibility for implementing emission reductions should therefore go well beyond the domestic reductions they can achieve by implementing the Energy [R]evolution. Tables 2.7 and 2.8 show the difference between their emissions under the two ER scenarios and the emission reductions they would be responsible for if the RCI is used to distribute their global obligations more equitably.

The difference between their domestic emissions in the ER scenarios and the levels under the RCI system defines the responsibility that these countries will have to fund the implementation of the Energy [R]evolution scenario in developing countries

image GREENPEACE AND AN INDEPENDENT NASA-FUNDED SCIENTIST COMPLETED MEASUREMENTS OF MELT LAKES ON THE GREENLAND ICE SHEET THAT SHOW ITS VULNERABILITY TO WARMING TEMPERATURES.

table 2.7: greenhouse development emission allocation - energy [r]evolution base case

FOSSIL CO_2 EMISSION IN [MT CO_2]	1990	2015 GDR EMISSION RIGHTS	2015 DOMESTIC EMISSION RIGHTS UNDER ADV. E[R]	2015 MITIGATION FUND	2020 GDR EMISSION RIGHTS	2020 DOMESTIC EMISSION RIGHTS UNDER ADV. E[R]	2020 MITIGATION FUND	2030 GDR EMISSION RIGHTS	2030 DOMESTIC EMISSION RIGHTS UNDER ADV. E[R]	2030 MITIGATION FUND
OECD	**11,405**	**10,834**	**11,716**	**-882**	**8,143**	**9,919**	**-1,775**	**2,926**	**7,253**	**-4,327**
North America	5,756	5,732	6,094	-361	4,357	5,223	-865	1,740	3,655	-1,915
United States	5,009	4,847	5,183	-336	3,618	4,393	-775	1,278	3,043	-1,765
Mexico	302	406	394	12	361	363	-2	276	279	-2
Canada	445	479	516	-37	378	466	-88	186	334	-148
Europe	4,026	3,263	3,642	-379	2,394	2,947	-553	648	2,209	-1,561
Pacific	1,623	1,838	1,980	-142	1,392	1,749	-357	538	1,389	-851
Non-OECD	**9,542**	**18,023**	**28,308**	**885**	**18,587**	**16,810**	**1,777**	**19,037**	**14,707**	**4,330**
Transition Economies	4,158	2,598	2,382	216	2,418	1,931	487	2,077	1,440	637
Asia	3,596	11,734	11,170	564	12,498	11,526	972	13,284	10,252	3,032
China	2,277	8,226	7,830	396	8,503	8,033	470	8,065	6,557	1,508
India	607	1,712	1,626	86	2,054	1,807	247	2,861	2,035	826
Other Asia	712	1,796	1,714	82	1,940	1,686	254	2,358	1,660	698
Africa	566	962	1,001	39	922	1,013	91	887	1,031	143
Middle East	608	1,661	1,555	105	1,768	1,439	329	1,978	1,248	730
Latin America	613	1,069	1,030	39	981	901	80	811	736	75
World	**20,947**	**28,857**	**28,854**		**26,730**	**26,729**		**21,963**	**21,960**	

table 2.8: greenhouse development emission allocation - advanced energy [r]evolution base case

FOSSIL CO_2 EMISSION IN [MT CO_2]	1990	2015 GDR EMISSION RIGHTS	2015 DOMESTIC EMISSION RIGHTS UNDER ADV. E[R]	2015 MITIGATION FUND	2020 GDR EMISSION RIGHTS	2020 DOMESTIC EMISSION RIGHTS UNDER ADV. E[R]	2020 MITIGATION FUND	2030 GDR EMISSION RIGHTS	2030 DOMESTIC EMISSION RIGHTS UNDER ADV. E[R]	2030 MITIGATION FUND
OECD	**11,405**	**10,524**	**11,317**	**-793**	**7,359**	**9,327**	**-1,969**	**911**	**5,941**	**-5,029**
North America	5,756	5,575	5,841	-266	3,956	4,749	-793	694	2,724	-2,030
United States	5,009	4,709	4,942	-233	3,267	3,965	-698	370	2,188	-1,818
Mexico	302	399	396	3	341	350	-9	218	246	-29
Canada	445	468	503	-36	349	434	-85	106	290	-184
Europe	4,026	3,160	3,488	-328	2,134	2,908	-774	-11	1,931	-1,942
Pacific	1,623	1,789	1,988	-199	1,269	1,671	-402	229	1,286	-1,057
Non-OECD	**9,542**	**17,892**	**17,109**	**783**	**18,161**	**16,179**	**1,983**	**17,459**	**12,436**	**5,022**
Transition Economies	4,158	2,571	2,382	189	2,342	1,906	436	1,837	1,303	534
Asia	3,596	11,671	11,142	529	12,266	11,067	1,199	12,301	8,485	3,817
China	2,277	8,178	7,813	366	8,323	7,875	448	7,324	5,744	1,580
India	607	1,709	1,620	90	2,039	1,524	515	2,742	1,332	1,410
Other Asia	712	1,784	1,709	74	1,904	1,667	236	2,236	1,409	827
Africa	566	953	998	44	895	970	74	804	889	85
Middle East	608	1,646	1,571	75	1,729	1,393	336	1,857	1,124	733
Latin America	613	1,051	1,016	34	929	843	86	659	636	23
World	**20,947**	**28,417**	**28,426**		**25,520**	**25,506**		**18,370**	**18,377**	

nuclear power and climate protection

GLOBAL

3

image SIGN ON A RUSTY DOOR AT CHERNOBYL ATOMIC STATION.

"safety and security risks, radioactive waste, nuclear proliferation..."

GREENPEACE INTERNATIONAL
CLIMATE CAMPAIGN

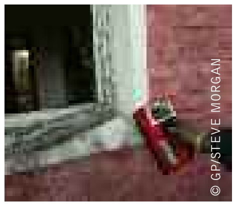


image MEASURING RADIATION LEVELS OF A HOUSE IN THE TOWN OF PRIPYAT THAT WAS LEFT ABANDONED AFTER THE NUCLEAR DISASTER.

© GP/STEVE MORGAN

Nuclear energy is a relatively minor industry with major problems. It covers just one sixteenth of the world's primary energy consumption, a share set to decline over the coming decades. The average age of operating commercial nuclear reactors is 23 years, so more power stations are being shut down than started. In 2008, world nuclear production fell by 2% compared to 2006, and the number of operating reactors as of January 2010 was 436, eight less than at the historical peak of 2002.

In terms of new power stations, the amount of nuclear capacity added annually between 2000 and 2009 was on average 2,500 MWe. This was six times less than wind power (14,500 MWe per annum between 2000 and 2009). In 2009, 37,466 MW of new wind power capacity was added globally to the grid, compared to only 1,068 MW of nuclear. This new wind capacity will generate as much electricity as 12 nuclear reactors; the last time the nuclear industry managed to add this amount of new capacity in a single year was in 1988.

Despite the rhetoric of a 'nuclear renaissance', the industry is struggling with a massive increase in costs and construction delays as well as safety and security problems linked to reactor operation, radioactive waste and nuclear proliferation.

a solution to climate protection?

The promise of nuclear energy to contribute to both climate protection and energy supply needs to be checked against reality. In the most recent Energy Technology Perspectives report published by the International Energy Agency[17], for example, its Blue Map scenario outlines a future energy mix which would halve global carbon emissions by the middle of this century. To reach this goal the IEA assumes a massive expansion of nuclear power between now and 2050, with installed capacity increasing four-fold and electricity generation reaching 9,857 TWh/year, compared to 2,608 TWh in 2007. In order to achieve this, the report says that 32 large reactors (1,000 MWe each) would have to be built every year from now until 2050. This would be unrealistic, expensive, hazardous and too late to make a difference. Even so, according to the IEA scenario, such a massive nuclear expansion would cut carbon emissions by less than 5%.

unrealistic: Such a rapid growth is practically impossible given the technical limitations. This scale of development was achieved in the history of nuclear power for only two years at the peak of the state-driven boom of the mid-1980s. It is unlikely to be achieved again, not to mention maintained for 40 consecutive years. While 1984 and 1985 saw 31 GW of newly added nuclear capacity, the decade average was 17 GW each year. In the past ten years, less than three large reactors have been brought on line annually, and the current production capacity of the global nuclear industry cannot deliver more than an annual six units.

expensive: The IEA scenario assumes very optimistic investment costs of $2,100/kWe installed, in line with what the industry has been promising. The reality indicates three to four times that much. Recent estimates by US business analysts Moody's (May 2008) put the cost of nuclear investment as high as $7,500/kWe. Price quotes for projects under preparation in the US cover a range from $5,200 to 8,000/kWe.[18] The latest cost estimate for the first French EPR pressurised water reactor being built in Finland is $5,000/kWe, a figure likely to increase for later reactors as prices escalate. The Wall Street Journal has reported that the cost index for nuclear components has risen by 173% since 2000 – a near tripling over the past eight years.[19] Building 1,400 large reactors of 1,000 MWe, even at the current cost of about $7,000/kWe, would require an investment of US$9.8 trillion.

hazardous: Massive expansion of nuclear energy would necessarily lead to a large increase in related hazards. These include the risk of serious reactor accidents, the growing stockpiles of deadly high level nuclear waste which will need to be safeguarded for thousands of years, and potential proliferation of both nuclear technologies and materials through diversion to military or terrorist use. The 1,400 large operating reactors in 2050 would generate an annual 35,000 tonnes of spent fuel (assuming they are light water reactors, the most common design for most new projects). This also means the production of 350,000 kilograms of plutonium each year, enough to build 35,000 crude nuclear weapons.

Most of the expected electricity demand growth by 2050 will occur in non-OECD countries. This means that a large proportion of the new reactors would need to be built in those countries in order to have a global impact on emissions. At the moment, the list of countries with announced nuclear ambitions is long and worrying in terms of their political situation and stability, especially with the need to guarantee against the hazards of accidents and proliferation for many decades. The World Nuclear Association listed the Emerging Nuclear Energy Countries in February 2010. In Europe this included Italy, Albania, Serbia, Portugal, Norway, Poland, Belarus, Estonia, Latvia, Ireland and Turkey. In the Middle East and North Africa: Iran, Gulf states including UAE, Yemen, Israel, Syria, Jordan, Egypt, Tunisia, Libya, Algeria and Morocco. In central and southern Africa: Nigeria, Ghana, Uganda and Namibia. In South America: Chile, Ecuador and Venezuela. In central and southern Asia: Azerbaijan, Georgia, Kazakhstan, Mongolia and Bangladesh. In South East Asia: Indonesia, Philippines, Vietnam, Thailand, Malaysia, Australia and New Zealand.

slow: Climate science says that we need to reach a peak of global greenhouse gas emissions in 2015 and reduce them by 20% by 2020. Even in developed countries with an established nuclear infrastructure it takes at least a decade from the decision to build a reactor to the delivery of its first electricity, and often much longer. This means that even if the world's governments decided to implement strong nuclear expansion now, only a few reactors would start generating electricity before 2020. The contribution from nuclear power towards reducing emissions would come too late to help.

references
17 'ENERGY TECHNOLOGY PERSPECTIVES 2008 - SCENARIOS & STRATEGIES TO 2050', IEA.
18 PLATTS, 2008; *ENERGY BIZ*, MAY/JUNE 2008
19 *WALL STREET JOURNAL*, 29 MAY 2008

nuclear power blocks solutions

Even if the ambitious nuclear scenario is implemented, regardless of costs and hazards, the IEA concludes that the contribution of nuclear power to reductions in greenhouse gas emissions from the energy sector would be only 4.6% - less than 3% of the global overall reduction required.

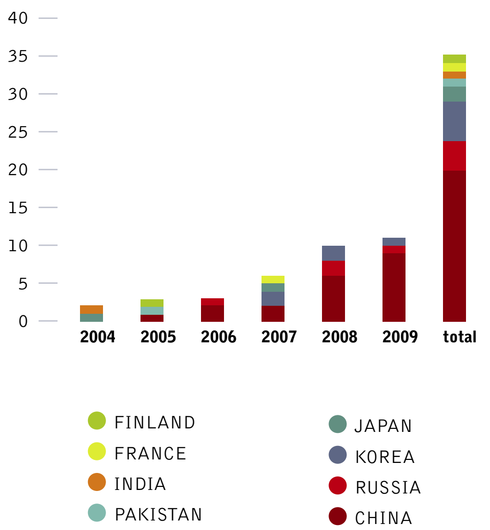
There are other technologies that can deliver much larger emission reductions, and much faster. Their investment costs are lower and they do not create global security risks. Even the IEA finds that the combined potential of efficiency savings and renewable energy to cut emissions by 2050 is more than ten times larger than that of nuclear.

The world has limited time, finance and industrial capacity to change our energy sector and achieve a large reduction in greenhouse emissions. Choosing the pathway of spending $10 trillion on nuclear development would be a fatally wrong decision. It would not save the climate but it would necessarily take resources away from solutions described in this report and at the same time create serious global security hazards. Therefore new nuclear reactors are a clearly dangerous obstacle to the protection of the climate.

nuclear power in the energy [r]evolution scenario

For the reasons explained above, the Energy [R]evolution scenario envisages a nuclear phase-out. Existing reactors would be closed at the end of their average operational lifetime of 35 years. We assume that no new construction is started and only two thirds of the reactors currently under construction will be finally put into operation.

figure 3.1: new reactor construction starts in past six years. OUT OF 35 NEW REACTORS WHOSE CONSTRUCTION HAS STARTED SINCE 2004, ONLY TWO ARE LOCATED IN EUROPE (FINLAND AND FRANCE).



the dangers of nuclear power

Although the generation of electricity through nuclear power produces much less carbon dioxide than fossil fuels, there are multiple threats to people and the environment from its operations.

The main risks are:

- Nuclear Proliferation
- Nuclear Waste
- Safety Risks

These are the background to why nuclear power has been discounted as a future technology in the Energy [R]evolution Scenario.

1. nuclear proliferation

Manufacturing a nuclear bomb requires fissile material - either uranium-235 or plutonium-239. Most nuclear reactors use uranium as a fuel and produce plutonium during their operation. It is impossible to adequately protect a large reprocessing plant in order to prevent the diversion of plutonium to nuclear weapons. A small-scale plutonium separation plant can be built in four to six months, so any country with an ordinary reactor can produce nuclear weapons relatively quickly.

The result is that nuclear power and nuclear weapons have grown up like Siamese twins. Since international controls on nuclear proliferation began, Israel, India, Pakistan and North Korea have all obtained nuclear weapons, demonstrating the link between civil and military nuclear power. Both the International Atomic Energy Agency (IAEA) and the Nuclear Non-proliferation Treaty (NPT) embody an inherent contradiction - seeking to promote the development of 'peaceful' nuclear power whilst at the same time trying to stop the spread of nuclear weapons.

Israel, India and Pakistan all used their civil nuclear operations to develop weapons capability, operating outside international safeguards. North Korea developed a nuclear weapon even as a signatory of the NPT. A major challenge to nuclear proliferation controls has been the spread of uranium enrichment technology to Iran, Libya and North Korea. The Director General of the International Atomic Energy Agency, Mohamed El Baradei, has said that "should a state with a fully developed fuel-cycle capability decide, for whatever reason, to break away from its non-proliferation commitments, most experts believe it could produce a nuclear weapon within a matter of months".[20]

The United Nations Intergovernmental Panel on Climate Change has also warned that the security threat of trying to tackle climate change with a global fast reactor programme (using plutonium fuel) "would be colossal".[21] Even without fast reactors, all of the reactor designs currently being promoted around the world could be fuelled by MOX (mixed oxide fuel), from which plutonium can be easily separated.

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20 MOHAMED ELBARADEI, 'TOWARDS A SAFER WORLD', *ECONOMIST*, 18 OCTOBER 2003
21 IPCC WORKING GROUP II, 'IMPACTS, ADAPTATIONS AND MITIGATION OF CLIMATE CHANGE: SCIENTIFIC-TECHNICAL ANALYSES', 1995

image NUCLEAR REACTOR IN LIANYUNGANG, CHINA.

Restricting the production of fissile material to a few 'trusted' countries will not work. It will engender resentment and create a colossal security threat. A new UN agency is needed to tackle the twin threats of climate change and nuclear proliferation by phasing out nuclear power and promoting sustainable energy, in the process promoting world peace rather than threatening it.

2. nuclear waste

The nuclear industry claims it can 'dispose' of its nuclear waste by burying it deep underground, but this will not isolate the radioactive material from the environment forever. A deep dump only slows down the release of radioactivity into the environment. The industry tries to predict how fast a dump will leak so that it can claim that radiation doses to the public living nearby in the future will be "acceptably low". But scientific understanding is not sufficiently advanced to make such predictions with any certainty.

As part of its campaign to build new nuclear stations around the world, the industry claims that problems associated with burying nuclear waste are to do with public acceptability rather than technical issues. It points to nuclear dumping proposals in Finland, Sweden or the United States to underline its argument.

The most hazardous waste is the highly radioactive waste (or spent) fuel removed from nuclear reactors, which stays radioactive for hundreds of thousands of years. In some countries the situation is exacerbated by 'reprocessing' this spent fuel, which involves dissolving it in nitric acid to separate out weapons-usable plutonium. This process leaves behind a highly radioactive liquid waste. There are about 270,000 tonnes of spent nuclear waste fuel in storage, much of it at reactor sites. Spent fuel is accumulating at around 12,000 tonnes per year, with around a quarter of that going for reprocessing.[22] No country in the world has a solution for high level waste.

The IAEA recognises that, despite its international safety requirements, "...radiation doses to individuals in the future can only be estimated and that the uncertainties associated with these estimates will increase for times farther into the future."

The least damaging option for waste already created at the current time is to store it above ground, in dry storage at the site of origin, although this option also presents major challenges and threats. The only real solution is to stop producing the waste.

3. safety risks

Windscale (1957), Three Mile Island (1979), Chernobyl (1986) and Tokaimura (1999) are only a few of the hundreds of nuclear accidents which have occurred to date.

- A simple power failure at a Swedish nuclear plant in 2006 highlighted our vulnerability to nuclear catastrophe. Emergency power systems at the Forsmark plant failed for 20 minutes during a power cut and four of Sweden's ten nuclear power stations had to be shut down. If power was not restored there could have been a major incident within hours. A former director of the Forsmark plant later said that "it was pure luck there wasn't a meltdown". The closure of the plants removed at a stroke roughly 20% of Sweden's electricity supply.
- A nuclear chain reaction must be kept under control, and harmful radiation must, as far as possible, be contained within the reactor, with radioactive products isolated from humans and carefully managed. Nuclear reactions generate high temperatures, and fluids used for cooling are often kept under pressure. Together with the intense radioactivity, these high temperatures and pressures make operating a reactor a difficult and complex task.
- The risks from operating reactors are increasing and the likelihood of an accident is now higher than ever. Most of the world's reactors are more than 25 years old and therefore more prone to age related failures. Many utilities are attempting to extend their life from the 30 years or so they were originally designed for up to 60 years, posing new risks.
- De-regulation has meanwhile pushed nuclear utilities to decrease safety-related investments and limit staff whilst increasing reactor pressure and operational temperature and the burn-up of the fuel. This accelerates ageing and decreases safety margins.

"despite the rhetoric of a 'nuclear-renaissance', the industry is struggling with a massive increase in costs and construction delays as well as safety and security problems."

references
22 'WASTE MANAGEMENT IN THE NUCLEAR FUEL CYCLE', WORLD NUCLEAR ASSOCIATION, INFORMATION AND ISSUE BRIEF, FEBRUARY 2006 (WWW.WORLD-NUCLEAR.ORG/INFO/INF04.HTM)

figure 3.2: the nuclear fuel chain

U#92

1. uranium mining

Uranium, used in nuclear power plants, is extracted from mines in a handful of countries. Over 90% of supply comes from just seven countries: Canada, Kazakhstan, Australia, Namibia, Russia, Niger and Uzbekistan. Mine workers breathe in radioactive gas from which they are in danger of contracting lung cancer. Uranium mining produces huge quantities of mining debris, including radioactive particles that can contaminate surface water and food.

2. uranium enrichment

Natural uranium and concentrated 'yellow cake' contain just 0.7% of the fissionable uranium isotope 235. To be suitable for use in most nuclear reactors, its share must go up to 3 or 5% via enrichment. This process can be carried out in 16 facilities around the world. 80% of the total volume is rejected as 'tails', a waste product. Enrichment generates massive amounts of 'depleted uranium' that ends up as long-lived radioactive waste or is used in weapons or as tank shielding.

3. fuel rod – production

Enriched material is converted into uranium dioxide and compressed to pellets in fuel rod production facilities. These pellets fill 4 metre long tubes called fuel rods. There are 29 fuel rod production facilities globally. The worst accident in this type of facility happened in September 1999 in Tokaimura, Japan, when two workers died. Several hundred workers and villagers were also exposed to radiation.

4. power plant operation

Uranium nuclei are split in a nuclear reactor, releasing energy which heats up water. The compressed steam is converted in a turbine generator into electricity. This process creates a radioactive 'cocktail' which involves more than 100 products. One of these is the highly toxic and long-lasting plutonium. Radioactive material can enter the environment through accidents at nuclear power plants. The worst accident to date happened at Chernobyl in the then Soviet Union in 1986. A typical nuclear reactor generates enough plutonium every year for the production of 40 nuclear weapons.

5. reprocessing

Reprocessing involves the chemical extraction of contaminated uranium and plutonium from used reactor fuel rods. There are now over 230,000 kilograms of plutonium stockpiled around the world from reprocessing – five kilograms is sufficient for one nuclear bomb. Reprocessing is not the same as recycling: the volume of waste increases many tens of times and millions of litres of radioactive waste are discharged into the sea and air each day. The process also demands the transport of radioactive material and nuclear waste by ship, rail, air and road around the world. An accident or terrorist attack could release vast quantities of nuclear material into the environment. There is no way to guarantee the safety of nuclear transport.

6. waste storage

There is not a single final storage facility for highly radioactive nuclear waste available anywhere in the world. Safe secure storage of high level waste over thousands of years remains unproven, leaving a deadly legacy for future generations. Despite this the nuclear industry continues to generate more and more waste each day.

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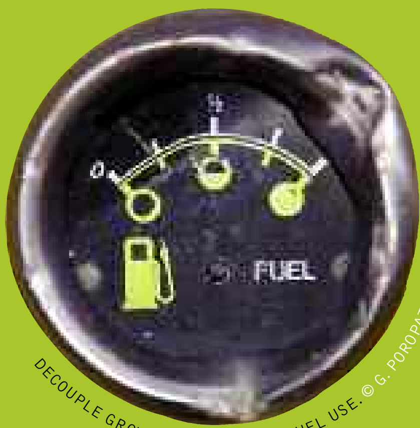


DECOUPLE GROWTH FROM FOSSIL FUEL USE. © G. POROPAT/DREAMSTIME

"half the solution to climate change is the smart use of power."

GREENPEACE INTERNATIONAL
CLIMATE CAMPAIGN

The climate change imperative demands nothing short of an energy revolution. The expert consensus is that this fundamental shift must begin immediately and be well underway within the next ten years in order to avert the worst impacts. What is needed is a complete transformation of the way we produce, consume and distribute energy, and at the same time maintain economic growth. Nothing short of such a revolution will enable us to limit global warming to less than a rise in temperature of well below 2° Celsius, above which the impacts become devastating.

Current electricity generation relies mainly on burning fossil fuels, with their associated CO_2 emissions, in very large power stations which waste much of their primary input energy. More energy is lost as the power is moved around the electricity grid network and converted from high transmission voltage down to a supply suitable for domestic or commercial consumers. The system is innately vulnerable to disruption: localised technical, weather-related or even deliberately caused faults can quickly cascade, resulting in widespread blackouts. Whichever technology is used to generate electricity within this old fashioned configuration, it will inevitably be subject to some, or all, of these problems. At the core of the energy revolution there therefore needs to be a change in the way that energy is both produced and distributed.

key principles

the energy [r]evolution can be achieved by adhering to five key principles:

1. **respect natural limits – phase out fossil fuels by the end of this century** We must learn to respect natural limits. There is only so much carbon that the atmosphere can absorb. Each year we emit over 25 billion tonnes of carbon equivalent; we are literally filling up the sky. Geological resources of coal could provide several hundred years of fuel, but we cannot burn them and keep within safe limits. Oil and coal development must be ended.

   While the basic Energy [R]evolution scenario has a reduction target for energy related CO_2 emissions of 50% from 1990 levels by 2050, the advanced case goes one step further and aims for a reduction target of over 80%.

2. **equity and fairness** As long as there are natural limits there needs to be a fair distribution of benefits and costs within societies, between nations and between present and future generations. At one extreme, a third of the world's population has no access to electricity, whilst the most industrialised countries consume much more than their fair share.

   The effects of climate change on the poorest communities are exacerbated by massive global energy inequality. If we are to address climate change, one of the principles must be equity and fairness, so that the benefits of energy services – such as light, heat, power and transport – are available for all: north and south, rich and poor. Only in this way can we create true energy security, as well as the conditions for genuine human wellbeing.

   The Energy [R]evolution scenario has a target to achieve energy equity as soon as technically possible. By 2050 the average per capita emission should be between 1 and 2 tonnes of CO_2.

3. **implement clean, renewable solutions and decentralise energy systems** There is no energy shortage. All we need to do is use existing technologies to harness energy effectively and efficiently. Renewable energy and energy efficiency measures are ready, viable and increasingly competitive. Wind, solar and other renewable energy technologies have experienced double digit market growth for the past decade.

   Just as climate change is real, so is the renewable energy sector. Sustainable decentralised energy systems produce less carbon emissions, are cheaper and involve less dependence on imported fuel. They create more jobs and empower local communities. Decentralised systems are more secure and more efficient. This is what the energy revolution must aim to create.

"THE STONE AGE DID NOT END FOR LACK OF STONE, AND THE OIL AGE WILL END LONG BEFORE THE WORLD RUNS OUT OF OIL."

Sheikh Zaki Yamani, former Saudi Arabian oil minister

   To stop the earth's climate spinning out of control, most of the world's fossil fuel reserves – coal, oil and gas – must remain in the ground. Our goal is for humans to live within the natural limits of our small planet.

4. **decouple growth from fossil fuel use** Starting in the developed countries, economic growth must be fully decoupled from fossil fuel usage. It is a fallacy to suggest that economic growth must be predicated on their increased combustion.

   We need to use the energy we produce much more efficiently, and we need to make the transition to renewable energy and away from fossil fuels quickly in order to enable clean and sustainable growth.

5. **phase out dirty, unsustainable energy** We need to phase out coal and nuclear power. We cannot continue to build coal plants at a time when emissions pose a real and present danger to both ecosystems and people. And we cannot continue to fuel the myriad nuclear threats by pretending nuclear power can in any way help to combat climate change. There is no role for nuclear power in the Energy [R]evolution .

from principles to practice

In 2007, renewable energy sources accounted for 13% of the world's primary energy demand. Biomass, which is mostly used for heating, was the main renewable energy source. The share of renewable energy in electricity generation was 18%. The contribution of renewables to primary energy demand for heat supply was around 24%. About 80% of primary energy supply today still comes from fossil fuels, and 6% from nuclear power.[23]

The time is right to make substantial structural changes in the energy and power sector within the next decade. Many power plants in industrialised countries, such as the USA, Japan and the European Union, are nearing retirement; more than half of all operating power plants are over 20 years old. At the same time developing countries, such as China, India and Brazil, are looking to satisfy the growing energy demand created by their expanding economies.

references
23 'ENERGY BALANCE OF NON-OECD COUNTRIES' AND 'ENERGY BALANCE OF OECD COUNTRIES', IEA, 2009

image GREENPEACE OPENS A SOLAR ENERGY WORKSHOP IN BOMA. A MOBILE PHONE GETS CHARGED BY A SOLAR ENERGY POWERED CHARGER.

Within the next ten years, the power sector will decide how this new demand will be met, either by fossil and nuclear fuels or by the efficient use of renewable energy. The Energy [R]evolution scenario is based on a new political framework in favour of renewable energy and cogeneration combined with energy efficiency.

To make this happen both renewable energy and cogeneration – on a large scale and through decentralised, smaller units – have to grow faster than overall global energy demand. Both approaches must replace old generating technologies and deliver the additional energy required in the developing world.

As it is not possible to switch directly from the current large scale fossil and nuclear fuel based energy system to a full renewable energy supply, a transition phase is required to build up the necessary infrastructure. Whilst remaining firmly committed to the promotion of renewable sources of energy, we appreciate that gas, used in appropriately scaled cogeneration plants, is valuable as a transition fuel, and able to drive cost-effective decentralisation of the energy infrastructure. With warmer summers, tri-generation, which incorporates heat-fired absorption chillers to deliver cooling capacity in addition to heat and power, will become a particularly valuable means of achieving emissions reductions.

a development pathway

The Energy [R]evolution envisages a development pathway which turns the present energy supply structure into a sustainable system. There are three main stages to this.

step 1: energy efficiency

The Energy [R]evolution is aimed at the ambitious exploitation of the potential for energy efficiency. It focuses on current best practice and technologies that will become available in the future, assuming continuous innovation. The energy savings are fairly equally distributed over the three sectors – industry, transport and domestic/business. Intelligent use, not abstinence, is the basic philosophy for future energy conservation.

The most important energy saving options are improved heat insulation and building design, super efficient electrical machines and drives, replacement of old style electrical heating systems by renewable heat production (such as solar collectors) and a reduction in energy consumption by vehicles used for goods and passenger traffic. Industrialised countries, which currently use energy in the most inefficient way, can reduce their consumption drastically without the loss of either housing comfort or information and entertainment electronics. The Energy [R]evolution scenario uses energy saved in OECD countries as a compensation for the increasing power requirements in developing countries. The ultimate goal is stabilisation of global energy consumption within the next two decades. At the same time the aim is to create 'energy equity' – shifting the current one-sided waste of energy in the industrialised countries towards a fairer worldwide distribution of efficiently used supply.

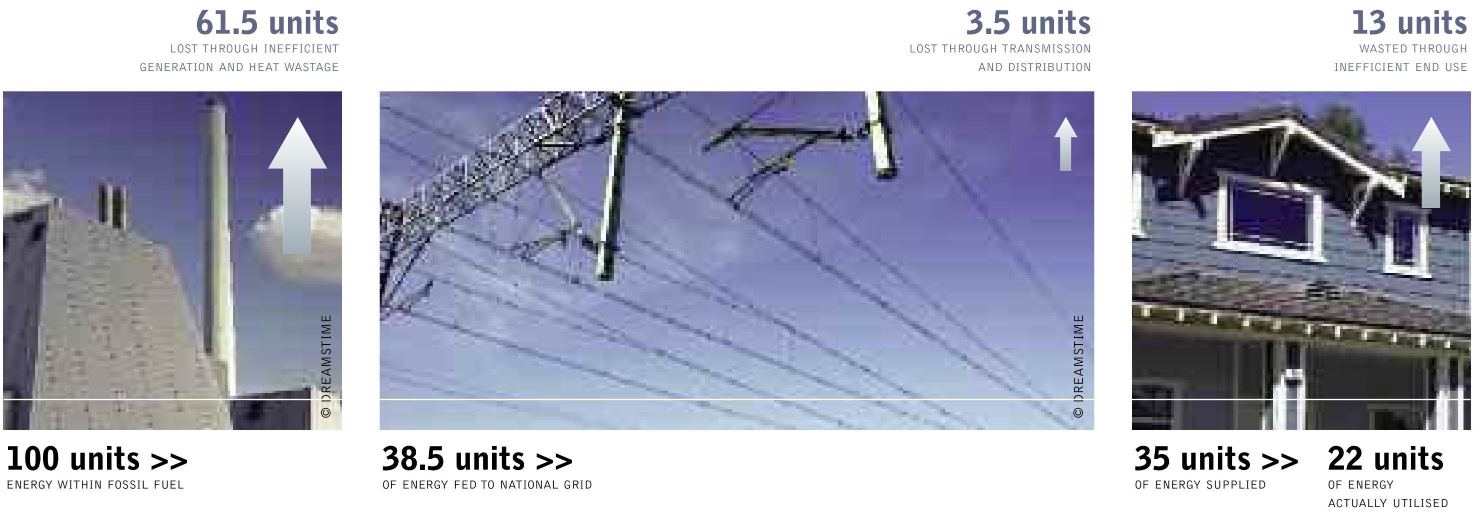
A dramatic reduction in primary energy demand compared to the IEA's Reference scenario (see chapter 6) – but with the same GDP and population development - is a crucial prerequisite for achieving a significant share of renewable energy sources in the overall energy supply system, compensating for the phasing out of nuclear energy and reducing the consumption of fossil fuels.

step 2: the renewable energy [r]evolution

decentralised energy and large scale renewables In order to achieve higher fuel efficiencies and reduce distribution losses, the Energy [R]evolution scenario makes extensive use of Decentralised Energy (DE). This is energy generated at or near the point of use.

DE is connected to a local distribution network system, supplying homes and offices, rather than the high voltage transmission system. The proximity of electricity generating plant to consumers allows any waste heat from combustion processes to be piped to nearby buildings, a system known as cogeneration or combined heat and power. This means that nearly all the input energy is put to use, not just a fraction as with traditional centralised fossil fuel plant.

figure 4.1: centralised energy infrastructures waste more than two thirds of their energy



DE also includes stand-alone systems entirely separate from the public networks, for example heat pumps, solar thermal panels or biomass heating. These can all be commercialised at a domestic level to provide sustainable low emission heating. Although DE technologies can be considered 'disruptive' because they do not fit the existing electricity market and system, with appropriate changes they have the potential for exponential growth, promising 'creative destruction' of the existing energy sector.

A huge proportion of global energy in 2050 will be produced by decentralised energy sources, although large scale renewable energy supply will still be needed in order to achieve a fast transition to a renewables dominated system. Large offshore wind farms and concentrating solar power (CSP) plants in the sunbelt regions of the world will therefore have an important role to play.

cogeneration The increased use of combined heat and power generation (CHP) will improve the supply system's energy conversion efficiency, whether using natural gas or biomass. In the longer term, a decreasing demand for heat and the large potential for producing heat directly from renewable energy sources will limit the need for further expansion of CHP.

renewable electricity The electricity sector will be the pioneer of renewable energy utilisation. Many renewable electricity technologies have been experiencing steady growth over the past 20 to 30 years of up to 35% annually and are expected to consolidate at a high level between 2030 and 2050. By 2050, under the Energy [R]evolution scenario, the majority of electricity will be produced from renewable energy sources. The anticipated growth of electricity use in transport will further promote the effective use of renewable power generation technologies.

renewable heating In the heat supply sector, the contribution of renewables will increase significantly. Growth rates are expected to be similar to those of the renewable electricity sector. Fossil fuels will be increasingly replaced by more efficient modern technologies, in particular biomass, solar collectors and geothermal. By 2050, renewable energy technologies will satisfy the major part of heating and cooling demand.

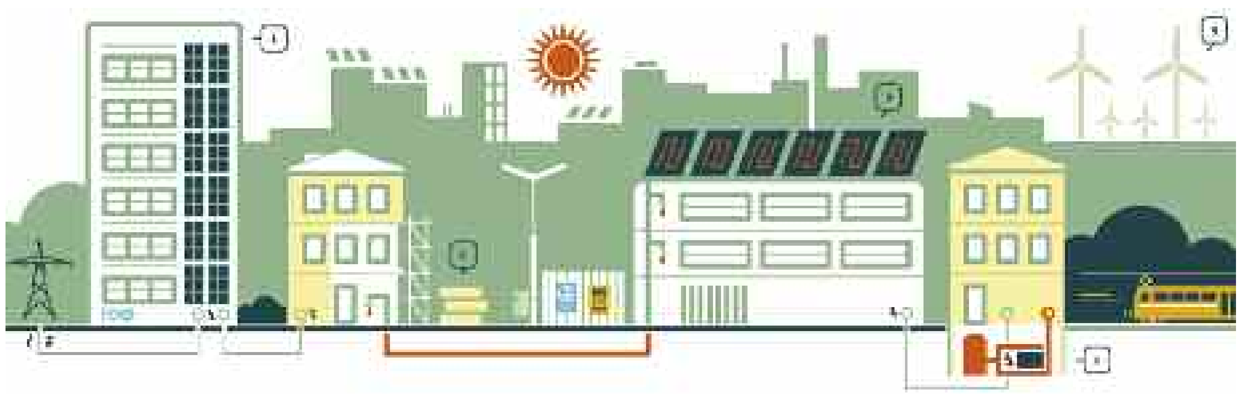
transport Before new technologies, including hybrid or electric cars and new fuels such as bio fuels, can play a substantial role in the transport sector, the existing large efficiency potentials have to be exploited. In this study, biomass is primarily committed to stationary applications; the use of bio fuels for transport is limited by the availability of sustainably grown biomass.[24] Electric vehicles will therefore play an even more important role in improving energy efficiency in transport and substituting for fossil fuels.

Overall, to achieve an economically attractive growth of renewable energy sources, a balanced and timely mobilisation of all technologies is essential. Such a mobilisation depends on the resource availability, cost reduction potential and technological maturity. And alongside technology driven solutions, lifestyle changes - like simply driving less and using more public transport – have a huge potential to reduce greenhouse gas emissions.

figure 4.2: a decentralised energy future

EXISTING TECHNOLOGIES, APPLIED IN A DECENTRALISED WAY AND COMBINED WITH EFFICIENCY MEASURES AND ZERO EMISSION DEVELOPMENTS, CAN DELIVER LOW CARBON COMMUNITIES AS ILLUSTRATED HERE. POWER IS GENERATED USING EFFICIENT COGENERATION TECHNOLOGIES PRODUCING BOTH HEAT (AND SOMETIMES COOLING) PLUS ELECTRICITY, DISTRIBUTED VIA LOCAL NETWORKS. THIS SUPPLEMENTS THE ENERGY PRODUCED FROM BUILDING INTEGRATED GENERATION. ENERGY SOLUTIONS COME FROM LOCAL OPPORTUNITIES AT BOTH A SMALL AND COMMUNITY SCALE. THE TOWN SHOWN HERE MAKES USE OF – AMONG OTHERS – WIND, BIOMASS AND HYDRO RESOURCES. NATURAL GAS, WHERE NEEDED, CAN BE DEPLOYED IN A HIGHLY EFFICIENT MANNER.

city



1. **PHOTOVOLTAIC, SOLAR FAÇADES** WILL BE A DECORATIVE ELEMENT ON OFFICE AND APARTMENT BUILDINGS. PHOTOVOLTAIC SYSTEMS WILL BECOME MORE COMPETITIVE AND IMPROVED DESIGN WILL ENABLE ARCHITECTS TO USE THEM MORE WIDELY.
2. **RENOVATION CAN CUT ENERGY CONSUMPTION OF OLD BUILDINGS** BY AS MUCH AS 80% - WITH IMPROVED HEAT INSULATION, INSULATED WINDOWS AND MODERN VENTILATION SYSTEMS.
3. **SOLAR THERMAL COLLECTORS** PRODUCE HOT WATER FOR BOTH THEIR OWN AND NEIGHBOURING BUILDINGS.
4. **EFFICIENT THERMAL POWER (CHP) STATIONS** WILL COME IN A VARIETY OF SIZES - FITTING THE CELLAR OF A DETACHED HOUSE OR SUPPLYING WHOLE BUILDING COMPLEXES OR APARTMENT BLOCKS WITH POWER AND WARMTH WITHOUT LOSSES IN TRANSMISSION.
5. **CLEAN ELECTRICITY** FOR THE CITIES WILL ALSO COME FROM FARTHER AFIELD. OFFSHORE WIND PARKS AND SOLAR POWER STATIONS IN DESERTS HAVE ENORMOUS POTENTIAL.

references
24 SEE CHAPTER 13

image THE TRUCK DROPS ANOTHER LOAD OF WOOD CHIPS AT THE BIOMASS POWER PLANT IN LELYSTAD, THE NETHERLANDS.

new business model

The Energy [R]evolution scenario will also result in a dramatic change in the business model of energy companies, utilities, fuel suppliers and the manufacturers of energy technologies. Decentralised energy generation and large solar or offshore wind arrays which operate in remote areas, without the need for any fuel, will have a profound impact on the way utilities operate in 2020 and beyond.

While today the entire power supply value chain is broken down into clearly defined players, a global renewable power supply will inevitably change this division of roles and responsibilities. The following table provides an overview of today's value chain and how it would change in a revolutionised energy mix.

While today a relatively small number of power plants, owned and operated by utilities or their subsidiaries, are needed to generate the required electricity, the Energy [R]evolution scenario projects a future share of around 60 to 70% of small but numerous decentralised power plants performing the same task. Ownership will therefore shift towards more private investors and away from centralised utilities. In turn, the value chain for power companies will shift towards project development, equipment manufacturing and operation and maintenance.

table 4.2: utilities today

FUEL SUPPLY	(LARGE SCALE) GENERATION	TRADING	TRANS-MISSION	DISTRIBUTION	SALES
utilities					
		trader (e.g. banks)		local DSO	
	IPP		TSO		retailer
mining companies					

FUEL SUPPLY	(LARGE & SMALL SCALE) GENERATION	TRADING	TRANS-MISSION STORAGE	DISTRIBUTION RENEWABLE GENERATION	SALES RENEWABLE GENERATION
utilities					investors
		trader (e.g. banks)		local DSO	
	IPP		TSO		retailer
mining companies			IT companies		

IPP = INDEPENDEND POWER PRODUCER
TSO = TRANSMISSION SYSTEM OPERATOR
LOCAL DSO = LOCAL DISTRIBUTION SYSTEM OPERATOR

table 4.1: power plant value chain

TASK & MARKET PLAYER	(LARGE SCALE) GENERATION	PROJECT DEVELOPMENT	INSTALLATION	PLANT OWNER	OPERATION & MAINTANANCE	FUEL SUPPLY	DISTRIBUTION	SALES
STATUS QUO	Very few new power plants + central planning			large scale generation in the hand of few IPP´s & utilities		global mining operations	grid operation still in the hands of utilities	
MARKET PLAYER								
Utility								
Mining company								
Component manufacturer								
Engineering companies & project developers								
ENERGY [R]EVOLUTION POWER MARKET	many smaller power plants + decentralized planning			large number of players e.g. IPP´s, utilities, private consumer, building operators		no fuel needed (except biomass)	grid operation under state control	
MARKET PLAYER								
Utility								
Mining company								
Component manufacturer								
Engineering companies & project developers								

Simply selling electricity to customers will play a smaller role, as the power companies of the future will deliver a total power plant to the customer, not just electricity. They will therefore move towards becoming service suppliers for the customer. The majority of power plants will also not require any fuel supply, with the result that mining and other fuel production companies will lose their strategic importance.

The future pattern under the Energy [R]evolution will see more and more renewable energy companies, such as wind turbine manufacturers, also becoming involved in project development, installation and operation and maintenance, whilst utilities will lose their status. Those traditional energy supply companies which do not move towards renewable project development will either lose market share or drop out of the market completely.

rural electrification[25] Energy is central to reducing poverty, providing major benefits in the areas of health, literacy and equity. More than a quarter of the world's population has no access to modern energy services. In sub-Saharan Africa, 80% of people have no electricity supply. For cooking and heating, they depend almost exclusively on burning biomass – wood, charcoal and dung.

Poor people spend up to a third of their income on energy, mostly to cook food. Women in particular devote a considerable amount of time to collecting, processing and using traditional fuel for cooking. In India, two to seven hours each day can be devoted to the collection of cooking fuel. This is time that could be spent on child care, education or income generation. The World Health Organisation estimates that 2.5 million women and young children in developing countries die prematurely each year from breathing the fumes from indoor biomass stoves.

The Millennium Development Goal of halving global poverty by 2015 will not be reached without adequate energy to increase production, income and education, create jobs and reduce the daily grind involved in having to just survive. Halving hunger will not come about without energy for more productive growing, harvesting, processing and marketing of food. Improving health and reducing death rates will not happen without energy for the refrigeration needed for clinics, hospitals and vaccination campaigns. The world's greatest child killer, acute respiratory infection, will not be tackled without dealing with smoke from cooking fires in the home. Children will not study at night without light in their homes. Clean water will not be pumped or treated without energy.

The UN Commission on Sustainable Development argues that "to implement the goal accepted by the international community of halving the proportion of people living on less than US $1 per day by 2015, access to affordable energy services is a prerequisite".

the role of sustainable, clean renewable energy To achieve the dramatic emissions cuts needed to avoid climate change – in the order of 80% in OECD countries by 2050 – will require a massive uptake of renewable energy. The targets for renewable energy must be greatly expanded in industrialised countries both to substitute for fossil fuel and nuclear generation and to create the necessary economies of scale necessary for global expansion. Within the Energy [R]evolution scenario we assume that modern renewable energy sources, such as solar collectors, solar cookers and modern forms of bio energy, will replace inefficient, traditional biomass use.

step 3: optimised integration – renewables 24/7

A complete transformation of the energy system will be necessary to accommodate the significantly higher shares of renewable energy expected under the Energy [R]evolution scenario. The grid network of cables and sub-stations that brings electricity to our homes and factories was designed for large, centralised generators running at huge loads, usually providing what is known as 'baseload' power. Renewable energy has had to fit in to this system as an additional slice of the energy mix and adapt to the conditions under which the grid currently operates. If the Energy [R]evolution scenario is to be realised, this will have to change.

Some critics of renewable energy say it is never going to be able to provide enough power for our current energy use, let alone for the projected growth in demand. This is because it relies mostly on natural resources, such as the wind and sun, which are not available 24/7. Existing practice in a number of countries has already shown that this is wrong, and further adaptations to how the grid network operates will enable the large quantities of renewable generating capacity envisaged in this report to be successfully integrated.

We already have the sun, wind, geothermal sources and running rivers available right now, whilst ocean energy, biomass and efficient gas turbines are all set to make a massive contribution in the future. Clever technologies can track and manage energy use patterns, provide flexible power that follows demand through the day, use better storage options and group customers together to form 'virtual batteries'. With all these solutions we can secure the renewable energy future needed to avert catastrophic climate change. Renewable energy 24/7 is technically and economically possible, it just needs the right policy and the commercial investment to get things moving and 'keep the lights on'.[26]

the new electricity grid

The electricity 'grid' is the collective name for all the cables, transformers and infrastructure that transport electricity from power plants to the end users. In all networks, some energy is lost as it is travels, but moving electricity around within a localised distribution network is more efficient and results in less energy loss.

The existing electricity transmission (main grid lines) and distribution system (local network) was mainly designed and planned 40 to 60 years ago. All over the developed world, the grids were built with large power plants in the middle and high voltage alternating current (AC) transmission power lines connecting up to the areas where the power is used. A lower voltage distribution network then carries the current to the final consumers. This is known as a centralised grid system, with a relatively small number of large power stations mostly fuelled by coal or gas.

references

25 SUSTAINABLE ENERGY FOR POVERTY REDUCTION: AN ACTION PLAN', IT POWER/GREENPEACE INTERNATIONAL, 2002.
26 THE ARGUMENTS AND TECHNICAL SOLUTIONS OUTLINED HERE ARE EXPLAINED IN MORE DETAIL IN THE EUROPEAN RENEWABLE ENERGY COUNCIL/GREENPEACE REPORT, "[R]ENEWABLES 24/7: INFRASTRUCTURE NEEDED TO SAVE THE CLIMATE", NOVEMBER 2009.

image THE WIND TURBINES ARE GOING TO BE USED FOR THE CONSTRUCTION OF AN OFFSHORE WINDFARM AT MIDDELGRUNDEN WHICH IS CLOSE TO COPENHAGEN, DENMARK.

In the future we need to change the grid network so that it does not rely on large conventional power plants but instead on clean energy from a range of renewable sources. These will typically be smaller scale power generators distributed throughout the grid. A localised distribution network is more efficient and avoids energy losses during long distance transmission. There will also be some concentrated supply from large renewable power plants. Examples of these large generators of the future are the massive wind farms already being built in Europe's North Sea and the plan for large areas of concentrating solar mirrors to generate energy in Southern Europe or Northern Africa.

The challenge ahead is to integrate new generation sources and at the same time phase out most of the large scale conventional power plants, while still keeping the lights on. This will need novel types of grids and an innovative power system architecture involving both new technologies and new ways of managing the network to ensure a balance between fluctuations in energy demand and supply.

The key elements of this new power system architecture are micro grids, smart grids and an efficient large scale super grid. The three types of system will support and interconnect with each other (see Figure 4.3).

A major role in the construction and operation of this new system architecture will be played by the IT sector. Because a smart grid has power supplied from a diverse range of sources and locations it relies on the gathering and analysis of a large quantity of data. This requires software, hardware and networks that are capable of delivering data quickly, and responding to the information that they contain. Providing energy users with real time data about their energy consumption patterns and the appliances in their buildings, for example, helps them to improve their energy efficiency, and will allow appliances to be used at a time when a local renewable supply is plentiful, for example when the wind is blowing.

There are numerous IT companies offering products and services to manage and monitor energy. These include IBM, Fujitsu, Google, Microsoft and Cisco. These and other giants of the telecommunications and technology sector have the power to make the grid smarter, and to move us faster towards a clean energy future. Greenpeace has initiated the 'Cool IT' campaign to put pressure on the IT sector to make such technologies a reality.

hybrid systems

The developed world has extensive electricity grids supplying power to nearly 100% of the population. In parts of the developing world, however, many rural areas get by with unreliable grids or polluting electricity, for example from stand-alone diesel generators. This is also very expensive for small communities.

The electrification of rural areas that currently have no access to any power system cannot go ahead as it has in the past. A standard approach in developed countries has been to extend the grid by installing high or medium voltage lines, new substations and a low voltage distribution grid. But when there is low potential electricity demand, and long distances between the existing grid and rural areas, this method is often not economically feasible.

Electrification based on renewable energy systems with a hybrid mix of sources is often the cheapest as well as the least polluting alternative. Hybrid systems connect renewable energy sources such as wind and solar power to a battery via a charge controller, which stores the generated electricity and acts as the main power supply. Back-up supply typically comes from a fossil fuel, for example in a wind-battery-diesel or PV-battery-diesel system. Such decentralised hybrid systems are more reliable, consumers can be involved in their operation through innovative technologies and they can make best use of local resources. They are also less dependent on large scale infrastructure and can be constructed and connected faster, especially in rural areas.

Finance can often be an issue for relatively poor rural communities wanting to install such hybrid renewable systems. Greenpeace has therefore developed a model in which projects are bundled together in order to make the financial package large enough to be eligible for international investment support. In the Pacific region, for example, power generation projects from a number of islands, an entire island state such as the Maldives or even several island states could be bundled into one project package. This would make it large enough for funding as an international project by OECD countries. Funding could come from a mixture of a feed-in tariff and a fund which covers the extra costs, as proposed in the "[R]enewables 24/7" report, and known as a Feed-in Tariff Support Mechanism. In terms of project planning, it is essential that the communities themselves are directly involved in the process.

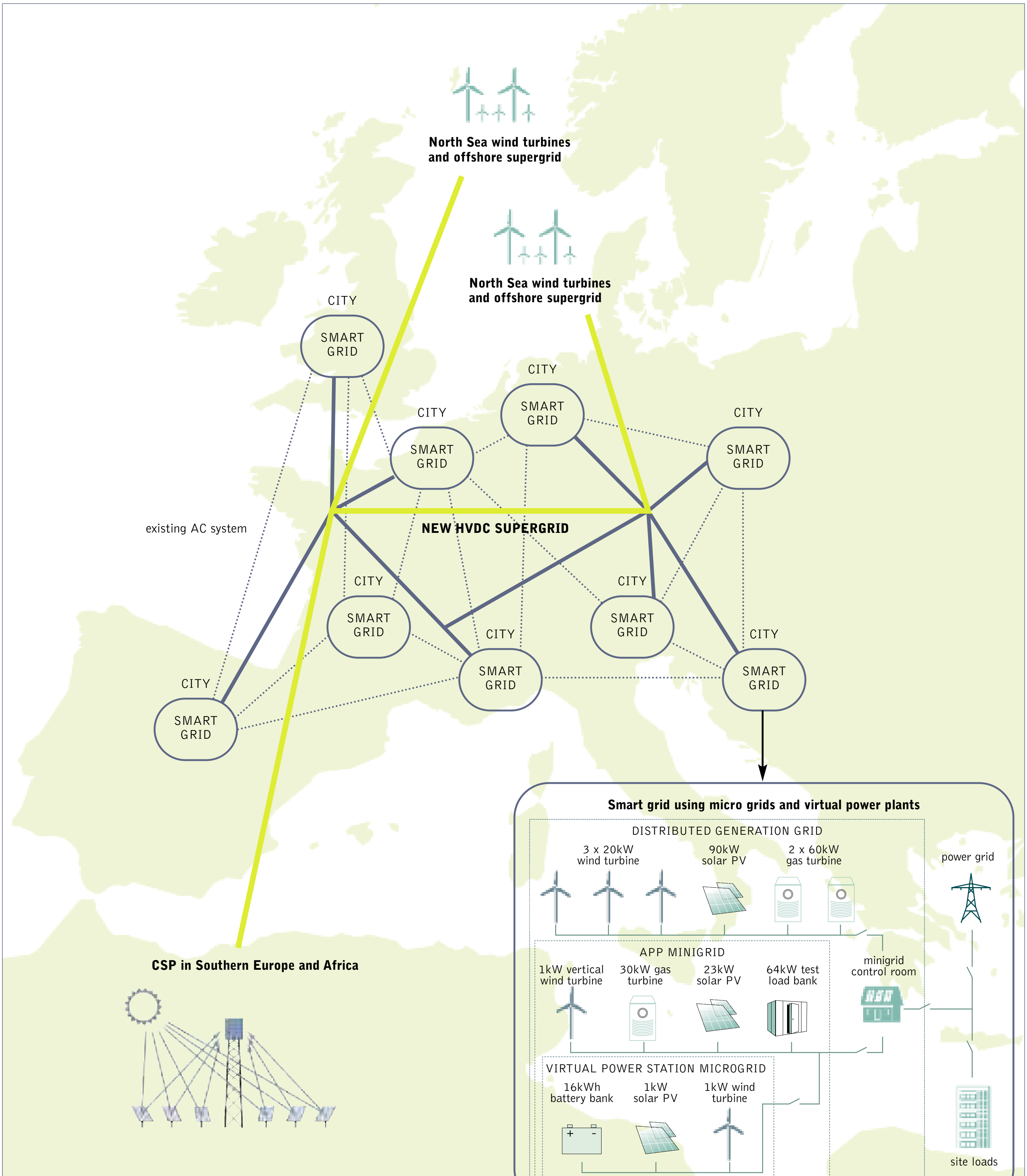
elements in the new power system architecture

A **hybrid system** based on more than one generating source, for example solar and wind power, is a method of providing a secure supply in remote rural areas or islands, especially where there is no grid-connected electricity. This is particularly appropriate in developing countries. In the future, several hybrid systems could be connected together to form a **micro grid** in which the supply is managed using smart grid techniques.

A **smart grid** is an electricity grid that connects decentralised renewable energy sources and cogeneration and distributes power highly efficiently. Advanced communication and control technologies such as smart electricity meters are used to deliver electricity more cost effectively, with lower greenhouse intensity and in response to consumer needs. Typically, small generators such as wind turbines, solar panels or fuels cells are combined with energy management to balance out the load of all the users on the system. Smart grids are a way to integrate massive amounts of renewable energy into the system and enable the decommissioning of older centralised power stations.

A **super grid** is a large scale electricity grid network linking together a number of countries, or connecting areas with a large supply of renewable electricity to an area with a large demand - ideally based on more efficient HVDC (High Voltage Direct Current) cables. An example of the former would be the interconnection of all the large renewable based power plants in the North Sea. An example of the latter would be a connection between Southern Europe and Africa so that renewable energy could be exported from an area with a large renewable resource to urban centres where there is high demand.

figure 4.3: overview of the future power system with high penetration of renewables



source ENERGYNAUTICS

image THE MARANCHON WIND TURBINE FARM IN GUADALAJARA, SPAIN IS THE LARGEST IN EUROPE WITH 104 GENERATORS, WHICH COLLECTIVELY PRODUCE 208 MEGAWATTS OF ELECTRICITY, ENOUGH POWER FOR 590,000 PEOPLE, ANUALLY.

smart grids

The task of integrating renewable energy technologies into existing power systems is similar in all power systems around the world, whether they are large centralised networks or island systems. The main aim of power system operation is to balance electricity consumption and generation.

Thorough forward planning is needed to ensure that the available production can match demand at all times. In addition to balancing supply and demand, the power system must also be able to:

- Fulfil defined power quality standards – voltage/frequency - which may require additional technical equipment, and
- Survive extreme situations such as sudden interruptions of supply, for example from a fault at a generation unit or a breakdown in the transmission system.

Integrating renewable energy by using a smart grid means moving away from the issue of baseload power towards the question as to whether the supply is flexible or inflexible. In a smart grid a portfolio of flexible energy providers can follow the load during both day and night (for example, solar plus gas, geothermal, wind and demand management) without blackouts.

A number of European countries have already shown that it is possible to integrate large quantities of variable renewable power generation into the grid network and achieve a high percentage of the total supply. In Denmark, for example, the average supplied by wind power is about 20%, with peaks of more than 100% of demand. On those occasions surplus electricity is exported to neighbouring countries. In Spain, a much larger country with a higher demand, the average supplied by wind power is 14%, with peaks of more than 50%.

Until now renewable power technology development has put most effort into adjusting its technical performance to the needs of the existing network, mainly by complying with grid codes, which cover such issues as voltage frequency and reactive power. However, the time has come for the power systems themselves to better adjust to the needs of variable generation. This means that they must become flexible enough to follow the fluctuations of variable renewable power, for example by adjusting demand via demand-side management and/or deploying storage systems

The future power system will no longer consist of a few centralised power plants but instead of tens of thousands of generation units such as solar panels, wind turbines and other renewable generation, partly distributed in the distribution network, partly concentrated in large power plants such as offshore wind parks.

The trade off is that power system planning will become more complex due to the larger number of generation assets and the significant share of variable power generation causing constantly changing power flows. Smart grid technology will be needed to support power system planning. This will operate by actively supporting day-ahead forecasts and system balancing, providing real-time information about the status of the network and the generation units, in combination with weather forecasts. It will also play a significant role in making sure systems can meet the peak demand at all times and make better use of distribution and transmission assets, thereby keeping the need for network extensions to the absolute minimum.

To develop a power system based almost entirely on renewable energy sources will require a new overall power system architecture, including smart grid technology. This concept will need substantial amounts of further work to fully emerge.[27] Figure 4.4 shows a simplified graphic representation of the key elements in future renewable-based power systems using smart grid technology.

A range of options are available to enable the large-scale integration of variable renewable energy resources into the power supply system. These include demand side management, the concept of a Virtual Power Plant and a number of choices for the storage of power.

The level and timing of **demand for electricity** can be managed by providing consumers with financial incentives to reduce or shut off their supply at periods of peak consumption. This system is already used for some large industrial customers. A Norwegian power supplier even involves private household customers by sending them a text message with a signal to shut down. Each household can decide in advance whether or not they want to participate. In Germany, experiments are being conducted with time flexible tariffs so that washing machines operate at night and refrigerators turn off temporarily during periods of high demand.

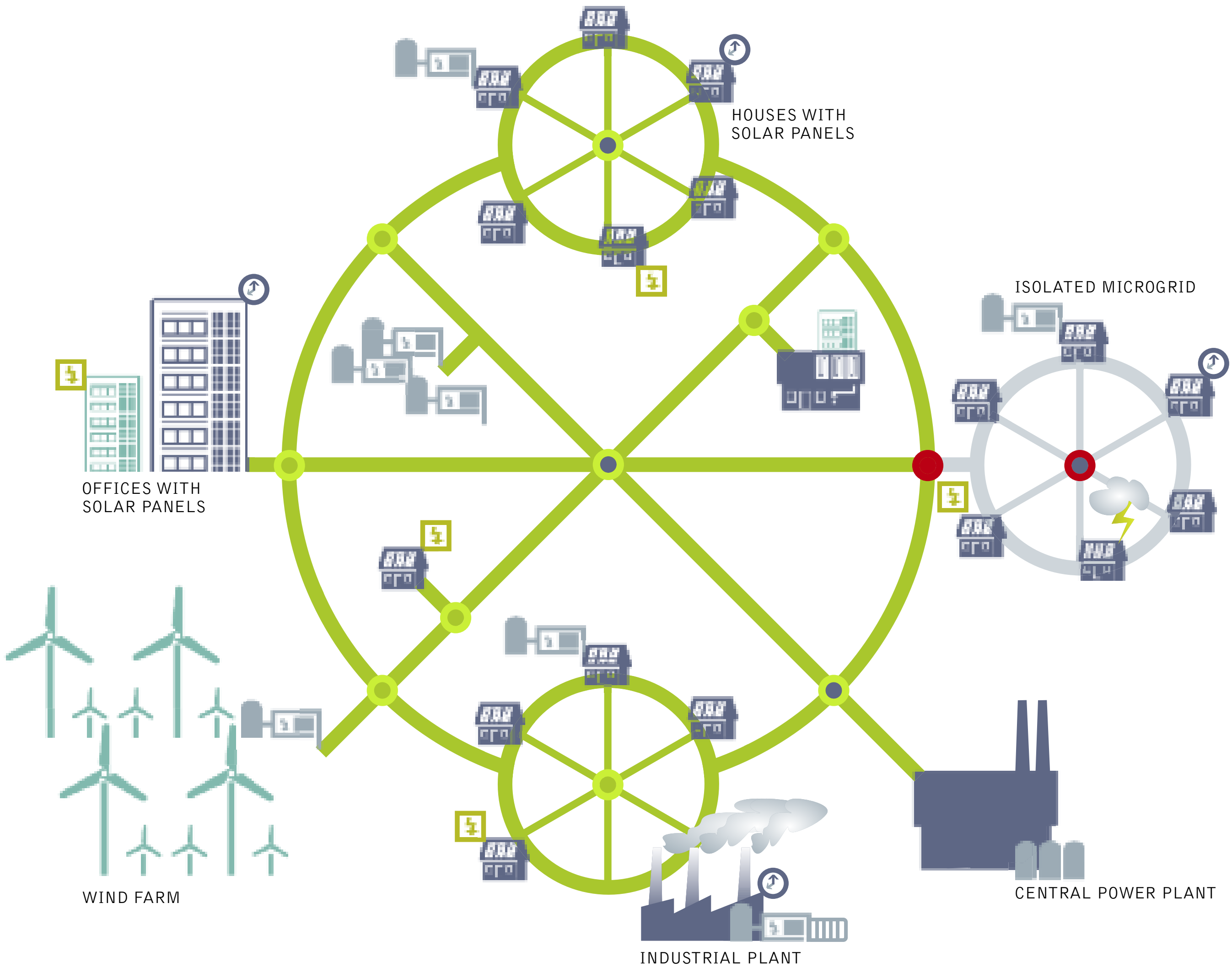
This type of demand side management has been simplified by advances in communications technology. In Italy, for example, 30 million innovative electricity counters have been installed to allow remote meter reading and control of consumer and service information. Many household electrical products or systems, such as refrigerators, dishwashers, washing machines, storage heaters, water pumps and air conditioning, can be managed either by temporary shut-off or by rescheduling their time of operation, thus freeing up electricity load for other uses and dovetailing it with variations in renewable supply.

A **Virtual Power Plant** (VPP) interconnects a range of real power plants (for example solar, wind and hydro) as well as storage options distributed in the power system using information technology. A real life example of a VPP is the Combined Renewable Energy Power Plant developed by three German companies.[28] This system interconnects and controls 11 wind power plants, 20 solar power plants, four CHP plants based on biomass and a pumped storage unit, all geographically spread around Germany. The VPP combines the advantages of the various renewable energy sources by carefully monitoring (and anticipating through weather forecasts) when the wind turbines and solar modules will be generating electricity. Biogas and pumped storage units are then used to make up the difference, either delivering electricity as needed in order to balance short term fluctuations or temporarily storing it.[29] Together the combination ensures sufficient electricity supply to cover demand.

references
27 SEE ALSO ECOGRID PHASE 1 SUMMARY REPORT, AVAILABLE AT: HTTP://WWW.ENERGINET.DK/NR/RDONLYRES/8B1A4A06-CBA3-41DA-9402-B56C2C288FB0/0/ECOGRIDDK_PHASE1_SUMMARYREPORT.PDF
28 SEE ALSO HTTP://WWW.KOMBIKRAFTWERK.DE/INDEX.PHP?ID=27
29 SEE ALSO HTTP://WWW.SOLARSERVER.DE/SOLARMAGAZIN/ANLAGEJANUAR2008_E.HTML

figure 4.4: the smart-grid vision for the energy [r]evolution

A VISION FOR THE FUTURE – A NETWORK OF INTEGRATED MICROGRIDS THAT CAN MONITOR AND HEAL ITSELF.



- **PROCESSORS** EXECUTE SPECIAL PROTECTION SCHEMES IN MICROSECONDS
- **SENSORS** ON 'STANDBY' – DETECT FLUCTUATIONS AND DISTURBANCES, AND CAN SIGNAL FOR AREAS TO BE ISOLATED
- **SENSORS** 'ACTIVATED' – DETECT FLUCTUATIONS AND DISTURBANCES, AND CAN SIGNAL FOR AREAS TO BE ISOLATED
- **SMART APPLIANCES** CAN SHUT OFF IN RESPONSE TO FREQUENCY FLUCTUATIONS
- **DEMAND MANAGEMENT** USE CAN BE SHIFTED TO OFF-PEAK TIMES TO SAVE MONEY
- **GENERATORS** ENERGY FROM SMALL GENERATORS AND SOLAR PANELS CAN REDUCE OVERALL DEMAND ON THE GRID
- **STORAGE** ENERGY GENERATED AT OFF-PEAK TIMES COULD BE STORED IN BATTERIES FOR LATER USE
- **DISTURBANCE IN THE GRID**

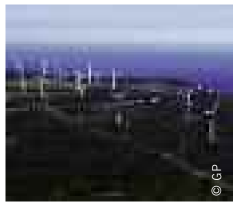


image LE NORDAIS WINDMILL PARK, ONE OF THE MOST IMPORTANT IN AMERICA, LOCATED ON THE GASPÈ PENINSULA IN CAP-CHAT, QUEBEC, CANADA.

A number of mature and emerging technologies are viable options for **storing electricity**. Of these, pumped storage can be considered the most established technology.Pumped storage is a type of hydroelectric power station that can store energy. Water is pumped from a lower elevation reservoir to a higher elevation during times of low cost, off-peak electricity. During periods of high electrical demand, the stored water is released through turbines. Taking into account evaporation losses from the exposed water surface and conversion losses, roughly 70 to 85% of the electrical energy used to pump the water into the elevated reservoir can be regained when it is released. Pumped storage plants can also respond to changes in the power system load demand within seconds.

Pumped storage has been successfully used for many decades all over the world. In 2007 the European Union had 38 GW of pumped storage capacity, representing 5% of total electrical capacity.

Another way of 'storing' electricity is to use it to directly meet the demand from electric vehicles. The number of electric cars and trucks is expected to increase dramatically under the Energy [R]evolution scenario. The Vehicle-to-Grid (V2G) concept, for example, is based on electric cars equipped with batteries that can be charged during times when there is surplus renewable generation and then discharged to supply peaking capacity or ancillary services to the power system while they are parked. During peak demand times cars are often parked close to main load centres, for instance outside factories, so there would be no network issues. Within the V2G concept a Virtual Power Plant would be built using ICT technology to aggregate the electric cars participating in the relevant electricity markets and to meter the charging/de-charging activities. In 2009 the EDISON demonstration project was launched to develop and test the infrastructure for integrating electric cars into the power system of the Danish island of Bornholm.

the super grid

A Greenpeace simulation study has shown that extreme situations with low solar radiation and little wind in many parts of Europe are not frequent, but they can occur (see box "A European Super Grid"). The power system, even with massive amounts of renewable energy, must be adequately designed to cope with such an event. A key element in achieving this is through the construction of new onshore and offshore super grids.

In the Energy [R]evolution scenario it is assumed that about 70% of all generation is distributed and located close to load centres. The remaining 30% will be large scale renewable generation such as large offshore wind farms or large arrays of concentrating solar power plants. A North Sea offshore super grid, for example, would enable the efficient integration of renewable energy into the power system across the whole North Sea region, linking the UK, France, Germany, Belgium, the Netherlands, Denmark and Norway. By aggregating power generation from wind farms spread across the whole area, periods of very low or very high power flows would be reduced to a negligible amount. A dip in wind power generation in one area would be balanced by higher production in another area, even hundreds of kilometres away. Over a year, an installed offshore wind power capacity of 68.4 GW in the North Sea would be able to generate an estimated 247 TWh of electricity.

The cost of developing the grid is expected to be between €15 and 20 billion. This investment would not only allow the broad integration of renewable energy but also unlock unprecedented power trading opportunities and cost efficiency. In a recent example, a new 600 kilometre-long power line between Norway and the Netherlands cost €600 million to build, but is already generating a daily cross-border trade valued at €800,000.[30]

references
30 GREENPEACE REPORT, 'NORTH SEA ELECTRICITY GRID [R]EVOLUTION', SEPTEMBER 2008.

a european super grid

The Greenpeace report "[R]enewables 24/7" examined weather patterns across Europe in order to work out what kind of grid technology would be needed to achieve a secure power supply based on the Energy [R]evolution energy mix, which relies extensively on variable sources such as wind and solar power. Although we know that there are technically enough resources to power the whole continent with renewables – solar in the south, wind in the north plus geothermal, biomass and cogeneration – a new network of interactive smart grids will be needed, in turn interconnected with a 'super grid' providing transmission capacity for large scale renewables such as offshore wind and concentrated solar power. This new grid design also needs to take into account rare events when weather-based renewable energy in certain areas drops below the supply level needed.

To evaluate the frequency of extreme events, the study analysed Europe-wide wind data for the last 30 years. The resulting simulations showed that problems could occur particularly in winter, when electricity demand is high and solar production low. Over the last 30 years, however, the potential power production from wind during the winter months in the Energy [R]evolution scenario would have dropped below 50 GW for only 0.4% of the time, equivalent to once a year if the average duration of the event was 12 hours.

In terms of the balance between wind and solar production, the study selected key 'extreme events' and created a model of power supply based on the Energy [R]evolution supply mix.

The results were:

- In an extreme summer event of high demand and extremely low wind (as in August 2003), the available power from locally distributed solar PV would be enough to compensate for the lack of wind. Therefore no change to the existing grid would be needed.
- In an extreme winter event of high demand and low solar power production in most parts of Europe, combined with low wind power production in Central and Northern Europe (as in January 1997), electricity would have to be transmitted from Northern Europe (mainly hydro power) and from Southern Europe (mainly solar power) into Central Europe. For this to be achieved by renewable energy, a new super grid would be needed.
- In an extreme autumn event (as in November 1987), with very low solar radiation and low wind production, reinforcement of the existing high voltage grid, as well as installation of the proposed super grid, would be sufficient.

To be able to provide a reliable, secure power supply to Europe, taking into account extreme weather and high demand scenarios, the study therefore proposed:

- Strengthening 34 high voltage AC interconnections between neighbouring countries in Europe: 5,347 km of upgrades at a cost of approximately €3 billion.
- 17 new or strengthened high voltage DC interconnections within Europe: 5,125 km of upgrades at a cost of approximately €16 billion.
- Up to 15 new high voltage DC 'super grid' connections, including 11 within Europe of up to 6,000 km at a cost of approximately €100 billion and 4 links between Europe and Africa to import concentrating solar electricity with a total length of 5,500 to 6,000 km at a cost of approximately €90 billion.

Altogether the proposal would cost around €209 billion per year up to 2050. Assuming the level of electricity consumption in the Energy [R]evolution scenario, this would increase the cost of every kWh of electricity by about 0.15 cents over 40 years. However, the final cost of the required grids needs further research, especially the availability of storage capacity within Europe, for example from electric vehicles. Further optimisation in the energy generation mix could also significantly reduce the cost of providing the links between North Africa and Europe.

scenarios for a future energy supply

GLOBAL

SCENARIO BACKGROUND
MAIN SCENARIO ASSUMPTIONS
POPULATION DEVELOPMENT
ECONOMIC GROWTH
OIL & GAS PRICE PROJECTIONS
COST OF CO_2 EMISSIONS
COST PROJECTIONS
SUMMARY OF RENEWABLE ENERGY COST DEVELOPMENT
ASSUMED GROWTH RATES IN DIFFERENT SCENARIOS

5

image WIND TURBINE IN SAMUT SAKHON, THAILAND. © GP/VINAI DITHAJOHN

"towards a sustainable global energy supply system."

GREENPEACE INTERNATIONAL
CLIMATE CAMPAIGN

Moving from principles to action on energy supply and climate change mitigation requires a long-term perspective. Energy infrastructure takes time to build up; new energy technologies take time to develop. Policy shifts often also need many years to take effect. Any analysis that seeks to tackle energy and environmental issues therefore needs to look ahead at least half a century.

Scenarios are important in describing possible development paths, to give decision-makers an overview of future perspectives and to indicate how far they can shape the future energy system. Two different kinds of scenario are used here to characterise the wide range of possible pathways for a future energy supply system: a Reference Scenario, reflecting a continuation of current trends and policies, and the Energy [R]evolution Scenarios, which are designed to achieve a set of dedicated environmental policy targets.

The **Reference Scenario** is based on the reference scenario published by the International Energy Agency (IEA) in World Energy Outlook 2009 (WEO 2009).[31] This only takes existing international energy and environmental policies into account. Its assumptions include, for example, continuing progress in electricity and gas market reforms, the liberalisation of cross-border energy trade and recent policies designed to combat environmental pollution. The Reference scenario does not include additional policies to reduce greenhouse gas emissions. As the IEA's projection only covers a time horizon up to 2030, it has also been extended by extrapolating its key macroeconomic and energy indicators forward to 2050. This provides a baseline for comparison with the Energy [R]evolution scenario.

The **Energy [R]evolution Scenario** has a key target to reduce worldwide carbon dioxide emissions down to a level of around 10 Gigatonnes per year by 2050 in order to keep the increase in global temperature under +2°C. A second objective is the global phasing out of nuclear energy. First published in 2007, then updated and expanded in 2008, this latest revision also serves as a baseline for the more ambitious "advanced" Energy [R]evolution scenario. To achieve its targets, the scenario is characterised by significant efforts to fully exploit the large potential for energy efficiency, using currently available best practice technology. At the same time, all cost-effective renewable energy sources are used for heat and electricity generation as well as the production of bio fuels. The general framework parameters for population and GDP growth remain unchanged from the Reference Scenario.

The **Advanced Energy [R]evolution Scenario** is aimed at an even stronger decrease in CO_2 emissions, especially given the uncertainty that even 10 Gigatonnes might be too much to keep global temperature rises at bay. All general framework parameters such as population and economic growth remain unchanged. The efficiency pathway for industry and "other sectors" is also the same as in the basic Energy [R]evolution scenario. What is different is that the advanced scenario incorporates a stronger effort to develop better technologies to achieve CO_2 reduction. So the transport sector factors in lower demand (compared to the basic scenario), resulting from a change in driving patterns and a faster uptake of efficient combustion vehicles and – after 2025 – a larger share of electric and plug-in hybrid vehicles.

Given the enormous and diverse potential for renewable power, the advanced scenario also foresees a shift in the use of renewables from power to heat. Assumptions for the heating sector therefore include a faster expansion of the use of district heat and hydrogen and more electricity for process heat in the industry sector. More geothermal heat pumps are also used, which leads – combined with a larger share of electric drives in the transport sector – to a higher overall electricity demand. In addition a faster expansion of solar and geothermal heating systems is assumed.

In all sectors, the latest market development projections of the renewables industry[32] have been taken into account (see table 5.13 Annual growth rates of RE energy technologies). In developing countries in particular, a shorter operational lifetime for coal power plants, of 20 instead of 40 years, has been assumed in order to allow a faster uptake of renewables. The speedier introduction of electric vehicles, combined with the implementation of smart grids and faster expansion of super grids (about ten years ahead of the basic Energy [R]evolution scneario) - allows a higher share of fluctuating renewable power generation (photovoltaic and wind) to be employed. The 30% mark for the proportion of renewables in the global energy supply is therefore passed just after 2020 (ten years ahead of the basic Energy [R]evolution scenario).

The global quantities of biomass and large hydro power remain the same in both Energy [R]evolution scenarios, for reasons of sustainability.

These scenarios by no means claim to predict the future; they simply describe three potential development pathways out of the broad range of possible 'futures'. The Energy [R]evolution Scenarios are designed to indicate the efforts and actions required to achieve their ambitious objectives and to illustrate the options we have at hand to change our energy supply system into one that is sustainable.

scenario background

The scenarios in this report were jointly commissioned by Greenpeace and the European Renewable Energy Council from the Institute of Technical Thermodynamics, part of the German Aerospace Center (DLR). The supply scenarios were calculated using the MESAP/PlaNet simulation model adopted in the previous Energy [R]evolution studies.[33] Some detailed analyses carried out during preparation of the 2008 Energy [R]evolution study were also used as input to this update. The energy demand projections were developed for the 2008 study by Ecofys Netherlands, based on an analysis of the future potential for energy efficiency measures. The biomass potential, judged according to Greenpeace sustainability criteria, has been developed especially for this scenario by the German Biomass Research Centre. The future development pathway for car technologies is based on a special report produced in 2008 by the Institute of Vehicle Concepts, DLR for Greenpeace International. These studies are described briefly below.

references
31 INTERNATIONAL ENERGY AGENCY, 'WORLD ENERGY OUTLOOK 2007', 2007
32 SEE EREC, RE-THINKING 2050, GWEC, EPIA ET AL
33 'ENERGY [R]EVOLUTION: A SUSTAINABLE WORLD ENERGY OUTLOOK', GREENPEACE INTERNATIONAL, 2007 AND 2008

image GEOTHERMAL ACTIVITY NEAR HOLSSELSNALAR CLOSE TO REYKJAVIK, ICELAND.

- **Energy efficiency study**. The aim of the Ecofys study was to develop a low energy demand scenario for the period 2005 to 2050 covering the world regions as defined in the IEA's World Energy Outlook report series. Calculations were made for each decade from 2010 onwards. Energy demand was split up into electricity and fuels. The sectors which were taken into account were industry, transport and 'other' consumers, including households and services. Under the low energy demand scenario, worldwide final energy demand is reduced by 38% in 2050 in comparison to the Reference scenario, resulting in a final energy demand of 376 EJ (ExaJoules). The energy savings are fairly equally distributed over the three sectors of industry, transport and other uses. The most important energy saving options are efficient passenger and freight transport and improved heat insulation and building design. Chapter 11 provides more details about this study. The resulting demand projections of this study have been updated on the basis of the reference scenario from IEA´s World Energy Outlook 2009.

- **The future for cars**. The Institute of Vehicle Concepts in Stuttgart, Germany has developed a global scenario for light duty vehicles (LDV) covering ten world regions. The aim was to produce a demanding but feasible scenario to lower global CO_2 emissions from LDVs within the context of the overall objectives of this report. The approach takes into account a vast range of technical measures to reduce the energy consumption of vehicles, but also considers the dramatic increase in vehicle ownership and annual mileage taking place in developing countries. The major parameters are vehicle technology, alternative fuels, changes in sales of different vehicle sizes (segment split) and changes in vehicle kilometres travelled (modal split). The scenario assumes that a large share of renewable electricity will be available in the future.

  A combination of ambitious efforts towards higher efficiency in vehicle technologies, a major switch to grid-connected electric vehicles and incentives for vehicle users to save carbon dioxide lead to the conclusion that it is possible to reduce LDV CO_2 emissions from 'well-to-wheel' in 2050 by roughly 25%[34] compared to 1990 and 40% compared to 2005. By 2050, in this scenario, 60% of the final energy used in road transport will still come from fossil sources, mainly gasoline and diesel. Renewable electricity will cover 25%, bio fuels 13% and hydrogen 2%. Total energy consumption will be reduced by 17% in 2050 compared to 2005, however, in spite of enormous increases in fuel use in some regions of the world. The peak in global CO_2 emissions from transport occurs between 2010 and 2015. From 2010 onwards, new legislation in the US and Europe will contribute to breaking the upwards trend. From 2020, the effect of introducing grid-connected electric cars can be clearly seen. Chapter 13 provides more details of this report.

  This study still forms the basis for the LDV development pathway in the updated Energy [R]evolution scenarios, but has been modified on the basis of changed statistical data for the new reference year 2007 as well as changes in the reference scenario from IEA´s World Energy Outlook 2009.

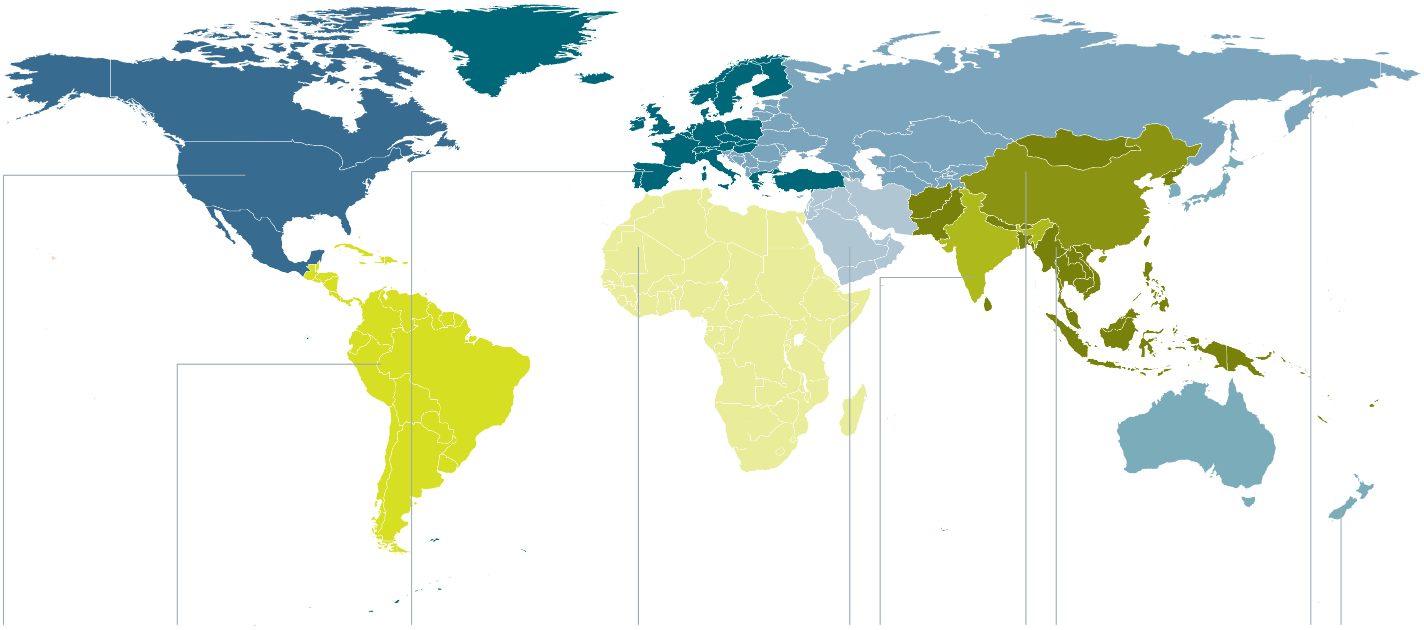
- **The global potential for sustainable bio energy**. As part of the Energy [R]evolution scenario, Greenpeace also commissioned the German Biomass Research Centre (the former Institute for Energy and Environment) to look at the worldwide potential for energy crops up to 2050. A summary of this report can be found in Chapter 8.

references
34 THERE IS NO RELIABLE NUMBER AVAILABLE FOR GLOBAL LDV EMISSIONS IN 1990, SO A ROUGH ESTIMATE HAS BEEN MADE.

main scenario assumptions

Development of a global energy scenario requires the use of a multi-region model in order to reflect the significant structural differences between different countries' energy supply systems. The International Energy Agency breakdown of world regions, as used in the ongoing series of World Energy Outlook reports, has been chosen because the IEA also provides the most comprehensive global energy statistics.[35] In line with the Energy [R]evolution 2008, this new edition maintains the ten region approach. The definitions of the ten world regions are shown in Figure 5.1.

figure 5.1: world regions used in the scenarios BASED ON IEA



oecd north america

Canada, Mexico, United States

latin america

Antigua and Barbuda, Argentina, Bahamas, Barbados, Belize, Bermuda, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Dominica, Dominican Republic, Ecuador, El Salvador, French Guiana, Grenada, Guadeloupe, Guatemala, Guyana, Haiti, Honduras, Jamaica, Martinique, Netherlands Antilles, Nicaragua, Panama, Paraguay, Peru, St. Kitts-Nevis-Anguila, Saint Lucia, St. Vincent and Grenadines, Suriname, Trinidad and Tobago, Uruguay, Venezuela

oecd europe

Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Luxembourg, the Netherlands, Norway, Poland, Portugal, Slovak Republic, Spain, Sweden, Switzerland, Turkey, United Kingdom

africa

Algeria, Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Cape Verde, Central African Republic, Chad, Comoros, Congo, Democratic Republic of Congo, Cote d'Ivoire, Djibouti, Egypt, Equatorial Guinea, Eritrea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Libya, Madagascar, Malawi, Mali, Mauritania, Mauritius, Morocco, Mozambique, Namibia, Niger, Nigeria, Reunion, Rwanda, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, Somalia, South Africa, Sudan, Swaziland, United Republic of Tanzania, Togo, Tunisia, Uganda, Zambia, Zimbabwe

middle east

Bahrain, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, Syria, United Arab Emirates, Yemen

india

India

china

People's Republic of China including Hong Kong

developing asia

Afghanistan, Bangladesh, Bhutan, Brunei, Cambodia, Chinese Taipei, Fiji, French Polynesia, Indonesia, Kiribati, Democratic People's Republic of Korea, Laos, Macao, Malaysia, Maldives, Mongolia, Myanmar, Nepal, New Caledonia, Pakistan, Papua New Guinea, Philippines, Samoa, Singapore, Solomon Islands, Sri Lanka, Thailand, Vietnam, Vanuatu

transition economies

Albania, Armenia, Azerbaijan, Belarus, Bosnia-Herzegovina, Bulgaria, Croatia, Estonia, Serbia and Montenegro, former Republic of Macedonia, Georgia, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Moldova, Romania, Russia, Slovenia, Tajikistan, Turkmenistan, Ukraine, Uzbekistan, Cyprus*, Malta*

oecd pacific

Australia, Japan, Korea (South), New Zealand

* CYPRUS AND MALTA ARE ALLOCATED TO THE TRANSITION ECONOMIES FOR STATISTICAL REASONS

references

35 'ENERGY BALANCE OF NON-OECD COUNTRIES' AND 'ENERGY BALANCE OF OECD COUNTRIES', IEA, 2009.

image A LARGE SOLAR SYSTEM OF $63M^2$ RISES ON THE ROOF OF A HOTEL IN CELERINA, SWITZERLAND. THE COLLECTOR IS EXPECTED TO PRODUCE HOT WATER AND HEATING SUPPORT AND CAN SAVE ABOUT 6,000 LITERS OF OIL PER YEAR. THUS, THE CO_2 EMISSIONS AND COMPANY COSTS CAN BE REDUCED.

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1. population development

One important underlying factor in energy scenario building is future population development. Population growth affects the size and composition of energy demand, directly and through its impact on economic growth and development. World Energy Outlook 2009 uses the United Nations Development Programme (UNDP) projections for population development. For this study the most recent population projections from UNDP up to 2050 are applied.[36]

Table 5.1 shows that, based on UNDP's 2009 assessment, the world's population is expected to grow by 0.86% per year on average over the period 2007 to 2050, from 6.7 billion people in 2007 to more than 9.1 billion by 2050. Population growth will slow over the projection period, from 1.2% per year during 2007-2010 to 0.4% per year during 2040-2050. The updated projections show a small decrease in population by 2050 of around 19 million compared to the previous edition. This will scarcely reduce the demand for energy. The population of the developing regions will continue to grow most rapidly. The Transition Economies will face a continuous decline, followed after a short while by the OECD Pacific countries. OECD Europe and OECD North America are expected to maintain their population, with a peak in around 2020/2030 and a slight decline afterwards. The share of the population living in today's non-OECD countries will increase from the current 82% to 85% in 2050. China's contribution to world population will drop from 20% today to 16% in 2050. Africa will remain the region with the highest growth rate, leading to a share of 22% of world population in 2050. Satisfying the energy needs of a growing population in the developing regions of the world in an environmentally friendly manner is a key challenge for achieving a global sustainable energy supply.

2. economic growth

Economic growth is a key driver for energy demand. Since 1971, each 1% increase in global Gross Domestic Product (GDP) has been accompanied by a 0.6% increase in primary energy consumption. The decoupling of energy demand and GDP growth is therefore a prerequisite for reducing demand in the future. Most global energy/economic/ environmental models constructed in the past have relied on market exchange rates to place countries in a common currency for estimation and calibration. This approach has been the subject of considerable discussion in recent years, and the alternative of purchasing power parity (PPP) exchange rates has been proposed. Purchasing power parities compare the costs in different currencies of a fixed basket of traded and non-traded goods and services and yield a widely-based measure of the standard of living. This is important in analysing the main drivers of energy demand or for comparing energy intensities among countries.

Although PPP assessments are still relatively imprecise compared to statistics based on national income and product trade and national price indexes, they are considered to provide a better basis for global scenario development.[37] Thus all data on economic development in WEO 2009 refers to purchasing power adjusted GDP. However, as WEO 2009 only covers the time period up to 2030, the projections for 2030-2050 are based on our own estimates.

table 5.1: population development projections

(IN MILLIONS)

REGION	2007	2010	2015	2020	2030	2040	**2050**
World	6,671	6,909	7,302	7,675	8,309	8,801	**9,150**
OECD Europe	540	548	558	566	575	578	**575**
OECD North America	449	462	483	503	537	561	**577**
OECD Pacific	200	201	202	201	197	190	**180**
Transition Economies	340	339	339	337	331	321	**311**
India	1,165	1,214	1,294	1,367	1,485	1,565	**1,614**
China	1,336	1,361	1,403	1,439	1,471	1,464	**1,426**
Other Developing Asia	1,011	1,056	1,131	1,203	1,333	1,439	**1,516**
Latin America	462	478	503	526	563	588	**600**
Africa	965	1,033	1,153	1,276	1,524	1,770	**1,998**
Middle East	202	215	235	255	293	326	**353**

source UN WORLD POPULATION PROSPECTS - 2008 REVISION

table 5.2: gdp development projections

(AVERAGE ANNUAL GROWTH RATES)

REGION	2007-2015	2015-2030	2030-2040	2040-2050	**2007-2050**
World	3.30%	3.00%	2.70%	2.44%	3.39%
OECD Europe	1.00%	1.80%	1.30%	1.10%	1.37%
OECD North America	1.80%	2.27%	1.55%	1.45%	1.77%
OECD Pacific	1.10%	1.23%	1.33%	1.40%	1.27%
Transition Economies	4.60%	3.77%	2.60%	2.54%	3.38%
India	7.00%	5.90%	3.20%	2.50%	4.65%
China	8.80%	4.40%	3.20%	2.55%	4.74%
Other Developing Asia	7.20%	4.60%	2.50%	2.20%	4.13%
Latin America	3.10%	2.50%	2.60%	2.40%	2.65%
Africa	4.70%	3.10%	3.40%	3.40%	3.65%
Middle East	4.50%	4.00%	2.30%	2.00%	3.20%

source 2005-2030, IEA WEO 2009; 2030-2050, OWN ASSUMPTIONS

references
36 'WORLD POPULATION PROSPECTS: THE 2008 REVISION', UNITED NATIONS, POPULATION DIVISION, DEPARTMENT OF ECONOMIC AND SOCIAL AFFAIRS (UNDP), 2009.

references
37 NORDHAUS, W, 'ALTERNATIVE MEASURES OF OUTPUT IN GLOBAL ECONOMIC-ENVIRONMENTAL MODELS: PURCHASING POWER PARITY OR MARKET EXCHANGE RATES?', REPORT PREPARED FOR IPCC EXPERT MEETING ON EMISSION SCENARIOS, US-EPA WASHINGTON DC, JANUARY 12-14, 2005.

Prospects for GDP growth have decreased considerably since the previous study, due to the financial crisis at the beginning of 2009, although underlying growth trends continue much the same. GDP growth in all regions is expected to slow gradually over the coming decades. World GDP is assumed to grow on average by 3.1% per year over the period 2007-2030, compared to 3.1% from 1971 to 2007, and on average by 3.4% per year over the entire modelling period. China and India are expected to grow faster than other regions, followed by the Other Developing Asia countries, Africa and the Transition Economies. The Chinese economy will slow as it becomes more mature, but will nonetheless become the largest in the world in PPP terms early in the 2020s. GDP in OECD Europe and OECD Pacific is assumed to grow by around 1.8 and 1.2% per year over the projection period, while economic growth in OECD North America is expected to be slightly higher. The OECD share of global PPP-adjusted GDP will decrease from 55% in 2005 to 29% in 2050.

3. oil and gas price projections

The recent dramatic fluctuations in global oil prices have resulted in slightly higher forward price projections for fossil fuels. Under the 2004 'high oil and gas price' scenario from the European Commission, for example, an oil price of just $34 per barrel was assumed in 2030. More recent projections of oil prices by 2030 in the IEA's WEO 2009 range from $2008 80/bbl in the lower prices sensitivity case up to $2008 150/bbl in the higher prices sensitivity case. The reference scenario in WEO 2009 predicts an oil price of $2008 115/bbl.

Since the first Energy [R]evolution study was published in 2007, however, the actual price of oil has moved over $100/bbl for the first time, and in July 2008 reached a record high of more than $140/bbl.

Although oil prices fell back to $100/bbl in September 2008 and around $80/bbl in April 2010 the projections in the IEA reference scenario might still be considered too conservative. Taking into account the growing global demand for oil we have assumed a price development path for fossil fuels based on the IEA WEO 2009 higher prices sensitivity case extrapolated forward to 2050 (see Table 5.3).

As the supply of natural gas is limited by the availability of pipeline infrastructure, there is no world market price for gas. In most regions of the world the gas price is directly tied to the price of oil. Gas prices are therefore assumed to increase to $24-29/GJ by 2050.

4. cost of CO_2 emissions

Assuming that a CO_2 emissions trading system is established across all world regions in the longer term, the cost of CO_2 allowances needs to be included in the calculation of electricity generation costs. Projections of emissions costs are even more uncertain than energy prices, however, and available studies span a broad range of future estimates. As in the previous Energy [R]evolution study we assume CO_2 costs of $10/t$CO_2$ in 2015, rising to $50/t$CO_2$ by 2050. Additional CO_2 costs are applied in Kyoto Protocol Non-Annex B (developing) countries only after 2020.

table 5.3: development projections for fossil fuel prices in $2008

	UNIT	2000	2005	2007	2008	2010	2015	2020	2025	2030	2040	2050
Crude oil imports												
IEA WEO 2009 "Reference"	barrel	34.30	50.00	75.00	97.19		86.67	100	107.5	115		
USA EIA 2008 "Reference"	barrel					86.64		69.96		82.53		
USA EIA 2008 "High Price"	barrel					92.56		119.75		138.96		
Energy [R]evolution 2010	barrel						110.56	130.00	140.00	150.00	150.00	150.00
Natural gas imports												
IEA WEO 2009 "Reference"												
United States	GJ	5.00	2.32	3.24	8.25		7.29	8.87	10.04	11.36		
Europe	GJ	3.70	4.49	6.29	10.32		10.46	12.10	13.09	14.02		
Japan LNG	GJ	6.10	4.52	6.33	12.64		11.91	13.75	14.83	15.87		
Energy [R]evolution 2010												
United States	GJ			3.24		8.70		10.70	12.40	14.38	18.10	23.73
Europe	GJ			6.29		10.89		16.56	17.99	19.29	22.00	26.03
Japan LNG	GJ			6.33		13.34		18.84	20.37	21.84	24.80	29.30
Hard coal imports												
OECD steam coal imports												
Energy [R]evolution 2010	tonne			69.45		120.59	116.15	135.41	139.50	142.70	160.00	172.30
IEA WEO 2009 "Reference"	tonne	41.22	49.61	69.45		120.59	91.05	104.16	107.12	109.4		
Biomass (solid)												
Energy [R]evolution 2010												
OECD Europe	GJ			7.4		7.7	8.2	9.2		10.0	10.3	10.5
OECD Pacific and North America	GJ			3.3		3.4	3.5	3.8		4.3	4.7	5.2
Other regions	GJ			2.7		2.8	3.2	3.5		4.0	4.6	4.9

source 2000-2030, IEA WEO 2009 HIGHER PRICES SENSITIVITY CASE FOR CRUDE OIL, GAS AND STEAM COAL; 2040-2050 AND OTHER FUELS, OWN ASSUMPTIONS.

image FIRE BOAT RESPONSE CREWS BATTLE THE BLAZING REMNANTS OF THE OFFSHORE OIL RIG DEEPWATER HORIZON APRIL 21, 2010. MULTIPLE COAST GUARD HELICOPTERS, PLANES AND CUTTERS RESPONDED TO RESCUE THE DEEPWATER HORIZON'S 126 PERSON CREW.

table 5.4: assumptions on CO_2 emissions cost development

($/t$CO_2$)

COUNTRIES	2015	2020	2030	2040	**2050**
Kyoto Annex B countries	10	20	30	40	**50**
Non-Annex B countries		20	30	40	**50**

5. cost projections for efficient fossil fuel generation and carbon capture and storage (CCS)

While the fossil fuel power technologies in use today for coal, gas, lignite and oil are established and at an advanced stage of market development, further cost reduction potentials are assumed. The potential for cost reductions is limited, however, and will be achieved mainly through an increase in efficiency.[38]

There is much speculation about the potential for carbon capture and storage (CCS) to mitigate the effect of fossil fuel consumption on climate change, even though the technology is still under development.

CCS is a means of trapping CO_2 from fossil fuels, either before or after they are burned, and 'storing' (effectively disposing of) it in the sea or beneath the surface of the earth. There are currently three different methods of capturing CO_2: 'pre-combustion', 'post-combustion' and 'oxyfuel combustion'. However, development is at a very early stage and CCS will not be implemented - in the best case - before 2020 and will probably not become commercially viable as a possible effective mitigation option until 2030.

Cost estimates for CCS vary considerably, depending on factors such as power station configuration, technology, fuel costs, size of project and location. One thing is certain, however: CCS is expensive. It requires significant funds to construct the power stations and the necessary infrastructure to transport and store carbon. The IPCC assesses costs at $15-75 per tonne of captured CO_2 [39], while a recent US Department of Energy report found installing carbon capture systems to most modern plants resulted in a near doubling of costs.[40] These costs are estimated to increase the price of electricity in a range from 21-91%.[41]

Pipeline networks will also need to be constructed to move CO_2 to storage sites. This is likely to require a considerable outlay of capital.[42] Costs will vary depending on a number of factors, including pipeline length, diameter and manufacture from corrosion-resistant steel, as well as the volume of CO_2 to be transported. Pipelines built near population centres or on difficult terrain, such as marshy or rocky ground, are more expensive.[43]

The Intergovernmental Panel on Climate Change (IPCC) estimates a cost range for pipelines of $1-8/tonne of CO_2 transported. A United States Congressional Research Services report calculated capital costs for an 11 mile pipeline in the Midwestern region of the US at approximately $6 million. The same report estimates that a dedicated interstate pipeline network in North Carolina would cost upwards of $5 billion due to the limited geological sequestration potential in that part of the country.[44] Storage and subsequent monitoring and verification costs are estimated by the IPCC to range from $0.5-8/t$CO_2$ (for storage) and $0.1-0.3/t$CO_2$ (for monitoring). The overall cost of CCS could therefore serve as a major barrier to its deployment.[45]

For the above reasons, CCS power plants are not included in our financial analysis.

Table 5.5 summarises our assumptions on the technical and economic parameters of future fossil-fuelled power plant technologies. In spite of growing raw material prices, we assume that further technical innovation will result in a moderate reduction of future investment costs as well as improved power plant efficiencies. These improvements are, however, outweighed by the expected increase in fossil fuel prices, resulting in a significant rise in electricity generation costs.

table 5.5: development of efficiency and investment costs for selected power plant technologies

		2007	2015	2020	2030	2040	**2050**
Coal-fired condensing power plant	Efficiency (%)	45	46	48	50	52	**53**
	Investment costs ($/kW)	1,320	1,230	1,190	1,160	1,130	**1,100**
	Electricity generation costs including CO_2 emission costs ($cents/kWh)	6.6	9.0	10.8	12.5	14.2	**15.7**
	CO_2 emissions [a)](g/kWh)	744	728	697	670	644	**632**
Lignite-fired condensing power plant	Efficiency (%)	41	43	44	44.5	45	**45**
	Investment costs ($/kW)	1,570	1,440	1,380	1,350	1,320	**1,290**
	Electricity generation costs including CO_2 emission costs ($cents/kWh)	5.9	6.5	7.5	8.4	9.3	**10.3**
	CO_2 emissions [a)](g/kWh)	975	929	908	898	888	**888**
Natural gas combined cycle	Efficiency (%)	57	59	61	62	63	**64**
	Investment costs ($/kW)	690	675	645	610	580	**550**
	Electricity generation costs including CO_2 emission costs ($cents/kWh)	7.5	10.5	12.7	15.3	17.4	**18.9**
	CO_2 emissions [a)](g/kWh)	354	342	330	325	320	**315**

source DLR, 2010 [a)] CO_2 EMISSIONS REFER TO POWER STATION OUTPUTS ONLY; LIFE-CYCLE EMISSIONS ARE NOT CONSIDERED.

references
38 'GREENPEACE INTERNATIONAL BRIEFING: CARBON CAPTURE AND STORAGE', GOERNE, 2007.
39 ABANADES, J C ET AL., 2005, PG 10.
40 NATIONAL ENERGY TECHNOLOGY LABORATORIES, 2007.
41 RUBIN ET AL., 2005A, PG 40.
42 RAGDEN, P ET AL., 2006, PG 18.
43 HEDDLE, G ET AL., 2003, PG 17.
44 PARFOMAK, P & FOLGER, P, 2008, PG 5 AND 12.
45 RUBIN ET AL., 2005B, PG 4444.

6. cost projections for renewable energy technologies

The range of renewable energy technologies available today display marked differences in terms of their technical maturity, costs and development potential. Whereas hydro power has been widely used for decades, other technologies, such as the gasification of biomass, have yet to find their way to market maturity. Some renewable sources by their very nature, including wind and solar power, provide a variable supply, requiring a revised coordination with the grid network. But although in many cases these are 'distributed' technologies - their output being generated and used locally to the consumer - the future will also see large-scale applications in the form of offshore wind parks, photovoltaic power plants or concentrating solar power stations.

By using the individual advantages of the different technologies, and linking them with each other, a wide spectrum of available options can be developed to market maturity and integrated step by step into the existing supply structures. This will eventually provide a complementary portfolio of environmentally friendly technologies for heat and power supply and the provision of transport fuels.

Many of the renewable technologies employed today are at a relatively early stage of market development. As a result, the costs of electricity, heat and fuel production are generally higher than those of competing conventional systems - a reminder that the external (environmental and social) costs of conventional power production are not included in market prices. It is expected, however, that compared with conventional technologies, large cost reductions can be achieved through technical advances, manufacturing improvements and large-scale production. Especially when developing long-term scenarios spanning periods of several decades, the dynamic trend of cost developments over time plays a crucial role in identifying economically sensible expansion strategies.

To identify long-term cost developments, learning curves have been applied which reflect the correlation between cumulative production volumes of a particular technology and a reduction in its costs. For many technologies, the learning factor (or progress ratio) falls in the range between 0.75 for less mature systems to 0.95 and higher for well-established technologies. A learning factor of 0.9 means that costs are expected to fall by 10% every time the cumulative output from the technology doubles. Empirical data shows, for example, that the learning factor for PV solar modules has been fairly constant at 0.8 over 30 years whilst that for wind energy varies from 0.75 in the UK to 0.94 in the more advanced German market.

Assumptions on future costs for renewable electricity technologies in the Energy [R]evolution scenario are derived from a review of learning curve studies, for example by Lena Neij and others[46], from the analysis of recent technology foresight and road mapping studies, including the European Commission funded NEEDS project (New Energy Externalities Developments for Sustainability)[47] or the IEA Energy Technology Perspectives 2008, projections by the European Renewable Energy Council published in April 2010 ("RE-thinking 2050") and discussions with experts from a wide range of different sectors of the renewable energy industry.

photovoltaics (pv)

The worldwide photovoltaics (PV) market has been growing at over 40% per annum in recent years and the contribution it can make to electricity generation is starting to become significant. The importance of photovoltaics comes from its decentralised/centralised character, its flexibility for use in an urban environment and huge potential for cost reduction. Development work is focused on improving existing modules and system components by increasing their energy efficiency and reducing material usage. Technologies like PV thin film (using alternative semiconductor materials) or dye sensitive solar cells are developing quickly and present a huge potential for cost reduction. The mature technology crystalline silicon, with a proven lifetime of 30 years, is continually increasing its cell and module efficiency (by 0.5% annually), whereas the cell thickness is rapidly decreasing (from 230 to 180 microns over the last five years). Commercial module efficiency varies from 14 to 21%, depending on silicon quality and fabrication process.

The learning factor for PV modules has been fairly constant over the last 30 years, with a cost reduction of 20% each time the installed capacity doubles, indicating a high rate of technical learning. Assuming a globally installed capacity of 1000 GW between 2030 and 2040 in the basic Energy [R]evolution scenario, and with an electricity output of 1400 TWh/a , we can expect that generation costs of around 5-10 cents/kWh (depending on the region) will be achieved. During the following five to ten years, PV will become competitive with retail electricity prices in many parts of the world, and competitive with fossil fuel costs by 2030. The advanced Energy [R]evolution version shows faster growth, with PV capacity reaching 1,000 GW by 2025 – five years ahead of the basic scenario.

table 5.6: photovoltaics (pv) cost assumptions

	2007	2015	2020	2030	2040	2050
Energy [R]evolution						
Global installed capacity (GW)	6	98	335	1,036	1,915	**2,968**
Investment costs ($/kWp)	3,746	2,610	1,776	1,027	785	**761**
Operation & maintenance costs ($/kW/a)	66	38	16	13	11	**10**
Advanced Energy [R]evolution						
Global installed capacity (GW)	6	108	439	1,330	2,959	**4,318**
Investment costs ($/kWp)	3,746	2,610	1,776	1,027	761	**738**
Operation & maintenance costs ($/kW/a)	66	38	16	13	11	**10**

46 NEIJ, L, 'COST DEVELOPMENT OF FUTURE TECHNOLOGIES FOR POWER GENERATION - A STUDY BASED ON EXPERIENCE CURVES AND COMPLEMENTARY BOTTOM-UP ASSESSMENTS', ENERGY POLICY 36 (2008), 2200-2211.
47 WWW.NEEDS-PROJECT.ORG

image AERIAL VIEW OF THE WORLD'S LARGEST OFFSHORE WINDPARK IN THE NORTH SEA HORNS REV IN ESBJERG, DENMARK.

concentrating solar power

Solar thermal 'concentrating' power stations (CSP) can only use direct sunlight and are therefore dependent on high irradiation locations. North Africa, for example, has a technical potential which far exceeds local demand. The various solar thermal technologies (parabolic trough, power towers and parabolic dish concentrators) offer good prospects for further development and cost reductions. Because of their more simple design, 'Fresnel' collectors are considered as an option for additional cost trimming. The efficiency of central receiver systems can be increased by producing compressed air at a temperature of up to 1,000°C, which is then used to run a combined gas and steam turbine.

Thermal storage systems are a key component for reducing CSP electricity generation costs. The Spanish Andasol 1 plant, for example, is equipped with molten salt storage with a capacity of 7.5 hours. A higher level of full load operation can be realised by using a thermal storage system and a large collector field. Although this leads to higher investment costs, it reduces the cost of electricity generation.

Depending on the level of irradiation and mode of operation, it is expected that long term future electricity generation costs of 6-10 cents/kWh can be achieved. This presupposes rapid market introduction in the next few years.

wind power

Within a short period of time, the dynamic development of wind power has resulted in the establishment of a flourishing global market. While favourable policy incentives have made Europe the main driver for the global wind market, in 2009 more than three quarters of the annual capacity installed was outside Europe. This trend is likely to continue. The boom in demand for wind power technology has nonetheless led to supply constraints. As a consequence, the cost of new systems has increased. Because of the continuous expansion of production capacities, the industry is already resolving the bottlenecks in the supply chain, however. Taking into account market development projections, learning curve analysis and industry expectations, we assume that investment costs for wind turbines will reduce by 30% for onshore and 50% for offshore installations up to 2050.

table 5.7: concentrating solar power (csp) cost assumptions

	2007	2015	2020	2030	2040	**2050**
Energy [R]evolution						
Global installed capacity (GW)	1	25	105	324	647	**1,002**
Investment costs ($/kW)*	7,250	5,576	5,044	4,263	4,200	**4,160**
Operation & maintenance costs ($/kW/a)	300	250	210	180	160	**155**
Advanced Energy [R]evolution						
Global installed capacity (GW)	1	28	225	605	1,173	**1,643**
Investment costs ($/kW)*	7,250	5,576	5,044	4,200	4,160	**4,121**
Operation & maintenance costs ($/kW/a)	300	250	210	180	160	**155**

* INCLUDING HIGH TEMPERATURE HEAT STORAGE.

table 5.8: wind power cost assumptions

	2007	2015	2020	2030	2040	**2050**
Energy [R]evolution						
Installed capacity (on+offshore)	95	407	878	1,733	2,409	**2,943**
Wind onshore						
Investment costs ($/kWp)	1,510	1,255	998	952	906	**894**
O&M costs ($/kW/a)	58	51	45	43	41	**41**
Wind offshore						
Investment costs ($/kWp)	2,900	2,200	1,540	1,460	1,330	**1,305**
O&M costs ($/kW/a)	166	153	114	97	88	**83**
Advanced Energy [R]evolution						
Installed capacity (on+offshore)	95	494	1,140	2,241	3,054	**3,754**
Wind onshore						
Investment costs ($/kWp)	1,510	1,255	998	906	894	**882**
O&M costs ($/kW/a)	58	51	45	43	41	**41**
Wind offshore						
Investment costs ($/kWp)	2,900	2,200	1,540	1,460	1,330	**1,305**
O&M costs ($/kW/a)	166	153	114	97	88	**83**

biomass

The crucial factor for the economics of biomass utilisation is the cost of the feedstock, which today ranges from a negative cost for waste wood (based on credit for waste disposal costs avoided) through inexpensive residual materials to the more expensive energy crops. The resulting spectrum of energy generation costs is correspondingly broad. One of the most economic options is the use of waste wood in steam turbine combined heat and power (CHP) plants. Gasification of solid biomass, on the other hand, which opens up a wide range of applications, is still relatively expensive. In the long term it is expected that favourable electricity production costs will be achieved by using wood gas both in micro CHP units (engines and fuel cells) and in gas-and-steam power plants. Great potential for the utilisation of solid biomass also exists for heat generation in both small and large heating centres linked to local heating networks. Converting crops into ethanol and 'bio diesel' made from rapeseed methyl ester (RME) has become increasingly important in recent years, for example in Brazil, the USA and Europe. Processes for obtaining synthetic fuels from biogenic synthesis gases will also play a larger role.

A large potential for exploiting modern technologies exists in Latin and North America, Europe and the Transition Economies, either in stationary appliances or the transport sector. In the long term Europe and the Transition Economies will realise 20-50% of the potential for biomass from energy crops, whilst biomass use in all the other regions will have to rely on forest residues, industrial wood waste and straw. In Latin America, North America and Africa in particular, an increasing residue potential will be available.

In other regions, such as the Middle East and all Asian regions, increased use of biomass is restricted, either due to a generally low availability or already high traditional use. For the latter, using modern, more efficient technologies will improve the sustainability of current usage and have positive side effects, such as reducing indoor pollution and the heavy workloads currently associated with traditional biomass use.

geothermal

Geothermal energy has long been used worldwide for supplying heat, and since the beginning of the last century for electricity generation. Geothermally generated electricity was previously limited to sites with specific geological conditions, but further intensive research and development work has enabled the potential areas to be widened. In particular the creation of large underground heat exchange surfaces - Enhanced Geothermal Systems (EGS) - and the improvement of low temperature power conversion, for example with the Organic Rankine Cycle, open up the possibility of producing geothermal electricity anywhere. Advanced heat and power cogeneration plants will also improve the economics of geothermal electricity.

As a large part of the costs for a geothermal power plant come from deep underground drilling, further development of innovative drilling technology is expected. Assuming a global average market growth for geothermal power capacity of 9% per year up to 2020, adjusting to 4% beyond 2030, the result would be a cost reduction potential of 50% by 2050:

table 5.9: biomass cost assumptions

	2007	2015	2020	2030	2040	**2050**
Energy [R]evolution						
Biomass (electricity only)						
Global installed capacity (GW)	28	48	62	75	87	**107**
Investment costs ($/kW)	2,818	2,452	2,435	2,377	2,349	**2,326**
O&M costs ($/kW/a)	183	166	152	148	147	**146**
Biomass (CHP)						
Global installed capacity (GW)	18	67	150	261	413	**545**
Investment costs ($/kW)	5,250	4,255	3,722	3,250	2,996	**2,846**
O&M costs ($/kW/a)	404	348	271	236	218	**207**
Advanced Energy [R]evolution						
Biomass (electricity only)						
Global installed capacity (GW)	28	50	64	78	83	**81**
Investment costs ($/kW)	2,818	2,452	2,435	2,377	2,349	**2,326**
O&M costs ($/kW/a)	183	166	152	148	147	**146**
Biomass (CHP)						
Global installed capacity (GW)	18	65	150	265	418	**540**
Investment costs ($/kW)	5,250	4,255	3,722	3,250	2,996	**2,846**
O&M costs ($/kW/a)	404	348	271	236	218	**207**

table 5.10: geothermal cost assumptions

	2007	2015	2020	2030	2040	**2050**
Energy [R]evolution						
Geothermal (electricity only)						
Global installed capacity (GW)	10	19	36	71	114	**144**
Investment costs ($/kW)	12,446	10,875	9,184	7,250	6,042	**5,196**
O&M costs ($/kW/a)	645	557	428	375	351	**332**
Geothermal (CHP)						
Global installed capacity (GW)	1	3	13	37	83	**134**
Investment costs ($/kW)	12,688	11,117	9,425	7,492	6,283	**5,438**
O&M costs ($/kW/a)	647	483	351	294	256	**233**
Advanced Energy [R]evolution						
Geothermal (electricity only)						
Global installed capacity (GW)	10	21	57	191	337	**459**
Investment costs ($/kW)	12,446	10,875	9,184	5,196	4,469	**3,843**
O&M costs ($/kW/a)	645	557	428	375	351	**332**
Geothermal (CHP)						
Global installed capacity (GW)	0	3	13	47	132	**234**
Investment costs ($/kW)	12,688	11,117	9,425	7,492	6,283	**5,438**
O&M costs ($/kW/a)	647	483	351	294	256	**233**

image A COW INFRONT OF A BIOREACTOR IN THE BIOENERGY VILLAGE OF JUEHNDE. IT IS THE FIRST COMMUNITY IN GERMANY THAT PRODUCES ALL OF ITS ENERGY NEEDED FOR HEATING AND ELECTRICITY, WITH CO_2 NEUTRAL BIOMASS.

- for conventional geothermal power, from 7 $cents/kWh to about 2 $cents/kWh;
- for EGS, despite the presently high figures (about 20 $cents/kWh), electricity production costs - depending on the payments for heat supply - are expected to come down to around 5 $cents/kWh in the long term.

Because of its non-fluctuating supply and a grid load operating almost 100% of the time, geothermal energy is considered to be a key element in a future supply structure based on renewable sources. Up to now we have only used a marginal part of the potential. Shallow geothermal drilling, for example, makes possible the delivery of heating and cooling at any time anywhere, and can be used for thermal energy storage.

ocean energy

Ocean energy, particularly offshore wave energy, is a significant resource, and has the potential to satisfy an important percentage of electricity supply worldwide. Globally, the potential of ocean energy has been estimated at around 90,000 TWh/year. The most significant advantages are the vast availability and high predictability of the resource and a technology with very low visual impact and no CO_2 emissions. Many different concepts and devices have been developed, including taking energy from the tides, waves, currents and both thermal and saline gradient resources. Many of these are in an advanced phase of R&D, large scale prototypes have been deployed in real sea conditions and some have reached pre-market deployment. There are a few grid connected, fully operational commercial wave and tidal generating plants.

The cost of energy from initial tidal and wave energy farms has been estimated to be in the range of 15-55 $cents/kWh, and for initial tidal stream farms in the range of 11-22 $cents/kWh. Generation costs of 10-25 $cents/kWh are expected by 2020. Key areas for development will include concept design, optimisation of the device configuration, reduction of capital costs by exploring the use of alternative structural materials, economies of scale and learning from operation. According to the latest research findings, the learning factor is estimated to be 10-15% for offshore wave and 5-10% for tidal stream. In the medium term, ocean energy has the potential to become one of the most competitive and cost effective forms of generation. In the next few years a dynamic market penetration is expected, following a similar curve to wind energy.

Because of the early development stage any future cost estimates for ocean energy systems are uncertain. Present cost estimates are based on analysis from the European NEEDS project.[48]

hydro power

Hydropower is a mature technology with a significant part of its global resource already exploited. There is still, however, some potential left both for new schemes (especially small scale run-of-river projects with little or no reservoir impoundment) and for repowering of existing sites. The significance of hydropower is also likely to be encouraged by the increasing need for flood control and the maintenance of water supply during dry periods. The future is in sustainable hydropower which makes an effort to integrate plants with river ecosystems while reconciling ecology with economically attractive power generation.

table 5.11: ocean energy cost assumptions

	2007	2015	2020	2030	2040	2050
Energy [R]evolution						
Global installed capacity (GW)	0	9	29	73	168	**303**
Investment costs ($/kW)	7,216	3,892	2,806	2,158	1,802	**1,605**
Operation & maintenance costs ($/kW/a)	360	207	117	89	75	**66**
Advanced Energy [R]evolution						
Global installed capacity (GW)	0	9	58	180	425	**748**
Investment costs ($/kW)	7,216	3,892	2,806	1,802	1,605	**1,429**
Operation & maintenance costs ($/kW/a)	360	207	117	89	75	**66**

table 5.12: hydro power cost assumptions

	2007	2015	2020	2030	2040	2050
Energy [R]evolution						
Global installed capacity (GW)	922	1,043	1,206	1,307	1,387	**1,438**
Investment costs ($/kW)	2,705	2,864	2,952	3,085	3,196	**3,294**
Operation & maintenance costs ($/kW/a)	110	115	123	128	133	**137**
Advanced Energy [R]evolution						
Global installed capacity (GW)	922	1,111	1,212	1,316	1,406	**1,451**
Investment costs ($/kW)	2,705	2,864	2,952	3,085	3,196	**3,294**
Operation & maintenance costs ($/kW/a)	110	115	123	128	133	**137**

48 WWW.NEEDS-PROJECT.ORG

summary of renewable energy cost development

Figure 5.2 summarises the cost trends for renewable energy technologies as derived from the respective learning curves. It should be emphasised that the expected cost reduction is basically not a function of time, but of cumulative capacity, so dynamic market development is required. Most of the technologies will be able to reduce their specific investment costs to between 30% and 70% of current levels by 2020, and to between 20% and 60% once they have achieved full maturity (after 2040).

Reduced investment costs for renewable energy technologies lead directly to reduced heat and electricity generation costs, as shown in Figure 5.3. Generation costs today are around 8 to 26 $cents/kWh for the most important technologies, with the exception of photovoltaics. In the long term, costs are expected to converge at around 5-12 $cents/kWh. These estimates depend on site-specific conditions such as the local wind regime or solar irradiation, the availability of biomass at reasonable prices or the credit granted for heat supply in the case of combined heat and power generation.

assumed growth rates in different scenarios

In scientific literature[49] quantitative scenario modelling approaches are broadly separated into two groups: "top-down" and "bottom-up" models. While this classification might have made sense in the past, it is less appropriate today, since the transition between the two categories is continuous, and many models, while being rooted in one of the two traditions - macro-economic or energy-engineering - incorporate aspects from the other approach and thus belong to the class of so-called hybrid models.[50] In the energy-economic modelling community, macro-economic approaches are traditionally classified as top-down models and energy-engineering models as bottom-up. The Energy [R]evolution scenario is a "bottom-up" (technology driven) scenario and the assumed growth rates for renewable energy technology deployment are important drivers.

Around the world, however, energy modelling scenario tools are under constant development and in the future both approaches are likely to merge into one, with detailed tools employing both a high level of technical detail and economic optimisation. The Energy [R]evolution scenario uses a "classical" bottom-up model which has been constantly developed, and now includes calculations covering both the investment pathway and the employment effect (see Chapter 7).

figure 5.2: future development of renewable energy investment costs (NORMALISED TO CURRENT COST LEVELS) FOR RENEWABLE ENERGY TECHNOLOGIES

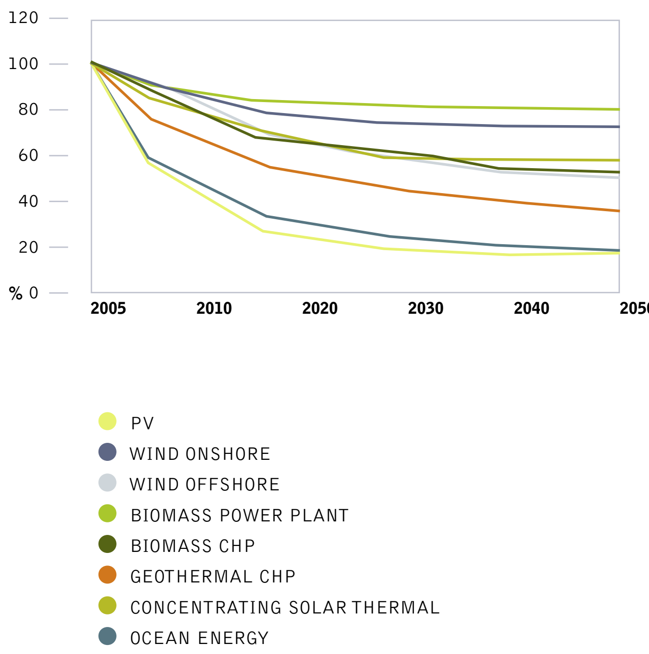
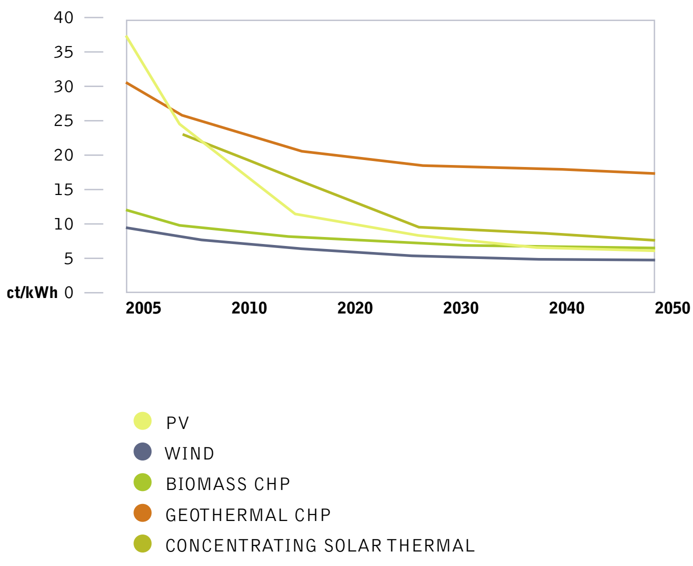


figure 5.3: expected development of electricity generation costs from fossil fuel and renewable options

EXAMPLE FOR OECD NORTH AMERICA



49 HERZOG *ET AL.*, 2005; BARKER *ET AL.*, 2007.
50 VAN VUUREN *ET AL.*; HOURCADE *ET AL.*, 2006.

image CONSTRUCTION OF WIND TURBINES.

table 5.13: assumed annual average growth rates for renewable technologies

	ENERGY PARAMETER GENERATION (TWh/a)					
REF	REF	E[R]	ADV E[R]	REF	E[R]	ADV E[R]
2020	27,248	25,851	25,919			
2030	34,307	30,133	30,901			
2050	46,542	37,993	43,922			
Solar						
PV-2020	108	437	594	17%	37%	42%
PV-2030	281	1,481	1,953	11%	15%	14%
PV-2050	640	4,597	6,846	10%	13%	15%
CSP-2020	38	321	689	17%	49%	62%
CSP-2030	121	1,447	2,734	14%	18%	17%
CSP-2050	254	5,917	9,012	9%	17%	14%
Wind						
On+Offshore-2020	1,009	2,168	2,849	12%	22%	26%
On+Offshore-2030	1,536	4,539	5,872	5%	9%	8%
On+Offshore-2050	2,516	8,474	10,841	6%	7%	7%
Geothermal						
2020 (power generation)	117	235	367	6%	14%	20%
2030 (power generation)	168	502	1,275	4%	9%	15%
2050 (power generation)	265	1,009	2,968	5%	8%	10%
2020 (heat&power)	6	65	66	13%	47%	47%
2030 (heat&power)	9	192	251	5%	13%	16%
2050 (heat&power)	19	719	1,263	9%	16%	20%
Bio energy						
2020 (power generation)	337	373	392	8%	9%	10%
2030 (power generation)	552	456	481	6%	2%	2%
2050 (power generation)	994	717	580	7%	5%	2%
2020 (heat&power)	186	739	742	2%	19%	19%
2030 (heat&power)	287	1,402	1,424	5%	7%	8%
2050 (heat&power)	483	3,013	2,991	6%	9%	9%
Ocean						
2020	3	53	119	15%	55%	70%
2030	11	128	420	13%	10%	15%
2050	25	678	1,943	10%	20%	19%
Hydro						
2020	4,027	4,029	4,059	2%	2%	2%
2030	4,679	4,370	4,416	2%	1%	1%
2050	5,963	5,056	5,108	3%	2%	2%

map 5.1: CO_2 emissions reference scenario and the advanced energy [r]evolution scenario

WORLDWIDE SCENARIO

EMISSIONS

CO_2

LEGEND

100-75 | 75-50 | 50-25 | 25-0 — % OF 1990 EMISSIONS IN THE 2050 ADVANCED ENERGY [R]EVOLUTION SCENARIO

REF — REFERENCE SCENARIO

E[R] — ADVANCED ENERGY [R]EVOLUTION SCENARIO

0 — 1000 KM

CO_2 — **EMISSIONS TOTAL** MILLION TONNES [mio t] | % OF 1990 EMISSIONS

EMISSIONS PER PERSON TONNES [t]

H HIGHEST | M MIDDLE | L LOWEST

OECD NORTH AMERICA

		REF mio t	REF %	E[R] mio t	E[R] %
CO_2	2007	6,686H	165	6,686	165
	2050	6,822	169	215M	5
		t		t	
Per person	2007	14.89H		14.89	
	2050	11.82H		0.37	

LATIN AMERICA

		REF mio t	REF %	E[R] mio t	E[R] %
CO_2	2007	1,010	167M	1,010	167
	2050	2,006	332M	119L	20
		t		t	
Per person	2007	2.18		2.18	
	2050	3.34		0.20L	

OECD EUROPE

		REF		E[R]	
		mio t	%	mio t	%
CO_2	2007	4,017M	100	4,017	100
	2050	3,798	94	215	5
		t		t	
per capita	2007	7.44		7.44	
	2050	6.61M		0.36	

MIDDLE EAST

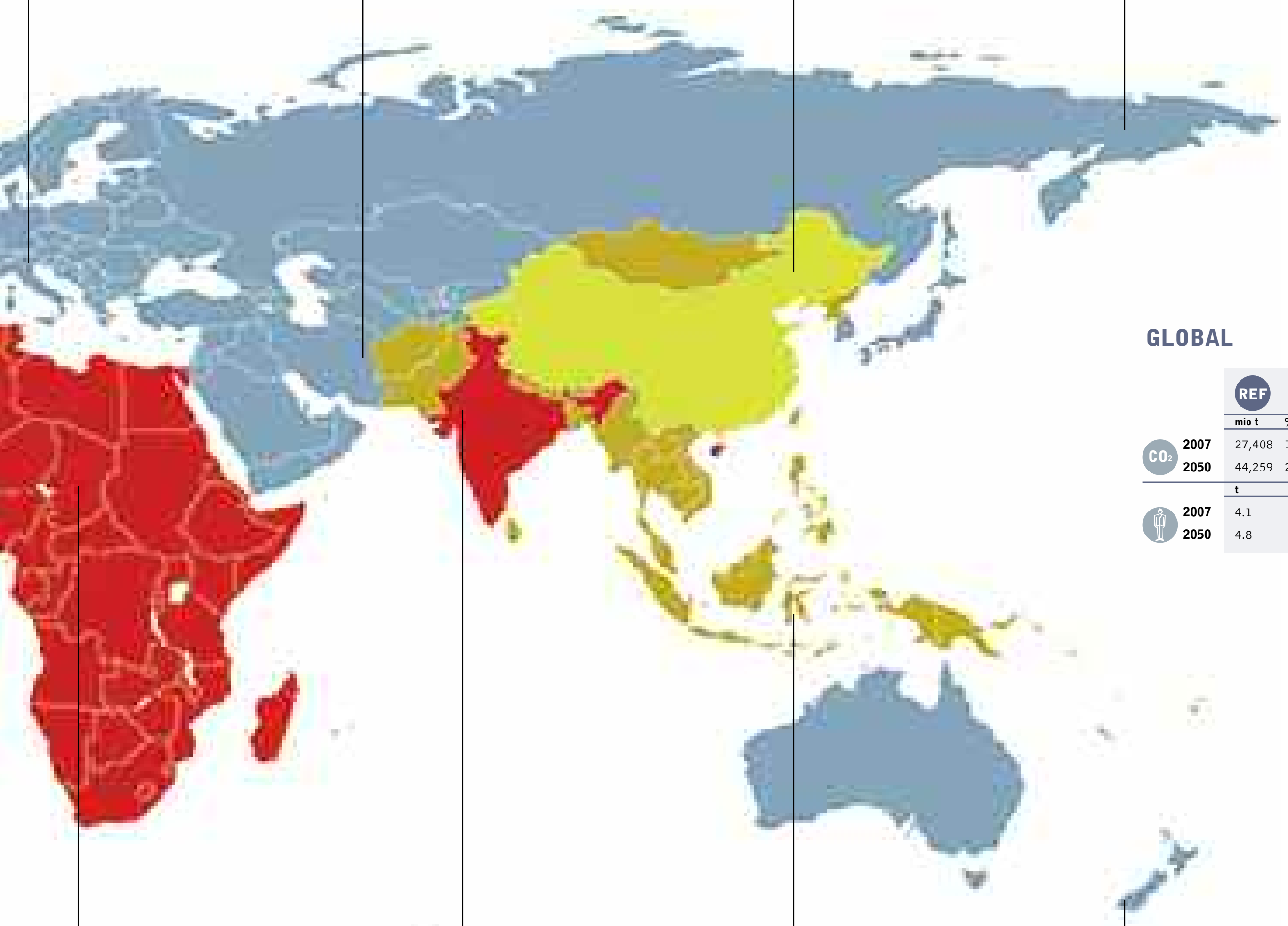
		REF		E[R]	
		mio t	%	mio t	%
CO_2	2007	1,374	234	1,374	234
	2050	3,208	546	122	21
		t		t	
per capita	2007	6.79M		6.79	
	2050	9.08		0.35	

CHINA

		REF		E[R]	
		mio t	%	mio t	%
CO_2	2007	5,852	261	5,852	261
	2050	12,460H	555	925H	41
		t		t	
per capita	2007	4.38		4.38	
	2050	8.74		0.65	

TRANSITION ECONOMIES

		REF		E[R]	
		mio t	%	mio t	%
CO_2	2007	2,650	66	2,650	66
	2050	3,564	88	258	6
		t		t	
per capita	2007	7.79		7.79	
	2050	11.47		0.83H	



GLOBAL

		REF		E[R]	
		mio t	%	mio t	%
CO_2	2007	27,408	131	27,408	131
	2050	44,259	211	3,267	16
		t		t	
per capita	2007	4.1		4.1	
	2050	4.8		0.4	

AFRICA

		REF		E[R]	
		mio t	%	mio t	%
CO_2	2007	881L	161	881	161
	2050	1,622L	297	423	77
		t		t	
per capita	2007	0.91L		0.91	
	2050	0.81L		0.21	

INDIA

		REF		E[R]	
		mio t	%	mio t	%
CO_2	2007	1,307	222	1,307	222
	2050	5,110	868	449	85
		t		t	
per capita	2007	1.12		1.12	
	2050	3.17		0.31	

DEVELOPING ASIA

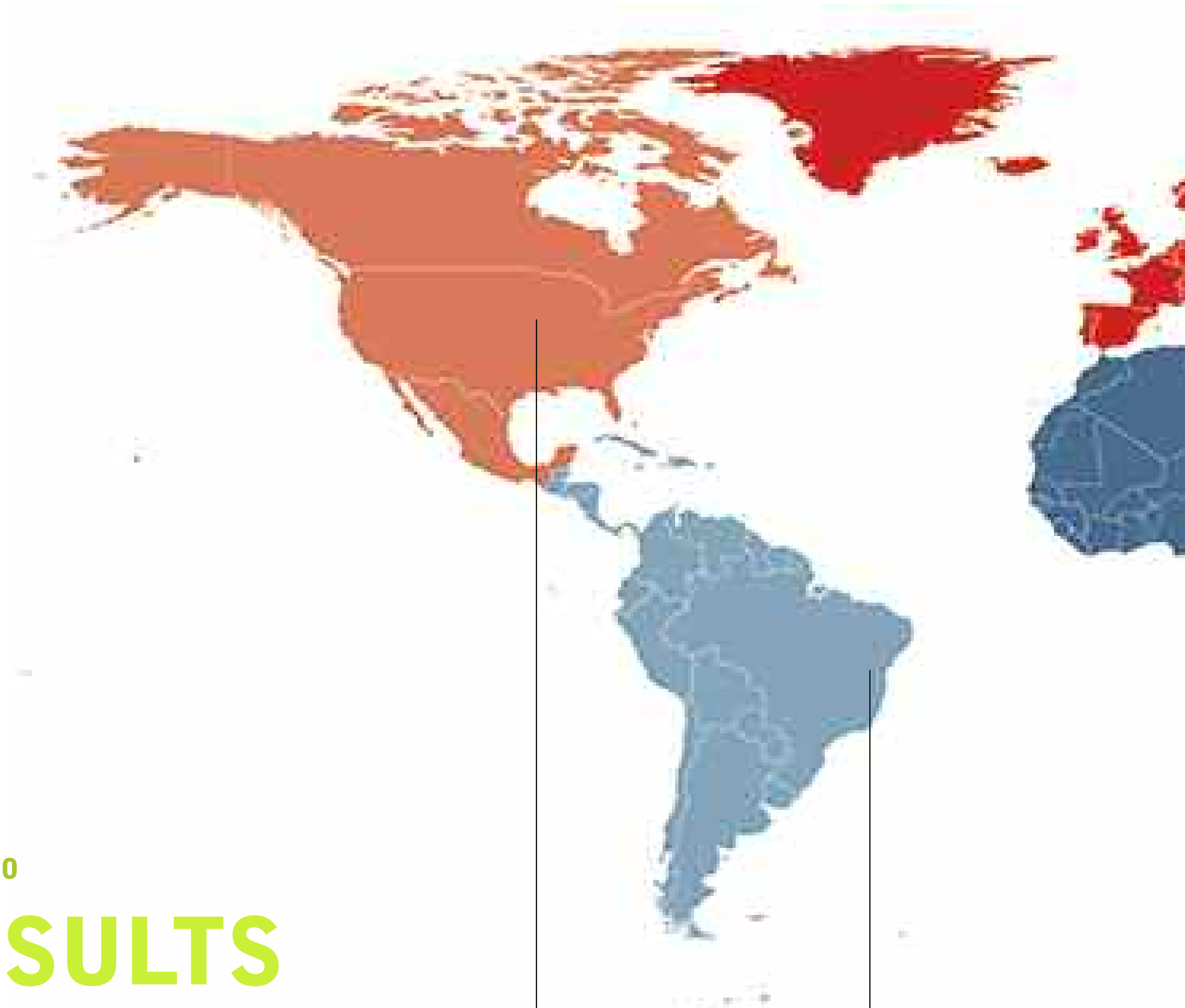
		REF		E[R]	
		mio t	%	mio t	%
CO_2	2007	1,488	216	1,488	216
	2050	3,846M	557	428	62
		t		t	
per capita	2007	1.47		1.47	
	2050	2.54		0.28	

OECD PACIFIC

		REF		E[R]	
		mio t	%	mio t	%
CO_2	2007	2,144	136	2,144	136
	2050	1,822	116	74	5
		t		t	
per capita	2007	10.70		10.70	
	2050	10.14		0.41M	

map 5.2: results reference scenario and the advanced energy [r]evolution scenario

WORLDWIDE SCENARIO



SCENARIO RESULTS

OECD NORTH AMERICA

	REF PE PJ	REF EL TWh	E[R] PE PJ	E[R] EL TWh
2007	115,758H	5,221H	115,758H	5,221
2050	129,374	7,917	70,227	7,925
Share of renewables % 2007	7	15	7	15
2050	15	25	85	98
Share of fossil fuels % 2007	85	67M	85	67M
2050	75	59M	9	2
Share of nuclear energy % 2007	8	18	NUCLEAR POWER PHASED OUT BY 2040	
2050	10	16		

LATIN AMERICA

	REF PE PJ	REF EL TWh	E[R] PE PJ	E[R] EL TWh
2007	22,513L	998	22,513L	998
2050	40,874	2,480	27,311	2,927
Share of renewables % 2007	29	70H	29	70H
2050	28	57H	88H	98
Share of fossil fuels % 2007	70L	28L	70L	28L
2050	69	40L	12L	2
Share of nuclear energy % 2007	1	2	NUCLEAR POWER PHASED OUT BY 2030	
2050	3	2		

LEGEND

> -50 | > -40 | > -30
> -20 | > -10 | > 0
> +10 | > +20 | > +30
> +40 | > +50

% CHANGE OF ENERGY CONSUMPTION IN THE ADVANCED ENERGY [R]EVOLUTION SCENARIO 2050 COMPARED TO CURRENT CONSUMPTION 2007

0 1000 KM

REF REFERENCE SCENARIO

E[R] ADVANCED ENERGY [R]EVOLUTION SCENARIO

SHARE OF RENEWABLES %

SHARE OF FOSSIL FUELS %

SHARE OF NUCLEAR ENERGY %

H HIGHEST | M MIDDLE | L LOWEST

PE PRIMARY ENERGY PRODUCTION/DEMAND IN PETA JOULE [PJ]

EL ELECTRICITY PRODUCTION/GENERATION IN TERAWATT HOURS [TWh]

OECD EUROPE

	REF		E[R]	
	PE PJ	EL TWh	PE PJ	EL TWh
2007	79,599	3,576	79,599	3,576
2050	82,634	5,351	46,754	4,233
	%		%	
2007	10	20	10	20
2050	21	42	85	97
	%		%	
2007	77	54	77	54
2050	71	46	16	2
	%		%	
2007	13	26H	NUCLEAR POWER PHASED OUT BY 2030	
2050	8	12		

MIDDLE EAST

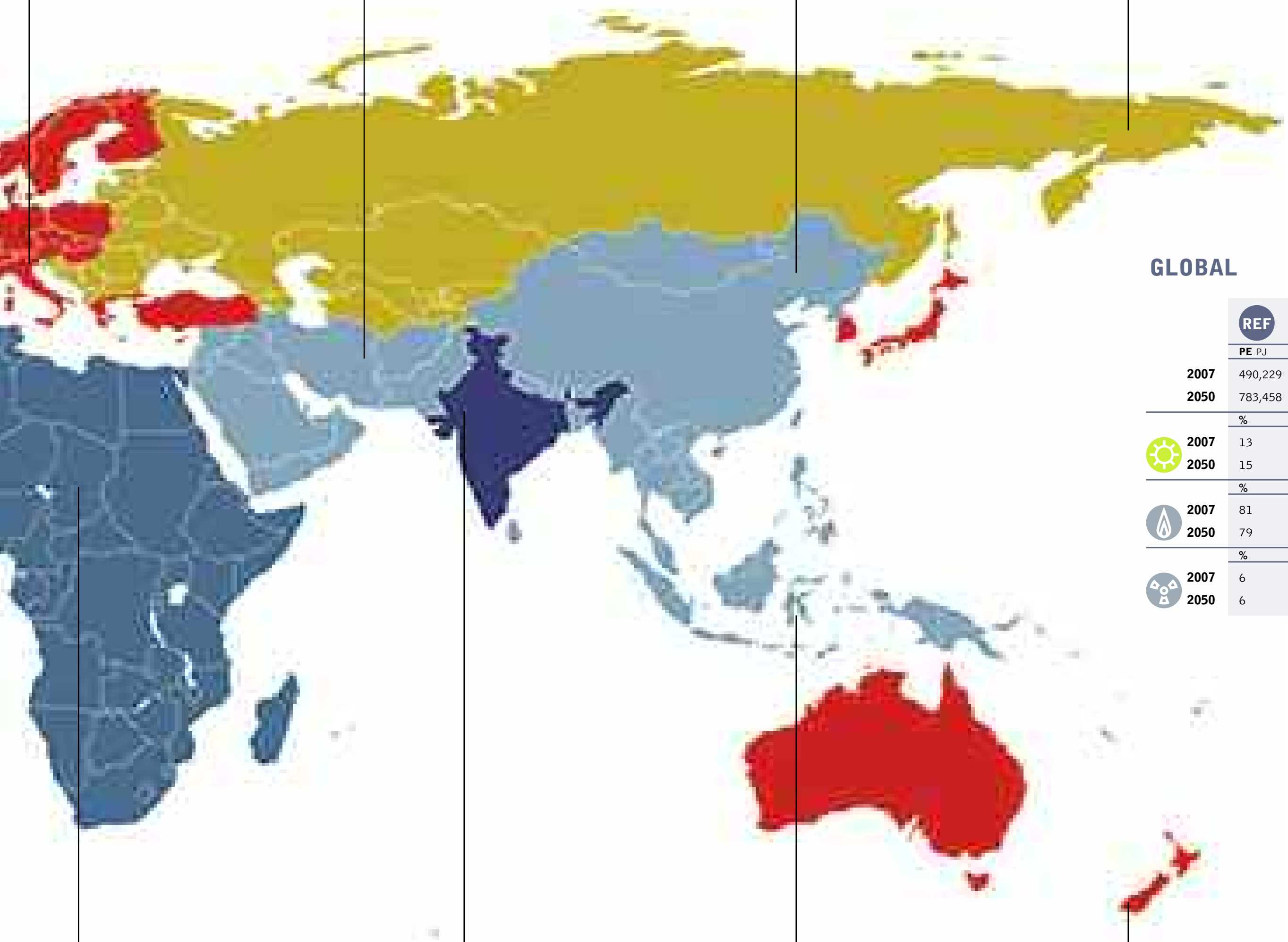
	REF		E[R]	
	PE PJ	EL TWh	PE PJ	EL TWh
2007	21,372	715	21,372	715
2050	51,281	2,404	27,475	2,786L
	%		%	
2007	1L	3	1L	3L
2050	2L	7	76	99H
	%		%	
2007	99H	97	99H	97H
2050	97H	92	23	1L
	%		%	
2007	0L	0	NO NUCLEAR ENERGY DEVELOPMENT	
2050	0L	0		

CHINA

	REF		E[R]	
	PE PJ	EL TWh	PE PJ	EL TWh
2007	83,922	3,319	83,922	3,319
2050	183,886H	12,188H	107,104H	10,190H
	%		%	
2007	12M	15	12M	15
2050	10	18	77L	90
	%		%	
2007	87	83	87	83
2050	85	75	23H	10H
	%		%	
2007	1	2	NUCLEAR POWER PHASED OUT BY 2045	
2050	5	7		

TRANSITION ECONOMIES

	REF		E[R]	
	PE PJ	EL TWh	PE PJ	EL TWh
2007	48,111M	1,685	48,111M	1,685
2050	64,449	3,110	34,710	2,438
	%		%	
2007	4	17M	4	17M
2050	7	22M	76	93
	%		%	
2007	89	65	89	65
2050	85	63	24	7
	%		%	
2007	7M	17	NUCLEAR POWER PHASED OUT BY 2045	
2050	8	15		



GLOBAL

	REF		E[R]	
	PE PJ	EL TWh	PE PJ	EL TWh
2007	490,229	19,773	490,229	19,773
2050	783,458	46,542	480,861	43,922
	%		%	
2007	13	18	13	18
2050	15	24	80	95
	%		%	
2007	81	68	81	68
2050	79	67	20	5
	%		%	
2007	6	14	NUCLEAR POWER PHASED OUT BY 2045	
2050	6	10		

AFRICA

	REF		E[R]	
	PE PJ	EL TWh	PE PJ	EL TWh
2007	26,355	615L	26,355	615L
2050	43,173	1,826L	35,805	2,490L
	%		%	
2007	48H	16	48H	16
2050	45H	36	79M	94
	%		%	
2007	51	82	51	82
2050	54L	62	20M	6
	%		%	
2007	0L	2	NUCLEAR POWER PHASED OUT BY 2025	
2050	0L	2		

INDIA

	REF		E[R]	
	PE PJ	EL TWh	PE PJ	EL TWh
2007	25,159	814	25,159	814
2050	77,7610M	4,918	52,120	5,062
	%		%	
2007	29	17	29	17
2050	13	12	78	93L
	%		%	
2007	70	81	70	81
2050	84	85	22	7
	%		%	
2007	1	2	NUCLEAR POWER PHASED OUT BY 2045	
2050	3	3		

DEVELOPING ASIA

	REF		E[R]	
	PE PJ	EL TWh	PE PJ	EL TWh
2007	31,903	978	31,903	978
2050	69,233	3,721	40,639	3,548
	%		%	
2007	27	16	27	16
2050	19	21	73L	94
	%		%	
2007	72	79	72	79
2050	79	77	27	6
	%		%	
2007	1	5M	NUCLEAR POWER PHASED OUT BY 2045	
2050	2	2		

OECD PACIFIC

	REF		E[R]	
	PE PJ	EL TWh	PE PJ	EL TWh
2007	37,588	1,851M	37,588	1,851M
2050	40,793	2,626	21,299L	2,322
	%		%	
2007	4	8	4	8
2050	10	16	84	98M
	%		%	
2007	84	70	84	70
2050	66	51	16	2M
	%		%	
2007	12H	22	NUCLEAR POWER PHASED OUT BY 2045	
2050	24H	33H		

key results of the global energy [r]evolution scenario

GLOBAL SCENARIO

OECD NORTH AMERICA
LATIN AMERICA
OECD EUROPE
AFRICA

MIDDLE EAST
TRANSITION ECONOMIES
INDIA

DEVELOPING ASIA
CHINA
OECD PACIFIC

6

image SOLAR PANEL. © BERND JUERGENS/DREAMSTIME

"for us to develop in a sustainable way, strong measures have to be taken to combat climate change."

HU JINTAO
PRESIDENT OF CHINA

image AERIAL PHOTO OF THE ANDASOL 1 SOLAR POWER STATION, EUROPE'S FIRST COMMERCIAL PARABOLIC TROUGH SOLAR POWER PLANT. ANDASOL 1 WILL SUPPLY UP TO 200,000 PEOPLE WITH CLIMATE-FRIENDLY ELECTRICITY AND SAVE ABOUT 149,000 TONNES OF CARBON DIOXIDE PER YEAR COMPARED WITH A MODERN COAL POWER PLANT.

image MAINTENANCE WORKERS FIX THE BLADES OF A WINDMILL AT GUAZHOU WIND FARM NEAR YUMEN IN GANSU PROVINCE, CHINA.

The development of future global energy demand is determined by three key factors:

- Population development: the number of people consuming energy or using energy services.
- Economic development, for which Gross Domestic Product (GDP) is the most commonly used indicator. In general, an increase in GDP triggers an increase in energy demand.
- Energy intensity: how much energy is required to produce a unit of GDP.

The Reference and both versions of the Energy [R]evolution scenarios are based on the same projections of population and economic development. The future development of energy intensity, however, differs between the reference and the two alternative cases, taking into account the measures to increase energy efficiency under both Energy [R]evolution scenarios.

projection of energy intensity

An increase in economic activity and a growing population does not necessarily have to result in an equivalent increase in energy demand. There is still a large potential for exploiting energy efficiency measures. Under the Reference scenario we assume that energy intensity will be reduced by 1.25% on average per year, leading to a reduction in final energy demand per unit of GDP of about 56% between 2007 and 2050. Under the Energy [R]evolution scenario it is assumed that active policy and technical support for energy efficiency measures will lead to an even higher reduction in energy intensity of almost 73%.

The advanced Energy [R]evolution scenario follows the same efficiency pathway, apart from in the transport sector, where a further reduction of 17% due to less vehicle use and lifestyle changes has been assumed. The increased share of electric vehicles in this scenario, with greater efficiency of electric drives, leads to a further decrease in final energy use.

development of global energy demand by sector

Combining the projections on population development, GDP growth and energy intensity results in future development pathways for the world's energy demand. These are shown in Figure 6.3 for the Reference and both Energy [R]evolution scenarios. Under the Reference scenario, total primary energy demand almost doubles from 490,230 PJ/a in 2007 to 783,458 PJ/a in 2050. In the Energy [R]evolution scenario, demand increases up to 2020 by 7% but then decreases slightly below today's level of 459,519 PJ/a by 2050. The advanced version leads to a demand of 500,762 PJ/a in 2030 and 465,995 PJ/a by 2050, similar to the basic Energy [R]evolution scenario.

The accelerated increase in energy efficiency, which is a crucial prerequisite for achieving a sufficiently large share of renewable energy sources in our energy supply, is beneficial not only for the environment but also for economics. Taking into account the full lifecycle costs, in most cases the implementation of energy efficiency measures saves money compared to creating an additional energy supply. A dedicated energy efficiency strategy therefore helps to compensate in part for the additional costs required during the market introduction phase of renewable energy technologies.

figure 6.1: global: energy intensity by world region under the reference scenario

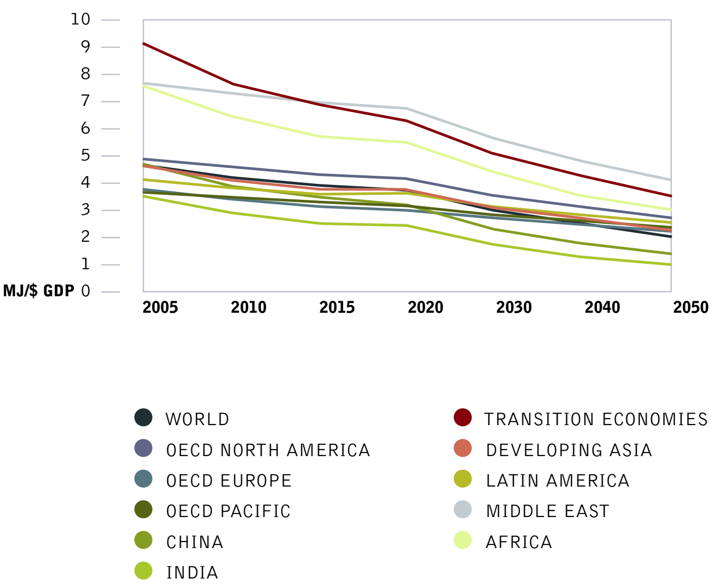
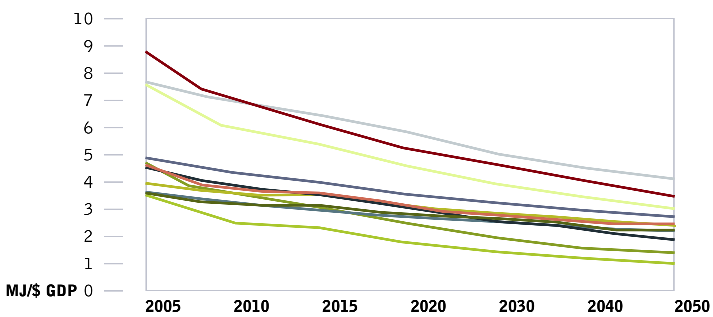


figure 6.2: global: energy intensity by world region under the energy [r]evolution scenario



global

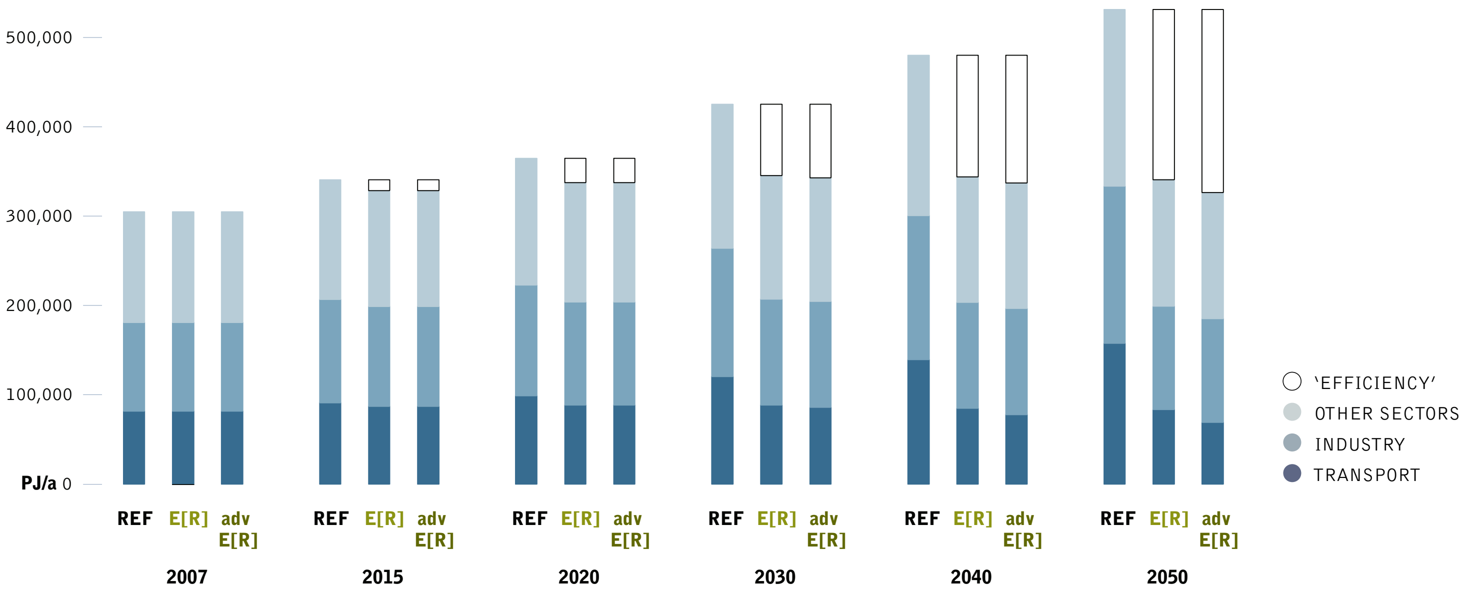
GLOBAL SCENARIO

OECD NORTH AMERICA
LATIN AMERICA
OECD EUROPE
AFRICA

MIDDLE EAST
TRANSITION ECONOMIES
INDIA

OTHER DEVELOPING ASIA
CHINA
OECD PACIFIC

figure 6.3: global: projection of total final energy demand by sector (REF, E[R] & advanced E[R])



development of global energy demand by sector

Under the Energy [R]evolution scenario, electricity demand is expected to increase disproportionately, with households and services the main source of growing consumption (see Figure 6.4). With the exploitation of efficiency measures, however, an even higher increase can be avoided, leading to electricity demand of around 31,795 TWh/a in the year 2050. Compared to the Reference scenario, efficiency measures avoid the generation of about 8,549 TWh/a. This reduction in energy demand can be achieved in particular by introducing highly efficient electronic devices using the best available technology in all demand sectors. Employment of solar architecture in both residential and commercial buildings will help to curb the growing demand for active air-conditioning.

Due to the increased use of electric drives instead of combustion engines in the transport sector and the bigger role of hydrogen in transport and also industry, electricity demand is significantly higher in the advanced Energy [R]evolution scenario. By 2030 the level of production reaches 30,901 TWh/a and 43,922 TWh/a by 2050, about 5.5% below the Reference scenario but 16% above the basic Energy [R]evolution version.

Efficiency gains in the heat supply sector are even larger. Under the Energy [R]evolution scenario, final demand for heat supply can even be reduced (see Figure 6.5). Compared to the Reference scenario, consumption equivalent to 49,357 PJ/a is avoided through efficiency gains by 2050. As a result of energy-related renovation of the existing stock of residential buildings, as well as the introduction of low energy standards and 'passive houses' for new buildings, enjoyment of the same comfort and energy services will be accompanied by a much lower future energy demand. The advanced version has an even lower energy demand in the heating sector, due to the increased use of electricity, for example through geothermal heat pumps.

In the transport sector, it is assumed under the Energy [R]evolution scenario that energy demand will increase by 12% to around 88,743 PJ/a in 2030 and then fall slightly afterwards to 83,507 PJ/a in 2050, saving 47% compared to the Reference scenario. This reduction can be achieved by the introduction of highly efficient vehicles, by shifting the transport of goods from road to rail and by changes in mobility-related behaviour patterns.

In the advanced version, more electric drives are used in the transport sector and hydrogen produced by electrolysis using fluctuating renewable electricity plays a much bigger role than in the basic scenario. After 2030, the final energy share of electric vehicles on the road increases to 14% and by 2050 up to 50%. More public transport systems also use electricity as well as there being a greater shift in transporting freight from road to rail.

image A WOMAN STUDIES SOLAR POWER SYSTEMS AT THE BAREFOOT COLLEGE. THE COLLEGE SPECIALISES IN SUSTAINABLE DEVELOPMENT AND PROVIDES A SPACE WHERE STUDENTS FROM ALL OVER THE WORLD CAN LEARN TO UTILISE RENEWABLE ENERGY. THE STUDENTS TAKE THEIR NEW SKILLS HOME AND GIVE THEIR VILLAGES CLEAN ENERGY.

image AN EXCAVATOR DIGS A HOLE AT GUAZHOU WIND FARM CONSTRUCTION SITE, CHINA, WHERE IT IS PLANNED TO BUILD 134 WINDMILLS.

figure 6.4: global: development of electricity demand by sector (REF, E[R] & advanced E[R])

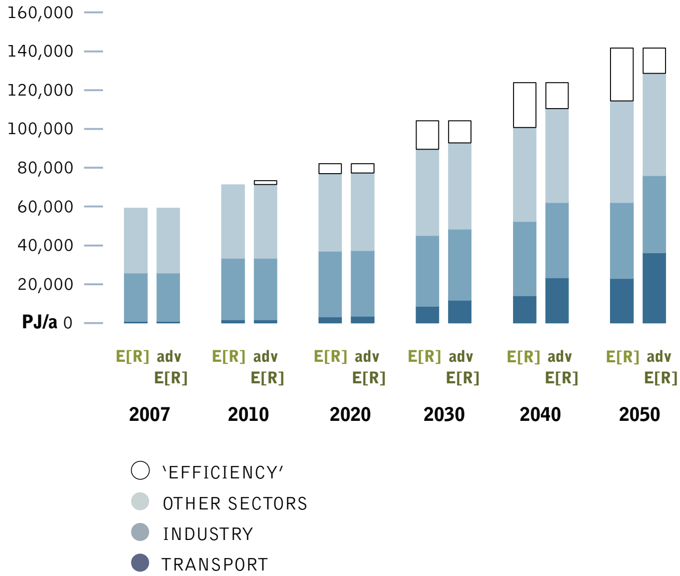
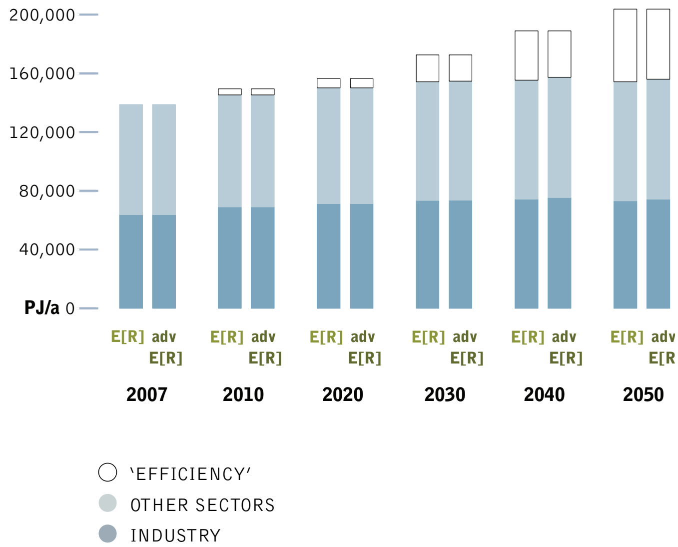


figure 6.5: global: development of heat demand by sector



development of global electricity generation

The development of the electricity supply sector is characterised by a dynamically growing renewable energy market and an increasing share of renewable electricity. This will compensate for the phasing out of nuclear energy and reduce the number of fossil fuel-fired power plants required for grid stabilisation. By 2050, 79% (in the Energy [R]evolution scenario) resp. 95% (in the advanced Energy [R]evolution scenario) of the electricity produced worldwide will come from renewable energy sources. 'New' renewables – mainly wind, solar thermal energy and PV – will contribute over 60% of electricity generation under the advanced Energy [R]evolution scenario and 79% in the basic version. The following strategy paves the way for a future renewable energy supply:

- The phasing out of nuclear energy and rising electricity demand will be met initially by bringing into operation new highly efficient gas-fired combined cycle power plants, plus an increasing capacity of wind turbines, biomass, concentrating solar power plants and solar photovoltaics. In the long term, wind will be the most important single source of electricity generation. In order to achieve the projections under the advanced Energy [R]evolution scenario, the lifetime of new coal power stations installed between 2007 and 2015 has been reduced from 40 to 20 years. This is especially important in China, where over 200,000 MW of new coal power plants have been built between 2002 and 2010. A 40 year lifetime would have led to an excessively large share of coal in the global power generation. Possible stranded investments could be addressed politically, for example through money from emissions trading or other climate and energy programmes.

- Solar energy, hydro and biomass will make substantial contributions to electricity generation. In particular, as non-fluctuating renewable energy sources, hydro and solar thermal, combined with efficient heat storage, are important elements in the overall generation mix. The advanced scenario can be achieved if annual growth rates in the renewables sector remain in the same range as over the past decade (25 – 35% annually) for the next 15 to 20 years. Both the wind and solar industries are confident that this is technically and economically possible, if the necessary political support is provided.

- The installed capacity of renewable energy technologies will grow from the current 1,080 GW to 9,585 GW in 2050. Increasing renewable capacity by a factor of nine within the next 40 years requires political support and well-designed policy instruments, however. There will be a considerable demand for investment in new production capacity over the next 20 years. As investment cycles in the power sector are long, decisions on restructuring the world's energy supply system need to be taken now.

- In the advanced Energy [R]evolution scenario, the total renewable installed capacity will grow to 3,359 GW by 2020 and 13,229 GW by 2050. A significant share of the fluctuating power generation will be used to supply electricity to vehicle batteries and to produce hydrogen as secondary fuel in transport and industry. By using load management strategies, both energy demands will reduce excess electricity generation and provide balancing power and energy to the energy systems.

To achieve an economically attractive growth in renewable energy sources, a balanced and timely mobilisation of all technologies is of great importance. This mobilisation depends on technical potentials, cost reduction and technological maturity. Figure 6.6 shows the comparative evolution of the different renewable technologies over time. Up to 2020, hydro power and wind will remain the main contributors to the growing market share. After 2020, the continuing growth of wind will be complemented by electricity from biomass, photovoltaic and solar thermal (CSP) energy.

For the advanced Energy [R]evolution scenario it is vital to implement infrastructure improvements such as smart grids, greater interconnection between these grids and large scale offshore wind networks as well as increased R&D for storage technologies. All these changes need to happen about ten years in advance of the basic Energy [R]evolution version.

global

GLOBAL SCENARIO

OECD NORTH AMERICA
LATIN AMERICA
OECD EUROPE
AFRICA

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OECD PACIFIC

figure 6.6: global: development of electricity generation structure under 3 scenarios

(REFERENCE, ENERGY [R]EVOLUTION AND ADVANCED ENERGY [R]EVOLUTION) ["EFFICIENCY" = REDUCTION COMPARED TO THE REFERENCE SCENARIO]

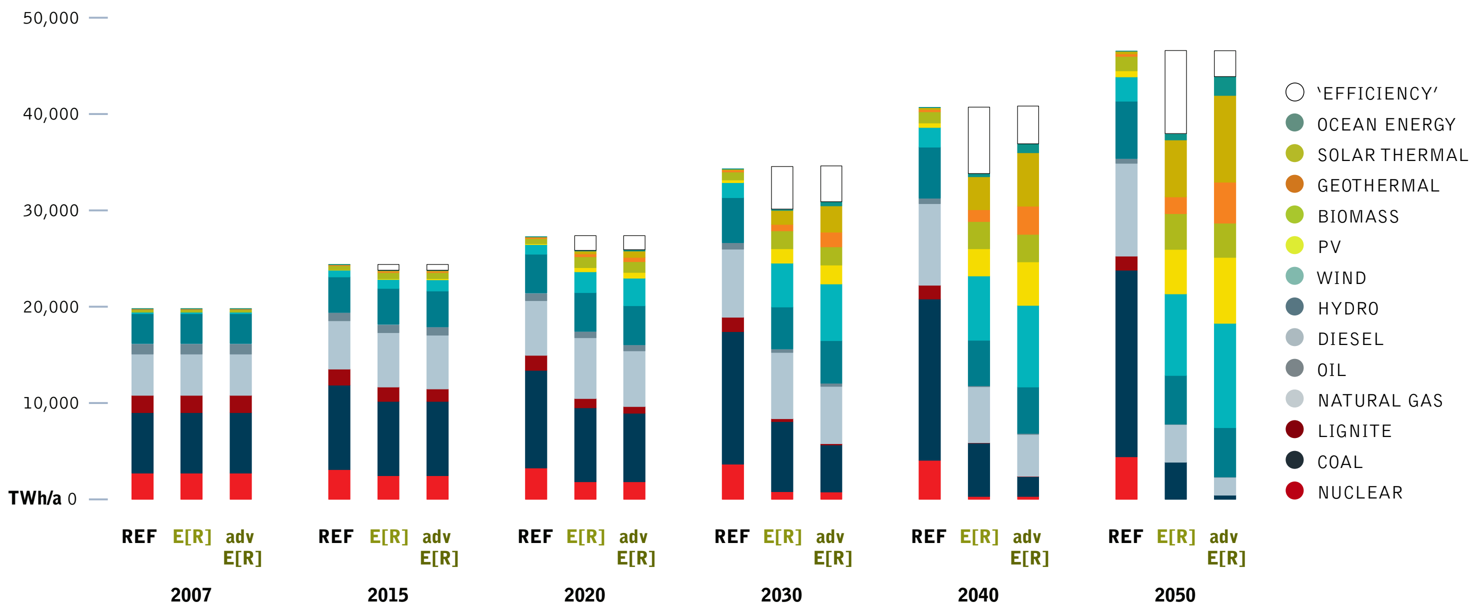


table 6.1: global: projection of renewable electricity generation capacity under both energy [r]evolution scenarios

IN GW

		2007	2020	2030	2040	2050
Hydro	E[R]	922	1,206	1,307	1,387	1,438
	advanced E[R]	922	1,212	1,316	1,406	1,451
Biomass	E[R]	46	212	336	500	652
	advanced E[R]	46	214	343	501	621
Wind	E[R]	95	878	1,733	2,409	2,943
	advanced E[R]	95	1,140	2,241	3,054	3,754
Geothermal	E[R]	11	49	108	196	279
	advanced E[R]	11	69	238	469	693
PV	E[R]	6	335	1.036	1,915	2,968
	advanced E[R]	6	439	1.330	2,959	4,318
CSP	E[R]	0	105	324	647	1,002
	advanced E[R]	0	225	605	1,173	1,643
Ocean energy	E[R]	0	29	73	168	303
	advanced E[R]	0	58	180	425	748
Total	**E[R]**	**1,080**	**2,813**	**4,917**	**7,224**	**9,585**
	advanced E[R]	**1,080**	**3,359**	**6,252**	**9,987**	**13,229**

future costs of electricity generation

Figure 6.7 shows that the introduction of renewable technologies under the Energy [R]evolution scenario slightly increases the costs of electricity generation compared to the Reference scenario. This difference will be less than 0.5 cents/kWh up to 2020. Any increase in fossil fuel prices beyond the projection given in Table 6.1, however, will reduce the gap. Because of the lower CO_2 intensity of electricity generation, by 2020 generation costs will become economically favourable under the Energy [R]evolution scenario and by 2050 will be more than 5 cents/kWh below those in the Reference version.

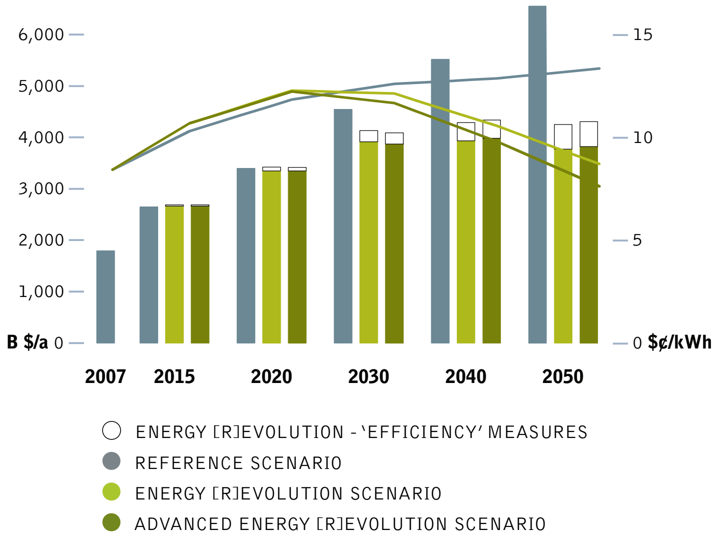
In both Energy [R]evolution scenarios the specific generation costs are almost the same up to 2030. By 2050, however, the advanced version results in a reduction of 4 cents/kWh compared to the Reference scenario, mainly because of greater economies of scale in the production of renewable power equipment. Due to the increased demand for electricity, especially in the transport sector, the overall supply costs in the advanced version are $37 billion higher in 2030 and $40 billion higher in 2050 than in the basic Energy [R]evolution scenario.

Due to growing demand, we face a significant increase in society's overall expenditure on electricity supply. Under the Reference scenario, the unchecked growth in demand, increase in fossil fuel prices and the cost of CO_2 emissions results in total electricity supply costs rising from today's US$ 1,750 billion per year to more than US$ 6,460 billion in 2050. Figure 6.7 shows that both Energy [R]evolution

image A RICE FIELD DESTROYED BY SALT WATER FROM HUGE TIDAL SURGES DURING THE CYCLONE ALIA IN BALI ISLAND IN THE SUNDARBANS.

image PORTLAND, IN THE STATE OF VICTORIA, WAS THE FIRST AUSTRALIAN COUNCIL TO RECEIVE A DEVELOPMENT APPLICATION FOR WIND TURBINES AND NOW HAS ENOUGH IN THE SHIRE TO PROVIDE ENERGY FOR SEVERAL LOCAL TOWNS COMBINED.

figure 6.7: global: development of total electricity supply costs & development of specific electricity generation costs under 3 scenarios



scenarios not only comply with global CO_2 reduction targets but also help to stabilise energy costs and relieve the economic pressure on society. Increasing energy efficiency and shifting energy supply to renewables leads to long term costs for electricity supply that are one third lower than in the Reference scenario. It becomes clear that pursuing stringent environmental targets in the energy sector also pays off in terms of economics.

future global employment

Worldwide, we would see more direct jobs created in the energy sector if we shifted to either of the Energy [R]evolution scenarios.

- By 2015 global power supply sector jobs in the Energy [R]evolution scenario are estimated to reach about 11.1 million, 3.1 million more than in the Reference scenario. The advanced version will lead to 12.5 million jobs by 2015.
- By 2020 over 6.5 million jobs in the renewables sector would be created due a much faster uptake of renewables, three-times more than today. The advanced version will lead to about one million jobs more than the basic Energy [R]evolution, due a much faster uptake of renewables.
- By 2030 the Energy [R]evolution scenario achieves about 10.6 million jobs, about two million more than the Reference scenario. Approximately 2 million new jobs are created between 2020 and 2030, twice as much as in the Reference case. The advanced scenario will lead to 12 million jobs, that is 8.5 million in the renewables sector alone. Without this fast growth in the renewable sector global power jobs will be a mere 2.4 million. Thus by implementing the E[R] there will be 3.2 million or over 33% more jobs by 2030 in the global power supply sector.

Figure 6.8a and 6.8b show the growth in employment under all scenarios for each technology up to 2020 and up to 2030. New jobs in both Energy [R]evolution scenarios are dominated by wind power and solar photovoltaics, coupled with losses in the coal sector, even in the Reference version.

figure 6.8a: global: employment if technology costs do not decline

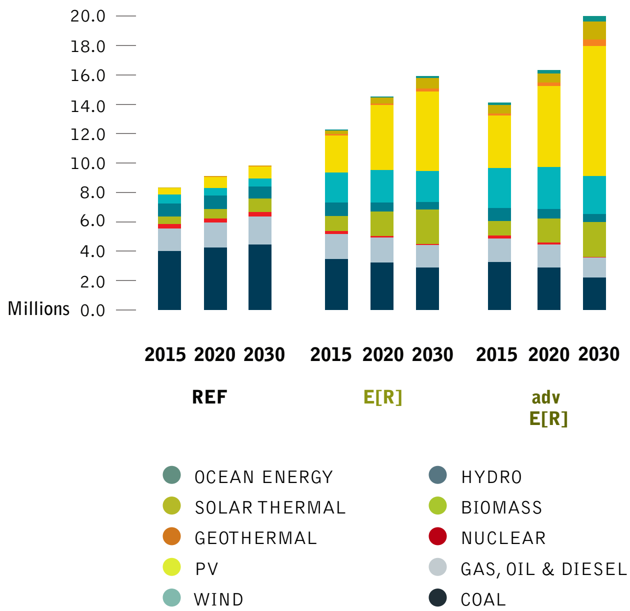
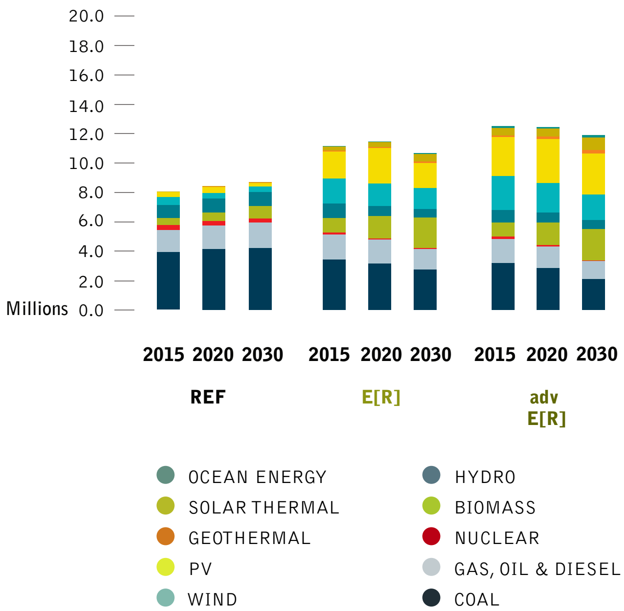


figure 6.8a: global: employment if technology costs decline



global

GLOBAL SCENARIO

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LATIN AMERICA
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AFRICA

MIDDLE EAST
TRANSITION ECONOMIES
INDIA

OTHER DEVELOPING ASIA
CHINA
OECD PACIFIC

table 7.8: global: employment under the reference, [r]evolution, & advanced scenarios in 2015, 2020 & 2030

	REFERENCE SCENARIO			ENERGY [R]EVOLUTION			ENERGY [R]EVOLUTION		
	2015	2020	2030	2015	2020	2030	2015	2020	2030
Jobs (millions)									
Construction and installation	1.6 m	1.7 m	1.3 m	3.0 m	2.8 m	2.0 m	3.8 m	3.4 m	3.1 m
Manufacturing	0.6 m	0.5 m	0.3 m	1.8 m	1.7 m	1.2 m	2.5 m	2.2 m	1.7 m
Operations and maintenance	1.6 m	1.7 m	2.0 m	1.9 m	2.6 m	3.3 m	1.9 m	2.7 m	3.6 m
Fuel supply	3.9 m	4.0 m	4.4 m	3.9 m	3.8 m	3.7 m	3.8 m	3.7 m	3.1 m
Coal and gas export	0.5 m	0.5 m	0.7 m	0.5 m	0.5 m	0.5 m	0.5 m	0.4 m	0.4 m
Total jobs	**8.0 m**	**8.4 m**	**8.7 m**	**11.1 m**	**11.4 m**	**10.6 m**	**12.5 m**	**12.4 m**	**11.9 m**
Global									
Coal	3.9 m	4.1 m	4.2 m	3.4 m	3.1 m	2.7 m	3.2 m	2.8 m	2.1 m
Gas, oil & diesel	1.5 m	1.6 m	1.7 m	1.7 m	1.6 m	1.4 m	1.6 m	1.5 m	1.2 m
Nuclear	0.3 m	0.3 m	0.3 m	0.2 m	0.1 m	0.0 m	0.2 m	0.1 m	0.0 m
Renewable	2.3 m	2.4 m	2.4 m	5.9 m	6.6 m	6.5 m	7.5 m	8.0 m	8.5 m
Total jobs	**8.0 m**	**8.4 m**	**8.7 m**	**11.1 m**	**11.4 m**	**10.6 m**	**12.5 m**	**12.4 m**	**11.9 m**
Global - Jobs									
Coal	3.93 m	4.15 m	4.20 m	3.43 m	3.13 m	2.74 m	3.22 m	2.82 m	2.11 m
Gas, oil & diesel	1.51 m	1.59 m	1.74 m	1.67 m	1.63 m	1.40 m	1.59 m	1.49 m	1.23 m
Nuclear	0.33 m	0.29 m	0.29 m	0.17 m	0.10 m	0.04 m	0.17 m	0.10 m	0.04 m
Biomass	0.48 m	0.59 m	0.86 m	0.96 m	1.51 m	2.11 m	0.96 m	1.52 m	2.14 m
Hydro	0.90 m	0.95 m	0.91 m	1.00 m	0.67 m	0.59 m	0.88 m	0.68 m	0.60 m
Wind	0.52 m	0.39 m	0.38 m	1.70 m	1.55 m	1.40 m	2.28 m	2.01 m	1.73 m
PV	0.32 m	0.40 m	0.25 m	1.85 m	2.40 m	1.71 m	2.67 m	2.99 m	2.77 m
Geothermal	0.02 m	0.02 m	0.02 m	0.07 m	0.09 m	0.12 m	0.10 m	0.18 m	0.27 m
Solar thermal	0.02 m	0.02 m	0.02 m	0.23 m	0.31 m	0.49 m	0.54 m	0.51 m	0.85 m
Ocean	0.00 m	0.00 m	0.00 m	0.05 m	0.04 m	0.06 m	0.12 m	0.12 m	0.16 m
Total jobs	**8.04 m**	**8.40 m**	**8.68 m**	**11.13 m**	**11.43 m**	**10.65 m**	**12.51 m**	**12.43 m**	**11.90 m**

If the Reference scenario becomes reality, the amount of jobs in the power sector would remain on todays level until 2030. This is despite an increase in electricity generation from coal to 40% by 2030. The main reason is that as prosperity and labour productivity increase, jobs per MW decrease. This is reflected in the 'regional adjustments'[51], which model how electricity generation tends to be more labour intensive in poorer countries than in wealthier ones. This change, based on increasing living standards in the developing world, accounts for two thirds of the reduction in coal jobs in developing countries.

China is responsible for one third of worldwide energy sector jobs in 2015, more than three quarters in coal power. The change in China's regional adjustment accounts for about 200,000 of the coal job losses projected in the Reference scenario.[52] A small expansion of the renewables sector would not counteract these losses. Jobs would not return to their 2010 levels, even combined with a 50% expansion in gas capacity.

The Energy [R]evolution scenario also has job losses in coal generation, because growth in capacity is almost zero. However, employment growth in renewable energy is so strong that there is a net gain of 4.1 million jobs by 2030, relative to the 2015 Reference case. The advanced case will lead to 8.5 million jobs in the renewables sector, compared to only 2.4 million in the reference case.

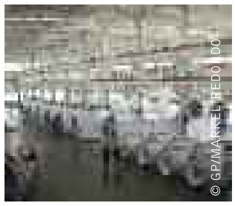
In both Energy [R]evolution scenarios we have been cautious in the calculations and applied 'decline factors' to represent how jobs per unit of energy can decrease over time, making the Greenpeace projections lower than in other studies. It may be the case, for example, that job creation per GWh in energy efficiency could increase as energy efficiency options are all 'used up'.

More details of the employment analysis can be found in Chapter 7.

51 REGIONAL ADJUSTMENTS ARE MADE BY USING 'JOB MULTIPLIERS' WHICH DIVIDE THE PROJECTED LABOUR PRODUCTIVITY IN THE OECD COUNTRIES AS A WHOLE BY THE PROJECTED LABOUR PRODUCTIVITY IN A PARTICULAR REGION.
52 COMPARED TO THE SITUATION OF MAINTAINING THE MULTIPLIER AT 1.9 IN 2020. IF NO MULTIPLIER WAS USED AT ALL, 2010 AND 2020 TOTALS WOULD BOTH BE REDUCED SIGNIFICANTLY.

image ANDASOL 1 SOLAR POWER STATION IS EUROPE'S FIRST COMMERCIAL PARABOLIC TROUGH SOLAR POWER PLANT. IT WILL SUPPLY UP TO 200,000 PEOPLE WITH CLIMATE-FRIENDLY ELECTRICITY AND SAVE ABOUT 149,000 TONNES OF CARBON DIOXIDE PER YEAR COMPARED WITH A MODERN COAL POWER PLANT.

image WORKERS AT GANSU JINFENG WIND POWER EQUIPMENT CO. LTD. IN JIUQUAN, GANSU PROVINCE, CHINA.



development of global heat and cooling demand

Development of renewables in the heat supply sector raises different issues. Today, renewables provide 24% of global primary energy demand for heat supply, the main contribution coming from the use of biomass. The lack of district heating networks is a severe structural barrier to the large scale utilisation of geothermal and solar thermal energy. Past experience shows that it is easier to implement effective support instruments in the grid-connected electricity sector than in the heat market, with its multitude of different actors. Dedicated support instruments are required to ensure a dynamic development.

In the Energy [R]evolution scenario, renewables provide more than 71% of global heating demand by 2050. The main elements of this shift are:

- Energy efficiency measures can decrease the current per capita demand for heat supply by 24% in spite of improving living standards.
- For direct heating, solar collectors, biomass/biogas as well as geothermal energy will increasingly substitute for fossil fuel-fired systems.
- A shift from coal and oil to natural gas in the remaining conventional applications will lead to a further reduction in CO_2 emissions.

In the Energy [R]evolution scenario 49,357 PJ/a is saved by 2050, or 24% compared to the Reference scenario. The advanced Energy [R]evolution scenario introduces renewable heating systems around five years ahead of the basic scenario. Solar collectors and geothermal heating systems achieve economies of scale via ambitious support programmes five to ten years earlier, resulting in a renewables share of 49% by 2030 and 91% by 2050.

development of global transport energy demand

In the transport sector it is assumed that, due to fast growing demand for services, energy consumption will continue to increase under the Energy [R]evolution scenario up to 2020. After that it will decrease, falling to a level of the current demand by 2050. Compared to the Reference scenario, transport energy demand is reduced overall by 47%. This reduction can be achieved by the introduction of highly efficient vehicles, by shifting the transport of goods from road to rail and by changes in mobility-related behaviour patterns. By introducing attractive alternatives to individual cars, the global fleet of light duty vehicles grows more slowly than in the Reference scenario. In 2050, electricity will meet 28% of the transport sector's total energy demand.

To achieve the aims of the advanced Energy [R]evolution scenario more drastic changes are required. Firstly, a further reduction in transport energy demand means less travelling, achieved partly by moving working and living areas closer together. Cities must be developed with short travel distances in mind rather than a huge urban sprawl. Secondly, increasing the share of electric vehicles significantly above the basic Energy [R]evolution scenario requires a breakthrough in storage technologies. Current battery systems for electric vehicles are still too expensive and too heavy and require a lengthy charging time. Hydrogen fuel cell vehicles are introduced in the advanced version in a significant share covering in addition renewable mobility for suitable applications and markets. Thirdly, renewable power generation must be able to cover the extra electricity demand from e-mobility and renewable hydrogen, as it would not save CO_2 if this additional electricity were generated in coal power plants. What is certain is that with currently known technologies, electrification of the transport system is the only option which can move us away from inefficient combustion engines and phase out fossil fuels. If these technology challenges are overcome, a final energy share of 14% electricity in transport by 2030 and 50% by 2050 is possible. Hydrogen will cover more than 5% of the global final energy consumption in transport by 2050.

figure 6.9: global: development of heat supply structure under 3 scenarios

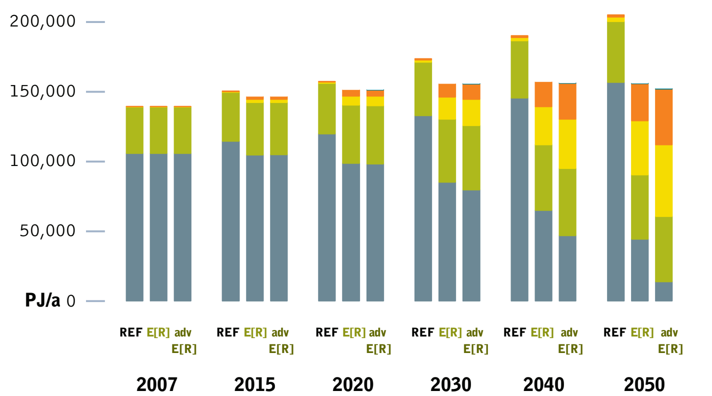
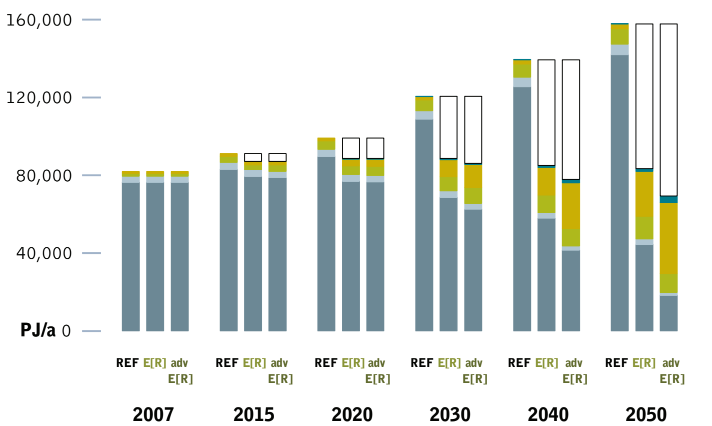


figure 6.10: global: transport under 3 scenarios



'EFFICIENCY' GEOTHERMAL SOLAR BIOMASS FOSSIL FUELS

global

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CHINA
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development of global primary energy consumption

Taking into account the assumptions discussed above, the resulting global primary energy consumption under the Energy [R]evolution scenario is shown in Figure 6.11. Compared to the Reference scenario, overall primary energy demand will be reduced by 41% in 2050. More than half of the remaining demand will be covered by renewable energy sources. Note that because of the 'efficiency method' used for the calculation of primary energy consumption, which postulates that the amount of electricity generation from hydro, wind, solar and geothermal energy equals the primary energy consumption, the share of renewables seems to be lower than their actual importance as energy suppliers.

The advanced Energy [R]evolution scenario would even achieve a renewable energy share of 39% by 2030 and 80% by 2050. In this projection almost the entire global electricity supply, including the majority of the energy used in buildings and industry, would come from renewable energy sources. The transport sector, in particular aviation and shipping, would be the last sector to become fossil fuel free.

None of these numbers - even in the advanced Energy [R]evolution scenario - utilise the maximum known technical potential of all the renewable resources. While the deployment rate compared to the technical potential for hydro power, for example, is relatively high at 36% in both the basic and the advanced Energy [R]evolution scenario, for photovoltaics only 4.7% has been used in the basic version and 6.4% in the advanced scenario.

figure 6.11: global: development of primary energy consumption under three scenarios

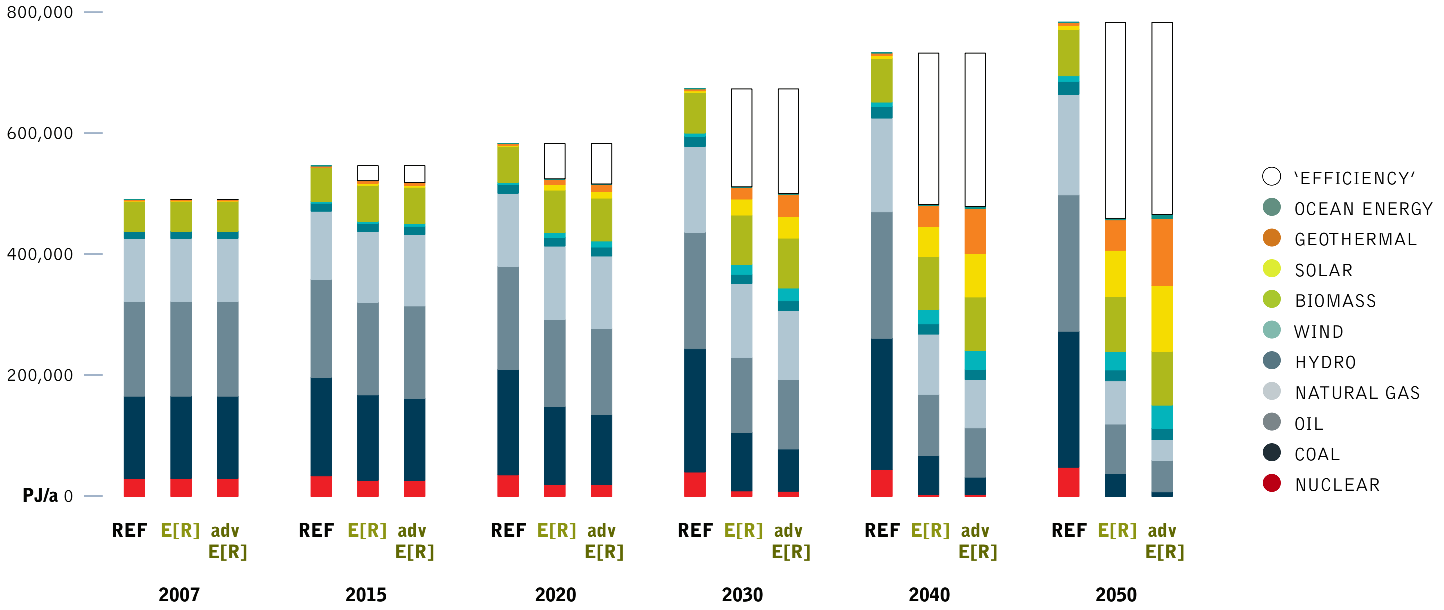
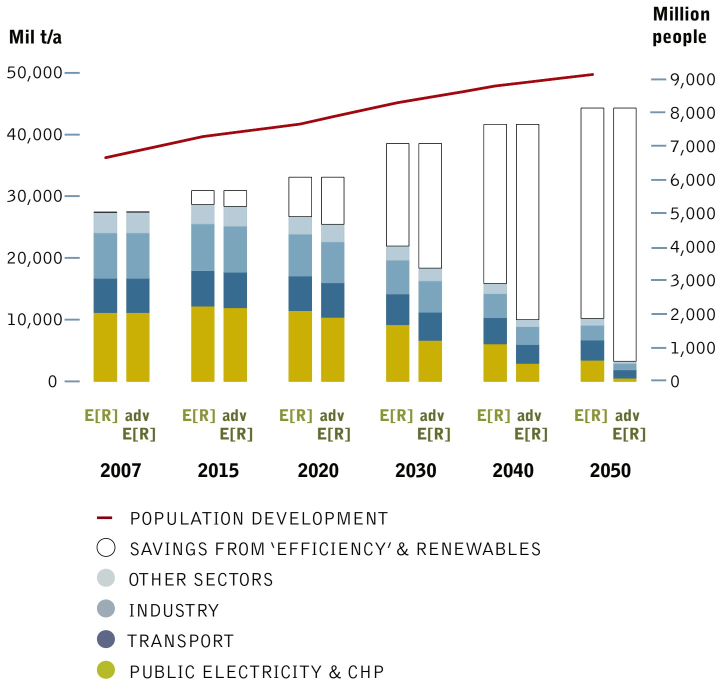


image TRAFFIC JAM IN BANGKOK, THAILAND.

image 100 KW PV GENERATING PLANT NEAR BELLINZONA-LOCARNO RAILWAY LINE. GORDOLA, SWITZERLAND.

figure 6.12: global: development of CO^2 emissions by sector under both energy [r]evolution scenarios



development of global CO_2 emissions

Whilst worldwide emissions of CO_2 will almost double under the Reference scenario, under the Energy [R]evolution scenario they will decrease from 27,408 million tonnes in 2007 to 10,202 million tonnes in 2050 (excluding international bunkers). Annual per capita emissions will drop from 4.1 t to 1.1 t. In spite of the phasing out of nuclear energy and increasing demand, CO_2 emissions will decrease in the electricity sector. In the long run efficiency gains and the increased use of renewable electricity will even reduce CO_2 emissions in the transport sector. With a share of 32% of total CO_2 in 2050, the power sector will fall significantly but remain the largest source of emissions, followed by transport.

The advanced Energy [R]evolution scenario will decrease global CO_2 emissions even further, resulting in emissions of 3,267 million tonnes CO_2/a by 2050 and a per capita level of 0.4 t CO_2/a. This would mean an overall CO_2 reduction of 84% from 1990 levels. Transport would retain the major share, accounting for 42% of all remaining energy related CO_2 emissions.

figure 6.13a: global: regional breakdown of CO_2 emissions in the advanced energy [r]evolution in 2050

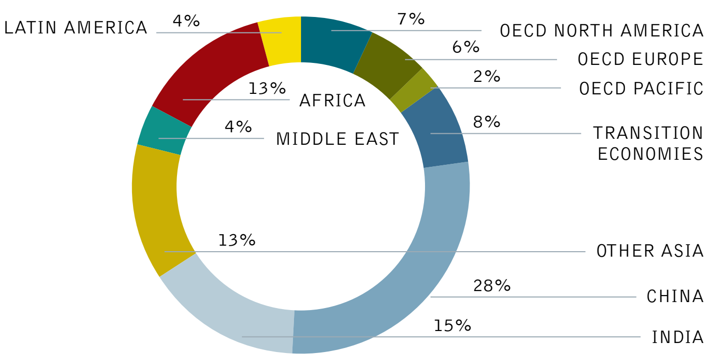
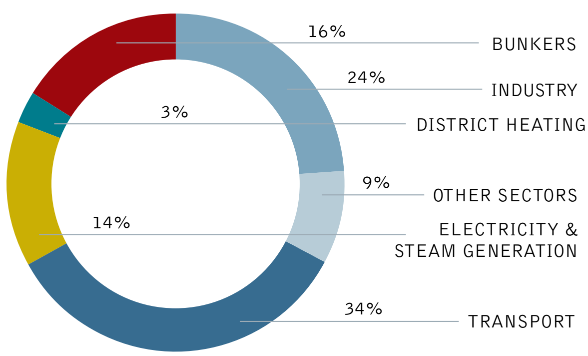


figure 6.13b: global: CO_2 emissions by sector in the advanced energy [r]evolution in 2050



regional breakdown of energy [r]evolution scenario The outcome of the Energy [R]evolution scenario for each region of the world shows how the global pattern is adapted to regional circumstances both in terms of predicted demand for energy and the potential for developing different sources of future supply.

oecd north america

GLOBAL SCENARIO

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oecd north america: energy demand by sector

Combining the projections on population development, GDP growth and energy intensity results in future development pathways for North America's final energy demand. These are shown in Figure 6.14 for the Reference and both Energy [R]evolution scenarios. Under the Reference scenario total primary energy demand increases by more than 12% from the current 115,803 PJ/a to 129,807 PJ/a in 2050. In the Energy [R]evolution scenario, primary energy demand decreases by 39% compared to current consumption and is expected to reach 70,222 PJ/a by 2050. In the advanced version, transport sector demand in OECD North America is 11% lower by 2050 than in the basic Energy [R]evolution scenario; other sectors remain basically the same.

Under the Energy [R]evolution scenario electricity demand is expected to decrease in the industry sector but to grow in the transport sector, whereas in the residential and service sectors electricity demand remains nearly constant (see Figure 6.15). Total electricity demand will rise to 5,578 TWh/a by the year 2050. Compared to the Reference scenario, efficiency measures in the industry, residential and service sectors avoid the generation of about 2,847 TWh/a. This reduction can be achieved in particular by introducing highly efficient electronic devices using the best available technology in all demand sectors.

Efficiency gains in the heat supply sector are even larger. Under the Energy [R]evolution scenario demand for heat supply is expected to decrease almost constantly (see Figure 6.16). Compared to the Reference scenario, consumption equivalent to 5,372 PJ/a is avoided through efficiency gains by 2050 in both Energy [R]evolution scenarios. As a result of energy-related renovation of the existing stock of residential buildings, as well as the introduction of low energy standards and 'passive houses' for new buildings, enjoyment of the same comfort and energy services will be accompanied by a much lower future energy demand.

In the transport sector, it is assumed under the Energy [R]evolution scenario that energy demand will decrease by half to 16,564 PJ/a by 2050, saving 50% compared to the Reference scenario. This reduction can be achieved by the introduction of highly efficient vehicles, by shifting the transport of goods from road to rail and by changes in mobility-related behaviour patterns. The advanced version will further decrease demand - through lifestyle changes, increased efficiency in transport systems and a higher share of electric drives - to 44% of the reference case.

figure 6.14: oecd north america: projection of total final energy demand by sector (REF, E[R] & advanced E[R])

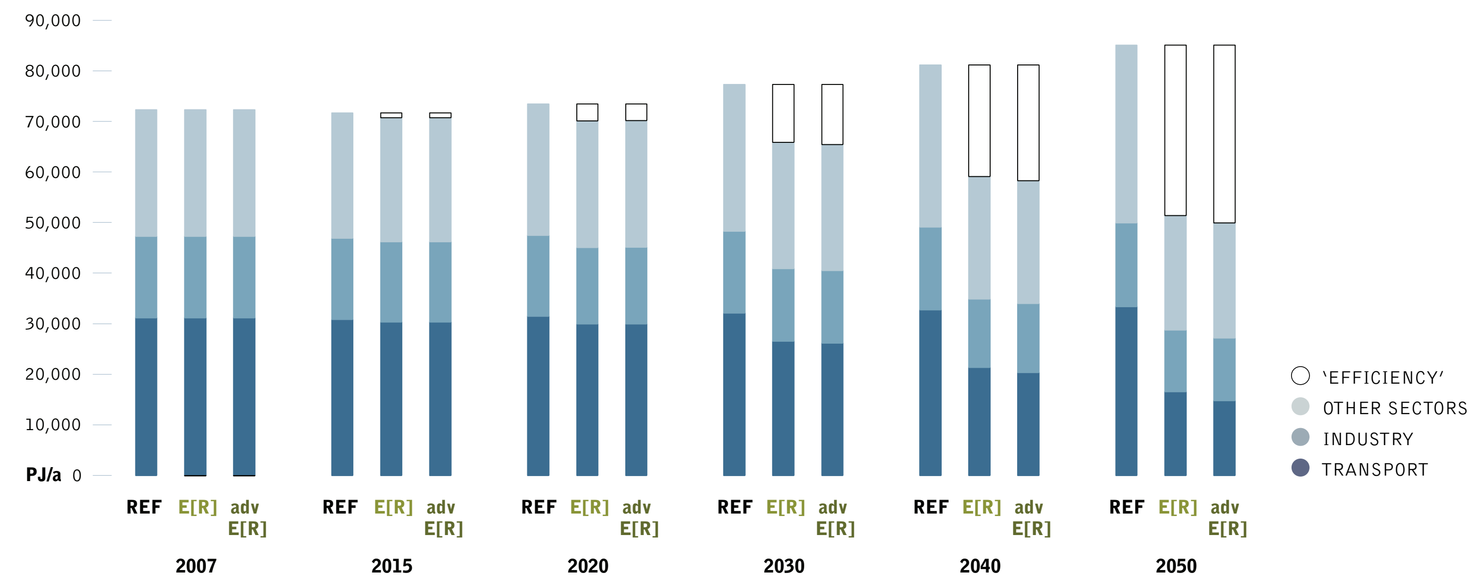
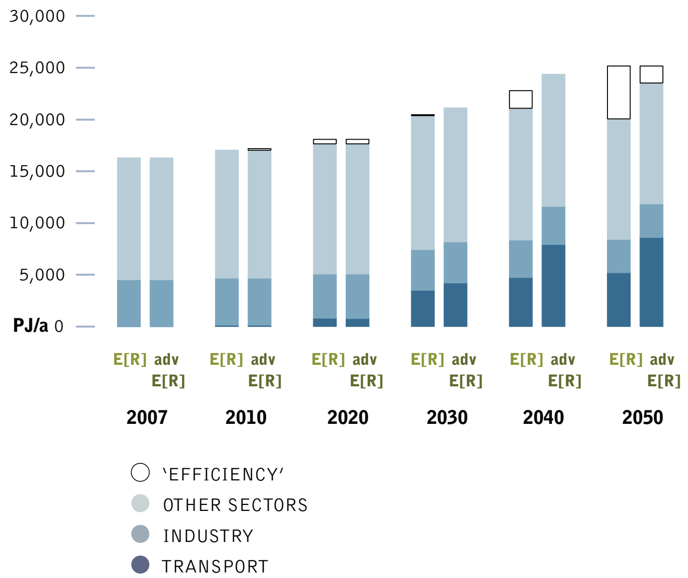


image CONTROL ROOM OF LUZ SOLAR POWER PLANT, CALIFORNIA, USA.

image LUZ INTERNATIONAL SOLAR POWER PLANT, CALIFORNIA, USA.

figure 6.15: oecd north america: development of electricity demand by sector (REF, E[R] & advanced E[R])



oecd north america: heating and cooling supply

Today, renewables meet 12% of OECD North America's primary energy demand for heat supply, the main contribution coming from the use of biomass. The lack of district heating networks is a severe structural barrier to the large scale utilisation of geothermal and solar thermal energy. Dedicated support instruments are required to ensure a dynamic development.

In the Energy [R]evolution scenario, renewables provide 73% of OECD North America's total heating demand by 2050.

- Energy efficiency measures help to reduce the currently growing demand for heating and cooling, in spite of improving living standards.
- In the industry sector solar collectors, biomass/biogas and geothermal energy are increasingly substituted for conventional fossil-fuelled heating systems.
- A shift from coal and oil to natural gas in the remaining conventional applications leads to a further reduction of CO_2 emissions.

In the Energy [R]evolution scenario 5,372 PJ/a is saved by 2050, or 21% compared to the Reference scenario. The advanced version introduces renewable heating systems around five years ahead of the basic scenario. Solar collectors and geothermal heating systems achieve economies of scale via ambitious support programmes five to ten years earlier, resulting in a renewables share of 51% by 2030 and 97% by 2050.

figure 6.16: oecd north america: development of heat demand by sector

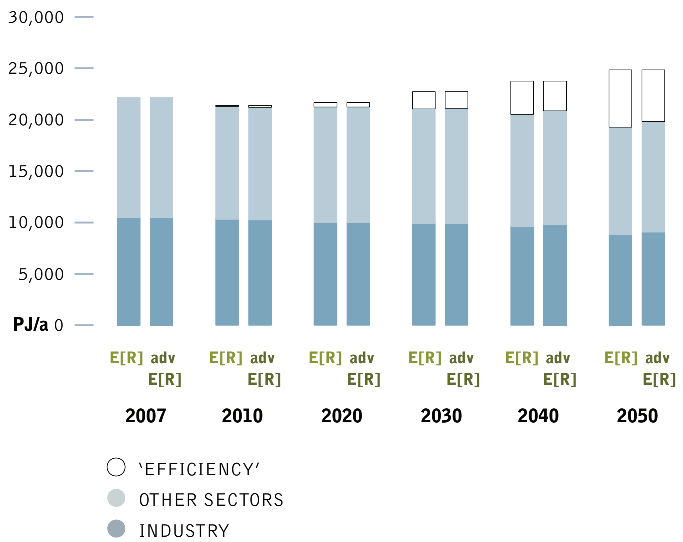
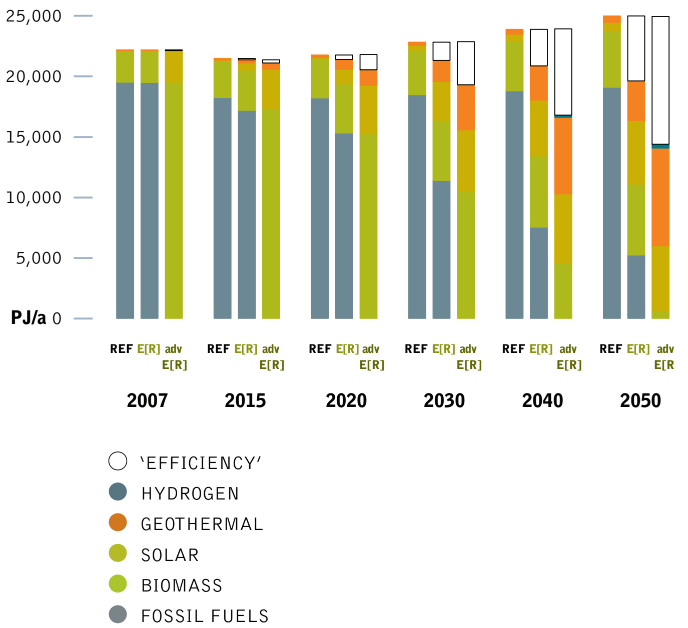


figure 6.17: oecd north america: development of heat supply structure under 3 scenarios



oecd north america

oecd north america: electricity generation

The development of the electricity supply sector is characterised by a dynamically growing renewable energy market and an increasing share of renewable electricity. This will compensate for the phasing out of nuclear energy and reduce the number of fossil fuel-fired power plants required for grid stabilisation. By 2050, 95% of the electricity produced in OECD North America will come from renewable energy sources. 'New' renewables – mainly wind, solar thermal energy and PV – will contribute over 68% of electricity generation. The advanced Energy [R]evolution scenario will not increase this share significantly. By 2030 77% and by 2050 98% will come from renewables, but the overall installed capacity of renewable generation (2,955 GW) will be higher than in the basic version.

Table 6.3 shows the comparative evolution of the different renewable technologies in OECD North America over time. Up to 2020, hydro power and wind will remain the main contributors to the growing market share. After 2020, the continuing growth of wind will be complemented by electricity from biomass, photovoltaic and solar thermal (CSP) energy.

table 6.3: oecd north america: projection of renewable electricity generation capacity under both energy [r]evolution scenarios

IN GW

		2007	2020	2030	2040	2050
Hydro	E[R]	183	227	237	248	255
	advanced E[R]	183	234	247	265	267
Biomass	E[R]	14	44	74	113	136
	advanced E[R]	14	48	79	114	123
Wind	E[R]	19	240	448	561	605
	advanced E[R]	19	401	642	747	797
Geothermal	E[R]	4	23	52	82	99
	advanced E[R]	4	31	79	130	143
PV	E[R]	1	120	402	653	821
	advanced E[R]	1	151	478	920	980
CSP	E[R]	0	57	173	263	270
	advanced E[R]	0	106	295	392	361
Ocean energy	E[R]	0	19	52	108	156
	advanced E[R]	0	32	85	235	284
Total	**E[R]**	**221**	**731**	**1,438**	**2,027**	**2,341**
	advanced E[R]	**221**	**1,004**	**1,905**	**2,804**	**2,955**

figure 6.18: oecd north america: development of electricity generation structure under 3 scenarios

(REFERENCE, ENERGY [R]EVOLUTION AND ADVANCED ENERGY [R]EVOLUTION) ["EFFICIENCY" = REDUCTION COMPARED TO THE REFERENCE SCENARIO]

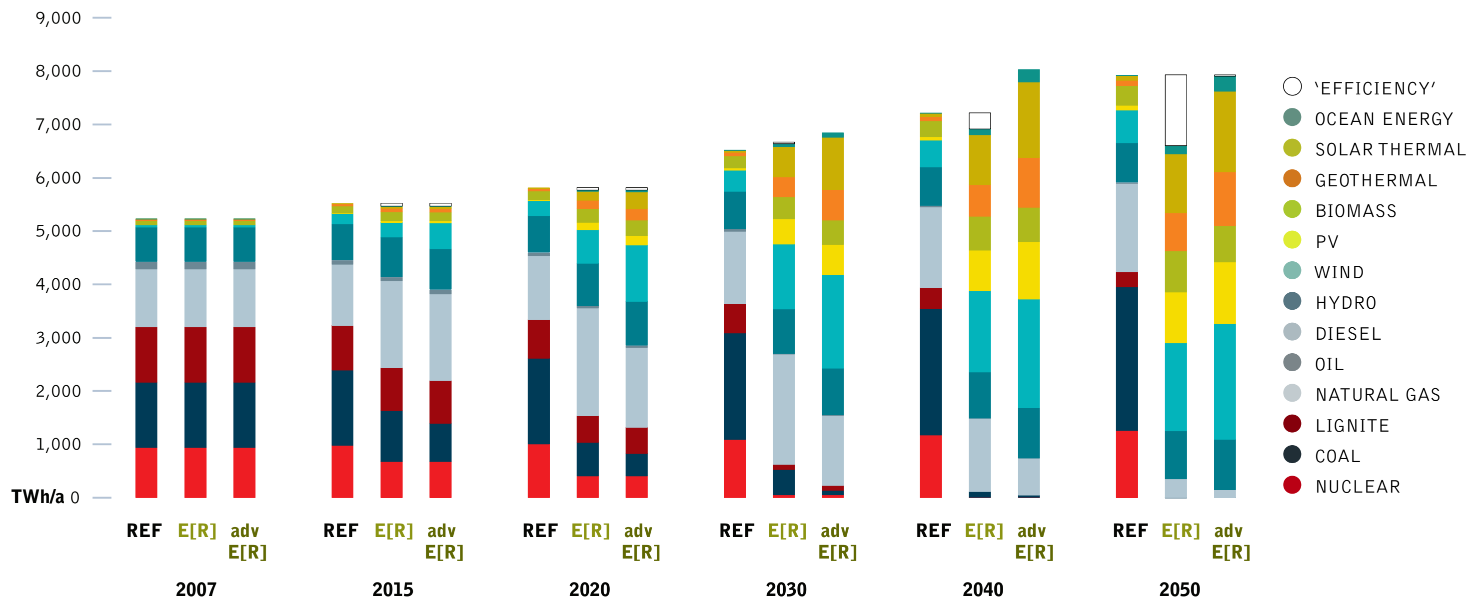
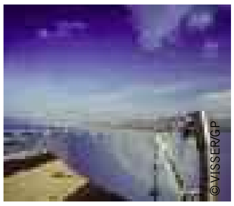


image CONCENTRATING SOLAR POWER (CSP) AT A SOLAR FARM IN DAGGETT, CALIFORNIA, USA.

image AN OFFSHORE DRILLING RIG DAMAGED BY HURRICANE KATRINA, GULF OF MEXICO.



oecd north america: future costs of electricity generation

Figure 6.19 shows that the introduction of renewable technologies under the Energy [R]evolution scenario significantly decreases the future costs of electricity generation compared to the Reference scenario. Because of the lower CO_2 intensity of electricity generation, costs will become economically favourable under the Energy [R]evolution scenario and by 2050 will be more than 5 $cents/kWh below those in the Reference version.

Under the Reference scenario, on the other hand, unchecked growth in demand, an increase in fossil fuel prices and the cost of CO_2 emissions result in total electricity supply costs rising from today's $470 billion per year to more than $1,150 billion in 2050. Figure 6.19 shows that the Energy [R]evolution scenario not only complies with OECD North America's CO_2 reduction targets but also helps to stabilise energy costs and relieve the economic pressure on society. Increasing energy efficiency and shifting energy supply to renewables lead to long term costs for electricity supply that are one third lower than in the Reference scenario.

Despite the increased demand for electricity, especially in the transport and industry sectors, the overall supply costs in the advanced version are $62 billion lower in 2030 but $108 billion higher in 2050 than in the basic Energy [R]evolution scenario.

oecd north america: job results

The Energy [R]evolution scenarios lead to more energy sector jobs in OECD North America at every stage of the projection.

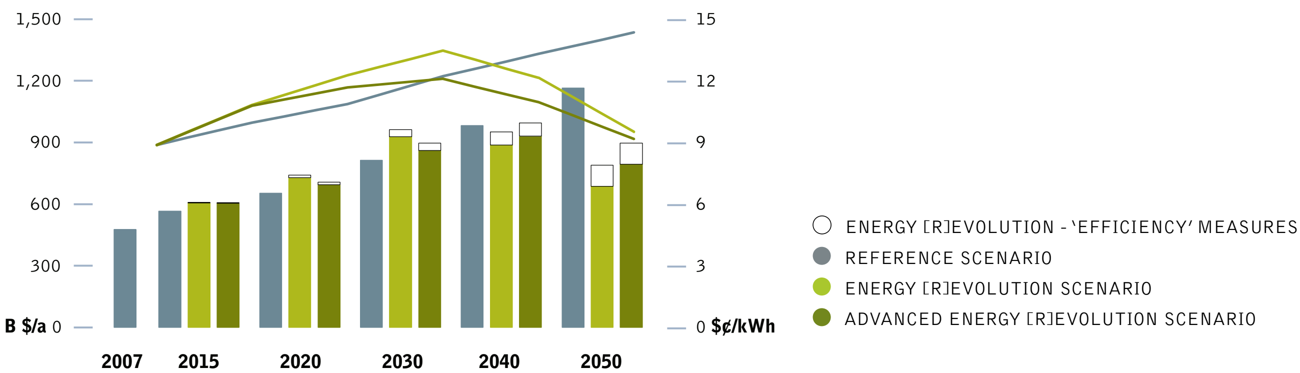
• There are 1.59 million power sector jobs in the Energy [R]evolution scenario and 2.01 million in the advanced version by 2015, compared to 660,000 in the Reference scenario.

• By 2020 job numbers reach over 1.6 million in the Energy [R]evolution scenario (1.85 million in the advanced version), one million more than in the Reference scenario.

• By 2030 job numbers remain roughly on 2020 levels in the Energy [R]evolution scenario to 1.4 million (1.7 million in the advanced version) and reach nearly 0.7 million in the Reference scenario.

Table 6.4 shows the increase in job numbers under both Energy [R]evolution scenarios for each technology up to 2020 and up to 2030. Both scenarios show losses in coal generation, but these are outweighed by employment growth in renewable technologies and gas. Wind shows particularly strong growth in both Energy [R]evolution scenarios by 2020, but by 2030 there is significant employment across a range of renewable technologies.

figure 6.19: oecd north america: development of total electricity supply costs & development of specific electricity generation costs under 3 scenarios



oecd north america

GLOBAL SCENARIO

OECD NORTH AMERICA
LATIN AMERICA
OECD EUROPE
AFRICA

MIDDLE EAST
TRANSITION ECONOMIES
INDIA

DEVELOPING ASIA
CHINA
OECD PACIFIC

table 6.4: oecd north america: employment & investment

	REFERENCE			ENERGY [R]EVOLUTION			ADVANCED ENERGY [R]EVOLUTION		
	2015	2020	2030	2015	2020	2030	2015	2020	2030
Jobs									
Construction & installation	0.12 m	0.10 m	0.09 m	0.62 m	0.59 m	0.34 m	0.80 m	0.72 m	0.57 m
Manufacturing	0.10 m	0.06 m	0.06 m	0.45 m	0.37 m	0.22 m	0.67 m	0.44 m	0.28 m
Operations & maintenance	0.24 m	0.27 m	0.32 m	0.29 m	0.41 m	0.60 m	0.31 m	0.48 m	0.70 m
Fuel	0.20 m	0.21 m	0.22 m	0.23 m	0.24 m	0.27 m	0.23 m	0.21 m	0.20 m
Total Jobs	**0.66 m**	**0.63 m**	**0.69 m**	**1.59 m**	**1.60 m**	**1.43 m**	**2.01 m**	**1.85 m**	**1.74 m**
Coal	0.15 m	0.14 m	0.14 m	0.08 m	0.05 m	0.02 m	0.07 m	0.04 m	0.01 m
Gas, oil and diesel	0.14 m	0.14 m	0.14 m	0.22 m	0.20 m	0.21 m	0.20 m	0.15 m	0.13 m
Nuclear	0.05 m	0.06 m	0.06 m	0.03 m	0.02 m	0.00 m	0.03 m	0.02 m	0.00 m
Renewables	0.32 m	0.30 m	0.34 m	1.26 m	1.34 m	1.19 m	1.72 m	1.64 m	1.61 m
Total Jobs	**0.66 m**	**0.63 m**	**0.69 m**	**1.59 m**	**1.60 m**	**1.43 m**	**2.01 m**	**1.85 m**	**1.74 m**

oecd north america: transport

A key target in OECD North America is to introduce incentives for people to drive smaller cars, something almost completely absent today. In addition, it is vital to shift transport use to efficient modes like rail, light rail and buses, especially in the expanding large metropolitan areas. Together with rising prices for fossil fuels, these changes reduce the huge growth in car sales projected under the Reference scenario. Energy demand from the transport sector is reduced to 50% in the Energy [R]evolution scenario and to 44% in the advanced version compared to the Reference scenario.

Highly efficient propulsion technology with hybrid, plug-in hybrid and battery-electric power trains will bring large efficiency gains. By 2030, electricity will provide 13% of the transport sector's total energy demand in the Energy [R]evolution scenario, while in the advanced version the share will already reach 16% in 2030 and 58% by 2050.

figure 6.20: oecd north america: transport under 3 scenarios

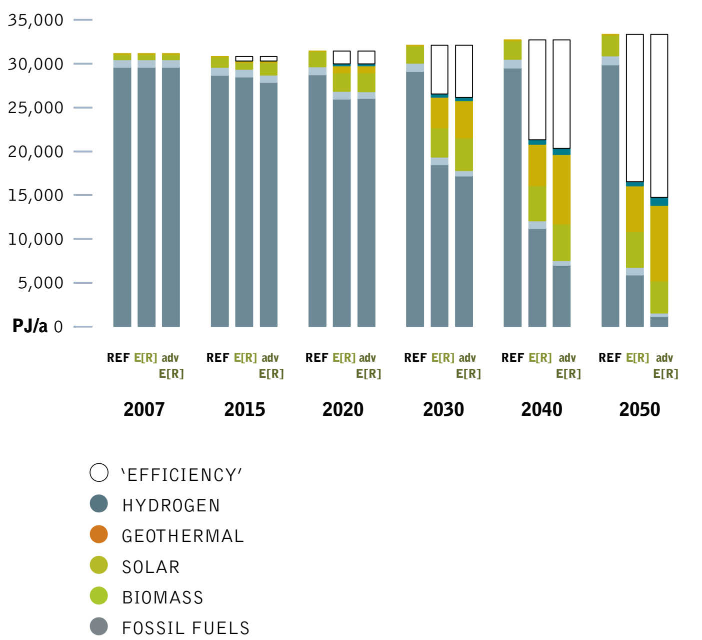


image SUN SETTING OFF THE GULF OF MEXICO.

image CONCENTRATING SOLAR POWER (CSP) AT A SOLAR FARM IN DAGGETT, CALIFORNIA, USA.

oecd north america: development of CO_2 emissions

Whilst OECD North America's emissions of CO_2 will increase by 2% between 2007 and 2050 under the Reference scenario, under the Energy [R]evolution scenario they will decrease from 6,681 million tonnes in 2007 to 942 million tonnes in 2050. Annual per capita emissions will drop from 14.9 t to 1.6 t. In spite of the phasing out of nuclear energy and increasing demand, CO_2 emissions will decrease in the electricity sector. In the long run efficiency gains and the increased use of renewable electricity in the transport sector will even reduce CO_2 emissions.

With a share of 46% of total CO_2, the transport sector will be the largest source of emissions in 2050. The advanced Energy [R]evolution scenario reduces energy related CO_2 emissions over a period ten to 15 years faster than the basic scenario, leading to 5.1 t per capita by 2030 and 0.4 t by 2050. By 2050, OECD North America's CO_2 emissions are 96% below 1990 levels.

oecd north america: primary energy consumption

Taking into account the assumptions discussed above, the resulting primary energy consumption under the Energy [R]evolution scenario is shown in Figure 6.22. Compared to the Reference scenario, overall primary energy demand will be reduced to 54% in 2050. Around 69% of the remaining demand will be covered by renewable energy sources.

The advanced version phases out coal and oil about ten to 15 years faster than the basic scenario. This is made possible mainly by the replacement of new coal power plants with renewables after a 20 rather than 40 year lifetime and a faster introduction of electric vehicles in the transport sector to replace oil combustion engines. This leads to an overall renewable primary energy share of 44% in 2030 and 85% in 2050. Nuclear power is phased out in both Energy [R]evolution scenarios soon after 2040.

figure 6.21: oecd north america: development of CO_2 emissions by sector under both energy [r]evolution scenarios

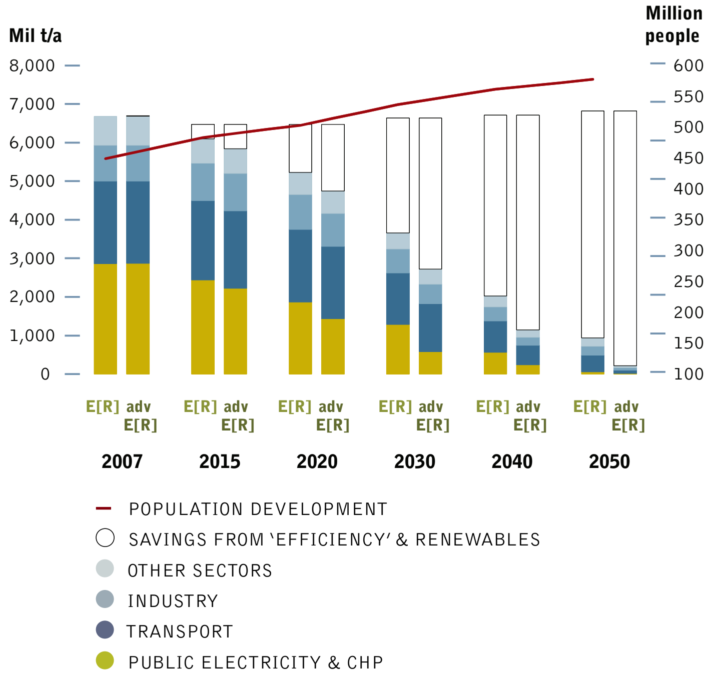
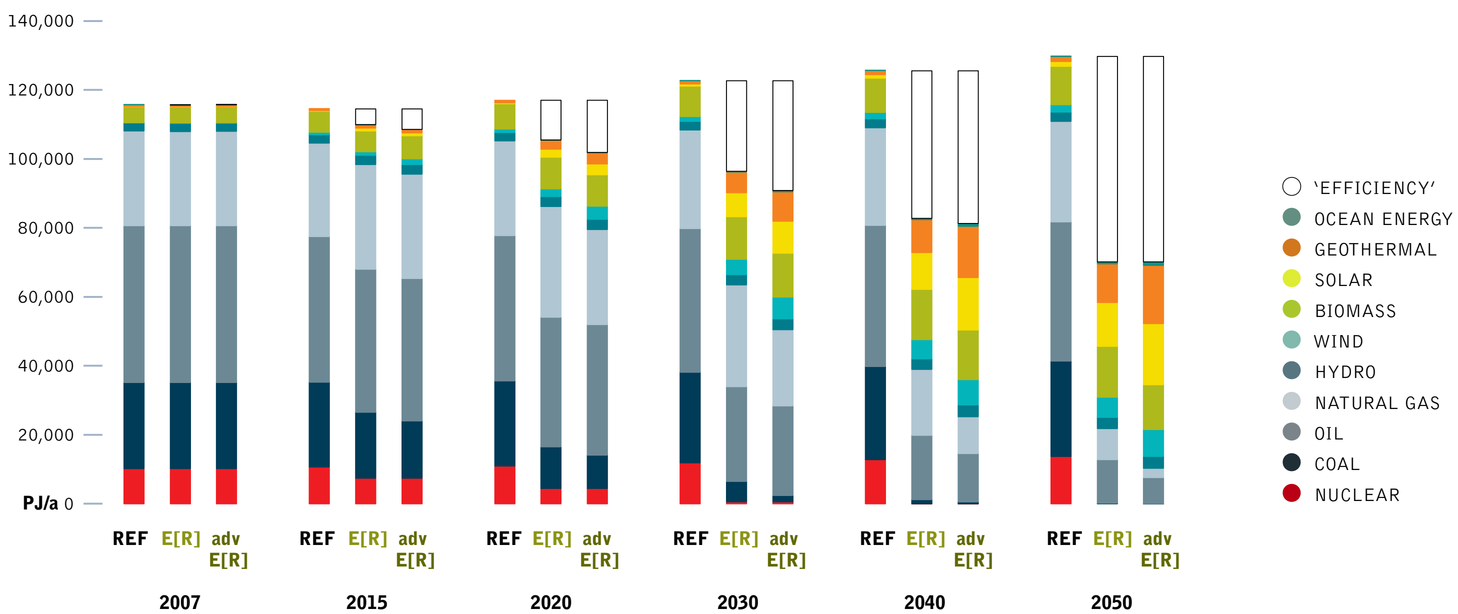


figure 6.22: oecd north america: development of primary energy consumption under three scenarios



latin america

latin america: energy demand by sector

Combining the projections on population development, GDP growth and energy intensity results in future development pathways for Latin America's energy demand. These are shown in Figure 6.23 for both the Reference and Energy [R]evolution scenarios. Under the Reference scenario total primary energy demand more than doubles from the current 22,733 PJ/a to 41,327 PJ/a in 2050. In the Energy [R]evolution scenario a smaller 25% increase from current consumption is expected by 2050, reaching 28,354 PJ/a and 27,326 PJ/a in the advanced version.

Under the Energy [R]evolution scenario, electricity demand is expected to increase disproportionately, with households and services the main source of growing consumption. This is due to wider access to energy services in developing countries (see Figure 6.24). With the exploitation of efficiency measures, however, an even higher increase can be avoided, leading to electricity demand of around 2,185 TWh/a in 2050. Compared to the Reference scenario, efficiency measures in the industry, residential and service sectors avoid the generation of about 388 TWh/a. This reduction can be achieved in particular by introducing highly efficient electronic devices. Employment of solar architecture in both residential and commercial buildings will help to curb the growing demand for air-conditioning.

The advanced Energy [R]evolution scenario introduces electric vehicles earlier, and more journeys – for both freight and passengers - are shifted to electric trains and public transport. Fossil fuels for industrial process heat generation are also phased out more quickly and replaced by electric geothermal heat pumps and hydrogen. This means that electricity production in the advanced version is higher, and reaches 2,502 TWh/a in 2050, 17% above the Reference case.

Efficiency gains in the heat supply sector are even larger. Under both Energy [R]evolution scenarios, final demand for heat supply can even be reduced (see Figure 6.25). Compared to the Reference scenario, consumption equivalent to 1,586 PJ/a is avoided through efficiency gains by 2050. In the transport sector, it is assumed under the Energy [R]evolution scenario that energy demand will increase by a 13% to 6,089 PJ/a by 2050, saving 53% compared to the Reference scenario.

The advanced Energy [R]evolution scenario goes one step further and factors in a faster decrease in transport energy demand after a peak in 2030. This is achieved through a mix of increased public transport, reduced annual person-kilometres and wider use of more efficient engines and electric drives. While electricity demand increases, the overall final energy use falls to 21,403 PJ/a, 37% lower than in the Reference case.

figure 6.23: latin america: projection of total final energy demand by sector (REF, E[R] & advanced E[R])

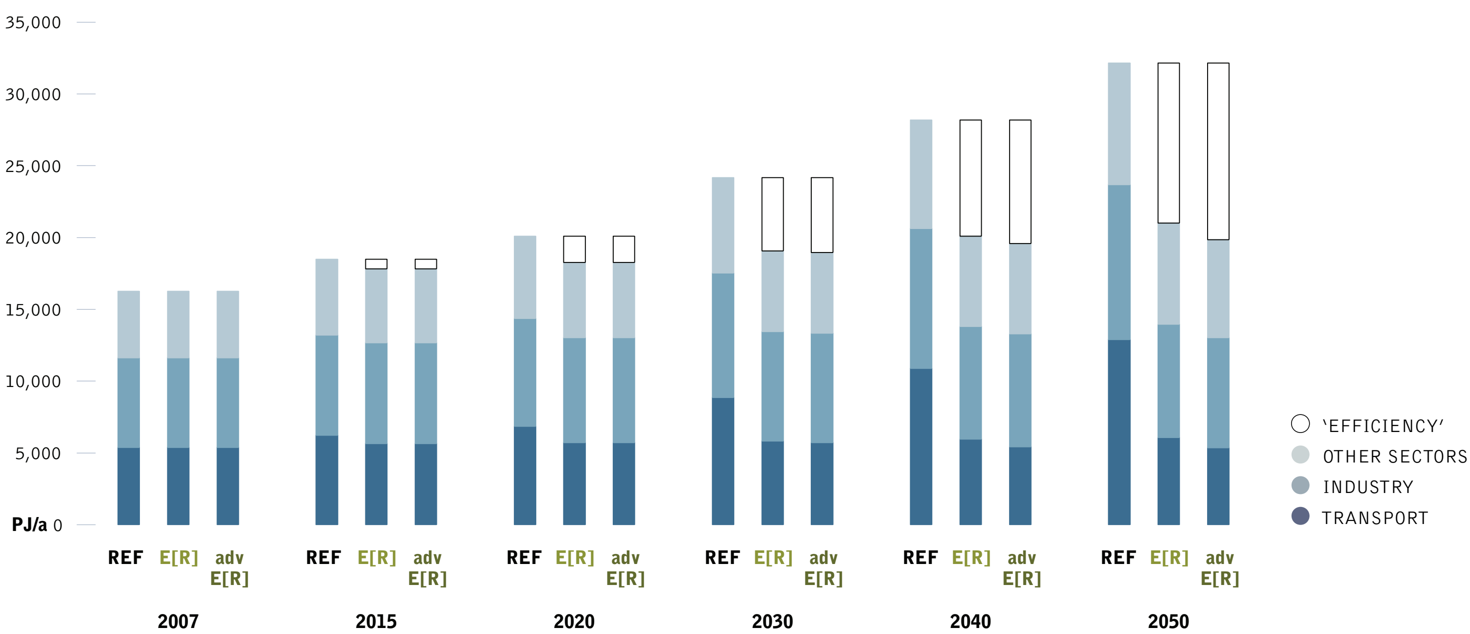


image VOLUNTEERS CHECK THE SOLAR PANELS ON TOP OF GREENPEACE POSITIVE ENERGY TRUCK, BRAZIL.

image WIND TURBINES IN FORTALEZ, CEARÀ, BRAZIL.

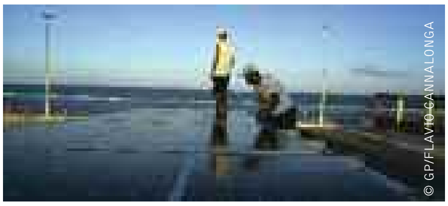
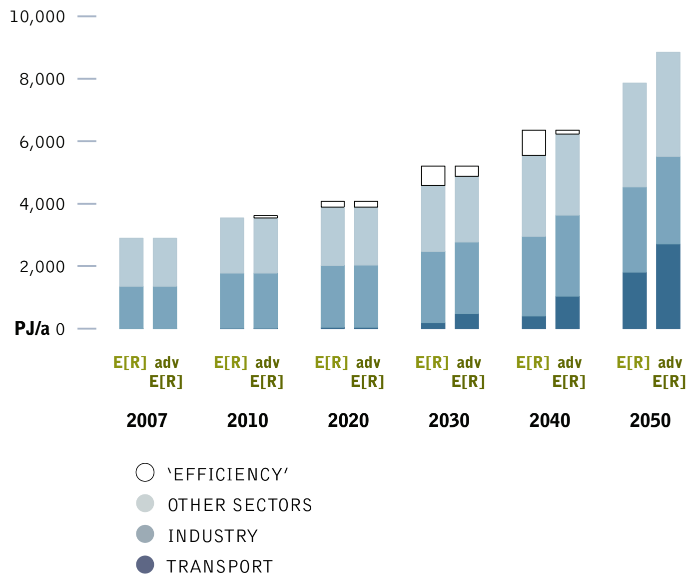


figure 6.24: latin america: development of electricity demand by sector (REF, E[R] & advanced E[R])



latin america: heating and cooling supply

Today, renewables provide around 39% of primary energy demand for heat supply in Latin America, the main contribution coming from the use of biomass. The availability of less efficient but cheap appliances is a severe structural barrier to efficiency gains. Large-scale utilisation of geothermal and solar thermal energy for heat supply will be largely restricted to the industrial sector.

In the Energy [R]evolution scenario renewables provide 81% of Latin America's total heating and cooling demand by 2050.

- Energy efficiency measures can restrict the future primary energy demand for heat and cooling supply to a 29% increase, in spite of improving living standards.
- In the industry sector solar collectors, biomass/biogas as well as geothermal energy are increasingly replacing conventional fossil-fuelled heating systems.
- A shift from coal and oil to natural gas in the remaining conventional applications leads to a further reduction of CO_2 emissions.

In the Energy [R]evolution scenario 1,586 PJ/a is saved by 2050, or 17% compared to the Reference scenario. The advanced Energy [R]evolution version introduces renewable heating systems around five years ahead of the basic scenario. Solar collectors and geothermal heating systems achieve economies of scale via ambitious support programmes five to ten years earlier, resulting in a renewables share of 66% by 2030 and 98% by 2050.

figure 6.25: latin america: development of heat demand by sector

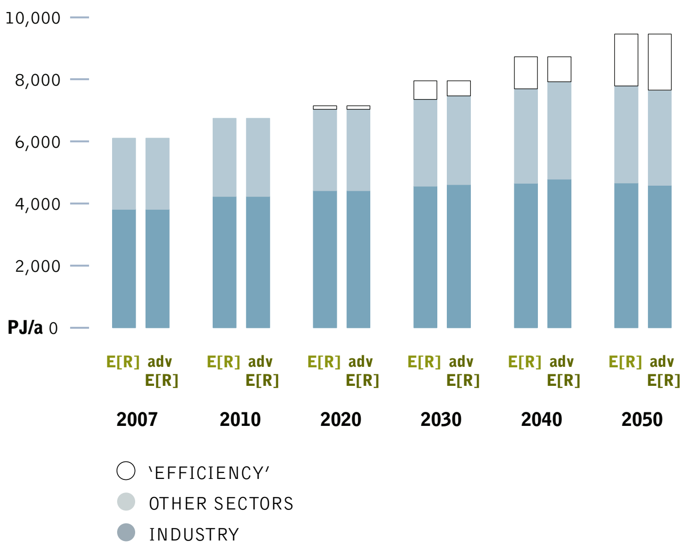
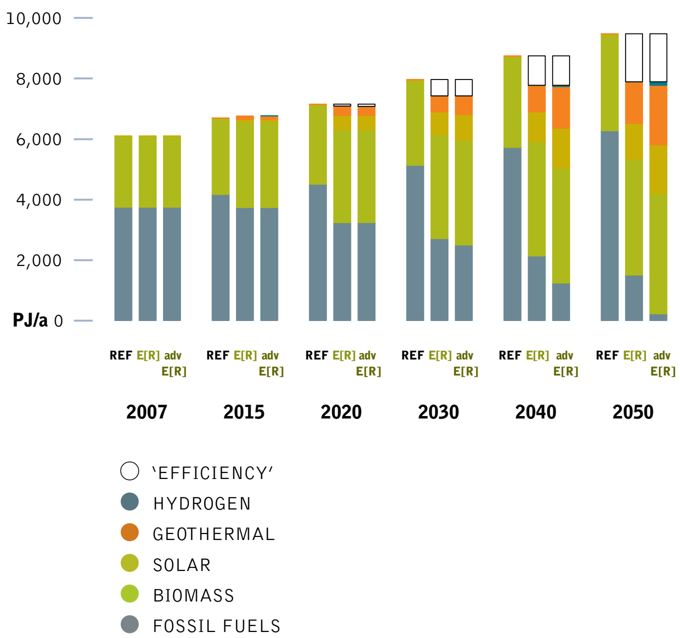


figure 6.26: latin america: development of heat supply structure under 3 scenarios



latin america

latin america: electricity generation

The development of the electricity supply sector is characterised by an increasing share of renewable electricity. By 2050, 97% of the electricity produced in Latin America will come from renewable energy sources. 'New' renewables – mainly wind, solar thermal energy and PV – will contribute more than 47% of electricity generation. The installed capacity of renewable energy technologies will grow from the current 143 GW to 705 GW in 2050, increasing renewable capacity by a factor of five within the next 40 years.

Figure 6.27 shows the comparative evolution of the different renewable technologies over time. Up to 2020, hydro power and wind will remain the main contributors to the growing market share. After 2020, the continuing growth of wind will be complemented by electricity from biomass, photovoltaic and solar thermal (CSP) energy.

The advanced Energy [R]evolution scenario projects a faster market development pathway, with higher annual growth rates achieving a renewable electricity share of 89% by 2030 and 98% by 2050. The installed capacity of renewables will reach 379 GW in 2030 and 842 GW by 2050, 19% higher than in the basic version.

None of these numbers - even in the advanced Energy [R]evolution scenario - utilise the maximum known technical potential of all the renewable resources. While the deployment rate compared to the technical potential for hydro power, for example, is relatively high at 33% in the advanced Energy [R]evolution scenario, for solar only less than 1% has been used both in the basic version and in the advanced scenario.

table 6.5: latin america: projection of renewable electricity generation capacity under both energy [r]evolution scenarios

IN GW

		2007	2020	2030	2040	2050
Hydro	E[R]	138	160	164	165	172
	advanced E[R]	138	160	164	165	172
Biomass	E[R]	4	23	44	60	82
	advanced E[R]	4	23	44	62	81
Wind	E[R]	0	33	72	160	280
	advanced E[R]	0	45	88	162	304
Geothermal	E[R]	1	3	4	9	16
	advanced E[R]	1	2	6	13	23
PV	E[R]	0	10	51	64	118
	advanced E[R]	0	20	63	114	193
CSP	E[R]	0	3	6	10	30
	advanced E[R]	0	6	13	29	52
Ocean energy	E[R]	0	1	1	3	8
	advanced E[R]	0	1	1	8	17
Total	**E[R]**	**143**	**233**	**342**	**473**	**705**
	advanced E[R]	**143**	**258**	**379**	**554**	**842**

figure 6.27: latin america: development of electricity generation structure under 3 scenarios

(REFERENCE, ENERGY [R]EVOLUTION AND ADVANCED ENERGY [R]EVOLUTION) ["EFFICIENCY" = REDUCTION COMPARED TO THE REFERENCE SCENARIO]

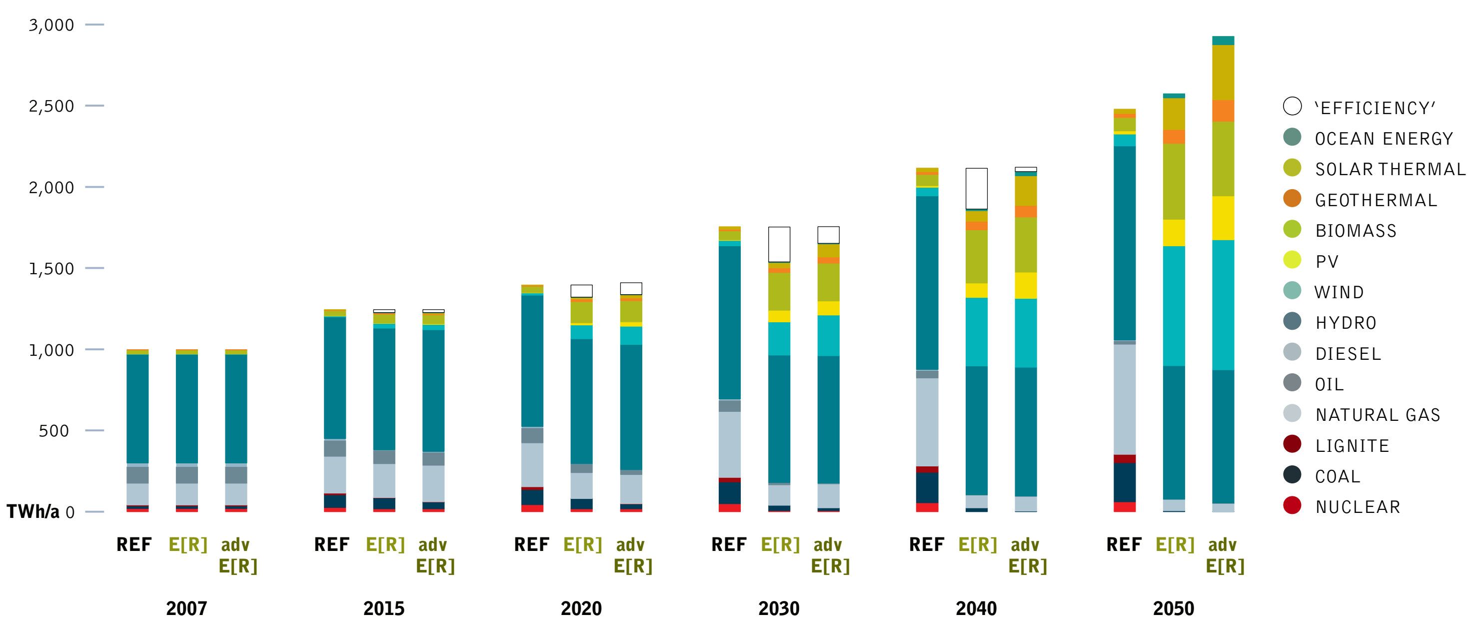


image GROUP OF YOUNG PEOPLE FEEL THE HEAT GENERATED BY A SOLAR COOKING STOVE IN BRAZIL.

image IN 2005 THE WORST DROUGHT IN MORE THAN 40 YEARS DAMAGED THE WORLD'S LARGEST RAIN FOREST IN THE BRAZILIAN AMAZON, WITH WILDFIRES BREAKING OUT, POLLUTED DRINKING WATER AND THE DEATH OF MILLIONS FISH AS STREAMS DRY UP.

latin america: future costs of electricity generation

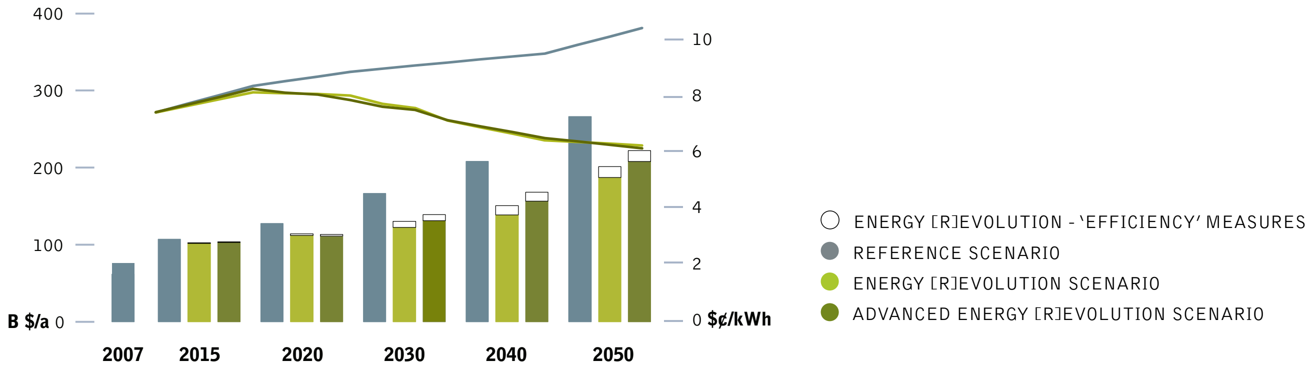
Figure 6.28 shows that the introduction of renewable technologies under the Energy [R]evolution scenario significantly decreases the future costs of electricity generation compared to the Reference scenario. Because of the lower CO_2 intensity of electricity generation, costs will become economically favourable under the Energy [R]evolution scenario and by 2050 will be more than 4 cents/kWh below those in the Reference scenario.

Under the Reference scenario, on the other hand, unchecked growth in demand, an increase in fossil fuel prices and the cost of CO_2 emissions result in total electricity supply costs rising from today's $75 billion per year to more than $260 billion in 2050. Figure 6.28 shows that the Energy [R]evolution scenario not only complies with Latin America's CO_2 reduction targets but also helps to stabilise energy costs and relieve the economic pressure on society. Increasing energy efficiency and shifting energy supply to renewables leads to long term costs for electricity supply that are one third lower than in the Reference scenario.

The advanced Energy [R]evolution scenario will lead to a higher proportion of variable power generation sources (PV, wind and ocean power), accounting for 21% by 2030. Expansion in the use of smart grids, demand side management and storage capacity through an increased share of electric vehicles will therefore be introduced to ensure better grid integration and power generation management.

In both Energy [R]evolution scenarios the specific generation costs are almost the same up to 2050. Due to the increased demand for electricity, especially in the transport and industry sectors, the overall supply costs in the advanced version are $9 billion higher in 2030 and $21 billion higher in 2050 than in the basic Energy [R]evolution scenario.

figure 6.28: latin america: development of total electricity supply costs & development of specific electricity generation costs under 3 scenarios



latin america: job results

The Energy [R]evolution scenarios result in more energy sector jobs in Latin America at every stage of the projection.

- There are 560,000 power sector jobs in the Energy [R]evolution scenario and 700,000 in the advanced version by 2015, compared to 430,000 in the Reference scenario.
- By 2020 job numbers reach over 720,000 in the Energy [R]evolution scenario (740,000 in the advanced version), 260,000 more than in the Reference scenario.
- By 2030 job numbers climb slightly in the Energy [R]evolution scenario to nearly 870,000, (980,000 in the advanced version) and reach only 570,000 in the Reference scenario.

Table 6.6 shows the change in job numbers under both Energy [R]evolution scenarios for each technology up to 2020 and up to 2030. Both scenarios show losses in coal generation, but these are outweighed by employment growth in renewable technologies and gas. Wind shows particularly strong growth in both Energy [R]evolution scenarios by 2020, but by 2030 there is significant employment across a range of renewable technologies.

latin america

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table 6.6: latin america: employment & investment

	REFERENCE			ENERGY [R]EVOLUTION			ADVANCED ENERGY [R]EVOLUTION		
	2015	2020	2030	2015	2020	2030	2015	2020	2030
Jobs									
Construction & installation	0.11 m	0.11 m	0.11 m	0.17 m	0.21 m	0.09 m	0.29 m	0.22 m	0.18 m
Manufacturing	0.01 m	0.01 m	0.02 m	0.06 m	0.07 m	0.13 m	0.09 m	0.07 m	0.14 m
Operations & maintenance	0.14 m	0.16 m	0.20 m	0.18 m	0.31 m	0.50 m	0.18 m	0.32 m	0.52 m
Fuel	0.17 m	0.19 m	0.24 m	0.15 m	0.15 m	0.15 m	0.14 m	0.13 m	0.15 m
Total Jobs	**0.43 m**	**0.48 m**	**0.57 m**	**0.56 m**	**0.72 m**	**0.87 m**	**0.70 m**	**0.74 m**	**0.98 m**
Coal	0.08 m	0.09 m	0.12 m	0.04 m	0.03 m	0.01 m	0.03 m	0.01 m	0.01 m
Gas, oil and diesel	0.11 m	0.12 m	0.14 m	0.10 m	0.07 m	0.04 m	0.10 m	0.06 m	0.04 m
Nuclear	0.01 m	0.01 m	0.01 m	0.00 m	0.00 m	0.00 m	0.00 m	0.00 m	0.00 m
Renewables	0.23 m	0.26 m	0.31 m	0.42 m	0.63 m	0.82 m	0.56 m	0.66 m	0.94 m
Total Jobs	**0.43 m**	**0.48 m**	**0.57 m**	**0.56 m**	**0.72 m**	**0.87 m**	**0.70 m**	**0.74 m**	**0.98 m**

latin america: transport

Despite a huge growth in transport services, the energy consumption in the transport sector by 2050 can be limited to 42% under the Energy [R]evolution scenario and 47% in the advanced case compared to the reference case. Dependence on fossil fuels for 90% of this supply is transformed by using 37% biofuels and 30% electricity in the basic version. The advanced Energy [R]evolution scenario increases the share of electricity in the transport sector up to 51%, while the use of biomass and shifted partly towards the power sector and industrial heat processes.

Both Energy [R]evolution scenarios assume measures to change the current pattern of car sales, with one third in future taken up by medium-sized vehicles and more than half by small vehicles. Technical progress increases the share of hybrid vehicles to 50% (75% in the advanced version) by 2050. Incentives to use more efficient transport modes reduce vehicle kilometres travelled to an average of 11,000 km per annum.

figure 6.29: latin america: transport under 3 scenarios

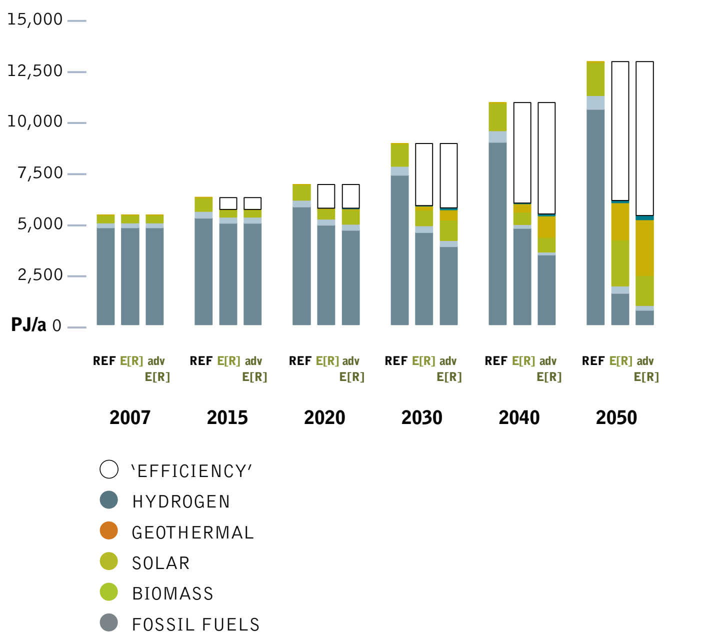


image CHILDREN IN THE FLOODED CACAO PEREIRA VILLAGE IN THE AMAZON, BRAZIL. THE NEGRO RIVER ROSE TO 29.77 METERS, SURPASSING THE MARK OF 29.69 METERS REGISTERED IN 1953, THE LAST RECORDED FLOOD.

image MAN MADE FIRES NEAR ARAGUAYA RIVER OUTSIDE THE ARAGUAYA NATIONAL PARK. FIRES ARE STARTED TO CLEAR THE LAND FOR FUTURE CATTLE USE.

latin america: development of CO_2 emissions

Whilst Latin America's emissions of CO_2 will almost double under the Reference scenario, under the Energy [R]evolution scenario they will decrease from 1,010 million tonnes in 2007 to 312 million tonnes in 2050. Annual per capita emissions will drop from 2.2 t to 0.5 t.

The advanced Energy [R]evolution scenario will shift the peak of energy related CO_2 emissions to approximately 5 years earlier than in the basis version, leading to 1.1 t per capita by 2030 and 0.2 t by 2050. By 2050, Latin America´s CO_2 emissions will be 80% below 1990 levels.

In spite of the phasing out of nuclear energy and increasing demand, CO_2 emissions will decrease in the electricity sector. In the long run efficiency gains and the increased use of renewable electricity in vehicles will even reduce CO_2 emissions in the transport sector. With a share of 54% of total CO_2 in 2050, the transport sector will remain the largest source of emissions.

latin america: primary energy consumption

Taking into account the assumptions discussed above, the resulting primary energy consumption under both Energy [R]evolution scenarios is shown in Figure 6.31. Compared to the Reference scenario, overall primary energy demand will be reduced by about 31%, and 34% in the advanced version, by 2050. Latin America's primary energy demand will increase from 22,513 PJ/a to 28,339 PJ/a (27,311 PJ/a in the advanced version). Under the advanced Energy [R]evolution scenario a share of around 88% of the remaining energy demand will be covered by renewable sources.

figure 6.30: latin america: development of CO_2 emissions by sector under both energy [r]evolution scenarios

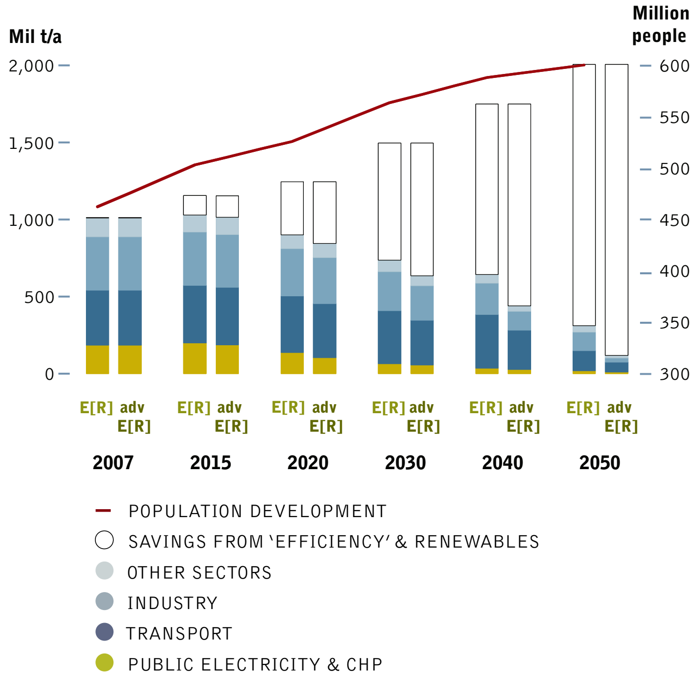
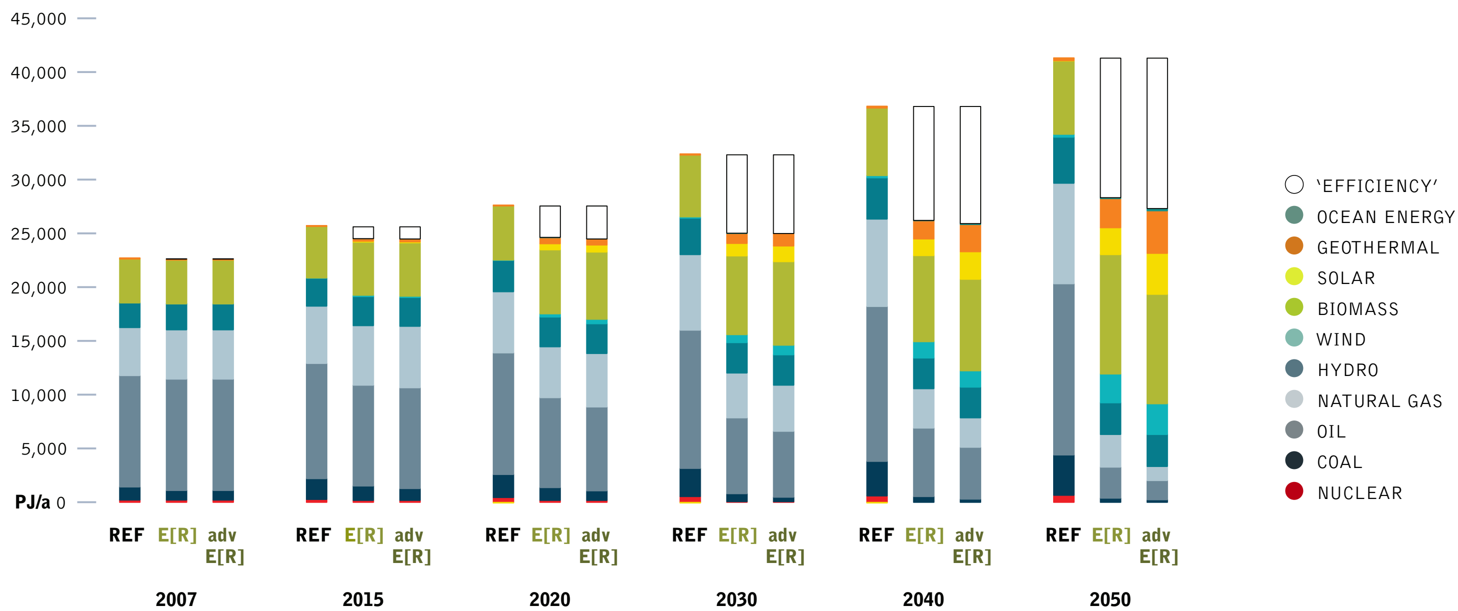


figure 6.31: latin america: development of primary energy consumption under three scenarios



oecd europe

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oecd europe: energy demand by sector

The future development pathways for Europe's energy demand are shown in Figure 6.32 for the Reference and both Energy [R]evolution scenarios. Under the Reference scenario, total primary energy demand in OECD Europe increases by more than 7% from the current 77,585 PJ/a to 83,102 PJ/a in 2050. The energy demand in 2050 in the Energy [R]evolution scenario decreases by 36% and 38% in the advanced case, compared to current consumption. By 2050 it is expected to reach 49,853 PJ/a and 48,489 PJ/a in the advanced scenario.

Efficiency gains in the heat supply sector are larger than in the electricty sector. Under both Energy [R]evolution scenarios, final demand for heat supply can even be reduced significantly (see Figure 6.34). Compared to the Reference scenario, consumption equivalent to 7,211 PJ/a, is avoided through efficiency gains by 2050. As a result of energy-related renovation of the existing stock of residential buildings, as well as the introduction of low energy standards and 'passive houses' for new buildings, enjoyment of the same comfort and energy services will be accompanied by a much lower future energy demand.

Under the Energy [R]evolution scenario, electricity demand in the industry as well as in the residential and service sectors is expected to decrease after 2015 (see Figure 6.33). Because of the growing use of electric vehicles however, electricity demand increases to 3,730 TWh/a in the year 2050. Compared to the Reference scenario, efficiency measures in industry and other sectors avoid the generation of about 1,850 TWh/a. This reduction in energy demand can be achieved in particular by introducing highly efficient electronic devices using the best available technology.

In the transport sector, it is assumed under the Energy [R]evolution scenario that energy demand will decrease by almost half to 8,848 PJ/a by 2050, saving 45% compared to the Reference scenario. This reduction can be achieved by the introduction of highly efficient vehicles, by shifting the transport of goods from road to rail and by changes in mobility related behaviour patterns.

The advanced Energy [R]evolution scenario introduces electric vehicles earlier and more transport - both from freight and persons - will be shifted towards electric trains and public transport. Besides fossil fuels are phased out quicker from industrial process heat generation and shifted towards electric geothermal heatpumps and hydrogen. Therefore the electricity demand in the advanved Energy [R]evolution is higher and reaches 4,375 TWh/a in 2050, 8% below the reference case.

figure 6.32: oecd europe: projection of total final energy demand by sector (REF, E[R] & advanced E[R])

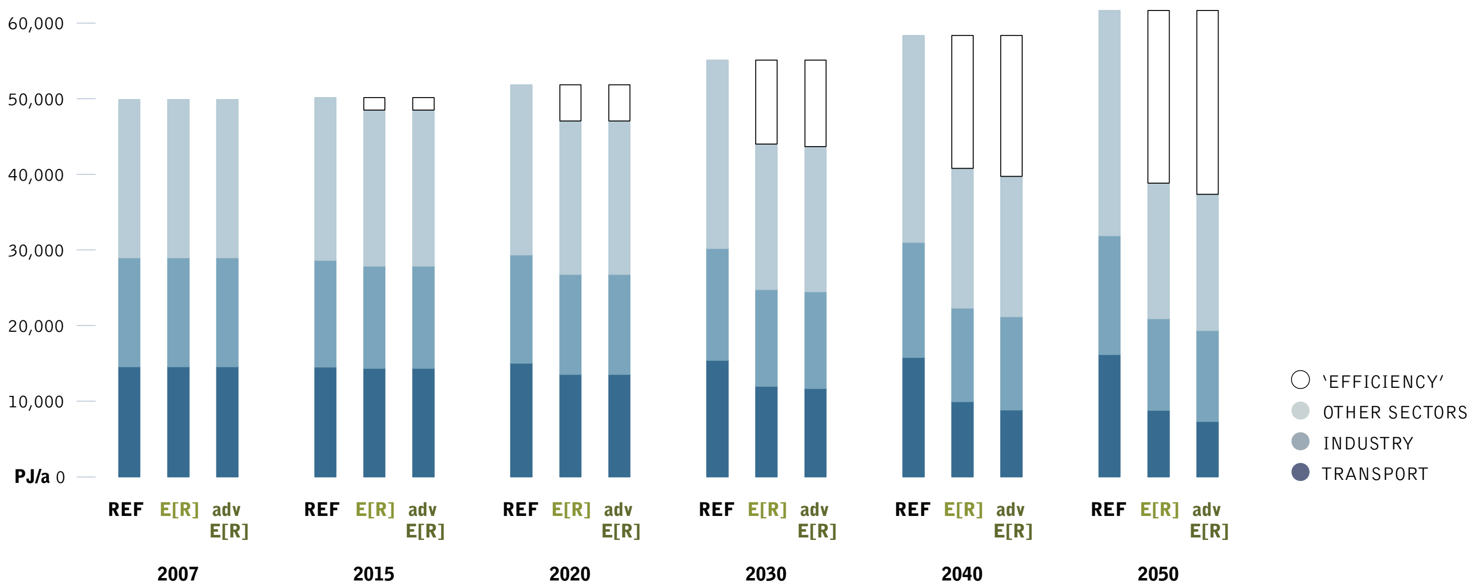
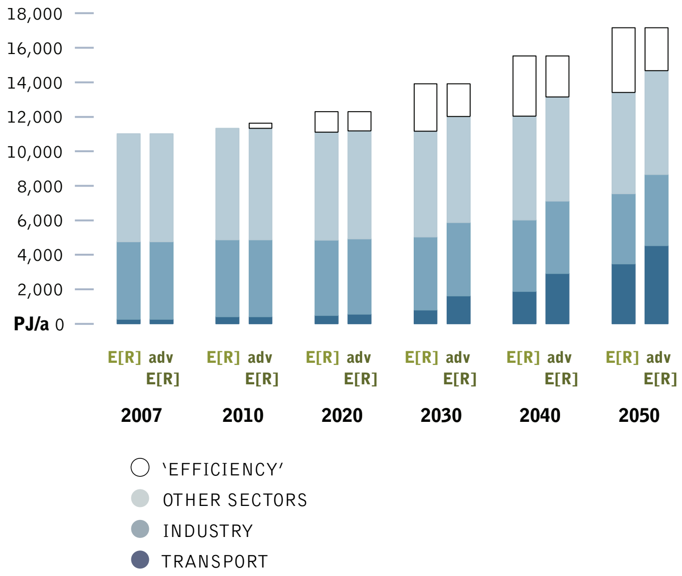


image image OFFSHORE WINDFARM, MIDDELGRUNDEN, COPENHAGEN, DENMARK.

image MAN USING METAL GRINDER ON PART OF A WIND TURBINE MAST IN THE VESTAS FACTORY, CAMBELTOWN, SCOTLAND, GREAT BRITAIN.

figure 6.33: oecd europe: development of electricity demand by sector (REF, E[R] & advanced E[R])



oecd europe: heating and cooling supply

Renewables currently provide 13% of OECD Europe's energy demand for heat supply, the main contribution coming from the use of biomass. The lack of district heating networks is a severe structural barrier to the large scale utilisation of geothermal and solar thermal energy. In the Energy [R]evolution scenario, renewables provide 62% of OECD Europe's total heating and cooling demand in 2050.

- Energy efficiency measures can decrease the current demand for heat supply by 27%, in spite of improving living standards.
- For direct heating, solar collectors, biomass/biogas as well as geothermal energy are increasingly substituting for fossil fuel-fired systems.

The advanced Energy [R]evolution case introduces efficiency measures e.g. via strict building standards and renewable heating systems around 5 years ahead of the Energy [R]evolution scenario.

- Energy efficiency: Compared to the Reference scenario, 7,211 PJ/a or 27% are safed by 2050.
- Solar collectors and geothermal heating systems achieve economies of scale via ambitious support programms 5 to 10 years earlier. The total RES share thereby increases to 42% by 2030 and 92% by 2050.

figure 6.34: oecd europe: development of heat demand by sector

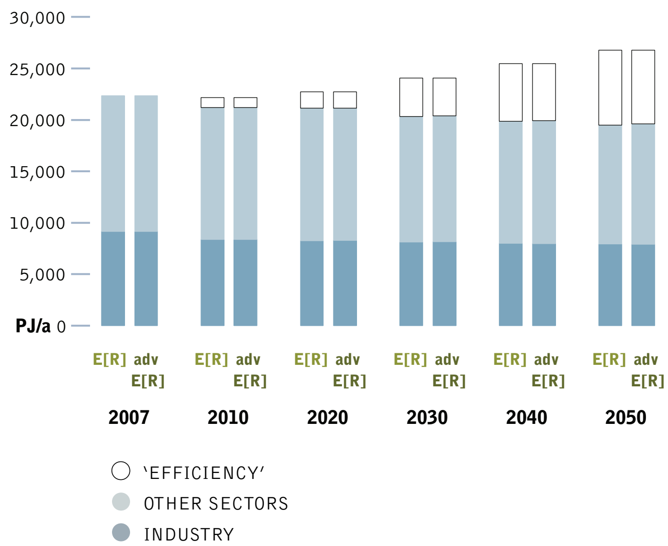
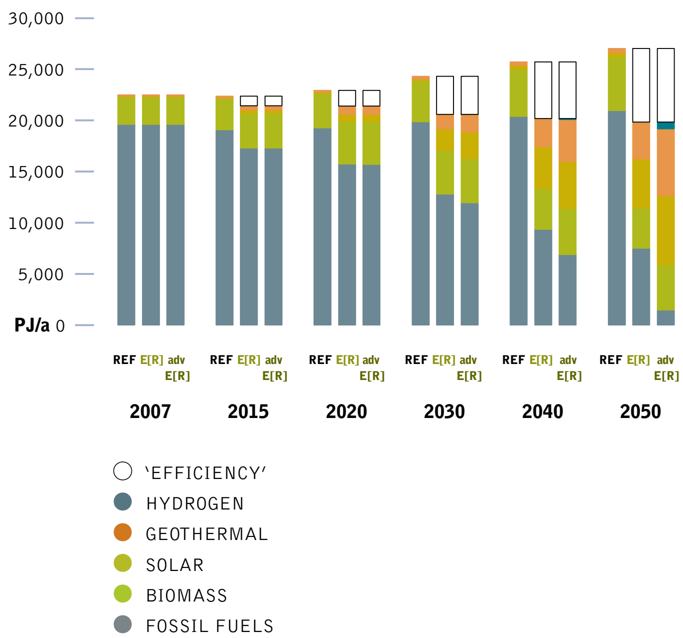


figure 6.35: oecd europe: development of heat supply structure under 3 scenarios



oecd europe

oecd europe: electricity generation

The development of the electricity supply sector in the Energy [R]evolution scenario is characterised by a dynamically growing renewable energy market. This will compensate for the phasing out of nuclear energy and reduce the number of fossil fuel-fired power plants required for grid stabilisation. By 2050, 91% of the electricity produced in OECD Europe will come from renewable energy sources. 'New' renewables – mainly wind, solar thermal energy and PV – will contribute 54% of electricity generation. The installed capacity of renewable energy technologies will grow from the current 269 GW to 1,175 GW in 2050, increasing renewable capacity by a factor of 4.

The advanced Energy [R]evolution scenario takes a faster market development with higher annual growth rates into account and will achieve a renewable electricity share from 69% by 2030 and 97% by 2050. The installed capacity of renewables will reach 966 GW in 2030 and 1,506 GW by 2050, 28% higher than in the Energy [R]evolution scenario.

Figure 6.36 shows the evolution of the European electricity mix under 3 different scenarios. Up to 2020 hydro and wind will remain the main contributors of the growing market share. After 2020, the continuing growth of wind will be complemented by elelctricty from biomass, photovoltaics and solar thermal (CSP) energy. The advanced Energy [R]evolution scenario will lead to a higher share of fluctuating power generation source (photovoltaic, wind and ocean) of 31% by 2030, therefore the expansion of smart grids, demand side management (DSM) and storage capacity from the increased share of electric vehicles will be used for a better grid integration and power generation management.

table 6.7: oecd europe: projection of renewable electricity generation capacity under both energy [r]evolution scenarios

IN GW

		2007	2020	2030	2040	2050
Hydro	E[R]	185	192	190	191	191
	advanced E[R]	185	192	190	191	191
Biomass	E[R]	21	59	76	97	113
	advanced E[R]	21	58	76	90	94
Wind	E[R]	57	249	340	413	448
	advanced E[R]	57	249	386	439	483
Geothermal	E[R]	2	4	8	21	29
	advanced E[R]	2	7	34	55	86
PV*	E[R]	5	120	179	301	348
	advanced E[R]	5	138	221	369	510
CSP	E[R]	0	9	17	27	33
	advanced E[R]	0	15	44	74	100
Ocean energy	E[R]	0	1	3	8	13
	advanced E[R]	0	3	15	26	42
Total	**E[R]**	**269**	**634**	**814**	**1,058**	**1,175**
	advanced E[R]	**269**	**663**	**966**	**1,243**	**1,506**

* ACCORDING TO INDUSTRY PROJECTIONS OUTLINED IN RE-THINKING 2050, A MUCH HIGHER INSTALLED CAPACITY FIGURE FOR PV IS ASSUMED (MORE THAN 900 GW BY 2050).

figure 6.36: oecd europe: development of electricity generation structure under 3 scenarios

(REFERENCE, ENERGY [R]EVOLUTION AND ADVANCED ENERGY [R]EVOLUTION) ["EFFICIENCY" = REDUCTION COMPARED TO THE REFERENCE SCENARIO]

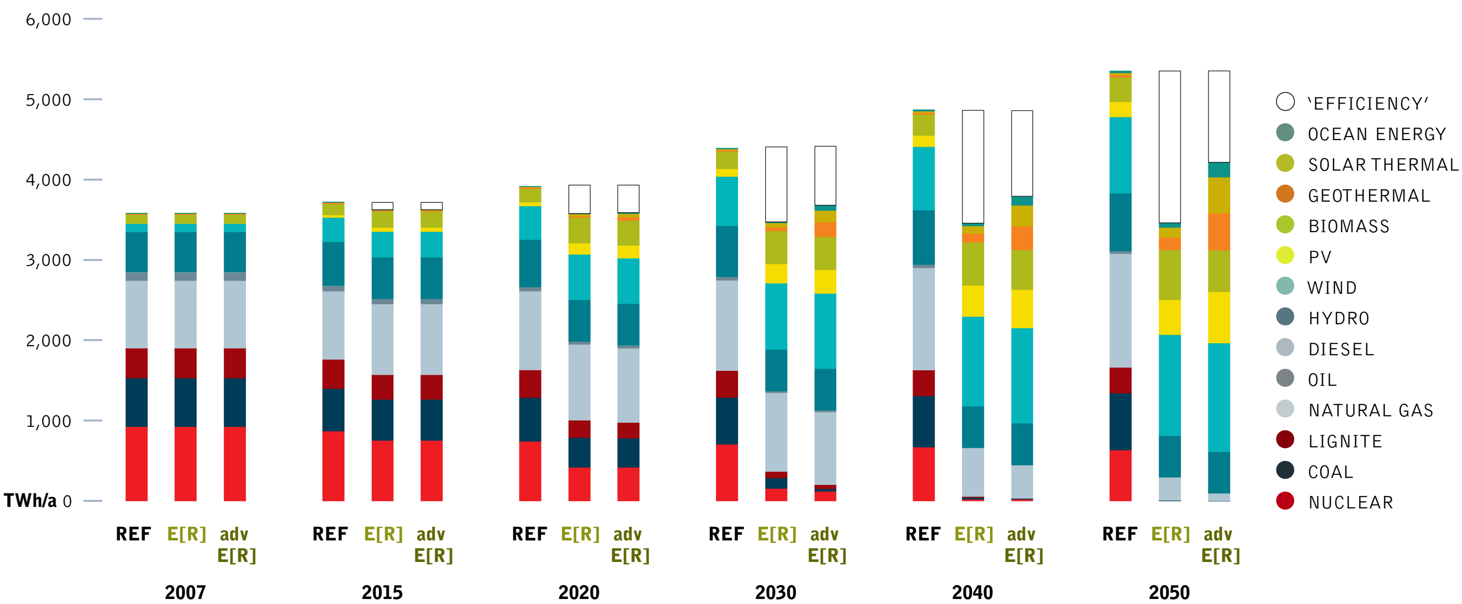
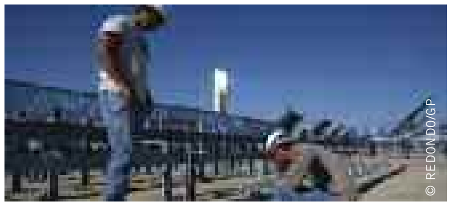


image PLANT NEAR REYKJAVIK WHERE ENERGY IS PRODUCED FROM THE GEOTHERMAL ACTIVITY.

image WORKERS EXAMINE PARABOLIC TROUGH COLLECTORS IN THE PS10 SOLAR TOWER PLANT AT SAN LUCAR LA MAYOR OUTSIDE SEVILLE, SPAIN, 2008.



oecd europe: future costs of electricity generation

Figure 6.37 shows that the introduction of renewable technologies under the Energy [R]evolution scenario slightly increases the costs of electricity generation compared to the Reference scenario. This difference will be less than 1 cent/kWh up to 2020, however. Because of the lower CO_2 intensity of electricity generation, electricity generation costs will become economically favourable under the Energy [R]evolution scenario by 2020, and by 2050 costs will be more than 4 cents/kWh below those in the Reference scenario.

Under the Reference scenario, the unchecked growth in demand, the increase in fossil fuel prices and the cost of CO_2 emissions result in total electricity supply costs rising from today's $309 billion per year to more than $685 billion in 2050. Figure 6.37 shows that the Energy [R]evolution scenario not only complies with Europe´s CO_2 reduction targets but also helps to stabilise energy costs and relieve the economic pressure on society. Increasing energy efficiency and shifting energy supply to renewables lead to long term costs for electricity supply that are one third lower than in the Reference scenario.

In both Energy [R]evolution scenarios the specific generation costs are almost on the same level until 2030. In 2050 the advanced Energy [R]evolution scenario has with 8 cents/kWh lower generation costs, because of better economics of scale in renewable power equipment.

oecd europe: job results

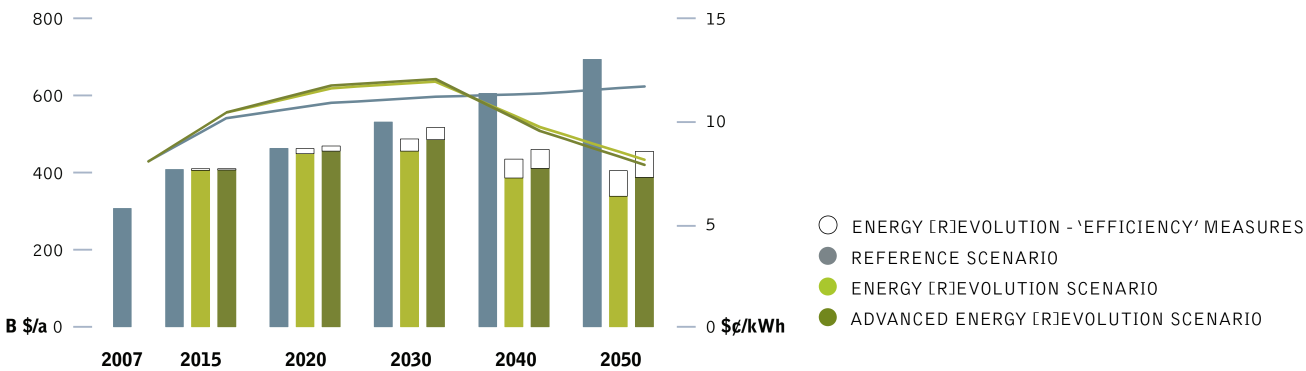
- There are 1.6 million power sector jobs in both Energy [R]evolution scenarios in OECD Europe in 2015 and 820,000 in the Reference scenario.
- In 2020, job numbers reach one million in the Energy [R]evolution scenario, 1.2 million in the advanced and 750,000 in the Reference scenario.
- Job numbers reach 1.6 million in 2030 in both Energy [R]evolution scenario, compared to 750,000 in the Reference scenario.

Table 6.8. shows the change in job numbers under all scenarios between 2015 and 2020, and 2020 and 2030. New renewable energy jobs in both [R]evolution scenarios are dominated by wind and solar technologies, and there are losses in the coal sector even in the reference case.

In case the decline factor in productivity for 2020 and 2030 will not factored in, the European renewable industry would employ over one million people by 2020 and 2030, compared to around 800,000.

There are more energy sector jobs in OECD Europe in both [R]evolution scenarios at every stage. In 2015, both Energy [R]evolution have about a quarter of a million jobs more than in the Reference scenario. By 2020, the [R]evolution scenarios have 250,000 (450,000 additional jobs). The gap between the two scenarios remains similar in 2030.

figure 6.37: oecd europe: development of total electricity supply costs & development of specific electricity generation costs under 3 scenarios



oecd europe

table 6.8: oecd europe: employment & investment

	REFERENCE			ENERGY [R]EVOLUTION			ADVANCED ENERGY [R]EVOLUTION		
	2015	2020	2030	2015	2020	2030	2015	2020	2030
Jobs									
Construction & installation	0.11 m	0.08 m	0.08 m	0.54 m	0.13 m	0.14 m	0.49 m	0.19 m	0.17 m
Manufacturing	0.14 m	0.10 m	0.06 m	0.43 m	0.24 m	0.19 m	0.48 m	0.33 m	0.23 m
Operations & maintenance	0.27 m	0.29 m	0.33 m	0.30 m	0.40 m	0.45 m	0.31 m	0.40 m	0.48 m
Fuel	0.29 m	0.28 m	0.28 m	0.34 m	0.28 m	0.19 m	0.32 m	0.27 m	0.15 m
Total Jobs	**0.82 m**	**0.75 m**	**0.75 m**	**1.62 m**	**1.03 m**	**0.98 m**	**1.59 m**	**1.19 m**	**1.04 m**
Coal	0.25 m	0.23 m	0.23 m	0.29 m	0.18 m	0.08 m	0.26 m	0.18 m	0.03 m
Gas, oil and diesel	0.05 m	0.05 m	0.05 m	0.06 m	0.05 m	0.05 m	0.06 m	0.05 m	0.05 m
Nuclear	0.04 m	0.03 m	0.03 m	0.03 m	0.02 m	0.01 m	0.03 m	0.02 m	0.01 m
Renewables	0.48 m	0.43 m	0.44 m	1.24 m	0.77 m	0.84 m	1.24 m	0.94 m	0.95 m
Total Jobs	**0.82 m**	**0.75 m**	**0.75 m**	**1.62 m**	**1.03 m**	**0.98 m**	**1.59 m**	**1.19 m**	**1.04 m**

oecd europe: transport

In the transport sector, it is assumed under the Energy [R]evolution scenario that an energy demand reduction of 7,354 PJ/a can be achieved by 2050, saving 45% compared to the Reference scenario. This reduction can be achieved by the introduction of highly efficient vehicles, by shifting the transport of goods from road to rail and by changes in mobility-related behaviour patterns. Implementing attractive alternatives to individual cars, the car stock is growing slower than in the Reference scenario.

A slight shift towards smaller cars triggered by economic incentives together with a significant shift in propulsion technology towards electrified power trains and a reduction of vehicle kilometres travelled by 0.25% per year leads to significant final energy savings. In 2030, electricity will provide 7% of the transport sector's total energy demand in the Energy [R]evolution, while in the advanced case the share will already be 14% in 2030 and 62% by 2050.

figure 6.38: oecd europe: transport under 3 scenarios

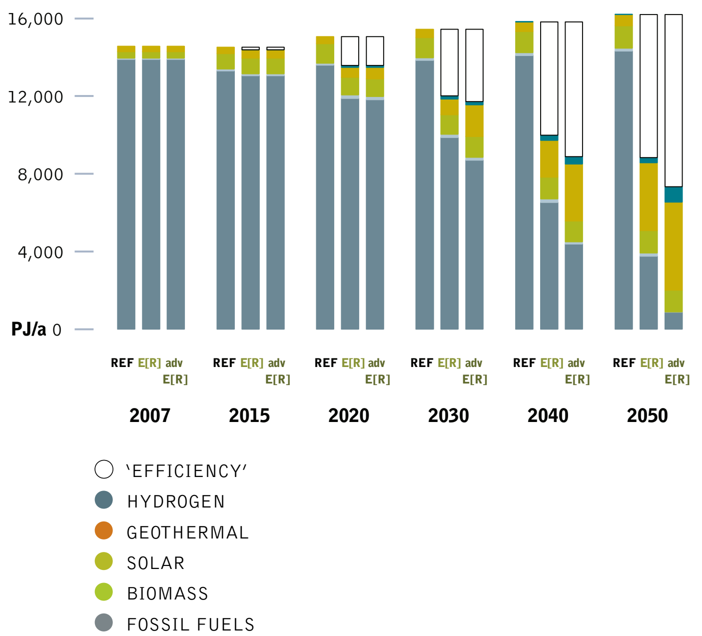


image INSTALLATION AND TESTING OF A WINDPOWER STATION IN RYSUMER NACKEN NEAR EMDEN WHICH IS MADE FOR OFFSHORE USAGE ONSHORE. A WORKER CONTROLS THE SECURITY LIGHTS AT DARK.

image THE MARANCHON WIND FARM IS THE LARGEST IN EUROPE WITH 104 GENERATORS, AND IS OPERATED BY IBERDROLA, THE LARGEST WIND ENERGY COMPANY IN THE WORLD.

oecd europe: development of CO_2 emissions

While CO_2 emissions in OECD Europe will decrease by 5% in the Reference scenario by 2050, under the Energy [R]evolution Scenario they will decrease from 4,017 million tonnes in 2007 to 850 million t in 2050. Annual per capita emissions will drop from 7.4 t to 1.5 t. In spite of the phasing out of nuclear energy and increasing demand, CO_2 emissions will decrease in the electricity sector. In the long run efficiency gains and the increased use of renewable electricity in vehicles will reduce emissions in the transport sector. With a share of 7% of total CO_2 in 2050, the power sector will drop below transport and other sectors as the largest sources of emissions.

The advanced Energy [R]evolution scenario reduces energy related CO_2 emissions about 10 to 15 years faster than the Energy [R]evolution scenario, leading to 3.4 t per capita by 2030 and 0.4 t by 2050. By 2050, OECD Europe´s CO_2 emissions are 5% of 1990 levels.

oecd europe: primary energy consumption

Taking into account the assumptions discussed above, the resulting primary energy consumption under the Energy [R]evolution scenario is shown in Figure 6.40. Compared to the Reference scenario, overall energy demand will be reduced by 45% in 2050. Around 63% of the remaining demand will be covered by renewable energy sources.

The Advanced scenario phases out coal and oil about 10 to 15 years faster than the Energy [R]evolution scenario. Main reasons for this is a replacement of new coal power plants with renewables after 20 years rather than 40 years lifetime in the Energy [R]evolution scenario and a faster introduction of electric vehicles in the transport sector to replace combustion engines. This leads to a renewable energy share of 40% in 2030 and 85% in 2050. Nuclear energy is phased out in both Energy [R]evolution scenarios just after 2030.

figure 6.39: oecd europe: development of CO_2 emissions by sector under both energy [r]evolution scenarios

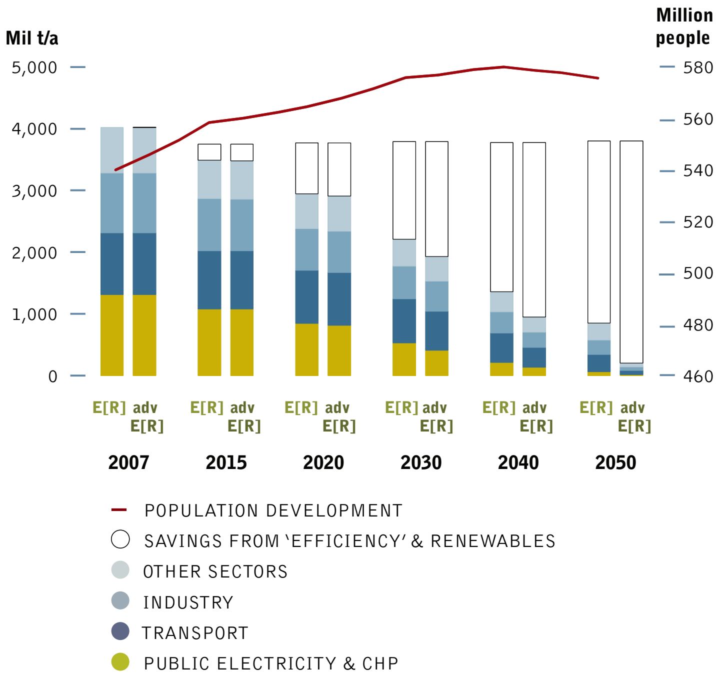
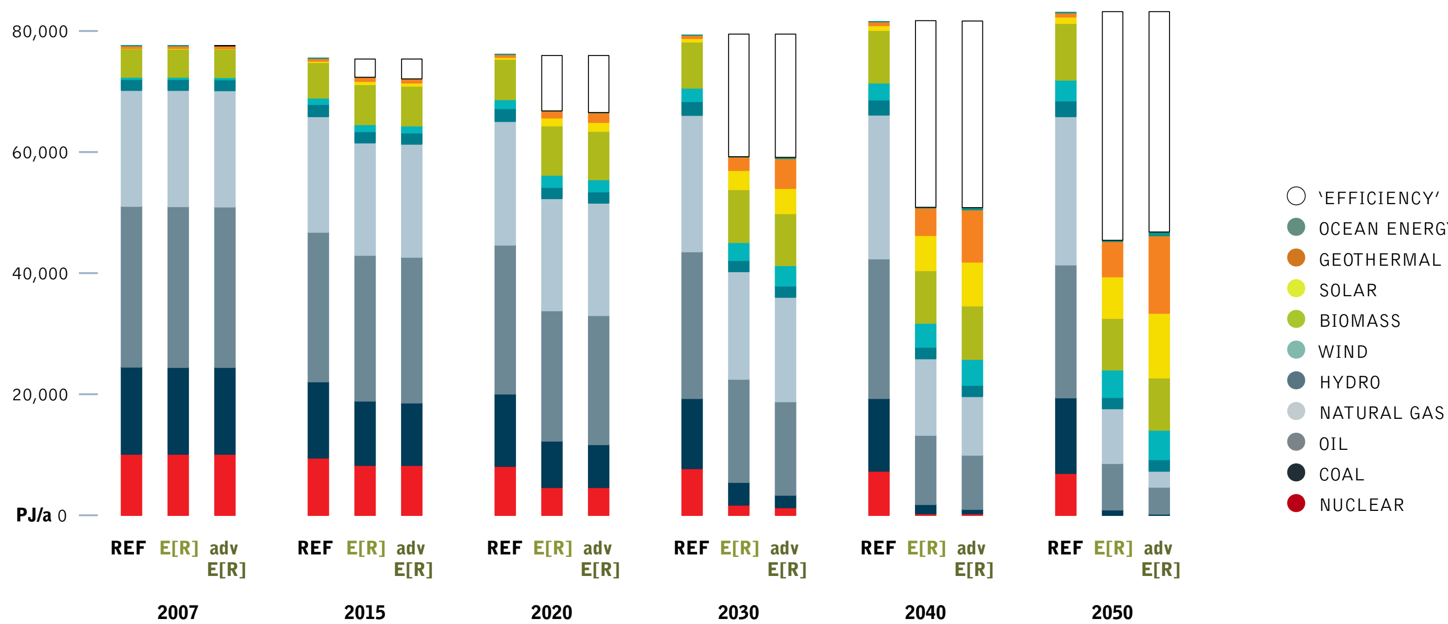


figure 6.40: oecd europe: development of primary energy consumption under three scenarios



africa

africa: energy demand by sector

Future development pathways for Africa´s energy demand are shown in Figure 6.41 for the Reference and both Energy [R]evolution scenarios. Under the Reference scenario, total primary energy demand in Africa increases by more than 63% from the current 26,380 PJ/a to 42,951 PJ/a in 2050. In both Energy [R]evolution scenarios a much smaller increase from the current consumption level is expected by 2050, reaching 34,403 PJ/a in the basic and 33,721 PJ/a in the advanced scenario.

Under the Energy [R]evolution scenario, electricity demand in Africa is expected to increase disproportionately, with households and services the main source of growing consumption (see Figure 6.42). With the exploitation of efficiency measures, however an even higher increase can be avoided, leading to electricity demand of 1,490 TWh/a in the year 2050. Compared to the Reference scenario, efficiency measures in the industry, residential and service sectors avoid the generation of about 146 TWh/a.

The advanced Energy [R]evolution scenario introduces electric vehicles earlier and more transport - both from freight and passengers - are shifted to electric trains and public transport. Besides fossil fuels for industrial process heat generation are also phased out more quickly and replaced by electric geothermal heat pumps and hydrogen. This means that electricity demand in the advanced version is higher and reaches 1,644 TWh/a in 2050, 4% above the reference case.

Efficiency gains in the heat and cooling supply sector are also significant. Under the Energy [R]evolution scenarios, final demand for heating and cooling can even be reduced (see Figure 6.43). Compared to the Reference scenario, consumption equivalent to 898 PJ/a are avoided through efficiency gains by 2050.

In the transport sector, it is assumed under both Energy [R]evolution scenarios that energy demand will almost double to 5,276 PJ/a by 2050, saving 25% compared to the Reference scenario. This reduction can be achieved by the introduction of highly efficient vehicles, by shifting the transport of goods from road to rail and by changes in mobility-related behaviour patterns. Because Africa, as a developing region, has a relatively low starting point for transport demand, the outcome (in terms of kilometres travelled per person and freight volumes) has not been reduced in the advanced Energy [R]evolution scenario any further than in the basic version. Due to a wider use of more efficient electric drives, however, the overall final energy demand in transport increases only to 4,376 PJ/a, 37% lower than in the Reference case.

figure 6.41: africa: projection of total final energy demand by sector (REF, E[R] & advanced E[R])

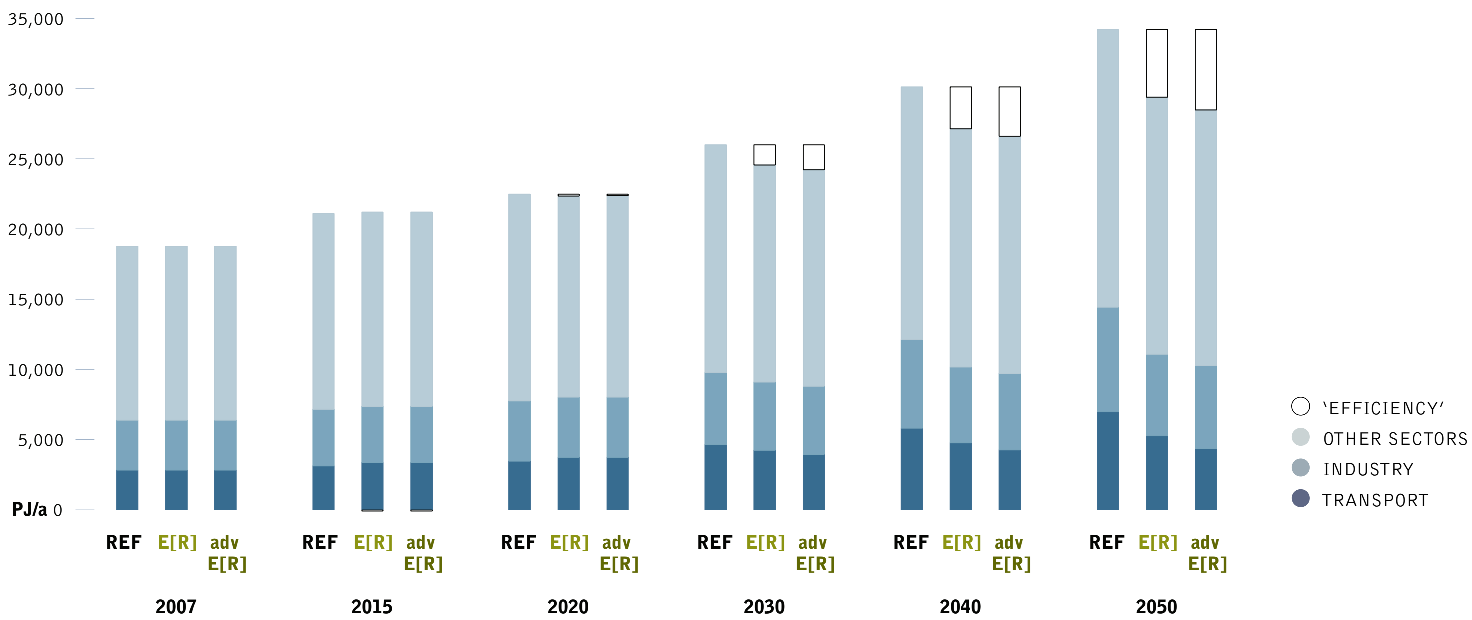
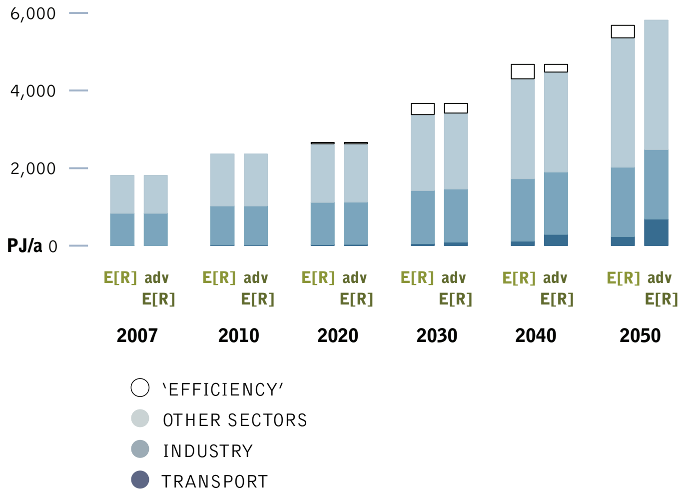


image GARIEP DAM, FREE STATE, SOUTH AFRICA.

image WOMEN FARMERS FROM LILONGWE, MALAWI STAND IN THEIR DRY, BARREN FIELDS CARRYING ON THEIR HEADS AID ORGANISATION HANDOUTS. THIS AREA, THOUGH EXTREMELY POOR HAS BEEN SELF-SUFFICIENT WITH FOOD. NOW THESE WOMEN'S CHILDREN ARE SUFFERING FROM MALNUTRITION.

figure 6.42: africa: development of electricity demand by sector (REF, E[R] & advanced E[R])



africa: heating and cooling supply

Today, renewables provide 75% of Africa's energy demand for heat supply, the main contribution coming from the use of traditional and often unsustainable biomass. The availability of less efficient but cheap appliances is a severe structural barrier to efficiency gains. Large scale utilisation of geothermal and solar thermal energy for heat supply is restricted to the industrial sector. Dedicated support instruments are required to ensure a continuously dynamic development of renewables in the heat market.

In the Energy [R]evolution scenario renewables provide 77% of Africa's total heating and cooling demand in 2050.

- Energy efficiency measures can restrict the future energy demand for heat and cooling supply to a 50% increase, in spite of improving living standards.
- In the industry sector solar collectors, biomass/biogas as well as geothermal energy are increasingly substituted for conventional fossil-fired heating systems.
- A shift from coal and oil to natural gas in the remaining conventional applications leads to a further reduction of CO_2 emissions.

The advanced Energy [R]evolution case introduces renewable heating and cooling systems around five years ahead of the basic scenario. Compared to the Reference scenario, 898 PJ/a or 6% are saved by 2050. North African countries can even use solar heat directly for industrial process heat. Together with the large potential for economic use of geothermal energy in the immediate future, the renewables share can rise to 78% under the advanced version by 2030 and 90% by 2050.

figure 6.43: africa: development of heat demand by sector

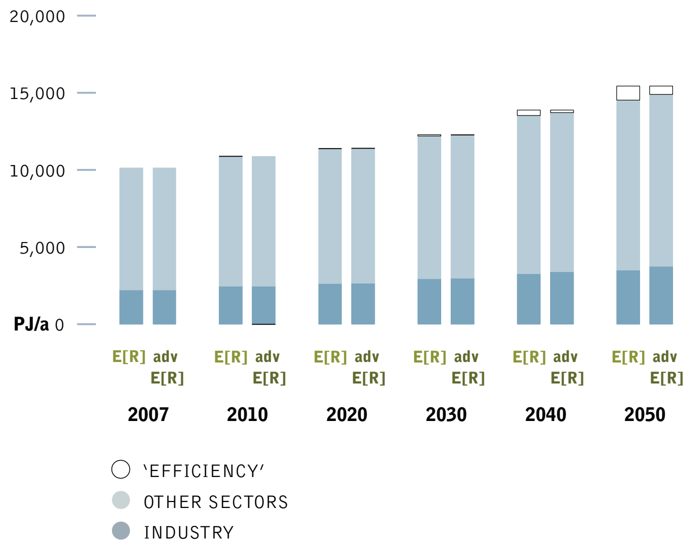
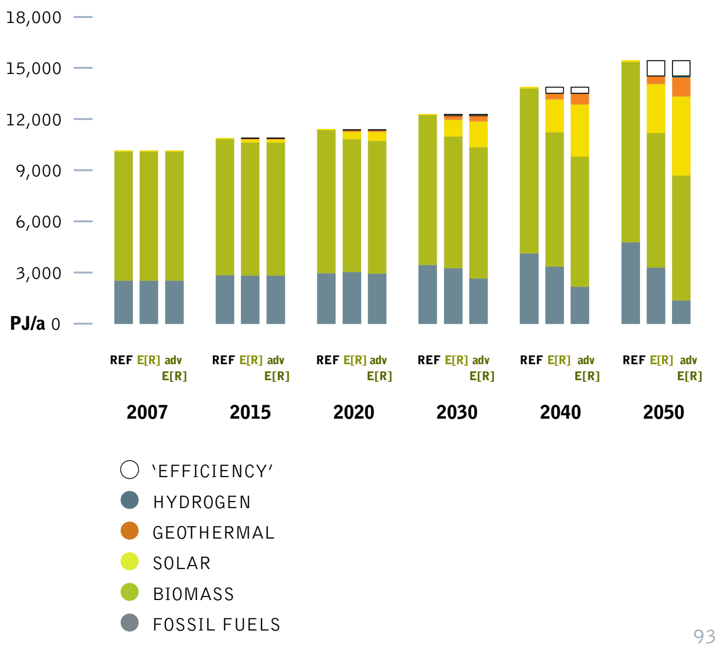


figure 6.44: africa: development of heat supply structure under 3 scenarios



africa

GLOBAL SCENARIO

OECD NORTH AMERICA
LATIN AMERICA
OECD EUROPE
AFRICA

MIDDLE EAST
TRANSITION ECONOMIES
INDIA

DEVELOPING ASIA
CHINA
OECD PACIFIC

africa: electricity generation

The development of the electricity supply sector in the Energy [R]evolution scenario is characterised by a dynamically growing renewable energy market and an increasing share of renewable electricity. By 2050, 78% of the electricity produced in Africa will come from renewable sources. A major driver for the expansion of solar power generation capacity will be the export of solar electricity to OECD Europe. 'New' renewables – mainly wind, solar thermal energy and PV – will contribute 66% of electricity generation. The installed capacity of renewable energy technologies will grow under the Energy [R]evolution scenario from the current 24 GW to 418 GW in 2050, increasing renewable capacity by a factor of 17.

The advanced version projects a faster market development with higher annual growth rates achieving a renewable electricity share of 52% by 2030 and 94% by 2050. The installed capacity of renewables will reach 172 GW in 2030 and 537 GW by 2050, 28% higher than in the basic version.

None of these numbers - even in the advanced Energy [R]evolution scenario - utilise the maximum known technical potential of all the renewable resources. While the deployment rate compared to the technical potential for geothermal power, for example, is relatively high at approx 2/3 in the advanced Energy [R]evolution scenario, for concentrated solar power only less than 1% has been used in the advanced version scenario. Figure 6.45 shows the cpmparative evolution of the renewable technologies over time. Up to 2020 hydro and wind will remain the main contributors to the growing market share. After 2020, the continuing growth of wind will be complemented by electricity from biomass, photovoltaics and solar thermal (CSP) energy.

table 6.9: africa: projection of renewable electricity generation capacity under both energy [r]evolution scenarios

IN GW

		2007	2020	2030	2040	2050
Hydro	E[R]	23	37	44	48	49
	advanced E[R]	23	37	44	48	49
Biomass	E[R]	0	4	6	7	8
	advanced E[R]	0	4	6	7	8
Wind	E[R]	1	12	24	37	44
	advanced E[R]	1	13	28	54	85
Geothermal	E[R]	0	1	3	5	6
	advanced E[R]	0	2	9	22	42
PV	E[R]	0	14	57	108	180
	advanced E[R]	0	14	57	108	185
CSP	E[R]	0	7	17	60	126
	advanced E[R]	0	14	20	83	140
Ocean energy	E[R]	0	1	2	3	4
	advanced E[R]	0	2	8	15	28
Total	**E[R]**	**24**	**76**	**153**	**267**	**418**
	advanced E[R]	**24**	**86**	**172**	**336**	**537**

figure 6.45: africa: development of electricity generation structure under 3 scenarios

(REFERENCE, ENERGY [R]EVOLUTION AND ADVANCED ENERGY [R]EVOLUTION) ["EFFICIENCY" = REDUCTION COMPARED TO THE REFERENCE SCENARIO]

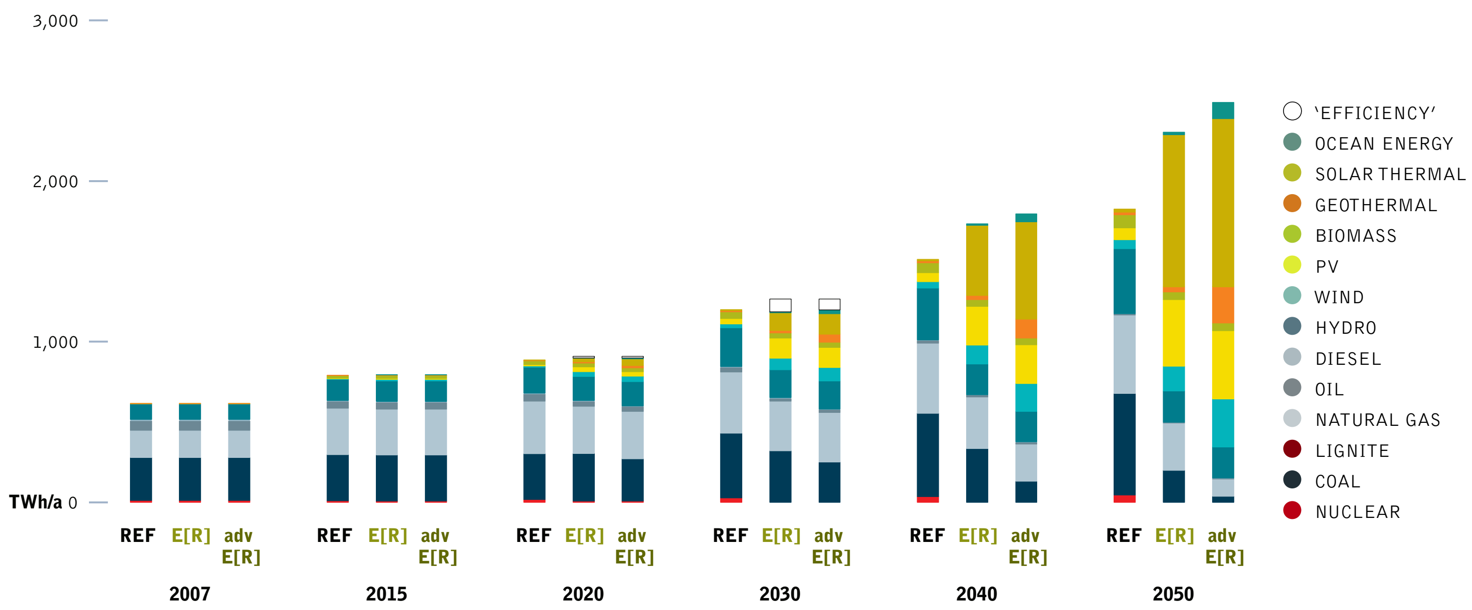
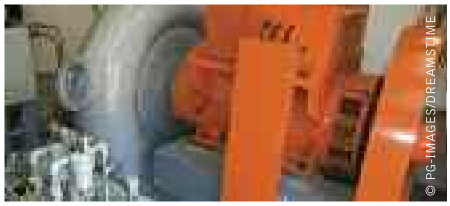


image FLOWING WATERS OF THE TUGELA RIVER IN NORTHERN DRAKENSBERG IN SOUTH AFRICA.

image A SMALL HYDRO ELECTRIC ALTERNATOR MAKES ELECTRICITY FOR A SMALL AFRICAN TOWN.



africa: future costs of electricity generation

Figure 6.46 shows that the introduction of renewable technologies under the Energy [R]evolution scenario significantly decreases the future costs of electricity generation compared to the Reference scenario. Because of the lower CO_2 intensity of electricity generation, electricity generation costs will become economically favourable under the Energy [R]evolution scenario by 2020, and by 2050 costs will be more than 6 cents/kWh below those in the Reference scenario.

Under the Reference scenario, by contrast, unchecked demand growth, an increase in fossil fuel prices and the cost of CO_2 emissions result in total electricity supply costs rising from today's $59 billion per year to more than $268 billion in 2050. Figure 6.46 shows that the Energy [R]evolution scenario not only complies with Africa´s CO_2 reduction targets but also helps to stabilise energy costs. Increasing energy efficiency and shifting energy supply to renewables leads to long term costs for electricity supply that are one third lower than in the Reference scenario.

In both Energy [R]evolution scenarios the specific generation costs are almost the same up to 2030. In 2050, however, the advanced version results in a reduction of 2 cents/kWh, mainly because of better economics of scale in renewable power equipment.

Due to the increased demand for electricity, especially in the transport and industry sector, the overall supply costs in the advanced version are $2 billion higher in 2030 than in the basic Energy [R]evolution scenario, however in 2050 they are $27 billion lower in the advanced scenario.

africa: job results

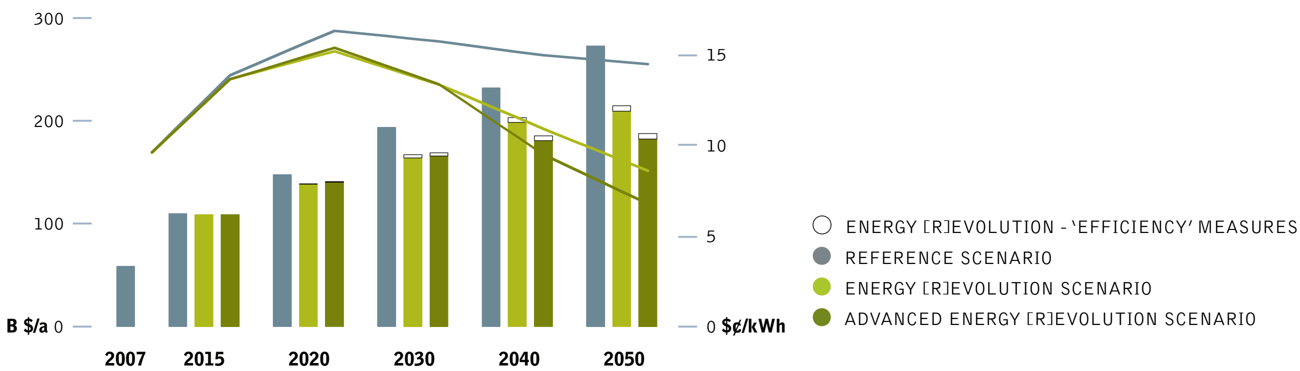
The Energy [R]evolution scenarios lead to more energy sector jobs in Africa at every stage of the projection.

- There are 1.29 million power sector jobs in the Energy [R]evolution scenario and 1.34 million in the advanced version by 2015, compared to 910,000 in the Reference scenario.
- By 2020 job numbers reach over 1.5 million in both Energy [R]evolution scenarios, 300,000 more than in the Reference scenario.
- By 2030 job numbers climb slightly in the Energy [R]evolution scenario to nearly 1.7 million, (1.8 million in the advanced version) and reach nearly 1.5 million in the Reference scenario.

Table 6.10 shows the increase in job numbers under both Energy [R]evolution scenarios for each technology up to 2020 and up to 2030. Both scenarios show losses in coal generation, but these are outweighed by employment growth in renewable technologies and gas. Wind shows particularly strong growth in the both Energy [R]evolution scenarios by 2020, but by 2030 there is significant employment across a range of renewable technologies.

It is assumed that all manufacturing occurs within Africa, and therefore the amount of jobs in the renewable industry will increase to over 1 million in both Energy [R]evolution scenarios, almost half a million jobs more than in the Reference scenario.

figure 6.46: africa: development of total electricity supply costs & development of specific electricity generation costs under 3 scenarios



africa

table 6.10: africa: employment & investment

	REFERENCE			ENERGY [R]EVOLUTION			ADVANCED ENERGY [R]EVOLUTION		
Jobs	2015	2020	2030	2015	2020	2030	2015	2020	2030
Construction & installation	0.23 m	0.37 m	0.35 m	0.49 m	0.60 m	0.55 m	0.55 m	0.61 m	0.62 m
Manufacturing	0.02 m	0.04 m	0.05 m	0.08 m	0.08 m	0.14 m	0.09 m	0.08 m	0.20 m
Operations & maintenance	0.18 m	0.22 m	0.36 m	0.19 m	0.26 m	0.40 m	0.19 m	0.28 m	0.43 m
Fuel	0.49 m	0.56 m	0.72 m	0.53 m	0.59 m	0.61 m	0.51 m	0.53 m	0.56 m
Total Jobs	**0.91 m**	**1.19 m**	**1.48 m**	**1.29 m**	**1.53 m**	**1.70 m**	**1.34 m**	**1.50 m**	**1.81 m**
Coal	0.09 m	0.16 m	0.21 m	0.10 m	0.12 m	0.13 m	0.10 m	0.09 m	0.07 m
Gas, oil and diesel	0.47 m	0.53 m	0.65 m	0.51 m	0.56 m	0.56 m	0.48 m	0.51 m	0.53 m
Nuclear	0.02 m	0.02 m	0.02 m	0.00 m	0.00 m	0.00 m	0.00 m	0.00 m	0.00 m
Renewables	0.33 m	0.49 m	0.61 m	0.68 m	0.86 m	1.01 m	0.76 m	0.89 m	1.22 m
Total Jobs	**0.91 m**	**1.19 m**	**1.48 m**	**1.29 m**	**1.53 m**	**1.70 m**	**1.34 m**	**1.50 m**	**1.81 m**

africa: transport

In the transport sector, it is assumed under the Energy [R]evolution scenario that energy demand will almost double to 5,276 PJ/a by 2050, saving 25% compared to the Reference scenario. This reduction can be achieved by the introduction of highly efficient vehicles, by shifting the transport of goods from road to rail and by changes in mobility-related behaviour patterns. The African vehicle stock, however, is projected to grow in all scenarios significantly by a factor of six.

Development of fuel efficiency is delayed by 20 years in the Energy [R]evolution scenario and by ten years in the advanced version compared to other world regions for economic reasons. By 2050, Africa will still have the lowest average fuel consumption. By 2030, electricity will provide 1% of the transport sector's total energy demand in the Energy [R]evolution, while in the advanced version the share will be 2% in 2030 and 16% by 2050.

figure 6.47: africa: transport under 3 scenarios

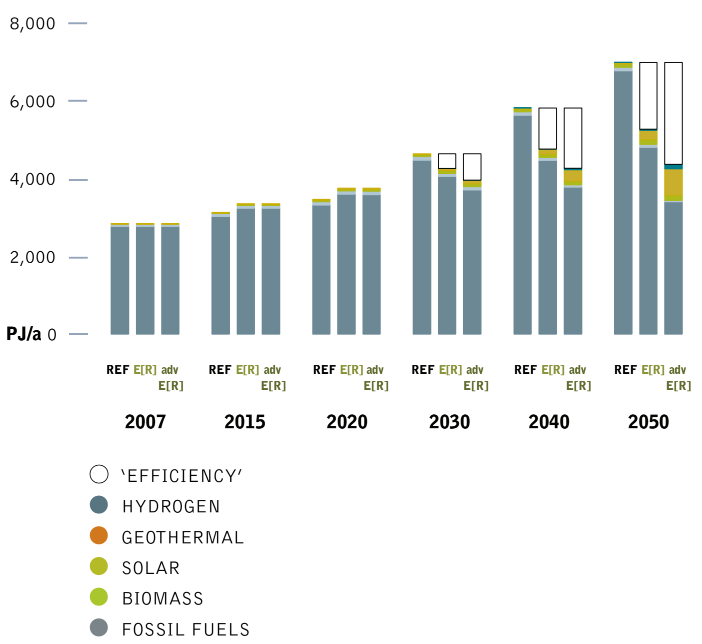


image MAMA SARA OBAMA, THE US PRESIDENT'S GRANDMOTHER, FLICKS ON THE LIGHTS AFTER A GREENPEACE TEAM INSTALLED A SOLAR POWER SYSTEM AT HER HOME IN KOGELO VILLAGE.

image STORM OVER SODWANA BAY, SOUTH AFRICA.

africa: development of CO_2 emissions

Whilst Africa´s emissions of CO_2 will almost double (+84%) under the Reference scenario by 2050, under the Energy [R]evolution scenario they will be stable (881 million t in 2007 and 880 million t in 2050). Annual per capita emissions will drop from 0.9 t to 0.4 t. In spite of increasing demand, CO_2 emissions decrease in the electricity sector. In the long run efficiency gains and the increased use of renewable electricity in vehicles will reduce emissions in the transport sector. With a share of 25% of total CO_2 in 2050, the power sector will drop below transport as the largest source of emissions.

The advanced Energy [R]evolution scenario will shift the emissions peak for energy related CO_2 about 10 years earlier than in the basic version, leading to 0.6 t per capita by 2030 and 0.2 t by 2050. By 2050, Africa´s CO_2 emissions are 59% of 1990 levels.

africa: primary energy consumption

Taking into account the assumptions discussed above, the resulting primary energy consumption under the Energy [R]evolution scenario is shown in Figure 6.49. Compared to the Reference scenario, overall energy demand will be reduced by 16% in 2050. Around 61% of the remaining demand will be covered by renewable energy sources.

The advanced version phases out coal and oil about 10 to 15 years faster than the basic scenario. This made possible by leapfrogging directly to a renewable energy future with financial help from industrialised countries. This leads to a renewable energy share of 57% in 2030 and 79% in 2050. Nuclear energy is phased out in both Energy [R]evolution scenarios just after 2020.

figure 6.48: africa: development of CO_2 emissions by sector under both energy [r]evolution scenarios

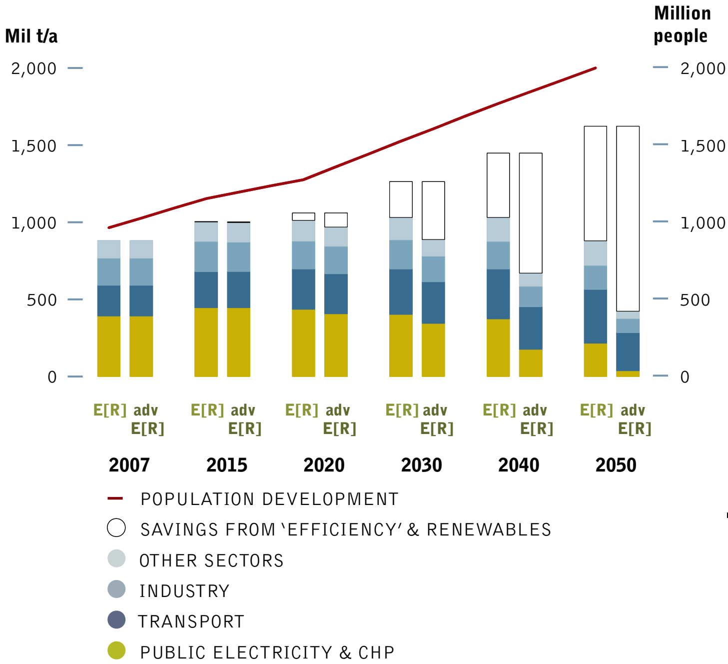
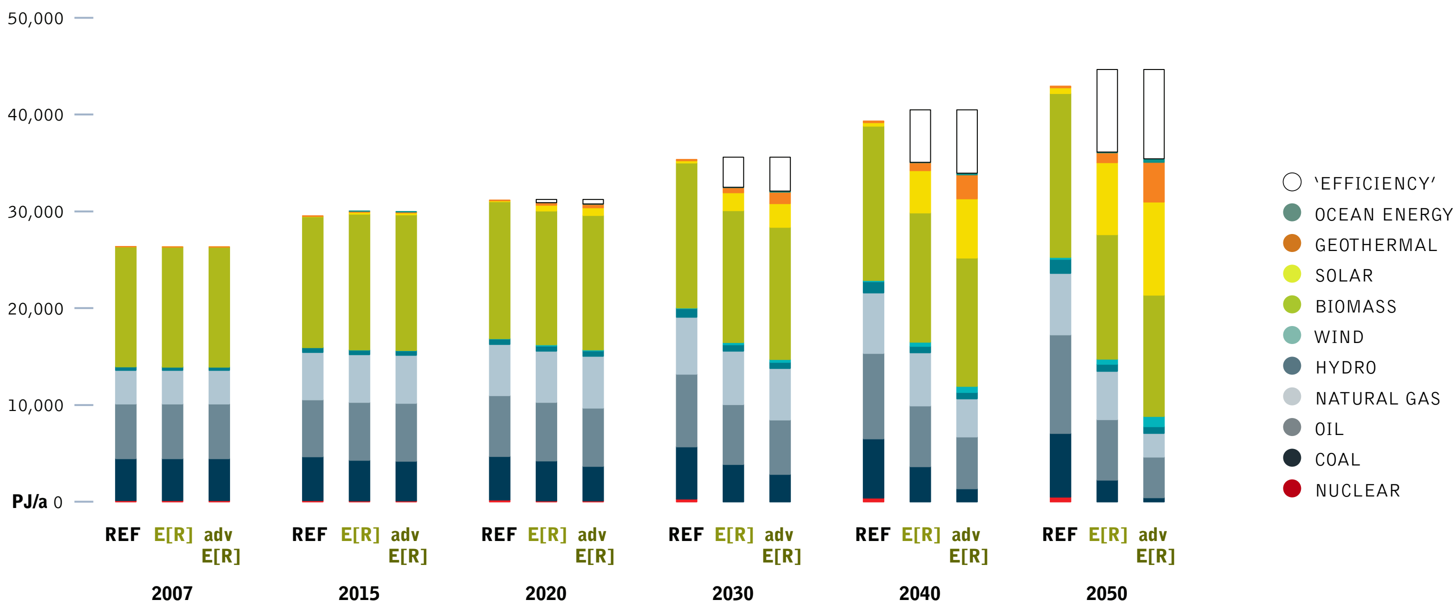


figure 6.49: africa: development of primary energy consumption under three scenarios



middle east

middle east: energy demand by sector

The future development pathways for the Middle East's final energy demand are shown in Figure 6.50 for the Reference and both Energy [R]evolution scenarios. Under the Reference, scenario total primary energy demand more than doubles from the current 21,363 PJ/a to 51,356 PJ/a in 2050. In the Energy [R]evolution scenario, a much smaller 28% increase from current consumption levels is expected by 2050, reaching 27,301 PJ/a.

Efficiency gains in the heat supply sector are even larger. Under the Energy [R]evolution scenario (see Figure 6.52), consumption equivalent to 2,005 PJ/a is avoided through efficiency measures by 2050. In the Middle East it is also possible to use concentrated solar power directly for industrial process heat; this explains the larger share of solar energy in the advanced version.

Under the Energy [R]evolution scenario, electricity demand is expected to increase disproportionately, with households and services the main source of growing consumption (see Figure 6.51), leading to an electricity demand of around 1,870 TWh/a in the year 2050. Compared to the Reference scenario, efficiency measures in the industry, residential and service sectors avoid the generation of about 754 TWh/a in industry, households, commerce and service.

In the transport sector it is assumed under the Energy [R]evolution scenario that energy demand will increase slightly compared to today's level, reaching 5,290 PJ/a by 2050, a saving of 52% compared to the Reference scenario. This reduction can be achieved by the introduction of highly efficient vehicles, by shifting the transport of goods from road to rail and by changes in mobility-related behaviour patterns.

The advanced Energy [R]evolution scenario goes one step further and factors even in a decrease in transport energy demand of 3% compared with today. This is achieved through a mix of increased public transport, reduced annual person kilometres and wider use of more efficient engines and electric drives. While electricity demand increases, the final energy use in the transport sector falls to 4,232 PJ/a, 61% lower than in the Reference case.

The advanced Energy [R]evolution scenario introduces electric vehicles earlier and more journeys – for both freight and passengers - are shifted to electric trains and public transport. Fossil fuels for industrial process heat generation are also phased out more quickly and replaced by electric geothermal heat pumps and hydrogen. This means that electricity demand in the advanced version is higher, and reaches 2,185 TWh/a in 2050, even 7% higher than the Reference case.

figure 6.50: middle east: projection of total final energy demand by sector (REF, E[R] & advanced E[R])

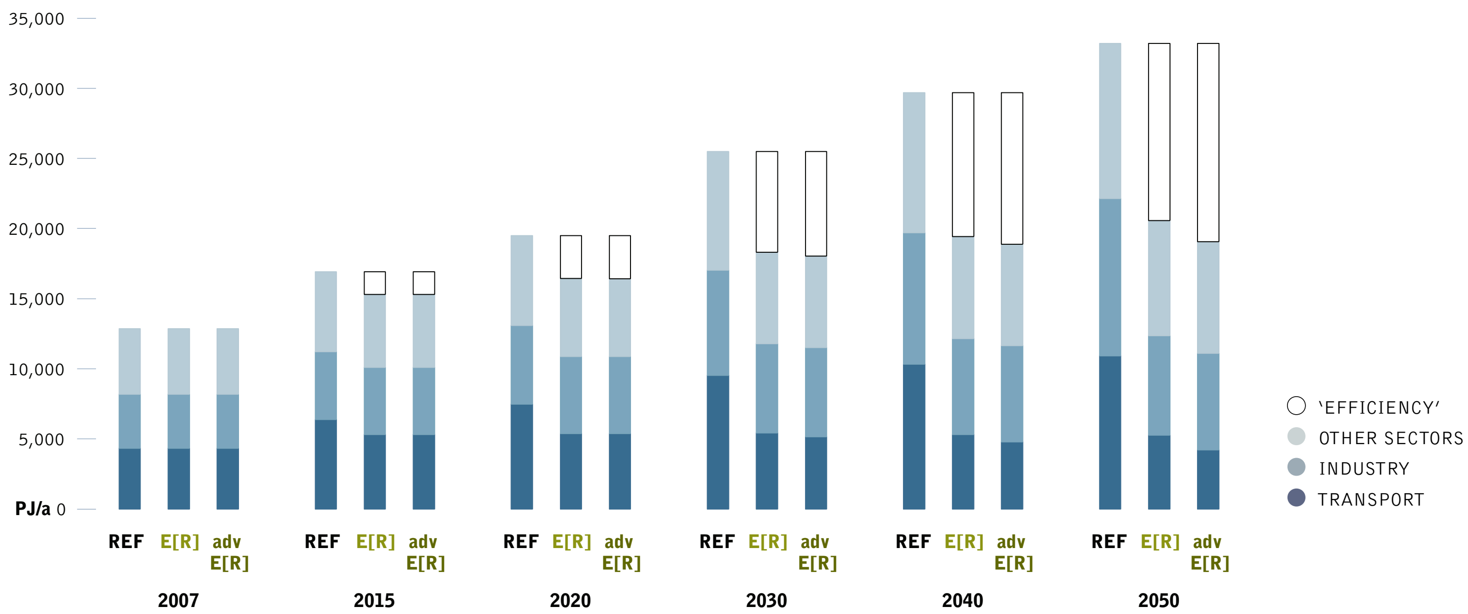
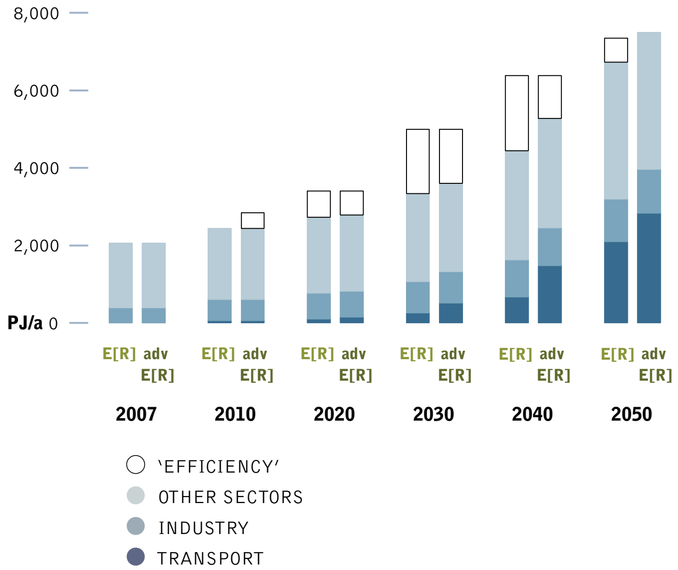


image A LARGE POWER PLANT ALONG THE ROCKY COASTLINE IN CAESAREA, ISRAEL.

image WIND TURBINES IN THE GOLAN HEIGHTS IN ISRAEL.

figure 6.51: middle east: development of electricity demand by sector (REF, E[R] & advanced E[R])



middle east: heating and cooling supply

Renewables currently provide only 1% of primary energy demand for heat and cooling supply in the Middle East, the main contribution coming from the use of biomass and solar collectors. Dedicated support instruments are required to ensure a continuously dynamic development of renewables in the heat market.

In the Energy [R]evolution scenario, renewables provide 84% of the Middle East's total heating and cooling demand in 2050.

- Energy efficiency measures can restrict the future primary energy demand for heat and cooling supply to a doubling rather than tripling, in spite of improving living standards.
- In the industry sector solar collectors, biomass/biogas as well as geothermal energy are increasingly substituting for conventional fossil-fuelled heating systems.

In the Energy [R]evolution scenario 2,005 PJ/a is saved by 2050, or 17% compared to the Reference scenario. The advanced Energy [R]evolution version introduces renewable heating systems around five years ahead of the basic scenario. Solar collectors and geothermal heating systems achieve economies of scale via ambitious support programmes five to ten years earlier, resulting in a renewables share of 33% by 2030 and 97% by 2050.

figure 6.52: middle east: development of heat demand by sector

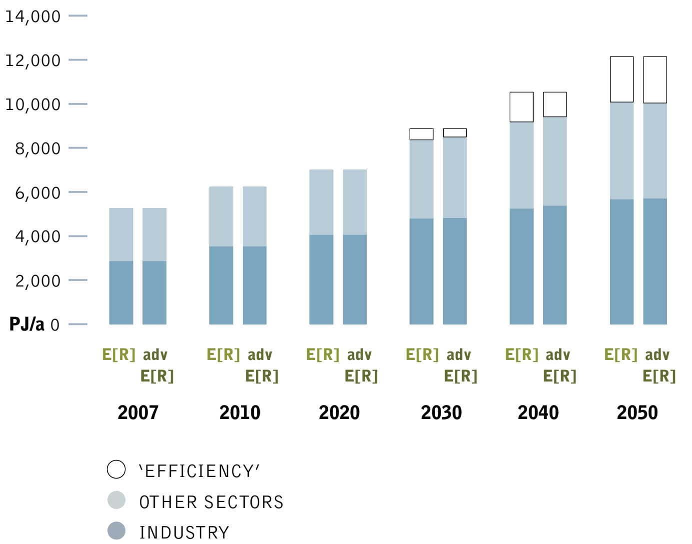
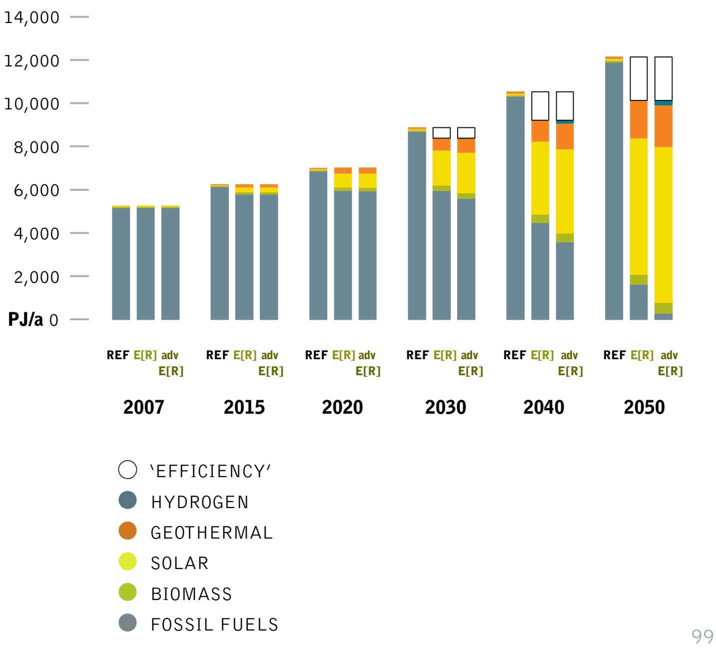


figure 6.53: middle east: development of heat supply structure under 3 scenarios



middle east

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middle east: electricity generation

The development of the electricity supply sector in the Energy [R]evolution scenarios is characterised by an increasing share of renewable electricity. By 2050, 98% of the electricity produced in the Middle East will come from renewable sources. 'New' renewables – mainly wind, solar thermal energy and PV – will contribute about 91% of electricity generation. The installed capacity of renewable energy technologies will grow from the current 10 GW to 653 GW in 2050, a very large increase over the next 40 years, requiring political support and well-designed policy instruments.

The advanced Energy [R]evolution scenario will not increase this share significantly. By 2030, 58% of electricity will come from renewables and 99% by 2050. However, the overall installed capacity (873 GW) will be higher than in the basic version.

None of these numbers - even in the advanced Energy [R]evolution scenario - utilise the maximum known technical potential of all the renewable resources. In the Middle East the solar energy potential is so large that it is possible to export around 300 TWh/a solar electricity from either photovoltaic or concentrated solar power stations to Europe, Africa or the Transition Economies via a transnational super grid. The advanced Energy [R]evolution scenario uses only 0.1% of the technical potential of CSP.

table 6.11: middle east: projection of renewable electricity generation capacity under both energy [r]evolution scenarios

IN GW

		2007	2020	2030	2040	2050
Hydro	E[R]	10	18	20	21	22
	advanced E[R]	10	18	20	21	22
Biomass	E[R]	0	2	3	5	8
	advanced E[R]	0	2	3	6	9
Wind	E[R]	0	25	61	80	110
	advanced E[R]	0	40	73	89	139
Geothermal	E[R]	0	2	5	8	12
	advanced E[R]	0	2	6	20	24
PV	E[R]	0	3	31	128	283
	advanced E[R]	0	12	47	210	332
CSP	E[R]	0	10	48	100	215
	advanced E[R]	0	20	63	205	330
Ocean energy	E[R]	0	0	0	1	1
	advanced E[R]	0	3	4	9	17
Total	**E[R]**	**10**	**61**	**168**	**343**	**653**
	advanced E[R]	**10**	**97**	**216**	**561**	**873**

figure 6.54: middle east: development of electricity generation structure under 3 scenarios

(REFERENCE, ENERGY [R]EVOLUTION AND ADVANCED ENERGY [R]EVOLUTION) ["EFFICIENCY" = REDUCTION COMPARED TO THE REFERENCE SCENARIO]

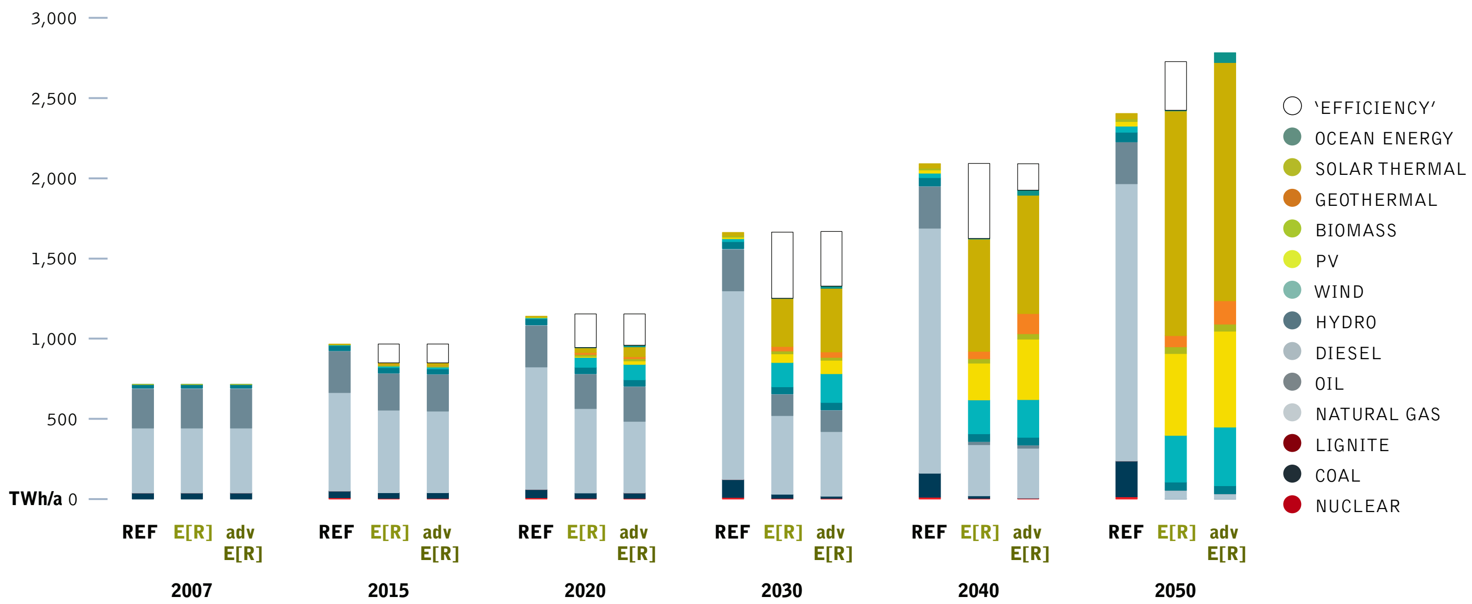


image THE BAHRAIN WORLD TRADE CENTER IN MANAMA GENERATES PART OF ITS OWN ENERGY USING WIND TURBINES.

image SUBURBS OF DUBAI, UNITED ARAB EMIRATES.

middle east: future costs of electricity generation

Figure 6.55 shows that the introduction of renewable technologies under the Energy [R]evolution scenario will lead to a significant reduction in electricity generation costs. Under the Reference scenario, on the other hand, the unchecked growth in demand, increase in fossil fuel prices and the cost of CO_2 emissions result in total electricity supply costs rising from today's $82 billion per year to more than $608 billion in 2050. Figure 6.55 shows that the Energy [R]evolution scenario also meets the Middle East's CO_2 reduction targets.

Increasing energy efficiency and shifting energy supply to renewables leads to long term costs for electricity supply that are significant lower than in the Reference scenario. This helps to stabilise energy costs and relieve the economic pressure on society.

In both Energy [R]evolution scenarios the specific generation costs are almost the same up to 2030. By 2050, however, the advanced version results in a 1.6 cents/kWh higher costs, mainly because of additional storage demand for the production of renewable power. Due to the increased electricty demand especially in the transport and industry sector the overall total supply costs in the advanced case are $69 billion in 2040 and $73 billion in 2050 higher than in the Energy [R]evolution scenario.

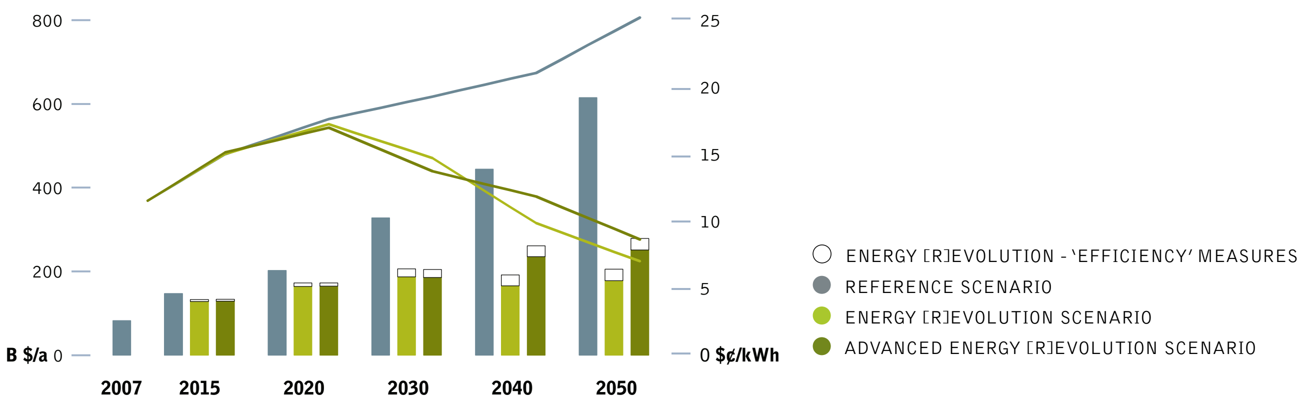
middle east: job results

The Energy [R]evolution scenarios lead to more energy sector jobs in the Middle East at every stage of the projection.

- There are 430,000 power sector jobs in the Energy [R]evolution scenario and 540,000 in the advanced version by 2015, compared to 370,000 in the Reference scenario.
- By 2020 job numbers reach over half a million in both Energy [R]evolution scenarios, 150,000 more than in the Reference scenario.
- By 2030 job numbers climb slightly in the Energy [R]evolution scenario to nearly 560,000, (750,000 in the advanced version) and reach 510,000 in the Reference scenario.

Table 6.12 shows the increase in job numbers under both Energy [R]evolution scenarios for each technology up to 2020 and up 2030. Both scenarios show losses in the oil & gas sector, but these are outweighed by employment growth in renewable technologies and gas. Concentrated solar power shows particularly strong growth in both Energy [R]evolution scenarios by 2020, but by 2030 there is significant employment across a range of renewable technologies.

figure 6.55: middle east: development of total electricity supply costs & development of specific electricity generation costs under 3 scenarios



middle east

table 6.12: middle east: employment & investment

	REFERENCE			ENERGY [R]EVOLUTION			ADVANCED ENERGY [R]EVOLUTION		
	2015	2020	2030	2015	2020	2030	2015	2020	2030
Jobs									
Construction & installation	0.04 m	0.06 m	0.09 m	0.08 m	0.15 m	0.21 m	0.21 m	0.18 m	0.40 m
Manufacturing	0.00 m	0.01 m	0.01 m	0.03 m	0.04 m	0.03 m	0.07 m	0.04 m	0.06 m
Operations & maintenance	0.04 m	0.05 m	0.05 m	0.05 m	0.07 m	0.10 m	0.05 m	0.09 m	0.12 m
Fuel	0.28 m	0.31 m	0.36 m	0.27 m	0.27 m	0.21 m	0.25 m	0.24 m	0.18 m
Total Jobs	**0.37 m**	**0.42 m**	**0.51 m**	**0.43 m**	**0.53 m**	**0.56 m**	**0.57 m**	**0.54 m**	**0.75 m**
Coal	0.01 m	0.02 m	0.02 m	0.00 m	0.00 m	0.01 m	0.01 m	0.00 m	0.00 m
Gas, oil and diesel	0.32 m	0.35 m	0.45 m	0.29 m	0.28 m	0.21 m	0.26 m	0.25 m	0.18 m
Nuclear	0.00 m	0.00 m	0.00 m	0.00 m	0.00 m	0.00 m	0.00 m	0.00 m	0.00 m
Renewables	0.04 m	0.05 m	0.05 m	0.14 m	0.24 m	0.34 m	0.31 m	0.29 m	0.57 m
Total Jobs	**0.37 m**	**0.42 m**	**0.51 m**	**0.43 m**	**0.53 m**	**0.56 m**	**0.57 m**	**0.54 m**	**0.75 m**

middle east: transport

In an area of major indigenous oil resources, transport is currently powered 100% by fossil fuels. Under the Energy [R]evolution scenario, rising prices, together with other incentives, lead to a projected share for renewable electricity of 43% in this sector. Highly efficient electrified cars – plug-in-hybrid and battery vehicles – contribute a total of 20% in energy savings, although the car fleet is still projected to grow by a factor of five by 2050. By 2030 electricity will provide 5% of the transport sector's final energy demand in the Energy [R]evolution scenario, while in the advanced case the share will already reach 10% in 2030 and 67% by 2050.

figure 6.56: middle east: transport under 3 scenarios

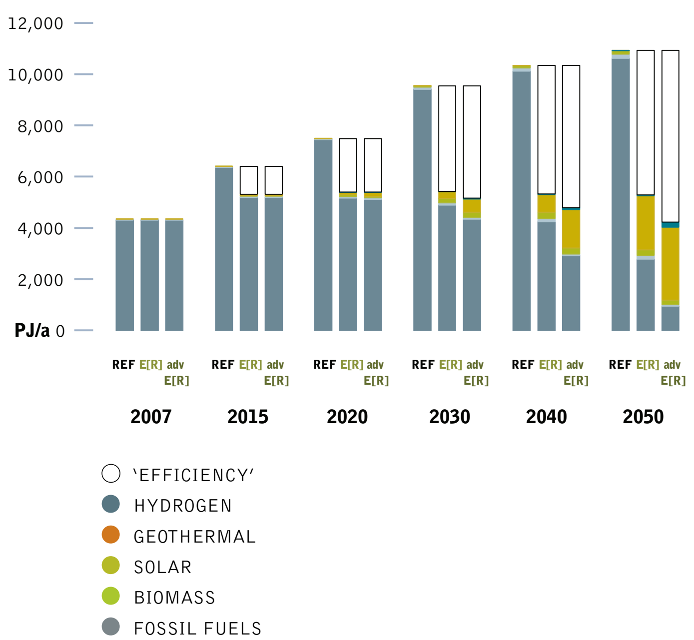


image A RIVER IN AFGHANISTAN.

image GREENPEACE SURVEY OF GULF WAR OIL POLLUTION IN KUWAIT. AERIAL VIEW OF OIL IN THE SEA.

middle east: development of CO_2 emissions

While CO_2 emissions in the Middle East will more than double under the Reference scenario by 2050 and are thus far removed from a sustainable development path, under the Energy [R]evolution scenario emissions will decrease from 1,374 million tonnes in 2007 to 387 million tonnes by 2050. Annual per capita emissions will drop from 6.8 t to 1.1 t. In spite of an increasing electricity demand, CO_2 emissions will decrease strongly in the electricity sector. In the long run efficiency gains and the increased use of renewable electricity in vehicles will even reduce CO_2 emissions in the transport sector.

The advanced Energy [R]evolution scenario will accelerate the decrease of energy related CO_2 emissions compared to the basic version, leading to 3.8 t per capita by 2030 and 0.3 t by 2050. By 2050 the Middle East's CO_2 emissions will be 21% of 1990 levels.

middle east: primary energy consumption

Taking into account the assumptions discussed above, the resulting primary energy consumption under the Energy [R]evolution scenario is shown in Figure 6.58. Compared to the Reference scenario, overall energy demand will be reduced in 2050 by 45%. The Middle East's primary energy demand will increase from 21,360 PJ/a to 28,393 PJ/a. 63% of the remaining demand will be covered by renewable energy sources.

The advanced version phases out coal and oil about ten to 15 years faster than the basic scenario. This is made possible mainly by the replacement of new coal power plants with renewables after a 20 rather than 40 year lifetime and a faster introduction of electric vehicles in the transport sector to replace oil combustion engines. This leads to an overall renewable primary energy share of 22% in 2030 and 76% in 2050.

figure 6.57: middle east: development of CO_2 emissions by sector under both energy [r]evolution scenarios

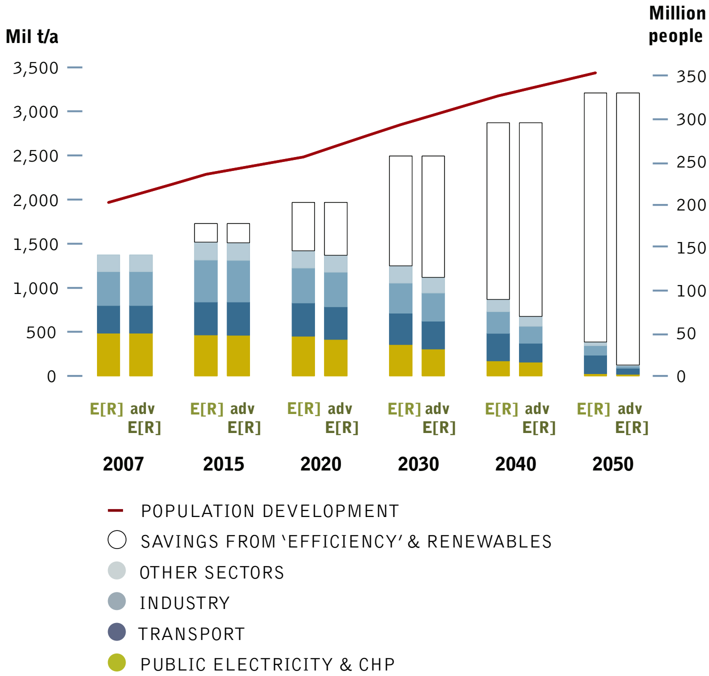
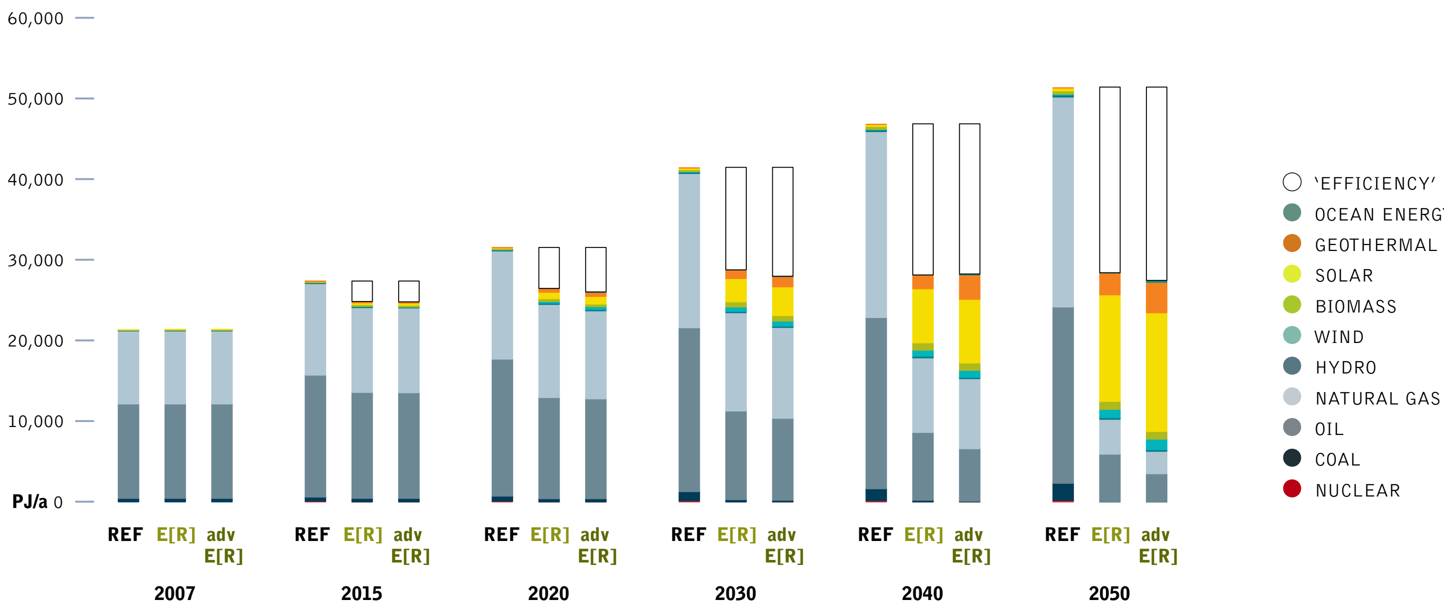


figure 6.58: middle east: development of primary energy consumption under three scenarios



transition economies

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transition economies: energy demand by sector

The future development pathways for the energy demand of the Transition Economies are shown in Figure 6.59 for the Reference and both Energy [R]evolution scenarios. Under the Reference scenario, total primary energy demand in the Transition Economies increases by more than 33% from the current 48,016 PJ/a to 63,988 PJ/a in 2050. The energy demand in 2050 in the Energy [R]evolution scenario decreases by 30% in the basic and 28% in the advanced case, compared to current consumption. By 2050 it is expected to reach 33,742 PJ/a and 34,697 PJ/a in the advanced scenario.

Under the Energy [R]evolution scenario, electricity demand in the industry as well as in the residential and service sectors is expected to decrease after 2015 (see Figure 6.60). Because of the growing use of electric vehicles however, electricity demand increases to 1,646 TWh/a in the year 2050. Compared to the Reference case efficiency measures avoid the generation of about 1,012 TWh/a. The advanced Energy [R]evolution scenario introduces electric vehicles earlier and more journeys – for both freight and passengers - are shifted to electric trains and public transport. Fossil fuels for industrial process heat generation are also phased out more quickly and replaced by electric geothermal heat pumps and hydrogen. This means that electricity demand in the advanced version is higher, and reaches 1,867 TWh/a in 2050, still 22% below the Reference case.

Efficiency gains in the heat supply sector are larger than in the electricity sector. Under both Energy [R]evolution scenarios, final demand for heat supply can even be reduced significantly (see Figure 6.61).

In the Energy [R]evolution scenario, efficiency measures in industry and other sectors avoid the generation of about 1,012 TWh/a electricity. This reduction in energy demand can be achieved in particular by introducing highly efficient electronic devices using the best available technology.

Compared to the Reference scenario, heat consumption equivalent to 9,101 PJ/a is avoided through efficiency gains by 2050. In the transport sector, it is assumed under the Energy [R]evolution scenario that energy demand will decrease to 4,137 PJ/a by 2050, saving 60% compared to the Reference scenario. This is achieved through a mix of increased public transport, reduced annual person-kilometres and wider use of more efficient engines and electric drives. The advanced Energy [R]evolution scenario goes one step further and factors in a faster decrease in transport energy demand of 64%. While electricity demand increases, the overall final energy use falls to 3,737 PJ/a.

figure 6.59: transition economies: projection of total final energy demand by sector (REF, E[R] & advanced E[R])

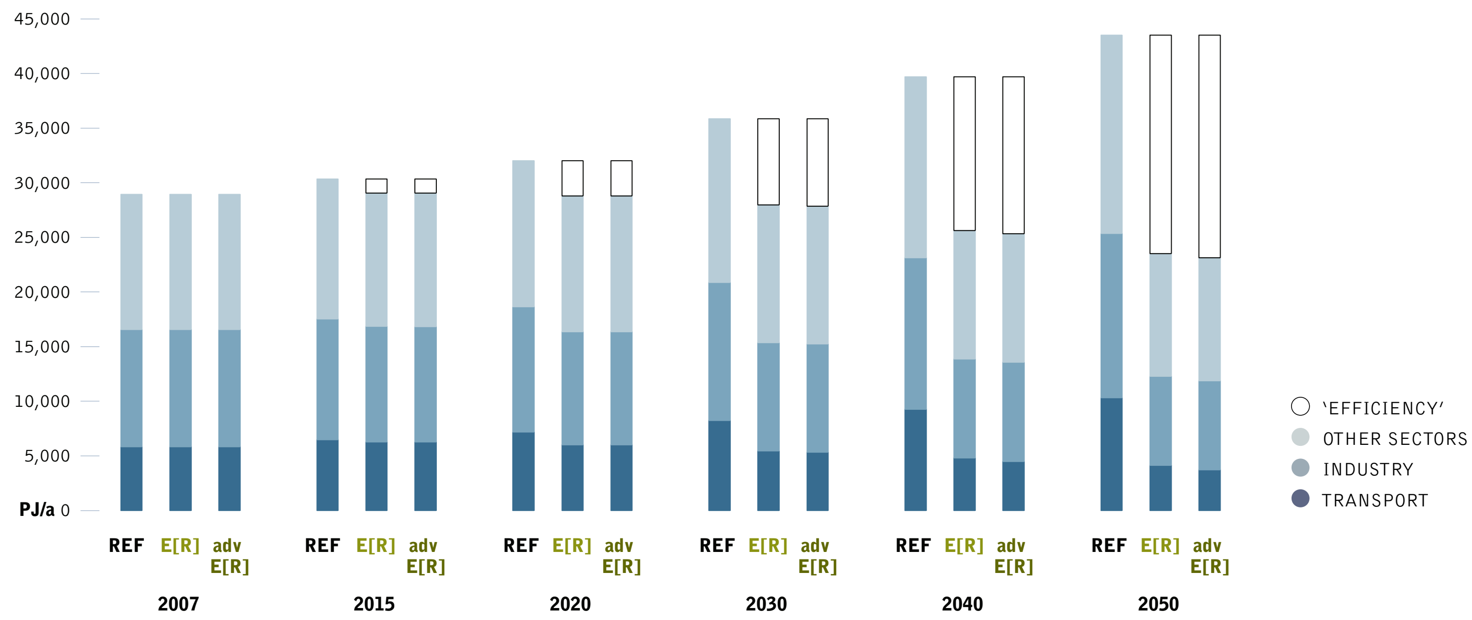
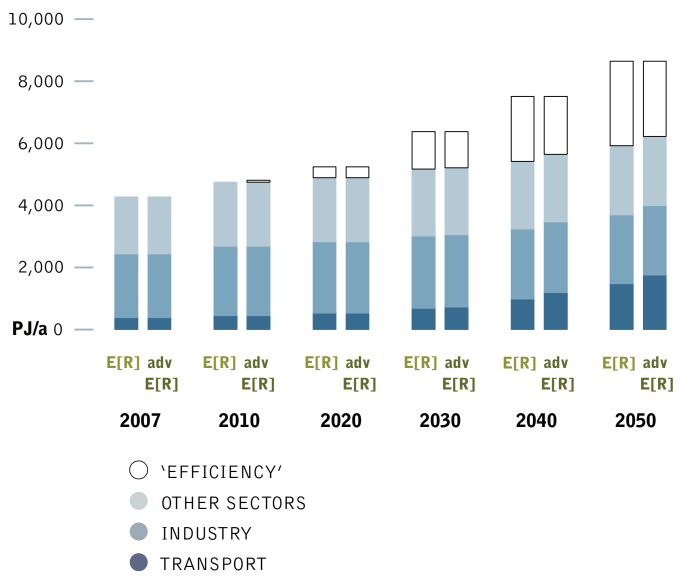


image AN INDIGENOUS NENET WOMAN WITH HER REINDEER. THE NENETS PEOPLE MOVE EVERY 3 OR 4 DAYS SO THAT THEIR HERDS DO NOT OVER GRAZE THE GROUND. THE ENTIRE REGION AND ITS INHABITANTS ARE UNDER HEAVY THREAT FROM GLOBAL WARMING AS TEMPERATURES INCREASE AND RUSSIA'S ANCIENT PERMAFROST MELTS.

image A SITE OF A DISAPPEARED LAKE AFTER PERMAFROST SUBSIDENCE IN RUSSIA.

figure 6.60: transition economies: development of electricity demand by sector (REF, E[R] & advanced E[R])



transition economies: heating and cooling supply

Renewables currently provide 3% of Transition Economies' energy demand for heat supply, the main contribution coming from the use of biomass. The lack of modern and efficient district heating networks is a barrier to the large scale utilisation of geothermal and solar thermal energy. Dedicated support instruments are required to ensure a dynamic development. In the Energy [R]evolution scenario, renewables provide 74% of Transition Economies's total heating demand in 2050.

- Energy efficiency measures can decrease heat demand by 37% in spite of improving living standards.
- For direct heating, solar collectors, biomass/biogas as well as geothermal energy are increasingly substituting for fossil fuel-fired systems.
- A shift from coal and oil to natural gas in the remaining conventional applications will lead to a further reduction of CO_2 emissions.

The advanced Energy [R]evolution version introduces efficiency measures e.g. via strict building standards and renewable heating systems around 5 years ahead of the Energy [R]evolution scenario. Compared to the Reference scenario, 9101 PJ/a or 37% are safed by 2050. Solar collectors and geothermal heating systems achieve economies of scale via ambitious support programmes five to ten years earlier, resulting in a renewable share of 50% by 2030 and 89% by 2050.

figure 6.61: transition economies: development of heat demand by sector

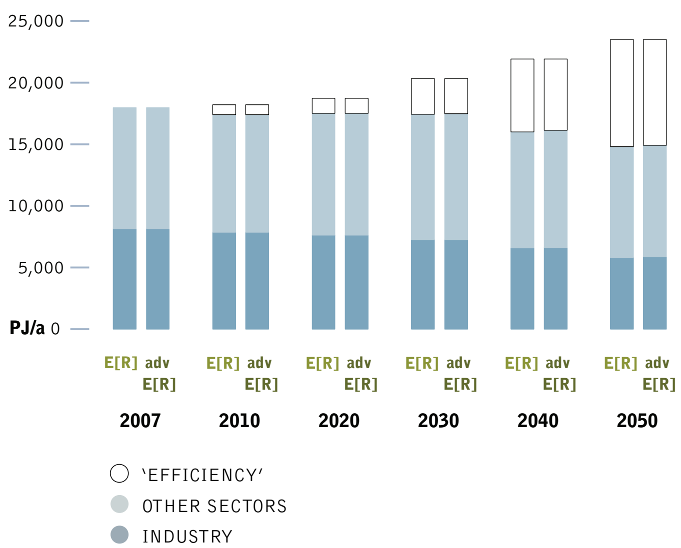
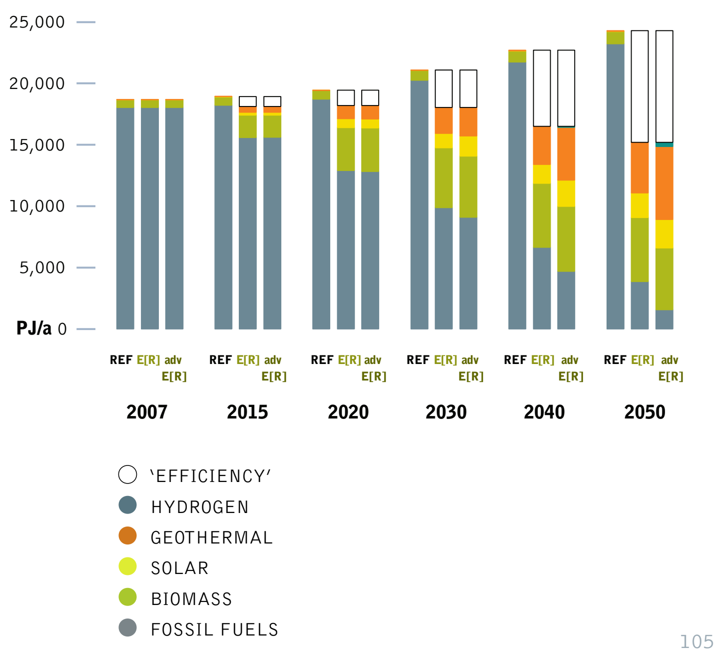


figure 6.62: transition economies: development of heat supply structure under 3 scenarios



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transition economies: electricity generation

The development of the electricity supply sector in the Energy [R]evolution scenario is characterised by a dynamically growing renewable energy market. This will compensate for the phasing out of nuclear energy and reduce the number of fossil fuel-fired power plants required for grid stabilisation. By 2050, 81% of the electricity produced in the Transition Economies will come from renewable energy sources. 'New' renewables – mainly wind, solar thermal energy and PV – will contribute 33% of electricity generation. The installed capacity of renewable energy technologies will grow from the current 91 GW to 554 GW in 2050, increasing renewable capacity by a factor of 6. This will require political support and well-designed policy instruments. The advanced Energy [R]evolution scenario projects a faster market development with higher annual growth rates achieving a renewable electricity share of 53% by 2030 and 93% by 2050. The installed capacity of renewables will reach 330 GW in 2030 and 735 GW by 2050, 33% higher than in the basic version.

None of these numbers - even in the advanced Energy [R]evolution scenario - utilise the maximum known technical potential of all the renewable resources. While the deployment rate compared to the technical potential for hydro power, for example, is relatively high at 28% in the advanced Energy [R]evolution scenario, for photovoltaic only 0.4% has been used in the advanced scenario.

Figure 6.63 shows the expansion rate of the different renewable technologies over time. Up to 2020, hydro power and wind will remain the main contributors to the growing market share. After 2020, the continuing growth of wind will be complemented by electricity from biomass, photovoltaic and geothermal energy.

table 6.13: transition economies: projection of renewable electricity generation capacity under both Energy [R]evolution scenarios

IN GW

		2007	2020	2030	2040	2050
Hydro	E[R]	90	108	110	111	110
	advanced E[R]	90	108	110	112	112
Biomass	E[R]	0	40	52	66	80
	advanced E[R]	0	40	52	74	90
Wind	E[R]	0	12	74	149	227
	advanced E[R]	0	21	100	209	323
Geothermal	E[R]	0	3	10	18	25
	advanced E[R]	0	3	11	30	50
PV	E[R]	0	3	42	79	100
	advanced E[R]	0	3	47	121	142
CSP	E[R]	0	0	2	3	3
	advanced E[R]	0	0	2	4	5
Ocean energy	E[R]	0	4	6	7	9
	advanced E[R]	0	4	9	12	13
Total	**E[R]**	**91**	**171**	**295**	**433**	**554**
	advanced E[R]	**91**	**180**	**330**	**563**	**735**

figure 6.63: transition economies: development of electricity generation structure under 3 scenarios

(REFERENCE, ENERGY [R]EVOLUTION AND ADVANCED ENERGY [R]EVOLUTION) ["EFFICIENCY" = REDUCTION COMPARED TO THE REFERENCE SCENARIO]

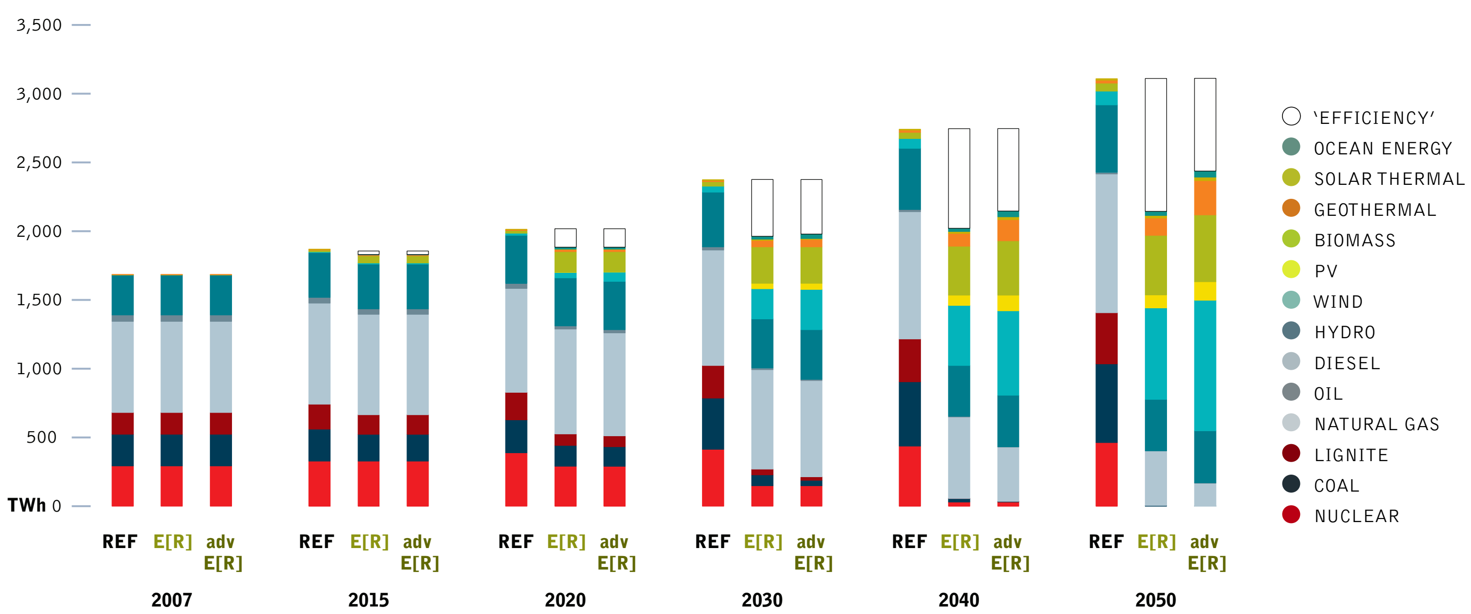
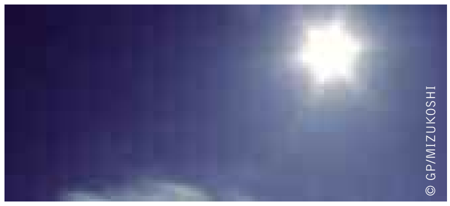


image CHERNOBYL NUCLEAR POWER STATION, UKRAINE.

image THE SUN OVER LAKE BAIKAL, RUSSIA.



transition economies: future costs of electricity generation

Figure 6.64 shows that the introduction of renewable technologies under the Energy [R]evolution scenario slightly increases the costs of electricity generation compared to the Reference scenario. This difference will be less than 1 cent/kWh up to 2020, however. Because of the lower CO_2 intensity of electricity generation, by 2020 costs will become economically favourable under the Energy [R]evolution scenario, and by 2050 costs will be more than 5 cents/kWh below those in the Reference scenario. Due to growing demand, there will be a significant increase in society's expenditure on electricity supply. Under the Reference scenario, total electricity supply costs will rise from today's $163 billion per year to more than $555 billion in 2050. Figure 6.64 shows that the Energy [R]evolution scenario not only complies with Transition Economies` CO_2 reduction targets but also helps to stabilise energy costs and relieve the economic pressure on society. Long term costs for electricity supply are one third lower than in the Reference scenario.

In both Energy [R]evolution scenarios the specific generation costs are almost on the same level until 2030. In 2050 the advanced Energy [R]evolution scenario has with 8 cents/kWh lower generation costs, because of greater economics of scale in renewable power equipment. Despite the increased electricity demand especially in the transport and industry sector the overall total supply costs in the advanced case are $26 billion in 2030 and $32 billion in 2050 lower than in the Energy [R]evolution scenario.

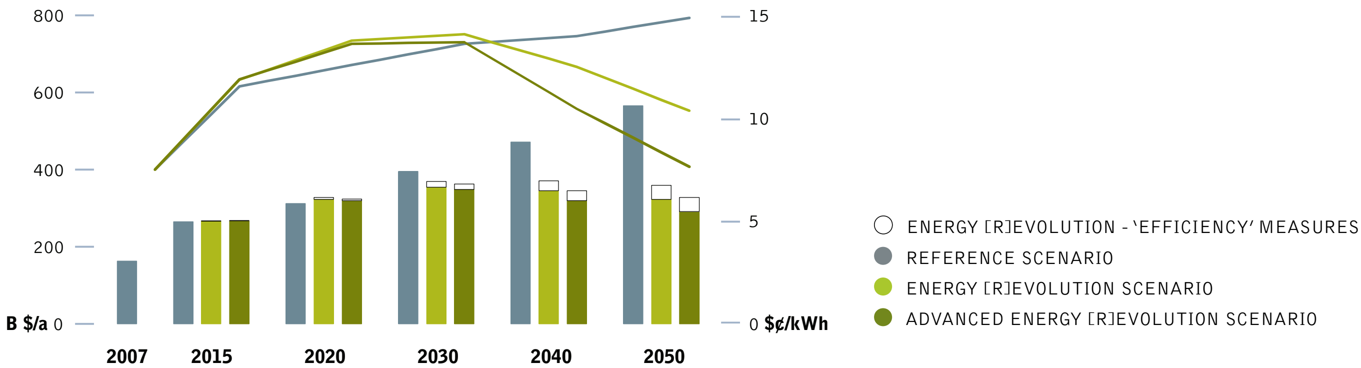
transition economies: job results

The Energy [R]evolution scenarios lead to more energy sector jobs in the Transition Economies at every stage of the projection.

- There are 750,000 power sector jobs in both Energy [R]evolution scenario by 2015, compared to 600,000 in the Reference scenario.
- By 2020 job numbers reach over 960,000 in both Energy [R]evolution scenarios, 350,000 more than in the Reference scenario.
- By 2030 job numbers in the renewable sector climb slightly in the advanced Energy [R]evolution scenario to nearly 700,000 and remain at around 600,000 in the basic version, while in the Reference scenario, there are only 120,000 jobs in the renewables industry – equal to the gas power sector.

Table 6.14 shows the increase in job numbers under both Energy [R]evolution scenarios for each technology up to 2020 and up to 2030. Both scenarios show losses in coal generation, but these are outweighed by employment growth in renewable technologies and gas. Wind and biomass shows particularly strong growth in both Energy [R]evolution scenarios by 2020, but by 2030 there is significant employment across a range of renewable technologies.

figure 6.64: transition economies: development of total electricity supply costs & development of specific electricity generation costs under 3 scenarios



transition economies

table 6.14: transition economies: employment & investment

	REFERENCE			ENERGY [R]EVOLUTION			ADVANCED ENERGY [R]EVOLUTION		
	2015	2020	2030	2015	2020	2030	2015	2020	2030
Jobs									
Construction & installation	0.08 m	0.07 m	0.06 m	0.14 m	0.16 m	0.08 m	0.14 m	0.18 m	0.15 m
Manufacturing	0.01 m	0.02 m	0.02 m	0.02 m	0.07 m	0.07 m	0.04 m	0.09 m	0.12 m
Operations & maintenance	0.15 m	0.15 m	0.13 m	0.24 m	0.39 m	0.36 m	0.24 m	0.39 m	0.37 m
Fuel	0.36 m	0.37 m	0.43 m	0.36 m	0.34 m	0.23 m	0.34 m	0.30 m	0.20 m
Total Jobs	**0.60 m**	**0.61 m**	**0.64 m**	**0.75 m**	**0.96 m**	**0.75 m**	**0.75 m**	**0.96 m**	**0.84 m**
Coal	0.27 m	0.31 m	0.36 m	0.20 m	0.13 m	0.06 m	0.19 m	0.11 m	0.03 m
Gas, oil and diesel	0.15 m	0.14 m	0.13 m	0.18 m	0.19 m	0.12 m	0.17 m	0.16 m	0.11 m
Nuclear	0.06 m	0.04 m	0.03 m	0.03 m	0.02 m	0.01 m	0.03 m	0.02 m	0.01 m
Renewables	0.12 m	0.12 m	0.12 m	0.34 m	0.62 m	0.56 m	0.36 m	0.66 m	0.69 m
Total Jobs	**0.60 m**	**0.61 m**	**0.64 m**	**0.75 m**	**0.96 m**	**0.75 m**	**0.75 m**	**0.96 m**	**0.84 m**

transition economies: transport

Development of the transport sector is characterised by the diversification of energy sources towards more efficiency. Under the Energy [R]evolution scenario energy demand reduction of 6205 PJ/a can be achieved by 2050, saving 60% compared to the Reference scenario. This reduction can be achieved by the introduction of highly efficient vehicles, by shifting the transport of goods from road to rail and by changes in mobility-related behaviour patterns.

A slight shift towards smaller cars triggered by economic incentives together with a significant shift in propulsion technology towards electrified power trains and a reduction of vehicle kilometres travelled by 0.25% per year leads to significant final energy savings. By 2030, electricity will provide 13% of the transport sector's total energy demand in the Energy [R]evolution, while in the advanced case the share will already be 14% in 2030 and 47% by 2050.

figure 6.65: transition economies: transport under 3 scenarios

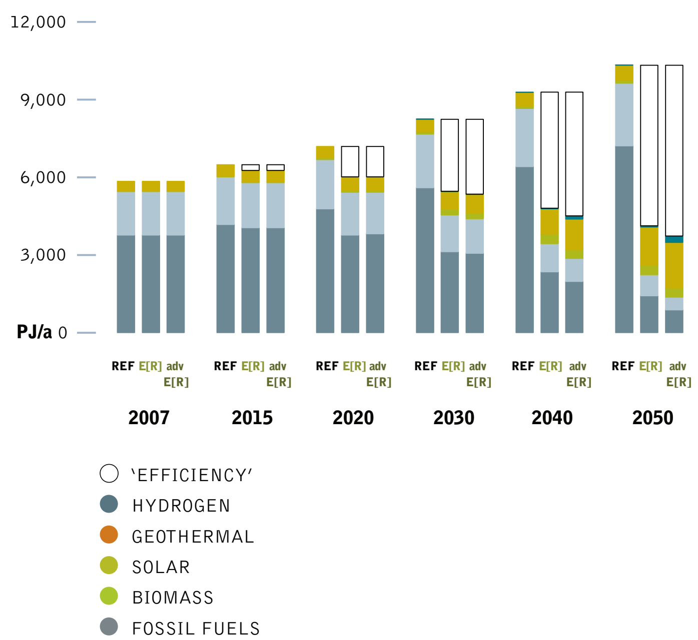


image LAKE BAIKAL, RUSSIA.

image SOLAR PANELS IN A NATURE RESERVE IN CAUCASUSU, RUSSIA.

transition economies: development of CO_2 emissions

Whilst emissions of CO_2 will increase by 35% under the Reference scenario by 2050, under the Energy [R]evolution scenario they will decrease from 2650 million tonnes in 2007 to 532 million t in 2050. Annual per capita emissions will drop from 7.8 t to 1.7 t. In spite of the phasing out of nuclear energy and increasing demand, CO_2 emissions will decrease in the electricity sector. In the long run efficiency gains and the increased use of renewable electricity in vehicles will reduce emissions in the transport sector. With a share of 40% of total CO_2 in 2050, the power sector will drop below transport and other sectors as the largest sources of emissions.

The advanced Energy [R]evolution scenario reduces energy related CO_2 emissions about 10 to 15 years faster than the basic scenario, leading to 3.9 t per capita by 2030 and 0.8 t by 2050. By 2050, Transition Economies´s CO_2 emissions are 6% of 1990 levels.

transition economies: primary energy consumption

Taking into account the assumptions outlined above, the resulting primary energy consumption under the Energy [R]evolution scenario is shown in Figure 6.67. Compared to the Reference scenario, overall energy demand will be reduced by 48% in 2050. Around 62% of the remaining demand will be covered by renewable energy sources.

The Advanced scenario phases out coal and oil about ten years faster than the basic scenario. This is made possible mainly by a quicker replacement of coal power plants with renewables after 20 years rather than 40 years lifetime in the Energy [R]evolution scenario and a faster introduction of electric vehicles in the transport sector to replace combustion engines. This leads to an overall renewable energy share of 37% in 2030 and 76% in 2050. Nuclear energy is phased out in both Energy [R]evolution scenarios soon after 2040.

figure 6.66: transition economies: development of CO_2 emissions by sector under both energy [r]evolution scenarios

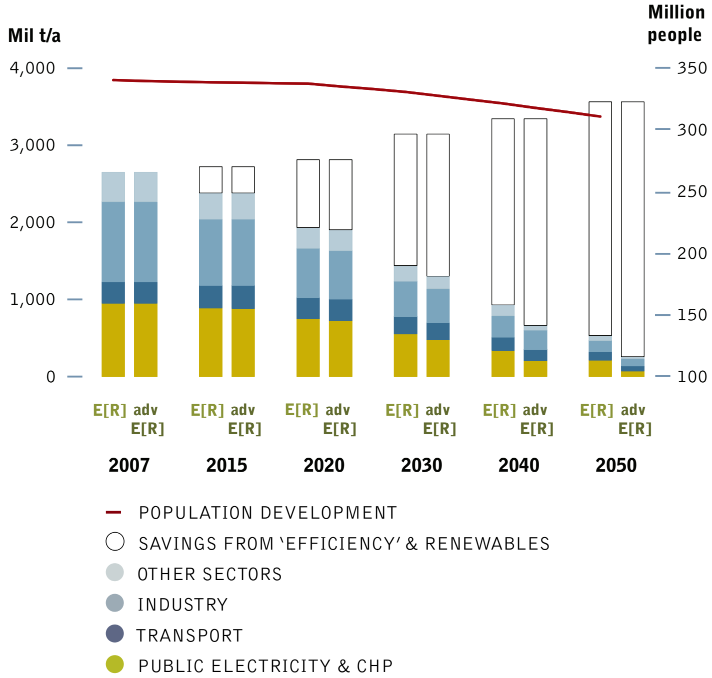
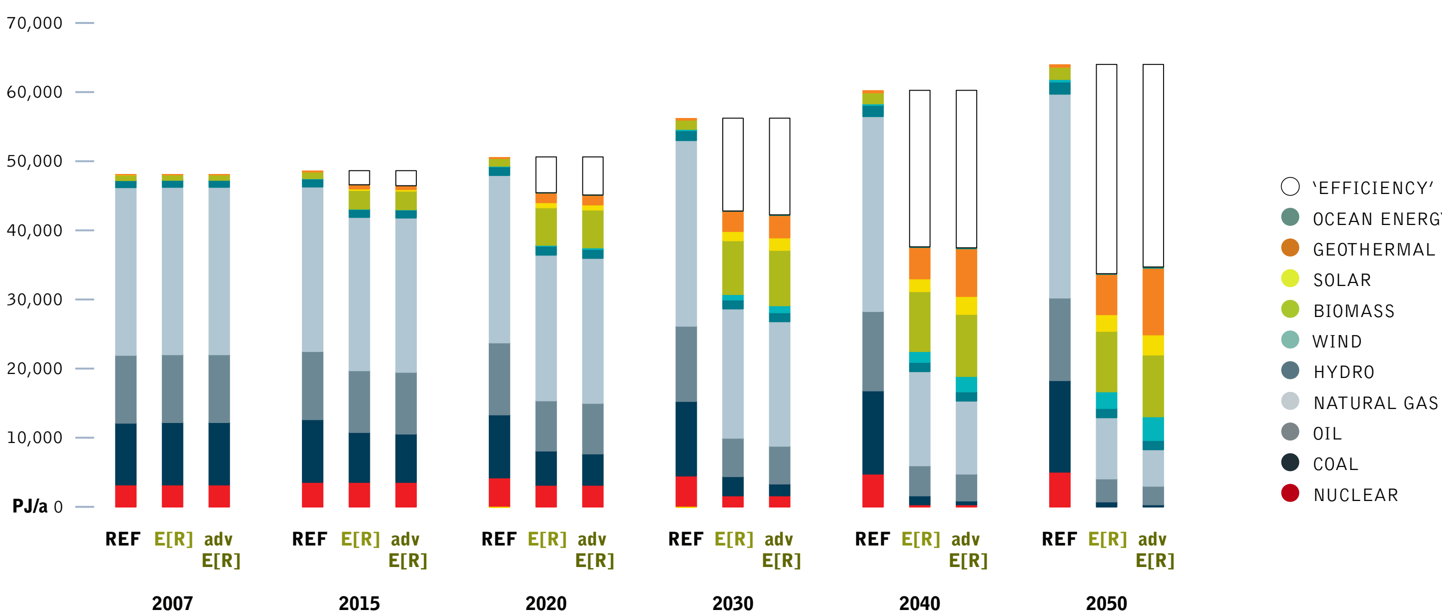


figure 6.67: transition economies: development of primary energy consumption under three scenarios



india

india: energy demand by sector

The potential future development pathways for India's primary energy demand are shown in Figure 6.68 for both the Reference and Energy [R]evolution scenarios. Under the Reference scenario, total energy demand triples from the current 25,203 PJ/a to 78,048 PJ/a in 2050. In the Energy [R]evolution scenario, by contrast, energy demand in India will increase by about 105% and is expected to reach 51,718 PJ/a by 2050. The advanced Energy [R]evolution scenario foresees a demand of 54,763 PJ/a by 2050 and is therefore roughly at the same level.

Under the Energy [R]evolution scenario, electricity demand is expected to increase substantially (see Figure 6.69). With the exploitation of efficiency measures, however, a higher increase can be avoided, leading to electricity demand of around 3,439 TWh/a in 2050. Compared to the Reference scenario, efficiency measures in industry and other sectors avoid the generation of about 615 TWh/a. This reduction can be achieved in particular by introducing highly efficient electronic devices using the best available technology in all demand sectors.

The advanced Energy [R]evolution scenario introduces electric vehicles earlier while more journeys – for both freight and passengers - are shifted to electric trains and public transport. Fossil fuels for industrial process heat generation are also phased out more quickly and replaced by electric geothermal heat pumps and hydrogen. This means that electricity demand in the advanced version is higher, and reaches 4,047 TWh/a in 2050.

Efficiency gains for heat and cooling supply are also significant. Under the Energy [R]evolution scenario, final demand for heating and cooling can even be reduced (see Figure 6.70). Compared to the Reference scenario, consumption equivalent to 5,110 PJ/a is avoided through efficiency gains by 2050.

In the transport sector, it is assumed, with a fast growing economy, that under the Energy [R]evolution scenario energy demand will increase dramatically - from 1,708 PJ/a in 2007 to 8,677 PJ/a by 2050. This still saves 42% compared to the Reference scenario. This reduction can be achieved by the introduction of highly efficient vehicles, shifting freight transport from road to rail and by changes in travel behaviour. Because India, as a developing country, has a relatively low starting point, transport demand (in terms of kilometres per person and freight volumes) has not been reduced any further than in the basic version. Due to a wider use of more efficient electric drives, however, overall final energy demand in transport falls to 7,277 PJ/a, 51% lower than in the Reference case.

figure 6.68: india: projection of total final energy demand by sector (REF, E[R] & advanced E[R])

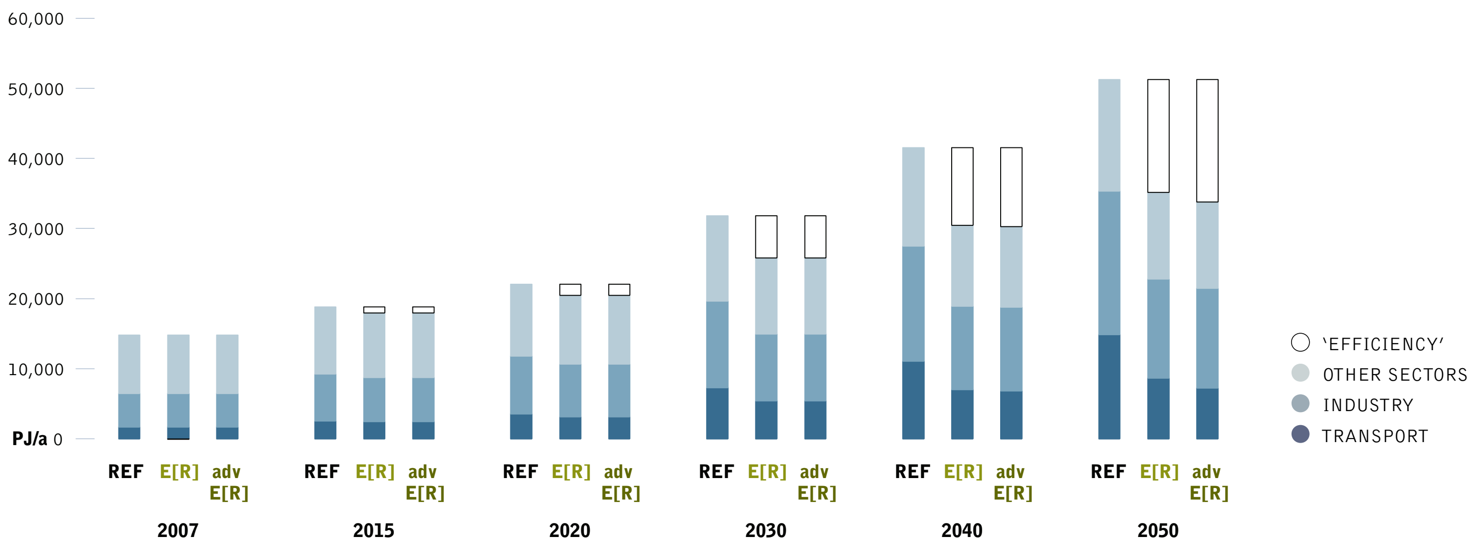
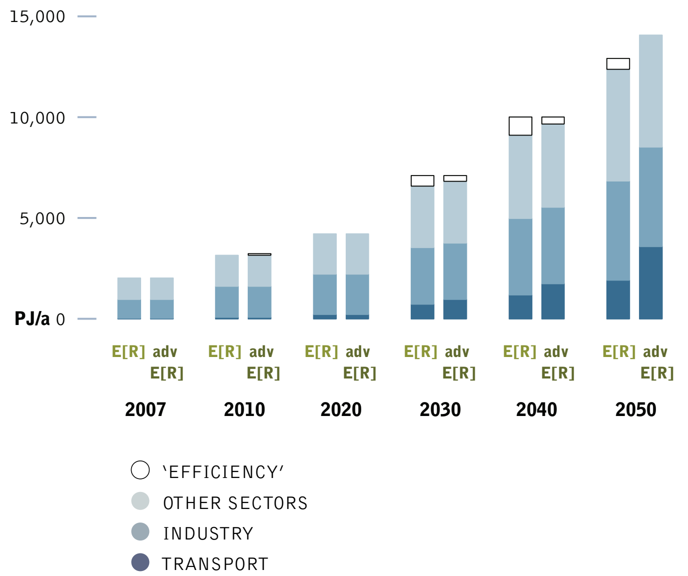


image AJIT DAS LIVES IN GHORAMARA ISLAND AND IS ONE OF THE MANY PEOPLE AFFECTED BY SEA LEVEL RISE: "WE CANNOT STAY HERE BECAUSE OF THE GANGA'S FLOODING. WE HAVE MANY PROBLEMS. WE DON'T KNOW WHERE WE WILL GO OR WHAT WE WILL DO. WE CANNOT BRING OUR GRANDCHILDREN UP HERE. WHATEVER THE GOVERNMENT DECIDES FOR US, WE SHALL FOLLOW THEIR GUIDANCE. EVERYTHING IS GOING UNDER THE WATER. WHILE THE EDGE OF THE LAND IS BREAKING IN GHORAMARA, THE MIDDLE OF THE RIVER IS BECOMING SHALLOWER. WE DON'T KNOW WHERE WE WILL GO OR WHAT WE WILL DO".

image VILLAGERS ORDER THEMSELVES INTO QUEUE TO RECEIVE SOME EMERGENCY RELIEF SUPPLY PROVIDED BY A LOCAL NGO. SCIENTISTS ESTIMATE THAT OVER 70,000 PEOPLE, LIVING EFFECTIVELY ON THE FRONT LINE OF CLIMATE CHANGE, WILL BE DISPLACED FROM THE SUNDARBANS DUE TO SEA LEVEL RISE BY THE YEAR 2030.

figure 6.69: india: development of electricity demand by sector (REF, E[R] & advanced E[R])



india: heating and cooling supply

Renewables presently provide 60% of energy demand for heat and cooling supply in India, the main contribution coming from the use of biomass. Dedicated support instruments are required to ensure a continuously dynamic development of renewables in the heat market. In the Energy [R]evolution scenario, renewables will provide 71% of India's heating and cooling demand by 2050.

- Energy efficiency measures will restrict future energy demand for heat and cooling supply to an increase of 74% relative to 2005, in spite of improving living standards. This compares to 133% in the Reference scenario.
- In the industry sector solar collectors, biomass/biogas and geothermal energy are increasingly substituted for conventional fossil-fuelled heating systems.
- A shift from coal and oil to natural gas in the remaining conventional applications leads to a further reduction of CO_2 emissions.

In the Energy [R]evolution scenario 5,110 PJ/a is saved by 2050, or 25% compared to the Reference scenario. The advanced Energy [R]evolution version introduces renewable heating and cooling systems around five years ahead of the basic scenario. India can use concentrated solar energy to generate heat for industrial processes in its north western provinces.

figure 6.70: india: development of heat demand by sector

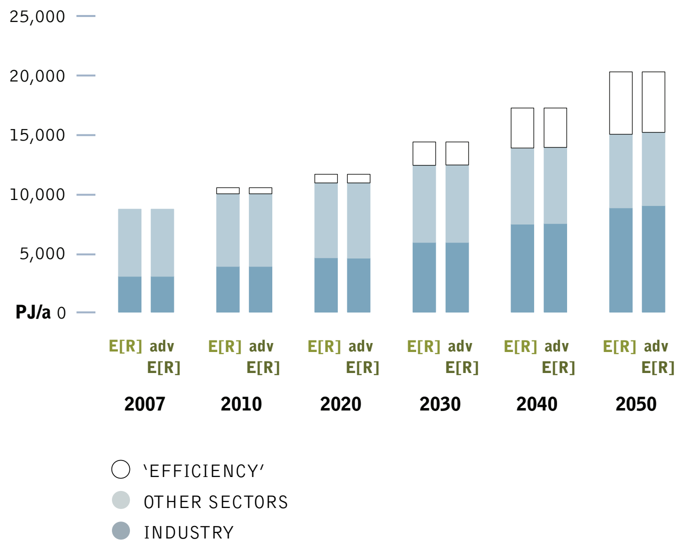
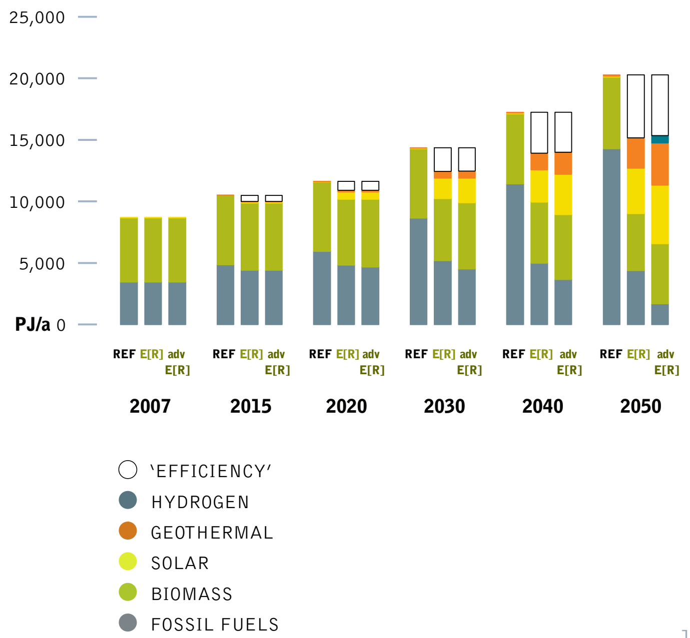


figure 6.71: india: development of heat supply structure under 3 scenarios



india

india: electricity generation

By 2050, about 62% of the electricity produced in India will come from renewable energy sources. 'New' renewables – mainly wind, solar thermal energy and PV – will contribute almost 45% of electricity generation. The installed capacity of renewable energy technologies will grow from the current 44 GW to 775 GW in 2050, a substantial increase over the next 40 years.

The advanced Energy [R]evolution scenario projects a faster market development pathway, with higher annual growth rates achieving a renewable electricity share of 64% by 2030 and 93% by 2050. The installed capacity of renewables will reach 510 GW in 2030 and 1,325 GW by 2050, 71% higher than in the basic version.

Table 6.15 shows the comparative evolution of different renewable technologies over time. Up to 2030, hydro power and wind will remain the main contributors. After 2020, the continuing growth of wind will be complemented by electricity from biomass, photovoltaic and solar thermal (CSP) energy.

While the advanced scenario uses 10% of the known technical potential for PV, 17% for tide and wave and just 5% of the solar thermal potential, the "official" figure for India´s wind potential is only 100 GW. The overall installed capacity of wind power by 2050 in the advanced version is 346 GW, 3.5 times higher, however. This is because both the Global Wind Energy Council and Greenpeace International believe that India's wind potential is several times higher than officially recognised, mainly as a result of historic wind speed measurements being taken at a height of only 50 metres – and not the 80 m which is the typical height of a modern wind turbine.

When the United States reworked its wind potential calculations, a change from 50 to 80 m measurement height tripled the overall potential. A new analysis for China has also shown that the wind potential will be 640 GW by 2030 (Science, Vol 325, page 1380, M.B.McElroy et al., September 2009) . We are therefore confident that the projected installed capacity of 346 GW by 2050 for India is realistic.

table 6.15: india: projection of renewable electricity generation capacity under both Energy [R]evolution scenarios

IN GW

		2007	2020	2030	2040	2050
Hydro	E[R]	36	56	57	57	57
	advanced E[R]	36	56	57	57	57
Biomass	E[R]	0	8	21	44	73
	advanced E[R]	0	8	21	44	73
Wind	E[R]	8	69	128	172	230
	advanced E[R]	8	93	210	288	346
Geothermal	E[R]	0	2	6	18	31
	advanced E[R]	0	9	38	70	95
PV	E[R]	0	7	41	99	245
	advanced E[R]	0	30	111	237	482
CSP	E[R]	0	3	13	62	131
	advanced E[R]	0	24	53	124	216
Ocean energy	E[R]	0	1	2	4	7
	advanced E[R]	0	7	22	31	56
Total	**E[R]**	**44**	**146**	**268**	**455**	**775**
	advanced E[R]	**44**	**227**	**510**	**851**	**1,325**

figure 6.72: india: development of electricity generation structure under 3 scenarios

(REFERENCE, ENERGY [R]EVOLUTION AND ADVANCED ENERGY [R]EVOLUTION) ["EFFICIENCY" = REDUCTION COMPARED TO THE REFERENCE SCENARIO]

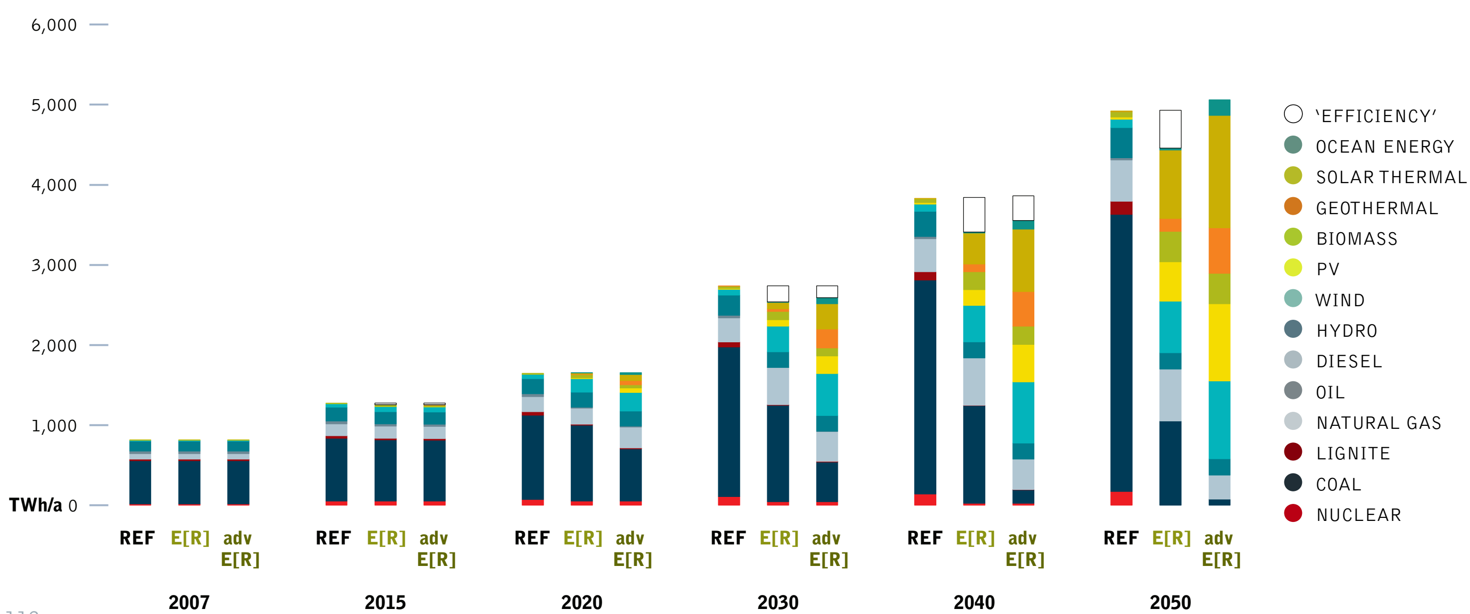


image A LOCAL BENGALI WOMAN PLANTS A MANGROVE (SUNDARI) SAPLING ON SAGAR ISLAND IN THE ECOLOGICALLY SENSITIVE SUNDERBANS RIVER DELTA REGION, IN WEST BENGAL. THOUSANDS OF LOCAL PEOPLE WILL JOIN THE MANGROVE PLANTING INITIATIVE LED BY PROFESSOR SUGATA HAZRA FROM JADAVAPUR UNIVERSITY, WHICH WILL HELP TO PROTECT THE COAST FROM EROSION AND WILL ALSO PROVIDE NUTRIENTS FOR FISH AND CAPTURE CARBON IN THEIR EXTENSIVE ROOT SYSTEMS.

image FEMALE WORKER CLEANING A SOLAR OVEN AT A COLLEGE IN TILONIA, RAJASTHAN, INDIA.

india: future costs of electricity generation

Figure 6.73 shows that the introduction of renewable technologies under the Energy [R]evolution scenario significantly decreases the future costs of electricity generation compared to the Reference scenario. Because of the lower CO_2 intensity of electricity generation, costs will become economically favourable under the Energy [R]evolution scenario and by 2050 will be more than 3 cents/kWh below those in the Reference version.

Under the Reference scenario, by contrast, a massive growth in demand, increased fossil fuel prices and the cost of CO_2 emissions result in total electricity supply costs rising from today's $69 billion per year to more than $605 billion in 2050. Figure 6.73 shows that the Energy [R]evolution scenario not only complies with India's CO_2 reduction targets but also helps to stabilise energy costs. Increasing energy efficiency and shifting energy supply to renewables leads to long term costs for electricity supply that are one third lower than in the Reference scenario.

In both Energy [R]evolution scenarios the specific electricity generation costs are almost the same up to 2030. By 2050, however, the advanced version results in a reduction of 7 cents/kWh, mainly because of greater economies of scale in the production of renewable power equipment. Although the demand for electricity increases, especially in the transport.

india: job results

The Energy [R]evolution scenarios lead to more energy sector jobs in India at every stage of the projection.

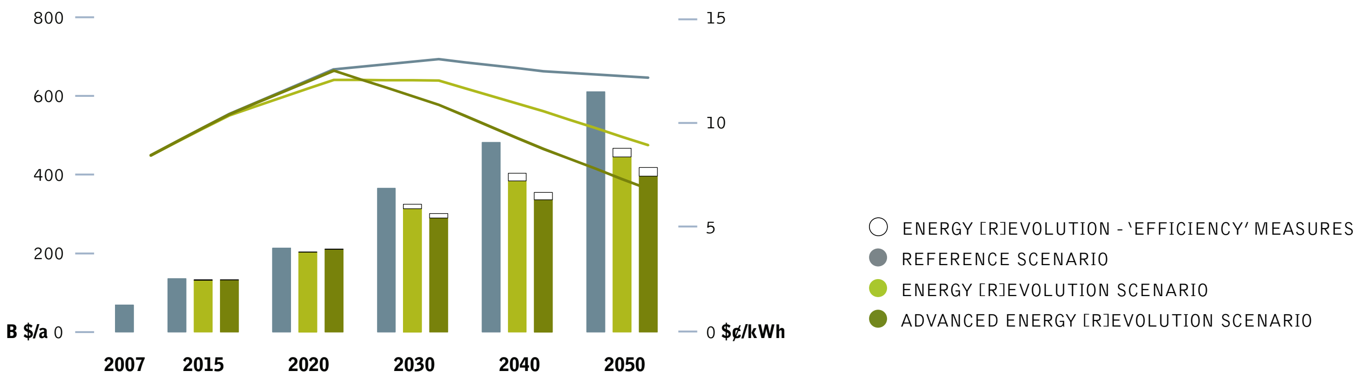
• There are around 1 million power sector jobs in the basic Energy [R]evolution scenario by 2015, compared to 710,000 in the Reference scenario.

• By 2020 job numbers reach over one million in the Energy [R]evolution scenario (1.26 million in the advanced version), 430,000 more than in the Reference scenario.

• By 2030 job numbers climb in the renewable sector to about half a million in both Energy [R]evolution scenarios, and only 90,000 in the Reference scenario. The decline in the renewables sector between 2020 and 2030 is due to the assumed cost reduction for renewables.

Table 6.16 shows the increase in job numbers under both Energy [R]evolution scenarios for each technology up to 2020 and up to 2030. Both scenarios show some losses in coal generation, but these are outweighed by employment growth in renewable technologies and gas. Wind, solar pv and concentrated solar power shows particularly strong growth in the both Energy [R]evolution scenarios by 2020, but by 2030 there is significant employment across a range of renewable technologies.

figure 6.73: india: development of total electricity supply costs & development of specific electricity generation costs under 3 scenarios



india

GLOBAL SCENARIO

OECD NORTH AMERICA
LATIN AMERICA
OECD EUROPE
AFRICA

MIDDLE EAST
TRANSITION ECONOMIES
INDIA

DEVELOPING ASIA
CHINA
OECD PACIFIC

table 6.16: india: employment & investment

	REFERENCE			ENERGY [R]EVOLUTION			ADVANCED ENERGY [R]EVOLUTION		
	2015	2020	2030	2015	2020	2030	2015	2020	2030
Jobs									
Construction & installation	0.18 m	0.25 m	0.13 m	0.24 m	0.20 m	0.10 m	0.46 m	0.32 m	0.18 m
Manufacturing	0.06 m	0.07 m	0.04 m	0.26 m	0.21 m	0.11 m	0.43 m	0.36 m	0.19 m
Operations & maintenance	0.08 m	0.09 m	0.08 m	0.11 m	0.14 m	0.16 m	0.11 m	0.17 m	0.20 m
Fuel	0.38 m	0.42 m	0.56 m	0.41 m	0.46 m	0.54 m	0.42 m	0.41 m	0.32 m
Total Jobs	**0.71 m**	**0.83 m**	**0.81 m**	**1.01 m**	**1.02 m**	**0.90 m**	**1.41 m**	**1.26 m**	**0.89 m**
Coal	0.53 m	0.64 m	0.68 m	0.50 m	0.52 m	0.52 m	0.41 m	0.39 m	0.29 m
Gas, oil and diesel	0.04 m	0.04 m	0.03 m	0.04 m	0.04 m	0.03 m	0.05 m	0.04 m	0.03 m
Nuclear	0.02 m	0.01 m	0.01 m	0.01 m	0.00 m	0.00 m	0.01 m	0.00 m	0.00 m
Renewables	0.11 m	0.14 m	0.09 m	0.47 m	0.45 m	0.35 m	0.95 m	0.83 m	0.57 m
Total Jobs	**0.71 m**	**0.83 m**	**0.81 m**	**1.01 m**	**1.02 m**	**0.90 m**	**1.41 m**	**1.26 m**	**0.89 m**

india: transport

India's car market is projected to grow by a factor of 16 from 2000 to 2050. The market is characterised by small cars (70%), a proportion which is maintained up to 2050. Although India will remain a low price car market for some time, the key to efficiency is through electrified power trains, hybrid, plug-in and battery electric vehicles. Stringent energy efficiency measures will also limit the growth of transport energy demand by 2050 to about a factor of 5 compared to 2007.

By 2030, electricity will provide 14% of the transport sector's total energy demand under the Energy [R]evolution scenario, while in the advanced version the share will already reach 18% in 2030 and 49% by 2050.

figure 6.74: india: transport under 3 scenarios

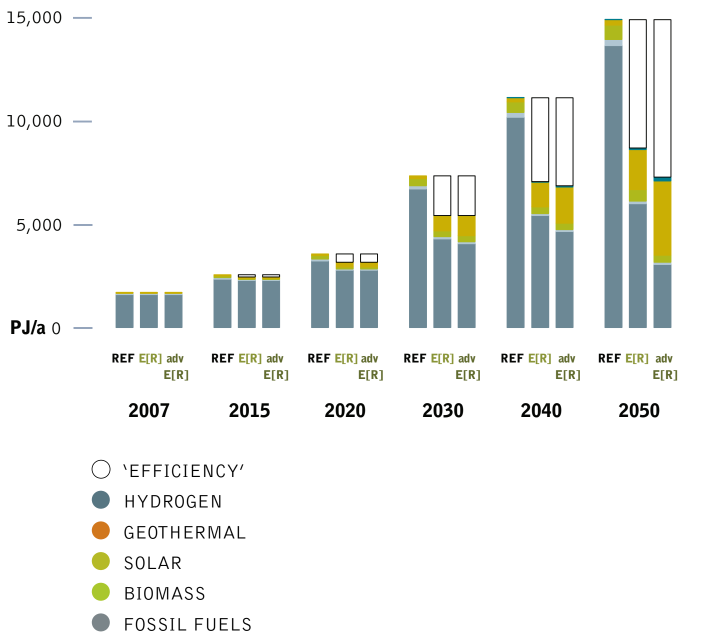


image NANLINIKANT BISWAS, FARMER AGE 43. FIFTEEN YEARS AGO NANLINIKANT'S FAMILY ONCE LIVED WHERE THE SEA IS NOW. THEY WERE AFFLUENT AND OWNED 4 ACRES OF LAND. BUT RISING SEAWATER INCREASED THE SALINITY OF THE SOIL UNTIL THEY COULD NO LONGER CULTIVATE IT, KANHAPUR, ORISSA, INDIA.

image A SOLAR DISH WHICH IS ON TOP OF THE SOLAR KITCHEN AT AUROVILLE, TAMIL NADU, INDIA.

india: development of CO_2 emissions

Whilst India's emissions of CO_2 will almost triple under the Reference scenario, under the Energy [R]evolution scenario they will increase from 1,307 million tonnes in 2007 to 1,620 mt in 2050. Annual per capita emissions will drop from 1.1 t to 1 t.

The advanced Energy [R]evolution scenario will shift the peak of energy related CO_2 emissions to more than 10 years earlier than in the basic version, leading to 0.9 t per capita by 2030 and 0.3 t by 2050. By 2050, India´s CO_2 emissions will be 85% of 1990 levels.

india: primary energy consumption

Taking into account the assumptions discussed above, the resulting primary energy consumption under the Energy [R]evolution scenario is shown in Figure 6.76. Compared to the Reference Scenario, overall energy demand will be reduced by 34% in 2050. Around 49% of the remaining demand will be covered by renewable energy sources.

The advanced scenario phases out coal and oil about 10 to 15 years faster than the Energy [R]evolution scenario. Main reasons for this is a replacement of new coal power plants with renewables after 20 years rather than 40 years lifetime in the Energy [R]evolution scenario and a faster introduction of electric vehicles in the transport sector to replace oil combustion engines. This leads to a renewable energy share of 49% in 2030 and 78% in 2050. Nuclear energy is phased out in both Energy [R]evolution scenarios just after 2030.

figure 6.75: india: development of CO_2 emissions by sector under both energy [r]evolution scenarios

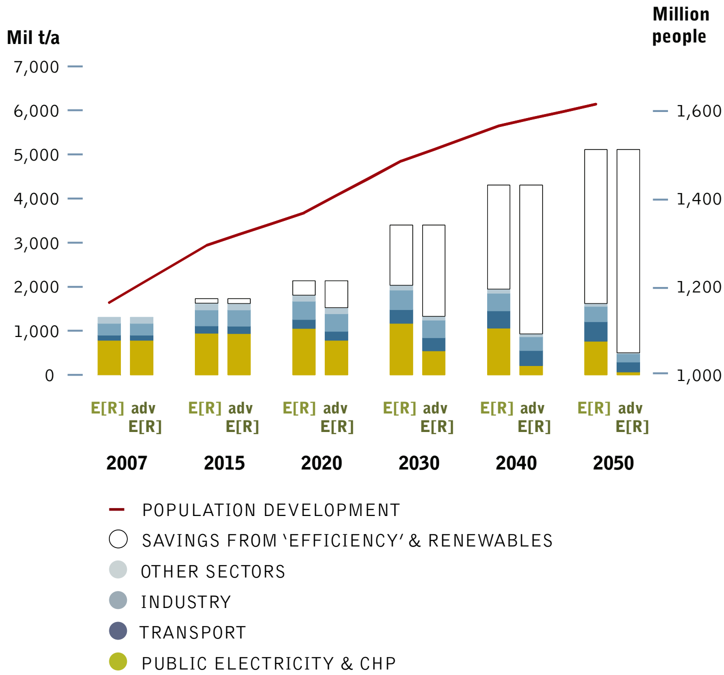
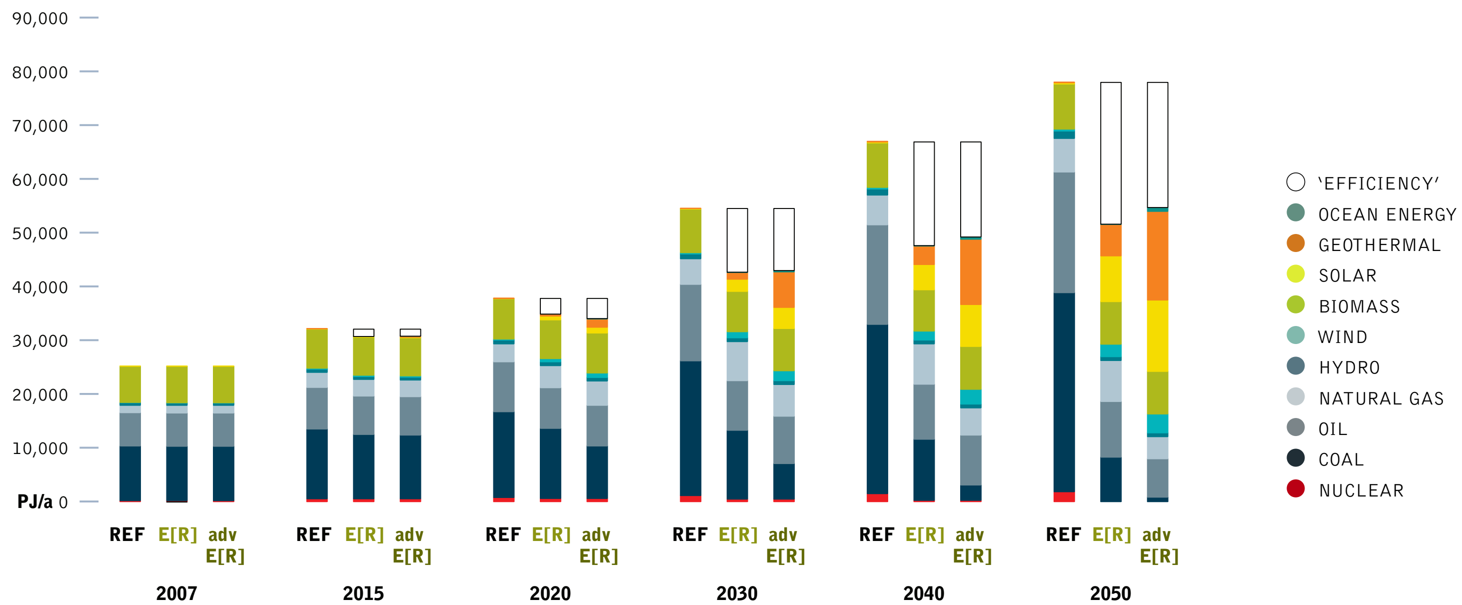


figure 6.76: india: development of primary energy consumption under three scenarios



developing asia

developing asia: energy demand by sector

The future development pathways for the Developing Asia region's primary energy demand are shown in Figure 6.77 for both the Reference and Energy [R]evolution scenarios. Under the Reference scenario, total energy demand more than doubles from the current 31,880 PJ/a to 69,171 PJ/a in 2050. In the Energy [R]evolution scenario, a much smaller 34% increase in consumption is expected by 2050, reaching 42,611 PJ/a. The advanced Energy [R]evolution scenario projects a demand of 40,549PJ/a by 2050 and is therefore roughly at the same level.

Under the Energy [R]evolution scenario, electricity demand is expected to increase disproportionately in Developing Asia (see Figure 6.78). With the introduction of serious efficiency measures in the industry, residential and service sectors, however, an even higher increase can be avoided, leading to electricity demand of around 2,171 TWh/a in 2050. Compared to the Reference scenario, efficiency measures avoid the generation of about 1,329 TWh/a. The advanced Energy [R]evolution scenario introduces electric vehicles earlier while more journeys – for both freight and passengers - are shifted to electric trains and public transport. Fossil fuels for industrial process heat generation are also phased out more quickly and replaced by electric geothermal heat pumps and hydrogen. This means that electricity demand in the advanced version is higher, and reaches 3,548 TWh/a in 2050, still 5% below the Reference case.

Efficiency gains in the heat supply sector are also significant (see Figure 6.79). Compared to the Reference scenario, consumption equivalent to 3,566 PJ/a is avoided through efficiency measures by 2050.

In the transport sector, it is assumed under the Energy [R]evolution scenario that energy demand will rise to 8,016 PJ/a by 2050, saving 43% compared to the Reference scenario. As this is a developing region it has a relatively low starting point for transport energy demand. In the advanced Energy [R]evolution scenario transport demand has therefore not been reduced (in terms of kilometres per person and freight volume) any further than in the basic version. Due to a wider use of more efficient electric drives, however, electricity demand increases but the overall final energy demand falls to 6,416 PJ/a, 54% lower than in the Reference case.

figure 6.77: developing asia: projection of total final energy demand by sector (REF, E[R] & advanced E[R])

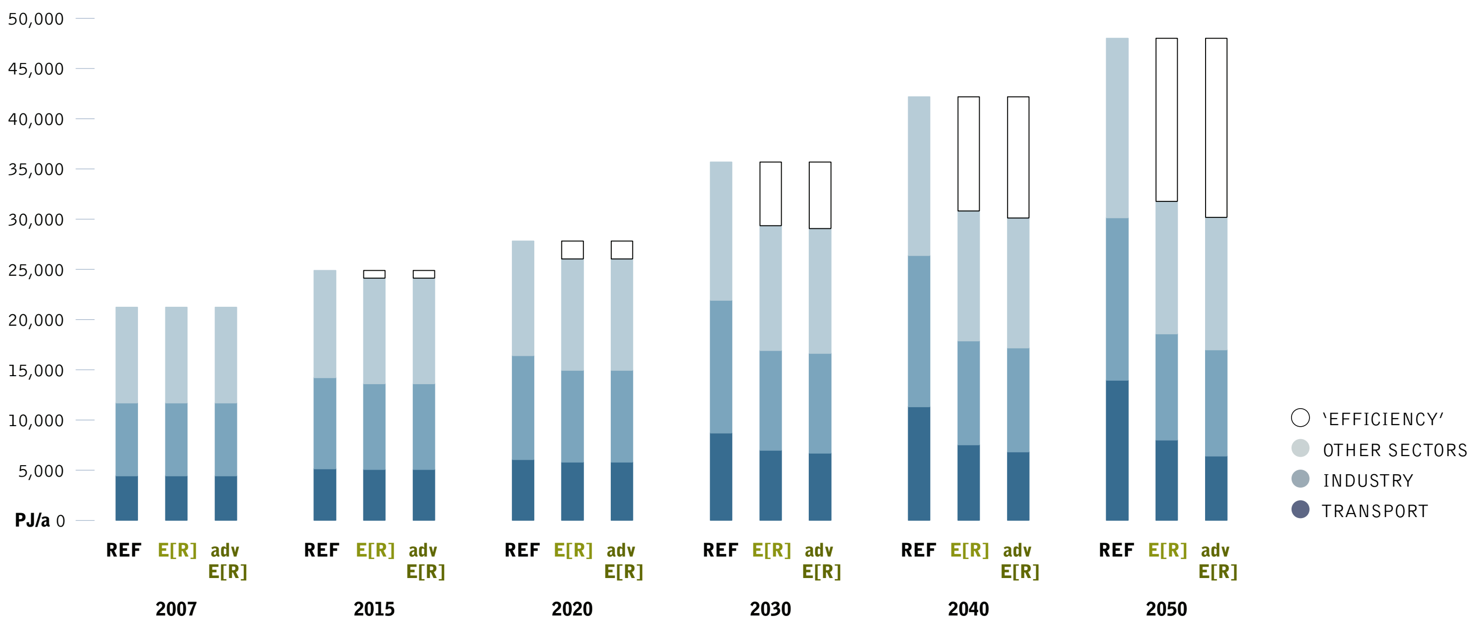
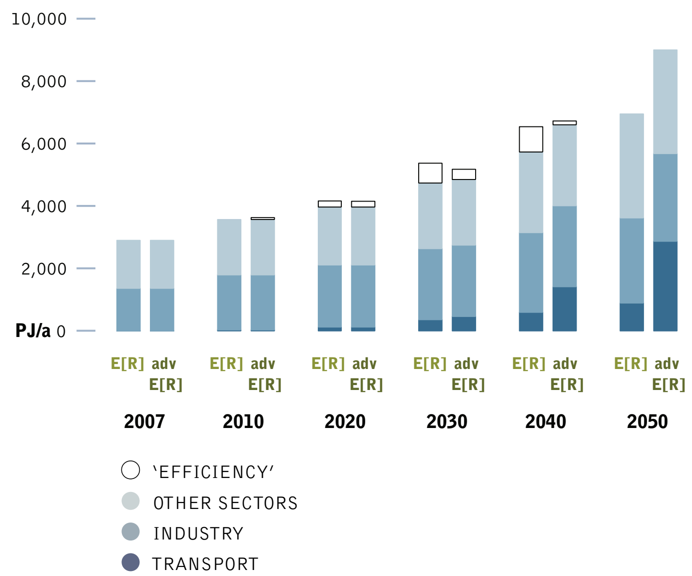


image A WOMAN PREPARING FOOD IN THE PHILIPPINES.

image AMIDST SCORCHING HEAT, AN ELDERLY FISHERWOMAN GATHERS SHELLS IN LAM TAKONG DAM, WHERE WATERS HAVE DRIED UP DUE TO PROLONGED DROUGHT. GREENPEACE LINKS RISING GLOBAL TEMPERATURES AND CLIMATE CHANGE TO THE ONSET OF ONE OF THE WORST DROUGHTS TO HAVE STRUCK THAILAND, CAMBODIA,VIETNAM AND INDONESIA IN RECENT MEMORY. SEVERE WATER SHORTAGE AND DAMAGE TO AGRICULTURE HAS AFFECTED MILLIONS.

figure 6.78: developing asia: development of electricity demand by sector (REF, E[R] & advanced E[R])



developing asia: heating and cooling supply

Today, renewables provide around 49% of primary energy demand for heat and cooling supply in Other Developing Asia, the main contribution coming from the use of biomass. The availability of less efficient but cheap appliances is a severe structural barrier to efficiency gains. Large-scale utilisation of geothermal and solar thermal energy for heat supply will be largely restricted to the industrial sector.

In the Energy [R]evolution scenario renewables provide 72% of Other Developing Asia's total heating and cooling demand by 2050.

- Energy efficiency measures can restrict the future primary energy demand for heat and cooling supply to a 45% increase, in spite of improving living standards.
- In the industry sector solar collectors, biomass/biogas as well as geothermal energy are increasingly replacing conventional fossil-fuelled heating systems.
- A shift from coal and oil to natural gas in the remaining conventional applications leads to a further reduction of CO_2 emissions.

In the Energy [R]evolution scenario 3,566 PJ/a is saved by 2050, or 19% compared to the Reference scenario. The advanced version introduces renewable heating systems around five years ahead of the basic scenario. Solar collectors and geothermal heating systems achieve economies of scale via ambitious support programmes five to ten years earlier, resulting in a renewables share of 58% by 2030 and 85% by 2050.

figure 6.79: developing asia: development of heat demand by sector

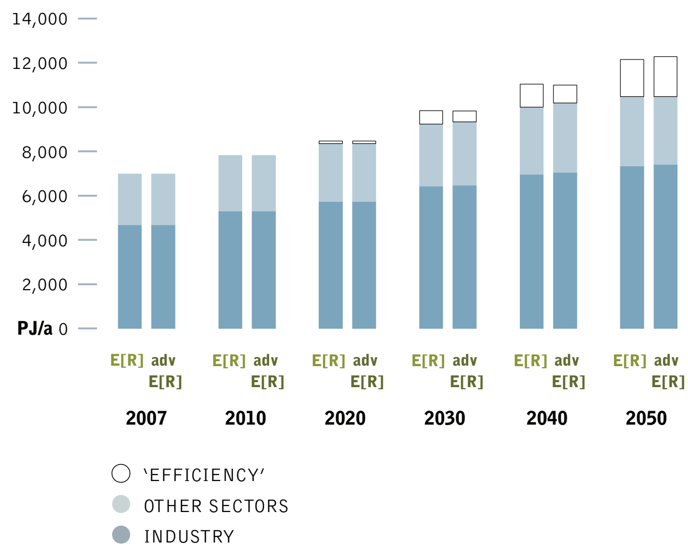
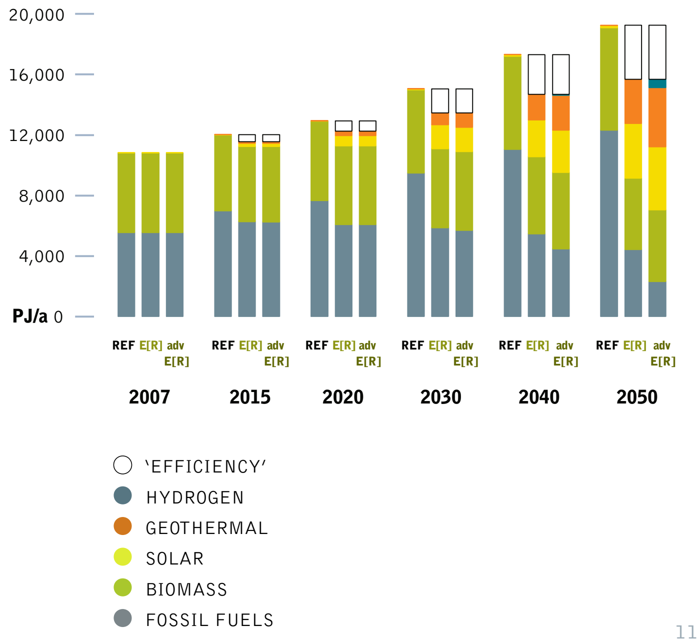


figure 6.80: developing asia: development of heat supply structure under 3 scenarios



developing asia

developing asia: electricity generation

The development of the electricity supply sector is characterised by an increasing share of renewable electricity. By 2050, 74% of the electricity produced in Other Developing Asia will come from renewable energy sources. 'New' renewables – mainly wind, solar thermal energy and PV – will contribute more than 57% of electricity generation. The installed capacity of renewable energy technologies will grow from the current 48 GW to 616 GW in 2050, increasing renewable capacity by a factor of 13 within the next 40 years.

Figure 6.81 shows the comparative evolution of the different renewable technologies over time. Up to 2020, hydro power and wind will remain the main contributors to the growing market share. After 2020, the continuing growth of wind will be complemented by electricity from biomass, photovoltaics and solar thermal (CSP) energy.

The advanced Energy [R]evolution scenario projects a faster market development pathway, with higher annual growth rates achieving a renewable electricity share of 59% by 2030 and 94% by 2050. The installed capacity of renewables will reach 363 GW in 2030 and 1,037 GW by 2050, 68% higher than in the basic version.

None of these numbers - even in the advanced Energy [R]evolution scenario - utilise the maximum known technical potential of all the renewable resources. While the deployment rate compared to the technical potential for hydro power, for example, is relatively high at 20% in the advanced Energy [R]evolution scenario, for photovoltaic less than 3% has been used in the advanced scenario.

table 6.17: developing asia: projection of renewable electricity generation capacity under both Energy [R]evolution scenarios

IN GW

		2007	2020	2030	2040	2050
Hydro	E[R]	44	71	81	89	96
	advanced E[R]	44	71	81	89	96
Biomass	E[R]	1	6	12	17	22
	advanced E[R]	1	6	11	14	17
Wind	E[R]	0	33	103	178	201
	advanced E[R]	0	35	130	213	291
Geothermal	E[R]	3	7	13	20	26
	advanced E[R]	3	7	26	50	63
PV	E[R]	0	11	59	142	231
	advanced E[R]	0	13	79	172	414
CSP	E[R]	0	4	8	17	30
	advanced E[R]	0	5	20	49	92
Ocean energy	E[R]	0	1	3	5	10
	advanced E[R]	0	2	16	33	64
Total	**E[R]**	**48**	**133**	**278**	**468**	**616**
	advanced E[R]	**48**	**140**	**363**	**620**	**1,038**

figure 6.81: developing asia: development of electricity generation structure under 3 scenarios

(REFERENCE, ENERGY [R]EVOLUTION AND ADVANCED ENERGY [R]EVOLUTION) ["EFFICIENCY" = REDUCTION COMPARED TO THE REFERENCE SCENARIO]

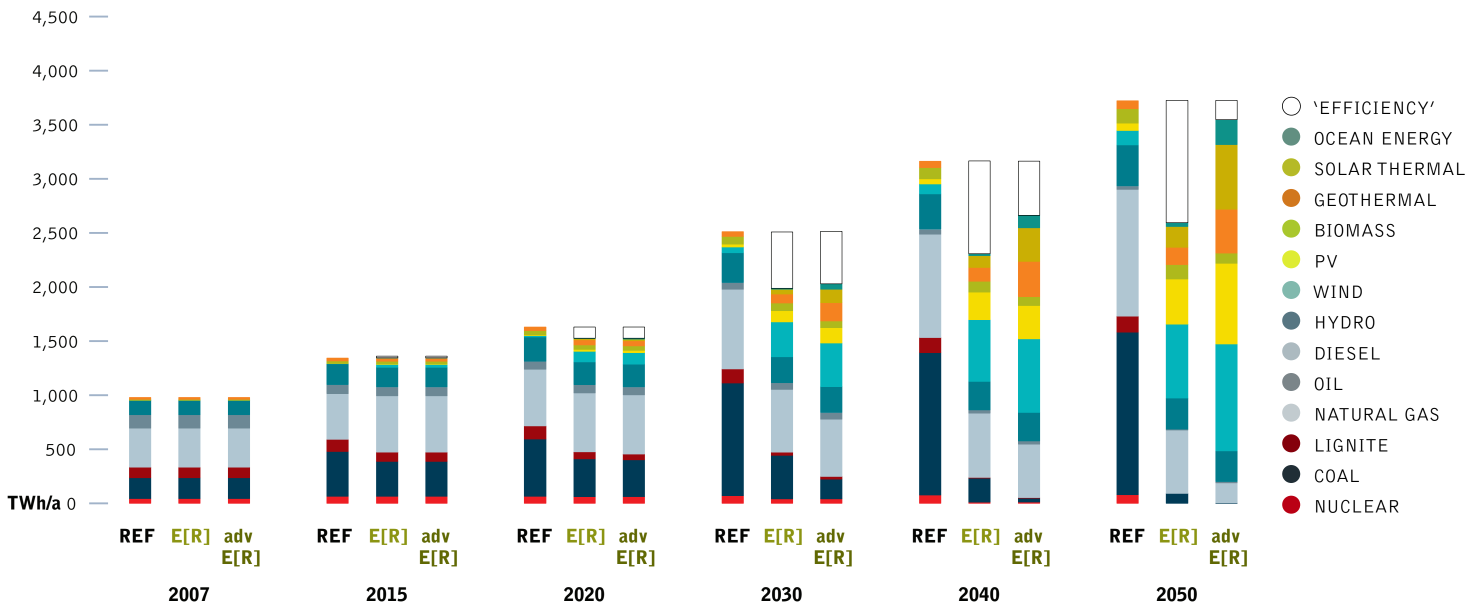


image GREENPEACE DONATES A SOLAR POWER SYSTEM TO A COASTAL VILLAGE IN ACEH, INDONESIA, ONE OF THE WORST HIT AREAS BY THE TSUNAMI IN DECEMBER 2004. IN COOPERATION WITH UPLINK, A LOCAL DEVELOPMENT NGO, GREENPEACE OFFERED ITS EXPERTISE ON ENERGY EFFICIENCY AND RENEWABLE ENERGY AND INSTALLED RENEWABLE ENERGY GENERATORS FOR ONE OF THE BADLY HIT VILLAGES BY THE TSUNAMI.

image A WOMAN GATHERS FIREWOOD ON THE SHORES CLOSE TO THE WIND FARM OF ILOCOS NORTE, AROUND 500 KILOMETERS NORTH OF MANILA.

developing asia: future costs of electricity generation

Figure 6.82 shows that the introduction of renewable technologies under the Energy [R]evolution scenario significantly decreases the future costs of electricity generation compared to the Reference scenario. Because of the lower CO_2 intensity of electricity generation, costs will become economically favourable under the Energy [R]evolution scenario and by 2050 will be more than 6 cents/kWh below those in the Reference scenario.

Under the Reference scenario, on the other hand, unchecked growth in demand, an increase in fossil fuel prices and the cost of CO_2 emissions result in total electricity supply costs rising from today's $100 billion per year to more than $612 billion in 2050. Figure 6.82 shows that the Energy [R]evolution scenario not only complies with Other Developing Asia's CO_2 reduction targets but also helps to stabilise energy costs and relieve the economic pressure on society. Increasing energy efficiency and shifting energy supply to renewables leads to long term costs for electricity supply that are one third lower than in the Reference scenario.

The advanced Energy [R]evolution scenario will lead to a higher proportion of variable power generation sources (PV, wind and ocean power), accounting for 29% by 2030. Expansion in the use of smart grids, demand side management and storage capacity through an increased share of electric vehicles will therefore be introduced to ensure better grid integration and power generation management.

In both Energy [R]evolution scenarios the specific generation costs are almost the same up to 2050. Despite the increased demand for electricity, especially in the transport and industry sectors, the overall supply costs in the advanced version are $8 billion lower in 2030 and $24 billion lower in 2050 than in the basic Energy [R]evolution scenario.

developing asia: job results

The Energy [R]evolution scenarios lead to more energy sector jobs in Developing Asia at every stage of the projection.

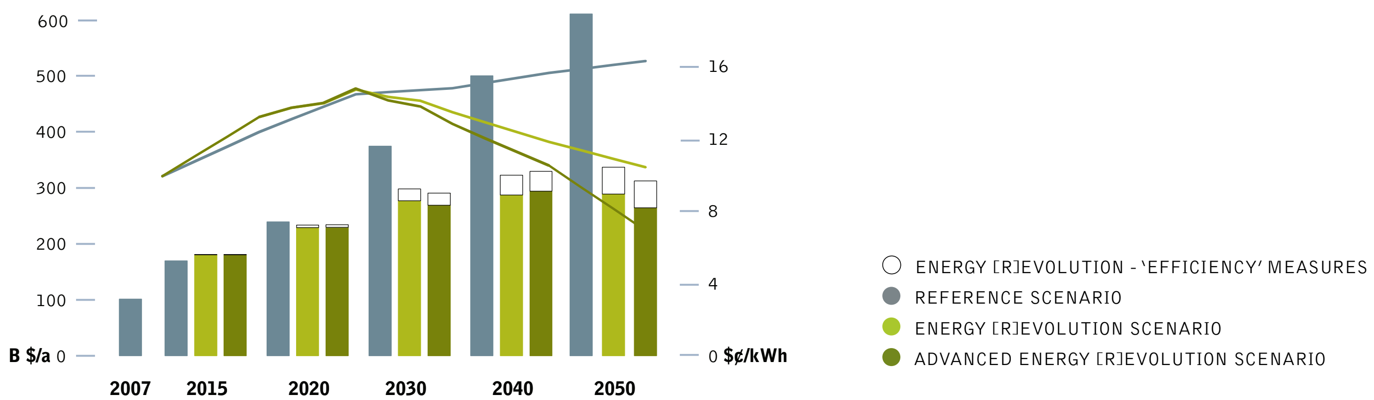
• There are around 650,000 power sector jobs in both Energy [R]evolution scenarios by 2015, compared to 610,000 in the Reference scenario.

• By 2020, job numbers in the renewables industry reach over 700,000 in the Energy [R]evolution scenario (780,000 in the advanced version), half a million more than in the Reference scenario.

• By 2030 job numbers in the renewables industry remain in both Energy [R]evolution scenario at 2020 levels. The slightly higher employment numbers in the reference scenario is due to the projected coal export. Those exports will not be possible, if other world regions will implement an energy revolution.

Table 6.18 shows the increase in job numbers under both Energy [R]evolution scenarios for each technology up to 2020 and up to 2030. Both scenarios show losses in coal generation, but these are outweighed by employment growth in renewable technologies and gas. Solar technologies show particularly strong growth in the both Energy [R]evolution scenarios by 2020, but by 2030 there is significant employment across a range of renewable technologies.

figure 6.82: developing asia: development of total electricity supply costs & development of specific electricity generation costs under 3 scenarios



developing asia

table 6.18: developing asia: employment & investment

	REFERENCE			ENERGY [R]EVOLUTION			ADVANCED ENERGY [R]EVOLUTION		
Jobs	2015	2020	2030	2015	2020	2030	2015	2020	2030
Construction & installation	0.13 m	0.17 m	0.08 m	0.15 m	0.20 m	0.13 m	0.17 m	0.27 m	0.17 m
Manufacturing	0.02 m	0.04 m	0.02 m	0.05 m	0.08 m	0.08 m	0.05 m	0.11 m	0.10 m
Operations & maintenance	0.09 m	0.10 m	0.12 m	0.10 m	0.12 m	0.15 m	0.10 m	0.12 m	0.16 m
Fuel	0.38 m	0.39 m	0.48 m	0.35 m	0.30 m	0.24 m	0.33 m	0.28 m	0.17 m
Total Jobs	**0.61 m**	**0.70 m**	**0.70 m**	**0.65 m**	**0.70 m**	**0.60 m**	**0.66 m**	**0.78 m**	**0.59 m**
Coal	0.32 m	0.39 m	0.45 m	0.21 m	0.18 m	0.15 m	0.20 m	0.15 m	0.08 m
Gas, oil and diesel	0.15 m	0.13 m	0.09 m	0.17 m	0.15 m	0.10 m	0.17 m	0.14 m	0.09 m
Nuclear	0.01 m	0.01 m	0.01 m	0.01 m	0.00 m	0.00 m	0.01 m	0.00 m	0.00 m
Renewables	0.14 m	0.17 m	0.15 m	0.26 m	0.36 m	0.35 m	0.29 m	0.48 m	0.42 m
Total Jobs	**0.61 m**	**0.70 m**	**0.70 m**	**0.65 m**	**0.70 m**	**0.60 m**	**0.66 m**	**0.78 m**	**0.59 m**

developing asia: transport

Despite a huge growth in transport services, the increase in energy consumption in the transport sector by 2050 can be limited to 57% under the Energy [R]evolution scenario and 46% in the advanced case. Dependence on fossil fuels for 90% of this supply is transformed by using 7% biofuels and 11% electricity in the basic version. The advanced Energy [R]evolution scenario increases the share of electricity in the transport sector up to 45%, while the use of biofuels/biomass has been reduced and shifted towards the power sector and industrial heat processes.

Both Energy [R]evolution scenarios assume measures to change the current pattern of car sales, with one third in future taken up by medium-sized vehicles and more than half by small vehicles. Technical progress increases the share of hybrid vehicles significantly. Incentives to use more efficient transport modes reduce vehicle kilometres travelled to an average of 11,000 km per annum.

figure 6.83: developing asia: transport under 3 scenarios

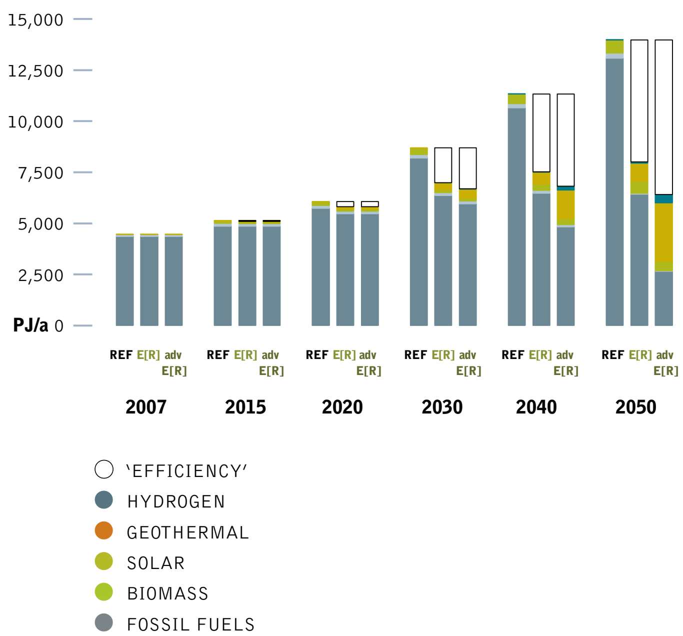


image MAJESTIC VIEW OF THE WIND FARM IN ILOCOS NORTE, AROUND 500 KILOMETRES NORTH OF MANILA. THE 25 MEGAWATT WIND FARM, OWNED AND OPERATED BY DANISH FIRM NORTHWIND, IS THE FIRST OF ITS KIND IN SOUTHEAST ASIA.

image A MAN WORKING IN A RICE FIELD IN THE PHILIPPINES.

developing asia: development of CO_2 emissions

Whilst Other Developing Asia's emissions of CO_2 will increase by 158% under the Reference scenario, under the Energy [R]evolution scenario they will decrease from 1,488 million tonnes in 2007 to 1,085 mt in 2050. Annual per capita emissions will drop from 1.5 t to 0.7 t. The advanced Energy [R]evolution scenario will induce a faster reduction of energy related CO_2 emissions than in the basic version, leading to 1.1 t per capita by 2030 - 10 years earlier than in the basis version and 0.3 t by 2050. By 2050, Other Developing Asia's CO_2 emissions are 62% of 1990 levels.

In spite of the phasing out of nuclear energy and increasing demand in the Energy [R]evolution scenario, CO_2 emissions will decrease in the electricity sector. In the long run efficiency gains and the increased use of renewable electricity in vehicles will even reduce CO_2 emissions in the transport sector. With a share of 55% of total CO_2 in 2050, the transport sector will remain the largest source of emissions.

developing asia: primary energy consumption

Taking into account the assumptions discussed above, the resulting primary energy consumption under the Energy [R]evolution scenario is shown in Figure 6.85. Compared to the Reference scenario, overall energy demand in the Energy [R]evolution scenario will be reduced by 38% in 2050. Around 51% of the remaining demand will be covered by renewable energy sources. Under the advanced Energy [R]evolution scenario a share of around 73% of the remaining energy demand will be covered by renewable sources.

figure 6.84: developing asia: development of CO_2 emissions by sector under both energy [r]evolution scenarios

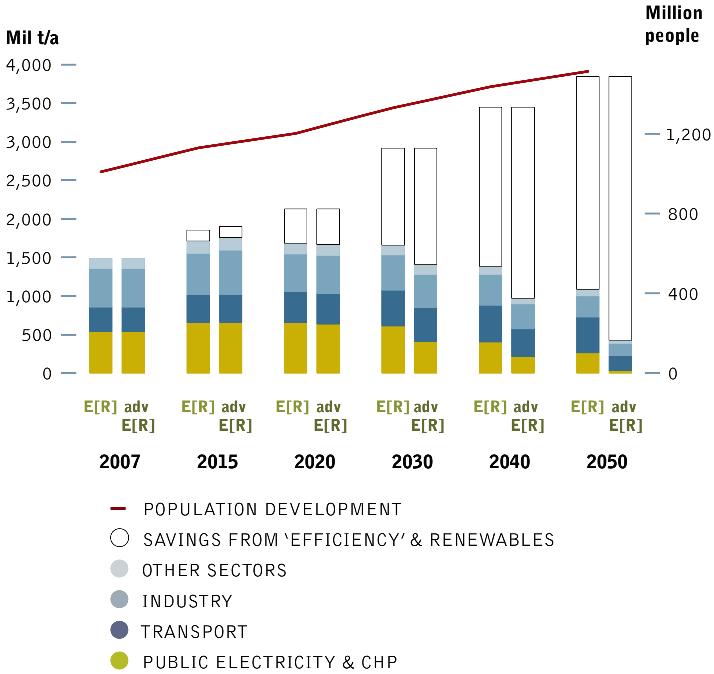
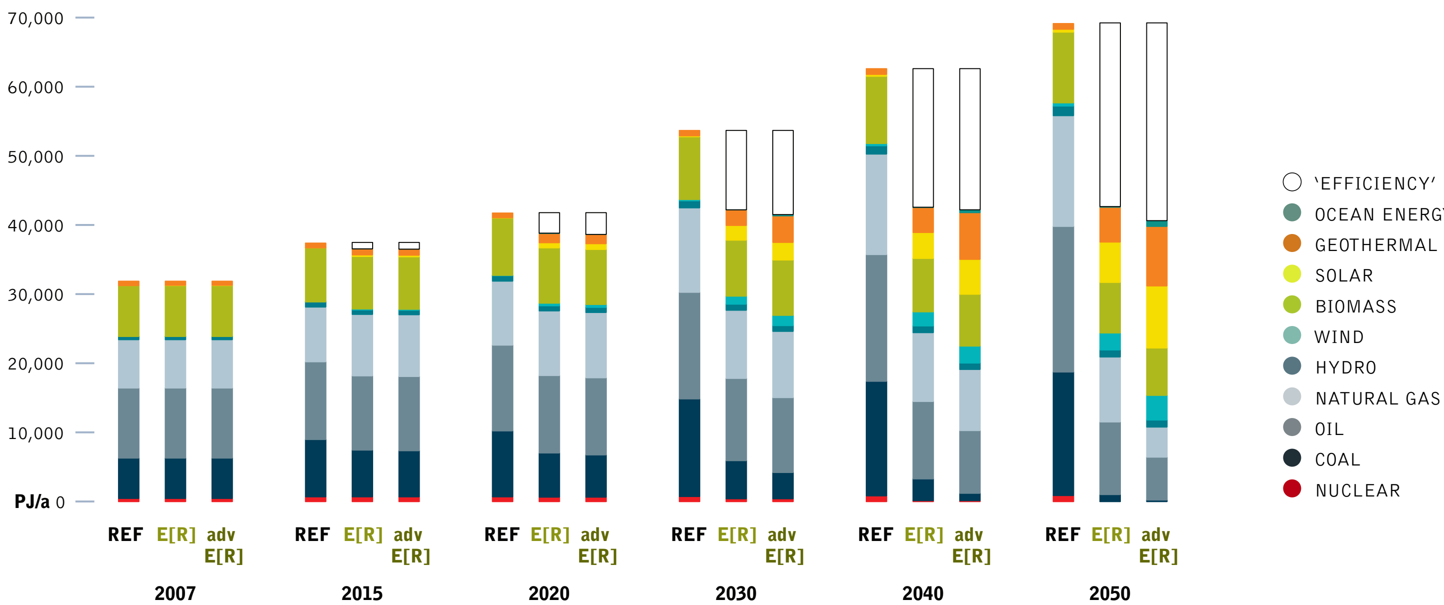


figure 6.85: developing asia: development of primary energy consumption under three scenarios



china

GLOBAL SCENARIO | OECD NORTH AMERICA | LATIN AMERICA | OECD EUROPE | AFRICA | MIDDLE EAST | TRANSITION ECONOMIES | INDIA | DEVELOPING ASIA | **CHINA** | OECD PACIFIC

china: energy demand by sector

The future development pathways for China's final energy demand are shown in Figure 6.86 for both the Reference and Energy [R]evolution scenarios. Under the Reference scenario, total primary energy demand increases by a factor of 2.2 from the current 83,922 PJ/a to 183,886 PJ/a in 2050. In the Energy [R]evolution scenario, primary energy demand increases up to 2020 by 39% and then decreases to a level of 100,191 PJ/a in 2050. The advanced Energy [R]evolution scenario envisages a demand of 107,104 PJ/a by 2050 and is therefore roughly at the same level.

Under the Energy [R]evolution scenario, electricity demand is expected to increase disproportionately (see Figure 6.87). With the exploitation of efficiency measures, however, an even higher increase can be avoided, leading to electricity demand of around 7,693 TWh/a in the year 2050. Compared to the Reference scenario, efficiency measures in industry and other sectors avoid the generation of about 3,562 TWh/a. The advanced Energy [R]evolution scenario introduces electric vehicles earlier while more journeys – for both freight and passengers - are shifted to electric trains and public transport. Fossil fuels for industrial process heat generation are also phased out more quickly and replaced by electric geothermal heat pumps and hydrogen. This means that electricity demand in the advanced version is higher, and reaches 8,748 TWh/a in 2050.

Efficiency gains in the heat supply sector are also large. Compared to the Reference scenario, consumption equivalent to 12,778 PJ/a is avoided through efficiency measures by 2050 under the Energy [R]evolution scenario.

In the transport sector it is assumed under the Energy [R]evolution scenario that energy demand will increase considerably, from 5,882 PJ/a in 2007 to 17,096 PJ/a by 2050. However this still saves 50% compared to the Reference scenario. By 2030 electricity will provide 13% of the transport sector's total energy demand in the Energy [R]evolution scenario, while in the advanced version the share will already reach 19% in 2030 and 54% by 2050. The advanced scenario assumes no further transport demand reduction (passenger kilometres or freight) than in the basic version.

figure 6.86: china: projection of total final energy demand by sector (REF, E[R] & advanced E[R])

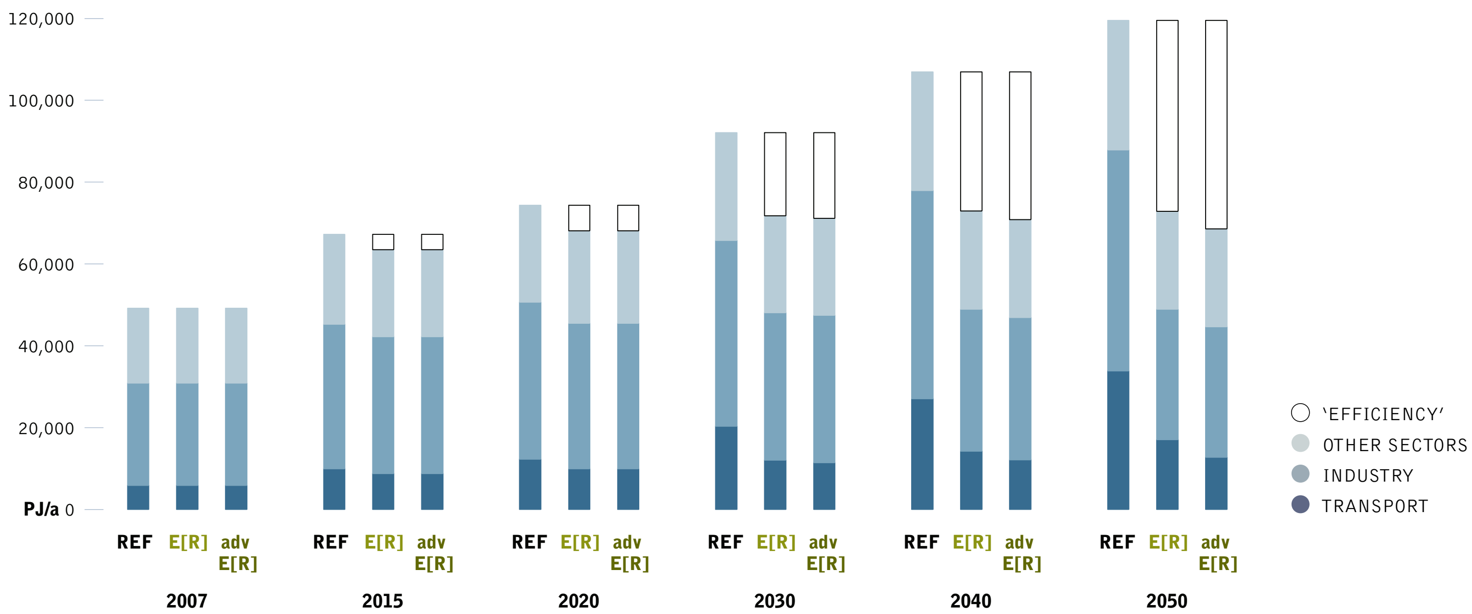


image WANG WAN YI, AGE 76, AND LINANG JUN QIN, AGE 72, EAT NOODLES IN THEIR ONE ROOM HOME CARVED OUT OF THE SANDSTONE, A TYPICAL DWELLING FOR LOCAL PEOPLE IN THE REGION. DROUGHT IS ONE OF THE MOST HARMFUL NATURAL HAZARDS IN NORTHWEST CHINA. CLIMATE CHANGE HAS A SIGNIFICANT IMPACT ON CHINA'S ENVIRONMENT AND ECONOMY.

image image THE BLADES OF A WINDMILL SIT ON THE GROUND WAITING FOR INSTALLATION AT GUAZHOU WIND FARM NEAR YUMEN IN GANSU PROVINCE.

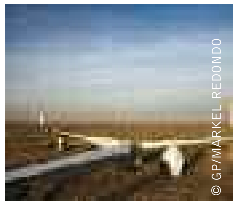
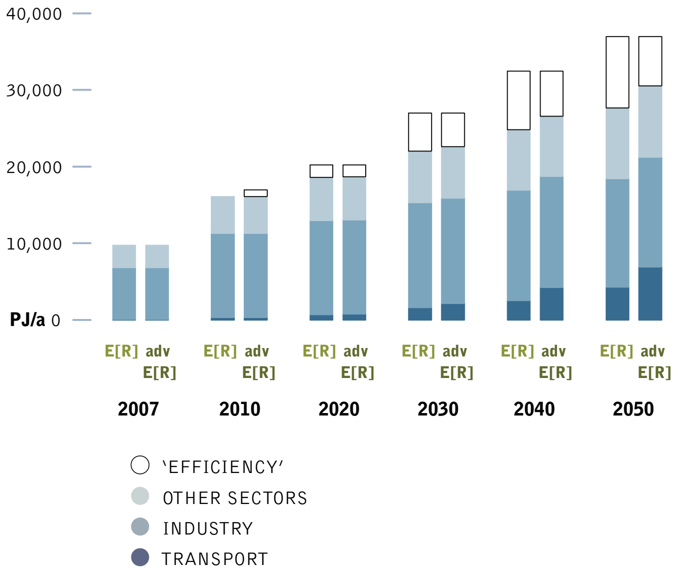


figure 6.87: china: development of electricity demand by sector (REF, E[R] & advanced E[R])



china: heating and cooling supply

Today, renewables provide 24% of energy demand for heat and cooling supply in China, the main contribution coming from the use of biomass. In the Energy [R]evolution scenario, renewables provide 65% of China's total heating and cooling demand by 2050.

- Energy efficiency measures will restrict the future energy demand for heat and cooling supply in 2050 to an increase of 12%, compared to 58% in the Reference scenario, in spite of improving living standards.
- In the industry sector solar collectors, biomass/biogas as well as geothermal energy are increasingly substituted for conventional fossil-fired heating systems.
- A shift from coal and oil to natural gas in the remaining conventional applications leads to a further reduction of CO_2 emissions.

In the Energy [R]evolution scenario efficiency measures save 12,459 PJ/a by 2050, or 29% compared to the Reference scenario. The advanced Energy [R]evolution version introduces renewable heating and cooling systems around five years ahead of the basic scenario. China can use concentrated solar energy to generate heat for industrial processes in its north western provinces. Efficient use of heating and architecture which avoids the need for air conditioning can reduce the overall demand. Solar collectors and geothermal heating systems achieve economies of scale via ambitious support programmes five to ten years earlier, resulting in a renewables share of 33% by 2030 and 87% by 2050.

figure 6.88: china: development of heat demand by sector

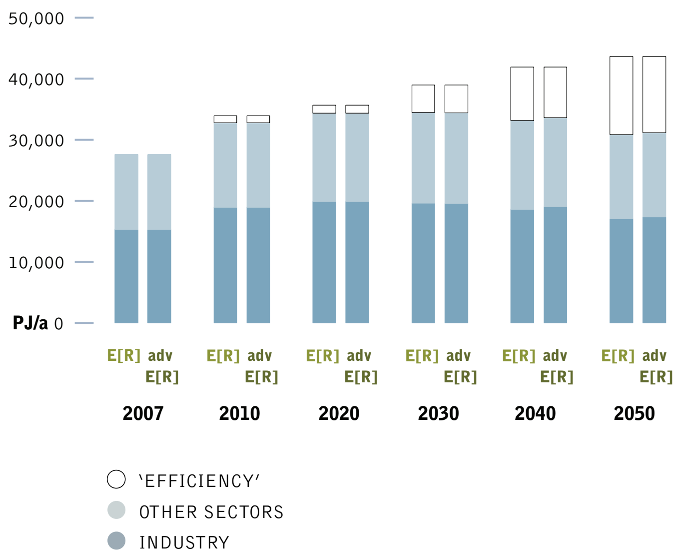
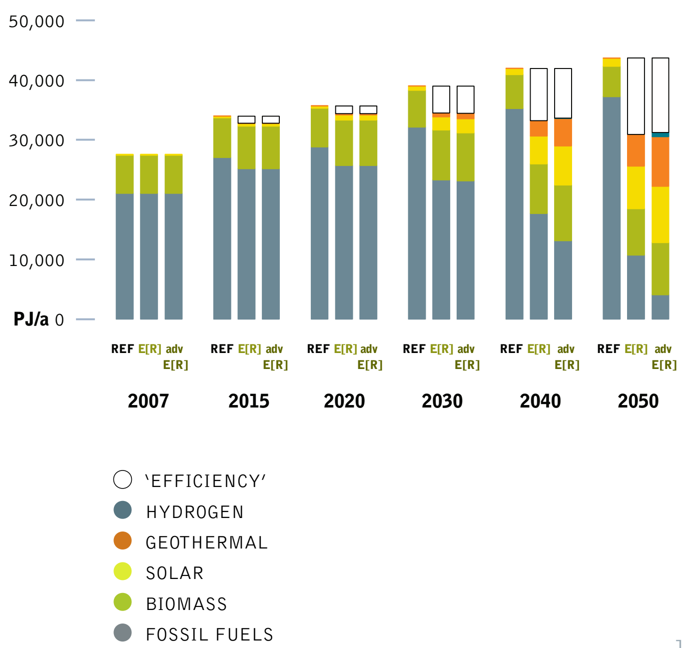


figure 6.89: china: development of heat supply structure under 3 scenarios



china

GLOBAL SCENARIO

OECD NORTH AMERICA
LATIN AMERICA
OECD EUROPE
AFRICA

MIDDLE EAST
TRANSITION ECONOMIES
INDIA

OTHER DEVELOPING ASIA
CHINA
OECD PACIFIC

china : electricity generation

A dynamically growing renewable energy market will compensate for the phasing out of nuclear energy and reduce the number of fossil fuel-fired power plants required for grid stabilisation. By 2050, 65% of the electricity produced in China will come from renewable energy sources. 'New' renewables – mainly wind, solar thermal energy and PV – will contribute 39% of electricity generation. The installed capacity of renewable energy technologies will grow from the current 152 GW to 1,721 GW in 2050, an enormous increase. There will be a considerable demand for investment in new production capacity over the next 20 years.

The advanced Energy [R]evolution scenario projects a faster market development pathway, with higher annual growth rates achieving a renewable electricity share of 46% by 2030 and 90% by 2050. The installed capacity of renewables will reach 1,138 GW in 2030 and 2,610 GW by 2050, 52% higher than in the basic version.

Table 6.19 shows the comparative evolution of the different renewable technologies over time. Up to 2020, hydro power and wind will remain the main contributors to the growing market share. After 2020, the continuing growth of wind will be complemented by electricity from biomass, photovoltaic and solar thermal energy.

While the advanced scenario uses 11% of the known technical potential for CSP power and only 6% of the solar photovoltaic potential, a greater contribution is expected from hydro and wind power. The total installed capacity of wind power by 2050 in the advanced version is 703 GW, significantly higher than in the basic scenario. A new analysis by M.B.McElroy et all (Science, Vol 325, page 1380, September 2009), however, has shown that China's wind potential could reach 640 GW by 2030, enough to cover the country's current electricity demand three times over.

table 6.19: china: projection of renewable electricity generation capacity under both Energy [R]evolution scenarios

IN GW

		2007	2020	2030	2040	2050
Hydro	E[R]	145	256	317	369	397
	advanced E[R]	145	256	317	369	397
Biomass	E[R]	1	16	36	67	96
	advanced E[R]	1	16	37	68	90
Wind	E[R]	6	163	403	516	541
	advanced E[R]	6	196	513	651	703
Geothermal	E[R]	0	1	3	10	25
	advanced E[R]	0	1	21	66	147
PV	E[R]	0	11	103	221	432
	advanced E[R]	0	22	155	586	803
CSP	E[R]	0	9	37	98	155
	advanced E[R]	0	21	84	177	282
Ocean energy	E[R]	0	0	1	19	74
	advanced E[R]	0	1	10	31	189
Total	**E[R]**	**152**	**456**	**899**	**1,300**	**1,721**
	advanced E[R]	**152**	**513**	**1,138**	**1,946**	**2,610**

figure 6.90: china: development of electricity generation structure under 3 scenarios

(REFERENCE, ENERGY [R]EVOLUTION AND ADVANCED ENERGY [R]EVOLUTION) ["EFFICIENCY" = REDUCTION COMPARED TO THE REFERENCE SCENARIO]

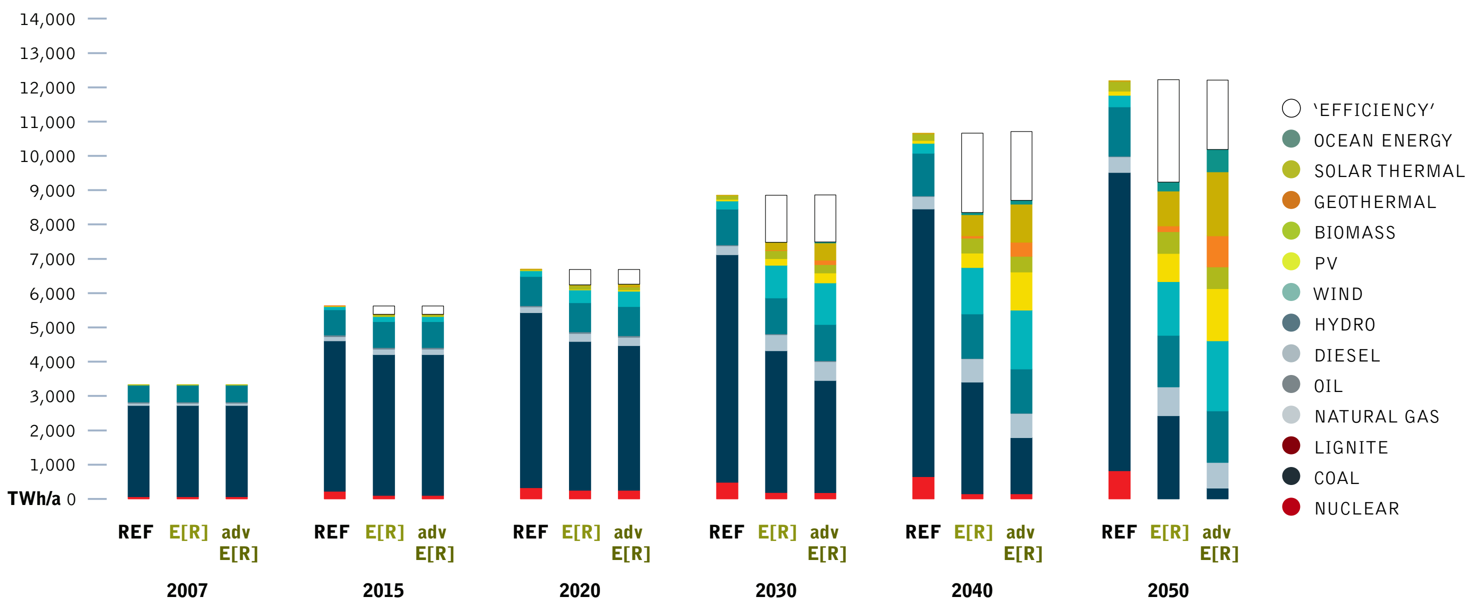


image A WORKER ENTERS A TURBINE TOWER FOR MAINTENANCE AT DABANCHENG WIND FARM. CHINA'S BEST WIND RESOURCES ARE MADE POSSIBLE BY THE NATURAL BREACH IN TIANSHAN (TIAN MOUNTAIN).

image WOMEN WEAR MASKS AS THEY RIDE BIKES TO WORK IN THE POLLUTED TOWN OF LINFEN. LINFEN, A CITY OF ABOUT 4.3 MILLION, IS ONE OF THE MOST POLLUTED CITIES IN THE WORLD. CHINA'S INCREASINGLY POLLUTED ENVIRONMENT IS LARGELY A RESULT OF THE COUNTRY'S RAPID DEVELOPMENT AND CONSEQUENTLY A LARGE INCREASE IN PRIMARY ENERGY CONSUMPTION, WHICH IS ALMOST ENTIRELY PRODUCED BY BURNING COAL.

china : future costs of electricity generation

Figure 6.91 shows that the introduction of renewable technologies under the Energy [R]evolution scenario significantly decreases the future costs of electricity generation compared to the Reference scenario. Because of the lower CO_2 intensity of electricity generation, costs in China will become economically favourable under the Energy [R]evolution scenario and by 2050 will be almost 3 cents/kWh below those in the Reference scenario.

Under the Reference scenario, by contrast, the unchecked growth in demand, increase in fossil fuel prices and the cost of CO_2 emissions result in total electricity supply costs rising from today's $256 billion per year to more than $1,386 billion in 2050. Figure 6.91 shows that the Energy [R]evolution scenario not only complies with China's CO_2 reduction targets but also helps to stabilise energy costs. Increasing energy efficiency and shifting energy supply to renewables lead to long term costs for electricity supply that are significantly lower than in the Reference scenario.

In both Energy [R]evolution scenarios the specific generation costs are almost the same up to 2030. By 2050, however, the advanced version results in a reduction to 7 cents/kWh, mainly because of greater economies of scale in the production of renewable power equipment. Due to the increased demand for electricity, especially in the transport and industry sectors, the overall supply costs in the advanced version are $6,8 billion higher in 2030 than in the basic Energy [R]evolution scenario.

china : job results

The Energy [R]evolution scenarios lead to more energy sector jobs in China at every stage of the projection.

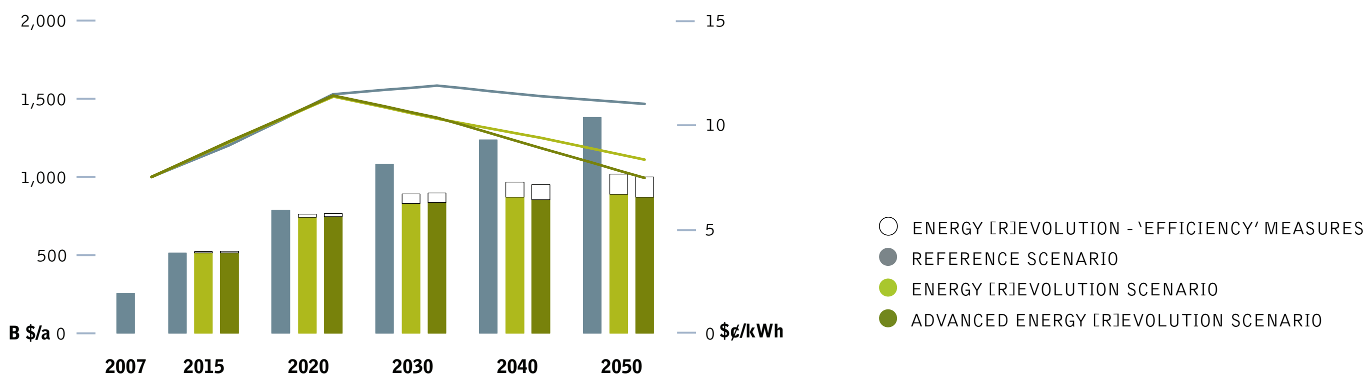
• There are 2.9 million power sector jobs in the Energy [R]evolution scenario and 3.1 million in the advanced version by 2015, compared to 2.7 million in the Reference scenario.

• By 2020 job numbers in the renewables sector reach over one million in the Energy [R]evolution scenario, 870,000 more than in the Reference scenario.

• By 2030 job numbers in both Energy [R]evolution scenarios employ 290,000 people (advanced 620,000) more than in the Reference scenario.

Table 6.20 shows the increase in job numbers under both Energy [R]evolution scenarios for each technology up to 2020 and up to 2030. Both scenarios show losses in coal generation, but these are outweighed by employment growth in renewable technologies and gas. Wind shows particularly strong growth in both Energy [R]evolution scenarios by 2020, but by 2030 there is significant employment across a range of renewable technologies.

figure 6.91: china: development of total electricity supply costs & development of specific electricity generation costs under 3 scenarios



china

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TRANSITION ECONOMIES
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OTHER DEVELOPING ASIA
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OECD PACIFIC

table 6.20: china: employment & investment

	REFERENCE			ENERGY [R]EVOLUTION			ADVANCED ENERGY [R]EVOLUTION		
Jobs	2015	2020	2030	2015	2020	2030	2015	2020	2030
Construction & installation	0.54 m	0.47 m	0.23 m	0.46 m	0.52 m	0.29 m	0.54 m	0.63 m	0.54 m
Manufacturing	0.20 m	0.13 m	0.06 m	0.40 m	0.47 m	0.20 m	0.53 m	0.62 m	0.33 m
Operations & maintenance	0.28 m	0.30 m	0.31 m	0.32 m	0.38 m	0.42 m	0.32 m	0.40 m	0.47 m
Fuel	1.72 m	1.69 m	1.67 m	1.70 m	1.69 m	1.66 m	1.70 m	1.69 m	1.56 m
Total Jobs	**2.74 m**	**2.58 m**	**2.28 m**	**2.89 m**	**3.06 m**	**2.57 m**	**3.10 m**	**3.34 m**	**2.90 m**
Coal	2.19 m	2.13 m	1.93 m	1.98 m	1.87 m	1.74 m	1.92 m	1.80 m	1.56 m
Gas, oil and diesel	0.04 m	0.03 m	0.02 m	0.05 m	0.06 m	0.04 m	0.06 m	0.08 m	0.04 m
Nuclear	0.07 m	0.06 m	0.05 m	0.04 m	0.01 m	0.01 m	0.04 m	0.01 m	0.01 m
Renewables	0.44 m	0.35 m	0.28 m	0.82 m	1.12 m	0.78 m	1.08 m	1.45 m	1.29 m
Total Jobs	**2.74 m**	**2.58 m**	**2.28 m**	**2.89 m**	**3.06 m**	**2.57 m**	**3.10 m**	**3.34 m**	**2.90 m**

china : transport

In 2050, the car fleet in China will be 20 times larger than today. Today, more medium to large-sized cars are driven in China with an unusually high annual mileage. With growing individual mobility, an increasing share of small efficient cars is projected, with vehicle kilometres driven resembling industrialised countries averages. More efficient propulsion technologies, including hybrid-electric power trains, and lightweight construction, will help to limit the growth in total transport energy demand to a factor of 2.9, reaching 17,096 PJ/a in 2050. As China already has a large fleet of electric vehicles, this will grow to the point where almost 25% of total transport energy is covered by electricity.

By 2030 electricity will provide 13% of the transport sector's total energy demand under the Energy [R]evolution scenario, while in the advanced version the share will already reach 19% in 2030 and 54% by 2050.

figure 6.92: china: transport under 3 scenarios

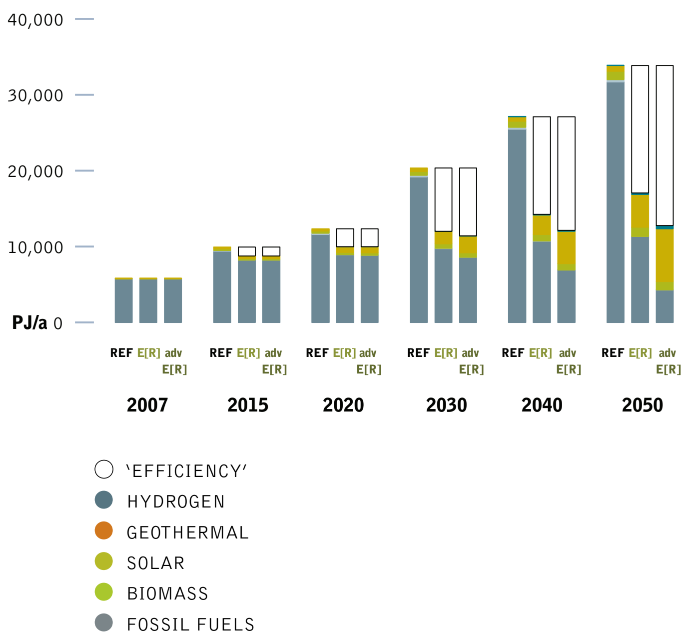


image A MAINTENANCE ENGINEER INSPECTS A WIND TURBINE AT THE NAN WIND FARM IN NAN'AO. GUANGDONG PROVINCE HAS ONE OF THE BEST WIND RESOURCES IN CHINA AND IS ALREADY HOME TO SEVERAL INDUSTRIAL SCALE WIND FARMS. MASSIVE INVESTMENT IN WIND POWER WILL HELP CHINA OVERCOME ITS RELIANCE ON CLIMATE DESTROYING FOSSIL FUEL POWER AND SOLVE ITS ENERGY SUPPLY PROBLEM.

image image A LOCAL TIBETAN WOMAN WHO HAS FIVE CHILDREN AND RUNS A BUSY GUEST HOUSE IN THE VILLAGE OF ZHANG ZONG USES SOLAR PANELS TO SUPPLY ENERGY FOR HER BUSINESS.

china: development of CO_2 emissions

Whilst China's emissions of CO_2 will almost more than double under the Reference scenario, under the Energy [R]evolution scenario they will decrease from 5,852 million tonnes in 2007 to 3,209 million tonnes in 2050. Annual per capita emissions will drop from 4.4 t to 2.3 t.

The advanced Energy [R]evolution scenario will shift the peak of energy related CO_2 emissions to 2025 a few years earlier than in the basic version, leading to 3.9 t per capita by 2030 and 0.6 t by 2050. By 2050, China's CO_2 emissions will then be 41% of 1990 levels.

china: primary energy consumption

Taking into account the above assumptions, the resulting primary energy consumption under the Energy [R]evolution scenario is shown in Figure 6.94. Compared to the Reference scenario, overall primary energy demand will be reduced by 46% in 2050. Around 47% of the remaining demand will be covered by renewable energy sources. The advanced version phases out coal and oil about ten to 15 years faster than the basic scenario. This is made possible mainly by the replacement of new coal power plants with renewables after a 20 rather than 40 year lifetime and a faster introduction of electric vehicles in the transport sector to replace combustion engines. This leads to an overall renewable energy share of 27% in 2030 and 77% in 2050.

figure 6.93: china: development of CO_2 emissions by sector under both energy [r]evolution scenarios

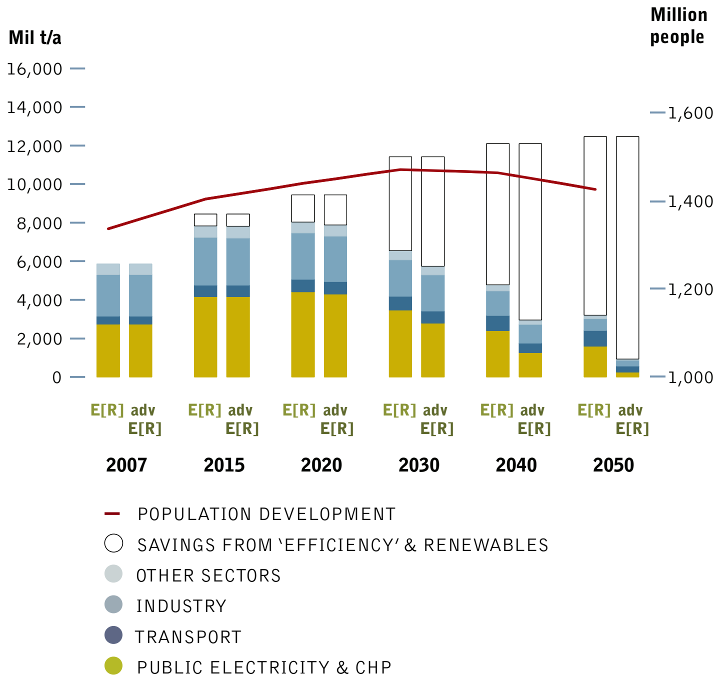
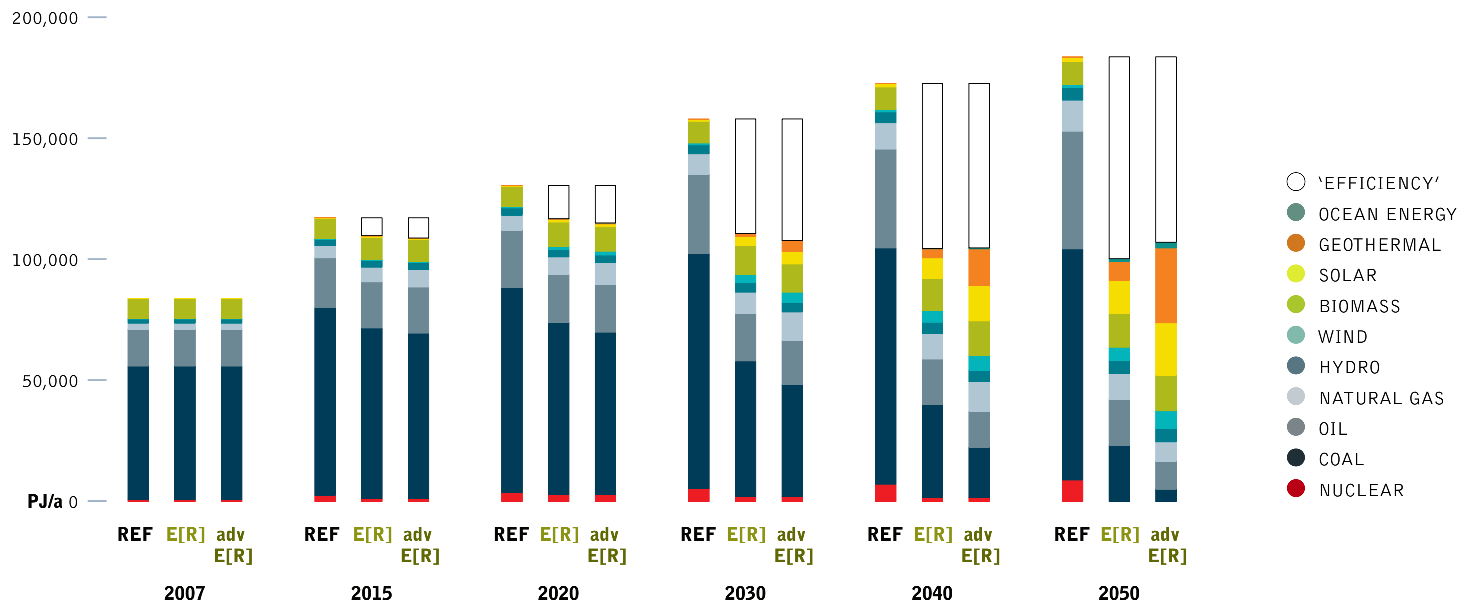


figure 6.94: china: development of primary energy consumption under three scenarios



oecd pacific

oecd pacific: energy demand by sector

The future development pathways for OECD Pacific's final energy demand are shown in Figure 6.95 for the Reference and both Energy [R]evolution scenarios. Under the Reference scenario, total primary energy demand in OECD Pacific increases by more than 9% from the current 37,588 PJ/a to 40,793 PJ/a in 2050. In the Energy [R]evolution scenario, by contrast, energy demand decreases by 40% and 43% in the advanced case, compared to current consumption and it is expected by 2050 to reach 22,417 PJ/a and 21,299 PJ/a in the advanced scenario. Under the Energy [R]evolution scenario, electricity demand in the industrial, residential and services sectors is expected to fall slightly below the current level (see Figure 6.96). The growing use of electric vehicles however, leads to an increased demand reaching a level of 1,994 TWh/a 2050. Electricity demand in the Energy [R]evolution scenario is still 763 TWh/a lower than in the Reference scenario in 2050.

The advanced Energy [R]evolution scenario introduces electric vehicles earlier while more journeys - for both freight and persons - will be shifted towards electric trains and public transport. Fossil fuels for industrial process heat generation are also phased out more quickly and replaced by electric geothermal heat pumps and hydrogen. This means that electricity demand in the advanved Energy [R]evolution is higher and reaches 2,139 TWh/a in 2050, still 10% below the Reference case.

Efficiency gains in the heat supply sector are larger than in the electricty sector. Under both Energy [R]evolution scenarios, final demand for heat supply can even be reduced significantly (see Figure 6.97). Compared to the Reference scenario, consumption equivalent to 1,730 PJ/a is avoided through efficiency measures by 2050.

In the transport sector, it is assumed under the Energy [R]evolution scenario that energy demand will decrease by 40% to 3,514 PJ/a by 2050, saving 23% compared to the Reference scenario. The advanced version factors in a faster decrease of the final energy demand for transport. This can be achieved through a mix of increased public transport, reduced annual person kilometres and wider use of more efficient engines and electric drives. While electricity demand increases, the overall final energy use falls to 3,163 PJ/a, 46% lower than in the Reference case.

figure 6.95: oecd pacific: projection of total final energy demand by sector (REF, E[R] & advanced E[R])

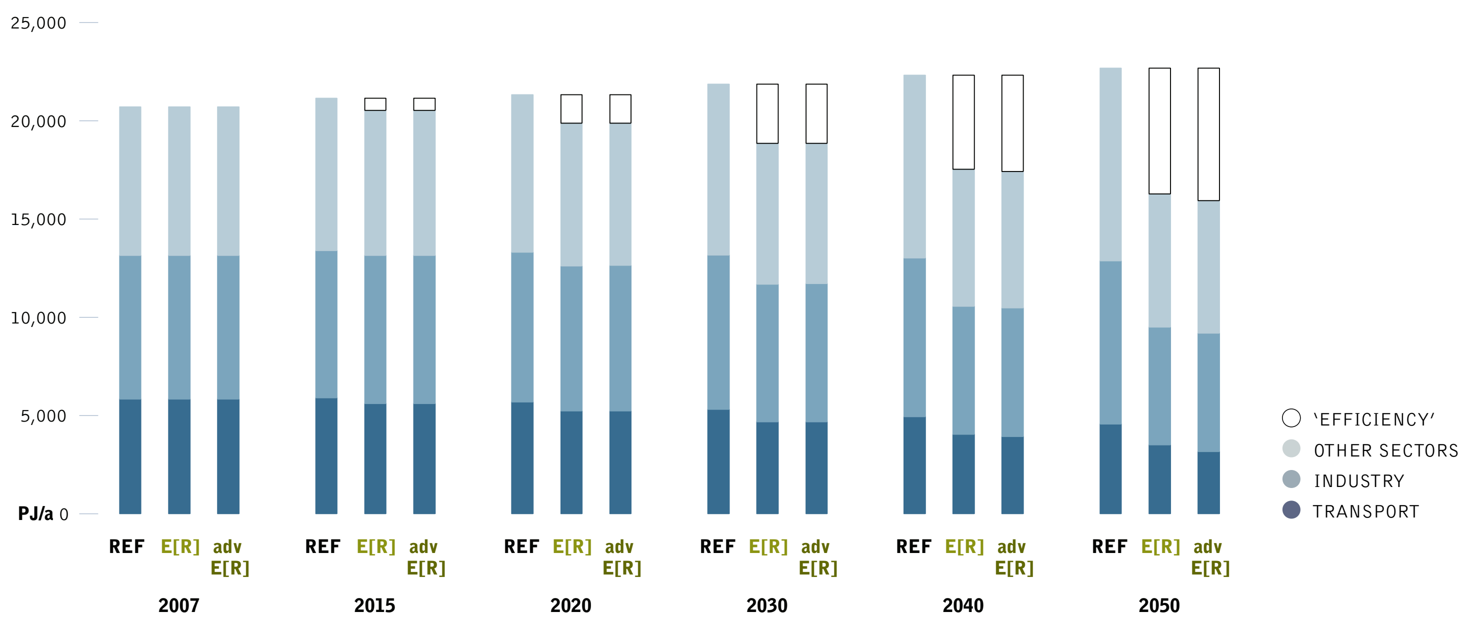


image PORTLAND, IN THE STATE OF VICTORIA, WAS THE FIRST AUSTRALIAN COUNCIL TO RECEIVE A DEVELOPMENT APPLICATION FOR WIND TURBINES AND NOW HAS ENOUGH IN THE SHIRE TO PROVIDE ENERGY FOR SEVERAL LOCAL TOWNS COMBINED.

image THE FORTUNES OF THE TOWN OF INNAMINCKA ARE ABOUT TO CHANGE, BECAUSE THEY ARE SITTING ON THE EDGE OF THE COOPER BASIN. IT MAY BE SIZZLING ABOVE GROUND, BUT THE ROCKS FIVE KILOMETRES BELOW INNAMINCKA ARE SUPER-HEATED, PROVIDING A NEW AND CLEAN SOURCE OF ENERGY. RESIDENT LEON, THE PUBLICAN SAYS, EVERYONE IN TOWN IS EXCITED, EVERYONE HAS TO LIVE NEXT TO A NOISY GENERATOR. AND ANYTHING YOU DO OUT HERE IS EXPENSIVE, IT ALL HAS TO BE FREIGHTED IN. ANYWHERE YOU CAN SAVE SOME MONEY IS GREAT. UP UNTIL NOW, THE PUB HAS BEEN USING BETWEEN AROUND 3,000 LITRES OF DIESEL FUEL EVERY WEEK. WHEN THE NEW GENERATOR IS SWITCHED ON THAT SHOULD DROP TO ZERO.

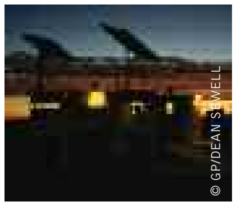
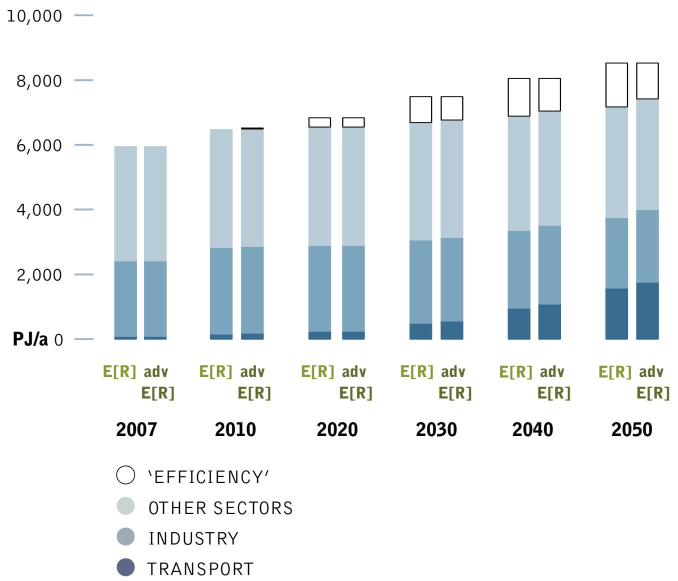


figure 6.96: oecd pacific: development of electricity demand by sector (REF, E[R] & advanced E[R])



oecd pacific: heating and cooling supply

Renewables currently provide 6% of OECD Pacific's energy demand for heat supply, the main contribution coming from biomass. Dedicated support instruments are required to ensure a dynamic future development. In the Energy [R]evolution scenario, renewables provide 74% of OECD Pacific's total heating and cooling demand in 2050.

- Energy efficiency measures can decrease the current demand for heat supply by 12%, in spite of improving living standards.
- For direct heating, solar collectors, biomass/biogas as well as geothermal energy are increasingly substituting for fossil fuel-fired systems.
- A shift from coal and oil to natural gas in the remaining conventional applications will lead to a further reduction of CO_2 emissions.

The advanced Energy [R]evolution case introduces renewable heating and cooling systems around 5 years ahead of the Energy [R]evolution scenario. Solar collectors and geothermal heating systems achieve economies of scale via ambitious support programmes 5 to 10 years earlier and reach a share of 41% by 2030 and 96% by 2050.

figure 6.97: oecd pacific: development of heat demand by sector

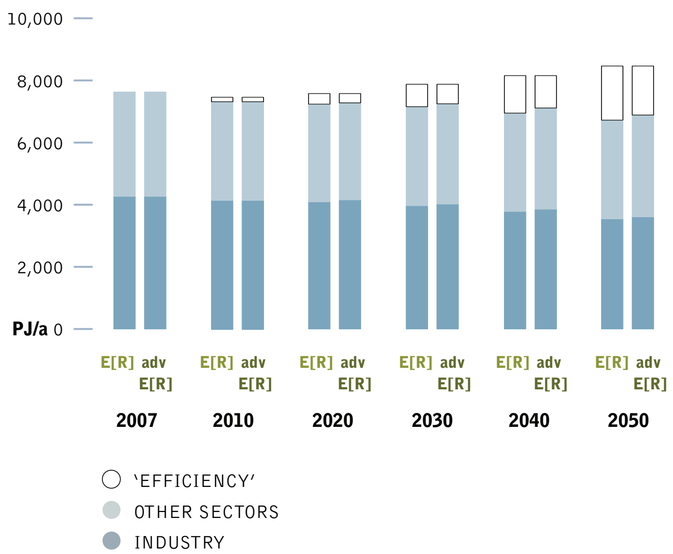
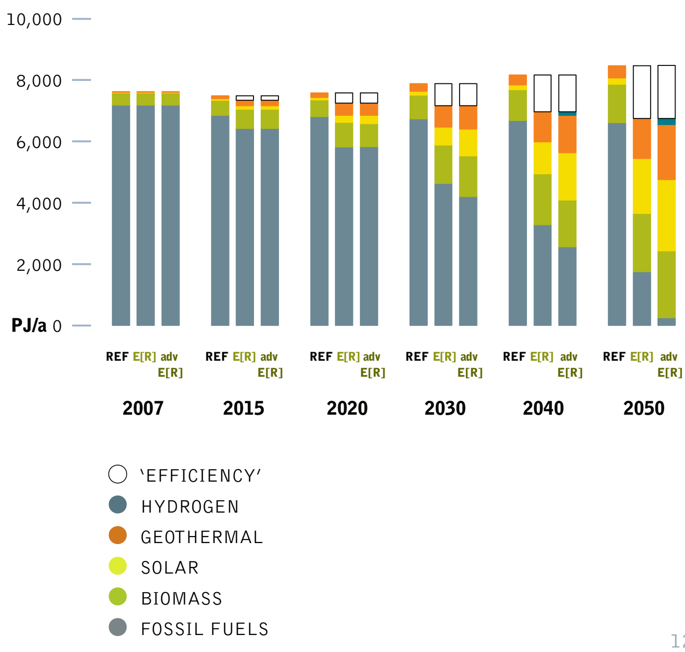


figure 6.98: oecd pacific: development of heat supply structure under 3 scenarios



oecd pacific

oecd pacific: electricity generation

A dynamically growing renewable energy market will compensate for the phasing out of nuclear energy and reduce the number of fossil fuel-fired power plants required for grid stabilisation. By 2050, 78% of the electricity produced in OECD Pacific will come from renewable energy sources. 'New' renewables – mainly wind, solar thermal energy and PV – will contribute 43% of electricity generation.

The installed capacity of renewable energy technologies will grow from the current 77 GW to 627 GW in 2050, increasing renewable capacity by a factor of 8. The advanced Energy [R]evolution scenario projects a faster market development with higher annual growth rates achieving a renewable electricity share of 35% by 2030 and 98% by 2050. The installed capacity of renewables will reach 273 GW in 2030 and 810 GW by 2050, 29% higher than in the basic version.

To achieve an economically attractive growth in renewable energy sources a balanced and timely mobilisation of all technologies is of great importance. Figure 6.99 shows the comparative of the different renewable technologies over time. Up to 2020 hydro and wind will remain the main contributors of the growing market share. After 2020, the continuing growth of wind will be complemented by elelctricity from biomass, photovoltaics and solar thermal (CSP) energy. The advanced Energy [R]evolution scenario will lead to a higher share of fluctuating power generation source (photovoltaic, wind and ocean) of 17% by 2030, therefore the expansion of smart grids, demand side management (DSM) and storage capacity from the increased share of electric vehicles will be used for a better grid integration and power generation management.

None of these numbers - even in the advanced Energy [R]evolution scenario - utilise the maximum known technical potential of all the renewable resources. While the deployment rate compared to the technical potential for geothermanl power, for example, is relatively high at 27% in the advanced Energy [R]evolution scenario, for PV only 0.4% has been used in the advanced scenario.

table 6.21: oecd pacific: projection of renewable electricity generation capacity under both Energy [R]evolution scenarios

IN GW

		2007	2020	2030	2040	2050
Hydro	E[R]	68	81	87	89	89
	advanced E[R]	68	81	87	89	89
Biomass	E[R]	4	8	14	23	33
	advanced E[R]	4	8	15	23	35
Wind	E[R]	4	41	79	144	257
	advanced E[R]	4	48	71	202	283
Geothermal	E[R]	1	3	4	5	9
	advanced E[R]	1	3	8	13	21
PV	E[R]	0	36	71	121	211
	advanced E[R]	0	36	71	121	279
CSP	E[R]	0	3	4	6	8
	advanced E[R]	0	13	11	36	66
Ocean energy	E[R]	0	1	4	11	21
	advanced E[R]	0	3	10	24	37
Total	**E[R]**	**77**	**173**	**263**	**399**	**627**
	advanced E[R]	**77**	**191**	**273**	**509**	**810**

figure 6.99: oecd pacific: development of electricity generation structure under 3 scenarios

(REFERENCE, ENERGY [R]EVOLUTION AND ADVANCED ENERGY [R]EVOLUTION) ["EFFICIENCY" = REDUCTION COMPARED TO THE REFERENCE SCENARIO]

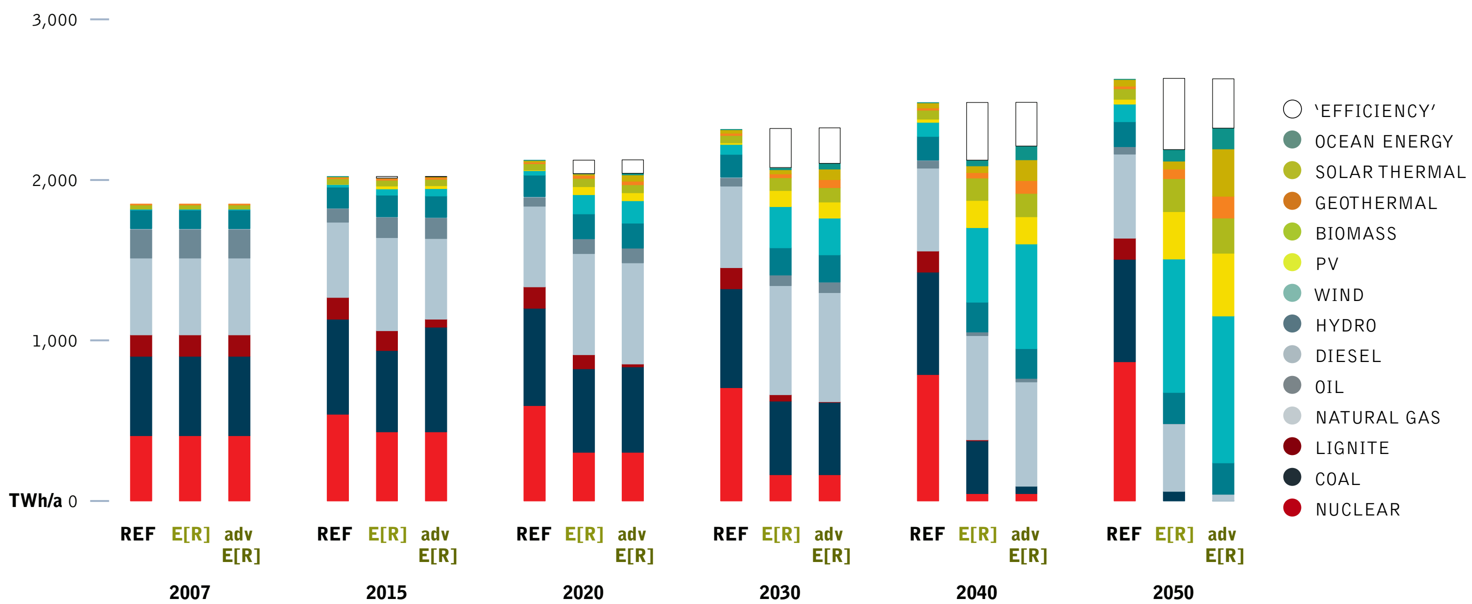


image SOLAR PANELS ON CONISTON STATION, NORTH WEST OF ALICE SPRINGS, NORTHERN TERRITORY.

image THE "CITIZENS' WINDMILL" IN AOMORI, NORTHERN JAPAN. PUBLIC GROUPS, SUCH AS CO-OPERATIVES, ARE BUILDING AND RUNNING LARGE-SCALE WIND TURBINES IN SEVERAL CITIES AND TOWNS ACROSS JAPAN.

oecd pacific: future costs of electricity generation

Figure 6.100 shows that the introduction of renewable technologies under the Energy [R]evolution scenario slightly increases the costs of electricity generation in the OECD Pacific compared to the Reference scenario. This difference will be small (1.3 cent/kWh) up to 2020, however. Because of the lower CO_2 intensity of electricity generation, electricity generation costs will become economically favourable under the Energy [R]evolution scenarios and by 2050 costs will be more than 2 cents/kWh below those in the Reference scenario.

Under the Reference scenario, by contrast, unchecked growth in demand, an increase in fossil fuel prices and the cost of CO_2 emissions result in total electricity supply costs rising from today's $163 billion per year to more than $322 billion in 2050. Figure 6.100 shows that the Energy [R]evolution scenario not only complies with OECD Pacific´s CO_2 reduction targets but also helps to stabilise energy costs. Increasing energy efficiency and shifting energy supply to renewables lead to long term costs for electricity supply that are one third lower than in the Reference scenario.

The advanced Energy [R]evolution scenario will lead to a higher proportion of variable power generation sources (PV, wind and ocean power), reaching 17% by 2030 and 62% by 2050. Expansion of smart grids, demand side management and storage capacity through an increased share of electric vehicles will therefore be used to ensure better grid integration and power generation management.

oecd pacific: job results

The Energy [R]evolution scenarios lead to more energy sector jobs in OECD Pacific at every stage of the projection.

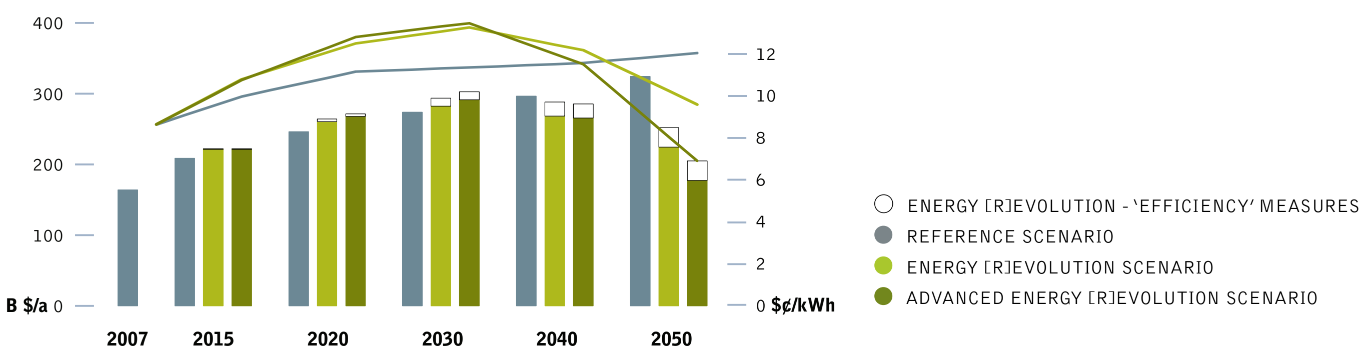
• There are 340,000 power sector jobs in the Energy [R]evolution scenario and 360,000 in the advanced version by 2015, compared to 200,000 in the Reference scenario.

• By 2020 job numbers in the renewables industry reach 180,000 in both Energy [R]evolution scenarios, 110,000 more than in the Reference scenario.

• By 2030 job numbers climb slightly in the Energy [R]evolution scenario to 290,000, (350,000 in the advanced version) and reach nearly 240,000 million in the Reference scenario. The employment in the renewables sector reaches around a quarter million in both Energy [R]evolution scenarios, about 4-times more than the regions coal industry.

Table 6.22 shows the increase in job numbers under both Energy [R]evolution scenarios for each technology up to 2020 and up to 2030. Both scenarios show some losses in coal generation, but these are outweighed by employment growth in renewable technologies and gas. Wind and solar shows particularly strong growth in the both Energy [R]evolution scenarios by 2020, but by 2030 there is significant employment across a range of renewable technologies.

figure 6.100: oecd pacific: development of total electricity supply costs & development of specific electricity generation costs under 3 scenarios



oecd pacific

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table 6.22: oecd pacific: employment & investment

	REFERENCE			ENERGY [R]EVOLUTION			ADVANCED ENERGY [R]EVOLUTION		
	2015	2020	2030	2015	2020	2030	2015	2020	2030
Jobs									
Construction & installation	0.04 m	0.03 m	0.05 m	0.14 m	0.08 m	0.07 m	0.16 m	0.08 m	0.09 m
Manufacturing	0.01 m	0.01 m	0.01 m	0.04 m	0.03 m	0.04 m	0.04 m	0.02 m	0.07 m
Operations & maintenance	0.08 m	0.08 m	0.10 m	0.09 m	0.10 m	0.12 m	0.09 m	0.10 m	0.13 m
Fuel	0.07 m	0.08 m	0.08 m	0.07 m	0.07 m	0.06 m	0.07 m	0.06 m	0.06 m
Total Jobs	**0.20 m**	**0.20 m**	**0.24 m**	**0.34 m**	**0.28 m**	**0.29 m**	**0.36 m**	**0.27 m**	**0.35 m**
Coal	0.05 m	0.05 m	0.06 m	0.04 m	0.05 m	0.03 m	0.04 m	0.04 m	0.03 m
Gas, oil and diesel	0.04 m	0.04 m	0.05 m	0.05 m	0.04 m	0.04 m	0.05 m	0.04 m	0.04 m
Nuclear	0.04 m	0.05 m	0.06 m	0.02 m	0.01 m	0.01 m	0.02 m	0.01 m	0.01 m
Renewables	0.06 m	0.06 m	0.07 m	0.23 m	0.18 m	0.22 m	0.25 m	0.18 m	0.28 m
Total Jobs	**0.20 m**	**0.20 m**	**0.24 m**	**0.34 m**	**0.28 m**	**0.29 m**	**0.36 m**	**0.27 m**	**0.35 m**

oecd pacific: transport

In the transport sector, it is assumed under the Energy [R]evolution scenario that an energy demand reduction of 1,050 PJ/a can be achieved by 2050, saving 23% compared to the Reference scenario. This reduction can be achieved by the introduction of highly efficient vehicles, by shifting the transport of goods from road to rail and by changes in mobility-related behaviour patterns. Implementing attractive alternatives to individual cars, the car stock is growing slower than in the Reference scenario.

A shift towards smaller cars triggered by economic incentives together with a significant shift in propulsion technology towards electrified power trains and a reduction of vehicle kilometres travelled by 0.25% per year leads to significant final energy savings. In 2030, electricity will provide 11% of the transport sector's total energy demand in the Energy [R]evolution, while in the advanced case the share will be 12% in 2030 and 56% by 2050.

figure 6.101: oecd pacific: transport under 3 scenarios

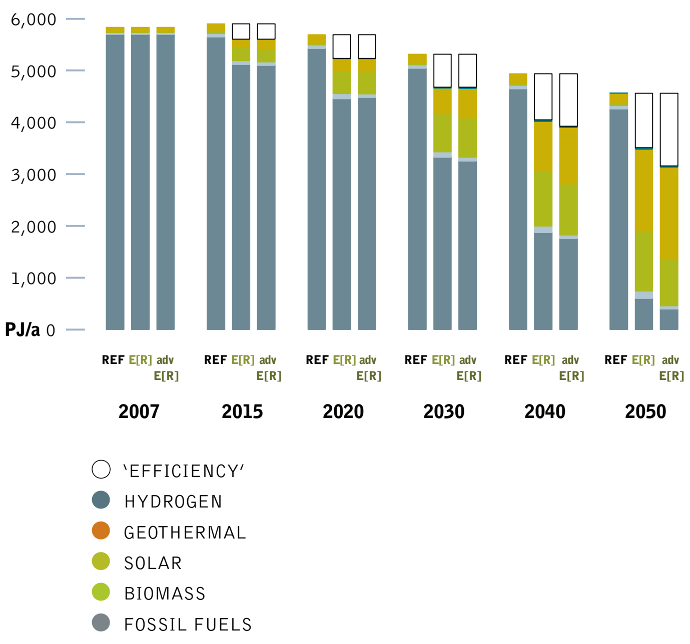


image GEOTHERMAL POWER STATION, NORTH ISLAND, NEW ZEALAND.

image WIND FARM LOOKING OVER THE OCEAN AT CAPE JERVIS, SOUTH AUSTRALIA.

oecd pacific: development of CO_2 emissions

Whilst the OECD Pacific´s emissions of CO_2 will decrease by 15% under the Reference scenario, under the Energy [R]evolution scenario they will decrease from 2,144 million tonnes in 2007 to 385 million t in 2050. Annual per capita emissions will fall from 10.7 t to 2.1 t. In the long run efficiency gains and the increased use of renewable electricity in vehicles will even reduce emissions in the transport sector. With a share of 51% of total CO_2 in 2050, the power sector will remain the largest sources of emissions.

The advanced Energy [R]evolution scenario reduces energy related CO_2 emissions about ten to 15 years faster than the basic scenario, leading to 6.5 t per capita by 2030 and 0.4 t by 2050. By 2050, OECD Pacific´s CO_2 emissions are 5% of 1990 levels.

oecd pacific: primary energy consumption

Taking into account the above assumptions, the resulting primary energy consumption under the Energy [R]evolution scenario is shown in Figure 6.103. Compared to the Reference scenario, overall energy demand will be reduced by 45% in 2050. Around 62% of the remaining demand will be covered by renewable energy sources.

The advanced version phases out coal and oil about 10 to 15 years faster than the basic scenario. This is made possible mainly by replacement of coal power plants with renewables after 20 rather than 40 years lifetime and a faster introduction of electric vehicles in the transport sector to replace oil combustion engines. This leads to an overall renewable primary energy share of 26% in 2030 and 84% in 2050. Nuclear energy is phased out in both Energy [R]evolution scenarios just after 2030.

figure 6.102: oecd pacific: development of CO_2 emissions by sector under both Energy R]evolution scenarios

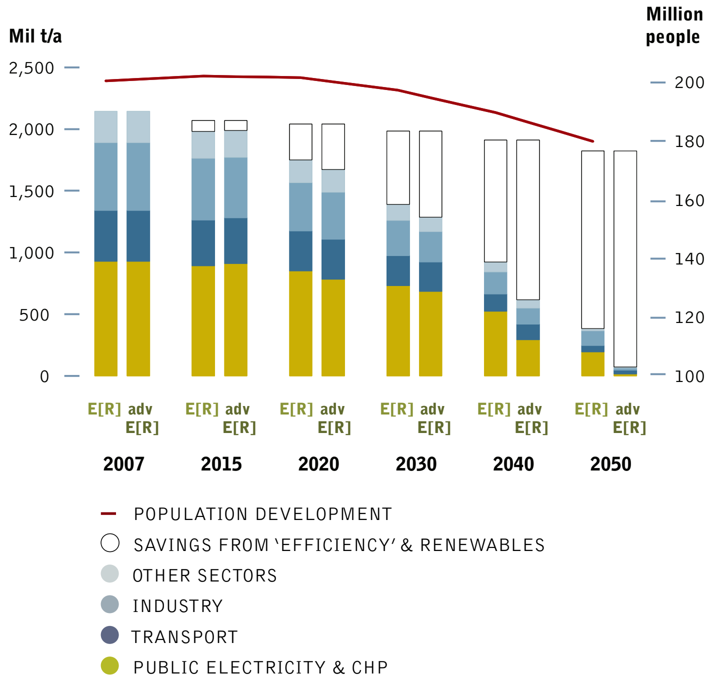
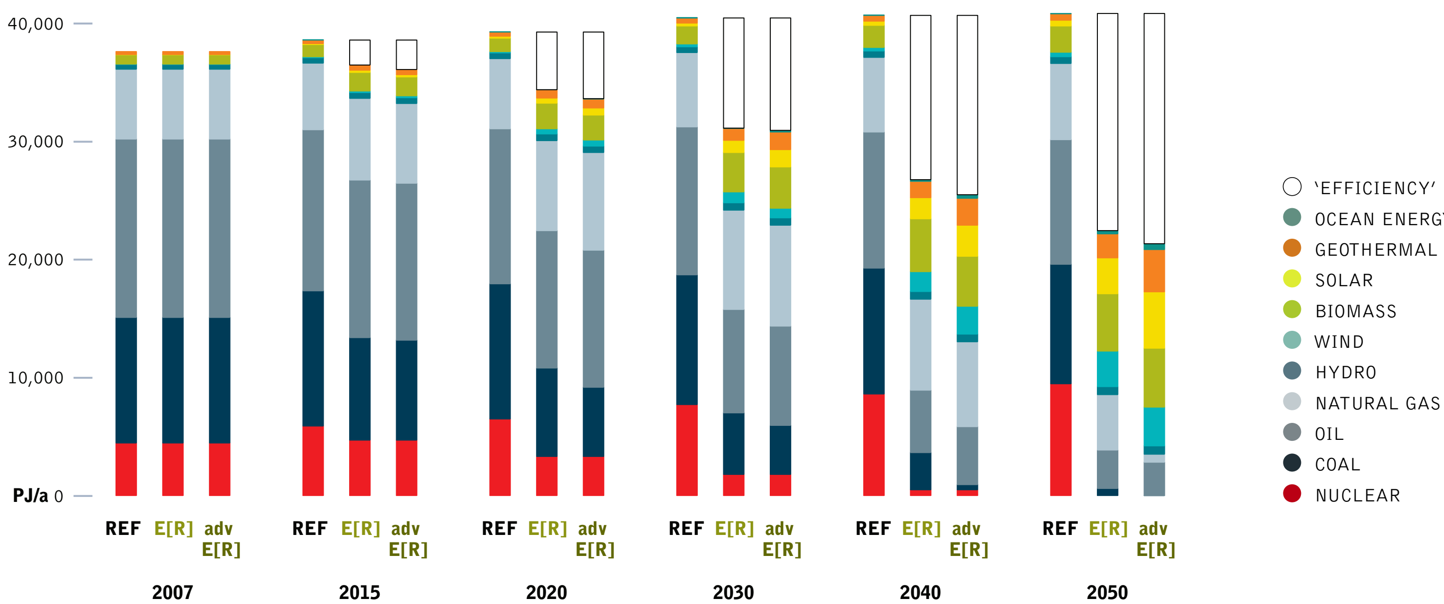


figure 6.103: oecd pacific: development of primary energy consumption under three scenarios



future investment and employment

GLOBAL SCENARIO

7

image PRODUCING WIND ROTORS FOR OFFSHORE WIND ENERGY IN RINGKOBING, DENMARK.
© PAUL LANGROCK/ZENIT/GP

"I often ask myself why this whole question needs to be so difficult, why governments have to be dragged kicking and screaming even when the cost is miniscule."

LYN ALLISON
LEADER OF THE AUSTRALIAN DEMOCRATS, SENATOR 2004-2008

image THE DABANCHENG WIND POWER ALONG THE URUMQI-TURPAN HIGHWAY, XINJIANG PROVINCE, CHINA. HOME TO ONE OF ASIA'S BIGGEST WIND FARMS AND A PIONEER IN THE INDUSTRY XINJIANG'S DABANCHENG IS CURRENTLY ONE OF THE LARGEST WIND FARMS IN CHINA, WITH 100 MEGAWATTS OF INSTALLED POWER GENERATING CAPACITY.

the global renewable energy market

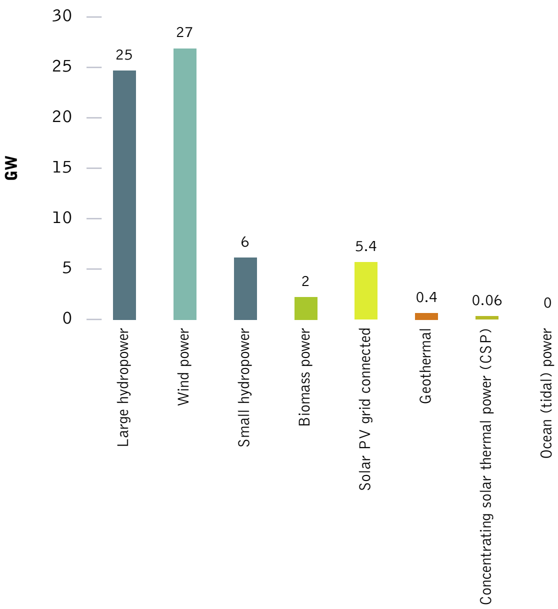
The renewable energy sector has been growing substantially over the last four years. In 2008, the increases in the installation level of both wind and solar power were particularly impressive. The total amount of renewable energy installed worldwide is reliably tracked by the Renewable Energy Policy Network for the 21st Century (REN21). Its latest global status report (2009) shows how the technologies have grown.

table 7.1: annual growth rates of global renewable energy

Wind	⬆29% in 2008	⬆600% since 2004
Solar photovoltaic (PV)	⬆70% in 2008	⬆250% since 2004
Small hydro power	⬆8% in 2008	⬆75% since 2004

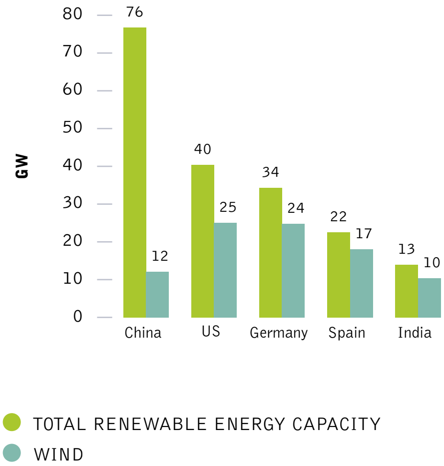
The global installed capacity of renewable energy at the end of 2008 was 1,128 GW. Of this, large hydro power made up around three quarters and wind approximately 11%. The new capacity commissioned in 2008 alone amounted to roughly 40 GW (excluding large hydro power), with the highest growth in wind power.

figure 7.1: new renewable energy installed worldwide, 2008, after REN 21 Renewable Energy Outlook 2008



The top five countries for new renewable energy in 2008 were China, the United States, Germany, Spain and India. China doubled its wind power capacity for the fifth year in a row. The growth of grid-connected solar PV in Spain was five times the level in 2007.

figure 7.2: top five countries for renewable energy installation in 2008, from Ren21 Renewable Energy Outlook 2008



making the switch For the first time in 2008 both the United States and the European Union added more capacity from renewable energy sources than from conventional generation (including gas, coal, oil and nuclear). By the end of the year renewable energy made up just 6.2% of the world's total installed energy capacity and 4.4% of generation. If large hydropower is included the total rises to 18%. However, new installations of renewable energy made up one quarter of the total fresh capacity[53], compared to just 10% in 2004. If large hydropower is included the total for the renewable sector increases to more than half of all newly commissioned capacity.[54]

Total global investment in renewable energy was $120 billion in 2008[55], at least four times more than in 2004. The United States contributed around 20% of this total. According to the United Nations Environment Programme (UNEP), total new investment in developed countries was $82.3 billion, and $36.6 billion in developing countries during 2008, an increase of 37% on 2007 levels.[56] For the first time, investment in renewable energy (including large hydropower) was greater than that in fossil fuel technologies by a margin of about $10 billion.

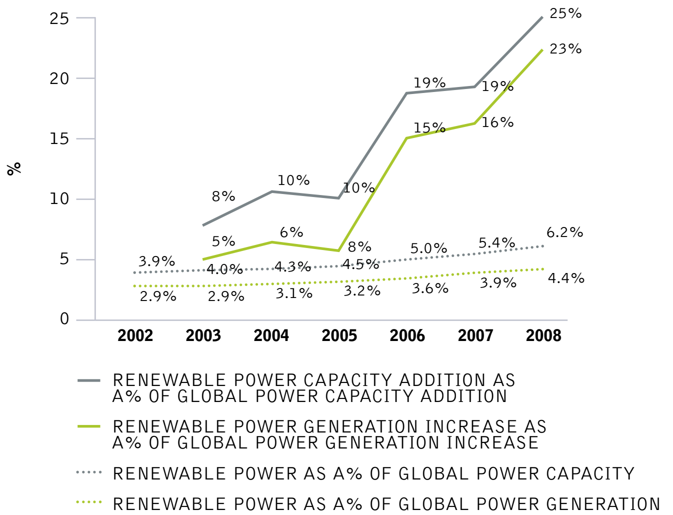
In 2008 there was crisis in the world's financial system and a number of banks, mortgage lenders and insurance companies failed. For renewable energy this meant there was less finance available for new projects. The full effects are not yet known, but early indications suggest that renewable energy has weathered the crisis better than most sectors. Wind energy in particular seems to have been relatively unaffected. In several developed countries, economic stimulus packages have included incentives for large scale renewable energies and energy efficiency programmes.

53 UNITED NATIONS ENVIRONMENT PROGRAMME (UNEP) AND NEW ENERGY FINANCE (2009) *GLOBAL TRENDS IN SUSTAINABLE ENERGY INVESTMENT 2009 - ANALYSIS OF TRENDS AND ISSUES IN THE FINANCING OF RENEWABLE ENERGY AND ENERGY EFFICIENCY.*
54 REN21 (2009) *RENEWABLES GLOBAL STATUS REPORT 2009*
55 REN21 (2009) *IBID*
56 UNITED NATIONS ENVIRONMENT PROGRAMME (UNEP) AND NEW ENERGY FINANCE (2009) *IBID*

policies and incentives The world policy landscape includes an increasing number of measures to encourage renewable energy. Examples include new solar PV subsidy programmes introduced in Australia, China, Japan, Luxembourg, the Netherlands and the United States. New laws and policy provisions for renewable energy have also been adopted in many developing countries, including Brazil, Chile, Egypt, Mexico, the Philippines, South Africa, Syria and Uganda. Several hundred cities and local governments around the world are actively planning or implementing renewable energy policies and frameworks linked to carbon dioxide emissions reduction.

The drivers of renewable energy are climate change, energy insecurity, fossil fuel depletion and new technology development. The price of many of these technologies is falling due to the global supply-demand equation; UNEP predicted, for example, that the price of solar panels would fall by 43% during 2009.[57] This economic resilience, combined with more and more firm policies mandates requiring a commitment to renewables, such as feed-in tariffs and renewable portfolio standards, mean that renewable energy will continue to grow.

figure 7.3: renewable power generation and capacity as a proportion of global power, 2003-2008%



source "GLOBAL TRENDS IN SUSTAINABLE ENERGY INVESTMENT 2009", UNEP/SEFI. (EXCLUDING LARGE HYDRO).

employment in global renewable energy

By the end of 2009 global employment in renewable energy was approximately 1.9 million. Although in the last ten years the advanced economies have shown leadership in encouraging renewable energy, developing countries are playing a growing role. China and Brazil, for example, account for a large share of the global total, with a strong commitment to both solar thermal and biomass development. Many jobs are created are in installation, operation and maintenance, as well as in biofuel feedstocks. The outlook for the future is bright: developing countries, such as Kenya with its solar technology potential, are expected to generate substantial numbers of jobs.

table 7.2: renewable electricity employment – selected countries and world

ENERGY SOURCE	SELECTED COUNTRIES	
Wind	United States	85,000[a]
	Spain	32,906[b]
	Denmark	21,612[c]
	Germany	87,100[d]
	India	10,000[e]
	World estimate	**400,000[a]**
Solar PV	United States	6,800[a]
	Spain	26,449[b]
	Germany	79,600[d]
	World estimate	**170,000[f]**
Solar Thermal electricity	United States	800[a]
	Spain	968[b]
Biomass power	United States	66,000[a]
	Spain	4,948[b]
	Germany	109,600[d]
Hydropower	Europe	20,000
	United States	8,000[a]
	Spain (small hydro)	6,661[b]
Geothermal	United States	9,000[g]
	Germany	9,300[a]
All sectors	**World estimate**	**1.7[f] - 1.9[g] million**

a 2009 data: GWEC 2010
b 2007 data: Nieto Sáinz J 2007, in UNEP 2008 Table 11.1-4.
c 2006 data: Danish Wind Industry Association
d 2009 data: BMU 2010
e 2007 data: Suzlon 2007
e 2006 data: REN21 2008 p7
f UNEP 2008 p295; the world total for renewable sector is the UNEP figure minus estimated jobs in solar thermal as these are nearly all in solar water heating.
g Greenpeace International, Sven Teske – based on own research and "Working for the Climate, September 2009, Amsterdam/Sydney

To ensure that the renewables sector provides large scale employment, a strong policy environment is essential. Some countries have already shown that renewable energy can form an important part of national economic strategies. Germany, for instance, views its investment in wind and solar PV as making a crucial contribution to its export markets. The government's intention is to gain a major slice of the world market in the coming decades, with most German jobs in these industries depending on export of wind turbines and solar panels. Although only a few countries currently have the requisite scientific and manufacturing know-how to develop such a strategy, the markets for wind and solar equipment in particular are experiencing rapid growth.

employment projections - methodology and assumptions

Greenpeace engaged the Australian-based Institute for Sustainable Futures (ISF) to model the employment effects of our 2009 sustainable future energy scenario compared to business as usual. The results, published in 2009 as "Working for the climate – Renewable Energy & The Green Job [R]evolution", form the basis for the calculations in the 2010 Energy [R]evolution scenarios.

57 UNITED NATIONS ENVIRONMENT PROGRAMME (UNEP) AND NEW ENERGY FINANCE (2009) *IBID*

image A WORKER SURVEYS THE EQUIPMENT AT ANDASOL 1 SOLAR POWER STATION, WHICH IS EUROPE'S FIRST COMMERCIAL PARABOLIC TROUGH SOLAR POWER PLANT. ANDASOL 1 WILL SUPPLY UP TO 200,000 PEOPLE WITH CLIMATE-FRIENDLY ELECTRICITY AND SAVE ABOUT 149,000 TONNES OF CARBON DIOXIDE PER YEAR COMPARED WITH A MODERN COAL POWER PLANT.

The model calculates indicative numbers for jobs that would either be created or lost under both the Energy [R]evolution and Reference scenarios, with the over-arching aim of showing the effect on employment if the world re-invents its energy mix to dramatically cut carbon emissions. While the basic Energy [R]evolution scenario assumes a four-fold increase in renewable energy, replacing nuclear and a proportion of coal-fired power, plus widespread energy efficiency improvements, the advanced scenario speeds up introduction of the renewables power market by about ten years. The Reference ('business as usual') scenario is based on the International Energy Agency 2009 reference projections.[58]

This section provides a simplified overview of how the calculations were performed and the employment factors determined. The detailed methodology is available in a separate report.[59] Chapters 5 and 6 contain all the data on how the scenarios were developed.

To calculate how many jobs will either be lost or created under the three scenarios requires a series of assumptions. These are summarised below.

- Start with the amount of electrical capacity that would be installed each year, and the amount of electricity generated per year under the Reference (business as usual) and the two Energy [R]evolution scenarios.
- Use 'employment factors' for each technology, which are the number of jobs per unit of electrical capacity (fossil as well as renewable), separated into manufacturing, construction, operation and maintenance and fuel supply.
- Take into account the 'local manufacturing' and 'domestic fuel production' for each region, in order to allocate the level of local jobs, and also to allocate imports to other regions.
- Multiply the electrical capacity and generation figures by the employment factors for each of the energy technologies.
- For non-OECD regions, apply a "regional job multiplier", which adjusts the OECD employment factors for different levels of labour-intensity in different parts of the world. Regional factors are used for coal mining, so no regional adjustment is needed in this case.
- For the 2020 and 2030 calculations, reduce the employment factors by a 'decline factor' for each technology; this reflects how employment falls as technology efficiencies improve.

The model used a range of inputs, including data from the International Energy Agency, US Energy Information Association, European Renewable Energy Council, European Wind Energy Association, US National Renewable Energy Laboratory, Renewable Energy Policy Project, census data from the United States, Australia and Canada, and the International Labour Organisation

These calculations only take into account direct employment, for example the construction team needed to build a new wind farm. They do not cover indirect employment, for example the extra services provided in a town to accommodate construction teams. Indirect employment provides significant numbers of jobs, but calculating the numbers is extremely speculative, particularly in a global study where conditions and technologies are so varied. However, including indirect job numbers could at least double the jobs created.[60]

table 7.3: methodology overview

MANUFACTURING (FOR DOMESTIC USE)	=	MW INSTALLED PER YEAR	×	MANUFACTURING EMPLOYMENT FACTOR	×	REGIONAL JOB MULTIPLIER	×	% OF LOCAL MANUFACTURING
MANUFACTURING (FOR EXPORT)	=	MW EXPORTED PER YEAR	×	MANUFACTURING EMPLOYMENT FACTOR	×	REGIONAL JOB MULTIPLIER		
CONSTRUCTION	=	MW INSTALLED PER YEAR	×	CONSTRUCTION EMPLOYMENT FACTOR	×	REGIONAL JOB MULTIPLIER		
OPERATION & MAINTENANCE	=	CUMULATIVE CAPACITY	×	O&M EMPLOYMENT FACTOR	×	REGIONAL JOB MULTIPLIER		
FUEL SUPPLY (NUCLEAR, OIL, DIESEL, BIOMASS)	=	ELECTRICITY GENERATION	×	FUEL EMPLOYMENT FACTOR	×	REGIONAL JOB MULTIPLIER		
FUEL SUPPLY (COAL)	=	ELECTRICITY GENERATION + NET COAL EXPORTS	×	REGIONAL FUEL EMPLOYMENT FACTOR	×	% OF LOCAL PRODUCTION		
FUEL SUPPLY (GAS)	=	ELECTRICITY GENERATION + NET GAS EXPORTS	×	FUEL EMPLOYMENT FACTOR	×	REGIONAL JOB MULTIPLIER	×	% OF LOCAL PRODUCTION
JOBS IN REGION	=	**MANUFACTURING**	+	**CONSTRUCTION**	+	**OPERATION & MAINTENANCE (O&M)**	+	**FUEL SUPPLY**
JOBS IN REGION 2010	=	**JOBS IN REGION**						
JOBS IN REGION 2020	=	**JOBS IN REGION** × TECHNOLOGY DECLINE FACTOR^{10} (NUMBER OF YEARS AFTER 2010)						
JOBS IN REGION 2030	=	**JOBS IN REGION** × TECHNOLOGY DECLINE FACTOR^{20} (NUMBER OF YEARS AFTER 2010)						

58 IEA 2009 WORLD ENERGY OUTLOOK.
59 RUTOVITZ, J. AND USHER, J. 2010. .METHODOLOGY FOR CALCULATING ENERGY SECTOR JOBS PREPARED FOR GREENPEACE INTERNATIONAL BY THE INSTITUTE FOR SUSTAINABLE FUTURES, UNIVERSITY OF TECHNOLOGY,, SYDNEY AUSTRALIA.
60 FOR EXAMPLE, BEDZEK R. 2007. RENEWABLE ENERGY AND ENERGY EFFICIENCY: ECONOMIC DRIVERS FORT HE 21ST CENTURY. REPORT PREPARED FOR THE AMERICAN SOLAR ENERGY SOCIETY. .

employment factors

The "employment factors" have been used to calculate how many jobs are required per unit of electrical capacity. They take into account jobs in manufacturing, construction, operation and maintenance and fuel. The tables below list the employment factors used in the calculations. These factors are calculated for OECD countries. For other regions, a regional adjustment was used.

Because of its dominance in current electricity supply, regional employment factors were calculated for coal mining in the 2009 analysis. The calculations included figures from national employment data where available, and historic coal production, with most data for 2006/2007. These employment factors have been projected to 2010 using the 2009 GDP growth data from IEA 2009, but the coal production and employment figures have not been updated.

It is important to note that coal is mined using extremely different methods around the world, and employment per unit of electricity also varies according to the type of coal and the efficiency of generation. In Australia, for example, coal is extracted at an average of 13,800 tonnes per person per year using highly mechanised processes while in Europe the average coal miner is responsible for only 1,800 tonnes per year. China is a special case: even though it currently has a very low average rate of extraction per person (700 tonnes per employee per year) this will change very soon, as thousands of small mines close and new super-mines open. For this reason, the model uses US employment factors (above current levels) for future coal production in China (for a detailed discussion of the coal employment factors see Rutovitz and Atherton, 2009).

table 7.5: employment factors for coal production and employment (MINING AND ASSOCIATED JOBS)

	EMPLOYMENT FACTOR (EXISTING GENERATION) *Jobs per GWh*	EMPLOYMENT FACTOR (NEW GENERATION) *Jobs per GWh*
World average[a]	0.4	0.25
OECD North America	0.03	0.02
OECD Europe	0.36	0.17
OECD Pacific	0.05	0.02
India	0.59	0.25
China	0.52	0.02
Africa	0.11	0.07
Transition economies	0.46	0.19
Developing Asia	Use world average as no employment data available	
Latin America	Use world average as no employment data available	
Middle east	Use world average as no employment data available	

source From Rutovitz and Atherton, 2009, projected to 2010 using 2009 figures for per capita GDP growth

table 7.4: summary of employment factors for use in global analysis

FUEL	CONSTRUCTION, MANUFACTURING & INSTALLATION *Person years/MW*	OPERATION & MAINTENANCE *Jobs/MW*	FUEL *Jobs/GWh*	MAIN REFERENCE
Coal	7.7	0.1	Regional factors used	NREL (JEDI model)
Gas	1.5	0.05	0.12	NREL (JEDI model)
Nuclear	16	0.3	0.001	Rutovitz and Atherton 2009
Biomass	4.3	3.1	0.2	EPRI 2001, DTI 2004
Hydro	11.3	0.2		Pembina 2004
Wind	15	0.4		EWEA 2009
PV	38.4	0.4		EPIA 2008A, BMU 2008a
Geothermal	6.4	0.7		GEA 2005
Solar thermal	10	0.3		EREC 2008
Ocean	10	0.3		SERG 2007/ SPOK ApS 2008
Multiplier for CHP		1.3		

image A WORKER STANDS BETWEEN WIND TURBINE ROTORS AT GANSU JINFENG WIND POWER EQUIPMENT CO. LTD. IN JIUQUAN, GANSU PROVINCE, CHINA.

The factors for gas generation were taken from a publicly available model called JEDI, developed by the National Renewable Energy Laboratory in Washington to help work out local benefits of different types of energy supply.

For nuclear energy, the factors for construction, manufacturing and installation were derived from a Nuclear Energy Institute 2009 factsheet, while operations and maintenance was calculated using Energy Information Administration data. Fuel employment was calculated from Australian census data.

For the renewable energies, employment factors were taken from industry data where available, as listed in Table 7.5, or derived, depending on the maturity of the technology.

A number of 'adjustment' factors were used to make the employment calculations more realistic, including:

- **regional job multipliers** The employment factors used in this model for all processes apart from coal mining reflect the situation in the (typically wealthier) OECD regions, so regional multipliers are applied to make the jobs per MW more realistic for other parts of the world. In developing countries it typically means more jobs per unit of electricity because of more labour intensive practices. The regional multipliers are the ratio of labour productivity in the region to labour productivity in the OECD. The multipliers change over the study period in line with the projections for GDP per capita. This reflects the fact that as prosperity increases, labour intensity tends to fall.
- **learning adjustments or 'decline factors'** This accounts for the projected reduction in the employment per MW of renewable and fossil fuel technologies over time, as technologies and companies become more efficient and production processes are scaled up. Decline factors are calculated from the cost reduction projected in the energy modelling, as generally, jobs per MW would fall in parallel with this trend.
- **local manufacturing and fuel production** Some regions do not manufacture the equipment needed for wind power or PV, for example, nor do they produce sufficient coal for their needs. The model takes into account the percentage of each technology which is made locally. The jobs in manufacturing components for export are counted in the region where they originate. The same applies to coal and gas, because they are traded internationally, so the model shows the region where the jobs are actually located.

future investment

investment in new power plants The overall global level of investment required in new power plants up to 2030 will be in the region of $15 trillion. A major driving force for investment in new generation capacity will be the ageing fleet of power plants in OECD countries. Utilities must choose which technologies to opt for within the next five to ten years based on national energy policies, in particular market liberalisation, renewable energy and CO_2 reduction targets. Within Europe, the EU emissions trading scheme could have a major impact on whether the majority of investment goes into fossil fuelled power plants or renewable energy and co-generation. In developing countries, international financial institutions will play a major role in future technology choices, as well as whether the investment costs for renewable energy become competitive with conventional power plants. In regions with a good wind regime, for example, wind farms can already produce electricity at the same cost levels as coal or gas power plants.

It would require $14.8 trillion in global investment for the Energy [R]evolution Scenario to become reality – approximately 27% higher than in the Reference Scenario ($11.2 trillion). The advanced Energy [R]evolution scenario would need $17.9 trillion, approximately 20% of the basic version. Under the Reference scenario, the levels of investment in renewable energy and fossil fuels are almost equal, about $4.8 trillion each up to 2030. Under the Energy [R]evolution Scenarios, however, the world shifts about 80% of investment towards renewables and cogeneration, whilst the advanced version makes the shift approximately five to ten years earlier. By then, the fossil fuel share of power sector investment would be focused mainly on combined heat and power and efficient gas-fired power plants.

The average annual investment in the power sector under the basic Energy [R]evolution Scenario between 2007 and 2030 would be approximately $644 billion and $782 billion in the advanced version. This is equal to the current amount of subsidies paid for fossil fuels globally in less than three years. Most investment in new power generation would occur in China, followed by North America and Europe. South Asia, including India, and East Asia, including Indonesia, Thailand and the Philippines, would also be 'hot spots' of new power generation investment.

fossil fuel power generation investment Under the Reference scenario, the main market expansion for new fossil fuel power plants would be in China, followed by North America, where the volume required would be equal to India and Europe combined. The advanced Energy [R]evolution Scenario would mean a far lower overall investment in fossil fuel power stations up to 2030; this would total of around $3.9 trillion, compared to $6.2 trillion required under the Reference Scenario.

In all scenarios, China will be by far the largest investor in coal power plants. Under the Reference scenario the current growth trend would continue up to 2030, although under the Energy [R]evolution scenario growth slows down significantly between 2011 and 2030. The advanced version would phase out new build coal power plants after 20 years of lifetime rather than 40, which could lead to stranded investments, depending on coal prices and CO_2 costs after 2030. In the Reference scenario the massive expansion of coal firing is due to activity in China, followed by the USA, India, East Asia and Europe.

figure 7.4: investment shares - reference versus energy [r]evolution

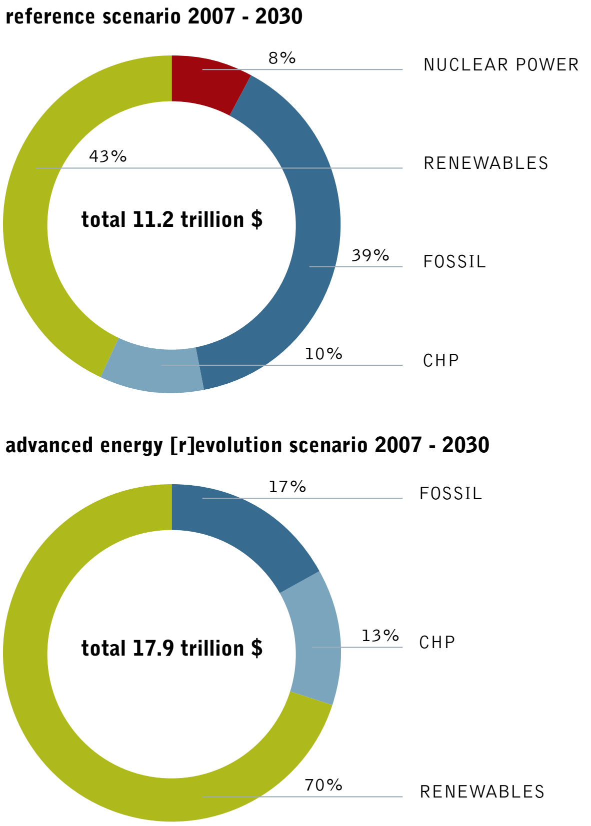
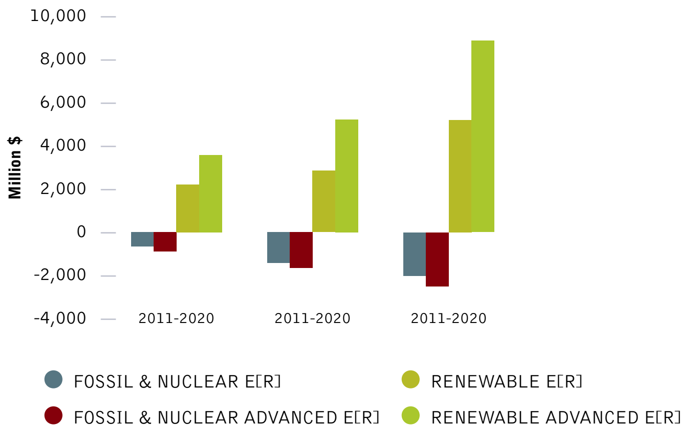


figure 2.4: change in cummulative power plant investment in both Energy [R]evolution scenarios



fuel cost savings with renewable energy The total fuel cost savings in the Energy [R]evolution Scenario reach a total of $4.1 trillion, or $180 billion per year. The advanced Energy [R]evolution has even higher fuel cost savings of $6.5 trillion, or $282 billion per year. This is because renewable energy has no fuel costs. Under the Reference scenario, the average annual additional fuel costs are higher than the additional investment requirements of the basic as well as the advanced Energy [R]evolution.

So in both cases the additional investment for renewable power plants refinance entirely via the fuel cost savings, which add up to $3.6 trillion ($6.9 trillion advanced) from today until 2030. This is enough to compensate for the entire investment in renewable and cogeneration capacity required to implement both of the Energy [R]evolution scenarios. These renewable energy sources would then go on to produce electricity without any further fuel costs beyond 2030, while the costs for coal and gas will continue to be a burden on national economies. Part of this money could be used to cover stranded investments in developing countries which may emerge under the advanced Energy [R]evolution scenario.

image A LOCAL WOMAN WORKS WITH TRADITIONAL AGRICULTURE PRACTICES JUST BELOW 21ST CENTURY ENERGY TECHNOLOGY. THE JILIN TONGYU TONGFA WIND POWER PROJECT, WITH A TOTAL OF 118 WIND TURBINES, IS A GRID CONNECTED RENEWABLE ENERGY PROJECT.

figure 7.5: cumulative power plant investments by region 2007-2030 in the energy [r]evolution scenarios

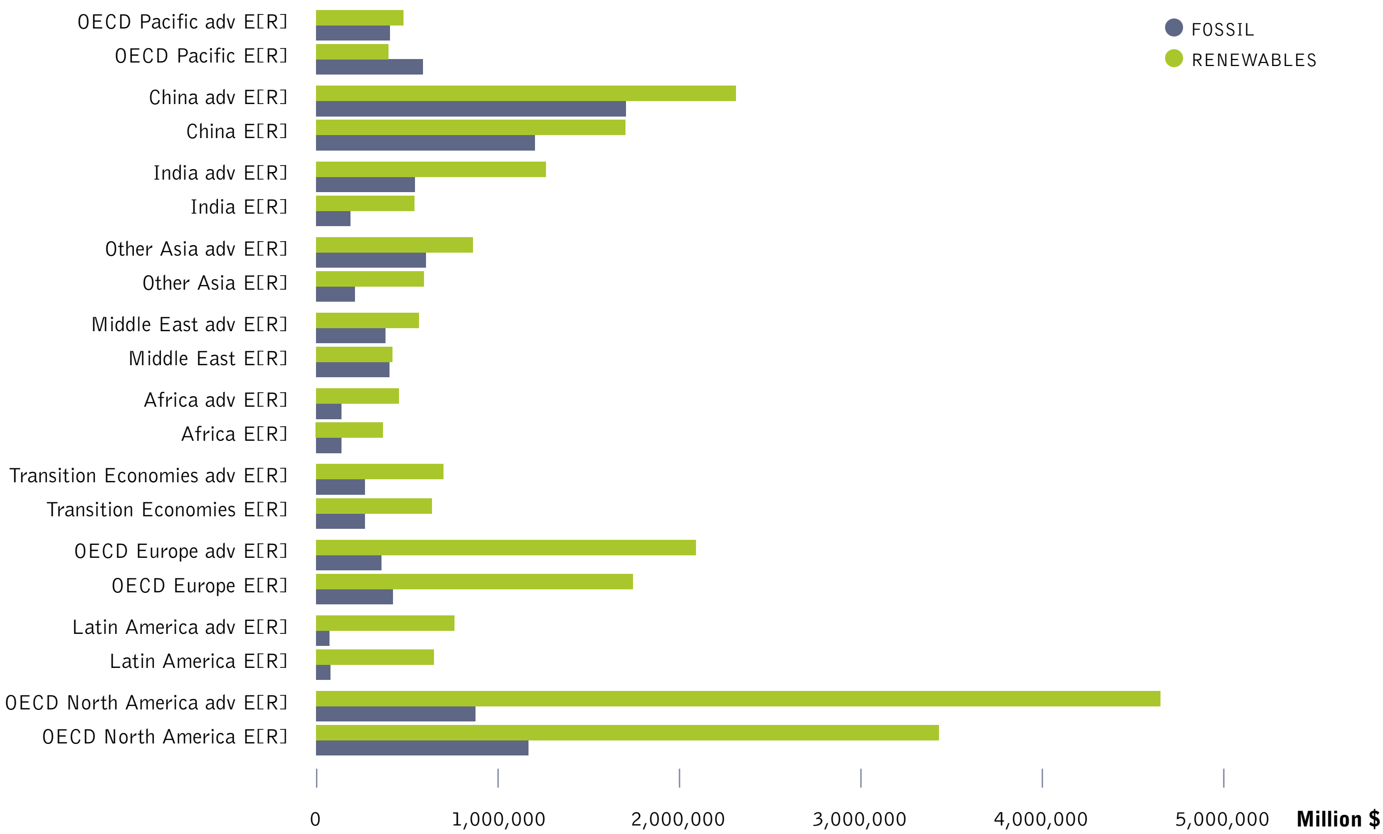


table 7.6: fuel cost savings and investment costs under the reference, energy[r]evolution and advanced energy [r]evolution

INVESTMENT COST	DOLLAR	2007-2010	2011-2020	2021-2030	2007-2030	2007-2030 AVERAGE PER YEAR
WORLD (2010) DIFFERENCE E[R] VERSUS REF						
Conventional (fossil & nuclear)	billion $	-11.4	-585	-1,149	-1,719	-75
Renewables (incl. CHP)	billion $	0	2,327	2,939	5,266	229
Total	billion $		1,768	1,790	3,547	154
WORLD (2010) DIFFERENCE ADV E[R] VERSUS REF						
Conventional (fossil & nuclear)	billion $	-11.4	-806	-1,443	-2,261	-98
Renewables (incl. CHP)	billion $	0	3,680	5,286	8,966	390
Total	billion $		2,874	3,843	6,705	292
CUMMULATED FUEL COST SAVINGS						
SAVINGS E[R] CUMMULATED IN $						
Fuel oil	billion $/a		138	560	698	30
Gas	billion $/a		-452	-144	-596	-26
Hard coal	billion $/a		676	3,181	3,857	168
Lignite	billion $/a		40	140	180	8
Total	billion $/a		402	3,737	4,139	180
SAVINGS ADV E[R] CUMMULATED IN $						
Fuel oil	billion $/a		137	589	727	32
Gas	billion $/a		-264	756	492	21
Hard coal	billion $/a		887	4,165	5,052	220
Lignite	billion $/a		50	155	205	9
Total	billion $/a		810	5,666	6,476	282

future growth rates

annual market potential for renewable power Annual market growth rates for renewable electricity in the Reference and Energy [R]evolution scenarios are very different, with the latter's projections based on recent experience in the market. The photovoltaic industry, for example, had an average annual growth rate of 35% between 1998 and 2008 (EPIA 2009), whilst the wind industry experienced a 30% annual growth rate over the same time period (GWEO 2009). Advanced technology roadmaps produced for the photovoltaic, concentrating solar power and wind industries further indicate that these growth rates can be maintained over the next decade, and then decline to between 20% and 10% from 2020 to 2030 and below 10% after that. Both Energy [R]evolution scenarios in fact assume lower annual growth rates for all renewable power technologies, in the range of about 20% up to 2025 and further declining to 10% or lower afterwards. Only concentrating solar power and ocean energy has higher annual growth rate projections.

In order to gain a better understanding of what different technologies can deliver, however, it is necessary to examine more closely how future production capacities can be achieved from the current baseline. The wind industry, for example, has a current annual production capacity of about 39,000 MW. If this output were not expanded, total capacity would reach about 1000 GW by the year 2050. This includes the need for "repowering" of older wind turbines after 20 years. But according to this scenario the share of wind electricity in global production by 2050 would need to grow from today's 1% to 5.4% under the Reference scenario and to 22.3% and 24.7% under the two Energy [R]evolution pathways. A relatively modest expansion from today's 39 GW production capacity, however, to about 74 GW (1010 GW, advanced) by 2020 and 178 GW (229 GW, advanced) in 2030 would

table 7.7: required production capacities for renewable energy technologies in different scenarios

	ANNUAL MARKET VOLUME (GW/A)			ELECTRICITY SHARE		
Solar	REF	E[R]	ADV E[R]	REF	E[R]	ADV E[R]
PV-2020	5	26	36	0.4%	1.7%	2.3%
PV-2030	18	91	124	0.8%	4.9%	6.3%
PV-2050	40	141	211	1.4%	12.1%	15.6%
CSP-2020	1	5	12	0.1%	1.2%	2.7%
CSP-2030	2	24	45	0.4%	4.8%	8.8%
CSP-2050	4	44	66	0.5%	15.6%	20.5%
Wind						
On+Offshore-2020	26	74	101	3.7%	8.4%	11.0%
On+Offshore-2030	60	178	229	4.5%	15.1%	19.0%
On+Offshore-2050	47	158	202	5.4%	22.3%	24.7%
Geothermal						
2020 (power generation)	1	2	4	0.4%	0.9%	1.4%
2030 (power generation)	2	7	18	0.5%	1.7%	4.1%
2050 (power generation)	2	7	21	0.6%	2.7%	6.8%
2020 (heat&power)	0	1	1	0.0%	0.3%	0.3%
2030 (heat&power)	0	3	5	0.0%	0.6%	0.8%
2050 (heat&power)	0	6	11	0.0%	1.9%	2.9%
Bio energy						
2020 (power generation)	3	4	4	1.2%	1.4%	1.5%
2030 (power generation)	10	8	8	1.6%	1.5%	1.6%
2050 (power generation)	6	5	4	2.1%	1.9%	1.3%
2020 (heat&power)	1	13	13	0.7%	2.9%	2.9%
2030 (heat&power)	6	26	27	0.8%	4.7%	4.6%
2050 (heat&power)	4	26	25	1.0%	7.9%	6.8%
Ocean						
2020	0	2	4	0.0%	0.2%	0.5%
2030	0	3	12	0.0%	0.4%	1.4%
2050	0	10	27	0.1%	1.8%	4.4%
Hydro						
2020	20	20	21	14.8%	15.6%	15.7%
2030	135	126	127	13.6%	14.5%	14.3%
2050	78	66	67	12.8%	13.3%	11.6%
Total renewables						
2020 (power generation incl CHP)	57	148	197	21.4%	32.6%	38.1%
2030 (power generation incl CHP)	232	466	593	22.3%	48.2%	60.9%
2050 (power generation incl CHP)	181	462	634	24.0%	79.4%	94.6%

image WORKERS BUILD A WIND TURBINE IN A FACTORY IN PATHUM THANI, THAILAND. THE IMPACTS OF SEA-LEVEL RISE DUE TO CLIMATE CHANGE ARE PREDICTED TO HIT HARD ON COASTAL COUNTRIES IN ASIA, AND CLEAN RENEWABLE ENERGY IS A SOLUTION.

lead to a total installed capacity of 1,700 GW (2,200 GW, advanced) in 2030, providing between 15% of world electricity in the basic version and 19% in the advanced case.

Table 7.7 provides an overview of the annual market volume of manufacturing capacity required to implement the quantity of renewable energy generation within the three scenarios. The good news is that the Energy [R]evolution demand does not even come close to the limit of the renewable industries' own projections. However, the scenario does assume that at the same time strong energy efficiency measures are taken in order to save resources and develop a more cost optimised energy supply.

key results by technology

future employment – key results by technology Table 7.8 shows that by 2020 there will be 3 million more jobs overall in the power sector under the Energy [R]evolution scenario - and 4 million more in the advanced version - than there would be under the Reference scenario. This does not include jobs in the energy efficiency scector, as these have not been calculated. In all scenarios there would be fewer jobs in coal between 2010 and 2020. Under the Energy [R]evolution scenarios the job losses in coal would be greater, however, and there is far stronger growth in the renewable energy sector, resulting in more overall employment.

By 2020 more than half of the direct electricity sector employment in the Energy [R]evolution scenario comes from renewable energy, even though renewables account for only 33% of electricity generation. The advanced version would result in two thirds of all jobs in renewable energy, based on 38% of the electricity generation. In the Reference scenario, on the other hand, renewable energy accounts for 30% of energy sector jobs and 21% of electricity generation. This relationship between electricity output and jobs reflects the fact that the renewables sector has greater "labour intensity" – or more people per unit of power produced. Coal is the largest employer in the reference scenario, making up nearly half of energy sector jobs throughout the period. In the Energy [R]evolution scenarios coal employment drops to 26% by 2030, and in the Advanced scenario to just 18%. This reduction is more than compensated for by the strong growth in the renewables sector.

In all scenarios, biomass employment grows the most by 2030. In the Energy [R]evolution scenarios, jobs are much more evenly spread across technologies than in the Reference scenario, with coal and biomass the largest employers at 2030 in the [R]evolution scenario, and with PV and biomass the largest employers in the Advanced scenario. The employment potential for each renewable technology and fuel is now examined in more detail.

table 7.8: global: employment under the reference, [r]evolution, and advanced scenarios in 2015, 2020 and 2030.

	REFERENCE SCENARIO			ENERGY [R]EVOLUTION			ENERGY [R]EVOLUTION		
	2015	2020	2030	2015	2020	2030	2015	2020	2030
Jobs (millions)									
Construction and installation	1.6 m	1.7 m	1.3 m	3.0 m	2.8 m	2.0 m	3.8 m	3.4 m	3.1 m
Manufacturing	0.6 m	0.5 m	0.3 m	1.8 m	1.7 m	1.2 m	2.5 m	2.2 m	1.7 m
Operations and maintenance	1.6 m	1.7 m	2.0 m	1.9 m	2.6 m	3.3 m	1.9 m	2.7 m	3.6 m
Fuel supply	3.9 m	4.0 m	4.4 m	3.9 m	3.8 m	3.7 m	3.8 m	3.7 m	3.1 m
Coal and gas export	0.5 m	0.5 m	0.7 m	0.5 m	0.5 m	0.5 m	0.5 m	0.4 m	0.4 m
Total jobs	**8.0 m**	**8.4 m**	**8.7 m**	**11.1 m**	**11.4 m**	**10.6 m**	**12.5 m**	**12.4 m**	**11.9 m**
Global									
Coal	3.9 m	4.1 m	4.2 m	3.4 m	3.1 m	2.7 m	3.2 m	2.8 m	2.1 m
Gas, oil & diesel	1.5 m	1.6 m	1.7 m	1.7 m	1.6 m	1.4 m	1.6 m	1.5 m	1.2 m
Nuclear	0.3 m	0.3 m	0.3 m	0.2 m	0.1 m	0.0 m	0.2 m	0.1 m	0.0 m
Renewable	2.3 m	2.4 m	2.4 m	5.9 m	6.6 m	6.5 m	7.5 m	8.0 m	8.5 m
Total jobs	**8.0 m**	**8.4 m**	**8.7 m**	**11.1 m**	**11.4 m**	**10.6 m**	**12.5 m**	**12.4 m**	**11.9 m**
Global - Jobs									
Coal	3.93 m	4.15 m	4.20 m	3.43 m	3.13 m	2.74 m	3.22 m	2.82 m	2.11 m
Gas, oil & diesel	1.51 m	1.59 m	1.74 m	1.67 m	1.63 m	1.40 m	1.59 m	1.49 m	1.23 m
Nuclear	0.33 m	0.29 m	0.29 m	0.17 m	0.10 m	0.04 m	0.17 m	0.10 m	0.04 m
Biomass	0.48 m	0.59 m	0.86 m	0.96 m	1.51 m	2.11 m	0.96 m	1.52 m	2.14 m
Hydro	0.90 m	0.95 m	0.91 m	1.00 m	0.67 m	0.59 m	0.88 m	0.68 m	0.60 m
Wind	0.52 m	0.39 m	0.38 m	1.70 m	1.55 m	1.40 m	2.28 m	2.01 m	1.73 m
PV	0.32 m	0.40 m	0.25 m	1.85 m	2.40 m	1.71 m	2.67 m	2.99 m	2.77 m
Geothermal	0.02 m	0.02 m	0.02 m	0.07 m	0.09 m	0.12 m	0.10 m	0.18 m	0.27 m
Solar thermal	0.02 m	0.02 m	0.02 m	0.23 m	0.31 m	0.49 m	0.54 m	0.51 m	0.85 m
Ocean	0.00 m	0.00 m	0.00 m	0.05 m	0.04 m	0.06 m	0.12 m	0.12 m	0.16 m
Total jobs	**8.04 m**	**8.40 m**	**8.68 m**	**11.13 m**	**11.43 m**	**10.65 m**	**12.51 m**	**12.43 m**	**11.90 m**

solar photovoltaics (pv)

The worldwide photovoltaics (PV) market has been growing at over 35% per annum in recent years and it can now make a significant contribution to electricity generation. Development work is focused on increasing the energy efficiency and reducing material usage of systems and modules. New technologies are developing quickly, including PV thin film (using alternative semiconductor materials) or dye sensitive solar cells, and these present a huge potential for cost reduction.

Photovoltaics have been following a fairly consistent pattern of cost reduction of 20% each time the capacity doubles; this scenario assumes a level of 5 to 10 ct/kWh by 2050, depending on the world region. Over the next five to ten years PV will become competitive with retail electricity prices in many parts of the world and competitive with fossil fuel costs by 2050.

Solar PV is a critical part of the energy mix – it can be used in decentralized or centralized formats, it is useful in an urban environment and has huge potential for cost reduction.

employment in pv Under the basic Energy [R]evolution scenario, solar PV would provide 5% of total electricity generation by 2030, and employs 1.7 million people. The advanced case would achieve a share of 6.3% and 2.8 million employees by 2030. In the Reference scenario, there are only 0.3 million employed in PV in 2015. Jobs in PV stay nearly constant from 2015 to 2030 in the three scenarios as the cost reduction in the technology and the projected increase in GDP per capita means the increase in capacity just keeps pace with the reduction in jobs per MW, so the employment advantage of the [R]evolution scenario is maintained.

concentrating solar power (csp)

Concentrating solar power is currently experiencing massive expansion, and costs are expected to be 6 to 10 ct/kWh in the long term.

Solar thermal 'concentrating' power stations (CSP) are suitable for areas with high levels of direct sunlight. The technical potential of North Africa for CSP, for example, is much greater than local demand.

There are various types of solar thermal technologies, offering good prospects for further development and cost reductions. The 'Fresnel' collectors have a simple design, and their costs are expected to fall with mass production. For central receiver systems, efficiency can be increased by producing compressed air at a temperature of up to 1,000°C; this is then used to run a combined gas and steam turbine.

Developments in storing heat will also reduce CSP electricity generation costs. The Spanish Andasol 1 plant, for example, is equipped with molten salt storage with a capacity of 7.5 hours. A higher level of full load operation can be realised by using a thermal storage system and a large collector field. These components increase initial investment costs but reduce the cost of electricity generation.

Employment in csp Under the Reference scenario, jobs in solar thermal technologies hold steady at around 20,000 over three decades. If the Energy [R]evolution was followed through, then by 2030 we would see more than a 20-fold increase in the employment opportunities from this technology. The highest proportion of jobs would be in construction and manufacturing. The advanced version could lead to 500,000 jobs and a total annual investment of US$296 billion by 2020.

table 7.9: capacity, investment and direct jobs – PV

		REFERENCE SCENARIO			ENERGY [R]EVOLUTION SCENARIOS					
	UNIT	2015	2020	2030	2015		2020		2030	
					BASE	ADVANCED	BASE	ADVANCED	BASE	ADVANCED
Energy parameters										
Installed capacity	GW	44	80	184	98	108	335	439	1,036	1,330
Generated electricity	TWh/a	55	108	281	121	132	437	594	1,481	1,953
Share of total supply	%	0.2%	0.4%	0.8%	0.5%	0.6%	1.7%	2.3%	4.9%	6.3%
Market & Investment										
Annual increase in capacity	GW/a	5	18	18	26	36	91	124	141	211
Annual investment	bill. $/a	33	20	20	73	95	98	124	177	226
Employment										
Direct jobs in construction manufaction, operation and maintenance		**0.3 m**	**0.4 m**	**0.3 m**	**1.9 m**	**2.7 m**	**2.4 m**	**3.0 m**	**1.7 m**	**2.8 m**

image TEST WINDMILL N90 2500, BUILT BY THE GERMAN COMPANY NORDEX, IN THE HARBOUR OF ROSTOCK. THIS WINDMILL PRODUCES 2.5 MEGA WATT AND IS TESTED UNDER OFFSHORE CONDITIONS. TWO TECHNICIANS WORKING INSIDE THE TURBINE.


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table 7.10: capacity, investment and direct jobs – CSP

	UNIT	REFERENCE SCENARIO 2015	2020	2030	ENERGY [R]EVOLUTION SCENARIOS 2015 BASE	2015 ADVANCED	2020 BASE	2020 ADVANCED	2030 BASE	2030 ADVANCED
Energy parameters										
Installed capacity	GW	5	12	27	25	28	105	225	324	605
Generated electricity	TWh/a	12	38	121	66	75	321	689	1,447	2,734
Share of total supply	%	0.1%	0.1%	0.4%	0.3%	0.3%	1.2%	2.7%	4.8%	8.8%
Market & Investment										
Annual increase in capacity	GW/a	1	2	4	5	12	24	45	44	66
Annual investment	bill. $/a	9	10	20	56	119	101	176	158	296
Employment										
Direct jobs in construction manufaction, operation and maintenance		**0.02 m**	**0.02 m**	**0.02 m**	**0.23 m**	**0.54 m**	**0.31 m**	**0.51 m**	**0.49 m**	**0.85 m**

wind

There is a flourishing global market for wind power, and the development costs are expected to fall by 30% on land and 50% for offshore installations.

The world's largest wind turbines, several of which have been installed in Germany, have a capacity of 6 MW. Favourable policy incentives in Europe have driven the global market. In 2009, however, more than 70% of the annual market was outside Europe and this trend is likely to continue.

There have been supply constraints following a boom in demand for wind power technology and this means that the cost of new systems has increased recently. The industry is now resolving those bottlenecks in the supply chain through expansion of production capacities, for example in China.

employment in wind energy Under the Energy [R]evolution scenario, wind would provide 15% of total electricity generation by 2030, and reach the same share in the advanced version just after 2020. Jobs in this sector would grow to 1.7 million in 2015 and to over 2 million in the Advanced scenario. By 2030 in the basic [R]evolution scenario jobs would fall back to 1.4 million (1.7 million in the advanced version). Under the Reference scenario, wind jobs reach only 0.5 million in 2015, and fall back to 0.4 million in 2030.

The effect of decline factors on wind power jobs is less marked, because the technology is further along the commercialisation path. If decline factors were not used, wind jobs would be 0.7 – 0.8 million higher in 2030 in the [R]evolution scenarios.

table 7.11: capacity, investment and direct jobs – wind

	UNIT	REFERENCE SCENARIO 2015	2020	2030	ENERGY [R]EVOLUTION SCENARIOS 2015 BASE	2015 ADVANCED	2020 BASE	2020 ADVANCED	2030 BASE	2030 ADVANCED
Energy parameters										
Installed capacity	GW	293	417	595	407	494	878	1,140	1,733	2,241
Generated electricity	TWh/a	677	1,009	1,536	941	1,165	2,168	2,849	4,539	5,872
Share of total supply	%	2.8%	3.7%	4.5%	4.0%	4.9%	8.4%	11.0%	15.1%	19.0%
Market & Investment										
Annual increase in capacity	GW/a	26	74	101	74	101	178	229	158	202
Annual investment	bill. $/a	42	32	92	90	122	101	126	209	266
Employment										
Direct jobs in construction manufaction, operation and maintenance		**0.5 m**	**0.4 m**	**0.4 m**	**1.7 m**	**2.3 m**	**1.5 m**	**2.0 m**	**1.4 m**	**1.7 m**

wave and tidal

The current cost of energy from tidal and wave energy projects has been estimated to be in the range of 15-55 cents/kWh, and for initial tidal stream farms in the range of 11-22 cents/kWh. For future plants, generation costs of 10-25cents/kWh are expected by 2020, with dynamic growth following the same pattern as wind energy.

Ocean energy, particularly offshore wave power, is a significant resource which could satisfy an important percentage of electricity supply worldwide. Globally, the potential for ocean energy has been estimated at enough to generate around 90,000 TWh/year. The most significant advantages are its vast availability and high predictability, plus technology with very low visual impact and no CO_2 emissions. Many different concepts and devices have been developed, with some at an advanced phase of research and development; large scale prototypes have been deployed in real sea conditions and some have reached pre-market deployment. A number of these are grid connected, fully operational generating plants.

Future areas for development will include concept design, optimisation of the device configuration, reduction of capital costs by exploring the use of alternative structural materials, economies of scale and learning from operation. According to the latest research findings, the learning factor is estimated to be 10-15% for offshore wave and 5-10% for tidal stream. In the medium term, ocean energy has the potential to become one of the most competitive and cost effective forms of generation. Present cost estimates are based on analysis from the European NEEDS project.

employment in wave and tidal energy Under the Reference scenario, this innovative clean technology would only employ approximately 1,000 people. Under the Energy [R]evolution projections, however, it would become a new entrant to the energy market, providing around 60,000 jobs in the basic scenario and 160,000 jobs in the advanced version by 2030.

geothermal

Geothermal power is considered to be a key element in future renewable energy supply. It has been used since the beginning of the last century for electricity generation, and even longer for supplying heat from below the earth. New intensive research and development work is widening the potential of sites that could be used to produce power. Specific new developments include large underground heat exchange surfaces (Enhanced Geothermal Systems) and the improvement of low temperature power conversion, for example with the Organic Rankine Cycle. The economics of geothermal electricity will also be improved by advanced heat and power cogeneration plants and further development of innovative drilling technology.

For conventional geothermal plants, costs are expected to drop from 7 cents/kWh to about 2 cents/kWh. Enhanced Geothermal Systems presently have high costs (about 20 cents/kWh), but these are expected to come down to around 5 cents/kWh in the long term, depending on the payments for heat supply. These price reductions assume a global average market growth for geothermal power capacity of 9% per year up to 2020, leveling out to 4% beyond 2030.

Geothermal energy has a non-fluctuating supply and a grid load operating almost 100% of the time. Until now we have just used a marginal part of the geothermal heating and cooling potential. Shallow geothermal drilling could deliver heating and cooling at any time anywhere, and can be used for thermal energy storage.

employment in geothermal energy Geothermal energy could contribute a significant proportion of the world's energy supply, quadrupling under the basic Energy [R]evolution scenario by 2030, and increasing 10-times in the advanced version, compared to the Reference scenario. This would correspond to triple the amount of jobs, around 120,000 (basic) and 270,000 (advanced) in 2030.

table 7.12: capacity, investment and direct jobs – ocean energy

		REFERENCE SCENARIO			ENERGY [R]EVOLUTION SCENARIOS					
	UNIT	2015	2020	2030	2015		2020		2030	
					BASE	ADVANCED	BASE	ADVANCED	BASE	ADVANCED
Energy parameters										
Installed capacity	GW	1	1	3	9	9	29	58	73	180
Generated electricity	TWh/a	2	3	11	13	13	53	119	128	420
Share of total supply	%	0.0%	0.0%	0.0%	0.1%	0.1%	0.2%	0.5%	0.4%	1.4%
Market & Investment										
Annual increase in capacity	GW/a	0	2	4	2	4	3	12	10	27
Annual investment	bill. $/a	0	1	1	10	20	11	30	22	50
Employment										
Direct jobs in construction manufaction, operation and maintenance		**0.001 m**	**0.001 m**	**0.002 m**	**0.05 m**	**0.12 m**	**0.04 m**	**0.12 m**	**0.06 m**	**0.16 m**

image THE BIOENERGY VILLAGE OF JUEHNDE, WHICH IS THE FIRST COMMUNITY IN GERMANY THAT PRODUCES ALL ITS ENERGY NEEDED FOR HEATING AND ELECTRICITY WITH CO_2 NEUTRAL BIOMASS.

table 7.13: capacity, investment and direct jobs – geothermal

		REFERENCE SCENARIO			ENERGY [R]EVOLUTION SCENARIOS					
	UNIT	2015	2020	2030	2015		2020		2030	
					BASE	ADVANCED	BASE	ADVANCED	BASE	ADVANCED
Energy parameters										
Installed capacity	GW	16	20	27	23	23	49	69	108	238
Generated electricity	TWh/a	99	123	176	140	145	300	432	695	1,526
Share of total supply	%	0.4%	0.5%	0.5%	0.6%	0.6%	1.2%	1.7%	2.3%	4.9%
Market & Investment										
Annual increase in capacity	GW/a	1	10	11	4	5	10	22	6	11
Annual investment	bill. $/a	10	9	25	28	48	30	108	64	162
Employment										
Direct jobs in construction manufaction, operation and maintenance		**0.02 m**	**0.02 m**	**0.02 m**	**0.07 m**	**0.10 m**	**0.09 m**	**0.18 m**	**0.12 m**	**0.27 m**

biomass

There is a broad spectrum of energy generation costs for biomass, reflecting the different feedstocks used. Costs range from a negative cost (or credit) for some waste woods to low cost for residual materials and then to more expensive energy crops. Using waste wood in steam turbine/combined heat and power (CHP) plants is one of the cheapest options. Gasification of solid biomass has a wide range of applications but is still relatively expensive.

In the long term it is expected that using wood generated gas both in micro-CHP units (engines and fuel cells) and in gas-and-steam power plants will be economically favorable. There is good potential to use solid biomass for heat generation in both small and large heating centers linked to local heating networks. In recent years converting crops into ethanol and 'bio diesel' made from rapeseed methyl ester (RME) has become increasingly important, for example in Brazil, the USA and Europe. Processes for obtaining synthetic fuels from biogenic synthesis gases will also play a larger role.

Latin and North America, Europe and the Transition Economies all have the potential to exploit modern technologies either in stationary appliances or the transport sector. In the long term, Europe and the Transition Economies will realise 20-50% of the potential for biomass from energy crops, whilst biomass use in all the other regions will have to rely on forest residues, industrial wood waste and straw. In Latin America, North America and Africa in particular, an increasing residue potential will be available.

In other regions, such as the Middle East and all Asian regions, the additional use of biomass is restricted, either due to a generally low availability or already high traditional use. For the latter a cleaner option is to use modern, more efficient technologies, improving sustainability and avoiding the current negative effects of indoor pollution and heavy workloads to transport the fuel.

employment in the biomass industry Biomass power could be supporting 2.1 million jobs in 2030 under both Energy [R]evolution scenarios, compared to less than 1 million in the Reference scenario.

table 7.14: capacity, investment and direct jobs – biomass

		REFERENCE SCENARIO			ENERGY [R]EVOLUTION SCENARIOS					
	UNIT	2015	2020	2030	2015		2020		2030	
					BASE	ADVANCED	BASE	ADVANCED	BASE	ADVANCED
Energy parameters										
Installed capacity	GW	71	88	140	115	115	212	214	336	343
Generated electricity	TWh/a	409	523	839	619	617	1,112	1,134	1,858	1,906
Share of total supply	%	1.7%	1.9%	2.4%	2.6%	2.6%	4.3%	4.4%	6.2%	6.2%
Market & Investment										
Annual increase in capacity	GW/a	4	34	29	17	18	34	35	30	29
Annual investment	bill. $/a	8	12	26	10	10	8	8	23	24
Employment										
Direct jobs in construction manufaction, operation and maintenance		**0.5 m**	**0.6 m**	**0.9 m**	**1.0 m**	**1.0 m**	**1.5 m**	**1.5 m**	**2.1 m**	**2.1 m**

fossil fuels and nuclear

An understanding of the international coal trade and the decreasing labour intensity of coal mining is essential to make projections for how a switch to renewable energy will affect energy sector jobs around the world. The full report for the 2009 employment study by the Institute for Sustainable Futures (Rutovitz and Atherton, 2009) provides detail of all the methodology to calculate employment related to coal-fired electricity generation.

The global trend for energy production from coal is for bigger mines that employ fewer people. China, for example, is expected to close at least 10,000 small mines and develop 16 'super mines' that will produce an average of 70 million tonnes per year each. Compared with a miner in a traditional rural Chinese mine, who produces 100 tonnes per year, a single worker in one of the large super mines is expected to produce 30,000 tonnes per year. Examples of average production in other countries is 14,000 tonnes per year in the US and 13,800 tonnes per year in Australia.

coal Under the Reference scenario jobs in coal fall by 6% from 2010 to 2020, and then stay virtually static from 2015 to 2030, despite a 40% increase in power generation. The main reasons are:

- Jobs per MW across all technologies falls as prosperity and labour productivity increases. In the model, regional job multipliers are applied to OECD employment factors in non-OECD regions to reflect this. The regional multipliers are higher in the early years and decrease over the study period as the difference between labour productivity in the OECD and other regions falls. As labour productivity reaches a par with OECD countries, employment per MW falls to OECD levels. If no regional multiplier is used in the model, coal employment at 2020 would be predicted to increase by 4% rather than decrease by 6% relative to 2010. That would model a future where China's projected rapid increase in prosperity and labour productivity does not occur.
- The decline factors applied to each technology reflect the reduction in costs. An annual decline of 0.3% is applied between 2010 and 2020 and 0.2% between 2020 and 2030. This relatively low annual decline does not affect coal sector employment substantially. If no decline factors are used then coal employment falls by 3% rather than 4% between 2010 and 2020.

Under the Energy [R]evolution scenario, growth in coal generating capacity is almost zero. By 2030 there is a slight fall in coal capacity, so there would be a corresponding reduction in coal sector jobs. The result is that installation and manufacturing jobs in the coal sector fall to almost zero. Under the advanced version there would be no growth in coal capacity up to 2015 and a decline immediately afterwards. By 2030, coal capacity contributes only 15% of global energy supply, a fall reflected in the reduced number of jobs. As the scenarios emphasise, however, any losses are offset by very high growth in employment in renewable energy, which would not occur if coal is allowed to continue to dominate the global energy mix.

gas, oil/diesel and nuclear

- For gas, global employment is between 1.5 million and 1.7 million jobs between 2015 and 2020 in all scenarios. Under the Energy [R]evolution, gas plays an important role as a transition fuel, so the same amount of employees are needed as under business as usual. By 2030, however, there are 1.7 million gas jobs in the reference case, with around 300,000 less in the basic Energy [R]evolution scenario (500,000 less in the Advanced scenario). This is because the transition to renewable energy is accelerated in these scenarios due to the requirement to cut greenhouse gas emissions as fast as possible after 2015.
- For nuclear, annual investment would drop to zero by 2030 in both Energy [R]evolution scenarios, with a corresponding sharp decline in employment in the nuclear sector.

table 7.15: capacity, investment and direct jobs – coal

	UNIT	REFERENCE SCENARIO 2015	2020	2030	ENERGY [R]EVOLUTION SCENARIOS 2015 BASE	2015 ADVANCED	2020 BASE	2020 ADVANCED	2030 BASE	2030 ADVANCED
Energy parameters										
Installed capacity	GW	1,604	1,836	2,465	1,480	1,430	1,430	1,308	1,410	954
Generated electricity	TWh/a	8,752	10,117	13,756	7,938	7,716	7,700	6,989	7,269	4,829
Share of total supply	%	35.9%	37.1%	40.1%	33.4%	32.4%	29.8%	27.0%	24.1%	15.6%
Market & Investment										
Annual increase in capacity	GW/a	47	63		-	-	-	-	-	-
Annual investment	bill. $/a	104	107	280	56	44	27	10	25	8
Employment										
Direct jobs in construction manufaction, operation and maintenance		**3.9 m**	**4.1 m**	**4.2 m**	**3.4 m**	**3.2 m**	**3.1 m**	**2.8 m**	**2.7 m**	**2.1 m**

table 7.16: capacity, investment and direct jobs – gas, oil, diesel and nuclear

	REFERENCE SCENARIO 2015	2020	2030	ENERGY [R]EVOLUTION SCENARIOS 2015 BASE	2015 ADVANCED	2020 BASE	2020 ADVANCED	2030 BASE	2030 ADVANCED
Jobs									
Gas, oil & diesel	1.51 m	1.59 m	1.74 m	1.67 m	1.63 m	1.40 m	1.59 m	1.49 m	1.23 m
Nuclear	0.33 m	0.29 m	0.29 m	0.17 m	0.10 m	0.04 m	0.17 m	0.10 m	0.04 m
Total jobs	**1.84 m**	**1.88 m**	**2.03 m**	**1.84 m**	**1.73 m**	**1.43 m**	**1.76 m**	**1.59 m**	**1.26 m**

energy resources & security of supply

8

AROUND 80% OF GLOBAL ENERGY DEMAND IS MET BY FINITE FOSSIL FUELS. © R. KASPRZAK/DREAMSTIME

“the issue of security of supply is now at the top of the energy policy agenda.”

GREENPEACE INTERNATIONAL
CLIMATE CAMPAIGN

The issue of security of supply is now at the top of the energy policy agenda. Concern is focused both on price security and the security of physical supply. At present around 80% of global energy demand is met by fossil fuels. The unrelenting increase in energy demand is matched by the finite nature of these resources. At the same time, the global distribution of oil and gas resources does not match the distribution of demand. Some countries have to rely almost entirely on fossil fuel imports. The maps on the following pages provide an overview of the availability of different fuels and their regional distribution. Information in this chapter is based partly on the report 'Plugging the Gap'[61], as well as information from the International Energy Agency's World Energy Outlook 2008 and 2009 reports.

status of global fuel supplies

Oil is the lifeblood of the modern global economy, as the effects of the supply disruptions of the 1970s made clear. It is the number one source of energy, providing 32% of the world's needs and the fuel employed almost exclusively for essential uses such as transportation. However, a passionate debate has developed over the ability of supply to meet increasing consumption, a debate obscured by poor information and stirred by recent soaring prices.

the reserves chaos

Public data about oil and gas reserves is strikingly inconsistent, and potentially unreliable for legal, commercial, historical and sometimes political reasons. The most widely available and quoted figures, those from the industry journals *Oil & Gas Journal and World Oil*, have limited value as they report the reserve figures provided by companies and governments without analysis or verification. Moreover, as there is no agreed definition of reserves or standard reporting practice, these figures usually stand for different physical and conceptual magnitudes. Confusing terminology - 'proved', 'probable', 'possible', 'recoverable', 'reasonable certainty' - only adds to the problem.

Historically, private oil companies have consistently underestimated their reserves to comply with conservative stock exchange rules and through natural commercial caution. Whenever a discovery was made, only a portion of the geologist's estimate of recoverable resources was reported; subsequent revisions would then increase the reserves from that same oil field over time. National oil companies, mostly represented by OPEC (Organisation of Petroleum Exporting Countries), have taken a very different approach. They are not subject to any sort of accountability and their reporting practices are even less clear. In the late 1980s, the OPEC countries blatantly overstated their reserves while competing for production quotas, which were allocated as a proportion of the reserves. Although some revision was needed after the companies were nationalised, between 1985 and 1990, OPEC countries increased their apparent joint reserves by 82%. Not only were these dubious revisions never corrected, but many of these countries have reported untouched reserves for years, even if no sizeable discoveries were made and production continued at the same pace. Additionally, the Former Soviet Union's oil and gas reserves have been overestimated by about 30% because the original assessments were later misinterpreted.

Whilst private companies are now becoming more realistic about the extent of their resources, the OPEC countries hold by far the majority of the reported reserves, and their information is as unsatisfactory as ever. Their conclusions should therefore be treated with considerable caution. To fairly estimate the world's oil resources a regional assessment of the mean backdated (i.e. 'technical') discoveries would need to be performed.

non-conventional oil reserves

A large share of the world's remaining oil resources is classified as 'non-conventional'. Potential fuel sources such as oil sands, extra heavy oil and oil shale are generally more costly to exploit and their recovery involves enormous environmental damage. The reserves of oil sands and extra heavy oil in existence worldwide are estimated to amount to around 6 trillion barrels, of which between 1 and 2 trillion barrels are believed to be recoverable if the oil price is high enough and the environmental standards low enough.

One of the worst examples of environmental degradation resulting from the exploitation of unconventional oil reserves is the oil sands that lie beneath the Canadian province of Alberta and form the world's second-largest proven oil reserves after Saudi Arabia. Producing crude oil from these 'tar sands' - a heavy mixture of bitumen, water, sand and clay found beneath more than 54,000 square miles[62] of prime forest in northern Alberta, an area the size of England and Wales - generates up to four times more carbon dioxide, the principal global warming gas, than conventional drilling. The booming oil sands industry will produce 100 million tonnes of CO_2 a year (equivalent to a fifth of the UK's entire annual emissions) by 2012, ensuring that Canada will miss its emission targets under the Kyoto treaty. The oil rush is also scarring a wilderness landscape: millions of tonnes of plant life and top soil are scooped away in vast opencast mines and millions of litres of water diverted from rivers. Up to five barrels of water are needed to produce a single barrel of crude and the process requires huge amounts of natural gas. It takes two tonnes of the raw sands to produce a single barrel of oil.

gas

Natural gas has been the fastest growing fossil energy source over the last two decades, boosted by its increasing share in the electricity generation mix. Gas is generally regarded as an abundant resource and public concerns about depletion are limited to oil, even though few in-depth studies address the subject. Gas resources are more concentrated, and a few massive fields make up most of the reserves. The largest gas field in the world holds 15% of the Ultimate Recoverable Resources (URR), compared to 6% for oil. Unfortunately, information about gas resources suffers from the same bad practices as oil data because gas mostly comes from the same geological formations, and the same stakeholders are involved.

61 'PLUGGING THE GAP - A SURVEY OF WORLD FUEL RESOURCES AND THEIR IMPACT ON THE DEVELOPMENT OF WIND ENERGY', GLOBAL WIND ENERGY COUNCIL/RENEWABLE ENERGY SYSTEMS, 2006.
62 *THE INDEPENDENT*, 10 DECEMBER 2007

image PLATFORM/OIL RIG DUNLIN IN THE NORTH SEA SHOWING OIL POLLUTION.

image ON A LINFEN STREET, TWO MEN LOAD UP A CART WITH COAL THAT WILL BE USED FOR COOKING. LINFEN, A CITY OF ABOUT 4.3 MILLION, IS ONE OF THE MOST POLLUTED CITIES IN THE WORLD. CHINA'S INCREASINGLY POLLUTED ENVIRONMENT IS LARGELY A RESULT OF THE COUNTRY'S RAPID DEVELOPMENT AND CONSEQUENTLY A LARGE INCREASE IN PRIMARY ENERGY CONSUMPTION, WHICH IS ALMOST ENTIRELY PRODUCED BY BURNING COAL.

Most reserves are initially understated and then gradually revised upwards, giving an optimistic impression of growth. By contrast, Russia's reserves, the largest in the world, are considered to have been overestimated by about 30%. Owing to geological similarities, gas follows the same depletion dynamic as oil, and thus the same discovery and production cycles. In fact, existing data for gas is of worse quality than for oil, with ambiguities arising over the amount produced, partly because flared and vented gas is not always accounted for. As opposed to published reserves, the technical ones have been almost constant since 1980 because discoveries have roughly matched production.

shale gas[63]

Natural gas production, especially in the United States, has recently involved a growing contribution from non-conventional gas supplies such as shale gas. Conventional natural gas deposits have a well-defined geographical area, the reservoirs are porous and permeable, the gas is produced easily through a wellbore and does not generally require artificial stimulation. Non-conventional deposits, on the other hand, are often lower in resource concentration, more dispersed over large areas and require well stimulation or some other extraction or conversion technology. They are also usually more expensive to develop per unit of energy.

Research and investment in non-conventional gas resources has increased significantly in recent years due to the rising price of conventional natural gas. In some areas the technologies for economic production have already been developed, in others it is still at the research stage. Extracting shale gas, however, usually goes hand in hand with environmentally hazardous processes. Even so, it is expected to increase.

coal

Coal was the world's largest source of primary energy until it was overtaken by oil in the 1960s. Today, coal supplies almost one quarter of the world's energy. Despite being the most abundant of fossil fuels, coal's development is currently threatened by environmental concerns; hence its future will unfold in the context of both energy security and global warming.

Coal is abundant and more equally distributed throughout the world than oil and gas. Global recoverable reserves are the largest of all fossil fuels, and most countries have at least some. Moreover, existing and prospective big energy consumers like the US, China and India are self-sufficient in coal and will be for the foreseeable future. Coal has been exploited on a large scale for two centuries, so both the product and the available resources are well known; no substantial new deposits are expected to be discovered. Extrapolating the demand forecast forward, the world will consume 20% of its current reserves by 2030 and 40% by 2050. Hence, if current trends are maintained, coal would still last several hundred years.

table 8.1: overview of fossil fuel reserves and resources

RESERVES, RESOURCES AND ADDITIONAL OCCURRENCES OF FOSSIL ENERGY CARRIERS ACCORDING TO DIFFERENT AUTHORS. **C** CONVENTIONAL (PETROLEUM WITH A CERTAIN DENSITY, FREE NATURAL GAS, PETROLEUM GAS, **NC** NON-CONVENTIONAL) HEAVY FUEL OIL, VERY HEAVY OILS, TAR SANDS AND OIL SHALE, GAS IN COAL SEAMS, AQUIFER GAS, NATURAL GAS IN TIGHT FORMATIONS, GAS HYDRATES). THE PRESENCE OF ADDITIONAL OCCURRENCES IS ASSUMED BASED ON GEOLOGICAL CONDITIONS, BUT THEIR POTENTIAL FOR ECONOMIC RECOVERY IS CURRENTLY VERY UNCERTAIN. IN COMPARISON: IN 1998, THE GLOBAL PRIMARY ENERGY DEMAND WAS 402EJ (UNDP ET AL., 2000).

ENERGY CARRIER		WEO 2009, WEO 2008, WEO 2007 EJ	BROWN, 2002 EJ	IEA, 2002c EJ		IPCC, 2001a EJ		NAKICENOVIC ET AL., 2000 EJ		UNDP ET AL., 2000 EJ		BGR, 1998 EJ
Gas	reserves	182 tcm[a]	5,600	6,200	c	5,400	c	5,900	c	5,500	c	5,300
					nc	8,000	nc	8,000	nc	9,400	nc	100
	resources	405 tcm[a]	9,400	11,100	c	11,700	c	11,700	c	11,100	c	7,800
					nc	10,800	nc	10,800	nc	23,800	nc[d]	111,900
	additional occurrences	921 tcm[a]				796,000		799,700		930,000		
Oil	reserves	2,369 bb[b]	5,800	5,700	c	5,900	c	6,300	c	6,000	c	6,700
					nc	6,600	nc	8,100	nc	5,100	nc	5,900
	resources		10,200	13,400	c	7,500	c	6,100	c	6,100	c	3,300
					nc	15,500	nc	13,900	nc	15,200	nc	25,200
	additional occurrences					61,000		79,500		45,000		
Coal	reserves	847 bill tonnes[c]	23,600	22,500		42,000		25,400		20,700		16,300
	resources		26,000	165,000		100,000		117,000		179,000		179,000
	additional occurrences	921 tcm[c]				121,000		125,600				
Total resource (reserves + resources)			**180,600**	**223,900**		**212,200**		**213,200**		**281,900**		**361,500**
Total occurrence						**1,204,200**		**1,218,000**		**1,256,000**		

sources & notes A) WEO 2009, B) OIL WEO 2008, PAGE 205 TABLE 9.1 C) IEA WEO 2008, PAGE 127 & WEC 2007. D) INCLUDING GAS HYDRATES. SEE TABLE FOR ALL OTHER SOURCES.

63 INTERSTATE NATURAL GAS ASSOCIATION OF AMERICA (INGAA), "AVAILABILITY, ECONOMICS AND PRODUCTION POTENTIAL OF NORTH AMERICAN UNCONVENTIONAL NATURAL GAS SUPPLIES", NOVEMBER 2008

map 8.1: oil reference scenario and the advanced energy [r]evolution scenario

WORLDWIDE SCENARIO

OECD NORTH AMERICA

		REF		E[R]	
		TMB	%	TMB	%
Reserves	2007	69.3	5.6%	69.3	5.6%
		MB	PJ	MB	PJ
Consumption per region	2007	7,429H	45,466H	7,429H	45,466H
	2050	6,594H	40,352H	1,225	7,494
		L		L	
Consumption per person	2007	2,707H		2,707H	
	2050	1,816H		337	

LATIN AMERICA

		REF		E[R]	
		TMB	%	TMB	%
Reserves	2007	111.2	9.0%	111.2	9.0%
		MB	PJ	MB	PJ
Consumption per region	2007	1,691	10,349	1,691	10,349
	2050	2,597	15,895	292	1,788
		L		L	
Consumption per person	2007	598		598	
	2050	653		73	

NON RENEWABLE RESOURCE

OIL

LEGEND

>60 | 50-60 | 40-50 | 30-40 | 20-30 | 10-20 | 5-10 | 0-5 % RESOURCES GLOBALLY

REF REFERENCE SCENARIO

E[R] ADVANCED ENERGY [R]EVOLUTION SCENARIO

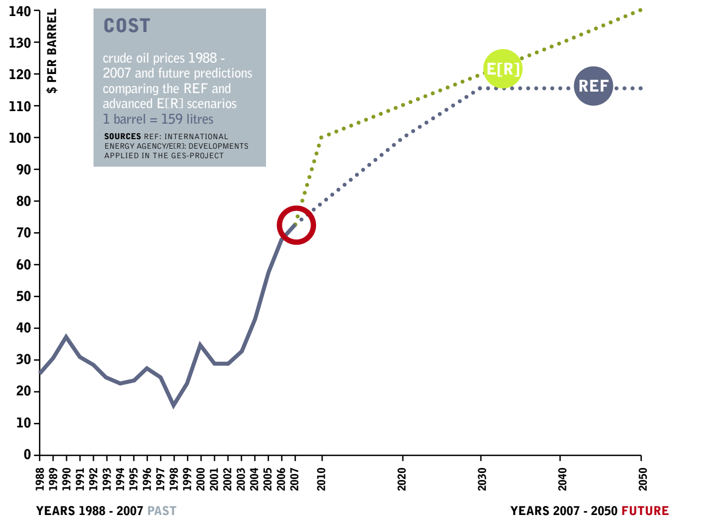
0 1000 KM

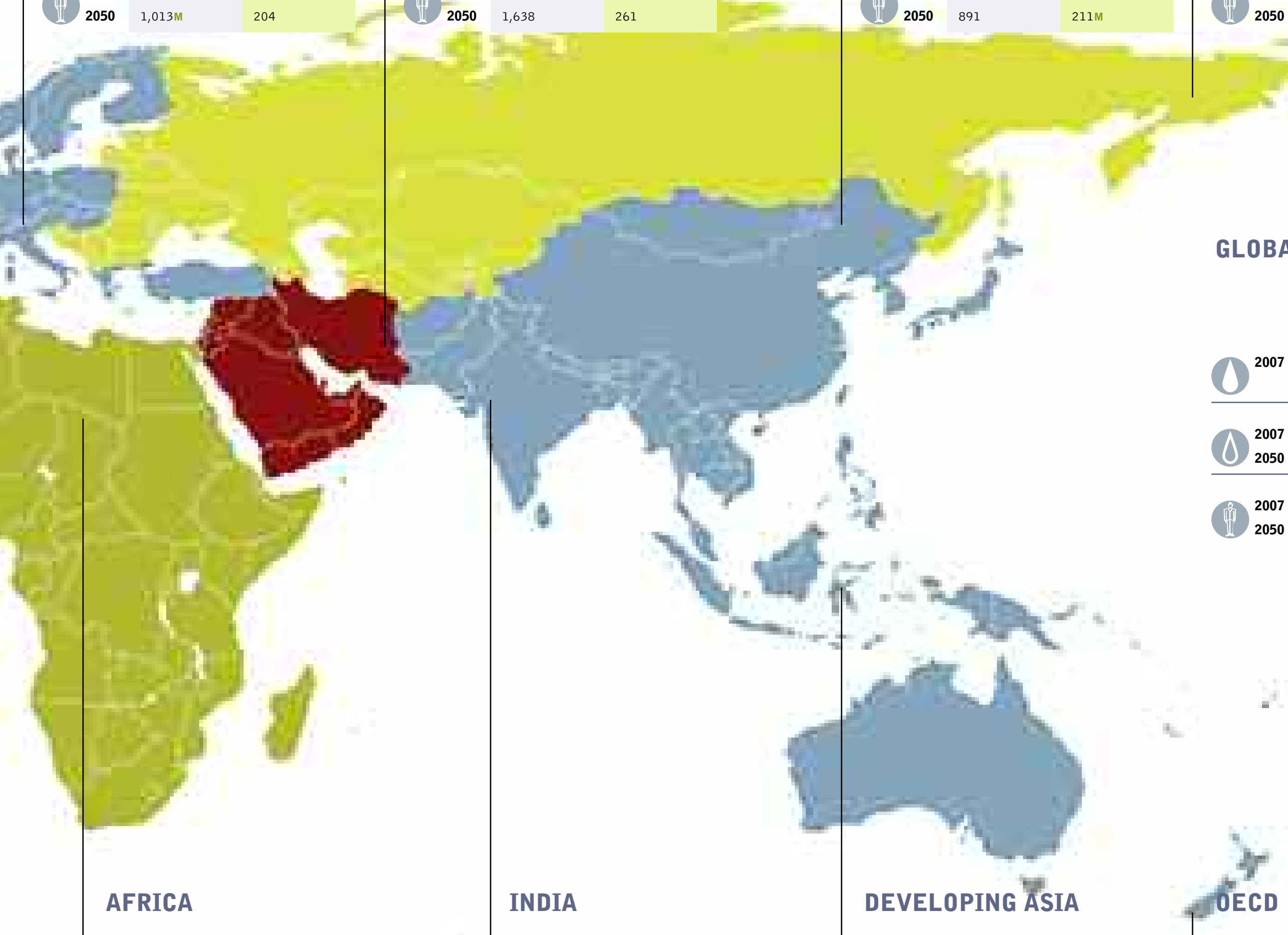
RESERVES TOTAL THOUSAND MILLION BARRELS [TMB] | SHARE IN % OF GLOBAL TOTAL [END OF 2007]

CONSUMPTION PER REGION MILLION BARRELS [MB] | PETA JOULE [PJ]

CONSUMPTION PER PERSON LITERS [L]

H HIGHEST | M MIDDLE | L LOWEST





OECD EUROPE

		REF		E[R]	
		TMB	%	TMB	%
	2007	16.9	1.4%M	16.9	1.4%M
		MB	PJ	MB	PJ
	2007	4,337	26,541	4,337	4,418
	2050	3,590M	21,970M	722M	9,361M
		L		L	
	2007	1,285		1,285	
	2050	1,013M		204	

MIDDLE EAST

		REF		E[R]	
		TMB	%	TMB	%
	2007	755.3H	61.0%H	755.3H	61.0%H
		MB	PJ	MB	PJ
	2007	1,913	11,709	1,913	11,709
	2050	3,574	21,871	569	3,482
		L		L	
	2007	1,617		1,617	
	2050	1,638		261	

CHINA

		REF		E[R]	
		TMB	%	TMB	%
	2007	15.5	1.3%	15.5	1.3%
		MB	PJ	MB	PJ
	2007	2,445	14,966	2,445	14,966
	2050	7,946	48,629	1,881H	11,513H
		L		L	
	2007	294		294	
	2050	891		211M	

TRANSITION ECONOMIES

		REF		E[R]	
		TMB	%	TMB	%
	2007	87.6	10.1%L	87.6	10.1%L
		MB	PJ	MB	PJ
	2007	1,605	9,826	1,605	9,826
	2050	1,953L	11,955L	441L	2,701L
		L		L	
	2007	748M		748M	
	2050	1,057		239	

GLOBAL

		REF		E[R]	
		TMB	%	TMB	%
	2007	1,199	100%	1,199	100%
		MB	PJ	MB	PJ
	2007	25,477	155,919	25,477	155,919
	2050	36,762	224,981	8,459	51,770
		L		L	
	2007	623		623	
	2050	637		147	

AFRICA

		REF		E[R]	
		TMB	%	TMB	%
	2007	117.5M	9.5%	117.5M	9.5%
		MB	PJ	MB	PJ
	2007	924	5,654	924	5,654
	2050	1,667	10,202	689	4,214
		L		L	
	2007	159		159	
	2050	133L		55L	

INDIA

		REF		E[R]	
		TMB	%	TMB	%
	2007	5.5	0.5%	5.5	0.5%
		MB	PJ	MB	PJ
	2007	1,011L	6,187L	1,011	6,187
	2050	3,669	22,455	1,169	7,152
		L		L	
	2007	142L		142L	
	2050	352		112	

DEVELOPING ASIA

		REF		E[R]	
		TMB	%	TMB	%
	2007	14.8	1.2%	14.8	1.2%
		MB	PJ	MB	PJ
	2007	1,656	10,136	1,656	10,136
	2050	3,448	21,099	1,014	6,204
		L		L	
	2007	270		270	
	2050	365		107	

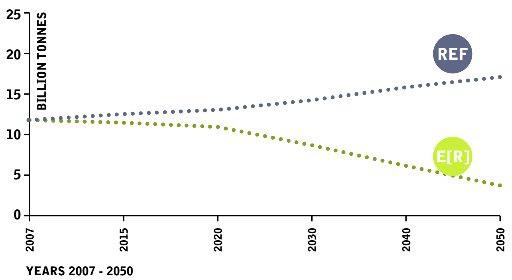
OECD PACIFIC

		REF		E[R]	
		TMB	%	TMB	%
	2007	5.1L	0.4%	5.1L	0.4%
		MB	PJ	MB	PJ
	2007	2,465M	15,089M	2,465	15,086
	2050	1,724	10,552	458	2,805
		L		L	
	2007	1,958		1,958	
	2050	1,539		409H	

CO_2 EMISSIONS FROM OIL

comparison between the REF and advanced E[R] scenarios 2007 - 2050 billion tonnes

SOURCE GPI/EREC

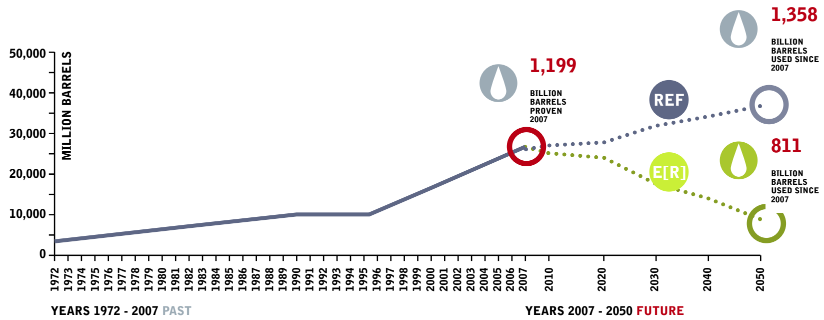


RESERVES AND CONSUMPTION

oil reserves versus global demand, production and consumption. global consumption comparison between the REF and advanced E[R] scenarios.

million barrels. 1 barrel = 159 litres

SOURCE BP 2008



map 8.2: gas reference scenario and the advanced energy [r]evolution scenario

WORLDWIDE SCENARIO

OECD NORTH AMERICA

		REF		E[R]	
		tn m³	%	tn m³	%
Reserves	2007	8.0	4.4%	8.0	4.4%
		bn m³	PJ	bn m³	PJ
Consumption per region	2007	722H	27,435H	722H	27,435H
	2050	767H	29,144H	71H	2,688H
		m³		m³	
Consumption per person	2007	1,608		1,608	
	2050	1,328		123	

LATIN AMERICA

		REF		E[R]	
		tn m³	%	tn m³	%
Reserves	2007	7.7	4.3%	7.7	4.3%
		bn m³	PJ	bn m³	PJ
Consumption per region	2007	117	4,465	117	4,465
	2050	246M	9,358M	34	1,303
		m³		m³	
Consumption per person	2007	254		254	
	2050	410		57	

NON RENEWABLE RESOURCE

GAS

LEGEND

>50 | 40-50 | 30-40 | 20-30 | 10-20 | 5-10 | 0-5 % RESOURCES GLOBALLY

REF REFERENCE SCENARIO

E[R] ADVANCED ENERGY [R]EVOLUTION SCENARIO

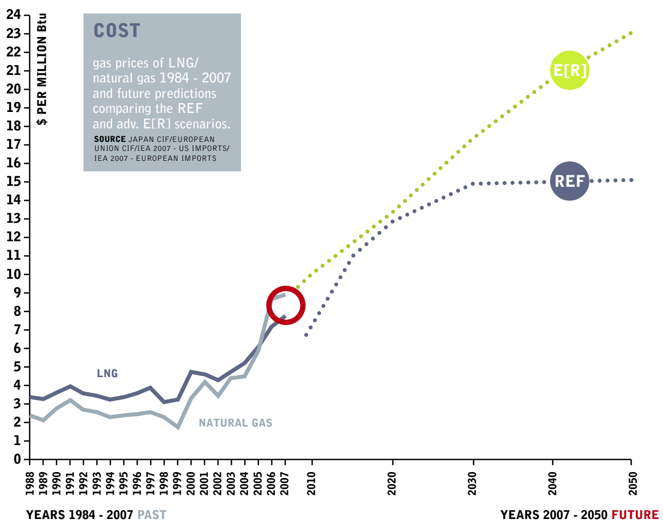
0 1000 KM

RESERVES TOTAL TRILLION CUBIC METRES [tn m³] | SHARE IN % OF GLOBAL TOTAL [END OF 2007]

CONSUMPTION PER REGION BILLION CUBIC METRES [bn m³] | PETA JOULE [PJ]

CONSUMPTION PER PERSON CUBIC METRES [m³]

H HIGHEST | **M** MIDDLE | **L** LOWEST



OECD EUROPE

	REF		E[R]	
	tn m³	%	tn m³	%
2007	9.8	5.4%	9.8	5.4%
	bn m³	PJ	bn m³	PJ
2007	504	19,170	504	19,170
2050	644	24,469	69	2,613
	m³		m³	
2007	934		934	
2050	1,120M		120	

MIDDLE EAST

	REF		E[R]	
	tn m³	%	tn m³	%
2007	73.2H	40.4%H	73.2H	40.4%H
	bn m³	PJ	bn m³	PJ
2007	238M	9,056M	239	9,056
2050	685	26,034	74	2,805
	m³		m³	
2007	1,178		1,178	
2050	1,939		209M	

CHINA

	REF		E[R]	
	tn m³	%	tn m³	%
2007	1.9	1.0%	1.9	1.0%
	bn m³	PJ	bn m³	PJ
2007	71	2,716	71	2,716
2050	341	12,953	212	8,061
	m³		m³	
2007	54		54	
2050	239		149	

TRANSITION ECONOMIES

	REF		E[R]	
	tn m³	%	tn m³	%
2007	53.3	29.4%	53.3	29.4%
	bn m³	PJ	bn m³	PJ
2007	638	24,225	638	24,225
2050	776	29,478	138	5,248
	m³		m³	
2007	1,874H		1,874H	
2050	2,496H		444H	

GLOBAL

	REF		E[R]	
	tn m³	%	tn m³	%
2007	181	100%	181	100%
	bn m³	PJ	bn m³	PJ
2007	2,759	104,846	2,759	104,846
2050	4,381	166,489	902	34,285
	m³		m³	
2007	424		424	
2050	478		99	

AFRICA

	REF		E[R]	
	tn m³	%	tn m³	%
2007	14.6M	8.0%M	14.6M	8.0%M
	bn m³	PJ	bn m³	PJ
2007	91	3,472	91	3,472
2050	167	6,338	65	2,456
	m³		m³	
2007	95		95	
2050	83		32L	

INDIA

	REF		E[R]	
	tn m³	%	tn m³	%
2007	1.1L	0.6%L	1.1L	0.6%L
	bn m³	PJ	bn m³	PJ
2007	37L	1,397L	37L	1,397L
2050	164L	6,227L	107M	4,075M
	m³		m³	
2007	32L		32L	
2050	102L		66	

DEVELOPING ASIA

	REF		E[R]	
	tn m³	%	tn m³	%
2007	8.6	4.8%	8.6	4.8%
	bn m³	PJ	bn m³	PJ
2007	184	6,998	184	6,998
2050	422	16,020	115	4,368
	m³		m³	
2007	182		182	
2050	278		76	

OECD PACIFIC

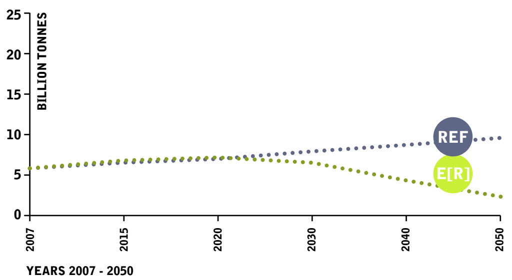
	REF		E[R]	
	tn m³	%	tn m³	%
2007	2.9	1.6%	2.9	1.6%
	bn m³	PJ	bn m³	PJ
2007	156	5,912	156	5,912
2050	170	6,467	18L	667L
	m³		m³	
2007	776M		776M	
2050	946		98	

CO_2 EMISSIONS FROM GAS

comparison between the REF and adv. E[R] scenarios 2007 - 2050

billion tonnes

SOURCE GPI/EREC



RESERVES AND CONSUMPTION

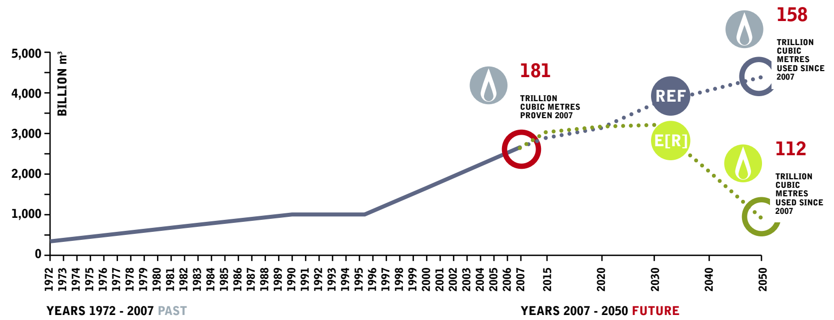
gas reserves versus global demand, production and consumption. global consumption comparison between the REF and advanced E[R] scenarios.

billion cubic metres

SOURCE 1970-2008 BP, 2007-2050 GPI/EREC

REF global consumption

ADV E[R] global consumption



map 8.3: coal reference scenario and the advanced energy [r]evolution scenario

WORLDWIDE SCENARIO

OECD NORTH AMERICA

		REF		E[R]	
		mn t	%	mn t	%
Reserves	2007	250,510	29.6%	250,510	29.6%
		mn t	PJ	mn t	PJ
Consumption per region	2007	1,882	24,923	1,882	24,923
	2050	1,351	27,255	6	134
		t		t	
Consumption per person	2007	2.4		2.4	
	2050	2.0		0.0	

LATIN AMERICA

		REF		E[R]	
		mn t	%	mn t	%
Reserves	2007	16,276	1.9%	16,276	1.9%
		mn t	PJ	mn t	PJ
Consumption per region	2007	45	891	45	891
	2050	165	3,122	11	247
		t		t	
Consumption per person	2007	0.1		0.1	
	2050	0.2		0.0	

NON RENEWABLE RESOURCE

COAL

LEGEND

>60 | 50-60 | 40-50 | 30-40 | 20-30 | 10-20 | 5-10 | 0-5 % RESOURCES GLOBALLY

REF REFERENCE SCENARIO

E[R] ADVANCED ENERGY [R]EVOLUTION SCENARIO

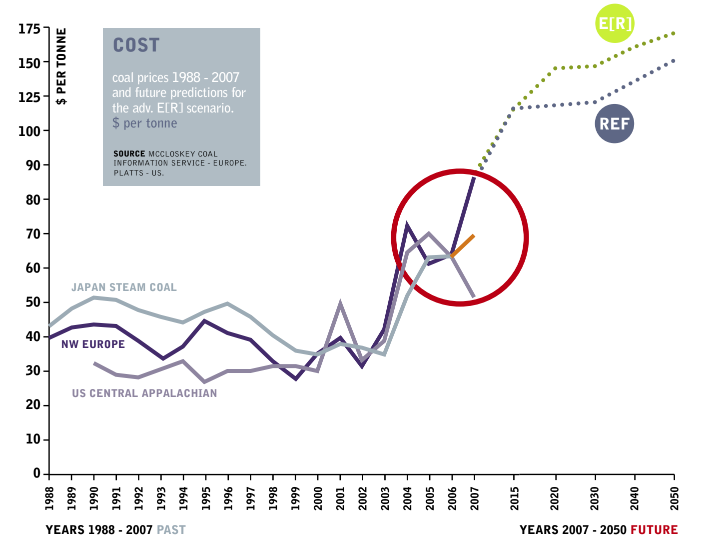
0 1000 KM

RESERVES TOTAL MILLION TONNES [mn t] | SHARE IN % OF GLOBAL TOTAL [END OF 2007]

CONSUMPTION PER REGION MILLION TONNES [mn t] | PETA JOULE [PJ]

CONSUMPTION PER PERSON TONNES [t]

H HIGHEST | M MIDDLE | L LOWEST



OECD EUROPE

	REF		E[R]	
	mn t	%	mn t	%
2007	50,063	5.9%	50,063	5.9%
	mn t	PJ	mn t	PJ
2007	897	14,371	897	14,371
2050	710	11,899	10	231
	t		t	
2007	1.2		1.2	
2050	0.9		0.0	

MIDDLE EAST

	REF		E[R]	
	mn t	%	mn t	%
2007	1,386	0.2%L	1,386	0.2%L
	mn t	PJ	mn t	PJ
2007	19L	437L	19	437
2050	91L	2,092L	1L	13
	t		t	
2007	0.0L		0.0	
2050	0.2L		0.0	

CHINA

	REF		E[R]	
	mn t	%	mn t	%
2007	114,500	13.5%	114,500	13.5%
	mn t	PJ	mn t	PJ
2007	2,403H	55,333H	2,403	55,333
2050	4,148H	95,527H	218H	5,027H
	t		t	
2007	1.8		1.8	
2050	2.9H		0.2H	

TRANSITION ECONOMIES

	REF		E[R]	
	mn t	%	mn t	%
2007	222,183	26%	222,183	26%
	mn t	PJ	mn t	PJ
2007	532	9,003	532	9,003
2050	904	13,665	14	327
	t		t	
2007	1.1		1.1	
2050	1.9M		0.0	

GLOBAL

	REF		E[R]	
	mn t	%	mn t	%
2007	846,496	100%	846,496	100%
	mn t	PJ	mn t	PJ
2007	7,319	135,890	7,319	135,890
2050	10,751	225,244	326	7,501
	t		t	
2007	0.9		0.9	
2050	1.1		0.0	

AFRICA

	REF		E[R]	
	mn t	%	mn t	%
2007	49,605	5.9%	49,605	5.9%
	mn t	PJ	mn t	PJ
2007	188	4,330	188	4,330
2050	303	6,977	19	427
	t		t	
2007	0.2		0.2	
2050	0.2		0.0	

INDIA

	REF		E[R]	
	mn t	%	mn t	%
2007	56,498	6.7%M	56,498	6.7%M
	mn t	PJ	mn t	PJ
2007	459	10,126	459	10,126
2050	1,692	36,709	37	851
	t		t	
2007	0.4		0.4	
2050	1.0		0.0	

DEVELOPING ASIA

	REF		E[R]	
	mn t	%	mn t	%
2007	7,814	0.9%	7,814	0.9%
	mn t	PJ	mn t	PJ
2007	330	5,824	330	5,824
2050	868M	17,902	9	217
	t		t	
2007	0.3		0.3	
2050	0.5		0.0	

OECD PACIFIC

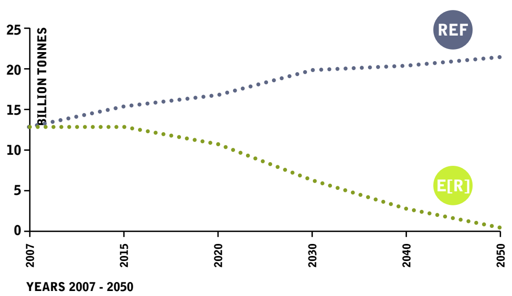
	REF		E[R]	
	mn t	%	mn t	%
2007	77,661	9%	77,661	9%
	mn t	PJ	mn t	PJ
2007	565	10,652	565	10,652
2050	518	10,097	1L	27
	t		t	
2007	2.3		2.3	
2050	2.4		0.0	

CO_2 EMISSIONS FROM COAL

comparison between the REF and adv. E[R] scenarios 2007 - 2050

billion tonnes

SOURCE GPI/EREC

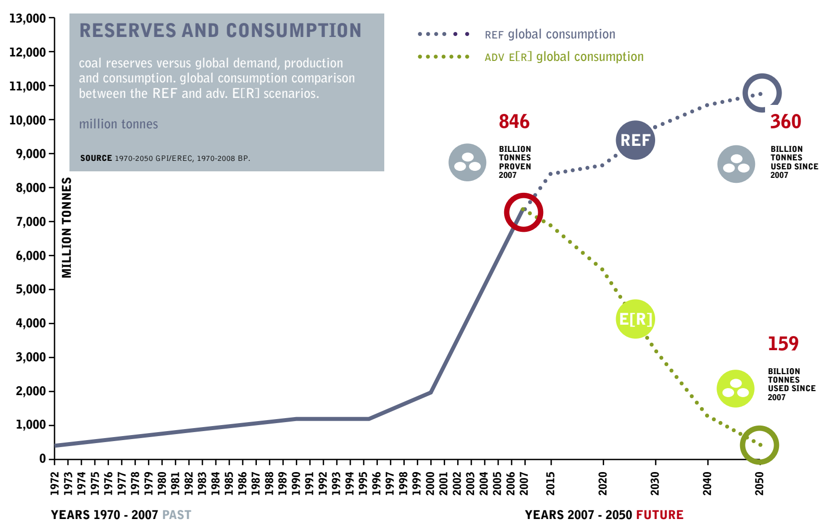


RESERVES AND CONSUMPTION

coal reserves versus global demand, production and consumption. global consumption comparison between the REF and adv. E[R] scenarios.

million tonnes

SOURCE 1970-2050 GPI/EREC, 1970-2008 BP.



map 8.4: nuclear reference scenario and the advanced energy [r]evolution scenario

WORLDWIDE SCENARIO

OECD NORTH AMERICA

		REF t	REF %	E[R] t	E[R] %
Reserves	2007	680,109	21.5%	680,109	21.5%
		TWh		TWh	
Generation	2007	941H		NUCLEAR POWER PHASED OUT BY 2040	
	2050	1,259H			
		PJ		PJ	
Consumption per region	2007	10,260H		10,260H	
	2050	13,735H		0	
		kWh		kWh	
Consumption per person	2007	2,094H		2,094H	
	2050	2,181		0	

LATIN AMERICA

		REF t	REF %	E[R] t	E[R] %
Reserves	2007	95,045	3%	95,045	3%
		TWh		TWh	
Generation	2007	20		PHASED OUT BY 2030	
	2050	60			
		PJ		PJ	
Consumption per region	2007	214		214	
	2050	655		0	
		kWh		kWh	
Consumption per person	2007	42		42	
	2050	100		0	

NON RENEWABLE RESOURCE

NUCLEAR

LEGEND

>30 | 20-30 | 10-20 | 5-10 | 0-5 — % RESOURCES GLOBALLY

REF — **REFERENCE SCENARIO**

E[R] — **ADVANCED ENERGY [R]EVOLUTION SCENARIO**

0 — 1000 KM

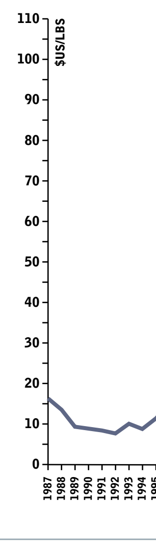
RESERVES TOTAL TONNES | SHARE IN % OF GLOBAL TOTAL [END OF 2007]

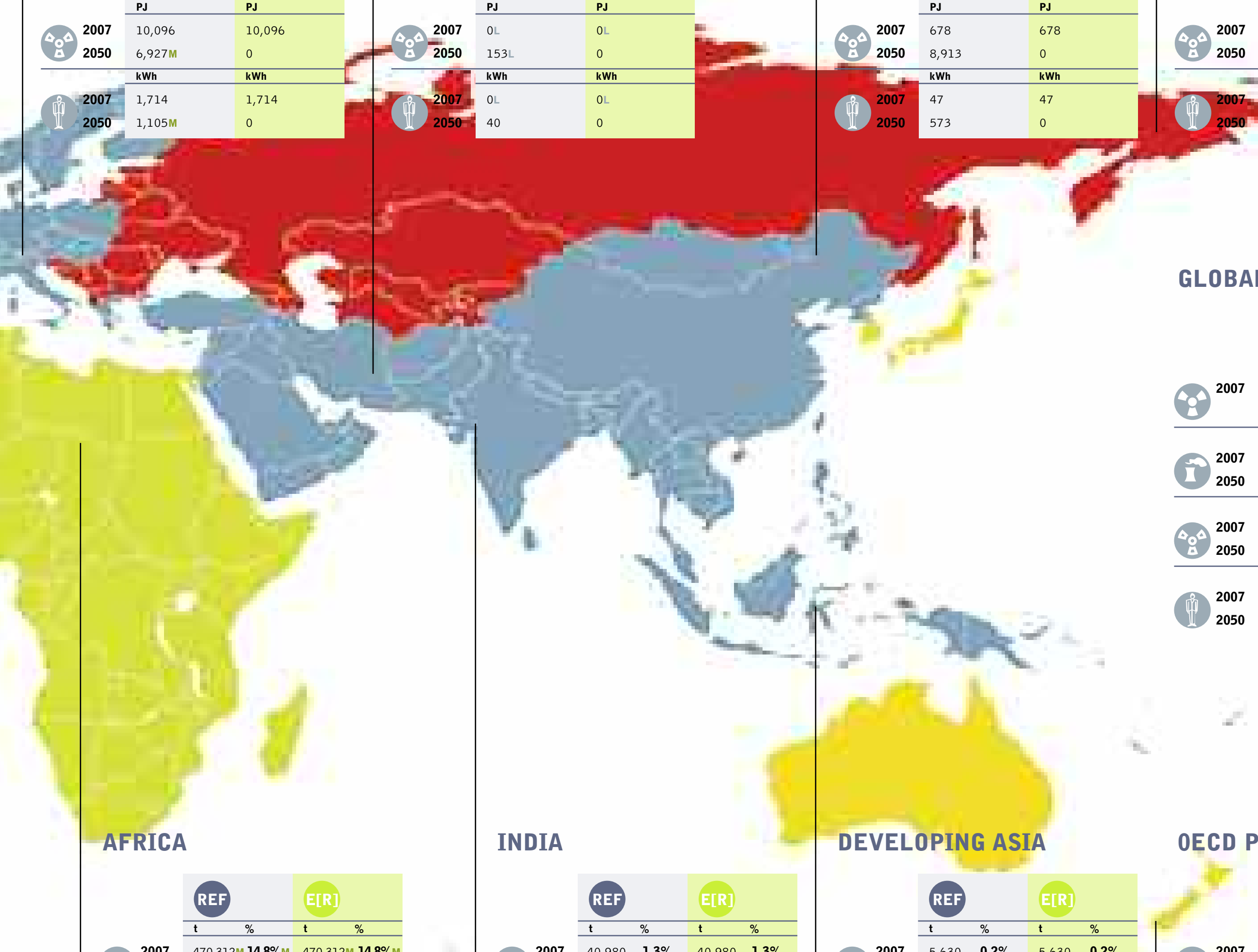
GENERATION PER REGION TERAWATT HOURS [TWh]

CONSUMPTION PER REGION PETA JOULE [PJ]

CONSUMPTION PER PERSON KILOWATT HOURS [kWh]

H HIGHEST | M MIDDLE | L LOWEST





OECD EUROPE

	REF	E[R]
	t %	t %
2007	56,445 1.8%	56,445 1.8%
	TWh	TWh
2007	925	PHASED OUT BY 2030
2050	635M	
	PJ	PJ
2007	10,096	10,096
2050	6,927M	0
	kWh	kWh
2007	1,714	1,714
2050	1,105M	0

MIDDLE EAST

	REF	E[R]
	t %	t %
2007	370L 0%L	370L 0%L
	TWh	TWh
2007	0L	NO NUCLEAR ENERGY DEVELOPMENT
2050	14L	
	PJ	PJ
2007	0L	0L
2050	153L	0
	kWh	kWh
2007	0L	0L
2050	40	0

CHINA

	REF	E[R]
	t %	t %
2007	35,060 1.1%	35,060 1.1%
	TWh	TWh
2007	62	NUCLEAR POWER PHASED OUT BY 2045
2050	817	
	PJ	PJ
2007	678	678
2050	8,913	0
	kWh	kWh
2007	47	47
2050	573	0

TRANSITION ECONOMIES

	REF	E[R]
	t %	t %
2007	1,043,687H 32.9%H	1,043,687H 32.9%H
	TWh	TWh
2007	293M	NUCLEAR POWER PHASED OUT BY 2045
2050	463	
	PJ	PJ
2007	3,197M	3,197M
2050	5,051	0
	kWh	kWh
2007	861M	861M
2050	1,490	0

GLOBAL

	REF	E[R]
	t %	t %
2007	3,169,238 100%	3,169,238 100%
	TWh	TWh
2007	2,719	NUCLEAR POWER PHASED OUT BY 2045
2050	4,413	
	PJ	PJ
2007	29,664	29,664
2050	48,142	0
	kWh	kWh
2007	418	418
2050	481	0

AFRICA

	REF	E[R]
	t %	t %
2007	470,312M 14.8%M	470,312M 14.8%M
	TWh	TWh
2007	11	NUCLEAR POWER PHASED OUT BY 2025
2050	45	
	PJ	PJ
2007	123	123
2050	491	0
	kWh	kWh
2007	12	12
2050	23L	0

INDIA

	REF	E[R]
	t %	t %
2007	40,980 1.3%	40,980 1.3%
	TWh	TWh
2007	17	NUCLEAR POWER PHASED OUT BY 2045
2050	172	
	PJ	PJ
2007	183	183
2050	1,876	0
	kWh	kWh
2007	17	17
2050	172	0

DEVELOPING ASIA

	REF	E[R]
	t %	t %
2007	5,630 0.2%	5,630 0.2%
	TWh	TWh
2007	44	NUCLEAR POWER PHASED OUT BY 2045
2050	80	
	PJ	PJ
2007	476	476
2050	873	0
	kWh	kWh
2007	43	43
2050	53	0

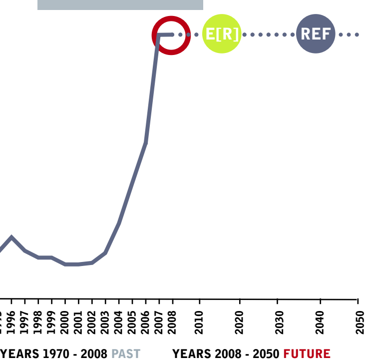
OECD PACIFIC

	REF	E[R]
	t %	t %
2007	741,600 23.4%	741,600 23.4%
	TWh	TWh
2007	407	NUCLEAR POWER PHASED OUT BY 2045
2050	868	
	PJ	PJ
2007	4,437	4,437
2050	9,469	0
	kWh	kWh
2007	2,030	2,030
2050	4,827H	0

COST

yellow cake prices 1987 - 2008 and future predictions comparing the REF and adv. E[R] scenarios
tonnes

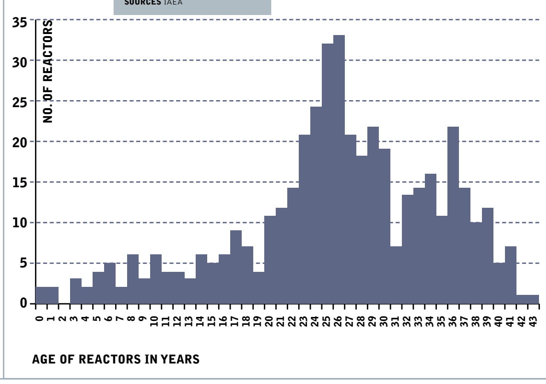
SOURCES REF: INTERNATIONAL ENERGY AGENCY/E[R]: DEVELOPMENTS APPLIED IN THE GES-PROJECT



REACTORS

age and number of reactors worldwide

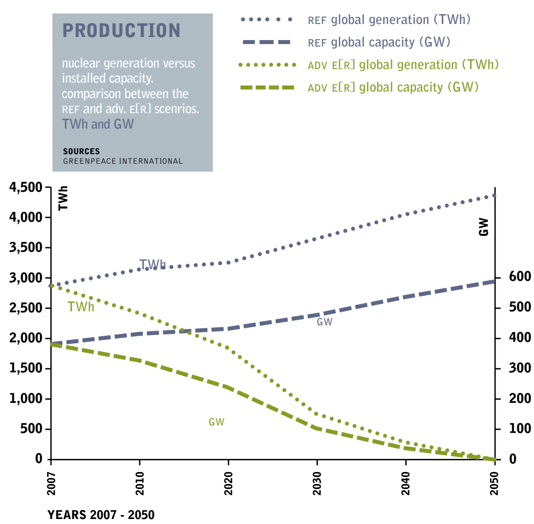
SOURCES IAEA



PRODUCTION

nuclear generation versus installed capacity. comparison between the REF and adv. E[R] scenrios. TWh and GW

SOURCES GREENPEACE INTERNATIONAL



GREENPEACE
DESIGN WWW.ONEHEMISPHERE.SE **CONCEPT** SVEN TESKE/GREENPEACE INTERNATIONAL.

table 8.2: assumptions on fossil fuel use in the energy [r]evolution scenario

Oil	2007	2015	2020	2030	2040	2050
Reference [PJ]	155,920	161,847	170,164	192,431	209,056	224,983
Reference [million barrels]	25,477	26,446	27,805	31,443	34,159	36,762
E[R] [PJ]		153,267	143,599	123,756	101,186	81,833
E[R] [million barrels]		25,044	23,464	20,222	16,534	13,371
Adv E[R] [PJ]		152,857	142,747	115,002	81,608	51,770
Adv E[R] [million barrels]		24,977	23,325	18,791	13,335	8,459
Gas	2007	2015	2020	2030	2040	2050
Reference [PJ]	104,845	112,931	121,148	141,706	155,015	166,487
Reference [billion cubic metres = 10E9m³]	2,759	2,972	3,188	3,729	4,079	4,381
E[R] [PJ]		116,974	121,646	122,337	99,450	71,383
E[R] [billion cubic metres = 10E9m³]		3,078	3,201	3,219	2,617	1,878
Adv E[R] [PJ]		118,449	119,675	114,122	79,547	34,285
Adv E[R] [billion cubic metres = 10E9m³]		3,117	3,149	3,003	2,093	902
Coal	2007	2015	2020	2030	2040	2050
Reference [PJ]	135,890	162,859	162,859	204,231	217,356	225,245
Reference [million tonnes]	7,319	8,306	8,306	9,882	10,408	10,751
E[R] [PJ]		140,862	140,862	96,846	64,285	37,563
E[R] [million tonnes]		7,217	7,217	4,407	2,810	1,631
Adv E[R] [PJ]		135,005	135,005	69,871	28,652	7,501
Adv E[R] [million tonnes]		6,829	6,829	3,126	1,250	326

nuclear

Uranium, the fuel used in nuclear power plants, is a finite resource whose economically available reserves are limited. Its distribution is almost as concentrated as oil and does not match global consumption. Five countries - Canada, Australia, Kazakhstan, Russia and Niger - control three quarters of the world's supply. As a significant user of uranium, however, Russia's reserves will be exhausted within ten years.

Secondary sources, such as old deposits, currently make up nearly half of worldwide uranium reserves. These will soon be used up, however. Mining capacities will have to be nearly doubled in the next few years to meet current needs.

A joint report by the OECD Nuclear Energy Agency and the International Atomic Energy Agency[64] estimates that all existing nuclear power plants will have used up their nuclear fuel, employing current technology, within less than 70 years. Given the range of scenarios for the worldwide development of nuclear power, it is likely that uranium supplies will be exhausted sometime between 2026 and 2070. This forecast includes the use of mixed oxide fuel (MOX), a mixture of uranium and plutonium.

renewable energy

Nature offers a variety of freely available options for producing energy. Their exploitation is mainly a question of how to convert sunlight, wind, biomass or water into electricity, heat or power as efficiently, sustainably and cost-effectively as possible.

On average, the energy in the sunshine that reaches the earth is about one kilowatt per square metre worldwide. According to the Research Association for Solar Power, power is gushing from renewable energy sources at a rate of 2,850 times more energy than is needed in the world. In one day, the sunlight which reaches the earth produces enough energy to satisfy the world's current power requirements for eight years. Even though only a percentage of that potential is technically accessible, this is still enough to provide just under six times more power than the world currently requires.

Before looking at the part renewable energies can play in the range of scenarios in this report, however, it is worth understanding the upper limits of their potential. To start with, the overall technical potential of renewable energy – the amount that can be produced taking into account the primary resources, the socio-geographical constraints and the technical losses in the conversion process – is huge and several times higher than current total energy demand.

64 'URANIUM 2003: RESOURCES, PRODUCTION AND DEMAND'

image SOLON AG PHOTOVOLTAICS FACILITY IN ARNSTEIN OPERATING 1,500 HORIZONTAL AND VERTICAL SOLAR "MOVERS". LARGEST TRACKING SOLAR FACILITY IN THE WORLD. EACH "MOVER" CAN BE BOUGHT AS A PRIVATE INVESTMENT FROM THE S.A.G. SOLARSTROM AG, BAYERN, GERMANY.

image WIND ENERGY PARK NEAR DAHME. WIND TURBINE IN THE SNOW OPERATED BY VESTAS.

Assessments of the global technical potential vary significantly from 2,477 Exajoules per annum (EJ/a) (Nitsch 2004) up to 15,857 EJ/a (UBA 2009). Based on the global primary energy demand in 2007 (IEA 2009) of 503 EJ/a, the total technical potential of renewable energy sources at the upper limit would exceed demand by a factor of 32. However, barriers to the growth of renewable energy technologies may come from economical, political and infrastructural constraints. That is why the technical potential will never be realised in total.

Assessing long term technical potentials is subject to various uncertainties. The distribution of the theoretical resources, such as the global wind speed or the productivity of energy crops, is not always well analysed. The geographical availability is subject to variations such as land use change, future planning decisions on where certain technologies are allowed, and accessibility of resources, for example underground geothermal energy. Technical performance may take longer to achieve than expected. There are also uncertainties in terms of the consistency of the data provided in studies, and underlying assumptions are often not explained in detail.

The meta study by the DLR (German Aerospace Agency), Wuppertal Institute and Ecofys, commissioned by the German Federal Environment Agency, provides a comprehensive overview of the technical renewable energy potential by technologies and world region.[66] This survey analysed ten major studies of global and regional potentials by organisations such as the United Nations Development Programme and a range of academic institutions. Each of the major renewable energy sources was assessed, with special attention paid to the effect of environmental constraints on their overall potential. The study provides data for the years 2020, 2030 and 2050 (see Table 8.3).

The complexity of calculating renewable energy potentials is particularly great because these technologies are comparatively young and their exploitation involves changes to the way in which energy is both generated and distributed. Whilst a calculation of the theoretical and geographical potentials has only a few dynamic parameters, the technical potential is dependent on a number of uncertainties.

definition of types of energy resource potential[65]

theoretical potential The theoretical potential identifies the physical upper limit of the energy available from a certain source. For solar energy, for example, this would be the total solar radiation falling on a particular surface.

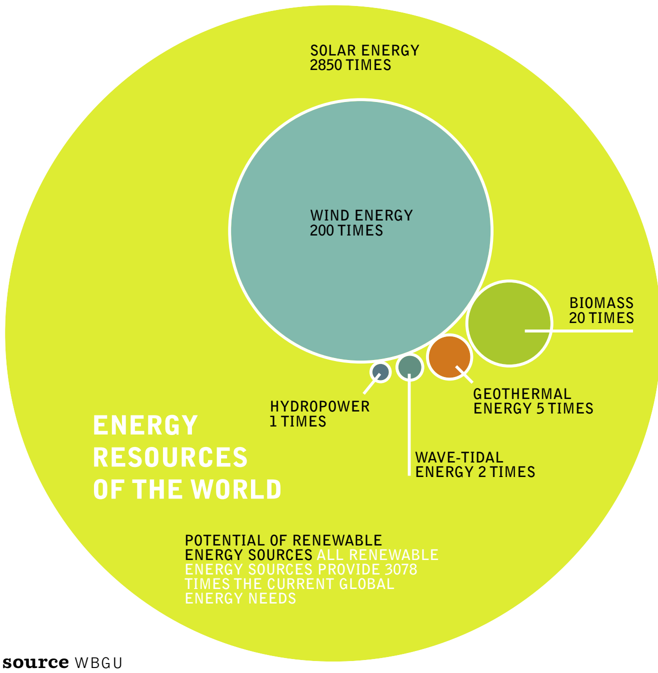
conversion potential This is derived from the annual efficiency of the respective conversion technology. It is therefore not a strictly defined value, since the efficiency of a particular technology depends on technological progress.

technical potential This takes into account additional restrictions regarding the area that is realistically available for energy generation. Technological, structural and ecological restrictions, as well as legislative requirements, are accounted for.

economic potential The proportion of the technical potential that can be utilised economically. For biomass, for example, those quantities are included that can be exploited economically in competition with other products and land uses.

sustainable potential This limits the potential of an energy source based on evaluation of ecological and socio-economic factors.

figure 8.1: energy resources of the world

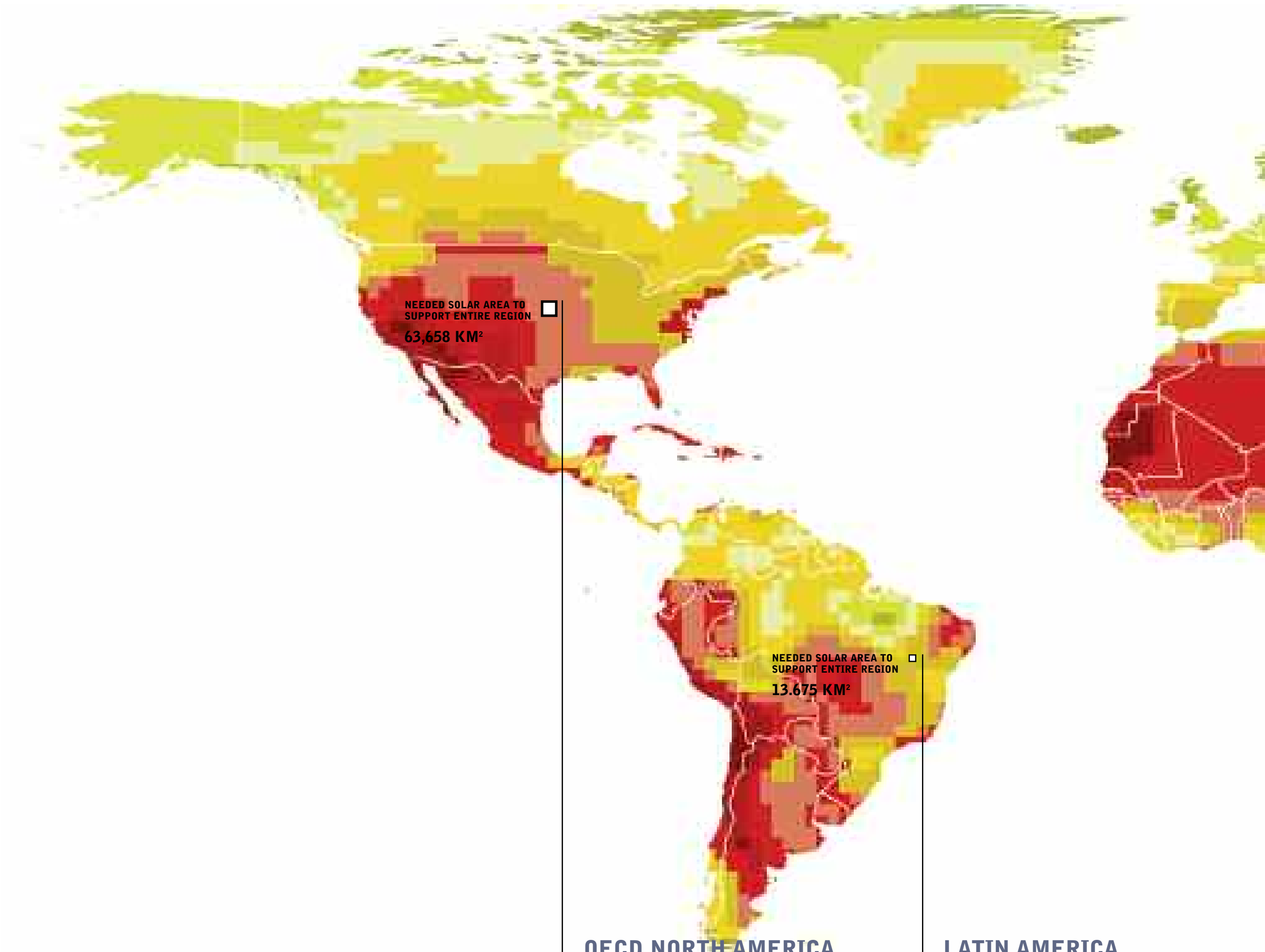


source WBGU

65 WBGU (GERMAN ADVISORY COUNCIL ON GLOBAL CHANGE).
66 DLR, WUPPERTAL INSTITUTE, ECOFYS, 'ROLE AND POTENTIAL OF RENEWABLE ENERGY AND ENERGY EFFICIENCY FOR GLOBAL ENERGY SUPPLY', COMMISSIONED BY GERMAN FEDERAL ENVIRONMENT AGENCY, FKZ 3707 41 108, MARCH 2009;

map 8.5: solar reference scenario and the advanced energy [r]evolution scenario

WORLDWIDE SCENARIO



RENEWABLE RESOURCE

SOLAR

OECD NORTH AMERICA

	REF %	REF PJ	E[R] %	E[R] PJ
2007	0.06M	64H		
2050	1.04M	1,343	25M	17,683
		kWh		kWh
2007		40		
2050		646		8,508

LATIN AMERICA

	REF %	REF PJ	E[R] %	E[R] PJ
2007	0.03	6		
2050	0.52	214	14L	3,799L
		kWh		kWh
2007		4		
2050		99		1,758

LEGEND

2600-2800 | 2400-2600 | 2200-2400 | 2000-2200 | 1800-2000 | 1600-1800 | 1400-1600 | 1200-1400 | 1000-1200 | 800-1000 | 600-800 | 400-600 | 200-400 | 0-200

RADIATION IN kW/h PER SQUARE METER
SOURCE DLR

REF REFERENCE SCENARIO

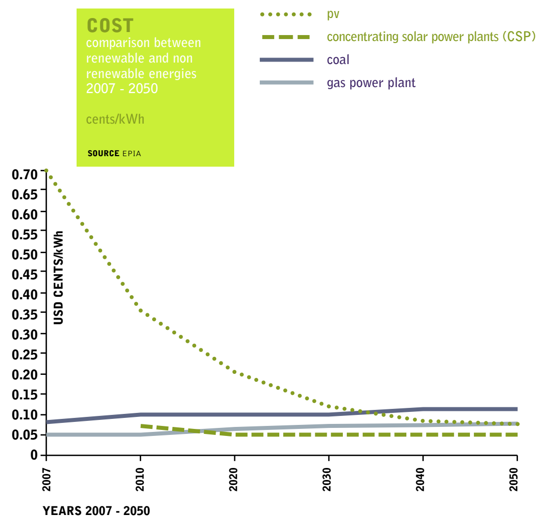
E[R] ADVANCED ENERGY [R]EVOLUTION SCENARIO

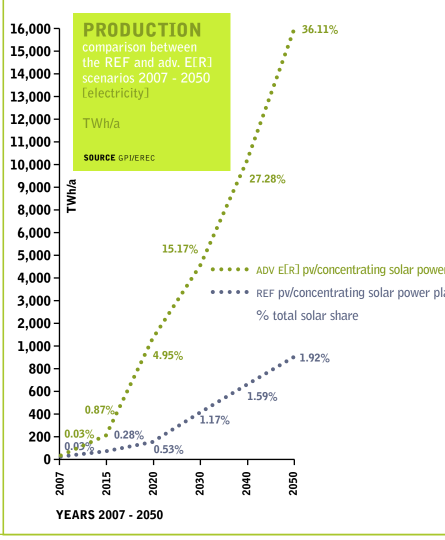
0 1000 KM

PRODUCTION PER REGION % OF GLOBAL SHARE | PETA JOULE [PJ]

PRODUCTION PER PERSON KILOWATT HOUR [kWh]

H HIGHEST | **M** MIDDLE | **L** LOWEST





OECD EUROPE

	REF %	REF PJ	E[R] %	E[R] PJ
2007	0.09M	70		
2050	1.42H	1,173	23	10,680
		kWh		kWh
2007		36M		
2050		567		5,160M

MIDDLE EAST

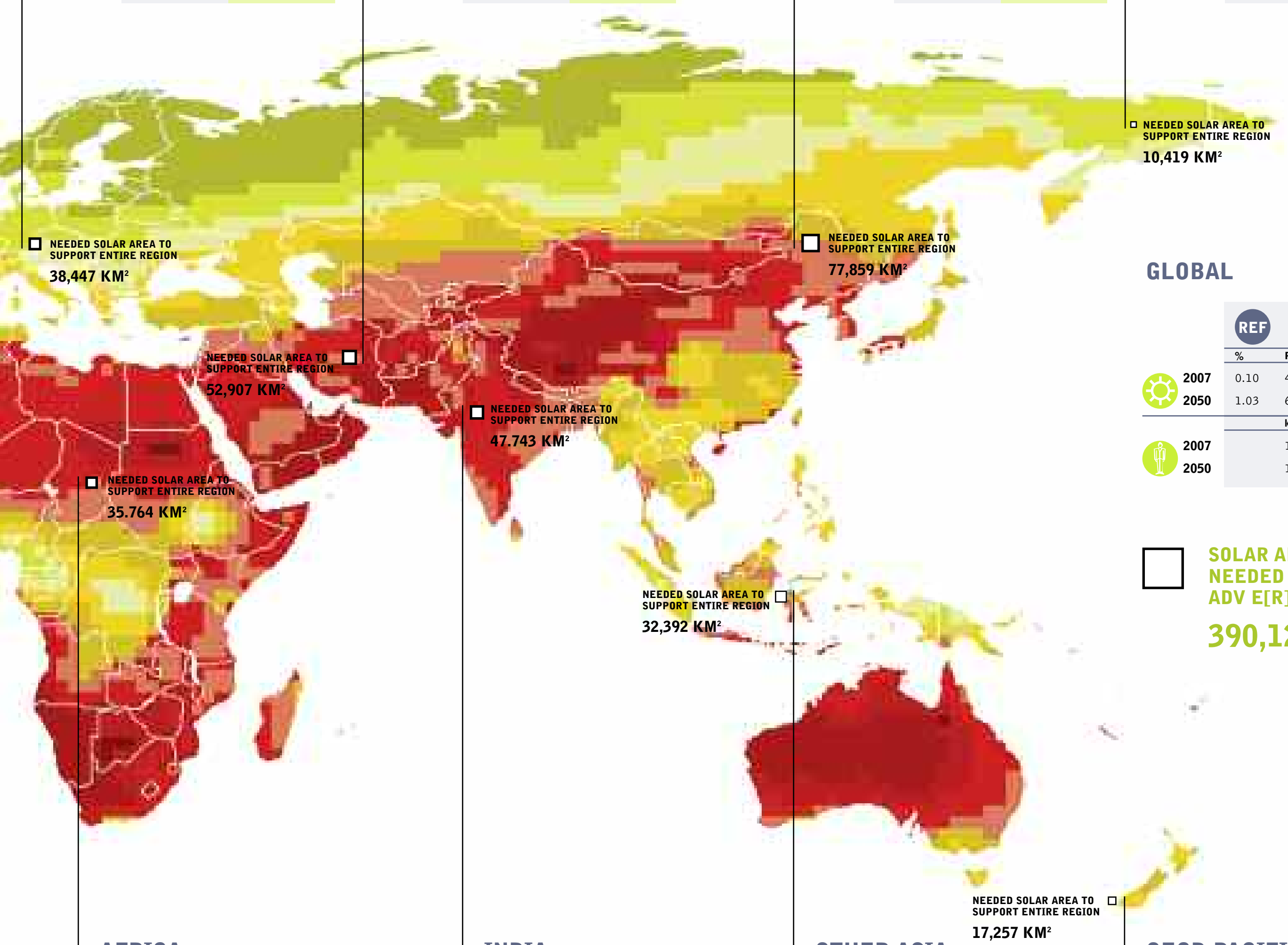
	REF %	REF PJ	E[R] %	E[R] PJ
2007	0.17H	36		
2050	0.62	319	53H	14,696
		kWh		kWh
2007		50H		
2050		251		11,552H

CHINA

	REF %	REF PJ	E[R] %	E[R] PJ
2007	0.22L	182L		
2050	0.95	1,754H	20	21,628H
		kWh		kWh
2007		38		
2050		342M		4,213

TRANSITION ECONOMIES

	REF %	REF PJ	E[R] %	E[R] PJ
2007	0.01L	2		
2050	0.10L	63L	8,34	2,894
		kWh		kWh
2007		2		
2050		56		2,586



GLOBAL

	REF %	REF PJ	E[R] %	E[R] PJ
2007	0.10	402		
2050	1.03	6,322	23.26	108,367
		kWh		kWh
2007		17		
2050		192		2,468

SOLAR AREA NEEDED TO SUPPORT ADV E[R] 2050 SCENARIO

390,122 KM²

AFRICA

	REF %	REF PJ	E[R] %	E[R] PJ
2007	0.00	1		
2050	0.94	405	28	9,934
		kWh		kWh
2007		0.2		
2050		56L		1,380

INDIA

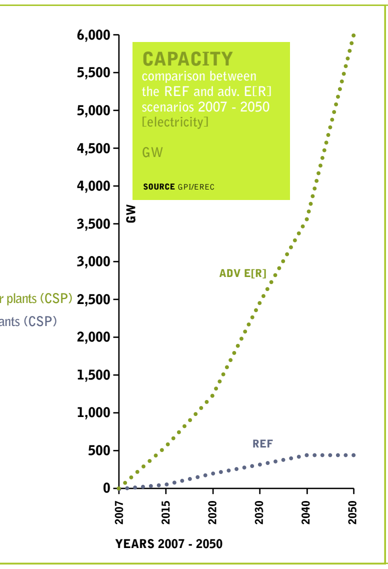
	REF %	REF PJ	E[R] %	E[R] PJ
2007	0.02L	6L		
2050	0.23	182	24	13,262M
		kWh		kWh
2007		1		
2050		31		2,282

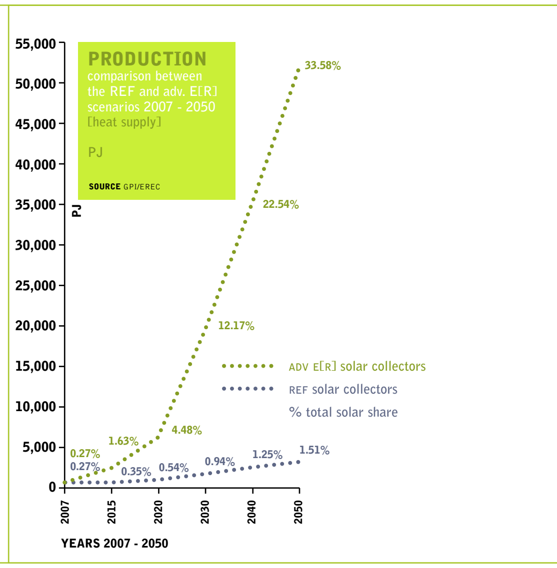
OTHER ASIA

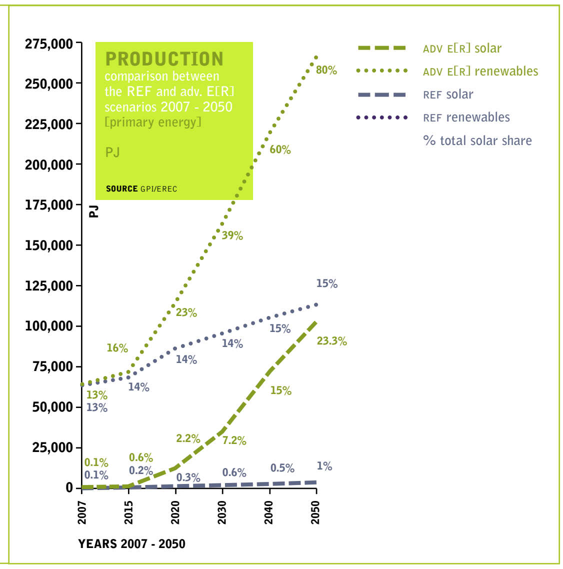
	REF %	REF PJ	E[R] %	E[R] PJ
2007	0.01L	4L		
2050	0.58	405	22	8,998
		kWh		kWh
2007		1L		
2050		74		1,649L

OECD PACIFIC

	REF %	REF PJ	E[R] %	E[R] PJ
2007	0.08	30M		
2050	1.14	466M	23	4,794
		kWh		kWh
2007		42		
2050		719H		7,405

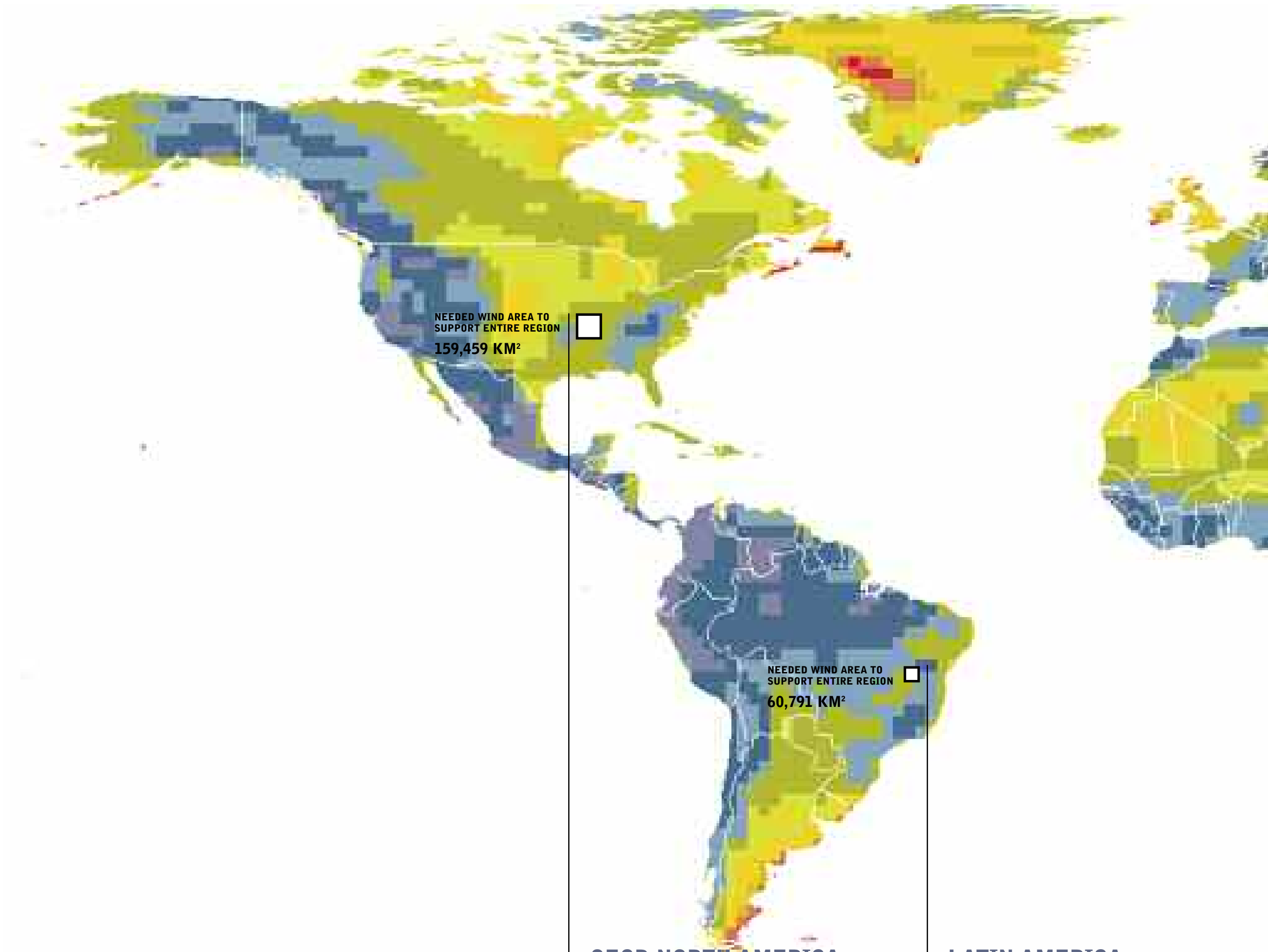






map 8.6: wind reference scenario and the advanced energy [r]evolution scenario

WORLDWIDE SCENARIO



OECD NORTH AMERICA

		REF %	REF PJ	E[R] %	E[R] PJ
Production per region	2007	0.12M	136		
	2050	1.71	2,210	11.11	7,805H
			kWh		kWh
Production per person	2007		84		
	2050		1,064		3,755

LATIN AMERICA

		REF %	REF PJ	E[R] %	E[R] PJ
Production per region	2007	0.02	3		
	2050	0.65	266	10.54	2,878
			kWh		kWh
Production per person	2007		2		
	2050		123		1,332

RENEWABLE RESOURCE

WIND

LEGEND

>11 | 10-11 | 9-10 | 8-9 | 7-8 | 6-7 | 5-6 | 4-5 | 3-4 | 1-2 | 0-1

AVERAGE WIND SPEED IN METRES PER SECOND
SOURCE DLR

REF REFERENCE SCENARIO

E[R] ADVANCED ENERGY [R]EVOLUTION SCENARIO

0 1000 KM

PRODUCTION PER REGION % OF GLOBAL SHARE | PETA JOULE [PJ]

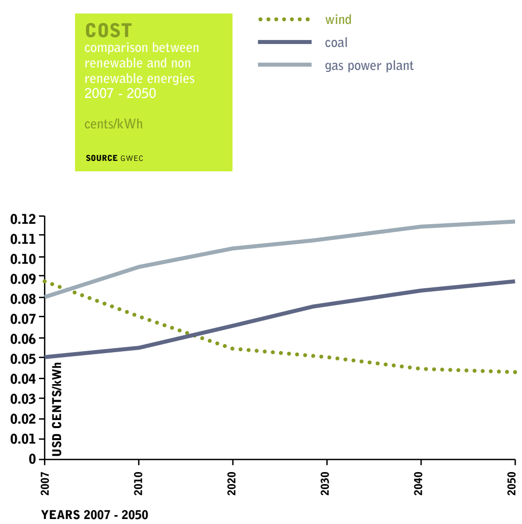
PRODUCTION PER PERSON KILOWATT HOUR [kWh]

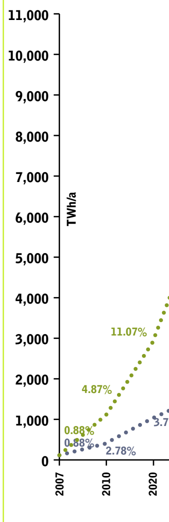
H HIGHEST | M MIDDLE | L LOWEST

COST
comparison between renewable and non renewable energies 2007 - 2050

cents/kWh

SOURCE GWEC





OECD EUROPE

	REF %	REF PJ	E[R] %	E[R] PJ
2007	0.49H	379H		
2050	4.14H	3,420H	10.41	4,867
		kWh		**kWh**
2007		195H		
2050		1,652H		2,352M

MIDDLE EAST

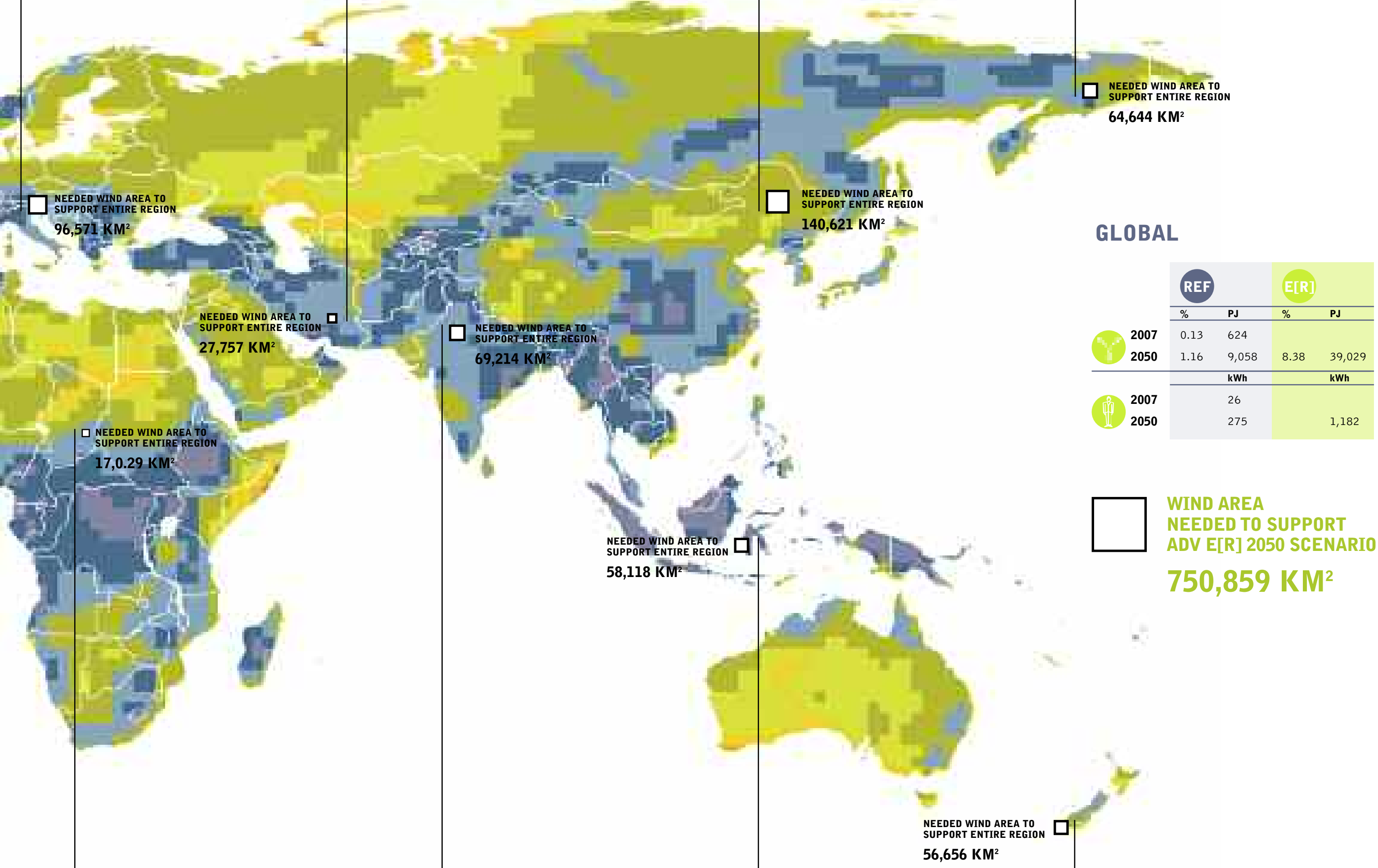
	REF %	REF PJ	E[R] %	E[R] PJ
2007	0.00L	1L		
2050	0.26L	133L	4.78	1,314
		kWh		**kWh**
2007		1		
2050		105		1,033

CHINA

	REF %	REF PJ	E[R] %	E[R] PJ
2007	0.04	32		
2050	0.66	1,220M	6.85M	7,340
		kWh		**kWh**
2007		7		
2050		238		1,430

TRANSITION ECONOMIES

	REF %	REF PJ	E[R] %	E[R] PJ
2007	0.00	1		
2050	0.56	360	9.83	3,413
		kWh		**kWh**
2007		1		
2050		322M		3,050



GLOBAL

	REF %	REF PJ	E[R] %	E[R] PJ
2007	0.13	624		
2050	1.16	9,058	8.38	39,029
		kWh		**kWh**
2007		26		
2050		275		1,182

WIND AREA NEEDED TO SUPPORT ADV E[R] 2050 SCENARIO

750,859 KM²

AFRICA

	REF %	REF PJ	E[R] %	E[R] PJ
2007	0.02	4		
2050	0.47	202	3.00L	1,073L
		kWh		**kWh**
2007		1		
2050		28L		149L

INDIA

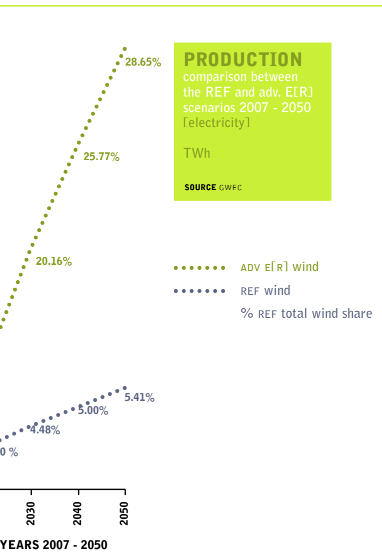
	REF %	REF PJ	E[R] %	E[R] PJ
2007	0.17	42M		
2050	0.48	374	6.38	3,488
		kWh		**kWh**
2007		10		
2050		64		600

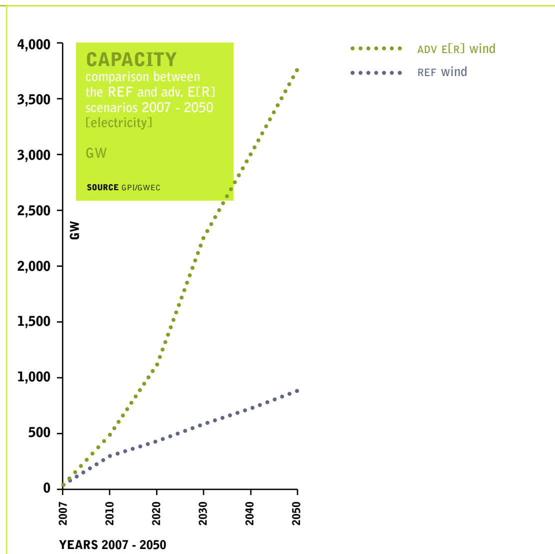
ASIA

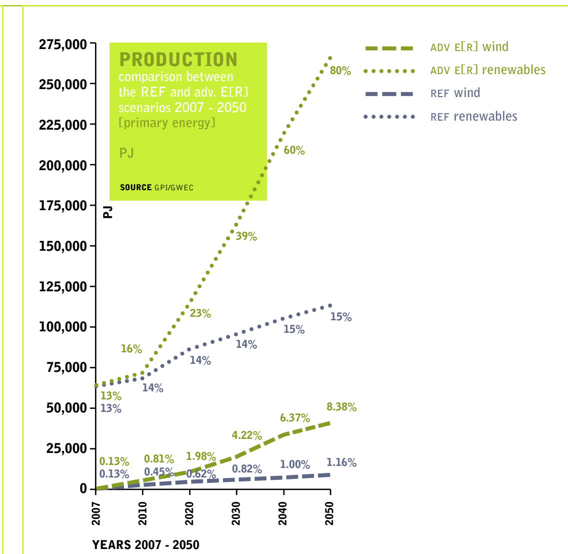
	REF %	REF PJ	E[R] %	E[R] PJ
2007	0.01	2L		
2050	0.69	475	8.75	3,557
		kWh		**kWh**
2007		0L		
2050		87		652

OECD PACIFIC

	REF %	REF PJ	E[R] %	E[R] PJ
2007	0.06	24		
2050	0.97M	396	15.47H	3,294M
		kWh		**kWh**
2007		33M		
2050		611		5,089H







DESIGN WWW.ONEHEMISPHERE.SE CONCEPT SVEN TESKE/GREENPEACE INTERNATIONAL.

table 8.3: technical potential by renewable energy technology for 2020, 2030 and 2050

	TECHNICAL POTENTIAL ELECTRICITY EJ/YEAR ELECTRIC POWER							TECHNICAL POTENTIAL HEAT EJ/A		TECHNICAL POTENTIAL PRIMARY ENERGY EJ/A		
	SOLAR CSP	SOLAR PV	HYDRO POWER	WIND ON-SHORE	WIND OFF-SHORE	OCEAN ENERGY	GEO-THERMAL ELECTRIC	GEO-THERMAL DIRECT USES	SOLAR WATER HEATING	BIOMASS RESIDUES	BIOMASS ENERGY CROPS	TOTAL
World 2020	1,125.9	5,156.1	47.5	368.6	25.6	66.2	4.5	498.5	113.1	58.6	43.4	7,505
World 2030	1,351.0	6,187.3	48.5	361.7	35.9	165.6	13.4	1,486.6	117.3	68.3	61.1	9,897
World 2050	1,688.8	8,043.5	50.0	378.9	57.4	331.2	44.8	4,955.2	123.4	87.6	96.5	15,857
World energy demand 2007: 502.9 EJ/a[a]												
Technical potential in 2050 versus world primary energy demand 2007.	3.4	16.0	0.1	0.8	0.1	0.7	0.1	9.9	0.2	0.2	0.2	32

source DLR, WUPPERTAL INSTITUTE, ECOFYS; ROLE AND POTENTIAL OF RENEWABLE ENERGY AND ENERGY EFFICIENCY FOR GLOBAL ENERGY SUPPLY; COMMISSIONED BY THE GERMAN FEDERAL ENVIRONMENT AGENCY FKZ 3707 41 108, MARCH 2009; POTENTIAL VERSUS ENERGY DEMAND: S. TESKE
a IEA 2009

A technology breakthrough, for example, could have a dramatic impact, changing the technical potential assessment within a very short time frame. Considering the huge dynamic of technology development, many existing studies are based on out of date information. The estimates in the DLR study could therefore be updated using more recent data, for example significantly increased average wind turbine capacity and output, which would increase the technical potentials still further.

Given the large unexploited resources which exist, even without having reached the full development limits of the various technologies, it can be concluded that the technical potential is not a limiting factor to expansion of renewable energy generation.

It will not be necessary to exploit the entire technical potential, however, nor would this be unproblematic. Implementation of renewable energies has to respect sustainability criteria in order to achieve a sound future energy supply. Public acceptance is crucial, especially bearing in mind that the decentralised character of many renewable energy technologies will move their operation closer to consumers. Without public acceptance, market expansion will be difficult or even impossible. The use of biomass, for example, has become controversial in recent years as it is seen as competing with other land uses, food production or nature conservation. Sustainability criteria will have a huge influence on whether bio-energy in particular can play a central role in future energy supply.

As important as the technical potential of worldwide renewable energy sources is their market potential. This term is often used in different ways. The general understanding is that market potential means the total amount of renewable energy that can be implemented in the market taking into account the demand for energy, competing technologies, any subsidies available as well as the current and future costs of renewable energy sources. The market potential may therefore in theory be larger than the economic potential. To be realistic, however, market potential analyses have to take into account the behaviour of private economic agents under specific prevailing conditions, which are of course partly shaped by public authorities. The energy policy framework in a particular country or region will have a profound impact on the expansion of renewable energies.

the global potential for sustainable biomass

As part of background research for the Energy [R]evolution Scenario, Greenpeace commissioned the German Biomass Research Centre, the former Institute for Energy and Environment, to investigate the worldwide potential for energy crops up to 2050. In addition, information has been compiled from scientific studies of the global potential and from data derived from state of the art remote sensing techniques, such as satellite images. A summary of the report's findings is given below; references can be found in the full report.[a]

assessment of biomass potential studies

Various studies have looked historically at the potential for bio energy and come up with widely differing results. Comparison between them is difficult because they use different definitions of the various biomass resource fractions. This problem is particularly significant in relation to forest derived biomass. Most research has focused almost exclusively on energy crops, as their development is considered to be more significant for satisfying the demand for bio energy. The result is that the potential for using forest residues (wood left over after harvesting) is often underestimated.

Data from 18 studies has been examined, with a concentration on those which report the potential for biomass residues. Among these there were ten comprehensive assessments with more or less detailed documentation of the methodology. The majority focus on the long-term potential for 2050 and 2100. Little information is available for 2020 and 2030. Most of the studies were published within the last ten years. Figure 8.2 shows the variations in potential by biomass type from the different studies.

Looking at the contribution of different types of material to the total biomass potential, the majority of studies agree that the most promising resource is energy crops from dedicated plantations. Only six give a regional breakdown, however, and only a few quantify all types of residues separately. Quantifying the potential of minor fractions, such as animal residues and organic wastes, is difficult as the data is relatively poor.

a SEIDENBERGER T., THRÄN D., OFFERMANN R., SEYFERT U., BUCHHORN M. AND ZEDDIES J. (2008). GLOBAL BIOMASS POTENTIALS. INVESTIGATION AND ASSESSMENT OF DATA. REMOTE SENSING IN BIOMASS POTENTIAL RESEARCH. COUNTRY-SPECIFIC ENERGY CROP POTENTIAL. GERMAN BIOMASS RESEARCH CENTRE (DBFZ). FOR GREENPEACE INTERNATIONAL. 137 P.

image THE BIOENERGY VILLAGE OF JUEHNDE WHICH WAS THE FIRST COMMUNITY IN GERMANY TO PRODUCE ALL ITS ENERGY NEEDED FOR HEATING AND ELECTRICITY, WITH CO_2 NEUTRAL BIOMASS.

image A NEWLY DEFORESTED AREA WHICH HAS BEEN CLEARED FOR AGRICULTURAL EXPANSION IN THE AMAZON, BRAZIL.

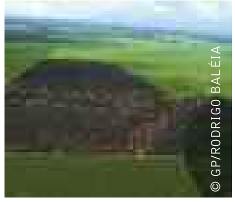
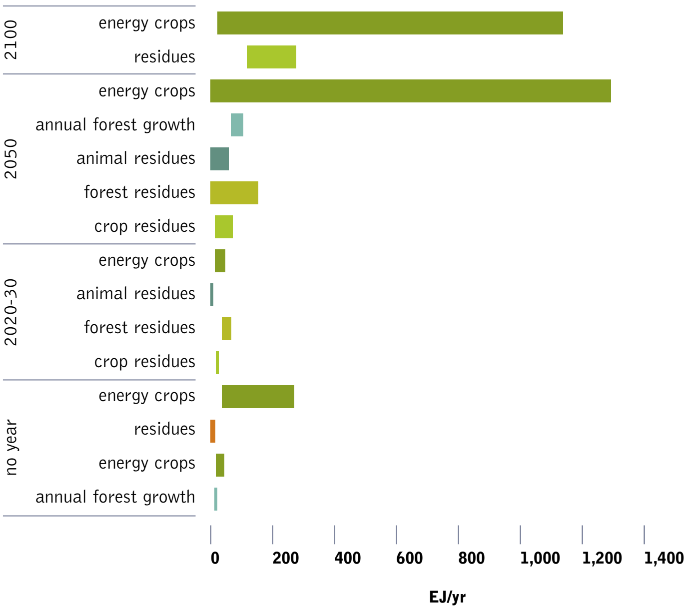


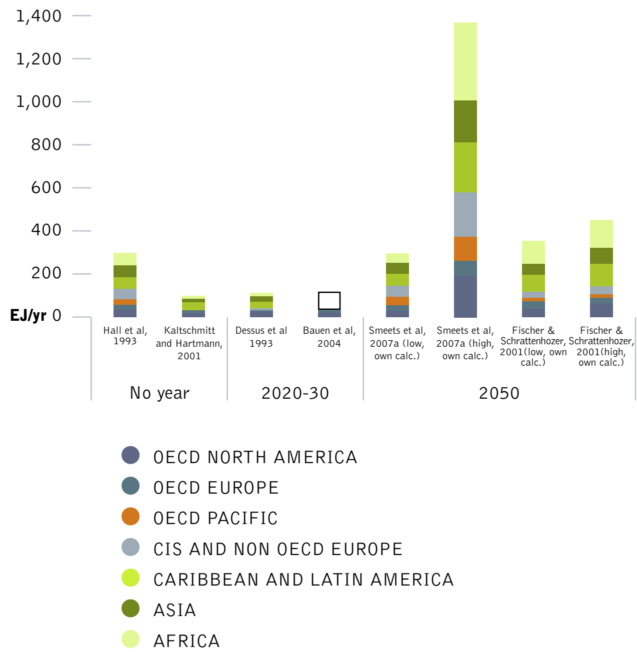
figure 8.2: ranges of potential for different biomass types



source GERMAN BIOMASS RESEARCH CENTRE (DBFZ)

figure 8.3: bio energy potential analysis from different authors

('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)



source GERMAN BIOMASS RESEARCH CENTRE (DBFZ)

potential of energy crops

Apart from the utilisation of biomass from residues, the cultivation of energy crops in agricultural production systems is of greatest significance. The technical potential for growing energy crops has been calculated on the assumption that demand for food takes priority. As a first step the demand for arable and grassland for food production has been calculated for each of 133 countries in different scenarios. These scenarios are:

- Business as usual (BAU) scenario: Present agricultural activity continues for the foreseeable future
- Basic scenario: No forest clearing; reduced use of fallow areas for agriculture
- Sub-scenario 1: Basic scenario plus expanded ecological protection areas and reduced crop yields
- Sub-scenario 2: Basic scenario plus food consumption reduced in industrialised countries
- Sub-scenario 3: Combination of sub-scenarios 1 and 2

In a next step the surpluses of agricultural areas were classified either as arable land or grassland. On grassland, hay and grass silage are produced, on arable land fodder silage and Short Rotation Coppice (such as fast-growing willow or poplar) are cultivated. Silage of green fodder and grass are assumed to be used for biogas production, wood from SRC and hay from grasslands for the production of heat, electricity and synthetic fuels. Country specific yield variations were taken into consideration.

The result is that the global biomass potential from energy crops in 2050 falls within a range from 6 EJ in Sub-scenario 1 up to 97 EJ in the BAU scenario.

The best example of a country which would see a very different future under these scenarios in 2050 is Brazil. Under the BAU scenario large agricultural areas would be released by deforestation, whereas in the Basic and Sub 1 scenarios this would be forbidden, and no agricultural areas would be available for energy crops. By contrast a high potential would be available under Sub-scenario 2 as a consequence of reduced meat consumption. Because of their high populations and relatively small agricultural areas, no surplus land is available for energy crop production in Central America, Asia and Africa. The EU, North America and Australia, however, have relatively stable potentials.

The results of this exercise show that the availability of biomass resources is not only driven by the effect on global food supply but the conservation of natural forests and other biospheres. So the assessment of future biomass potential is only the starting point of a discussion about the integration of bioenergy into a renewable energy system.

The total global biomass potential (energy crops and residues) therefore ranges in 2020 from 66 EJ (Sub-scenario 1) up to 110 EJ (Sub-scenario 2) and in 2050 from 94 EJ (Sub-scenario 1) to 184 EJ (BAU scenario). These numbers are conservative and include a level of uncertainty, especially for 2050. The reasons for this uncertainty are the potential effects of climate change, possible changes in the worldwide political and economic situation, a higher yield as a result of changed agricultural techniques and/or faster development in plant breeding.

figure 8.4: world wide energy crop potentials in different scenarios

The Energy [R]evolution takes a precautionary approach to the future use of biofuels. This reflects growing concerns about the greenhouse gas balance of many biofuel sources, and also the risks posed by expanded bio fuels crop production to biodiversity (forests, wetlands and grasslands) and food security. In particular, research commissioned by Greenpeace in the development of the Energy [R]evolution suggests that there will be acute pressure on land for food production and habitat protection in 2050. As a result, the Energy [R]evolution does not include any biofuels from energy crops at 2050, restricting feedstocks to a limited quantity of forest and agricultural residues. It should be stressed, however, that this conservative approach is based on an assessment of today's technologies and their associated risks. The development of advanced forms of biofuels which do not involve significant land-take, are demonstrably sustainable in terms of their impacts on the wider environment, and have clear greenhouse gas benefits, should be an objective of public policy, and would provide additional flexibility in the renewable energy mix.

Concerns have also been raised about how countries account for the emissions associated with biofuels production and combustion. The lifecycle emissions of different biofuels can vary enormously. Rules developed under the Kyoto Protocol mean that under many circumstances, countries are not held responsible for all the emissions associated with land-use change or management. At the same time, under the Kyoto Protocol and associated instruments such as the European Emissions Trading scheme, biofuels is 'zero-rated' for emissions as an energy source. To ensure that biofuels are produced and used in ways which maximize its greenhouse gas saving potential, these accounting problems will need to be resolved in future.

energy technologies

GLOBAL

FOSSIL FUEL TECHNOLOGIES
RENEWABLE ENERGY TECHNOLOGIES

9

“the technology is here, all we need is political will.”

CHRIS
SUPORTER, AUSTRALIA

image BIOGAS FACILITY "SCHRADEN BIOGAS" IN GROEDEN NEAR DRESDEN, GERMANY.

This chapter describes the range of technologies available now and in the future to satisfy the world's energy demand. The Energy [R]evolution scenario is focused on the potential for energy savings and renewable sources, primarily in the electricity and heat generating sectors.

fossil fuel technologies

The most commonly used fossil fuels for power generation around the world are coal and gas. Oil is still used where other fuels are not readily available, for example islands or remote sites, or where there is an indigenous resource. Together, coal and gas currently account for over half of global electricity supply.

coal combustion technologies In a conventional coal-fired power station, pulverised or powdered coal is blown into a combustion chamber where it is burned at high temperature. The resulting heat is used to convert water flowing through pipes lining the boiler into steam. This drives a steam turbine and generates electricity. Over 90% of global coal-fired capacity uses this system. Coal power stations can vary in capacity from a few hundred megawatts up to several thousand.

A number of technologies have been introduced to improve the environmental performance of conventional coal combustion. These include coal cleaning (to reduce the ash content) and various 'bolt-on' or 'end-of-pipe' technologies to reduce emissions of particulates, sulphur dioxide and nitrogen oxide, the main pollutants resulting from coal firing apart from carbon dioxide. Flue gas desulphurisation (FGD), for example, most commonly involves 'scrubbing' the flue gases using an alkaline sorbent slurry, which is predominantly lime or limestone based.

More fundamental changes have been made to the way coal is burned to both improve its efficiency and further reduce emissions of pollutants. These include:

- **integrated gasification combined cycle:** Coal is not burned directly but reacted with oxygen and steam to form a synthetic gas composed mainly of hydrogen and carbon monoxide. This is cleaned and then burned in a gas turbine to generate electricity and produce steam to drive a steam turbine. IGCC improves the efficiency of coal combustion from 38-40% up to 50%.
- **supercritical and ultrasupercritical:** These power plants operate at higher temperatures than conventional combustion, again increasing efficiency towards 50%.
- **fluidised bed combustion:** Coal is burned in a reactor comprised of a bed through which gas is fed to keep the fuel in a turbulent state. This improves combustion, heat transfer and the recovery of waste products. By elevating pressures within a bed, a high-pressure gas stream can be used to drive a gas turbine, generating electricity. Emissions of both sulphur dioxide and nitrogen oxide can be reduced substantially.
- **pressurised pulverised coal combustion:** Mainly being developed in Germany, this is based on the combustion of a finely ground cloud of coal particles creating high pressure, high temperature steam for power generation. The hot flue gases are used to generate electricity in a similar way to the combined cycle system.

Other potential future technologies involve the increased use of coal gasification. Underground Coal Gasification, for example, involves converting deep underground unworked coal into a combustible gas which can be used for industrial heating, power generation or the manufacture of hydrogen, synthetic natural gas or other chemicals. The gas can be processed to remove CO_2 before it is passed on to end users. Demonstration projects are underway in Australia, Europe, China and Japan.

gas combustion technologies Natural gas can be used for electricity generation through the use of either gas or steam turbines. For the equivalent amount of heat, gas produces about 45% less carbon dioxide during its combustion than coal.

Gas turbine plants use the heat from gases to directly operate the turbine. Natural gas fuelled turbines can start rapidly, and are therefore often used to supply energy during periods of peak demand, although at higher cost than baseload plants.

Particularly high efficiencies can be achieved through combining gas turbines with a steam turbine in combined cycle mode. In a **combined cycle gas turbine (CCGT)** plant, a gas turbine generator produces electricity and the exhaust gases from the turbine are then used to make steam to generate additional electricity. The efficiency of modern CCGT power stations can be more than 50%. Most new gas power plants built since the 1990s have been of this type.

At least until the recent increase in global gas prices, CCGT power stations have been the cheapest option for electricity generation in many countries. Capital costs have been substantially lower than for coal and nuclear plants and construction time shorter.

carbon reduction technologies Whenever a fossil fuel is burned, carbon dioxide (CO_2) is produced. Depending on the type of power plant, a large quantity of the gas will dissipate into the atmosphere and contribute to climate change. A hard coal power plant discharges roughly 720 grammes of carbon dioxide per kilowatt hour, a modern gas-fired plant about 370g CO_2/kWh. One method, currently under development, to mitigate the CO_2 impact of fossil fuel combustion is called carbon capture and storage (CCS). It involves capturing CO_2 from power plant smokestacks, compressing the captured gas for transport via pipeline or ship and pumping it into underground geological formations for permanent storage.

While frequently touted as the solution to the carbon problem inherent in fossil fuel combustion, CCS for coal-fired power stations is unlikely to be ready for at least another decade. Despite the 'proof of concept' experiments currently in progress, as a fully integrated process the technology remains unproven in relation to all of its operational components. Suitable and effective capture technology has not been developed and is unlikely to be commercially available any time soon; effective and safe long-term storage on the scale necessary has not been demonstrated; and serious concerns attach to the safety aspects of transport and injection of CO_2 into designated formations, while long term retention cannot reliably be assured.

image BROWN COAL SURFACE MINING IN HAMBACH, GERMANY. GIANT COAL EXCAVATOR AND SPOIL PILE.

Deploying the technology on coal power plants is likely to double construction costs, increase fuel consumption by 10-40%, consume more water, generate more pollutants and ultimately require the public sector to ensure that the CO_2 stays where it has been buried. In a similar way to the disposal of nuclear waste, CCS envisages creating a scheme whereby future generations monitor in perpetuity the climate pollution produced by their predecessors.

carbon dioxide storage In order to benefit the climate, captured CO_2 has to be stored somewhere permanently. Current thinking is that it can be pumped under the earth's surface at a depth of over 3,000 feet into geological formations, such as saline aquifers. However, the volume of CO_2 that would need to be captured and stored is enormous - a single coal-fired power plant can produce 7 million tonnes of CO_2 annually.

It is estimated that a single 'stabilisation wedge' of CCS (enough to reduce carbon emissions by 1 billion metric tonnes per year by 2050) would require a flow of CO_2 into the ground equal to the current flow out of the ground - and in addition to the associated infrastructure to compress, transport and pump it underground. It is still not clear that it will be technically feasible to capture and bury this much carbon, both in terms of the number of storage sites and whether they will be located close enough to power plants.

Even if it is feasible to bury hundreds of thousands of megatons of CO_2 there is no way to guarantee that storage locations will be appropriately designed and managed over the timescales required. The world has limited experience of storing CO_2 underground; the longest running storage project at Sleipner in the Norweigian North Sea began operation only in 1996. This is particularly concerning because as long as CO_2 is present in geological sites, there is a risk of leakage. Although leakages are unlikely to occur in well-characterised, managed and monitored sites, permanent storage stability cannot be guaranteed since tectonic activity and natural leakage over long timeframes are impossible to predict.

Sudden leakage of CO_2 can be fatal. Carbon dioxide is not itself poisonous, and is contained (approx. 0.04%) in the air we breathe. But as concentrations increase it displaces the vital oxygen in the air. Air with concentrations of 7 to 8% CO_2 by volume causes death by suffocation after 30 to 60 minutes.

There are also health hazards when large amounts of CO_2 are explosively released. Although the gas normally disperses quickly after leaking, it can accumulate in depressions in the landscape or closed buildings, since carbon dioxide is heavier than air. It is equally dangerous when it escapes more slowly and without being noticed in residential areas, for example in cellars below houses.

The dangers from such leaks are known from natural volcanic CO_2 degassing. Gas escaping at the Lake Nyos crater lake in Cameroon, Africa in 1986 killed over 1,700 people. At least ten people have died in the Lazio region of Italy in the last 20 years as a result of CO_2 being released.

carbon storage and climate change targets Can carbon storage contribute to climate change reduction targets? In order to avoid dangerous climate change, global greenhouse gas emissions need to peak by between 2015 and 2020 and fall dramatically thereafter. Power plants capable of capturing and storing CO_2 are still being developed, however, and won't become a reality for at least another decade, if ever. This means that even if CCS works, the technology would not make any substantial contribution towards protecting the climate before 2020.

Power plant CO_2 storage will also not be of any great help in attaining the goal of at least an 80% greenhouse gas reduction by 2050 in OECD countries. Even if CCS were to be available in 2020, most of the world's new power plants will have just finished being modernised. All that could then be done would be for existing power plants to be retrofitted and CO_2 captured from the waste gas flow. Retrofitting power plants would be an extremely expensive exercise. 'Capture ready' power plants are equally unlikely to increase the likelihood of retrofitting existing fleets with capture technology.

The conclusion reached in the Energy [R]evolution scenario is that renewable energy sources are already available, in many cases cheaper, and lack the negative environmental impacts associated with fossil fuel exploitation, transport and processing. It is renewable energy together with energy efficiency and energy conservation – and not carbon capture and storage – that has to increase worldwide so that the primary cause of climate change – the burning of fossil fuels like coal, oil and gas – is stopped.

Greenpeace opposes any CCS efforts which lead to:

- Public financial support to CCS, at the expense of funding renewable energy development and investment in energy efficiency.
- The stagnation of renewable energy, energy efficiency and energy conservation improvements
- Inclusion of CCS in the Kyoto Protocol's Clean Development Mechanism (CDM) as it would divert funds away from the stated intention of the mechanism, and cannot be considered clean development under any coherent definition of this term.
- The promotion of this possible future technology as the only major solution to climate change, thereby leading to new fossil fuel developments – especially lignite and black coal-fired power plants, and an increase in emissions in the short to medium term.

nuclear technologies

Generating electricity from nuclear power involves transferring the heat produced by a controlled nuclear fission reaction into a conventional steam turbine generator. The nuclear reaction takes place inside a core and surrounded by a containment vessel of varying design and structure. Heat is removed from the core by a coolant (gas or water) and the reaction controlled by a moderating element or "moderator".

Across the world over the last two decades there has been a general slowdown in building new nuclear power stations. This has been caused by a variety of factors: fear of a nuclear accident, following the events at Three Mile Island, Chernobyl and Monju, increased scrutiny of economics and environmental factors, such as waste management and radioactive discharges.

nuclear reactor designs: evolution and safety issues At the beginning of 2005 there were 441 nuclear power reactors operating in 31 countries around the world. Although there are dozens of different reactor designs and sizes, there are three broad categories either currently deployed or under development. These are:

Generation I: Prototype commercial reactors developed in the 1950s and 1960s as modified or enlarged military reactors, originally either for submarine propulsion or plutonium production.

Generation II: Mainstream reactor designs in commercial operation worldwide.

Generation III: New generation reactors now being built.

Generation III reactors include the so-called Advanced Reactors, three of which are already in operation in Japan, with more under construction or planned. About 20 different designs are reported to be under development[67], most of them 'evolutionary' designs developed from Generation II reactor types with some modifications, but without introducing drastic changes. Some of them represent more innovative approaches. According to the World Nuclear Association, reactors of Generation III are characterised by the following:

- A standardised design for each type to expedite licensing, reduce capital cost and construction time.
- A simpler and more rugged design, making them easier to operate and less vulnerable to operational upsets.
- Higher availability and longer operating life, typically 60 years.
- Reduced possibility of core melt accidents.
- Minimal effect on the environment.
- Higher burn-up to reduce fuel use and the amount of waste.
- Burnable absorbers ('poisons') to extend fuel life.

To what extent these goals address issues of higher safety standards, as opposed to improved economics, remains unclear.

Of the new reactor types, the European Pressurised Water Reactor (EPR) has been developed from the most recent Generation II designs to start operation in France and Germany.[68] Its stated goals are to improve safety levels - in particular to reduce the probability of a severe accident by a factor of ten, achieve mitigation from severe accidents by restricting their consequences to the plant itself, and reduce costs. Compared to its predecessors, however, the EPR displays several modifications which constitute a reduction of safety margins, including:

- The volume of the reactor building has been reduced by simplifying the layout of the emergency core cooling system, and by using the results of new calculations which predict less hydrogen development during an accident.
- The thermal output of the plant has been increased by 15% relative to existing French reactors by increasing core outlet temperature, letting the main coolant pumps run at higher capacity and modifying the steam generators.
- The EPR has fewer redundant pathways in its safety systems than a German Generation II reactor.

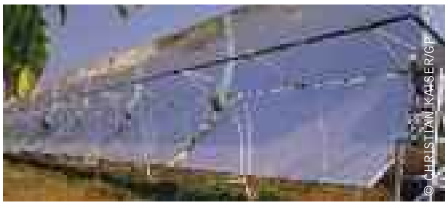
Several other modifications are hailed as substantial safety improvements, including a 'core catcher' system to control a meltdown accident. Nonetheless, in spite of the changes being envisaged, there is no guarantee that the safety level of the EPR actually represents a significant improvement. In particular, reduction of the expected core melt probability by a factor of ten is not proven. Furthermore, there are serious doubts as to whether the mitigation and control of a core melt accident with the core catcher concept will actually work.

Finally, **Generation IV** reactors are currently being developed with the aim of commercialisation in 20-30 years.

67 IAEA 2004; WNO 2004A.
68 HAINZ 2004.

image SOLAR PROJECT IN PHITSANULOK, THAILAND. SOLAR FACILITY OF THE INTERNATIONAL INSTITUTE AND SCHOOL FOR RENEWABLE ENERGY.

image SOLAR PANELS ON CONISTON STATION, NORTH WEST OF ALICE SPRINGS, NORTHERN TERRITORY.



renewable energy technologies

Renewable energy covers a range of natural sources which are constantly renewed and therefore, unlike fossil fuels and uranium, will never be exhausted. Most of them derive from the effect of the sun and moon on the earth's weather patterns. They also produce none of the harmful emissions and pollution associated with 'conventional' fuels. Although hydroelectric power has been used on an industrial scale since the middle of the last century, the serious exploitation of other renewable sources has a more recent history.

solar power (photovoltaics) There is more than enough solar radiation available all over the world to satisfy a vastly increased demand for solar power systems. The sunlight which reaches the earth's surface is enough to provide 2,850 times as much energy as we can currently use. On a global average, each square metre of land is exposed to enough sunlight to produce 1,700 kWh of power every year. The average irradiation in Europe is about 1,000 kWh per square metre, however, compared with 1,800 kWh in the Middle East.

Photovoltaic (PV) technology involves the generation of electricity from light. The essence of this process is the use of a semiconductor material which can be adapted to release electrons, the negatively charged particles that form the basis of electricity. The most common semiconductor material used in photovoltaic cells is silicon, an element most commonly found in sand. All PV cells have at least two layers of such semiconductors, one positively charged and one negatively charged. When light shines on the semiconductor, the electric field across the junction between these two layers causes electricity to flow. The greater the intensity of the light, the greater the flow of electricity. A photovoltaic system does not therefore need bright sunlight in order to operate, and can generate electricity even on cloudy days. Solar PV is different from a solar thermal collecting system (see below) where the sun's rays are used to generate heat, usually for hot water in a house, swimming pool etc.

The most important parts of a PV system are the cells which form the basic building blocks, the modules which bring together large numbers of cells into a unit, and, in some situations, the inverters used to convert the electricity generated into a form suitable for everyday use. When a PV installation is described as having a capacity of 3 kWp (peak), this refers to the output of the system under standard testing conditions, allowing comparison between different modules. In central Europe a 3 kWp rated solar electricity system, with a surface area of approximately 27 square metres, would produce enough power to meet the electricity demand of an energy conscious household.

There are several different PV technologies and types of installed system.

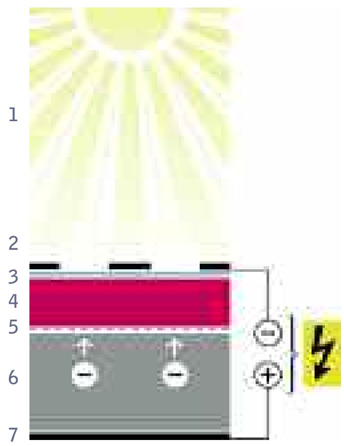
technologies

- **crystalline silicon technology** Crystalline silicon cells are made from thin slices cut from a single crystal of silicon (mono crystalline) or from a block of silicon crystals (polycrystalline or multi crystalline). This is the most common technology, representing about 80% of the market today. In addition, this technology also exists in the form of ribbon sheets.
- **thin film technology** Thin film modules are constructed by depositing extremely thin layers of photosensitive materials onto a substrate such as glass, stainless steel or flexible plastic. The latter opens up a range of applications, especially for building integration (roof tiles) and end-consumer purposes. Four types of thin film modules are commercially available at the moment: Amorphous Silicon, Cadmium Telluride, Copper Indium/Gallium Diselenide/Disulphide and multi-junction cells.
- **other emerging cell technologies** (at the development or early commercial stage): These include Concentrated Photovoltaic, consisting of cells built into concentrating collectors that use a lens to focus the concentrated sunlight onto the cells, and Organic Solar Cells, whereby the active material consists at least partially of organic dye, small, volatile organic molecules or polymer.

systems

- **grid connected** The most popular type of solar PV system for homes and businesses in the developed world. Connection to the local electricity network allows any excess power produced to be sold to the utility. Electricity is then imported from the network outside daylight hours. An inverter is used to convert the DC power produced by the system to AC power for running normal electrical equipment.
- **grid support** A system can be connected to the local electricity network as well as a back-up battery. Any excess solar electricity produced after the battery has been charged is then sold to the network. This system is ideal for use in areas of unreliable power supply.
- **off-grid** Completely independent of the grid, the system is connected to a battery via a charge controller, which stores the electricity generated and acts as the main power supply. An inverter can be used to provide AC power, enabling the use of normal appliances. Typical off-grid applications are repeater stations for mobile phones or rural electrification. Rural electrification means either small solar home systems covering basic electricity needs or solar mini grids, which are larger solar electricity systems providing electricity for several households.
- **hybrid system** A solar system can be combined with another source of power - a biomass generator, a wind turbine or diesel generator - to ensure a consistent supply of electricity. A hybrid system can be grid connected, stand alone or grid support.

figure 9.1: photovoltaics technology



1. LIGHT (PHOTONS)
2. FRONT CONTACT GRID
3. ANTI-REFLECTION COATING
4. N-TYPE SEMICONDUCTOR
5. BOARDER LAYOUT
6. P-TYPE SEMICONDUCTOR
7. BACKCONTACT

concentrating solar power (CSP) Concentrating solar power (CSP) plants, also called solar thermal power plants, produce electricity in much the same way as conventional power stations. They obtain their energy input by concentrating solar radiation and converting it to high temperature steam or gas to drive a turbine or motor engine. Large mirrors concentrate sunlight into a single line or point. The heat created there is used to generate steam. This hot, highly pressurised steam is used to power turbines which generate electricity. In sun-drenched regions, CSP plants can guarantee a large proportion of electricity production.

Four main elements are required: a concentrator, a receiver, some form of transfer medium or storage, and power conversion. Many different types of system are possible, including combinations with other renewable and non-renewable technologies, but there are four main groups of solar thermal technologies:

- **parabolic trough** Parabolic trough plants use rows of parabolic trough collectors, each of which reflect the solar radiation into an absorber tube. Synthetic oil circulates through the tubes, heating up to approximately 400°C. This heat is then used to generate electricity. Some of the plants under construction have been designed to produce power not only during sunny hours but also to store energy, allowing the plant to produce an additional 7.5 hours of nominal power after sunset, which dramatically improves their integration into the grid. Molten salts are normally used as storage fluid in a hot-and-cold two-tank concept. Plants in operation in Europe: Andasol 1 and 2 (50 MW +7.5 hour storage each); Puertollano (50 MW); Alvarado (50 MW) and Extresol 1 (50 MW + 7.5 hour storage).

- **central receiver or solar tower** A circular array of heliostats (large individually tracking mirrors) is used to concentrate sunlight on to a central receiver mounted at the top of a tower. A heat-transfer medium absorbs the highly concentrated radiation reflected by the heliostats and converts it into thermal energy to be used for the subsequent generation of superheated steam for turbine operation. To date, the heat transfer media demonstrated include water/steam, molten salts, liquid sodium and air. If pressurised gas or air is used at very high temperatures of about 1,000°C or more as the heat transfer medium, it can even be used to directly replace natural gas in a gas turbine, thus making use of the excellent efficiency (60%+) of modern gas and steam combined cycles.

  After an intermediate scaling up to 30 MW capacity, solar tower developers now feel confident that grid-connected tower power plants can be built up to a capacity of 200 MWe solar-only units. Use of heat storage will increase their flexibility. Although solar tower plants are considered to be further from commercialisation than parabolic trough systems, they have good longer-term prospects for high conversion efficiencies. Projects are being developed in Spain, South Africa and Australia.

- **parabolic dish** A dish-shaped reflector is used to concentrate sunlight on to a receiver located at its focal point. The concentrated beam radiation is absorbed into the receiver to heat a fluid or gas to approximately 750°C. This is then used to generate electricity in a small piston, Stirling engine or micro turbine attached to the receiver. The potential of parabolic dishes lies primarily for decentralised power supply and remote, stand-alone power systems. Projects are currently planned in the United States, Australia and Europe.

- **linear fresnel systems** Collectors resemble parabolic troughs, with a similar power generation technology, using a field of horizontally mounted flat mirror strips, collectively or individually tracking the sun. There is one plant currently in operation in Europe: Puerto Errado (2 MW).

figures 9.2: csp technologies: parabolic trough, central receiver/solar tower and parabolic dish

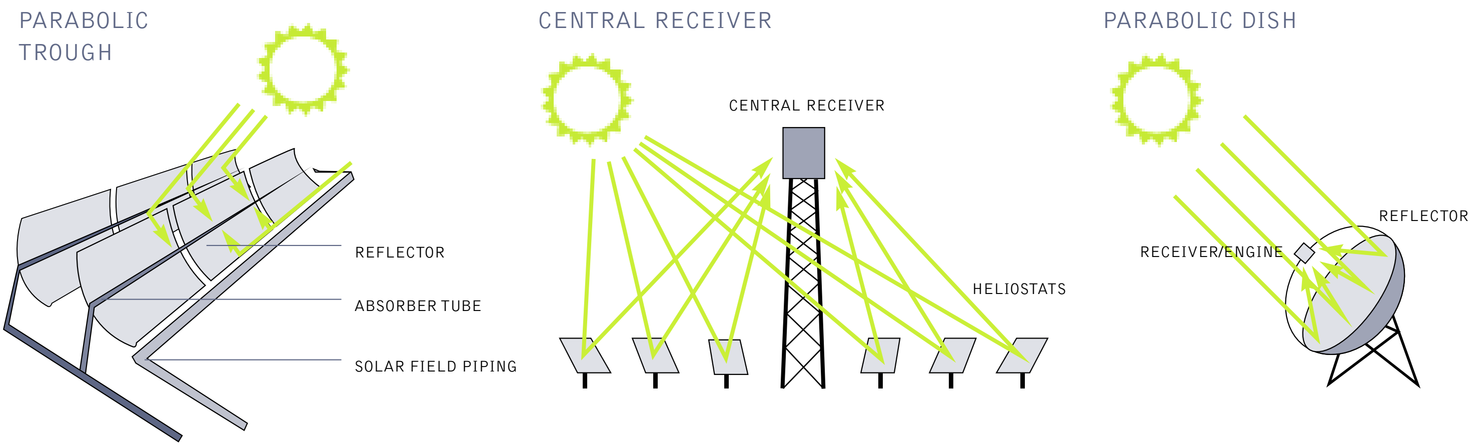


image SOLAR PANELS FEATURED IN A RENEWABLE ENERGY EXHIBIT ON BORACAY ISLAND, ONE OF THE PHILIPPINES' PREMIER TOURIST DESTINATIONS.

image VESTAS VM 80 WIND TURBINES AT AN OFFSHORE WIND PARK IN THE WESTERN PART OF DENMARK.

solar thermal collectors Solar thermal collecting systems are based on a centuries-old principle: the sun heats up water contained in a dark vessel. Solar thermal technologies on the market now are efficient and highly reliable, providing energy for a wide range of applications - from domestic hot water and space heating in residential and commercial buildings to swimming pool heating, solar-assisted cooling, industrial process heat and the desalination of drinking water.

Although mature products exist to provide domestic hot water and space heating using solar energy, in most countries they are not yet the norm. Integrating solar thermal technologies into buildings at the design stage or when the heating (and cooling) system is being replaced is crucial, thus lowering the installation cost. Moreover, the untapped potential in the non-residential sector will be opened up as newly developed technology becomes commercially viable.

solar domestic hot water and space heating Domestic hot water production is the most common application. Depending on the conditions and the system's configuration, most of a building's hot water requirements can be provided by solar energy. Larger systems can additionally cover a substantial part of the energy needed for space heating. There are two main types of technology:

- **vacuum tubes** The absorber inside the vacuum tube absorbs radiation from the sun and heats up the fluid inside. Additional radiation is picked up from the reflector behind the tubes. Whatever the angle of the sun, the round shape of the vacuum tube allows it to reach the absorber. Even on a cloudy day, when the light is coming from many angles at once, the vacuum tube collector can still be effective.
- **flat panel** This is basically a box with a glass cover which sits on the roof like a skylight. Inside is a series of copper tubes with copper fins attached. The entire structure is coated in a black substance designed to capture the sun's rays. These rays heat up a water and antifreeze mixture which circulates from the collector down to the building's boiler.

solar assisted cooling Solar chillers use thermal energy to produce cooling and/or dehumidify the air in a similar way to a refrigerator or conventional air-conditioning. This application is well-suited to solar thermal energy, as the demand for cooling is often greatest when there is most sunshine. Solar cooling has been successfully demonstrated and large-scale use can be expected in the future.

figure 9.3: flat panel solar technology

wind power Over the last 20 years, wind energy has become the world's fastest growing energy source. Today's wind turbines are produced by a sophisticated mass production industry employing a technology that is efficient, cost effective and quick to install. Turbine sizes range from a few kW to over 5,000 kW, with the largest turbines reaching more than 100m in height. One large wind turbine can produce enough electricity for about 5,000 households. State-of-the-art wind farms today can be as small as a few turbines and as large as several hundred MW.

The global wind resource is enormous, capable of generating more electricity than the world's total power demand, and well distributed across the five continents. Wind turbines can be operated not just in the windiest coastal areas but in countries which have no coastlines, including regions such as central Eastern Europe, central North and South America, and central Asia. The wind resource out at sea is even more productive than on land, encouraging the installation of offshore wind parks with foundations embedded in the ocean floor. In Denmark, a wind park built in 2002 uses 80 turbines to produce enough electricity for a city with a population of 150,000.

Smaller wind turbines can produce power efficiently in areas that otherwise have no access to electricity. This power can be used directly or stored in batteries. New technologies for using the wind's power are also being developed for exposed buildings in densely populated cities.

wind turbine design Significant consolidation of wind turbine design has taken place since the 1980s. The majority of commercial turbines now operate on a horizontal axis with three evenly spaced blades. These are attached to a rotor from which power is transferred through a gearbox to a generator. The gearbox and generator are contained within a housing called a nacelle. Some turbine designs avoid a gearbox by using direct drive. The electricity output is then channelled down the tower to a transformer and eventually into the local grid network.

Wind turbines can operate from a wind speed of 3-4 metres per second up to about 25 m/s. Limiting their power at high wind speeds is achieved either by 'stall' regulation – reducing the power output – or 'pitch' control – changing the angle of the blades so that they no longer offer any resistance to the wind. Pitch control has become the most common method. The blades can also turn at a constant or variable speed, with the latter enabling the turbine to follow more closely the changing wind speed.

The main design drivers for current wind technology are:

- high productivity at both low and high wind sites
- grid compatibility
- acoustic performance
- aerodynamic performance
- visual impact
- offshore expansion

Although the existing offshore market represents only just over 1% of the world's land-based installed wind capacity, the latest developments in wind technology are primarily driven by this emerging potential. This means that the focus is on the most effective ways to make very large turbines.

Modern wind technology is available for a range of sites - low and high wind speeds, desert and arctic climates. European wind farms operate with high availability, are generally well integrated into the environment and accepted by the public. In spite of repeated predictions of a levelling off at an optimum mid-range size, and the fact that wind turbines cannot get larger indefinitely, turbine size has increased year on year - from units of 20-60 kW in California in the 1980s up to the latest multi-MW machines with rotor diameters over 100 m. The average size of turbine installed around the world during 2009 was 1,599 kW, whilst the largest machine in operation is the Enercon E126, with a rotor diameter of 126 metres and a power capacity of 6 MW.

This growth in turbine size has been matched by the expansion of both markets and manufacturers. More than 150,000 wind turbines now operate in over 50 countries around the world. The US market is currently the largest, but there has also been impressive growth in Germany, Spain, Denmark, India and China.

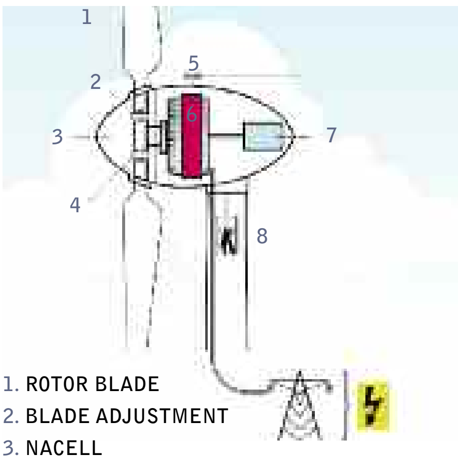
biomass energy Biomass is a broad term used to describe material of recent biological origin that can be used as a source of energy. This includes wood, crops, algae and other plants as well as agricultural and forest residues. Biomass can be used for a variety of end uses: heating, electricity generation or as fuel for transportation. The term 'bio energy' is used for biomass energy systems that produce heat and/or electricity and 'bio fuels' for liquid fuels used in transport. Biodiesel manufactured from various crops has become increasingly used as vehicle fuel, especially as the cost of oil has risen.

Biological power sources are renewable, easily stored, and, if sustainably harvested, CO_2 neutral. This is because the gas emitted during their transfer into useful energy is balanced by the carbon dioxide absorbed when they were growing plants.

Electricity generating biomass power plants work just like natural gas or coal power stations, except that the fuel must be processed before it can be burned. These power plants are generally not as large as coal power stations because their fuel supply needs to grow as near as possible to the plant. Heat generation from biomass power plants can result either from utilising a Combined Heat and Power (CHP) system, piping the heat to nearby homes or industry, or through dedicated heating systems. Small heating systems using specially produced pellets made from waste wood, for example, can be used to heat single family homes instead of natural gas or oil.

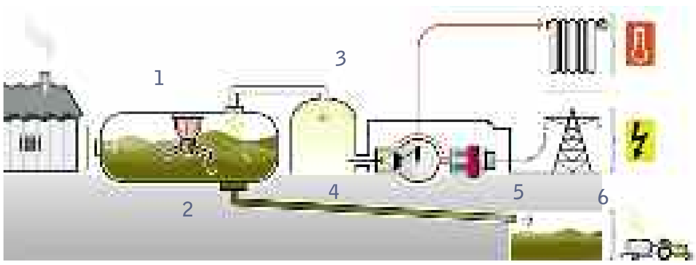
biomass technology A number of processes can be used to convert energy from biomass. These divide into thermal systems, which involve direct combustion of solids, liquids or a gas via pyrolysis or gasification, and biological systems, which involve decomposition of solid biomass to liquid or gaseous fuels by processes such as anaerobic digestion and fermentation.

figure 9.4: wind turbine technology



1. ROTOR BLADE
2. BLADE ADJUSTMENT
3. NACELL
4. ROTOR SHAFT
5. WIND MEASUREMENT
6. GENERATOR
7. SYSTEM CONTROL
8. LIFT

figure 9.5: biomass technology



1. HEATED MIXER
2. CONTAINMENT FOR FERMENTATION
3. BIOGAS STORAGE
4. COMBUSTION ENGINE
5. GENERATOR
6. WASTE CONTAINMENT

image THROUGH BURNING OF WOOD CHIPS THE POWER PLANT GENERATES ELECTRICITY, ENERGY OR HEAT. HERE WE SEE THE STOCK OF WOOD CHIPS WITH A CAPACITY OF 1000 M3 ON WHICH THE PLANT CAN RUN, UNMANNED, FOR ABOUT 4 DAYS. LELYSTAD, THE NETHERLANDS.

- **thermal systems**
  Direct combustion is the most common way of converting biomass into energy, for heat as well as electricity. Worldwide it accounts for over 90% of biomass generation. Technologies can be distinguished as either fixed bed, fluidised bed or entrained flow combustion. In **fixed bed combustion**, such as a grate furnace, primary air passes through a fixed bed, in which drying, gasification and charcoal combustion takes place. The combustible gases produced are burned after the addition of secondary air, usually in a zone separated from the fuel bed. In **fluidised bed combustion**, the primary combustion air is injected from the bottom of the furnace with such high velocity that the material inside the furnace becomes a seething mass of particles and bubbles. **Entrained flow combustion** is suitable for fuels available as small particles, such as sawdust or fine shavings, which are pneumatically injected into the furnace.

  Gasification Biomass fuels are increasingly being used with advanced conversion technologies, such as gasification systems, which offer superior efficiencies compared with conventional power generation. Gasification is a thermochemical process in which biomass is heated with little or no oxygen present to produce a low energy gas. The gas can then be used to fuel a gas turbine or combustion engine to generate electricity. Gasification can also decrease emission levels compared to power production with direct combustion and a steam cycle.

  Pyrolysis is a process whereby biomass is exposed to high temperatures in the absence of air, causing the biomass to decompose. The products of pyrolysis always include gas ('biogas'), liquid ('bio-oil') and solid ('char'), with the relative proportions of each depending on the fuel characteristics, the method of pyrolysis and the reaction parameters, such as temperature and pressure. Lower temperatures produce more solid and liquid products and higher temperatures more biogas.

- **biological systems**
  These processes are suitable for very wet biomass materials such as food or agricultural wastes, including farm animal slurry.

  Anaerobic digestion Anaerobic digestion means the breakdown of organic waste by bacteria in an oxygen-free environment. This produces a biogas typically made up of 65% methane and 35% carbon dioxide. Purified biogas can then be used both for heating and electricity generation.

  Fermentation Fermentation is the process by which growing plants with a high sugar and starch content are broken down with the help of micro-organisms to produce ethanol and methanol. The end product is a combustible fuel that can be used in vehicles.

  Biomass power station capacities typically range up to 15 MW, but larger plants are possible of up to 400 MW capacity, with part of the fuel input potentially being fossil fuel, for example pulverised coal. The world's largest biomass fuelled power plant is located at Pietarsaari in Finland. Built in 2001, this is an industrial CHP plant producing steam (100 MWth) and electricity (240 MWe) for the local forest industry and district heat for the nearby town. The boiler is a circulating fluidised bed boiler designed to generate steam from bark, sawdust, wood residues, commercial bio fuel and peat.

  A 2005 study commissioned by Greenpeace Netherlands concluded that it was technically possible to build and operate a 1,000 MWe biomass fired power plant using fluidised bed combustion technology and fed with wood residue pellets.[69]

biofuels Converting crops into ethanol and bio diesel made from rapeseed methyl ester (RME) currently takes place mainly in Brazil, the USA and Europe. Processes for obtaining synthetic fuels from 'biogenic synthesis' gases will also play a larger role in the future. Theoretically bio fuels can be produced from any biological carbon source, although the most common are photosynthetic plants. Various plants and plant-derived materials are used for bio fuel production.

Globally bio fuels are most commonly used to power vehicles, but can also be used for other purposes. The production and use of bio fuels must result in a net reduction in carbon emissions compared to the use of traditional fossil fuels to have a positive effect in climate change mitigation. Sustainable bio fuels can reduce the dependency on petroleum and thereby enhance energy security.

- **bioethanol** is a fuel manufactured through the fermentation of sugars. This is done by accessing sugars directly (sugar cane or beet) or by breaking down starch in grains such as wheat, rye, barley or maize. In the European Union bio ethanol is mainly produced from grains, with wheat as the dominant feedstock. In Brazil the preferred feedstock is sugar cane, whereas in the USA it is corn (maize). Bio ethanol produced from cereals has a by-product, a protein-rich animal feed called Dried Distillers Grains with Solubles (DDGS). For every tonne of cereals used for ethanol production, on average one third will enter the animal feed stream as DDGS. Because of its high protein level this is currently used as a replacement for soy cake. Bio ethanol can either be blended into gasoline (petrol) directly or be used in the form of ETBE (Ethyl Tertiary Butyl Ether).

- **biodiesel** is a fuel produced from vegetable oil sourced from rapeseed, sunflower seeds or soybeans as well as used cooking oils or animal fats. If used vegetable oils are recycled as feedstock for bio diesel production this can reduce pollution from discarded oil and provides a new way of transforming a waste product into transport energy. Blends of bio diesel and conventional hydrocarbon-based diesel are the most common products distributed in the retail transport fuel market.

  Most countries use a labelling system to explain the proportion of bio diesel in any fuel mix. Fuel containing 20% biodiesel is labelled B20, while pure bio diesel is referred to as B100. Blends of 20% bio diesel with 80% petroleum diesel (B20) can generally be used in unmodified diesel engines. Used in its pure form (B100) an engine may require certain modifications. Bio diesel can also be used as a heating fuel in domestic and commercial boilers. Older furnaces may contain rubber parts that would be affected by bio diesel's solvent properties, but can otherwise burn it without any conversion.

69 'OPPORTUNITIES FOR 1,000 MWE BIOMASS-FIRED POWER PLANT IN THE NETHERLANDS', GREENPEACE NETHERLANDS, 2005

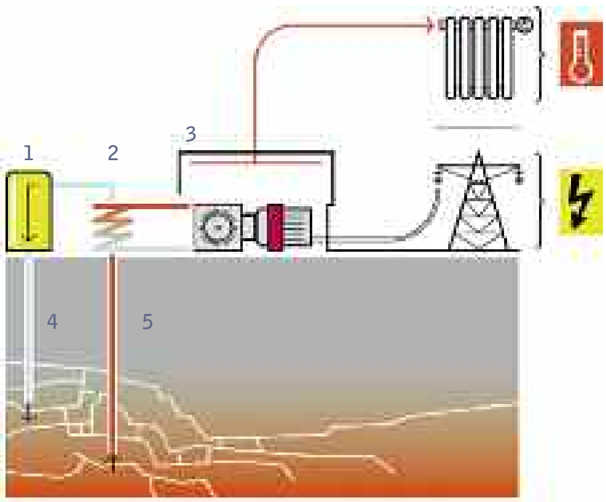
geothermal energy Geothermal energy is heat derived from deep underneath the earth's crust. In most areas, this heat reaches the surface in a very diffuse state. However, due to a variety of geological processes, some areas, including the western part of the USA, west and central Eastern Europe, Iceland, Asia and New Zealand are underlain by relatively shallow geothermal resources. These are classified as either low temperature (less than 90°C), moderate temperature (90° - 150°C) or high temperature (greater than 150°C). The uses to which these resources can be put depend on the temperature. The highest temperature is generally used only for electric power generation. Current global geothermal generation capacity totals approximately 10,700 MW, and the leading country is currently the USA, with over 3,000 MW, followed by the Philippines (1,900 MW) and Indonesia (1,200 MW). Low and moderate temperature resources can be used either directly or through ground-source heat pumps.

Geothermal power plants use the earth's natural heat to vaporise water or an organic medium. The steam created then powers a turbine which produces electricity. In the USA, New Zealand and Iceland this technique has been used extensively for decades. In Germany, where it is necessary to drill many kilometres down to reach the necessary temperatures, it is only in the trial stages. Geothermal heat plants require lower temperatures and the heated water is used directly.

hydro power Water has been used to produce electricity for about a century. Today, around one fifth of the world's electricity is produced from hydro power. Large hydroelectric power plants with concrete dams and extensive collecting lakes often have very negative effects on the environment, however, requiring the flooding of habitable areas. Smaller 'run-of-the-river' power stations, which are turbines powered by one section of running water in a river, can produce electricity in an environmentally friendly way.

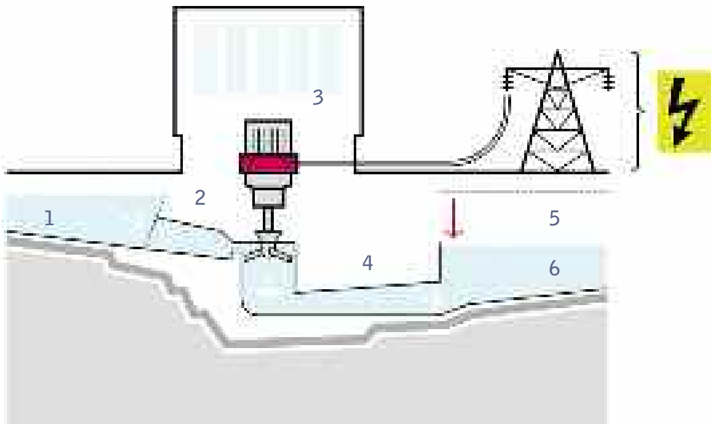
The main requirement for hydro power is to create an artificial head so that water, diverted through an intake channel or pipe into a turbine, discharges back into the river downstream. Small hydro power is mainly 'run-of-the-river' and does not collect significant amounts of stored water, requiring the construction of large dams and reservoirs. There are two broad categories of turbines. In an impulse turbine (notably the Pelton), a jet of water impinges on the runner designed to reverse the direction of the jet and thereby extracts momentum from the water. This turbine is suitable for high heads and 'small' discharges. Reaction turbines (notably Francis and Kaplan) run full of water and in effect generate hydrodynamic 'lift' forces to propel the runner blades. These turbines are suitable for medium to low heads and medium to large discharges.

figure 9.6: geothermal technology



1. PUMP
2. HEAT EXCHANGER
3. GAS TURBINE & GENERATOR
4. DRILLING HOLE FOR COLD WATER INJECTION
5. DRILLING HOLE FOR WARM WATER EXTRACTION

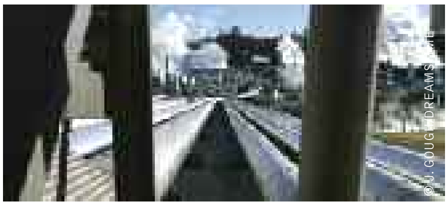
figure 9.7: hydro technology



1. INLET
2. SIEVE
3. GENERATOR
4. TURBINE
5. HEAD
6. OUTLET

image GEOTHERMAL POWER STATION, NORTH ISLAND, NEW ZEALAND.

image GEOTHERMAL ACTIVITY.



ocean energy

tidal power Tidal power can be harnessed by constructing a dam or barrage across an estuary or bay with a tidal range of at least five metres. Gates in the barrage allow the incoming tide to build up in a basin behind it. The gates then close so that when the tide flows out the water can be channelled through turbines to generate electricity. Tidal barrages have been built across estuaries in France, Canada and China but a mixture of high cost projections coupled with environmental objections to the effect on estuarial habitats has limited the technology's further expansion.

wave and tidal stream power In **wave power** generation, a structure interacts with the incoming waves, converting this energy to electricity through a hydraulic, mechanical or pneumatic power take-off system. The structure is kept in position by a mooring system or placed directly on the seabed/seashore. Power is transmitted to the seabed by a flexible submerged electrical cable and to shore by a sub-sea cable.

In **tidal stream** generation, a machine similar to a wind turbine rotor is fitted underwater to a column fixed to the sea bed; the rotor then rotates to generate electricity from fast-moving currents. 300 kW prototypes are in operation in the UK.

Wave power converters can be made up from connected groups of smaller generator units of 100 – 500 kW, or several mechanical or hydraulically interconnected modules can supply a single larger turbine generator unit of 2 – 20 MW. The large waves needed to make the technology more cost effective are mostly found at great distances from the shore, however, requiring costly sub-sea cables to transmit the power. The converters themselves also take up large amounts of space. Wave power has the advantage of providing a more predictable supply than wind energy and can be located in the ocean without much visual intrusion.

There is no commercially leading technology on wave power conversion at present. Different systems are being developed at sea for prototype testing. The largest grid-connected system installed so far is the 2.25 MW Pelamis, with linked semi-submerged cyclindrical sections, operating off the coast of Portugal. Most development work has been carried out in the UK.

Wave energy systems can be divided into three groups, described below.

- **shoreline devices** are fixed to the coast or embedded in the shoreline, with the advantage of easier installation and maintenance. They also do not require deep-water moorings or long lengths of underwater electrical cable. The disadvantage is that they experience a much less powerful wave regime. The most advanced type of shoreline device is the oscillating water column (OWC). One example is the Pico plant, a 400 kW rated shoreline OWC equipped with a Wells turbine constructed in the 1990s. Another system that can be integrated into a breakwater is the Seawave Slot-Cone converter.
- **near shore devices** are deployed at moderate water depths (~20-25 m) at distances up to ~500 m from the shore. They have the same advantages as shoreline devices but are exposed to stronger, more productive waves. These include 'point absorber systems'.
- **offshore devices** exploit the more powerful wave regimes available in deep water (>25 m depth). More recent designs for offshore devices concentrate on small, modular devices, yielding high power output when deployed in arrays. One example is the AquaBuOY system, a freely floating heaving point absorber system that reacts against a submersed tube, filled with water. Another example is the Wave Dragon, which uses a wave reflector design to focus the wave towards a ramp and fill a higher-level reservoir.

images 1. BIOMASS CROPS. **2.** OCEAN ENERGY. **3.** CONCENTRATING SOLAR POWER (CSP).

10

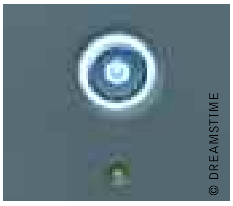
IN NORTH AMERICA ALONE WE COULD SHUT DOWN 16 DIRTY POWERPLANTS BY CHANGING TO CFLS AND LEDS. IN EUROPE WE COULD SHUT DOWN 11.

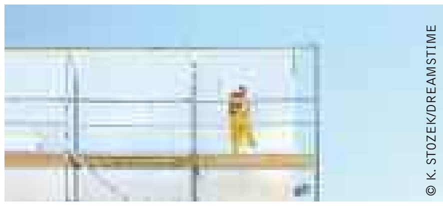
"today, we are wasting two thirds (61%) of the electricity we consume, mostly due to bad product design."

GREENPEACE INTERNATIONAL
CLIMATE CAMPAIGN

image STANDBY.

image WORK TEAM APPLYING STYROFOAM WALL INSULATION TO A NEWLY CONSTRUCTED BUILDING.





Using energy efficiently is cheaper than producing new energy from scratch and often has many other positive effects. An efficient clothes washing machine or dishwasher, for example, uses less power and less water. Efficiency also usually provides a higher level of comfort. A well-insulated house, for instance, will feel warmer in the winter, cooler in the summer and be healthier to live in. An efficient refrigerator will make less noise, have no frost inside, no condensation outside and will probably last longer. Efficient lighting will offer you more light where you need it. Efficiency is thus really better described as 'more with less'.

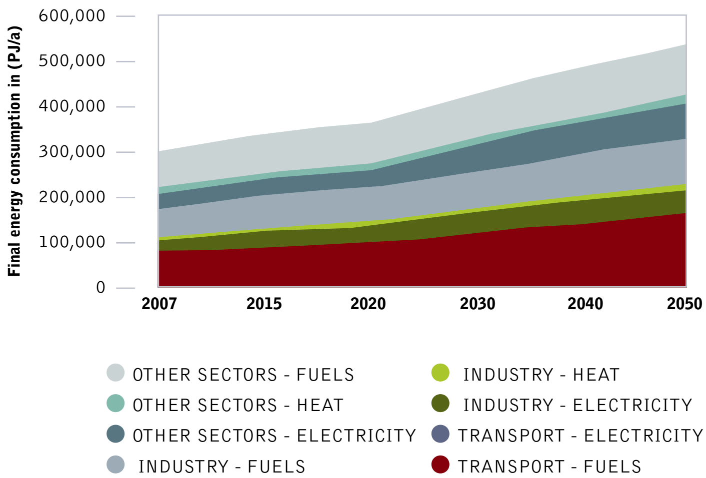
There are very simple steps every householder can take, such as putting additional insulation in the roof, using super-insulating glazing or buying a high-efficiency washing machine when the old one wears out. All of these examples will save both money and energy. But the biggest savings will not be found in such incremental steps. The real gains come from rethinking the whole concept - 'the whole house', 'the whole car' or even 'the whole transport system'. When you do this, energy needs can often be cut back by four to ten times.

In order to find out the global and regional energy efficiency potential, the Dutch institute Ecofys developed energy demand scenarios for the Greenpeace Energy [R]evolution analysis in 2008. These scenarios cover energy demand over the period 2005-2050 for ten world regions. Two low energy demand scenarios for energy efficiency improvements have been defined. The first is based on the best technical energy efficiency potentials and is called 'Technical'. The second is based on more moderate energy savings, taking into account implementation constraints in terms of costs and other barriers. This scenario is called 'Revolution'. The main results of the study are summarised below.

For the 2010 update of the Energy [R]evolution scenario, including the advanced version, this analysis has been reconfigured using the latest IEA statistics from World Energy Outlook 2009. The levels of final energy demand have therefore been adjusted, resulting in particular in lower overall fuel consumption in the industrial sector than previously assumed. In addition, an increased share of electric vehicles in the advanced scenario results in a lower final energy demand required to meet the same level of transport activity. Apart from that, the overall efficiency targets for each technology (based on actual demand in PJ/a) for the years 2030, 2040 and 2050 have not been changed.

The starting point for the original Ecofys analysis (based on the IEA's WEO 2007) was that worldwide final energy demand was expected to grow by 95% between 2005 and 2050, from 290 EJ to 570 EJ, if we continue with business as usual. Based on the 2009 figures, the extrapolation of final energy demand in the Reference scenario results in 531 EJ by the year 2050.

figure 10.1: energy demand growth under the reference scenario, 2007-2050 by sector IEA WEO 2009



Growth in the transport sector is projected to be the largest, with energy demand expected to grow from 84 EJ in 2007 to 183 EJ by 2050. Demand from buildings and agriculture is expected to grow the least, from 91 EJ in 2007 to 124 EJ by 2050.

Under the Energy [R]evolution scenario, however, growth in energy demand can be limited to an increase of 28% up to 2050 in comparison to the 2007 level, whilst taking into account implementation constraints in terms of costs and other barriers.

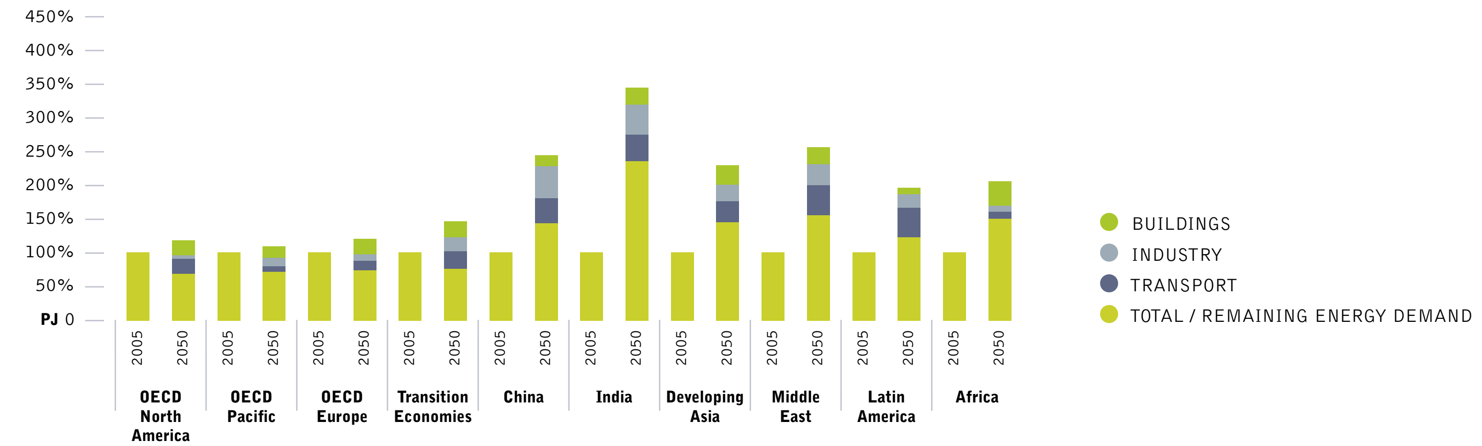
In Figure 10.2 the potential for energy efficiency improvements under this scenario are presented. The baseline is 2005 final energy demand per region. Table 10.1 shows that total worldwide energy demand has reduced to 376 PJ by 2050, with a breakdown by sector.

table 10.1: change in energy demand by 2050 in comparison to 2005 level

SECTOR	[R]EVOLUTION SCENARIO	REFERENCE SCENARIO
Industry	+17%	+77%
Transport	+2%	+93%
Buildings and Agriculture	+14%	+60%
Total	**+12%**	**+74%**

figure 10.2: potential for energy efficiency improvements per world region in energy [r]evolution scenario

ENERGY DEMAND FOR ALL SECTORS (NORMALISED BASED ON 2005 PJ)



energy efficient households

A breakdown of domestic electricity use by end-use equipment in the core EU-15 countries is shown in Figure 10.3 and of electricity use in the EU services sector in Figure 10.4.

Based on the results from three studies[70], we have assumed the following breakdowns for energy use in households (fuel and electricity) under the Reference scenario in 2050. Insufficient information is available to enable a breakdown by world region. We assume, however, that the pattern for different regions will converge over the years.

Since an estimated 80% of fuel use in buildings is for space heating, the energy efficiency improvement potential here is considered to be large. In order to determine the potential for improvement in space heating efficiency we looked at the energy demand per m² floor area per heating degree day (HDD). Heating degree days indicate the number of degrees that a day's average temperature is under 18° Celsius, the temperature below which buildings need to be heated.

figure 10.3: breakdown of electricity use for residential end-use equipment in EU-15 countries in 2004

(BERTOLDI & ATANASIU, 2006)

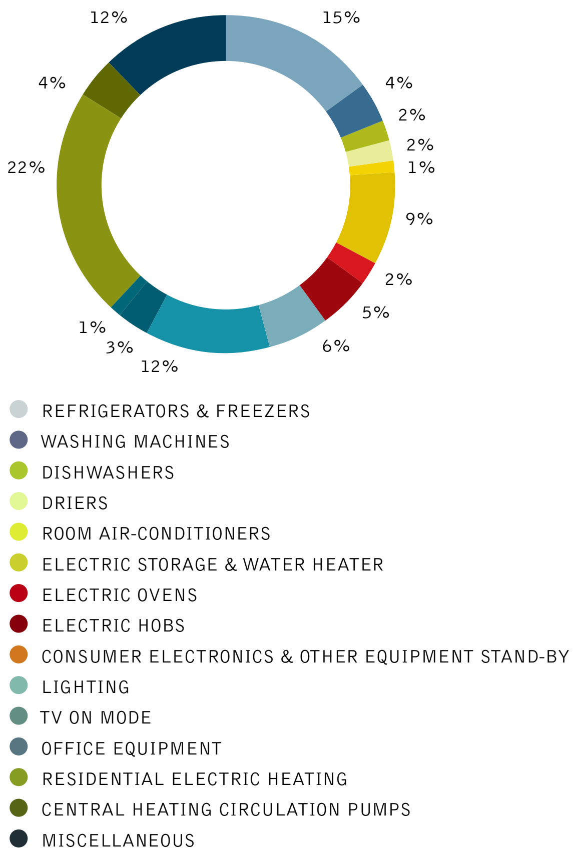
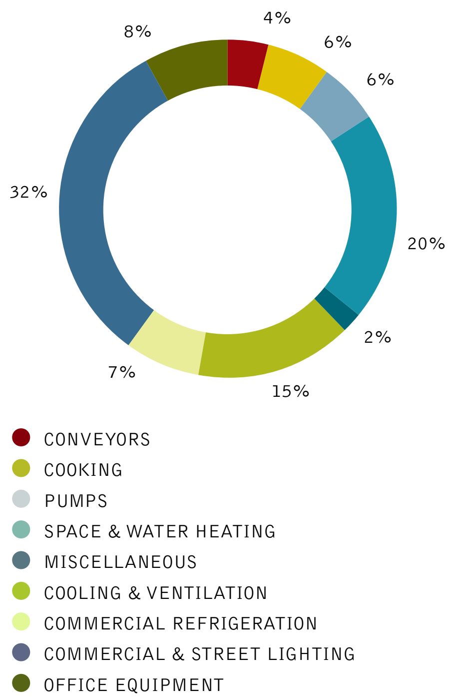


figure 10.4: breakdown of electricity consumption in the EU services sector

(BERTOLDI & ATANASIU, 2006)



70 BERTOLDI, P. AND B. ATANASIU. 'ELECTRICITY CONSUMPTION AND EFFICIENCY TRENDS IN THE ENLARGED EUROPEAN UNION - STATUS REPORT 2006', INSTITUTE FOR ENVIRONMENT AND SUSTAINABILITY, IEA (2006), ENERGY TECHNOLOGY PERSPECTIVES 2006 – SCENARIOS AND STRATEGIES TO 2050 AND WBCSD (2005), PATHWAYS TO 2050 – ENERGY AND CLIMATE CHANGE. WORLD BUSINESS COUNCIL ON SUSTAINABLE DEVELOPMENT, SWITZERLAND. WWW.WBCSD.ORG/PLUGINS/DOCSEARCH/DETAILS.ASP?TYPE=DOCDET&OBJECTID=MTCZNZA

image A ROOM AT A NEWLY CONSTRUCTED HOME IS SPRAYED WITH LIQUID INSULATING FOAM BEFORE THE DRYWALL IS ADDED.

image FUTURISTIC SOLAR HEATED HOME MADE FROM CEMENT AND PARTIALLY COVERED IN THE EARTH.

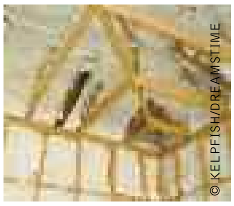


table 10.2: **break down of energy use in households**

FUEL USE 2050	ELECTRICITY USE 2050
Hot water (15%)	Air conditioning (8%)
Cooking (5%)	Lighting (15%)
Space heating (80%)	Standby (8%)
	Cold appliances (15%)
	Appliances (30%)
	Other (e.g. electric heating) (24%)

The typical current heating demand for dwellings is 70-120 kJ/m.[71] Dwellings with a low energy use consume below 32 kJ/m²/HDD, however, more than 70% less than the current level. An example of how a low energy household would operate is shown below.

the low energy household

Technologies to reduce energy demand applied in this typical household are[72]:

- Triple-glazed windows with low emittance coatings. These windows greatly reduce heat loss to 40% compared to windows with one layer. The low emittance coating also prevents energy waves in sunlight coming through, reducing the need for cooling.
- Insulation of roofs, walls, floors and basement. Proper insulation reduces heating and cooling demand by 50% in comparison to typical energy demand.
- Passive solar techniques make use of the sun's rays throughout the building's design – both siting and window orientation. The term 'passive' indicates that no mechanical equipment is used. All solar gains come through the windows.
- Balanced ventilation with heat recovery means that heated indoor air is channelled to a heat recovery unit and used to heat incoming outdoor air.

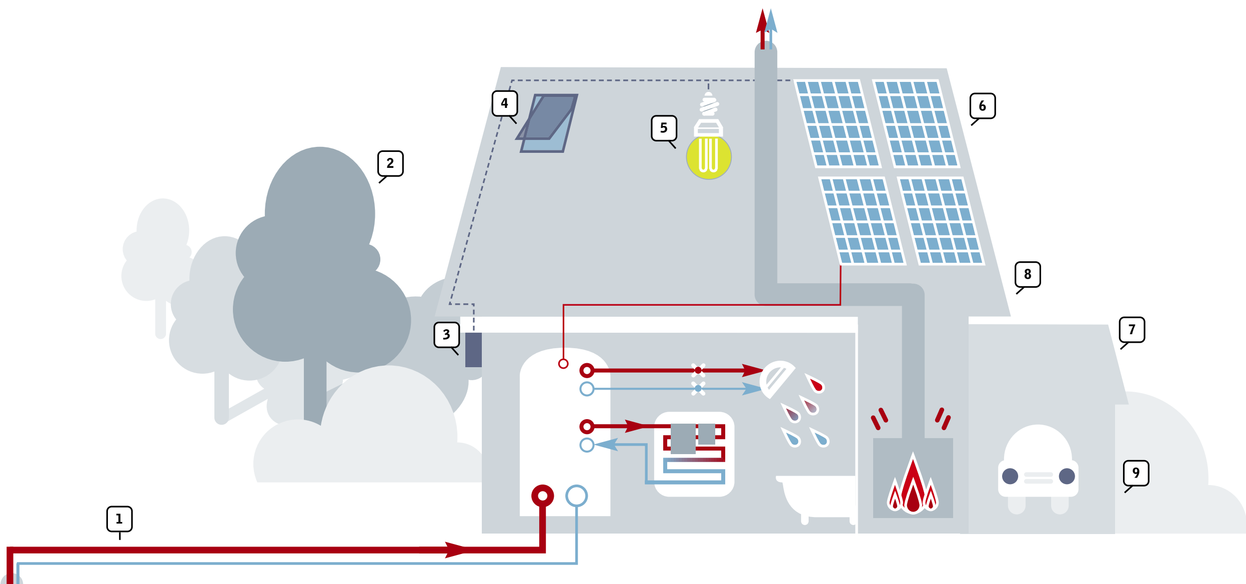
Current space heating demands in kJ per square metre per heating degree day for OECD dwellings are given in the table below.

table 10.3: **space heating demands in OECD dwellings in 2004**

REGION	SPACE HEATING (KJ/M²/HDD)
OECD Europe	113
OECD North America	78
OECD Pacific	52

source OECD/IEA, 2007

figure 10.5: **elements of new building design that can substantially reduce energy use** (WBCSD, 2005)



1. HEAT PUMP SYSTEMS THAT UTILISE THE STABLE TEMPERATURE IN THE GROUND TO SUPPORT AIR CONDITIONING IN SUMMER AND HEATING OR HOT WATER SUPPLY IN WINTER.
2. TREES TO PROVIDE SHADE AND COOLING IN SUMMER, AND SHIELD AGAINST COLD WIND IN WINTER.
3. NEW BATTERY TECHNOLOGY FOR THE STORAGE OF THE ELECTRICITY PRODUCED BY SOLAR PANELS.
4. TRANSPARENT DESIGN TO REDUCE THE NEED FOR LIGHTING. "LOW-E" GLASS COATING TO REDUCE THE AMOUNT OF HEAT ABSORBED FROM SUNLIGHT THROUGH THE WINDOWS (WINDOWS WITH THE REVERSE EFFECT CAN BE INSTALLED IN COLDER CLIMATES).
5. EFFICIENT LIGHT BULBS.
6. SOLAR PHOTOVOLTAIC PANELS FOR ELECTRICITY PRODUCTION AND SOLAR THERMAL PANELS FOR WATER HEATING.
7. ROOMS THAT ARE NOT NORMALLY HEATED (E.G. A GARAGE) SERVING AS ADDITIONAL INSULATION.
8. VENTILATED DOUBLE SKIN FAÇADES TO REDUCE HEATING AND COOLING REQUIREMENTS.
9. WOOD AS A BUILDING MATERIAL WITH ADVANTAGEOUS INSULATION PROPERTIES, WHICH ALSO STORES CARBON AND IS OFTEN PRODUCED WITH BIOMASS ENERGY.

71 BASED ON IEA, 2007 ENERGY USE IN THE NEW MILLENIUM – TRENDS IN IEA COUNTRIES. INTERNATIONAL ENERGY AGENCY, PARIS.

72 BASED ON WBCSD (2005), IEA (2006), JOOSEN ET AL (2002). SECTORAL OBJECTIVES OF EMISSION REDUCTION. ASSIGNMENT FOR EUROPEAN COMMISSION. HTTP://EC.EUROPA.EU/ENVIRONMENT/ENVECO/CLIMATE_CHANGE/PDF/TOP_DOWN_ANALYSIS_XSUM.PDF

space heating savings for new buildings We have assumed under the Energy [R]evolution scenario that all new dwellings in OECD regions will be low energy buildings using 48 kJ/m²/HDD. Since there is no data on current average energy consumption for dwellings in non-OECD countries, we have had to make assumptions for these regions. The potential for fuel savings[73] is considered to be small in developing regions and about the same as the OECD in the Transition Economies. For this study we have taken the potential for developing regions to be equal to a 1.4% energy efficiency improvement per year, including replacing existing homes with more energy efficient housing (retrofitting). In the Transition Economies we have assumed the average OECD savings potential. For new homes, the savings compared to the average current dwelling are given in Table 10.4.

table 10.4: space heating savings in new buildings in comparison to typical current dwellings

REGION	[R]EVOLUTION SCENARIO
OECD Europe	58%
OECD North America	38%
OECD Pacific	8%
Transition Economies	35%

space heating savings by retrofit As well as constructing efficient new buildings there is a large savings potential to be found in retrofitting existing buildings. Important retrofit options are more efficient windows and insulation. According to the OECD/IEA, the first can save 39% of space heating energy demand while the latter can save 32% of space heating or cooling. Energy consumption in existing buildings in Europe could therefore decrease by more than 50%.[74] In all regions of the world we have assumed the same relative reductions as for new buildings, but taking into account the current average efficiency of dwellings in different regions. For existing homes, the savings compared to the average current dwelling are given in the table below.

table 10.5: space heating savings in existing buildings in comparison to typical current dwellings

REGION	[R]EVOLUTION SCENARIO
OECD Europe	40%
OECD North America	26%
OECD Pacific	5%
Transition Economies	24%

In order to calculate the overall potential we need to know the share of new and existing buildings in 2050. The United Nations Economic Commission for Europe (UNECE) database[75] contains data on the total housing stock, including the increase from new construction. We have assumed that the total housing stock grows at the same pace as the population. The number of existing dwellings also decreases each year due to a certain level of replacement. On average this is about 1.3% of the total housing stock per year, meaning a 40% replacement over 40 years, the equivalent of an average house lifetime of 100 years.

Table 10.6 illustrates that new dwellings in OECD Europe make up 7% of the total housing stock in 2050 and retrofits account for 41%. Although the UNECE database does not include data for countries in all regions of the world, the percentages of new and retrofit houses in 2050 are not dependent on the absolute number of dwellings but only on the rate of population growth and the 1.3% assumption. This means that we can use the rate of population growth to make forecasts for other regions (see 10.6).

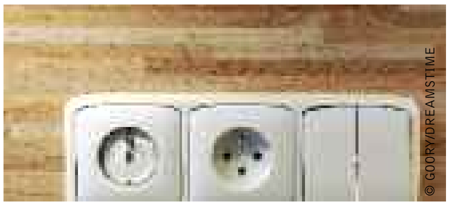
Total savings for space heating energy demand are calculated by multiplying the savings potentials for new and existing houses by the forecast share of dwellings in 2050 to obtain a weighed percentage reduction. For fuel use for hot water we have assumed the same annual percentage reduction as for space heating. For cooking we have assumed a 1.5% per year efficiency improvement.

table 10.6: forecast share of new dwellings in the housing stock in 2050

REGION	EXISTING BUILDINGS	NEW DWELLINGS DUE TO REPLACEMENT OF OLD BUILDINGS AS SHARE OF TOTAL DWELLINGS IN 2050	NEW DWELLINGS DUE TO POPULATION GROWTH AS SHARE OF TOTAL IN 2050
OECD Europe	52%	41%	7%
OECD North America	36%	29%	35%
OECD Pacific	55%	44%	1%
Transition Economies	55%	45%	0%
India	32%	25%	43%
China	49%	39%	12%
Developing Asia	29%	23%	48%
Latin America	33%	27%	40%
Middle East	22%	17%	61%
Africa	16%	13%	71%

73 ÜRGE-VORSATZ & NOVIKOVA (2008). POTENTIALS AND COSTS OF CARBON DIOXIDE MITIGATION IN THE WORLD'S BUILDINGS. ENERGY POLICY 36, PP. 642-661.
74 OECD/IEA,2006.
75 UNECE, 'HUMAN SETTLEMENT DATABASE', 2008.

images POWER SOCKETS AND SWITCH.



electricity savings by application

In order to determine savings for electricity demand in buildings, we examined the energy use and potential savings for the following different elements of power consumption:

- Standby
- Lighting
- Set-top boxes
- Freezers/fridges
- Computers/servers
- Air conditioning

1. standby power consumption Standby power consumption is the "lowest power consumption which cannot be switched off (influenced) by the user and may persist for an indefinite time when an appliance is connected to the mains electricity supply".[76] In other words, the energy available when an appliance is connected to the power supply is not being used. Some appliances also consume energy when they are not on standby and are also not being used for their primary function, for example when an appliance has reached the end of a cycle but the 'on' button is still engaged. This consumption does not fit into the definition of standby power but could still account for a substantial amount of energy use.

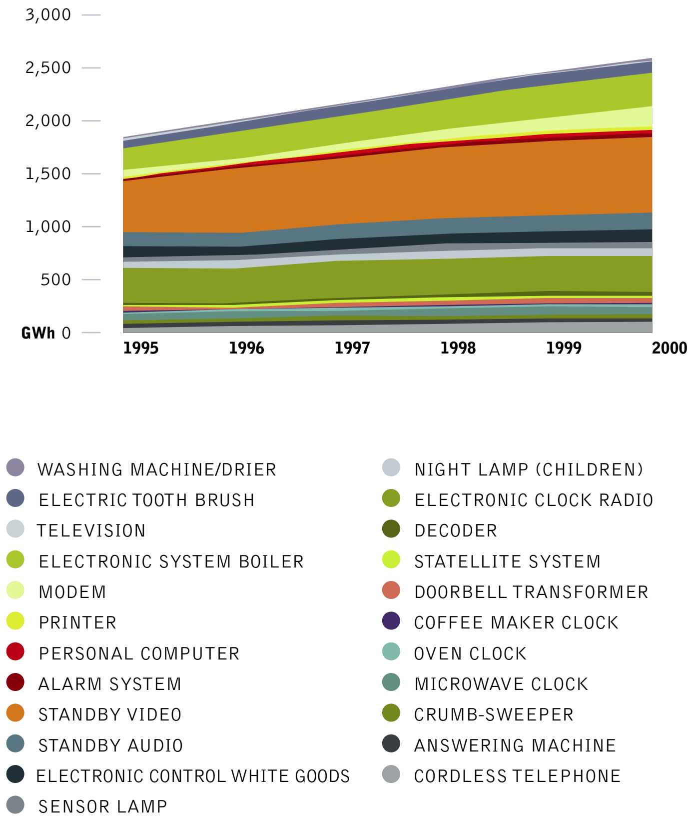
Reducing standby losses provides a major opportunity for cost-effective energy savings. Nowadays, many appliances can be remotely and/or instantly activated or have a continuous digital display, and therefore require a standby mode. Standby power accounts for 20–90W per home in developed nations, ranging from 4 to 10% of total residential electricity use[77] and 3-12% of total residential electricity use worldwide.[78] Printers use 30-40% of their full power requirement when idle, as do televisions and music equipment. Set-top boxes used in conjunction with televisions tend to consume even more energy on standby than in use. Typical standby use for different types of electrical devices is shown in Figure 10.8.

In developing nations, the quantity of appliances per household is growing substantially. In China, standby energy use has grown from almost zero in 1980 to a level of 50–200 kWh per year in an average urban home by the year 2000. Levels of standby power use in Chinese homes (on average 29W) are still below those in developed countries, but relatively large because Chinese appliances have a higher level of standby operation. Existing technologies are available to greatly reduce standby power at a low cost.

By 2050, if it remains unchecked, standby use is expected to be responsible for 8% of total electricity demand across all regions of the world. The World Business Council for Sustainable Development has assessed that a worldwide savings potential in standby use of between 72% and 82% is feasible. This is confirmed by research in the Netherlands[79], which showed that reducing the amount of power available for standby in all devices to just 1W would led to a saving of approximately 77%. We have adopted these reduction percentages for the Energy [R]evolution scenario (72% reduction). This results in an energy efficiency improvement of 3.1% per year.

figure 10.8: electricity use of standby power for different devices

(HARMELINK ET AL., 2005)



76 UNITED KINGDOM MARKET TRANSFORMATION PROGRAMME, 'BNXS15: STANDBY POWER CONSUMPTION - DOMESTIC APPLIANCES', 2008.
77 MEIER, A., J. LIN, J. LIU, T. LI, 'STANDBY POWER USE IN CHINESE HOMES', ENERGY AND BUILDINGS 36, PP. 1211-1216, 2004.
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79 HARMELINK M., K. BLOK, M. CHANG, W. GRAUS, S. JOOSEN, 'OPTIONS TO SPEED UP ENERGY SAVINGS IN THE NETHERLANDS (MOGELIJKHEDEN VOOR VERSNELLING VAN ENERGIEBESPARING IN NEDERLAND)', ECOFYS, UTRECHT, 2005

2. lighting Incandescent bulbs have been the most common lamps for a more than 100 years. These are the most inefficient type of lighting, however, since up to 95% of the electricity is converted into heat.[80] Incandescent lamps have a relatively short life-span (average of approximately 1,000 hours) but have a low initial cost and optimal colour rendering. Compact Fluorescent Lamps (CFLs) are more expensive than incandescent bulbs but they use about 75% less energy, produce 75% less heat and last about ten times longer.[81] Many governments have therefore passed measures to prohibit the sale of incandescent light bulbs, with the aim of encouraging use of more energy efficient lighting alternatives, both CFLs and Light Emitting Diode (LED) lamps. Brazil and Venezuela started to phase out incandescent bulbs in 2005, and other nations are planning scheduled phase-outs: Australia, Ireland and Switzerland in 2009; Argentina, Italy, Russia and the United Kingdom by 2011; Canada in 2012; the European Union by September 2009; and the USA between 2012 and 2014. It is very likely that the market share of CFLs will therefore increase significantly beyond 2015.

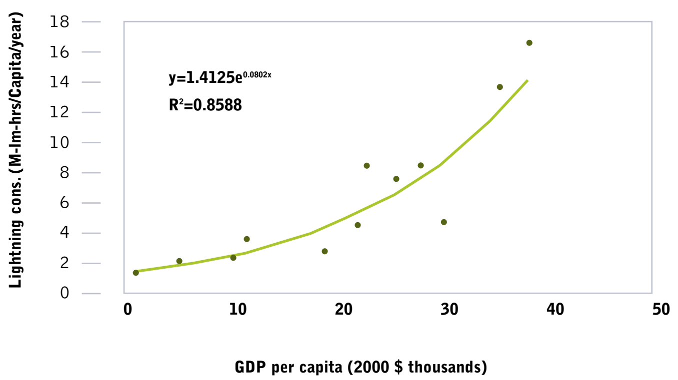
Globally, people consume 3 Mega-lumen-hrs (Mlmh) of residential electric light per capita/year. The average North American uses 13.2 Mlmh, the average Chinese 1.5 Mlmh - still 300 times the average artificial per capita light use in England in the nineteenth century. The average Japanese uses 18.5 Mlmh and the average European or Australian 2.7Mlmh. There is a clear relationship between GDP per capita and lighting consumption in Mlmh/cap/yr (see Figure 10.6).

Saving energy in lighting is not just a question of using more efficient lamps, however. Other approaches include making smarter use of daylight, reducing light absorption by luminaires (the fixture in which the lamp is housed), optimising lighting levels (levels in OECD countries commonly exceed recommended values), using automatic controls (turn off when no one is present, dim artificial light in response to rising daylight) and retrofitting buildings to make better use of daylight. Buildings designed to optimise daylight can receive up to 70% of their annual illumination needs from daylight, while a typical building will only get 20 to 25%.[82]

The IEA publication "Light's Labour's Lost" (2006) projects that the cost-effective savings potential from energy efficient lighting in 2030 is at least 38% of lighting electricity consumption, even disregarding newer and promising solid state lighting technologies such as LEDs. In order to determine the savings potential for lighting, it is important to know the percentage of households with energy efficient lamps and the penetration level of these lamps. In a study by Bertoldi & Atanasiu (2006), national lighting consumption and CFL penetration data is presented for the EU-27 countries (and candidate country Croatia). We used this data as the basis for household penetration rates and lighting electricity consumption in OECD Europe. Based on this and other studies already cited we estimate that a maximum of 80% savings can result from the introduction of efficient residential lighting compared to the present situation. These savings not only result from using energy efficient lamps but from behavioural changes and maximising daylight use. Since the penetration of energy efficient lamps differs per household, we have assumed an attainable savings potential of 70% in the Revolution scenario.

figure 10.6: lighting consumption Mlmh/capita/yr as a function of GDP per capita

(WAIDE, 2006)



3. set-top boxes Set-top boxes (STBs) are used to decode satellite or cable television programmes and are a major new source of energy demand. More than a billion are projected to be purchased worldwide over the next decade. The energy use of an average set-top box is 20-30 W, but it uses nearly the same amount of energy when switched off.[83] In the USA, STB energy use is estimated at 15 TWh/year, or about 1.3% of residential electricity use.[84] With more advanced uses, for instance digital video recorders (DVRs), STB energy use is forecast to triple to 45 TWh/year by 2010 – an 18% annual growth rate and 4% of 2010 residential electricity use.

Because of their short lifetimes (on average five years) and high ownership growth rates, STBs provide an opportunity for significant short term energy savings. Cable/satellite boxes without DVRs use 100 to 200 kWh of electricity per year, whilst combined with DVRs they use between 200 and 400 kWh per year. Media receiver boxes use less energy (around 35 kWh per year) but must be used in conjunction with existing audiovisual equipment and computers, thus adding another 35 kWh to the annual energy use of existing home electronics. Figure 10.7 shows the annual energy use of common household appliances. This shows that the energy use of some set-top boxes approaches that of existing major energy consuming appliances.

Reducing the energy use of set-top boxes is complicated by their complex operating and communication modes. Although improvements in power supply design and efficiency will be effective in reducing energy use, the greatest savings will be obtained through energy management measures. The study by Rainer et al. (2004) reports a savings potential of between 32% and 54% over five years (2005-2010). Assuming that these drastic measures have not yet been applied, and due to lack of data for other regions, we have taken these reduction percentages as the global potential up to 2050.

80 HENDEL-BLACKFORD ET AL., 2007. ENERGY EFFICIENCY IN LIFESTYLES: EUROPE AND JAPAN. ECOFYS, UTRECHT, NETHERLANDS.
81 ENERGY STAR, 'COMPACT FLUORESCENT LIGHT BULBS', 2008.
82 IEA, 2006.
83 OECD/IEA, 2006; HOROWITZ, 2007, NRDC STUDY OF SET TOP BOX AND GAME CONSOLE POWER USE
84 RAINER ET AL., 2004.

image FRIDGE.

image POWER PLUGS.

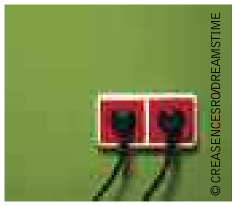
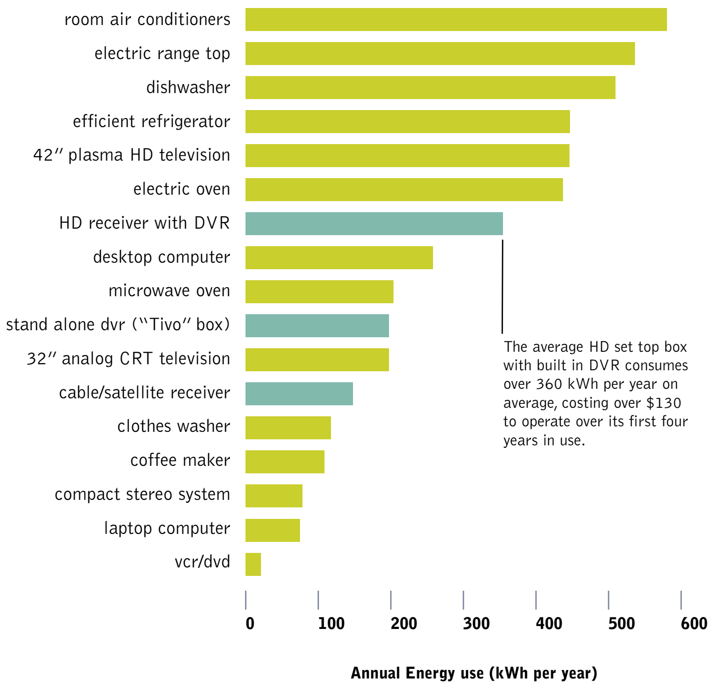


figure 10.7: annual energy use of common household appliances

(HOROWITZ, 2007)



4. cold appliances The average household in OECD Europe consumed 700 kWh/year of electricity for food refrigeration in 2000, compared with 1,000 kWh/year in Japan and 1,300 kWh/year in OECD North America. These figures illustrate differences in average household storage capacities, the ratio of frozen to fresh food storage capacity, ambient temperatures and humidity, and food storage temperatures and control (IEA, 2003). European households typically either have a refrigerator-freezer in the kitchen (sometimes with an additional freezer or refrigerator), or they have a refrigerator and a separate freezer. Practical height and width limits place constraints on the available internal storage space for an appliance. Similar constraints apply in Japanese households, where ownership of a single refrigerator-freezer is the norm, but are less pressing in OECD North America and Australia. In these countries almost all households have a refrigerator-freezer and many also have a separate freezer and occasionally a separate refrigerator (IEA, 2003).

The anticipated energy efficiency improvement for cold appliances is based on the situation in the EU. In 2003, 103 TWh were consumed by household cold appliances in the EU-15 countries (15% of total 2004 residential end use). An average energy label A++ cold appliance uses 120 kWh per year, while a comparable appliance of energy label B uses on average 300 kWh per year and a C label 600 kWh (EuroTopten project, 2008). The average energy label of appliances sold in EU-15 countries is still label B. If only A++ appliances were sold, energy consumption would be 60% less. The average lifetime of a cold appliance is 15 years, meaning that 15 years from the introduction of only A++ labelled appliances, 60% less energy would be used in EU-15 countries.

The European Commission (2005) has estimated a savings potential for cold appliances of 3.5% per year for the period 2003-2010. We have used this improvement rate for the technical potential in 2050 for all regions. This means that for the EU-15 countries the average cold appliance would use 72 kWh per year in 2050. For the Revolution scenario we have assumed a 2.5% per year efficiency improvement, corresponding to 64% in 2050.

5. computers and servers The average desktop computer uses about 120 W per hour - the monitor 75 W and the central processing unit 45 W - and the average laptop 30 W per hour. Current best practice monitors[85] use only 18 W (15 inch screen), which is 76% less than the average. Savings for computers are especially important in the commercial sector. According to a 2006 US study, computers and monitors have the highest energy consumption in an office after lighting. In Europe, office equipment use is considered to be less important , but estimates differ widely.[86] Some studies have shown that automatic and/or manual power management of computers and monitors can significantly reduce their energy consumption.

A power managed computer consumes less than half the energy of a standard machine[87], depending on how your computer is used; power management can reduce the annual energy consumption of a computer and monitor by as much as 80%.[88] Approximately half of all office computers are left on overnight and at weekends (75% of the time). Apart from switching off at night, using Liquid Crystal Display (LCD) monitors requires less energy than a Cathode Ray Tube (CRT). An average LCD screen uses 79% less energy than an average CRT monitor if both are power-managed.[89] Further savings can be made by ensuring computers enter low power mode when they are idle during the day. Another benefit of decreasing the power consumption of computers and monitors is that it reduces the load for air conditioning. According to a 2002 study by Roth et al (2002)[90], office equipment increases the air conditioning load by 0.2-0.5 kW per kW of office equipment power consumption.

The average computer with a CRT monitor in constant operation uses 1,236 kWh/y (482kWh/y for the computer and 754kWh/y for the monitor). With power management this reduces to 190 kWh/y (86+104). Effective power management can save 1,046 kWh per computer and CRT monitor per year, a reduction of 84%, or 505 kWh per computer and monitor per year. These examples illustrate that power management can have a greater effect than simply using more efficient equipment. The German website EcoTopten, for example, says that more efficient computers save 50-70% compared with older models and efficient flat-screens use 70% less energy than CRTs.

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88 WEBBER ET AL., 2006.
89 WEBBER ET AL., 2006.
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table 10.7: peak power breakdown by component for a typical server

COMPONENT	PEAK POWER (WATTS)
CPU	80
Memory	36
Disks	12
Peripheral slots	50
Motherboard	25
Fan	10
PSU losses	38
Total	**251**

source (FAN ET AL., 2007, US EPA, 2007A). PSU = POWER SUPPLY UNIT

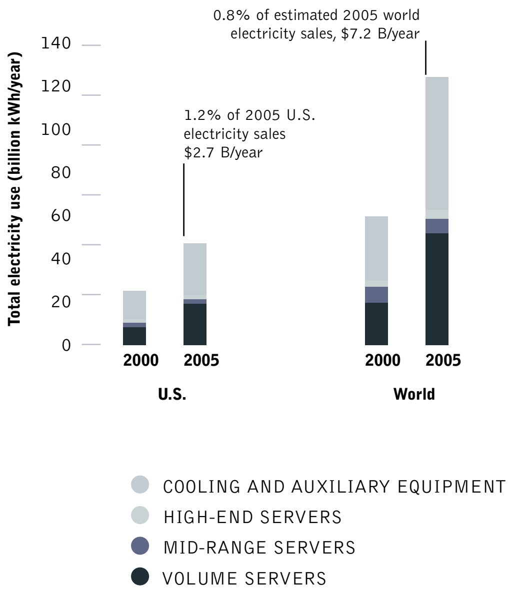
Servers are multiprocessor systems running commercial workloads.[91] The typical breakdown of peak power server use is shown in Figure 10.8.

Data centres are facilities that primarily contain electronic equipment used for data processing, data storage and communications networking.[92] 80% of servers are located in these data centres.[93] Worldwide, about three million data centres and 32 million servers are in operation. Approximately 25% of servers are located in the EU, but only 10% of data centres, meaning that on average each data centre hosts a relatively large number of servers (Fichter, 2007). The installed base of servers is growing rapidly due to an increasing demand for data processing and storage. New digital services such as music downloads, video-on-demand, online banking, electronic trading, satellite navigation and internet telephony spur this rapid growth, as well as the increasing penetration of computers and the internet in developing countries. Since systems have become more and more complex to handle increasingly large amounts of data, power and energy consumption (about 50% used for cooling[94]) have grown in parallel. The power density of data centres is rising by approximately 15% each year.[95] Aggregate electricity use for servers doubled over the period 2000 to 2005 both in the US and worldwide (see 10.13). Data centres accounted for roughly 1% of global electricity use in 2005 (14 GW) (Koomey, 2007).[96]

Power and energy consumption are key concerns for internet data centres and there is a significant potential for energy efficiency improvements. Existing technologies and design strategies have been shown to reduce the energy use of a typical server by 25% or more.[97] Energy management efforts in existing data centres could reduce their energy usage by around 20%, according to the US Environmental Protection Agency (EPA). The US EPA scenario for reducing server energy use includes measures such as enabling power management, consolidating servers and storage, using liquid instead of air cooling, improving the efficiency of chillers, pumps, fans and transformers and using combined heat and power. This bundle of measures could reduce electricity use by up to 56% compared to current efficiency trends (or 60% compared to historical trends), the EPA concludes. This assumes that only 50% of current data centres can introduce these measures. A significant savings potential is therefore available for servers and data centres around the world by

figure 10.8: total electricity use for servers in the US and world in 2000 and 2005, including associated cooling and auxiliary equipment

(KOOMEY, 2007)



2050. For computers and servers we have based the savings potential on the WBCSD 2005 report and other sources mentioned in this section. For the Technical scenario this would result in 70% savings, for the Revolution scenario 55% savings.

6. air conditioning In the USA about 14% of total electrical consumption is used to air condition buildings.[98] Increasing use of small air conditioning units (less than 12 kW output cooling power) in southern European cities, mainly during the summer months, is also driving up electricity consumption. Total residential electricity consumption for air conditioners in the EU-25 in 2005 was estimated to be between 7 and 10 TWh per year.[99] However, we should not underestimate the consumption level in developing countries. Many of these are located in warm climatic zones. With the rapid development of its economy and improving living standards, central air conditioning units are now widely used in China, for example. They currently account for about 20% of total Chinese electricity consumption.[100]

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97 US EPA, 2007A.
98 US DOE/EIA, 2007.
99 BERTOLDI & ATANASIU, 2006.
100 LU, 2007.

image COMPACT FLUORESCENT LAMP LIGHT BULB.

image WASHING MACHINE.

There are several options for technical savings in air conditioning equipment. One is to use a different refrigerant. Tests with the refrigerant Ikon B show possible energy consumption reductions of 20-25% compared to the commonly used liquids.[101] However, behavioural changes should not be overlooked. One example of a smart alternative to cooling a whole house was developed by the company Evening Breeze. This combined a mosquito net, bed and air conditioning so that only the bed had to be cooled instead of the whole bedroom.

There are also other options for cooling, such as geothermal cooling by heat pumps. This uses the same principle as geothermal heating - that the temperature at a certain depth below the earth's surface remains constant all year round. In winter we can therefore use this relatively high temperature to warm our houses. Conversely, we can use the relatively cold temperature in the summer to cool our houses. There are several technical concepts available, but all rely on transferring the heat from the air in a building to the earth. A refrigerant is used as the heat transfer medium. This concept is cost-effective.[102] Heat pumps have been gaining market share in a number of countries.[103]

Solar energy can also be used for cooling through the use of solar thermal energy or solar electricity to power a cooling appliance. Basic types of solar cooling technologies include absorption cooling (uses solar thermal energy to vaporise the refrigerant); desiccant cooling (uses solar thermal energy to regenerate the desiccant); vapour compression cooling (uses solar thermal energy to operate a Rankine-cycle heat engine); evaporative cooling; and heat pumps and air conditioners that can be powered by solar photovoltaic systems. To drive the pumps only 0.05 kWh of electricity is needed, instead of 0.35 kWh for regular air conditioning[104], representing a savings potential of 85%.

Not only is it important to use efficient air conditioning equipment, it is equally important to reduce the need for air conditioning in the first place. Important ways to reduce cooling demand are to use insulation to prevent heat from entering the building, to reduce the amount of inefficient appliances present in the house - such as incandescent lamps or old refrigerators that give off unusable heat, to use cool exterior finishes such as 'cool roof' technology or light-coloured wall paint, to improve windows, to use vegetation to reduce the amount of heat that comes into the house and to use ventilation instead of air conditioning units. For air conditioning we have assumed that the savings potential based on the 2005 WBCSD study and other sources mentioned in this section will amount to 55% savings under both the Energy [R]evolution scenarios.

total household savings

The technical savings potential up to 2050 from all the measures described so far is summarised in Table 10.8. Since it is not clear what assumptions the IEA WEO reference scenario was based on, we have assumed an efficiency improvement of 1% per year. Table 10.9 shows the energy efficiency improvements per year measured against the Reference scenario and used to derive the final energy demand in the Energy [R]evolution scenario. Electricity use in the 'other' sector is assumed to decline at the same rate as residential use (lighting, appliances, cold appliances, computers/servers and air conditioning). We have assumed a minimum energy efficiency improvement of 1.2% in the Technical scenario and 1.1% in the Revolution scenario, including autonomous improvements. For services and agriculture we have assumed the same percentage savings potential as for the household sector.

The new Reference scenario based on WEO 2009 data now includes a lower level of energy demand in the residential sector. Therefore the savings used in the new Energy [R]evolution scenarios are lower than the figures shown in the tables below. The resulting final energy demand reduction for the Energy [R]evolution scenarios compared to the Reference scenario is shown in Table 10.10 for each world region.

table 10.8: technical savings potential for different types of energy use in the buildings sector

(SAVINGS POTENTIALS ASSUMED FOR THE 2008 ENERGY [R]EVOLUTION STUDY ARE IN BRACKETS)

	HEATING NEW	HEATING RETROFIT	STANDBY	LIGHTING	APPLIANCES	COLD APPLIANCES	AIR CONDITIONING	COMPUTER/ SERVER	OTHER
OECD Europe	72 (58)	50 (40)	82 (72)	68 (60)	70 (50)	77 (64)	70 (55)	70 (55)	71 (57)
OECD North America	59 (38)	41 (26)		48 (42)					67 (53)
OECD Pacific	38 (8)	26 (5)		56 (49)					69 (55)
Transition Economies	56 (35)	39 (24)		76 (67)					73 (58)
China	43 (38)			20 (18)					61 (48)
India				76 (67)					73 (58)
Other dev. Asia									
Middle East									
Latin America									
Africa									

references

101 US DOE EERE (UNITED STATES DEPARTMENT OF ENERGY; ENERGY EFFICIENCY AND RENEW-ABLE ENERGY) (2008) INVENTIONS & INNOVATION PROJECT FACT SHEET. HIGH ENERGY EFFICIENCY AIR CONDITIONING. HTTP://WWW1.EERE.ENERGY.GOV/INVENTIONS/PDFS/NIMITZ.PDF.

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103 OECD/IEA, 2006.

104 AUSTRIAN ENERGY AGENCY (2006). KEEP COOL – LOCAL AND INDIVIDUAL ADAPTATION. HTTP://WWW.ENERGYAGENCY.AT/PUBL/PDF/KEEPCOOL_ADAPTATION.PDF

table 10.9: savings potential for different types of energy use in the buildings sector in the energy [r]evolution scenario 2008

(ENERGY [R]EVOLUTION 2008 POTENTIAL IN BRACKETS). PERCENTAGES ARE TOTAL EFFICIENCY IMPROVEMENT PER YEAR (INCLUDING 1% AUTONOMOUS IMPROVEMENT)

	HEATING NEW	HEATING RETROFIT	STANDBY	LIGHTING	APPLIANCES	COLD APPLIANCES	AIR CONDITIONING	COMPUTER/ SERVER	OTHER
OECD Europe	3.1 (2.1)	1.7 (1.3)	4.2 (3.1)	2.8 (2.3)	3.0 (1.7)	3.5 (2.5)	3.0 (2.0)	3.0 (2.0)	3.1 (2.1)
OECD North America	2.2 (1.2)	1.3 (1.1)		2.0 (1.7)					2.9 (2.0)
OECD Pacific	1.2 (1.1)	1.2 (1.1)		1.6 (1.4)					2.8 (1.9)
Transition Economies	2.2 (1.4)	1.2 (1.1)		3.5 (2.7)					3.2 (2.2)
China	1.4 (1.2)			1.2 (1.1)					2.8 (1.9)
India				3.5 (2.7)					3.2 (2.2)
Other dev. Asia									
Middle East									
Latin America									
Africa									

energy efficiency standards - steps towards an energy equity

the standard household In order to enable a specific level of energy demand as a basic "right" for all people in the world, we have developed the model of an efficient Standard Household. A fully equipped OECD household (including fridge, oven, TV, radio, music centre, computer, lights etc.) currently consumes between 1,500 and 3,400 kWh/a per person. With an average of two to four people per household the total consumption is therefore between 3,000 and 12,000 kWh/a. This demand could be reduced to about 550 kWh/a per person just by using the most efficient appliances available on the market today. This does not even include any significant lifestyle changes. Based on this assumption, the 'over-consumption' of all households in OECD countries totals more than 2,100 billion kilowatt-hours. Comparing this figure with the current per capita consumption in developing countries, they would have the right to use about 1,350 billion kilowatt-hours more. The 'oversupply' of OECD households could therefore fill the gap in energy supply to developing countries one and a half times over!

By implementing a strict technical standard for all electrical appliances, in order to achieve a level of 550 kWh/a per capita consumption, it would be possible to switch off more than 340 coal power plants in OECD countries.

table 10.10: reduction of final energy demand in other sectors (households, services and agriculture) by 2050 under the Energy [R]evolution scenarios compared to the Reference scenario (BASED ON WEO 2009)

	OTHER SECTORS ELECTRICITY	OTHER SECTORS FINAL ENERGY OTHER THAN ELECTRICITY
OECD Europe	-46%	-36%
OECD North America	-42%	-28%
OECD Pacific	-33%	-28%
Transition Economies	-45%	-36%
China	-27%	-23%
India	-12%	-29%
Other developing Asia	-39%	-15%
Middle East	-36%	-15%
Latin America	-16%	-18%
Africa	-6%	-7%

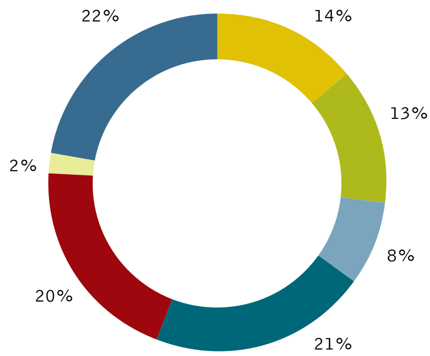
image WASHING MACHINE.

image COMPUTER.

energy efficiency standards - the potential is huge

Setting energy efficiency standards for electrical equipment could have a huge impact on the world's power sector. A large number of power plants could be switched off if strict technical standards were brought into force. Figure 10.10 below provides an overview of the theoretical potential for using efficiency standards based on currently available technology. The Energy [R]evolution scenario has not been calculated on the basis of this potential. However, this overview illustrates how many power plants producing electricity would not be needed if all global appliances were brought up to the highest efficiency standards.

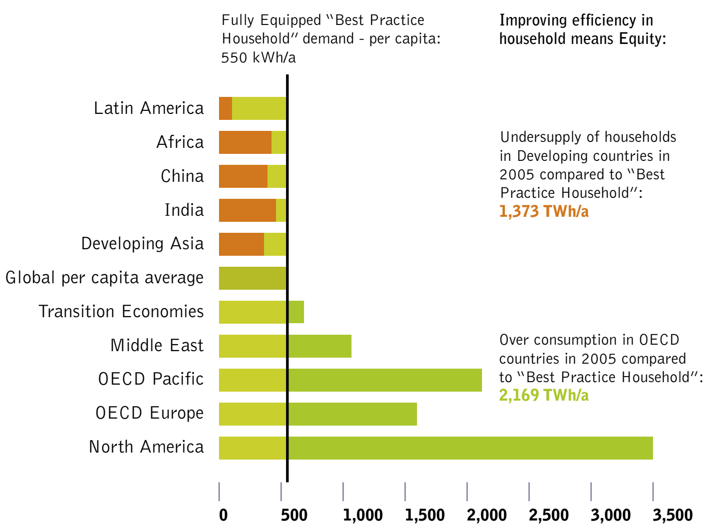
figure 10.10: electricity savings in households [energy [r]evolution versus reference] in 2050



LIGHTING
STAND BY
AIR CONDITIONING
APPLIANCES
COLD APPLIANCES
COMPUTERS/SERVERS
OTHER

source ECOFYS

figure 10.9: energy equity through efficiency standards



source SVEN TESKE/WINA GRAUS

table 10.11: effect on number of global operating power plants by introducing strict energy efficiency standards*

BASED ON CURRENTLY AVAILABLE TECHNOLOGY

	ELECTRICITY LIGHTING	ELECTRICITY STAND BY	ELECTRICITY AIR CONDITIONING	ELECTRICITY SET TOP BOXES	ELECTRICITY OTHER APPLIANCES	ELECTRICITY COLD APPLIANCES	ELECTRICITY COMPUTERS/ SERVERS	ELECTRICITY OTHER
	HOUSEHOLDS							
OECD Europe	16	11	11	2	27	15	2	23
OECD North America	32	19	19	3	47	26	4	42
OECD Pacific	5	5	5	1	13	7	1	11
China	3	3	3	1	7	4	1	6
Latin America	5	2	3	0	6	3	1	6
Africa	3	2	2	0	4	2	0	4
Middle East	5	2	3	0	6	3	1	6
Transition Economies	6	3	3	1	7	4	1	7
India	2	1	1	0	3	2	0	3
Other dev. Asia	4	2	2	0	6	3	1	5
World	80	50	52	9	126	69	11	113

* 1 POWER PLANT = 750 MW
source ECOFYS 2008.

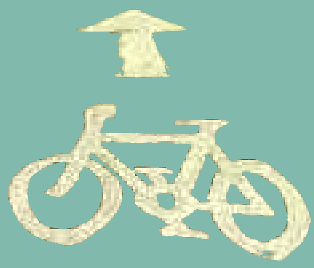
table 10.12: effect on number of global operating power plants by introducing strict energy efficiency standards* ***continued***

BASED ON CURRENTLY AVAILABLE TECHNOLOGY

	ELECTRICITY SERVICES COMPUTERS	ELECTRICITY SERVICES LIGHTING	ELECTRICITY SERVICES AIR CONDITIONING	ELECTRICITY SERVICES COLD APPLIANCES	ELECTRICITY SERVICES OTHER APPLIANCES	ELECTRICITY AGRICULTURE	TOTAL NUMBER OF COAL FIRED POWER PLANTS PHASED OUT DUE TO STRICT EFFICIENCY STANDARDS	INDUSTRY	**TOTAL INCL INDUSTRY**
OECD Europe	8	30	18	6	33	7	209	106	315
OECD North America	15	62	34	11	60	21	397	107	503
OECD Pacific	5	11	10	3	18	1	69	52	148
China	1	3	3	1	5	21	61	144	205
Latin America	2	8	4	1	7	3	52	39	90
Africa	1	3	1	0	2	6	30	23	53
Middle East	1	6	3	1	5	10	51	8	59
Transition Economies	2	9	4	1	7	8	62	63	125
India	0	2	1	0	1	14	31	23	54
Other dev. Asia	2	7	3	1	6	6	50	33	83
World	3	140	81	27	144	98	1,038	613	1,651

* 1 POWER PLANT = 750 MW
source ECOFYS 2008.

11



HALF THE SOLUTION TO CLIMATE CHANGE IS THE SMART USE OF POWER.

"...a mix of lifestyle changes and new technologies."

WINA GRAUS
ECOFYS, THE NETHERLANDS

Transport is a key element in reducing the level of greenhouse gases produced by energy consumption. 27% of current energy use comes from the transport sector – road, rail and sea. In order to assess the present status of global transport, including its carbon footprint, a special study was undertaken for the 2008 Energy [R]evolution report. Demand projections for both the basic and advanced scenarios in this year's report have been based on this analysis, although the reference year has been updated on the basis of IEA WEO 2009 figures. For the advanced Energy [R]evolution scenario, overall energy demand for private vehicles has been reduced further by 17%. This reflects the lower final energy demand resulting from an increased share of electric cars.

This section provides an overview of the selected measures required to develop a more energy efficient and sustainable transport system in the future. Some technologies will have to be modified to achieve more energy efficiency. In other situations, a simple modification will not be enough. The transport of people in megacities and urban areas will have to be almost entirely reorganised and public transport systems mixed with individual modes. Car sharing and public transport on demand are only the beginning of the transition needed to produce a more effective system that carries more people faster to their destination and using less energy.

For the 2008 Energy [R]evolution scenario, the Dutch research institute Ecofys and the German DLR Institute for Vehicle Concepts undertook a detailed analysis of the entire global transport sector, broken down by the ten IEA regions. Further details can be found at www.energy blueprint.info. This report uses those findings as the basic for its calculations.

the future of the transport sector in the energy [r]evolution scenario

Our analysis[105] shows that changes in patterns of passenger travel are partly a consequence of growing wealth. As GDP per capita increases, people tend to migrate towards faster, more flexible and more expensive travel modes (from buses and trains to cars and air). With faster modes, people also tend to travel further and do not reduce the amount of time spent travelling.[106] There is also a strong correlation between GDP growth and increases in freight transport. More economic activity will mean more transport of raw materials, intermediary products and final consumer goods.

Both a modal shift and a slowing of growth in forecast transport are therefore of great importance if serious emissions reductions are to be achieved. Furthermore, it is very important to make the remaining transport as clean as possible, signalling the role of energy efficiency improvements. Unlimited growth in the transport sector is simply not an option. A shift towards a sustainable energy system, which respects natural limits and saves the world's climate, requires a mix of lifestyle changes and new technologies. We basically need to use our cars less, fly less and use more public transport, as well as cutting down the transport kilometres for freight transport whilst introducing more new and highly efficient vehicles.

references
105 SEE ENERGY [R]EVOLUTION 10/2008, CHAPTER 11 & 12 AS WELL AS ECOFYS ANALYSIS 2008 -> WWW.ENERGYBLUEPRINT.INFO.
106 OECD/IEA, 2007.

technical potentials

We have looked at three options for decreasing energy demand in the transport sector:

- Reduction of transport demand.
- Modal shift from high energy intensive transport modes to low energy intensity.
- Energy efficiency improvements.

table 11.1: selection of measures and indicators

MEASURE	REDUCTION OPTION	INDICATOR
Reduction of transport demand	Reduction in volume of passenger transport in comparison to the Reference Scenario	Passenger km/capita
	Reduction in volume of freight transport in comparison to Reference Scenario	Tonne-km/unit of GDP
Modal shift	Modal shift from trucks to rail	MJ/tonne km
	Modal shift from cars to public transport	MJ/passenger km
Energy efficiency improvements	Efficient passenger cars (hybrid fuel cars)	MJ/vehicle km
	Efficient buses	MJ/passenger km
	Efficiency improvements in aircraft	MJ/passenger km
	Efficient freight vehicles	MJ/tonne km
	Efficiency improvements in ships	MJ/tonne km

step 1: reduction of transport demand

A reduction in transport demand involves cutting both passenger-kilometres per capita and limiting freight transport demand. The amount of freight transport is to a large extent linked to GDP development and therefore difficult to influence. However, by improved logistics, for example optimal load profiles for trucks, the demand can be limited.

passenger transport The first step is to look at reducing passenger transport demand. For this we need to examine the transport demand per capita today. This shows that in 2007, transport demand was highest in OECD North America, followed by the OECD Pacific, and lowest per capita in Africa and India.

The potential for reducing passenger transport demand is difficult to determine. For OECD countries, however, we have assumed that transport demand per capita can be reduced by 10% by 2050 in comparison to the Reference scenario. For the non-OECD countries we have assumed in both Energy [R]evolution scenarios – as a matter of equity – that no reduction in transport demand will take place because current demand is already quite low. We have made an exception for the Transition Economies, where we assume that demand can be reduced by 5% in 2050.

The table below shows the profile of passenger transport demand per capita in 2005, what would happen under the Reference scenario by 2050 and the reduced level of demand made possible by the Energy [R]evolution scenario, broken down by world region.

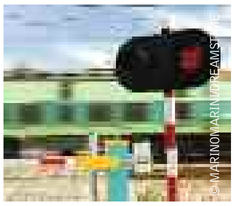


image TRAIN SIGNALS.

table 11.2: market share (by final energy consumption) of transport modes per region in 2050 in the energy [r]evolution and advanced energy [r]evolution scenarios

E[R]	OECD NORTH AMERICA	OECD EUROPE	OECD PACIFIC	TRANSITION ECONOMIES	CHINA	INDIA	OTHER DEVELOPING ASIA	MIDDLE EAST	LATIN AMERICA	AFRICA
Road	**76.8%**	**87.4%**	**84.9%**	**78.0%**	**65.6%**	**87.3%**	**93.1%**	**97.3%**	**87.8%**	**89.5%**
of which electric vehicle	19.1%	7.0%	18.0%	8.4%	9.0%	10.0%	0.5%	3.0%	7.7%	0.5%
of which gas vehicle	0.6%	1.3%	4.0%	1.5%	0.2%	1.6%	0.6%	3.0%	5.9%	0.6%
of which hybrid vehicle	52.5%	55.0%	52.0%	72.0%	50.2%	48.8%	45.0%	60.0%	74.3%	22.0%
of which hydrogen car	4.0%	3.6%	1.0%	1.9%	1.8%	1.0%	0.8%	0.8%	2.2%	0.7%
of which conventional vehicle	11.7%	31.2%	4.0%	15.1%	37.5%	33.5%	51.6%	32.3%	1.3%	75.5%
Rail	**5.0%**	**5.4%**	**9.1%**	**13.9%**	**14.9%**	**8.0%**	**3.5%**	**1.8%**	**0.8%**	**3.0%**
of which diesel train	8.5%	1.0%	13.0%	4.0%	45.0%	27.0%	10.0%	0.0%	50.0%	8.0%
of which electric train	91.5%	99.0%	87.0%	96.0%	55.0%	73.0%	90.0%	100.0%	50.0%	92.0%
Aviation (domestic)	**16.4%**	**4.3%**	**6.0%**	**6.5%**	**12.0%**	**3.0%**	**1.1%**	**0.9%**	**5.0%**	**6.2%**
Navigation (domestic)	**1.8%**	**2.9%**	**0.0%**	**1.6%**	**7.5%**	**1.7%**	**2.3%**	**0.0%**	**6.4%**	**1.3%**
ADV E[R]										
Road	**76.2%**	**82.8%**	**85.4%**	**76.2%**	**65.0%**	**86.1%**	**91.1%**	**97.2%**	**79.6%**	**88.5%**
of which electric vehicle	43.0%	19.0%	23.4%	10.0%	27.0%	21.0%	16.0%	18.4%	19.4%	0.5%
of which gas vehicle	0.5%	0.0%	1.5%	1.0%	0.2%	1.6%	0.6%	1.5%	4.8%	0.6%
of which hybrid vehicle	38.7%	67.0%	63.4%	72.0%	66.2%	69.4%	55.0%	75.0%	50.6%	43.7%
of which hydrogen car	8.2%	13.0%	1.0%	10.0%	5.0%	3.0%	7.0%	4.9%	5.0%	3.0%
of which conventional vehicle	0.2%	0.0%	0.2%	5.9%	0.4%	2.0%	19.9%	0.2%	0.2%	52.0%
Rail	**7.8%**	**9.5%**	**9.1%**	**16.0%**	**15.5%**	**9.2%**	**5.5%**	**1.8%**	**9.0%**	**4.0%**
of which diesel train	2.0%	0.5%	1.0%	2.0%	8.8%	20.0%	6.0%	0.0%	1.0%	7.0%
of which electric train	98.0%	99.5%	99.0%	98.0%	91.2%	80.0%	94.0%	100.0%	99.0%	93.0%
Aviation (domestic)	**14.1%**	**4.5%**	**5.5%**	**6.3%**	**10.1%**	**3.0%**	**1.1%**	**1.0%**	**5.0%**	**6.2%**
Navigation (domestic)	**1.9%**	**3.2%**	**0.0%**	**1.5%**	**9.4%**	**1.7%**	**2.3%**	**0.0%**	**6.3%**	**1.4%**

Policy measures for reducing passenger transport demand could include:

- Price incentives that increase transport costs
- Incentives for working from home
- Stimulating the use of video conferencing in businesses
- Improved cycle paths in cities

freight transport In the Reference scenario the largest absolute increase in freight transport demand is expected in the Transition Economies, whilst the largest percentage increase is forecast in China (383%). The potential for reducing demand for freight transport by improved logistics is difficult to estimate. For the Energy [R]evolution scenario we have assumed that freight transport demand can be reduced by 5% in comparison to the Reference scenario, although only through measures in the OECD and Transition Economies.

step 2: changes in transport mode

In order to decide which vehicles or transport systems are the most effective for each purpose, an analysis of the different technologies is needed. To calculate the energy savings achieved by shifting transport mode we need to know the energy use and intensity for each type of transport.[107] The following information is needed:

- Passenger transport: Energy demand per passenger kilometre, measured in MJ/p-km.
- Freight transport: Energy demand per kilometre of transported tonne of goods, measured in MJ/ tonne-km.

Passenger transport includes cars, minibuses, two and three wheelers, buses, passenger rail and air transport. Freight transport includes medium trucks, heavy trucks, national marine and freight rail. While there is a huge difference today between, for example, India and the USA in terms of car ownership versus the use of two-wheeled transport or buses, it is assumed under both Energy [R]evolution scenarios that these differences will be more evened out by 2050. There is a clear trend towards more public transport and less private cars.

references
107 WBCSD PROVIDES ESTIMATES FOR ENERGY INTENSITIES PER MODE.

travelling by rail is the most efficient Figure 11.1 shows the worldwide average specific energy consumption by transport mode under the Reference scenario in 2005 and 2050. This data differs considerably by world region, with large variations in specific energy consumption for each transport mode, but passenger transport by rail will consume 85% less energy in 2050 than car transport and by bus nearly 70% less energy. This means that there is a large energy savings potential to be realised by a modal shift.

freight transport The existing breakdown of freight transport shows a wide variation in total tonnes-km per year across the world regions. Both the Transition Economies and China have a very large proportion of rail transport, while Other Developing Asia and the Middle East have a very small share. The share of heavy and medium trucks is very large in the Other Developing Asia countries and OECD Europe. National marine transport plays an important role in the OECD Pacific. In the Reference scenario it is assumed that the difference between 2005 and 2050 is relatively small.

figure 11.1: world average (stock-weighted) passenger transport energy intensity for 2005 and 2050.

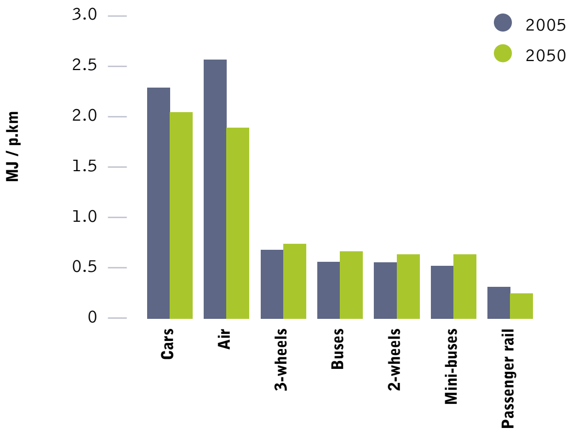
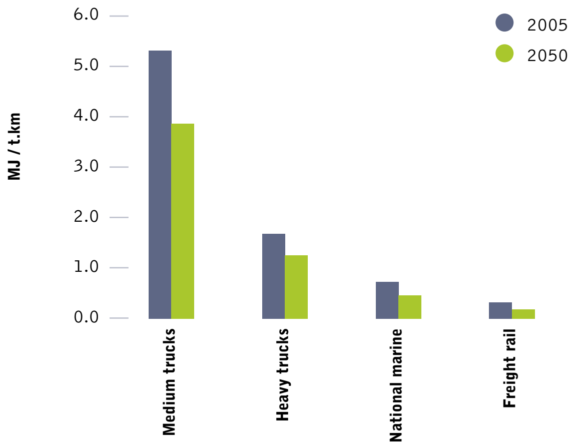


figure 11.2: world average (stock-weighted) freight transport energy intensity in 2005 and 2050



modal shift for passengers in the Energy [R]evolution scenario From the figures above we can conclude that in order to reduce transport energy demand by modal shift, passengers have to move from cars and air transport to the lower intensity rail and bus transport. As an indication of the action required we can take Japan as a 'best practice country'. In 2004, Japan had achieved a large share of passenger-km by rail (29%) thanks to the fact that it had established a strong urban and regional rail system.[108] Comparing different regions with the example of Japan, and assuming that 40 years is enough time to build up an extensive rail network, the following modal shifts have been assumed:

table 11.3: passenger modal shifts assumed in [r]evolution scenario

TRANSPORT	[R]EVOLUTION SCENARIO
From air to rail (short distances)	2.5%
From car to rail	2.5%
From car to bus	2.5%

This means that in the Energy [R]evolution scenario 2.5% of car transport shifts to rail and 2.5% to bus. In total this means a reduction in car transport of 7.5% in comparison to the Reference scenario.

transporting goods by rail is the most efficient Figure 11.2 shows the energy intensity for world average freight transport in 2005 and 2050 under the Reference scenario. Again, transporting goods by rail is the most energy efficient mode. Energy intensity for all modes of transport is expected to decrease by 2050.

modal shift for transporting goods in the Energy [R]evolution scenario From the figures above we can conclude that in order to reduce transport energy demand by modal shift, freight has to move from medium and heavy duty trucks to the less energy intensive freight rail and national marine. Canada is a 'best practice' country in this respect, with 29% of freight transported by trucks, 39% by rail and 32% by ships. Since the use of ships largely depends on the geography of the country, we do not propose a modal shift for national ships but instead a shift towards freight rail. China, OECD Pacific and the Transition Economies already have a low share of truck usage, so for these regions we will not assume a modal shift. For the other regions we have assumed the following changes:

table 11.4: freight modal shift in both Energy [R]evolution scenarios for all regions

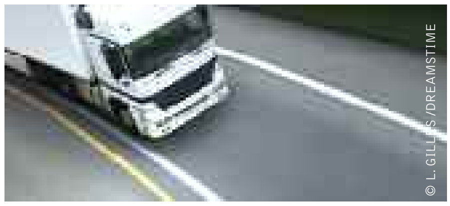
EXCEPT CHINA, THE TRANSITION ECONOMIES AND OECD PACIFIC

TRANSPORT	[R]EVOLUTION SCENARIO
From medium trucks to rail	+ 5%
From heavy trucks to rail	+ 2.5%

references
108 OECD/IEA, 2007.

image ITALIAN EUROSTAR TRAIN.

image TRUCK.



marine transport Since the WBCSD does not provide estimates for total national marine tonnes-km per year or energy intensities per region, we have calculated these ourselves. Data for energy intensity for the year 2005 in OECD countries was found in OECD/IEA 2007. For other regions we have assumed that the highest OECD estimate would hold. The 2050 intensities were extrapolated from 2005 data using a 1% per year autonomous efficiency improvement. The amount of t-km per year could then be calculated using the Reference scenario energy use divided by the energy intensity in MJ/t-km.

step 3: efficiency improvements or travelling with less energy Energy efficiency improvements are the third important way of reducing transport energy demand. This section explains the possibilities for improving energy efficiency[109] up to 2050 for each type of transport.

air transport Savings for air transport have been taken from Akerman, 2005.[110] He reports that a 65% reduction in fuel use is technically feasible by 2050. This has been applied to 2005 energy intensity data in order to calculate the potential. It is assumed that all regions have the same energy intensities in 2005 and 2050 due to lack of regionally-differentiated data. The projection of future energy intensity is based on IEA data over the 1990-2000 period, when intensity improved at about 0.7% per year.

passenger and freight trains Savings for passenger and freight rail transport have been taken from Fulton & Eads (2004). They report a historic improvement in the fuel economy of passenger rail of 1% per year and for freight rail of between 2 and 3% per year. Since no other studies are available we have therefore assumed a 1% improvement in energy efficiency per year for passenger rail and 2.5% for freight rail. Energy intensities for passenger rail transport are assumed to be the same for all regions due to a lack of sufficiently detailed data. The differentiation in energy intensity for freight rail is based on the assumption that regions with longer average freight transport distances (such as the US and former Soviet Union), and where more raw materials are transported (such as coal), will have a lower energy intensity than others. Future projections use ten year historic IEA data. Rail intensities are and will remain highest in OECD Europe and OECD Pacific and lowest in India.

buses and minibuses The company Enova Systems is promoting a 'clean bus' with a 100% improvement in fuel economy. We have adopted this improvement and applied it to 2005 energy intensity numbers per region. For minibuses the American Council for an Energy Efficient Economy reports[111] a fuel economy improvement of 55% by 2015. Since this is a very ambitious target and will most likely not be reached, we have extended it up to 2050 and adopted it as the technical potential. Currently, buses in North America consume far and away the most energy. The Reference scenario predicts an increase in all regions between 2005 and 2050. Although in general more efficient buses are being produced, this is offset by increases in average bus size, weight and power. OECD buses have much more powerful engines than non-OECD buses, but the latter are likely to catch up over this period.

case study: wind powered ships

Introduced to commercial operation in 2007, the SkySails system allows wind power, which has no fuel costs, to contribute to the motive power of large freight-carrying ships, which currently use increasingly expensive and environmentally damaging oil. Instead of a traditional sail fitted to a mast, the system uses large towing kites to contribute to the ship's propulsion. Shaped like paragliders, they are tethered to the vessel by ropes and can be controlled automatically, responding to wind conditions and the ship's trajectory.

The kites can operate at altitudes of between 100 and 300 metres, where stronger and more stable winds prevail. By means of dynamic flight patterns, the SkySails are able to generate five times more power per square metre of sail area than conventional sails. Depending on the prevailing winds, the company claims that a ship's average annual fuel costs can be reduced by 10 to 35%. Under optimal wind conditions, fuel consumption can temporarily be cut by up to 50%.

On the first voyage of the Beluga SkySails, a 133m long specially built cargo ship, the towing kite propulsion system was able to temporarily substitute for approximately 20% of the vessel's main engine power, even in moderate winds. The company is now planning a kite twice the size of this 160m^2 pilot. The designers say that virtually all sea-going cargo vessels can be fitted with the SkySails propulsion system without extensive modifications. If 1,600 ships would be equipped with these sails by 2015, it would save over 146 million tonnes of CO_2 a year, equivalent to about 15% of Germany's total emissions.

references

109 FOR THE REVOLUTION SCENARIO WE BASE THE POTENTIAL ON IMPLEMENTING 80% OF THE ENERGY EFFICIENCY IMPROVEMENTS, UNLESS OTHERWISE SPECIFIED.
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111 DECICCO ET AL., 2001.

trucks (freight by road) Elliott et al., 2006[112] give possible savings for heavy and medium-duty freight trucks. This list of reduction options is expanded in Lensink and De Wilde, 2007.[113] For medium duty trucks a fuel economy saving of 50% is reported by 2030 (mainly due to hybridisation). We applied this percentage to 2005 energy intensity data, calculated the fuel economy improvement per year and extrapolated this yearly growth rate up to 2050. For heavy duty trucks we applied the same methodology, arriving at a 39% savings. Current intensities are highest in the Middle East, India and Africa and lowest in OECD North America. The Reference scenario predicts that future values will converge, assuming past improvement percentages and assuming a higher learning rate in developing regions. The figures below show the energy intensity per region in the Reference scenario and in the two low energy demand scenarios.

marine transport National marine transport savings have also been taken from the Lensink and De Wilde study. They report 20% savings in 2030 for inland navigation as a realistic potential with currently available technology, and ultimate efficiency savings of up to 30% for the current fleet. To arrive at the potential in 2050, we used the same approach as described for road freight above. OECD Pacific has the lowest current energy intensity due to the fact that they have a large proportion of long haul trips where larger (less energy intensive) boats can be used. All energy intensities are expected to improve by 1% per year up to 2050.

motorcycles For two wheelers we have based the potential on IEA/SMP (2004)[114], where 0.3 MJ/p.km is the lowest value. For three wheelers we have assumed that the technical potential is 0.5 MJ/p.km in 2050. The uncertainty in these potentials is high, although two and three wheelers only account for 1.5% of transport energy demand.

passenger cars This section is based on a special study conducted by the DLR's Institute for Vehicle Concepts to investigate the potential for improving the efficiency of existing cars and moving towards greater use of hybrid or electric vehicles. Cars contribute about 45% of the greenhouse gas emissions from the entire transport sector, the largest proportion of any mode.

Many technologies can be used to improve the fuel efficiency of passenger cars. Examples include improvements in engines, weight reduction and friction and drag reduction.[115] The impact of the various measures on fuel efficiency can be substantial. Hybrid vehicles, combining a conventional combustion engine with an electric engine, have relatively low fuel consumption. The most well-known is the Toyota Prius, which originally had a fuel efficiency of about five litres of gasoline-equivalent per 100 km (litres ge/100 km). Recently, Toyota presented an improved version with a lower fuel consumption of 3.9 litres ge/100 km. There are suggestions that employing new lightweight materials, in combination with the new propulsion technologies, can bring fuel consumption levels down to 1 litre ge/100 km.

table 11.5: efficiency of cars and new developments

(BLOK, 2004, GE = GASOLINE EQUIVALENT)

BEST PRACTICE CURRENT & FUTURE EFFICIENCIES	FUEL CONSUMPTION (LITRES GE/100 KM)	SOURCE
Present average	10.4	IEA/SMP (2004)
Hybrids on the market (medium-sized cars)	~5 (1997) 4.3 (2003) 3.9 (2009)	EPA (2003) Toyota (2009)
Improved hybrids or fuel cell cars (average car)	2 – 3	USCAR (2002) Weiss et al (2000)
Ultralights	0.8 - 1.6	Von Weizsäcker et al (1998)

Based on SRU (2005)[116], the technical potential in 2050 for a diesel fuelled car is 1.6 and for a petrol car 2.0 litres ge/100 km. Based on the sources in Table 11.5, we have assumed 2.0 litres as the technical potential for Europe and adopted the same improvement in efficiency (about 3% per year) for other regions. In order to reach this target in time, these more efficient cars need to be on the market by 2030 – assuming that the maximum lifetime of a car is 20 years.

The figure below shows the energy intensity for cars in the Reference scenario and in the two alternative scenarios, after introducing the measures described in more detail below.

The energy intensities for car passenger transport are currently highest in OECD North America and Africa and lowest in OECD Europe. The Reference scenario shows a decrease in energy intensities in all regions, but the division between highest and lowest will remain the same, although there will be some convergence.

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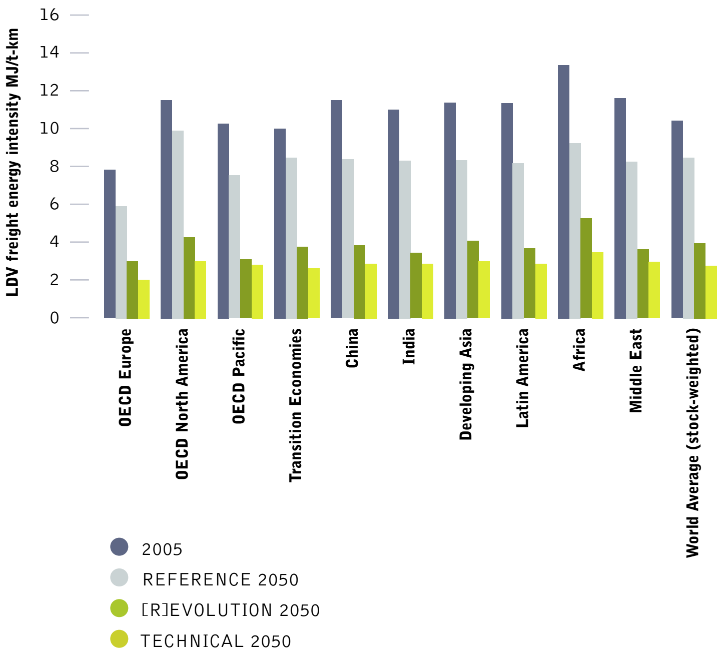
image TRANSPORT POLLUTION.

figure 11.3: energy intensities (litres ge/v-km) for cars in the reference and [r]evolution scenarios



the DLR passenger cars study

Since the global use of privately owned cars (light duty vehicles) currently accounts for more carbon dioxide emissions than any other form of transport, the DLR's Institute for Vehicle Concepts was commissioned for the 2008 Energy [R]evolution study to look specifically at the potential for reductions in this sector. Both the basic and advanced scenarios in this report are based on this analysis.

The starting point for this study is that the door has already been opened for both major technological changes and shifts in personal habits. Rising oil prices, increasing concern about climate change and, in some regions, legislation on everything from bio fuels to vehicle emissions, have together combined to put pressure on international vehicle manufacturers to investigate solutions. Numerous technical fixes are already in production which can improve the efficiency of the predominant internal combustion engine, as well as moving towards alternatives no longer based on fossil fuels.

Overall, the study concludes that a number of measures could help reduce the CO_2 emissions from cars very significantly to a target level of about 80g CO_2 per km within the European Union. These measures include a major shift to vehicles powered by (renewable) electricity, a range of efficiency improvements to the power trains of existing internal combustion engines and behavioural changes leading to an overall reduction in kilometres travelled.

methodology

DLR developed a global scenario for cars based on a detailed bottom-up model covering ten world regions. The aim was to produce a challenging but feasible scenario which would lower global CO_2 emissions within the context of the overall emission reduction objective. This approach takes into account a vast range of technical measures to reduce the energy consumption of vehicles, but also considers the dramatic increase in vehicle ownership and annual mileage taking place in developing countries. The turnover of replacement vehicles has been modelled over five year stages from 2005 to 2050. The scenario assumes that a large share of renewable electricity is available in the future. The major parameters for achieving increased efficiency are:

- vehicle technology
- alternative fuels
- changes in sales by vehicle size
- changes in vehicle kilometres travelled

As a reference scenario for the starting point in 2005, the analysis in the IEA/SMP model[117] has been used. This is the most comprehensive and detailed model available for CO_2 emissions from the global transport sector. For those technologies not included in the SMP model, we had to decide starting points for today's performance values (see below). We then created so-called 'target reference vehicles' (TRVs), which project the energy consumption feasible for each of the main fuel conversion technologies. This is described in the section 'Future vehicle technologies'. The TRVs will be introduced in the different regions of the world over a varying timescale. In general, the technologies to achieve the TRVs are aimed to be available for sale in 2050 - 40 years from now.

In general, we have first introduced the most recent - and most expensive - technologies in the currently industrialised countries, and postponed their introduction in the rest of the world. We have then used the option to change the energy source used to fuel light duty transport.

reference scenario

The IEA reference scenario developed for the Mobility 2030 project[118] was used as the starting point for the year 2005 key data and for comparison as a 'business as usual' scenario. It is important to note that for this scenario no major new policies were assumed to be implemented beyond those already introduced by 2003. While for some areas, such as pollution control, further so called policy trajectories have been assumed, this was not the case for fuel consumption. Trends in future fuel consumption are therefore based on historical (non-policy driven) trends.[119] If the serious discussions taking place in Europe and the United States on the regulation of fuel economy in new vehicles, together with legal guidelines and proposed long term targets, were taken into account, the business as usual case would be different. However, it is beyond the scope of this project to redefine the status quo. Nevertheless, we include the most recent political targets in our scenario.

Current starting point values for the world's regions and vehicle types are presented in Figure 11.4.

references

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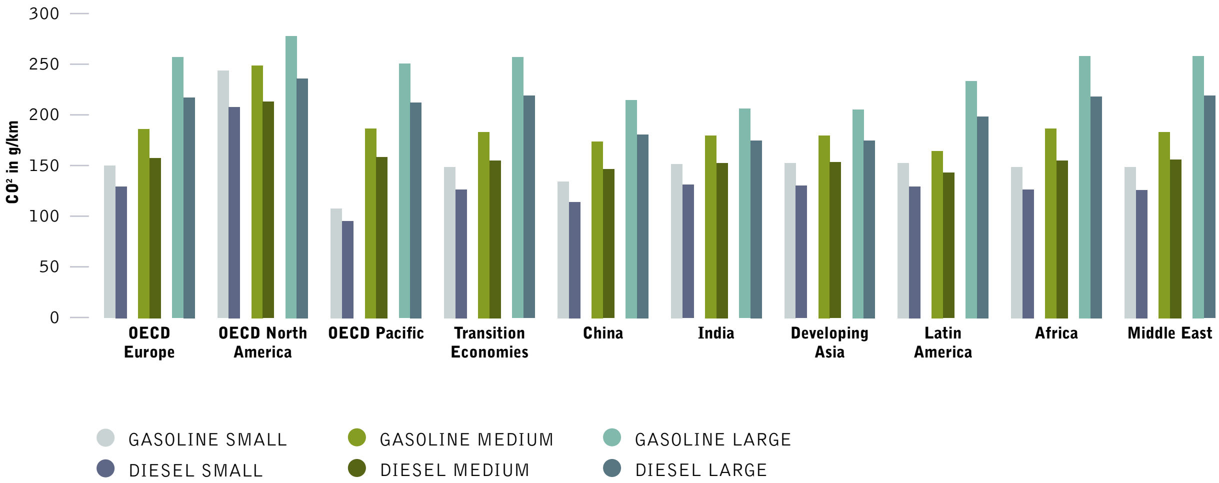
117 FULTON, L. AND G. EADS (2004): IEA/SMP MODEL DOCUMENTATION AND REFERENCE CASE PROJECTION

figure 11.4: reference values for CO_2 emissions for 2005 sales averages per vehicle segment, gasoline and diesel, and world region



cars of the future

The DLR study confirms that there is a huge potential for technical options to make today's vehicles more efficient while lowering their CO_2 emissions. A car today converts the energy in its fuel into mechanical energy in order to take the compartment we sit in from point A to B, but in a very inefficient way. Only 25% to 35% of the chemical energy in the fuel is converted into mechanical energy by the engine. The rest is lost as waste heat. Hybrid technologies mark an important starting point for making vehicles more efficient, whilst technologies to lower energy demand, such as lightweight design, reduced rolling resistance wheels and improved aerodynamics, will contribute to the achievement of very low fuel consumptions.

Renewable electricity can be produced almost everywhere in the world, and with declining costs in the future. Taking into account the enormous development in batteries in recent years, we believe that electric mobility as offered by battery electric cars and plug-in hybrid electric vehicles is the preferred way to make major reductions in the CO_2 emissions of cars.

Consumer behaviour is the third major key to a lower carbon world for the transport sector. Here we have relied on programmes, incentives and policy measures to support a shift towards low carbon emitting vehicles as well as reducing demand in general.

future vehicle technologies

The global vehicle market, with about 55 million vehicles sold per year, is enormous. Around five hundred automobile plants produce this huge quantity. Regional markets differ in the size of vehicles and fuel type used, but the propulsion technology used in all new cars globally does not differ very much. For the sake of simplicity, therefore, we have defined the reference target vehicles, which we use throughout the world, on the basis of their energy consumption 'tank-to-wheel', independent of the fuel used. The energy consumption for the reference target vehicles is presented in Figure 11.5.

figure 11.5: energy consumption of reference target vehicles for three size segments in litres of gasoline equivalent per 100 km (VALUES GIVEN FOR THE NEW EUROPEAN DRIVE CYCLE (NEDC) TEST CYCLE).

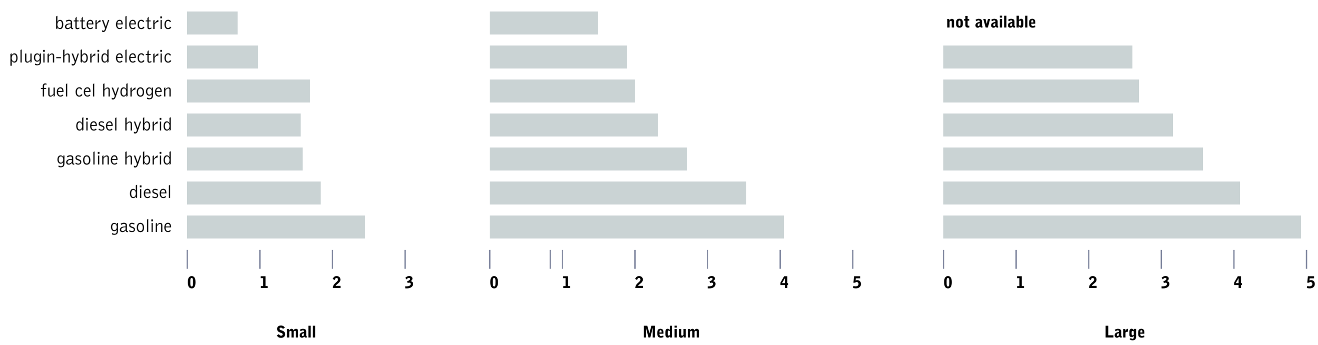


image 4 WHEEL DRIVE.

image PARKING SPACE FOR HYBRIDS ONLY.

Differences in energy consumption 'tank-to-wheel' shown in Figure 11.5 reflect the different efficiencies with which vehicles convert fuel energy into movement. The various fuels and energy sources have different qualities, depending on their upstream production processes. This is taken into account in the model. In the light of high energy prices and thus growing costs for individual mobility, we foresee a market for dedicated small commuter vehicles. These cars would serve predominantly for the transport of a single person, reflecting today's car usage in industrialised countries, although there will still be seats for three to five people. The 'small' passenger vehicle of the future is therefore projected to be smaller than it is today and consequently less energy intensive.[118]

Due to continuing differences in income level between the world's regions, the reference target vehicles are applied to new vehicle sales in the year 2050 for today's most industrialised regions: OECD Europe, North America and OECD Pacific. For all other regions, they are envisaged to enter the market in 2060, ten years later, and 20 years later in Africa.

gasoline and diesel cars

For traditional internal combustion engines, we have only allowed here for improvements in starting and stopping and no other hybrid features. Other vehicle adaptations to be introduced up to 2050 are described in more detail below.

For the small car sector we project a 1.8 litre/100 km (NEDC) four-seater diesel vehicle, as described in simulations by Friedrich.[121] We found corresponding results from our own simulations for a low-energy concept car with space for three adults and two children. For gasoline, we project 2.4 l/100 km. For the medium size sector, we project the potential for a 50% reduction in CO_2 for gasoline cars and 42% for diesel cars. Approximately half of these reductions will be derived from power train improvements (including starting and stopping) and half from an improvement in energy demand. Aerodynamics, rolling resistance and lightweight design will contribute as described below.

For the large size sector, a slightly higher 60% emissions reduction is predicted, resulting from higher mass reduction and greater downsizing potential. In addition, we have assumed political measures have been introduced, such as luxury taxes, in addition to high fuel costs, to reduce the sales of very large SUVs (Sport Utility Vehicles) for passenger transport. This means that the size of vehicles within the segment will also decrease over the years. Examples of future cross-over SUVs are projected, for example by Lovins and Cramer.[122]

Although considerable improvements are in sight for conventional gasoline and diesel engines without hybridisation, they will be technically hard to reach. Significant CO_2 reductions in the short to medium term will therefore be much easier and cheaper to achieve with the hybridisation of power trains.

hybrid vehicles

Hybrid drive trains consist of at least two different energy converters and two energy storage units. The most common is the hybrid-electric drive train, although there are also proposals for kinetic and hydraulic hybrids. Advantages of the combination of the internal combustion engine with a second source of power arise from avoiding inefficient working regimes, recuperation of braking energy, engine displacement downsizing and automated gear switch. For hybrid-electric vehicles there are several different architectures and levels of hybridisation proposed.

Hybrid vehicles have been available since the 1990s. In 2006, approximately 400,000 hybrid cars were sold, which is less than 1% of world car production. An increasing number of hybrid models are being announced, however. For this study we have used reference values of 4[123], 4.5[124] and 8.3[125] lge/100 km respectively for small, medium and large gasoline vehicles.[126]

For the reference target vehicles in 2050, we have projected the following values, depending on the vehicle segment.

small segment: As explained above, the small segment vehicle of the future will be a '1 litre car' - smaller and lighter than today. A dedicated vehicle in the 500 kg class, with three seats and with a highly efficient propulsion system, will be standard by 2050, especially for commuting or other journeys were no multi-purpose family type vehicle is necessary. The fuel consumption for this type of vehicle is projected to be 1.6 lge/100 km.

medium segment: We developed our vision of reaching 60g CO_2 per km for the medium segment following the technical building blocks described below, although this might not be the only way to reach the target.

- A 25% emissions reduction is envisaged by using turbo charging with variable turbine geometry, external cooled exhaust gas recirculation, gasoline direct injection (2nd generation) and variable valve control/cam phase shifting with respective scavenging strategies. These measures all result in a downsizing and down speeding of the engine.[127]
- An additional potential for a 25% saving, related to the previous step, will come from hybridisation and the benefits in terms of start/stop improvements, regenerative braking and further downsizing. Waste heat recovery by thermoelectric generators will contribute to the on-board power supply, which saves an additional 3 to 5%[128, 129].

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- A reduction in the vehicle's mass from 360 kg to 1,000 kg will reduce energy demand by about 18%.[130] To achieve lightweight construction, methods such as topology optimisation, multi-material design and highly integrated components will be used. Mass reductions of 60 to 120 kg for midsized cars have already been achieved.[131] The production and recycling processes of lightweight materials such as magnesium and carbon fibres will also be improved in 30-40 years time, thus avoiding a shift in emissions from the utilisation to the production phase.
- Aerodynamic resistance, aerodynamic drag and frontal areas offer further potential for improvements. By optimising the car's underside, engine air flows and contours we project an additional lowering of energy demand by 8%.
- Rolling resistance depends on the material used for the tyre, the construction of the tyre and its radius, tyre pressures and driving speed. The tyre industry has proposed new concepts for wheels which are intended to lower rolling resistance by 50% by 2030.[132, 133] Reducing the rolling coefficient by 1/1000 will lead to fuel savings of 0.08 l/100 km.[134] This results in an additional 12% CO_2 savings.
- Further potentials for energy savings will come from 'intelligent controllers' which improve energy management and drive train control strategies by recognising frequently driven journeys. Improved traffic management to help a driver find the energy optimised route might also make a contribution. Other options for hybridisation could come from free piston linear generators, which produce electricity with a constant high efficiency, at the same time avoiding part load conditions because of the variable cylinder capacity.[135]

From the technologies and potentials described here, we project that within the next 40 years an improvement of 64% in energy consumption for hybrid vehicles is achievable, resulting in 2.6 l/100 km or 60g CO_2/km for a middle sized car in the NEDC test cycle. This corresponds to an annual improvement of 2.2%. It is likely that other combinations will lead to similar results, for example by following full hybridisation first, with a potential saving of 44% [136][26] and adding complementary measures. We have also applied an 18% improvement in fuel consumption based on a realistic assessment of driving patterns.

The Volkswagen Golf V FSI 1.6 l, with a 1,360 kg mass and 163g CO_2/km in NEDC was used as a starting point. [137]

large segment: For large vehicles, the same technologies as described for the medium segment can be applied. We believe, however, that the potential for improvements is higher and project fuel consumption to reach 3.5 lge/100 km in 2050. In addition, we assume that political measures to reduce the sales of very large SUVs for passenger transport have been introduced, so that the size of vehicles within the segment will also decrease.

battery electric vehicles

Battery electric vehicles are already very efficient. A fuel consumption of 1.7 litres gasoline equivalent /100 km is reported for the Ford e-Ka[138], 2.1 l/100 km for the Ford Ecostar and 3.4 l/100 km for the Chrysler van.[139] In the future we anticipate reference target values of 0.7 l/100 km for small size cars based on simulations for micro cars and 1.4 l/100 km for medium size vehicles based on simulations of city and compact class vehicles. We do not consider battery vehicles for the large vehicle segment.

There is a considerable gap between test cycle results and real driving experience because of auxiliary power needs, for example for heating, cooling and other electrical services. We have therefore applied a factor of 1.7 to the transfer from test cycle to real world driving based on simulation results.

Battery electric vehicles carry their energy along on board in a chemical form. The future battery technology for vehicles will most probably be based on lithium because of good energy densities and cost prospects (see box "Urban vehicle of the future"). Remaining issues associated with the application of batteries in vehicles are safety, long term durability and costs. However, under the most optimistic estimates for battery development, battery electric vehicles will mainly be small vehicles and those with dedicated usage profiles like urban fleets. Other problems to be solved are fast recharging and cycle stability. Technical solutions have already been proposed, and the cost reduction target for batteries in the long term is to reach 1/40th of today's figures. An enormous amount of research is being carried out, as well as production of the first vehicle-type batteries. This scenario assumes the introduction of battery electric vehicles from 2015.

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image CHARGING AN ELECTRIC CAR.

plug-in-hybrid electric vehicles

Plug-in-hybrids are a combination of conventional hybrids and battery electric vehicles. They promise to provide both advantages: using low carbon and cheap energy from the grid, a wide travel range and grid independent driving when necessary. Fuel and energy consumption depend very much on the system layout and control strategy, combined with the distance, frequency and speed driven. We project 2.3, 2.4 and 4.5 lge/100 km for small, medium and large segment cars following the announced specification for the Volvo Recharge concept car and other input.[140]

By the year 2050 we project that plug-in hybrids will use 10% more energy in electric mode compared to our projection for battery electric vehicles, due to their increased weight. Once the battery is below the recharge limit, the conventional engine/generator will provide the energy in part or full. In this operating mode we again project 10% higher fuel consumption than their conventional hybrid counterparts. In terms of CO_2 balance the distribution of kilometres driven in electric and conventional modes is crucial. We anticipate that 80% of all kilometres will be driven in electric mode. In this scenario the introduction of plug-in-hybrid electric vehicles starts in 2015. In the advanced Energy [R]evolution scenario the introduction of plug-in hybrids also starts in 2015, but the market share grows much faster.

fuel cell hydrogen

Fuel cell vehicles have reached a high level of readiness for mass production. The polymer electrolyte membrane fuel cell provides high power density, resulting in low weight, cost and volume.[141] Average drive cycle efficiencies have reached 3.5 lge/100 km.[142] Major problems still to be solved are durability, operating temperature range and cost reductions. Hydrogen on-board storage to provide a large driving range is a further issue not finally solved. Nevertheless, the technology seems ready to begin the transition into the mass market.

The main problem in fact is not so much the vehicles themselves as the hydrogen they need. Before the vehicles can operate, a hydrogen infrastructure needs to be established. The investment involved is risky, not least because of the competing electric systems. Because of energy losses in the hydrogen production chain, electricity appears to be cheaper, easier to handle and more environmentally friendly – at least until there is renewable electricity in abundance.

The hydrogen fuel cell vehicle might find its niche, however, where the driving range of battery electric vehicles is too low and/or locally emission free driving is demanded or the freedom from grid-connecting is valued more highly. We have projected a 35% improvement compared to today's fuel cell vehicles as the target reference value because of the potential for both fuel cell system improvement and lightweight, rolling resistance and aerodynamic vehicles, as already described.

summary of energy savings in the transport sector in the energy [r]evolution scenario

The table below gives a summary of the energy efficiency improvement for passenger transport in the two low energy demand scenarios.

table 11.6: technical efficiency potential for world passenger transport

MJ/P-KM	REFERENCE SCENARIO 2005	REFERENCE SCENARIO 2050	[R]EVOLUTION SCENARIO 2050
Cars (L/100 v-km)	10.4	8.5	3.9
Cars (MJ/p-km)	2.2	2.0	0.9
Air	2.6	1.9	1.2
Buses	0.5	0.6	0.3
Mini-buses	0.5	0.6	0.3
Two wheels	0.5	0.6	0.3
Three wheels	0.7	0.7	0.5
Passenger rail	0.3	0.3	0.2

The table below gives a summary of the energy efficiency improvement for freight transport in the two low energy demand scenarios.

table 11.7: technical efficiency potential for world freight transport

MJ/P-KM	REFERENCE SCENARIO 2005	REFERENCE SCENARIO 2050	[R]EVOLUTION SCENARIO 2050
Medium trucks	5.4	3.9	2.3
Heavy trucks	1.7	1.3	0.7
Freight rail	0.2	0.2	0.1
National marine	0.7	0.5	0.5

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summary of scenario results for cars[143]

A combination of ambitious efforts to introduce higher efficiency vehicle technologies, a major switch to grid-connected electric vehicles and incentives for travellers to save CO_2 all lead to the conclusion that it is possible to reduce emissions from well-to-wheel in 2050 by roughly 25%[144] compared to 1990 and 40% compared to 2007. Even so, 74% of the final energy used in cars will still come from fossil fuel sources, 70% from gasoline and diesel. Renewable electricity covers 19% of total car energy demand, bio fuels cover 5% and hydrogen 2%. Energy consumption in total is reduced by 23% in 2050 compared to 2005, in spite of tremendous increases in some world regions. The peak in global CO_2 emissions occurs between 2010 and 2015. From 2010 onwards, new legislation in the US and Europe contributes towards breaking the upwards trend in emissions. From 2020 onwards we can see the effect of introducing grid-connected electric cars. The development of CO_2 emissions, taking into account upstream emissions, is shown in Figure 11.6.

case study: urban vehicle of the future

One example of a lightweight, efficient electric vehicle of the future is the EN-V launched by General Motors in China, together with local partner Shanghai Automotive Industry Corp, at the beginning of 2010.

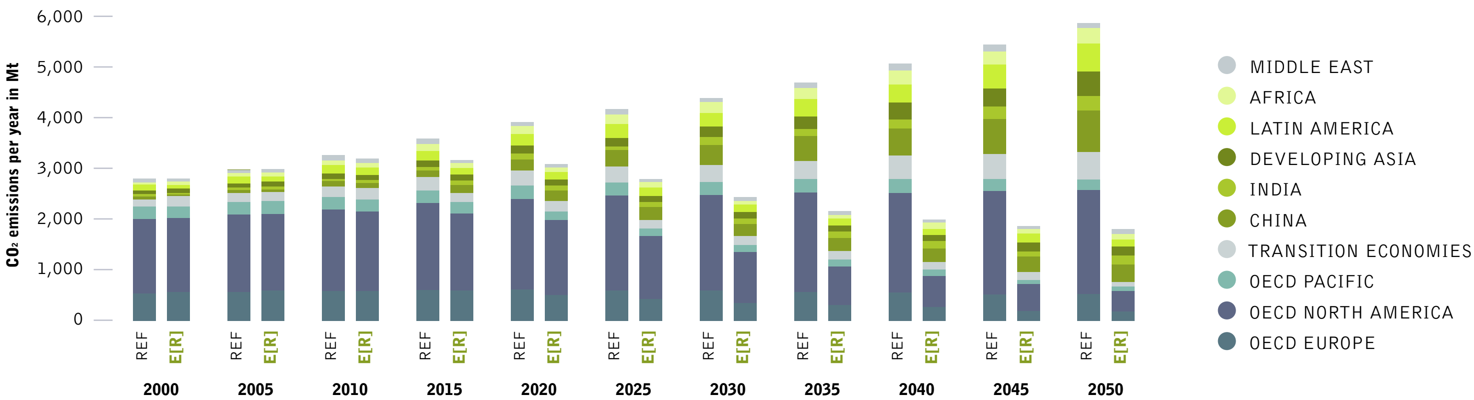
EN-V, short for Electric Networked-Vehicle, is a two seater passenger vehicle designed for use in crowded and congested urban road networks. Its lightweight construction involves a mix of carbon fibre, thermoplastic and acrylic, resulting in a final kerb weight of around 500 kilograms, about a third of the weight of a typical modern vehicle.

Drive power comes from electric motors mounted in each of the vehicles' two driving-mode wheels. Its dynamic stabilisation technology gives the EN-V the ability to carry two passengers and a small amount of cargo in a space footprint about a third the size of a traditional vehicle. With a length of just 1.5 metres it can turn round with ease. In addition, everything in the EN-V is 'drive-by-wire', supporting its ability to operate autonomously or under manual control. The motors not only provide power for acceleration but also bring the vehicle to a stop.

The motors are powered by arrays of lithium-ion batteries; once fully charged they can run for a distance of 40 kilometres. The EN-V also helps to improve the efficiency of the power infrastructure since it can communicate with the electricity grid to determine the best time to recharge, based on overall usage. This same communications system will enable passengers to enjoy autonomous operation of the vehicles during peak traffic times, as well as keep in touch with each other through a wireless connection.

source WWW.GM.COM

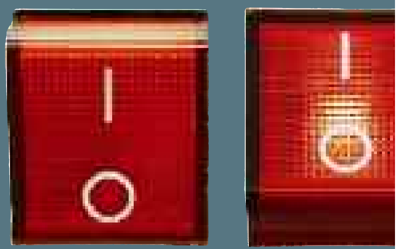
figure 11.6: well-to-wheel CO_2 emissions of light duty vehicles in the reference and energy [r]evolution scenarios from 2000 to 2050



references
143 THESE RESULTS ARE FROM THE DEVELOPMENT OF THE LDV SCENARIO WITH SEVERAL SPECIFIC ASSUMPTIONS ON E.G. UPSTREAM EMISSIONS ETC. WHICH ARE NOT COORDINATED WITH THE SCENARIO DEVELOPMENT OVER ALL SECTORS. ONLY THE MESAP MODEL WILL GIVE THE FINAL RESULTS.
144 THERE IS NO RELIABLE NUMBER FOR THE GLOBAL 1990 LDV EMISSIONS AVAILABLE, THEREFORE THIS HAS TO BE UNDERSTOOD AS A ROUGH ESTIMATE.

GLOBAL

12



STANDBY POWER IS WASTED POWER. GLOBALLY, WE HAVE 50 DIRTY POWER PLANTS RUNNING JUST FOR OUR WASTED STANDBY POWER. OR: IF WE WOULD REDUCE OUR STANDBY TO JUST 1 WATT, WE CAN AVOID THE BUILDING OF 50 NEW DIRTY POWER PLANTS.

"...so I urge the government to act and to act quickly."

LYN ALLISON
LEADER OF THE AUSTRALIAN DEMOCRATS, SENATOR 2004-2008

If the Energy [R]evolution is to happen, then governments around the world need to play a major part. Their contribution will include regulating the energy market, both on the supply and demand side, educating everyone from consumers to industrialists, and stimulating the market for renewable energy and energy efficiency by a range of economic mechanisms. They can also build on the successful policies already adopted by other countries.

To start with they need to agree on further binding emission reduction commitments in the second phase of the Kyoto Protocol. Only by setting stringent greenhouse gas emission reduction targets will the cost of carbon become sufficiently high to properly reflect its impact on society. This will in turn stimulate investments in renewable energy. Through massive funding for mitigation and technology cooperation, industrialised countries will also stimulate the development of renewable energy and energy efficiency in developing countries.

Alongside these measures specific support for the introduction of feed-in tariffs in the developing world - the extra costs of which could be funded by industrialised countries - could create similar incentives to those in countries like Germany and Spain, where the growth of renewable energy has boomed. Energy efficiency measures should be more strongly supported through the Kyoto process and its financial mechanisms.

Carbon markets can also play a distinctive role in making the Energy [R]evolution happen, although the functioning of the carbon market needs a thorough revision in order to ensure that the price of carbon is sufficiently high to reflect its real cost. Only then can we create a level playing field for renewable energy and be able to calculate the economic benefits of energy efficiency.

Industrialised countries should ensure that all financial flows to energy projects in developing countries are targeted towards renewable energy and energy efficiency. All financial assistance, whether through grants, loans or trade guarantees, directed towards supporting fossil fuel and nuclear power production, should be phased out in the next two to five years. International financial institutions, export credit agencies and development agencies should provide the required finance and infrastructure to create systems and networks to deliver the seed capital, institutional support and capacity to facilitate the implementation of the Energy [R]evolution in developing countries.

While any energy policy needs to be adapted to the local situation, we are proposing the following policies to encourage the Energy [R]evolution that all countries should adopt.

1. climate policy

Policies to limit the effects of climate change and move towards a renewable energy future must be based on penalising energy sources that contribute to global pollution.

Action: Phase out subsidies for fossil fuel and nuclear power production and inefficient energy use

The United Nations Environment Programme (UNEP) estimates (August 2008) the annual bill for worldwide energy subsidies at about $300 billion, or 0.7% of global GDP.[145] Approximately 80% of this is spent on funding fossil fuels and more than 10% to support nuclear energy. The lion's share is used to artificially lower the real price of fossil fuels. Subsidies (including loan guarantees) make energy efficiency less attractive, keep renewable energy out of the market place and prop up non-competitive and inefficient technologies.

Eliminating direct and indirect subsidies to fossil fuels and nuclear power would help move us towards a level playing field across the energy sector. Scrapping these payments would, according to UNEP, reduce greenhouse gas emissions by as much as 6% a year, while contributing 0.1% to global GDP. Many of these seemingly well intentioned subsidies rarely make economic sense anyway, and hardly ever address poverty, thereby challenging the widely held view that such subsidies assist the poor.

Instead, governments should use subsidies to stimulate investment in energy-saving measures and the deployment of renewable energy by reducing their investment costs. Such support could include grants, favourable loans and fiscal incentives, such as reduced taxes on energy efficient equipment, accelerated depreciation, tax credits and tax deductions.

The G-20 countries, meeting in Philadelphia in September 2009, called for world leaders to eliminate fossil fuel subsidies, but hardly any progress has been made since then towards implementing the resolution.

Action: Introduce the "polluter pays" principle

A substantial indirect form of subsidy comes from the fact that the energy market does not incorporate the external, societal costs of the use of fossil fuels and nuclear power. Pricing structures in the energy markets should reflect the full costs to society of producing energy.

This requires that governments apply a 'polluter pays' system that charges the emitters accordingly, or applies suitable compensation to non-emitters. Adoption of polluter pays taxation to electricity sources, or equivalent compensation to renewable energy sources, and exclusion of renewables from environment-related energy taxation, is essential to achieve fairer competition in the world's electricity markets.

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image A WOMAN IN FRONT OF HER FLOODED HOUSE IN SATJELLIA ISLAND. DUE TO THE REMOTENESS OF THE SUNDARBANS ISLANDS, SOLAR PANELS ARE USED BY MANY VILLAGERS. AS A HIGH TIDE INVADES THE ISLAND, PEOPLE REMAIN ISOLATED SURROUNDED BY THE FLOODS.

The real cost of conventional energy production includes expenses absorbed by society, such as health impacts and local and regional environmental degradation - from mercury pollution to acid rain – as well as the global negative impacts of climate change. Hidden costs include the waiving of nuclear accident insurance that is too expensive to be covered by the nuclear power plant operators. The Price Anderson Act, for instance, limits the liability of US nuclear power plants in the case of an accident to an amount of up to $98 million per plant, and only $15 million per year per plant, with the rest being drawn from an industry fund of up to $10 billion. After that the taxpayer becomes responsible.[146]

Although environmental damage should, in theory, be rectified by forcing polluters to pay, the environmental impacts of electricity generation can be difficult to quantify. How do you put a price on lost homes on Pacific Islands as a result of melting icecaps or on deteriorating health and human lives?

An ambitious project, funded by the European Commission - ExternE – has tried to quantify the full environmental costs of electricity generation. It estimates that the cost of producing electricity from coal or oil would double and that from gas would increase by 30% if external costs, in the form of damage to the environment and health, were taken into account. If those environmental costs were levied on electricity generation according to its impact, many renewable energy sources would not need any support. If, at the same time, direct and indirect subsidies to fossil fuels and nuclear power were removed, the need to support renewable electricity generation would seriously diminish or cease to exist.

One way to achieve this is by a carbon tax that ensures a fixed price is paid for each unit of carbon that is released into the atmosphere. Such taxes have, or are being, implemented in countries such as Sweden and the state of British Columbia. Another approach is through cap and trade, as operating in the European Union and planned in New Zealand and several US states. This concept gives pollution reduction a value in the marketplace.

In theory, cap and trade prompts technological and process innovations that reduce pollution down to the required levels. A stringent cap and trade can harness market forces to achieve cost-effective greenhouse gas emission reductions. But this will only happen if governments implement true 'polluter pays' cap and trade schemes that charge emitters accordingly.

Government programmes that allocate a maximum amount of emissions to industrial plants have proved to be effective in promoting energy efficiency in certain industrial sectors. To be successful, however, these allowances need to be strictly limited and their allocation auctioned.

2. energy policy and market regulation

Essential reforms are necessary in the electricity sector if new renewable energy technologies are to be implemented more widely.

Action: Reform the electricity market to allow better integration of renewable energy technologies

Complex licensing procedures and bureaucratic hurdles constitute one of the most difficult obstacles faced by renewable energy in many countries. A clear timetable for approving renewable energy projects should be set for all administrations at all levels, and they should receive priority treatment. Governments should propose more detailed procedural guidelines to strengthen the existing legislation and at the same time streamline the licensing procedures.

Other barriers include the lack of long term and integrated resource planning at national, regional and local level; the lack of predictability and stability in the markets; the grid ownership by vertically integrated companies and the absence of (access to) grids for large scale renewable energy sources, such as offshore wind power or concentrating solar power plants. The International Energy Agency has identified Denmark, Spain and Germany as example of best practice in a reformed electricity market that supports the integration of renewable energy.

In order to remove these market barriers, governments should:

- streamline planning procedures and permit systems and integrate least cost network planning;
- ensure access to the grid at fair and transparent prices;
- ensure priority access and transmission security for electricity generated from renewable energy resources, including fina;
- unbundle all utilities into separate generation, distribution and selling companies;
- ensure that the costs of grid infrastructure development and reinforcement are borne by the grid management authority rather than individual renewable energy projects;
- ensure the disclosure of fuel mix and environmental impact to end users;
- establish progressive electricity and final energy tariffs so that the price of a kWh costs more for those who consume more;
- set up demand-side management programmes designed to limit energy demand, reduce peak loads and maximise the capacity factor of the generation system. Demand-side management should also be adapted to facilitate the maximum possible share of renewable energies in the power mix;
- introduce pricing structures in the energy markets to reflect the full costs to society of producing energy.

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3. targets and incentives for renewables

At a time when governments around the world are in the process of liberalising their electricity markets, the increasing competitiveness of renewable energy should lead to higher demand. Without political support, however, renewable energy remains at a disadvantage, marginalised by distortions in the world's electricity markets created by decades of massive financial, political and structural support to conventional technologies. Developing renewables will therefore require strong political and economic efforts, especially through laws which guarantee stable tariffs over a period of up to 20 years.

At present new renewable energy generators have to compete with old nuclear and fossil fuelled power stations which produce electricity at marginal costs because consumers and taxpayers have already paid the interest and depreciation on the original investments. Political action is needed to overcome these distortions and create a level playing field.

Support mechanisms for different sectors and technologies can vary according to regional characteristics, priorities or starting points, but some general principles should apply. These are:

- **Long term stability:** Policy makers need to make sure that investors can rely on the long-term stability of any support scheme. It is absolutely crucial to avoid stop-and-go markets by changing the system or the level of support frequently.
- **Encouraging local and regional benefits and public acceptance:** A support scheme should encourage local/regional development, employment and income generation. It should also encourage public acceptance of renewables, including increased stakeholder involvement.

Incentives can be provided for renewable energy through both targets and price support mechanisms.

Action: Establish legally binding targets for renewable energy and combined heat and power generation

An increasing number of countries have established targets for renewable energy, either as a general target or broken down by sector for power, transport and heating. These are either expressed in terms of installed capacity or as a percentage of energy consumption. China and the European Union have a target for 20% renewable energy by 2020, for example, and New Zealand has a 90% by 2025 target.

Although these targets are not always legally binding, they have served as an important catalyst for increasing the share of renewable energy throughout the world. The electricity sector clearly needs a long term horizon, as investments are often only paid back after 20 to 40 years. Renewable energy targets therefore need to have short, medium and long term stages and must be legally binding in order to be effective. In order for the proportion of renewable energy to increase significantly, targets must also be set in accordance with the potential for each technology (wind, solar, biomass etc) and taking into account existing and planned infrastructure. Every government should carry out a detailed analysis of the potential and feasibility of renewable energies in its own country, and define, based on that analysis, the deadline for reaching, either individually or in cooperation with other countries, a 100% renewable energy supply.

Action: Provide a stable return for investors through price support mechanisms

Price support mechanisms for renewable energy are a practical means of correcting market failures in the electricity sector. Their aim is to support market penetration of those renewable energy technologies, such as wind and solar thermal, that currently suffer from unfair competition due to direct and indirect support to fossil fuel use and nuclear energy, and to provide incentives for technology improvements and cost reductions so that technologies such as PV, wave and tidal can compete with conventional sources in the future.

Overall, there are two types of incentive to promote the deployment of renewable energy. These are Fixed Price Systems where the government dictates the electricity price (or premium) paid to the producer and lets the market determine the quantity, and Renewable Quota Systems (in the USA referred to as Renewable Portfolio Standards) where the government dictates the quantity of renewable electricity and leaves it to the market to determine the price. Both systems create a protected market against a background of subsidised, depreciated conventional generators whose external environmental costs are not accounted for. Their aim is to provide incentives for technology improvements and cost reductions, leading to cheaper renewables that can compete with conventional sources in the future.

The main difference between quota based and price based systems is that the former aims to introduce competition between electricity producers. However, competition between technology manufacturers, which is the most crucial factor in bringing down electricity production costs, is present regardless of whether government dictates prices or quantities. Prices paid to wind power producers are currently higher in many European quota based systems (UK, Belgium, Italy) than in fixed price or premium systems (Germany, Spain, Denmark).

The European Commission has concluded that fixed price systems are to be preferred above quota systems. If implemented well, fixed price systems are a reliable, bankable support scheme for renewable energy projects, providing long term stability and leading to lower costs. In order for such systems to achieve the best possible results, however, priority access to the grid must be ensured.

fixed price systems

Fixed price systems include investment subsidies, fixed feed-in tariffs, fixed premium systems and tax credits.

- **Investment subsidies** are capital payments usually made on the basis of the rated power (in kW) of the generator. It is generally acknowledged, however, that systems which base the amount of support on generator size rather than electricity output can lead to less efficient technology development. There is therefore a global trend away from these payments, although they can be effective when combined with other incentives.
- **Fixed feed-in tariffs (FITs)** widely adopted in Europe, have proved extremely successful in expanding wind energy in

image A YOUNG INDIGENOUS NENET BOY PRACTICES WITH HIS ROPE. THE BOYS ARE GIVEN A ROPE FROM PRETTY MUCH THE MOMENT THEY ARE BORN. BY THE AGE OF SIX THEY ARE OUT HELPING LASSOING THE REINDEER. THE INDIGENOUS NENETS PEOPLE MOVE EVERY 3 OR 4 DAYS SO THAT THEIR REINDEER DO NOT OVER GRAZE THE GROUND AND THEY DO NOT OVER FISH THE LAKES. THE YAMAL PENINSULA IS UNDER HEAVY THREAT FROM GLOBAL WARMING AS TEMPERATURES INCREASE AND RUSSIAS ANCIENT PERMAFROST MELTS.

Germany, Spain and Denmark. Operators are paid a fixed price for every kWh of electricity they feed into the grid. In Germany the price paid varies according to the relative maturity of the particular technology and reduces each year to reflect falling costs. The additional cost of the system is borne by taxpayers or electricity consumers.

The main benefit of a FIT is that it is administratively simple and encourages better planning. Although the FIT is not associated with a formal Power Purchase Agreement, distribution companies are usually obliged to purchase all the production from renewable installations. Germany has reduced the political risk of the system being changed by guaranteeing payments for 20 years. The main problem associated with a fixed price system is that it does not lend itself easily to adjustment – whether up or down - to reflect changes in the production costs of renewable technologies.

- **Fixed premium systems** sometimes called an "environmental bonus" mechanism, operate by adding a fixed premium to the basic wholesale electricity price. From an investor perspective, the total price received per kWh is less predictable than under a feed-in tariff because it depends on a constantly changing electricity price. From a market perspective, however, it is argued that a fixed premium is easier to integrate into the overall electricity market because those involved will be reacting to market price signals. Spain is the most prominent country to have adopted a fixed premium system.
- **Tax credits** as operated in the US and Canada, offer a credit against tax payments for every kWh produced. In the United States the market has been driven by a federal Production Tax Credit (PTC) of approximately 1.8 cents per kWh. It is adjusted annually for inflation.

renewable quota systems

Two types of renewable quota systems have been employed - tendering systems and green certificate systems.

- **Tendering systems** involve competitive bidding for contracts to construct and operate a particular project, or a fixed quantity of renewable capacity in a country or state. Although other factors are usually taken into account, the lowest priced bid invariably wins. This system has been used to promote wind power in Ireland, France, the UK, Denmark and China. The downside is that investors can bid an uneconomically low price in order to win the contract, and then not build the project. Under the UK's NFFO (Non-Fossil Fuel Obligation) tender system, for example, many contracts remained unused. It was eventually abandoned. If properly designed, however, with long contracts, a clear link to planning consent and a possible minimum price, tendering for large scale projects could be effective, as it has been for offshore oil and gas extraction in Europe's North Sea.
- **Tradable green certificate (TGC) systems** operate by offering "green certificates" for every kWh generated by a renewable producer. The value of these certificates, which can be traded on a market, is then added to the value of the basic electricity. A green certificate system usually operates in combination with a rising quota of renewable electricity generation. Power companies are bound by law to purchase an increasing proportion of renewables input. Countries which have adopted this system include the UK and Italy in Europe and many individual states in the US, where it is known as a Renewable Portfolio Standard. Compared with a fixed tender price, the TGC model is more risky for the investor, because the price fluctuates on a daily basis, unless effective markets for long-term certificate (and electricity) contracts are developed. Such markets do not currently exist. The system is also more complex than other payment mechanisms.

4. renewables for heating and cooling

The crucial requirement for both heating and cooling is often forgotten in the energy mix. In many regions of the world, such as Europe, nearly half of the total energy demand is for heating/cooling. This demand can be met economically without relying on fossil fuels.

Policies should make sure that specific targets and appropriate measures to support renewable heating and cooling are part of any national renewables strategy. These should include financial incentives, awareness raising campaigns, training of installers, architects and heating engineers, and demonstration projects. For new buildings, and those undergoing major renovation, an obligation to cover a minimum share of heat consumption by renewables should be introduced, as already implemented in some countries. At the same time, increased R&D efforts should be undertaken, particularly in the fields of heat storage and renewable cooling.

Governments should also promote the development of combined heat and power generation in those industrial sectors that are most attractive for CHP - where there is a demand for heat either directly or through a local (existing or potential) district heating system. Governments should set targets and efficiency standards for CHP and provide financial incentives for investment in industrial installations.

5. energy efficiency and innovation

Action: Set stringent efficiency and emissions standards for appliances, buildings, power plants and vehicles

Policies and measures to promote energy efficiency exist in many countries. Energy and information labels, mandatory minimum energy performance standards and voluntary efficiency agreements are the most popular measures. Effective government policies usually contain two elements - those that push the market through standards and those that pull through incentives - and have proved to be an effective, low cost way to coordinate a transition to more energy efficiency.

The Japanese front-runner programme, for example, is a regulatory scheme with mandatory targets which gives incentives to manufacturers and importers of energy-consuming equipment to continuously improve the efficiency of their products. It operates by allowing today's best models on the market to set the level for future standards.

In the residential sector in industrialised countries, standby power consumption ranges from 20 to 60 watts per household, equivalent to 4 to 10% of total residential energy consumption. Yet the technology is available to reduce standby power to 1 watt. A global standard, as proposed by the IEA, could mandate this reduction. Japan, South Korea and the state of California have not waited for this international approach and have already adopted standby standards.

Governments should mandate the phase-out of incandescent and inefficient light bulbs and replace them with the most efficient lighting. Countries like Cuba, Venezuela and Australia have already banned incandescent light bulbs.

Governments should also set emissions standards for cars and power plants, such as those proposed in Europe for passenger cars of 120g CO_2/km and 350g/kWh for power plants. Similar emissions standards, as already implemented in China, Japan and the states of Washington and California, will support innovation and ensure that inefficient vehicles and power plants are outlawed.

Action: Support innovation in energy efficiency, low carbon transport systems and renewable energy production

Innovation will play an important role in making the Energy [R]evolution happen, and is needed to realise the ambition of ever-improving efficiency and emissions standards. Programmes supporting renewable energy and energy efficiency development and diffusion are a traditional focus of energy and environmental policies because energy innovations face barriers all along the energy supply chain (from R&D to demonstration projects to widespread deployment). Direct government support through a variety of fiscal instruments, such as tax incentives, is vital to hasten deployment of radically new technologies due to a lack of industry investment. This suggests that there is a role for the public sector in increasing investment directly and in correcting market and regulatory obstacles that inhibit investment in new technology

Governments need to invest in research and development for more efficient appliances and building techniques, in new forms of insulation, in new types of renewable energy production (such as tidal and wave power) as well as in a low carbon transport future, through the development of better batteries for plug-in electric cars or fuels for aviation from renewable sources. Governments need to engage in innovation themselves, both through publicly funded research and by supporting private research and development.

There are numerous ways to support innovation. The most important policies are those that reduce the cost of research and development, such as tax incentives, staff subsidies or project grants. Financial support for research and development on 'dead end' energy solutions such as nuclear fusion should be diverted to supporting renewable energy, energy efficiency and decentralised energy solutions.

Specific proposals for efficiency and innovation measures include:

appliances and lighting

Two types of renewable quota systems have been employed - tendering systems and green certificate systems.

- **Efficiency standards** Governments should set ambitious, stringent and mandatory efficiency standards for all energy consuming appliances that constantly respond to technical innovation and enforce the phase-out of the most inefficient appliances. These standards should allow the banning of inefficient products from the market, with penalties for non-compliance.
- **Consumer awareness** Governments should inform consumers and/or set up systems that compel retailers and manufacturers to do so, about the energy efficiency of the products they use and buy, including awareness-raising and educational programmes. Consumers often make their choices based on non-financial factors but lack the necessary information.
- **Energy labelling** Labels provide the means to inform consumers of the product's relative or absolute performance and energy operating costs. Governments should support the development of endorsement and comparison labels for electrical appliances.

buildings

- **Residential and commercial building codes** Governments should set mandatory building codes that require the use of a set share of renewable energy for heating and cooling and compliance with a limited annual energy consumption level. These codes should be regularly upgraded in order to make use of fresh products on the market and non-compliance should be penalised.
- **Financial incentives** Given that investment costs are often a barrier to implementing energy efficiency measures, in particular for retrofitting renewable energy options, governments should offer financial incentives including tax reductions schemes, investment subsidies and preferential loans.
- **Energy intermediaries and audit programmes** Governments should develop strategies and programmes to promote the education of architects, engineers and other professionals in the building sector as well as end-users about energy efficiency opportunities in new and existing buildings. As part of this strategy governments should invest in 'energy intermediaries' and energy audit programmes in order to assist professionals and consumers in identifying opportunities for improving the efficiency of their buildings.

transport

- **Emissions standards** Governments should regulate the efficiency of private cars and other transport vehicles in order to push manufacturers to reduce emissions through downsizing, design and technology improvement. Improvements in efficiency will reduce CO_2 emissions irrespective of the fuel used. After this further reductions could be achieved by using low-emission fuels. Emissions standards should provide for an average reduction of 5g CO_2/km/year in industrialised countries. These standards need to be mandatory. To dissuade car makers from overpowering high end cars a maximum CO_2 emissions limit for individual car models should be introduced.
- **Electric vehicles** Governments should develop incentives to promote the further development of electric cars and other efficient and sustainable low carbon transport technologies. Linking electric cars to a renewable energy grid is the best possible option to reduce emissions from the transport sector.
- **Transport demand management** Governments should invest in developing, improving and promoting low emission transport options, such as public and non-motorised transport, freight transport management programmes, teleworking and more efficient land use planning in order to limit journeys.

GLOBAL

13

"because we use such inefficient lighting, 80 coal fired power plants are running day and night to produce the energy that is wasted."

GREENPEACE INTERNATIONAL
CLIMATE CAMPAIGN

image COAL FIRED POWER PLANT.
© F. FUXA/DREAMSTIME

glossary of commonly used terms and abbreviations

CHP Combined Heat and Power
CO_2 Carbon dioxide, the main greenhouse gas
GDP Gross Domestic Product (means of assessing a country's wealth)
PPP Purchasing Power Parity (adjustment to GDP assessment to reflect comparable standard of living)
IEA International Energy Agency

J Joule, a measure of energy:
kJ = 1,000 Joules,
MJ = 1 million Joules,
GJ = 1 billion Joules,
PJ = 10^{15} Joules,
EJ = 10^{18} Joules

W Watt, measure of electrical capacity:
kW = 1,000 watts,
MW = 1 million watts,
GW = 1 billion watts

kWh Kilowatt-hour, measure of electrical output: TWh = 10^{12} watt-hours
t/Gt Tonnes, measure of weight: Gt = 1 billion tonnes

conversion factors - fossil fuels

FUEL				
Coal	23.03	MJ/t	1 cubic	0.0283 m^3
Lignite	8.45	MJ/t	1 barrel	159 liter
Oil	6.12	GJ/barrel	1 US gallon	3.785 liter
Gas	38000.00	kJ/m^3	1 UK gallon	4.546 liter

conversion factors - different energy units

FROM \ TO: MULTIPLY BY	TJ	Gcal	Mtoe	Mbtu	GWh
TJ	1	238.8	2.388×10^{-5}	947.8	0.2778
Gcal	4.1868×10^{-3}	1	$10^{(-7)}$	3.968	1.163×10^{-3}
Mtoe	4.1868×10^{4}	10^{7}	1	3968×10^{7}	11630
Mbtu	1.0551×10^{-3}	0.252	2.52×10^{-8}	1	2.931×10^{-4}
GWh	3.6	860	8.6×10^{-5}	3412	1

image MINOTI SINGH AND HER SON AWAIT FOR CLEAN WATER SUPPLY BY THE RIVERBANK IN DAYAPUR VILLAGE IN SATJELLIA ISLAND: "WE DO NOT HAVE CLEAN WATER AT THE MOMENT AND ONLY ONE TIME WE WERE LUCKY TO BE GIVEN SOME RELIEF. WE ARE NOW WAITING FOR THE GOVERNMENT TO SUPPLY US WITH WATER TANKS".

definition of sectors

The definition of different sectors below is the same as the sectoral breakdown in the IEA World Energy Outlook series.

All definitions below are from the IEA Key World Energy Statistics

Industry sector: Consumption in the industry sector includes the following subsectors (energy used for transport by industry is not included -> see under "Transport")

- Iron and steel industry
- Chemical industry
- Non-metallic mineral products e.g. glass, ceramic, cement etc.
- Transport equipment
- Machinery
- Mining
- Food and tobacco
- Paper, pulp and print
- Wood and wood products (other than pulp and paper)
- Construction
- Textile and Leather

Transport sector: The Transport sector includes all fuels from transport such as road , railway, aviation, domestic navigation. Fuel used for ocean, costal and inland fishing is included in "Other Sectors".

Other sectors: 'Other sectors' covers agriculture, forestry, fishing, residential, commercial and public services.

Non-energy use: Covers use of other petroleum products such as paraffin waxes, lubricants, bitumen etc.

global: reference scenario

table 13.1: global: electricity generation

TWh/a	2007	2015	2020	2030	2040	2050
Power plants	**17,734**	**22,009**	**24,670**	**31,277**	**37,223**	**42,672**
Coal	5,781	8,114	9,395	12,895	15,753	18,216
Lignite	1,657	1,505	1,415	1,317	1,295	1,309
Gas	3,087	3,723	4,272	5,466	6,624	7,660
Oil	945	713	641	544	460	389
Diesel	65	50	44	40	34	29
Nuclear	2,719	3,107	3,264	3,667	4,040	4,413
Biomass	162	265	337	552	780	994
Hydro	3,078	3,692	4,027	4,679	5,321	5,963
Wind	173	677	1,009	1,536	2,034	2,516
PV	5	55	108	281	462	640
Geothermal	60	95	117	168	217	265
Solar thermal power plants	0	12	38	121	186	254
Ocean energy	1	2	3	11	18	25
Combined heat & power production	**2,039**	**2,353**	**2,578**	**3,029**	**3,449**	**3,870**
Coal	490	639	724	860	999	1,150
Lignite	166	165	161	157	156	155
Gas	1,181	1,302	1,408	1,631	1,828	1,997
Oil	105	100	93	86	75	66
Biomass	97	143	186	287	378	483
Geothermal	1	4	6	9	13	19
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	1,487	1,583	1,659	1,827	1,963	2,115
Autoproducers	552	770	919	1,202	1,487	1,755
Total generation	**19,773**	**24,362**	**27,248**	**34,307**	**40,672**	**46,542**
Fossil	13,477	16,309	18,153	22,997	27,225	30,970
Coal	6,271	8,753	10,119	13,756	16,752	19,366
Lignite	1,823	1,669	1,576	1,474	1,451	1,464
Gas	4,268	5,025	5,680	7,097	8,452	9,657
Oil	1,050	812	734	630	536	454
Diesel	65	50	44	40	34	29
Nuclear	2,719	3,107	3,264	3,667	4,040	4,413
Hydrogen	0	0	0	0	0	0
Renewables	**3,578**	**4,946**	**5,831**	**7,643**	**9,408**	**11,159**
Hydro	3,078	3,692	4,027	4,679	5,321	5,963
Wind	173	677	1,009	1,536	2,034	2,516
PV	5	55	108	281	462	640
Biomass	259	409	523	839	1,158	1,477
Geothermal	62	99	123	176	230	284
Solar thermal	0	12	38	121	186	254
Ocean energy	1	2	3	11	18	25
Distribution losses	1,667	1,978	2,183	2,677	3,134	3,577
Own consumption electricity	1,655	2,000	2,225	2,691	3,161	3,643
Electricity for hydrogen production	0	0	0	1	2	4
Final energy consumption (electricity)	**16,450**	**20,390**	**22,840**	**28,954**	**34,406**	**39,360**
Fluctuating RES (PV, Wind, Ocean)	179	734	1,120	1,827	2,513	3,181
Share of fluctuating RES	0.9%	3.0%	4.1%	5.3%	6.2%	6.8%
RES share	**18.1%**	**20.3%**	**21.4%**	**22.3%**	**23.1%**	**24.0%**

table 13.2: global: heat supply

PJ/A	2007	2015	2020	2030	2040	2050
District heating plants	**8,852**	**8,699**	**8,742**	**8,776**	**8,864**	**8,691**
Fossil fuels	8,321	8,098	8,070	7,977	8,022	7,831
Biomass	525	594	664	789	828	841
Solar collectors	0	1	1	2	3	5
Geothermal	6	7	7	8	10	13
Heat from CHP	**8,073**	**9,545**	**10,336**	**11,840**	**13,245**	**14,889**
Fossil fuels	7,558	8,903	9,526	10,711	11,848	13,173
Biomass	502	614	771	1,074	1,312	1,580
Geothermal	13	28	39	56	85	136
Fuel cell (hydrogen)	0	0	0	0	0	0
Direct heating[1]	**122,577**	**132,004**	**137,961**	**152,268**	**166,932**	**180,124**
Fossil fuels	90,140	97,556	102,319	114,304	125,770	135,800
Biomass	32,053	33,904	34,796	36,337	38,794	41,224
Solar collectors	383	544	846	1,627	2,367	3,100
Geothermal	168	348	585	860	1,166	1,486
Total heat supply[1]	**139,669**	**150,596**	**157,623**	**173,749**	**190,207**	**205,190**
Fossil fuels	106,018	114,557	119,914	132,992	145,641	156,803
Biomass	33,080	35,112	36,231	38,200	40,934	43,645
Solar collectors	384	544	848	1,629	2,370	3,105
Geothermal	187	383	631	928	1,262	1,635
Fuel cell ((hydrogen)	0	0	0	0	0	0
RES share (including RES electricity)	**24%**	**24%**	**24%**	**23%**	**23%**	**24%**

1) heat from electricity (direct and from electric heat pumps) not included; covered in the model under 'electric appliances'

table 13.3: global: CO_2 emissions

MILL t/a	2007	2015	2020	2030	2040	2050
Condensation power plants	**9,957**	**11,905**	**13,043**	**16,020**	**17,145**	**17,763**
Coal	5,854	7,993	9,128	11,806	12,719	13,151
Lignite	1,874	1,636	1,464	1,327	1,255	1,244
Gas	1,448	1,676	1,910	2,436	2,794	3,051
Oil	667	542	490	405	341	287
Diesel	114	57	51	46	37	30
Combined heat & power production	**1,728**	**1,810**	**1,829**	**1,870**	**1,964**	**2,072**
Coal	611	718	741	730	780	840
Lignite	228	192	172	175	182	194
Gas	717	765	808	879	938	988
Oil	172	135	109	86	64	49
CO_2 emissions electricity & steam generation	**11,685**	**13,715**	**14,873**	**17,890**	**19,109**	**19,835**
Coal	6,466	8,711	9,869	12,536	13,499	13,991
Lignite	2,101	1,829	1,636	1,502	1,437	1,438
Gas	2,165	2,442	2,718	3,315	3,731	4,039
Oil & diesel	954	734	650	537	442	367
CO_2 emissions by sector	**27,408**	**30,922**	**33,074**	**38,528**	**41,662**	**44,259**
% of 1990 emissions	131%	148%	158%	184%	199%	211%
Industry	4,726	5,424	5,635	6,178	6,692	7,078
Other sectors	3,356	3,532	3,674	4,011	4,321	4,632
Transport	5,541	6,029	6,513	7,918	9,140	10,338
Electricity & steam generation	11,180	13,110	14,243	17,235	18,398	19,062
District heating	2,603	2,827	3,008	3,186	3,112	3,150
Population (Mill.)	6,670	7,302	7,675	8,309	8,801	9,150
CO_2 emissions per capita (t/capita)	**4.1**	**4.2**	**4.3**	**4.6**	**4.7**	**4.8**

table 13.4: global: installed capacity

GW	2007	2015	2020	2030	2040	2050
Power plants	**4,033**	**5,103**	**5,633**	**7,033**	**8,491**	**10,146**
Coal	1,010	1,445	1,664	2,274	2,782	3,220
Lignite	281	263	246	214	213	217
Gas	907	1,135	1,224	1,526	1,964	2,666
Oil	341	298	248	195	182	177
Diesel	60	49	44	41	36	34
Nuclear	373	412	428	476	531	590
Biomass	28	44	54	90	126	159
Hydro	922	1,099	1,196	1,382	1,539	1,681
Wind	95	293	417	595	739	883
PV	6	44	80	184	301	420
Geothermal	10	15	19	25	33	40
Solar thermal power plants	0	5	12	27	39	50
Ocean energy	0	1	1	3	6	8
Combined heat & power production	**523**	**629**	**662**	**760**	**841**	**921**
Coal	114	159	173	191	223	257
Lignite	41	42	38	30	30	30
Gas	288	330	355	440	479	509
Oil	62	70	62	47	41	39
Biomass	18	26	34	50	66	84
Geothermal	0	1	1	1	2	3
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	379	417	420	461	499	533
Autoproducers	143	212	242	300	342	389
Total generation	**4,556**	**5,732**	**6,295**	**7,793**	**9,332**	**11,067**
Fossil	3,103	3,792	4,052	4,959	5,949	7,148
Coal	1,123	1,604	1,837	2,465	3,005	3,477
Lignite	322	305	284	244	243	246
Gas	1,195	1,465	1,579	1,967	2,442	3,175
Oil	403	368	309	242	224	216
Diesel	60	49	44	41	36	34
Nuclear	373	412	428	476	531	590
Hydrogen	0	0	0	0	0	0
Renewables	**1,080**	**1,528**	**1,814**	**2,359**	**2,852**	**3,329**
Hydro	922	1,099	1,196	1,382	1,539	1,681
Wind	95	293	417	595	739	883
PV	6	44	80	184	301	420
Biomass	46	71	88	140	192	244
Geothermal	11	16	20	27	35	43
Solar thermal	0	5	12	27	39	50
Ocean energy	0	1	1	3	6	8
Fluctuating RES (PV, Wind, Ocean)	101	338	498	782	1,046	1,312
Share of fluctuating RES	2.2%	5.9%	7.9%	10.0%	11.2%	11.9%
RES share	**23.7%**	**26.7%**	**28.8%**	**30.3%**	**30.6%**	**30.1%**

table 13.6: global: primary energy demand

PJ/A	2007	2015	2020	2030	2040	2050
Total	**490,230**	**546,293**	**582,968**	**673,652**	**732,801**	**783,458**
Fossil	**396,654**	**437,637**	**465,563**	**538,368**	**581,427**	**616,715**
Hard coal	116,959	146,386	159,514	190,696	204,413	212,289
Lignite	18,932	16,473	14,737	13,535	12,944	12,956
Natural gas	104,845	112,931	121,148	141,706	155,015	166,487
Crude oil	155,920	161,847	170,164	192,431	209,056	224,983
Nuclear	**29,664**	**33,902**	**35,614**	**40,009**	**44,076**	**48,142**
Renewables	**63,911**	**74,754**	**81,791**	**95,275**	**107,298**	**118,601**
Hydro	11,082	13,291	14,497	16,844	19,156	21,467
Wind	624	2,437	3,632	5,530	7,322	9,058
Solar	402	786	1,372	3,075	4,702	6,322
Biomass	49,816	55,891	59,557	66,385	71,938	76,777
Geothermal	1,984	2,342	2,721	3,403	4,116	4,888
Ocean Energy	2	7	12	38	64	90
RES share	**13%**	**14%**	**14%**	**14%**	**15%**	**15%**

table 13.5: global: final energy demand

PJ/a	2007	2015	2020	2030	2040	2050
Total (incl. non-energy use)	**337,329**	**375,885**	**401,692**	**464,927**	**522,095**	**575,530**
Total (energy use)	**305,093**	**340,909**	**365,099**	**425,571**	**480,395**	**531,485**
Transport	**82,068**	**91,231**	**99,269**	**120,621**	**139,420**	**158,010**
Oil products	76,536	83,081	89,732	108,991	125,706	142,083
Natural gas	3,130	3,647	3,811	4,354	4,916	5,478
Biofuels	1,430	3,203	4,299	5,498	6,660	7,915
Electricity	973	1,300	1,427	1,774	2,133	2,524
RES electricity	171	257	304	402	504	622
Hydrogen	0	0	0	3	6	10
RES share Transport	**2.0%**	**3.8%**	**4.6%**	**4.9%**	**5.1%**	**5.4%**
Industry	**99,249**	**115,748**	**123,762**	**143,735**	**161,280**	**175,783**
Electricity	24,995	32,887	36,908	46,291	53,777	59,951
RES electricity	4,627	6,590	7,749	10,025	12,062	13,928
District heat	9,424	9,992	10,406	11,292	12,155	12,986
RES district heat	555	717	931	1,253	1,415	1,579
Coal	19,547	25,170	26,209	29,481	32,429	34,435
Oil products	13,517	13,756	14,082	14,891	15,658	16,271
Gas	23,871	24,685	26,070	29,215	32,221	34,767
Solar	5	35	97	186	274	362
Biomass and waste	7,877	9,154	9,859	12,142	14,459	16,599
Geothermal	12	69	131	237	307	412
Hydrogen	0	0	0	0	0	0
RES share Industry	**13.2%**	**14.3%**	**15.2%**	**16.6%**	**17.7%**	**18.7%**
Other Sectors	**123,776**	**133,930**	**142,069**	**161,215**	**179,695**	**197,692**
Electricity	33,253	39,218	43,890	56,169	67,952	79,220
RES electricity	5,842	8,014	9,550	12,902	16,316	19,809
District heat	6,546	7,140	7,525	8,098	8,651	9,213
RES district heat	438	489	552	625	668	704
Coal	4,535	5,025	5,031	4,800	4,499	4,309
Oil products	19,059	19,854	20,444	21,912	23,312	24,683
Gas	25,970	26,959	28,686	33,210	37,515	41,781
Solar	378	509	749	1,440	2,093	2,738
Biomass and waste	33,884	34,996	35,388	35,096	34,972	34,851
Geothermal	151	229	355	491	700	897
RES share Other Sectors	**32.9%**	**33.0%**	**32.8%**	**31.4%**	**30.5%**	**29.8%**
Total RES	**55,371**	**64,263**	**69,965**	**80,299**	**90,430**	**100,419**
RES share	**18.1%**	**18.9%**	**19.2%**	**18.9%**	**18.8%**	**18.9%**
Non energy use	**32,236**	**34,977**	**36,593**	**39,356**	**41,701**	**44,045**
Oil	24,832	26,267	27,278	29,009	30,518	32,027
Gas	6,084	6,901	7,383	8,190	8,800	9,410
Coal	1,320	1,808	1,931	2,157	2,383	2,608

global:energy [r]evolution scenario

table 13.7: global: electricity generation

TWh/a	2007	2015	2020	2030	2040	2050
Power plants	**17,734**	**21,183**	**22,642**	**25,829**	**28,296**	**31,404**
Coal	5,781	7,162	7,127	6,576	4,690	2,899
Lignite	1,657	1,372	889	272	31	0
Gas	3,087	4,197	4,603	4,902	3,865	2,038
Oil	945	708	565	338	93	15
Diesel	65	37	25	17	10	6
Nuclear	2,719	2,446	1,816	802	291	0
Biomass	162	279	373	456	556	717
Hydro	3,078	3,719	4,029	4,370	4,726	5,056
Wind	173	941	2,168	4,539	6,674	8,474
PV	5	121	437	1,481	2,827	4,597
Geothermal	60	123	235	502	800	1,009
Solar thermal power plants	0	66	321	1,447	3,408	5,917
Ocean energy	1	13	53	128	324	678
Combined heat & power production	**2,039**	**2,597**	**3,210**	**4,304**	**5,521**	**6,589**
Coal	490	575	573	693	861	948
Lignite	166	111	75	24	0	0
Gas	1,181	1,465	1,710	1,981	1,949	1,909
Oil	105	91	48	12	0	0
Biomass	97	340	739	1,402	2,277	3,013
Geothermal	1	16	65	192	433	719
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	1,487	1,651	1,872	2,330	2,818	3,171
Autoproducers	552	946	1,337	1974	2,702	3,418
Total generation	**19,773**	**23,781**	**25,851**	**30,133**	**33,817**	**37,993**
Fossil	13,477	15,717	15,615	14,814	11,501	7,813
Coal	6,271	7,736	7,700	7,269	5,552	3,846
Lignite	1,823	1,483	963	296	31	0
Gas	4,268	5,662	6,314	6,883	5,814	3,946
Oil	1,050	798	613	350	94	15
Diesel	65	37	25	17	10	6
Nuclear	2,719	2,446	1,816	802	291	0
Hydrogen	0	0	0	0	0	0
Renewables	**3,578**	**5,618**	**8,420**	**14,517**	**22,025**	**30,179**
Hydro	3,078	3,719	4,029	4,370	4,726	5,056
Wind	173	941	2,168	4,539	6,674	8,474
PV	5	121	437	1,481	2,827	4,597
Biomass	259	619	1,112	1,858	2,833	3,730
Geothermal	62	140	300	695	1,233	1,728
Solar thermal	0	66	321	1,447	3,408	5,917
Ocean energy	1	13	53	128	324	678
Distribution losses	1,667	1,979	2,138	2,488	2,693	2,829
Own consumption electricity	1,655	1,977	2,166	2,514	2,733	2,861
Electricity for hydrogen production	0	8	126	245	390	508
Final energy consumption (electricity)	**16,450**	**19,819**	**21,420**	**24,885**	**28,000**	**31,795**
Fluctuating RES (PV, Wind, Ocean)	179	1,075	2,658	6,148	9,825	13,749
Share of fluctuating RES	0.9%	4.5%	10.3%	20.4%	29.1%	36.2%
RES share	**18.1%**	**23.6%**	**32.6%**	**48.2%**	**65.1%**	**79.4%**
'Efficiency' savings (compared to Ref.)	**0**	**695**	**1,957**	**6,006**	**9,741**	**13,267**

table 13.8: global: heat supply

PJ/A	2007	2015	2020	2030	2040	2050
District heating plants	**8,852**	**8,984**	**9,182**	**9,596**	**10,097**	**10,340**
Fossil fuels	8,321	6,972	5,759	3,741	1,583	295
Biomass	525	1,461	2,023	2,731	3,043	2,854
Solar collectors	0	268	759	1,763	3,269	4,515
Geothermal	6	283	640	1,360	2,202	2,676
Heat from CHP	**8,073**	**10,819**	**14,101**	**18,714**	**23,379**	**27,475**
Fossil fuels	7,558	8,845	9,468	10,549	10,646	10,236
Biomass	502	1,841	4,088	6,527	8,990	11,028
Geothermal	13	134	545	1,638	3,743	6,211
Fuel cell (hydrogen)	0	0	0	0	0	0
Direct heating[1)]	**122,577**	**126,793**	**128,070**	**127,344**	**123,478**	**118,017**
Fossil fuels	90,140	89,014	83,567	70,887	52,833	33,977
Biomass	32,053	34,197	35,571	36,106	35,118	32,226
Solar collectors	383	2190	5,739	14,084	23,974	34,163
Geothermal	168	1392	3,194	6,266	11,552	17,651
Total heat supply[1)]	**139,669**	**146,596**	**151,353**	**155,654**	**156,953**	**155,833**
Fossil fuels	106,018	104,831	98,794	85,178	65,062	44,507
Biomass	33,080	37,498	41,682	45,365	47,151	46,109
Solar collectors	384	2,459	6,498	15,847	27,243	38,679
Geothermal	187	1,809	4,379	9,264	17,497	26,538
Fuel cell (hydrogen)	0	0	0	0	0	0
RES share (including RES electricity)	**24%**	**28%**	**35%**	**45%**	**59%**	**71%**
'Efficiency' savings (compared to Ref.)	**0**	**4,085**	**6,283**	**18,095**	**33,254**	**49,357**

1) heat from electricity (direct and from electric heat pumps) not included; covered in the model under 'electric appliances'

table 13.9: global: CO_2 emissions

MILL t/a	2007	2015	2020	2030	2040	2050
Condensation power plants	**9,957**	**11,034**	**10,396**	**8,145**	**5,151**	**2,613**
Coal	5,854	7,086	6,970	5,435	3,438	1,831
Lignite	1,874	1,490	913	269	28	0
Gas	1,448	1,879	2,052	2,169	1,604	765
Oil	667	535	430	250	68	11
Diesel	114	43	31	21	13	7
Combined heat & power production	**1,728**	**1,735**	**1,681**	**1,689**	**1,629**	**1,532**
Coal	611	648	606	606	644	635
Lignite	228	140	87	30	0	0
Gas	717	839	939	1,040	985	898
Oil	172	108	50	13	0	0
CO_2 emissions electricity & steam generation	**11,685**	**12,769**	**12,077**	**9,834**	**6,780**	**4,146**
Coal	6,466	7,734	7,576	6,040	4,081	2,466
Lignite	2,101	1,630	1,000	299	28	0
Gas	2,165	2,718	2,991	3,209	2,589	1,663
Oil & diesel	954	687	511	285	82	17
CO_2 emissions by sector	**27,408**	**28,667**	**26,712**	**21,962**	**15,884**	**10,202**
% of 1990 emissions	131%	137%	128%	105%	76%	49%
Industry	4,726	4,969	4,718	4,078	3,077	2,017
Other sectors	3,356	3,159	2,860	2,306	1,695	1,147
Transport	5,541	5,768	5,594	5,007	4,233	3,272
Electricity & steam generation	11,180	12,186	11,471	9,171	6,089	3,423
District heating	2,603	2,586	2,069	1,400	790	343
Population (Mill.)	6,670	7,302	7,675	8,309	8,801	9,150
CO_2 emissions per capita (t/capita)	**4.1**	**3.9**	**3.5**	**2.6**	**1.8**	**1.1**

table 13.10: global: installed capacity

GW	2007	2015	2020	2030	2040	2050
Power plants	**4,033**	**5,204**	**6,010**	**7,657**	**9,038**	**10,136**
Coal	1,010	1,286	1,276	1,206	924	611
Lignite	281	238	152	45	6	0
Gas	907	1,282	1,416	1,525	1,284	604
Oil	341	316	249	139	48	10
Diesel	60	39	27	18	11	5
Nuclear	373	327	239	105	38	0
Biomass	28	48	62	75	87	107
Hydro	922	1,110	1,206	1,307	1,387	1,438
Wind	95	407	878	1,733	2,409	2,943
PV	6	98	335	1,036	1,915	2,968
Geothermal	10	19	36	71	114	144
Solar thermal power plants	0	25	105	324	647	1,002
Ocean energy	0	9	29	73	168	303
Combined heat & power production	**523**	**691**	**822**	**1,101**	**1,350**	**1,527**
Coal	114	147	154	204	265	290
Lignite	41	30	18	5	0	0
Gas	288	383	459	586	589	557
Oil	62	61	29	7	0	0
Biomass	18	67	150	261	413	545
Geothermal	0	3	13	37	83	134
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	379	441	500	657	791	829
Autoproducers	143	250	323	443	559	698
Total generation	**4,556**	**5,895**	**6,832**	**8,757**	**10,388**	**11,662**
Fossil	3,103	3,782	3,780	3,735	3,126	2,078
Coal	1,123	1,433	1,430	1,410	1,189	902
Lignite	322	268	171	50	6	0
Gas	1,195	1,665	1,875	2,111	1,873	1,161
Oil	403	377	277	146	48	10
Diesel	60	39	27	18	11	5
Nuclear	373	327	239	105	38	0
Hydrogen	0	0	0	0	0	0
Renewables	**1,080**	**1,786**	**2,813**	**4,917**	**7,224**	**9,585**
Hydro	922	1,110	1,206	1,307	1,387	1,438
Wind	95	407	878	1,733	2,409	2,943
PV	6	98	335	1,036	1,915	2,968
Biomass	46	115	212	336	500	652
Geothermal	11	23	49	108	196	279
Solar thermal	0	25	105	324	647	1,002
Ocean energy	0	9	29	73	168	303
Fluctuating RES (PV, Wind, Ocean)	101	513.6	1,242.2	2,842.4	4,492.7	6,214.6
Share of fluctuating RES	2.2%	8.7%	18.2%	32.5%	43.2%	53.3%
RES share	**23.7%**	**30.3%**	**41.2%**	**56.2%**	**69.5%**	**82.2%**

table 13.11: global: primary energy demand

PJ/A	2007	2015	2020	2030	2040	2050
Total	**490,230**	**521,823**	**524,747**	**511,483**	**482,327**	**459,519**
Fossil	**396,654**	**411,102**	**393,705**	**342,939**	**264,921**	**190,779**
Hard coal	116,959	126,176	119,448	94,152	64,031	37,563
Lignite	18,932	14,686	9,011	2,694	254	0
Natural gas	104,845	116,974	121,646	122,337	99,450	71,383
Crude oil	155,920	153,267	143,599	123,756	101,186	81,833
Nuclear	**29,664**	**26,683**	**19,818**	**8,750**	**3,174**	**0**
Renewables	**63,911**	**84,038**	**111,223**	**159,794**	**214,232**	**268,740**
Hydro	11,082	13,388	14,503	15,732	17,014	18,201
Wind	624	3,388	7,803	16,340	24,026	30,506
Solar	402	3,131	9,228	26,388	49,689	76,529
Biomass	49,816	59,821	70,335	81,533	87,392	90,922
Geothermal	1,984	4,263	9,163	19,341	34,945	50,141
Ocean Energy	2	48	190	459	1,166	2,441
RES share	**13%**	**16%**	**21%**	**31%**	**44%**	**58%**
'Efficiency' savings (compared to Ref.)	**0**	**24,644**	**58,515**	**162,699**	**251,195**	**324,757**

table 13.12: global: final energy demand

PJ/a	2007	2015	2020	2030	2040	2050
Total (incl. non-energy use)	**337,329**	**363,889**	**373,926**	**384,213**	**384,488**	**383,107**
Total (energy use)	**305,093**	**328,912**	**337,681**	**345,664**	**344,089**	**340,933**
Transport	**82,068**	**87,277**	**88,691**	**88,743**	**85,104**	**83,507**
Oil products	76,536	79,533	77,002	68,750	58,070	44,633
Natural gas	3,130	3,397	3,438	3,325	2,895	2,731
Biofuels	1,430	2,584	4,582	7,297	8,976	11,720
Electricity	973	1,745	3,360	8,750	14,137	23,051
RES electricity	171	389	1,061	4,373	9,621	19,197
Hydrogen	0	18	309	622	1,026	1,372
RES share Transport	**2.0%**	**3.4%**	**6.7%**	**13.9%**	**23.1%**	**38.7%**
Industry	**99,249**	**111,751**	**115,355**	**118,471**	**118,590**	**115,823**
Electricity	24,995	31,722	33,780	36,476	38,386	39,201
RES electricity	4,627	7,396	10,578	16,750	23,816	29,675
District heat	9,424	10,628	12,017	14,734	17,833	20,683
RES district heat	555	2,249	4,329	7,749	12,038	16,050
Coal	19,547	21,880	20,473	16,199	9,758	2,582
Oil products	13,517	12,179	10,026	6,912	3,682	1,750
Gas	23,871	25,044	25,975	25,822	23,382	18,737
Solar	5	738	1,924	4,734	8,627	12,900
Biomass and waste	7,877	9,102	9,878	11,043	11,866	12,195
Geothermal	12	457	1,280	2,553	5,056	7,773
Hydrogen	0	0	0	0	0	0
RES share Industry	**13.2%**	**17.8%**	**24.3%**	**36.2%**	**51.8%**	**67.9%**
Other Sectors	**123,776**	**129,885**	**133,636**	**138,450**	**140,396**	**141,604**
Electricity	33,253	37,881	39,972	44,361	48,276	52,208
RES electricity	5,842	9,057	13,541	22,297	32,643	42,558
District heat	6,546	7,987	9,953	12,136	14,088	15,541
RES district heat	438	1,728	3,715	6,477	9,534	11,971
Coal	4,535	3,912	3,099	2,549	2,014	1,046
Oil products	19,059	17,837	15,088	10,095	5,963	3,424
Gas	25,970	24,739	24,142	21,672	17,017	12,232
Solar	378	1,452	3,814	9,350	15,347	21,263
Biomass and waste	33,884	35,361	36,078	35,424	32,571	28,009
Geothermal	151	715	1,488	2,863	5,120	7,880
RES share Other Sectors	**32.9%**	**37.2%**	**43.9%**	**55.2%**	**67.8%**	**78.9%**
Total RES	**55,371**	**71,232**	**92,389**	**131,269**	**175,979**	**222,370**
RES share	**18.1%**	**21.7%**	**27.4%**	**38.0%**	**51.1%**	**65.2%**
Non energy use	**32,236**	**34,977**	**36,245**	**38,549**	**40,398**	**42,174**
Oil	24,832	26,267	27,026	28,444	29,620	30,754
Gas	6,084	6,901	7,289	7,951	8,400	8,817
Coal	1,320	1,808	1,930	2,154	2,378	2,602

global: advanced energy [r]evolution scenario

table 13.13: global: electricity generation

TWh/a	2007	2015	2020	2030	2040	2050
Power plants	**17,734**	**21,191**	**22,703**	**26,604**	**31,733**	**37,840**
Coal	5,781	7,149	6,575	4,359	1,628	46
Lignite	1,657	1,192	631	114	10	0
Gas	3,087	4,110	4,049	3,874	2,630	476
Oil	945	713	537	323	93	14
Diesel	65	41	27	17	10	6
Nuclear	2,719	2,446	1,816	765	291	0
Biomass	162	291	392	481	560	580
Hydro	3,078	3,728	4,059	4,416	4,804	5,108
Wind	173	1,166	2,849	5,872	8,481	10,841
PV	5	132	594	1,953	4,511	6,846
Geothermal	60	130	367	1,275	2,236	2,968
Solar thermal power plants	0	81	689	2,734	5,561	9,012
Ocean energy	1	13	119	420	918	1,943
Combined heat & power production	**2,039**	**2,597**	**3,216**	**4,298**	**5,193**	**6,082**
Coal	490	571	562	539	448	388
Lignite	166	110	69	20	0	0
Gas	1,181	1,483	1,728	2,047	1,735	1,396
Oil	105	91	49	16	0	0
Biomass	97	326	742	1,424	2,300	2,991
Geothermal	1	15	66	251	700	1,263
Hydrogen	0	0	0	1	8	44
CHP by producer						
Main activity producers	1,487	1,651	1,862	2,304	2,548	2,769
Autoproducers	552	946	1,353	1,994	2,644	3,313
Total generation	**19,773**	**23,788**	**25,919**	**30,901**	**36,926**	**43,922**
Fossil	13,477	15,460	14,227	11,309	6,556	2,326
Coal	6,271	7,720	7,138	4,898	2,076	433
Lignite	1,823	1,302	700	134	10	0
Gas	4,268	5,592	5,777	5,921	4,366	1,873
Oil	1,050	804	586	339	94	14
Diesel	65	41	27	17	10	6
Nuclear	2,719	2,446	1,816	765	291	0
Hydrogen	0	0	0	1	8	44
Renewables	**3,578**	**5,882**	**9,876**	**18,827**	**30,071**	**41,552**
Hydro	3,078	3,728	4,059	4,416	4,804	5,108
Wind	173	1,166	2,849	5,872	8,481	10,841
PV	5	132	594	1,953	4,511	6,846
Biomass	259	617	1,134	1,906	2,860	3,571
Geothermal	62	145	432	1,526	2,936	4,230
Solar thermal	0	81	689	2,734	5,561	9,012
Ocean energy	1	13	119	420	918	1,943
Distribution losses	67	1,979	2,138	2,423	2,631	2,766
Own consumption electricity	1,655	1,977	2,156	2,387	2,504	2,579
Electricity for hydrogen production	0	8	143	299	682	1,303
Final energy consumption (electricity)	**16,450**	**19,826**	**21,482**	**25,792**	**31,109**	**37,246**
Fluctuating RES (PV, Wind, Ocean)	179	1,311	3,562	8,245	13,910	19,630
Share of fluctuating RES	0.9%	5.5%	13.7%	26.7%	37.7%	44.7%
RES share	**18.1%**	**24.7%**	**38.1%**	**60.9%**	**81.4%**	**94.6%**
'Efficiency' savings (compared to Ref.)	**0**	**695**	**1,955**	**5,973**	**9,612**	**13,014**

table 13.14: global: heat supply

PJ/A	2007	2015	2020	2030	2040	2050
District heating plants	**8,852**	**8,952**	**9,273**	**10,494**	**13,834**	**15,292**
Fossil fuels	8,321	6,971	5,799	3,621	2,090	138
Biomass	525	1,433	2,033	3,100	3,856	3,830
Solar collectors	0	267	766	2,101	4,606	6,829
Geothermal	6	281	675	1,673	3,282	4,495
Heat from CHP	**8,073**	**10,807**	**14,149**	**19,023**	**23,565**	**28,248**
Fossil fuels	7,558	8,888	9,508	10,278	8,165	6,176
Biomass	502	1,794	4,090	6,600	9,360	11,159
Geothermal	13	125	551	2,142	6,012	10,772
Fuel cell (hydrogen)	0	0	0	2	29	140
Direct heating[1)]	**122,577**	**126,839**	**127,931**	**126,136**	**118,756**	**108,686**
Fossil fuels	90,140	89,235	83,058	65,987	36,696	7,611
Biomass	32,053	34,090	35,630	36,181	34,919	31,922
Solar collectors	383	2,114	5,992	16,919	30,810	44,349
Geothermal	168	1,400	3,251	7,050	16,332	24,804
Total heat supply[1)]	**139,669**	**146,597**	**151,353**	**155,654**	**156,156**	**152,226**
Fossil fuels	106,018	105,094	98,365	79,886	46,951	13,925
Biomass	33,080	37,317	41,753	45,881	48,135	46,911
Solar collectors	384	2,381	6,758	19,020	35,415	51,178
Geothermal	187	1,806	4,477	10,865	25,626	40,072
Fuel cell (hydrogen)	0	0	0	2	29	140
RES share (including RES electricity)	**24%**	**28%**	**35%**	**49%**	**70%**	**91%**
'Efficiency' savings (compared to Ref.)	**0**	**4,085**	**6,283**	**18,095**	**33,254**	**49,357**

1) heat from electricity (direct and from electric heat pumps) not included; covered in the model under 'electric appliances'

table 13.15: global: CO_2 emissions

MILL t/a	2007	2015	2020	2030	2040	2050
Condensation power plants	**9,957**	**10,790**	**9,327**	**5,688**	**2,351**	**215**
Coal	5,854	7,069	6,426	3,595	1,173	29
Lignite	1,874	1,293	645	109	9	0
Gas	1,448	1,843	1,812	1,723	1,087	170
Oil	667	539	412	240	68	10
Diesel	114	46	32	21	13	7
Combined heat & power production	**1,728**	**1,741**	**1,677**	**1,591**	**1,185**	**881**
Coal	611	645	596	457	319	256
Lignite	228	139	82	28	0	0
Gas	717	846	946	1,090	866	625
Oil	172	110	52	17	0	0
CO_2 emissions electricity & steam generation	**11,685**	**12,531**	**11,003**	**7,280**	**3,537**	**1,096**
Coal	6466	7,715	7,022	4,052	1492	285
Lignite	2101	1,432	727	137	9	0
Gas	2165	2,689	2,758	2,812	1953	795
Oil & diesel	954	696	496	278	82	17
CO_2 emissions by sector	**27,408**	**28,344**	**25,467**	**18,370**	**10,005**	**3,267**
% of 1990 emissions	131%	135%	122%	88%	48%	16%
Industry	4,726	4,980	4,666	3,970	2,350	914
Other sectors	3,356	3,169	2,868	2,093	1,155	332
Transport	5,541	5,720	5,567	4,567	3,039	1,360
Electricity & steam generation	11,180	11,944	10,388	6,619	2,925	538
District heating	2,603	2,531	1,978	1,121	537	122
Population (Mill.)	6,670	7,302	7,675	8,309	8,801	9150
CO_2 emissions per capita (t/capita)	**4.1**	**3.9**	**3.3**	**2.2**	**1.1**	**0.4**

table 13.16: global: installed capacity

GW	2007	2015	2020	2030	2040	2050
Power plants	**4,033**	**5,265**	**6,180**	**8,166**	**10,694**	**12,704**
Coal	1,010	1,282	1,178	812	325	13
Lignite	281	211	111	19	2	0
Gas	907	1,257	1,186	1,143	832	222
Oil	341	324	242	133	48	9
Diesel	60	42	28	18	11	5
Nuclear	373	327	239	100	38	0
Biomass	28	50	64	78	83	81
Hydro	922	1,111	1,212	1,316	1,406	1,451
Wind	95	494	1,140	2,241	3,054	3,754
PV	6	108	439	1,330	2,959	4,318
Geothermal	10	21	57	191	337	459
Solar thermal power plants	0	30	225	605	1,173	1,643
Ocean energy	0	9	58	180	425	748
Combined heat & power production	**523**	**696**	**826**	**1,120**	**1,236**	**1,341**
Coal	114	147	153	151	118	107
Lignite	41	30	17	5	0	0
Gas	288	390	464	644	566	451
Oil	62	61	29	8	0	0
Biomass	18	65	150	265	418	540
Geothermal	0	3	13	47	132	234
Hydrogen	0	0	0	0	2	9
CHP by producer						
Main activity producers	379	445	501	675	691	670
Autoproducers	143	251	325	445	545	670
Total generation	**4,556**	**5,961**	**7,006**	**9,286**	**11,930**	**14,045**
Fossil	3,103	3,743	3,409	2,934	1,903	807
Coal	1,123	1,429	1,330	963	444	120
Lignite	322	241	129	24	2	0
Gas	1,195	1,647	1,650	1,788	1,398	673
Oil	403	385	271	141	49	9
Diesel	60	42	28	18	11	5
Nuclear	373	327	239	100	38	0
Hydrogen	0	0	0	0	2	9
Renewables	**1,080**	**1,891**	**3,359**	**6,252**	**9,987**	**13,229**
Hydro	922	1,111	1,212	1,316	1,406	1,451
Wind	95	494	1,140	2,241	3,054	3,754
PV	6	108	439	1,330	2,959	4,318
Biomass	46	115	214	343	501	621
Geothermal	11	23	69	238	469	693
Solar thermal	0	30	225	605	1,173	1,643
Ocean energy	0	9	58	180	425	748
Fluctuating RES (PV, Wind, Ocean)	101	610.9	1,637.9	3,750.9	6,438.5	8,820.8
Share of fluctuating RES	2.2%	10.2%	23.4%	40.4%	54.0%	62.8%
RES share	**23.7%**	**31.7%**	**47.9%**	**67.3%**	**83.7%**	**94.2%**

table 13.17: global: primary energy demand

PJ/A	2007	2015	2020	2030	2040	2050
Total	**490,230**	**518,643**	**516,472**	**500,762**	**479,473**	**465,995**
Fossil	**396,654**	**406,311**	**377,610**	**298,995**	**189,806**	**93,555**
Hard coal	116,959	122,107	108,639	68,639	28,569	7,501
Lignite	18,932	12,898	6,549	1,232	83	0
Natural gas	104,845	118,449	119,675	114,122	79,547	34,285
Crude oil	155,920	152,857	142,747	115,002	81,608	51,770
Nuclear	**29,664**	**26,683**	**19,818**	**8,346**	**3,174**	**0**
Renewables	**63,911**	**85,649**	**119,044**	**193,421**	**286,493**	**372,439**
Hydro	11,082	13,421	14,611	15,898	17,294	18,389
Wind	624	4,198	10,256	21,139	30,532	39,029
Solar	402	3,146	11,376	35,893	71,675	108,367
Biomass	49,816	60,427	70,581	82,355	89,012	88,768
Geothermal	1,984	4,409	11,790	36,624	74,676	110,892
Ocean Energy	2	48	428	1,512	3,305	6,995
RES share	**13%**	**17%**	**23%**	**39%**	**60%**	**80%**
'Efficiency' savings (compared to Ref.)	**0**	**27,802**	**66,790**	**173,419**	**254,049**	**318,386**

table 13.18: global: final energy demand

PJ/A	2007	2015	2020	2030	2040	2050
Total (incl. non-energy use)	**337,329**	**363,891**	**373,940**	**381,817**	**377,670**	**368,650**
Total (energy use)	**305,093**	**328,914**	**337,695**	**343,269**	**337,271**	**326,476**
Transport	**82,068**	**87,277**	**88,691**	**86,355**	**78,012**	**69,467**
Oil products	76,536	78,901	76,682	62,767	41,671	18,448
Natural gas	3,130	3,327	3,253	2,878	2,130	1,424
Biofuels	1,430	3,258	4,832	8,062	9,000	9,723
Electricity	973	1,772	3,574	11,888	23,420	36,354
RES electricity	171	402	1,321	7,692	19,531	34,613
Hydrogen	0	18	349	760	1,791	3,517
RES share Transport	**2.0%**	**4.2%**	**7.3%**	**19.1%**	**38.9%**	**68.9%**
Industry	**99,249**	**111,743**	**115,392**	**118,515**	**118,870**	**115,865**
Electricity	24,995	31,722	33,787	36,531	38,720	39,770
RES electricity	4,627	7,624	12,038	20,944	30,606	37,202
District heat	9,424	10,602	12,343	15,256	19,596	23,718
RES district heat	555	2,203	4,533	8,804	15,123	21,468
Coal	19,547	21,901	20,036	16,274	6,329	515
Oil products	13,517	12,277	9,847	6,141	2,802	815
Gas	23,871	25,059	25,852	24,719	18,404	6,025
Solar	5	736	2,173	5,546	12,048	17,457
Biomass and waste	7,877	8,989	10,045	11,197	12,252	12,564
Geothermal	12	457	1,310	2,851	7,743	11,330
Hydrogen	0	0	0	0	976	3,670
RES share Industry	**13.2%**	**17.9%**	**26.1%**	**41.6%**	**65.4%**	**86.3%**
Other Sectors	**123,776**	**129,894**	**133,612**	**138,399**	**140,389**	**141,145**
Electricity	33,253	37,880	39,972	44,424	48,406	52,551
RES electricity	5,842	9,635	16,114	27,991	39,913	50,000
District heat	6,546	7,968	9,769	12,740	16,136	18,145
RES district heat	438	1,697	3,606	7,158	12,504	16,629
Coal	4,535	3,979	3,142	2,658	978	23
Oil products	19,059	17,863	14,972	8,687	4,329	1,090
Gas	25,970	24,758	24,344	19,529	11,441	2,865
Solar	378	1,377	3,819	11,373	18,762	26,992
Biomass and waste	33,884	35,344	36,085	35,758	33,587	28,815
Geothermal	151	724	1,510	3,230	6,750	10,665
RES share Other Sectors	**32.9%**	**37.6%**	**45.8%**	**61.8%**	**79.4%**	**94.3%**
Total RES	**55,371**	**72,452**	**97,563**	**151,147**	**220,158**	**284,295**
RES share	**18.1%**	**22.0%**	**28.9%**	**44.0%**	**65.3%**	**87.1%**
Non energy use	**32,236**	**34,977**	**36,245**	**38,549**	**40,398**	**42,174**
Oil	24,832	26,267	27,026	28,444	29,627	30,761
Gas	6,084	6,901	7,289	7,951	8,400	8,817
Coal	1,320	1,808	1,930	2,154	2,371	2,595

global: total new investment by technology

table 13.19: global: total investment

MILLION $	2005-2010	2011-2020	2021-2030	2007-2030	2007-2030 AVERAGE PER YEAR
Reference scenario					
Conventional (fossil & nuclear)	**1,630,048**	**2,299,220**	**2,264,783**	**6,194,051**	**269,307**
Renewables (incl CHP)	**974,091**	**2,218,338**	**1,895,874**	**5,088,303**	**221,231**
Biomass	101,854	173,571	209,662	485,088	21,091
Hydro	549,927	1,095,820	956,401	2,602,148	113,137
Wind	177,442	422,529	322,490	922,460	40,107
PV	68,355	325,665	204,970	598,990	26,043
Geothermal	62,612	106,764	97,500	266,875	11,603
Solar thermal power plants	12,157	90,209	97,568	199,934	8,693
Ocean energy	1,743	3,781	7,284	12,808	557
Energy [R]evolution					
Conventional (fossil & nuclear)	**1,618,667**	**1,741,083**	**1,115,721**	**4,475,471**	**194,586**
Renewables (incl CHP)	**974,091**	**4,544,951**	**4,834,880**	**10,353,922**	**450,171**
Biomass	101,854	659,270	475,643	1,236,767	53,772
Hydro	549,927	1,186,011	736,767	2,472,705	107,509
Wind	177,442	902,767	1,006,011	2,086,220	90,705
PV	68,355	727,360	977,746	1,773,461	77,107
Geothermal	62,612	410,044	517,337	989,993	43,043
Solar thermal power plants	12,157	555,252	1,011,876	1,579,285	68,665
Ocean energy	1,743	104,246	109,500	215,489	9,369
Advanced Energy [R]evolution					
Conventional (fossil & nuclear)	**1,618,693**	**1,493,043**	**821,582**	**3,933,318**	**171,014**
Renewables (incl CHP)	**974,091**	**5,898,028**	**7,181,789**	**14,053,909**	**611,040**
Biomass	101,854	662,986	491,273	1,256,113	54,614
Hydro	549,927	1,057,927	747,056	2,354,909	102,387
Wind	177,442	1,219,748	1,259,782	2,656,973	115,521
PV	68,355	954,146	1,237,544	2,260,046	98,263
Geothermal	62,612	613,990	1,385,343	2,061,945	89,650
Solar thermal power plants	12,157	1,190,914	1,762,248	2,965,319	128,927
Ocean energy	1,743	198,317	298,543	498,604	21,678

notes

oecd north america: reference scenario

table 13.20: oecd north america: electricity generation

TWh/a	2007	2015	2020	2030	2040	2050
Power plants	**4,879**	**5,144**	**5,415**	**6,033**	**6,659**	**7,283**
Coal	1,168	1,355	1,542	1,916	2,259	2,558
Lignite	1,038	836	720	549	399	280
Gas	859	910	959	1,070	1,192	1,313
Oil	111	55	41	24	9	5
Diesel	11	10	8	7	6	6
Nuclear	941	981	1,010	1,093	1,176	1,259
Biomass	43	76	91	138	192	245
Hydro	645	677	686	704	722	740
Wind	38	193	281	392	503	614
PV	1	9	20	44	66	88
Geothermal	24	37	45	59	73	87
Solar thermal power plants	0	5	13	35	61	85
Ocean energy	0	0	0	1	2	3
Combined heat & power production	**342**	**370**	**396**	**479**	**554**	**634**
Coal	56	60	65	84	108	137
Lignite	1	2	2	0	0	0
Gas	227	232	241	283	314	346
Oil	19	19	18	18	16	12
Biomass	39	56	68	91	110	130
Geothermal	0	1	2	4	5	9
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	194	209	217	267	299	329
Autoproducers	148	161	179	212	256	305
Total generation	**5,221**	**5,514**	**5,810**	**6,512**	**7,214**	**7,917**
Fossil	3,489	3,479	3,595	3,951	4,304	4,657
Coal	1,224	1,414	1,606	2,000	2,368	2,695
Lignite	1,039	838	721	549	399	280
Gas	1,086	1,143	1,200	1,353	1,506	1,659
Oil	129	74	59	42	25	17
Diesel	11	10	8	7	6	6
Nuclear	941	981	1,010	1,093	1,176	1,259
Hydrogen	0	0	0	0	0	0
Renewables	**791**	**1,054**	**1,205**	**1,468**	**1,733**	**2,001**
Hydro	645	677	686	704	722	740
Wind	38	193	281	392	503	614
PV	1	9	20	44	66	88
Biomass	83	132	159	229	302	375
Geothermal	24	38	47	63	78	96
Solar thermal	0	5	13	35	61	85
Ocean energy	0	0	0	1	2	3
Distribution losses	363	388	412	444	476	508
Own consumption electricity	332	356	378	405	431	457
Electricity for hydrogen production	0	0	0	0	0	0
Final energy consumption (electricity)	**4,530**	**4,778**	**5,032**	**5,685**	**6,338**	**6,993**
Fluctuating RES (PV, Wind, Ocean)	39	202	301	437	571	705
Share of fluctuating RES	0.7%	3.7%	5.2%	6.7%	7.9%	8.9%
RES share	**15.2%**	**19.1%**	**20.7%**	**22.5%**	**24.0%**	**25.3%**

table 13.21: oecd north america: heat supply

PJ/A	2007	2015	2020	2030	2040	2050
District heating plants	**2**	**31**	**47**	**68**	**127**	**188**
Fossil fuels	0	29	44	66	123	183
Biomass	2	2	3	2	3	4
Solar collectors	0	0	0	0	0	0
Geothermal	0	0	0	0	0	0
Heat from CHP	**866**	**881**	**918**	**1,045**	**1,152**	**1,292**
Fossil fuels	686	673	672	725	780	851
Biomass	180	203	240	308	354	402
Geothermal	0	4	7	12	18	40
Fuel cell (hydrogen)	0	0	0	0	0	0
Direct heating[1]	**21,331**	**20,575**	**20,816**	**21,723**	**22,620**	**23,538**
Fossil fuels	18,855	17,575	17,521	17,713	17,923	18,092
Biomass	2372	2,806	2,947	3,365	3,781	4,237
Solar collectors	61	70	140	386	551	720
Geothermal	44	124	208	260	365	490
Total heat supply[1]	**22,198**	**21,487**	**21,781**	**22,836**	**23,899**	**25,018**
Fossil fuels	19,540	18,278	18,237	18,503	18,826	19,125
Biomass	2,554	3,011	3,189	3,675	4,138	4,643
Solar collectors	61	70	140	386	551	720
Geothermal	44	128	215	271	383	530
Fuel cell ((hydrogen)	0	0	0	0	0	0
RES share (including RES electricity)	**12.0%**	**14.9%**	**16.3%**	**19.0%**	**21.2%**	**23.6%**

1) heat from electricity (direct and from electric heat pumps) not included; covered in the model under 'electric appliances'

table 13.22: oecd north america: CO_2 emissions

MILL t/a	2007	2015	2020	2030	2040	2050
Condensation power plants	**2,746**	**2,639**	**2,637**	**2,801**	**2,865**	**2,940**
Coal	1,092	1,266	1,432	1,750	1,975	2,145
Lignite	1,182	936	759	575	383	249
Gas	379	391	412	453	496	538
Oil	85	40	29	17	6	4
Diesel	8.3	7.3	6.5	5.8	4.9	5.0
Combined heat & power production	**164**	**159**	**154**	**161**	**173**	**189**
Coal	51	49	47	51	56	67
Lignite	2	2	1	0	0	0
Gas	100	96	94	98	106	114
Oil	11	12	11	11	10	8
CO_2 emissions electricity & steam generation	**2,911**	**2,798**	**2,791**	**2,961**	**3,038**	**3,129**
Coal	1,142	1,316	1,479	1,802	2,032	2,211
Lignite	1,184	937	760	575	383	249
Gas	479	487	506	551	602	652
Oil & diesel	104	59	47	33	21	17
CO_2 emissions by sector	**6,686**	**6,469**	**6,469**	**6,637**	**6,715**	**6,822**
% of 1990 emissions	120%	116%	116%	119%	121%	122%
Industry	611	574	557	529	505	484
Other sectors	752	680	689	712	736	761
Transport	2,134	2,067	2,073	2,101	2,128	2,155
Electricity & steam generation	2,870	2,754	2,743	2,906	2,970	3,046
District heating	319	394	406	390	375	377
Population (Mill.)	449	483	503	537	561	577
CO_2 emissions per capita (t/capita)	**14.9**	**13.4**	**12.9**	**12.4**	**12.0**	**11.8**

table 13.23: oecd north america: installed capacity

GW	2007	2015	2020	2030	2040	2050
Power plants	**1,121**	**1,176**	**1,234**	**1,353**	**1,499**	**1,648**
Coal	183	213	245	294	346	392
Lignite	162	131	114	84	61	42
Gas	362	370	382	409	444	479
Oil	66	37	20	11	6	5
Diesel	21	18	16	13	11	11
Nuclear	115	120	123	133	143	153
Biomass	7	11	13	20	27	34
Hydro	183	186	188	192	197	201
Wind	19	75	106	141	181	221
PV	1	8	17	37	56	74
Geothermal	4	5	7	8	10	12
Solar thermal power plants	0	2	4	11	17	21
Ocean energy	0	0	0	1	2	3
Combined heat & power production	**106**	**119**	**121**	**141**	**145**	**160**
Coal	10	11	12	15	19	25
Lignite	0	0	0	0	0	0
Gas	79	88	89	104	99	104
Oil	10	10	7	6	6	6
Biomass	7	10	12	16	20	23
Geothermal	0	0	0	1	1	1
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	69	75	72	84	90	98
Autoproducers	37	44	49	58	55	62
Total generation	**1,227**	**1,295**	**1,355**	**1,494**	**1,645**	**1,808**
Fossil	892	879	886	935	992	1,064
Coal	193	224	257	308	365	416
Lignite	162	131	115	83	60	42
Gas	441	458	471	512	543	583
Oil	75	48	27	17	12	11
Diesel	21	18	16	13	11	11
Nuclear	115	120	123.1	133.1	143	153
Hydrogen	0	0	0	0	0	0
Renewables	**221**	**297**	**346**	**426**	**509**	**591**
Hydro	183	186	188	192	197	201
Wind	19	75	106	141	181	220
PV	1	8	16	37	56	74
Biomass	14	20.4	25	36	47	58
Geothermal	4	6	7	9	11	13
Solar thermal	0	2	4	11	17	21
Ocean energy	0	0	0	1	2	3
Fluctuating RES (PV, Wind, Ocean)	20	83	123	179	239	298
Share of fluctuating RES	1.6%	6.4%	9.0%	12.0%	14.5%	16.5%
RES share	**18.0%**	**22.9%**	**25.6%**	**28.5%**	**31.0%**	**32.7%**

table 13.24: oecd north america: primary energy demand

PJ/A	2007	2015	2020	2030	2040	2050
Total	**115,758**	**114,511**	**116,903**	**122,485**	**125,327**	**129,374**
Fossil	**97,824**	**93,807**	**94,083**	**96,257**	**95,930**	**96,751**
Hard coal	14,252	16,046	17,647	20,864	23,209	25,015
Lignite	10,671	8,444	6,849	5,184	3,450	2,240
Natural gas	27,435	27,073	27,407	28,565	28,322	29,144
Crude oil	45,466	42,245	42,179	41,643	40,949	40,352
Nuclear	**10,260**	**10,702**	**11,018**	**11,924**	**12,829**	**13,735**
Renewables	**7,674**	**10,002**	**11,801**	**14,304**	**16,567**	**18,889**
Hydro	2,323	2,437	2,470	2,534	2,599	2,664
Wind	136	695	1,012	1,411	1,811	2,210
Solar	64	121	255	671	1,004	1,343
Biomass	4,647	6,187	7,346	8,759	9,943	11,115
Geothermal	502	562	720	925	1,202	1,545
Ocean Energy	0	0	0	4	7	11
RES share	**6.6%**	**8.7%**	**10.1%**	**11.7%**	**13.2%**	**14.5%**

table 13.25: oecd north america: final energy demand

PJ/a	2007	2015	2020	2030	2040	2050
Total (incl. non-energy use)	**80,323**	**78,829**	**80,602**	**84,380**	**88,178**	**92,001**
Total (energy use)	**72,347**	**71,712**	**73,484**	**77,346**	**81,228**	**85,134**
Transport	**31,163**	**30,857**	**31,485**	**32,113**	**32,741**	**33,369**
Oil products	29,612	28,679	28,762	29,141	29,516	29,890
Natural gas	856	912	913	949	989	1,029
Biofuels	646	1,213	1,757	1,966	2,175	2,386
Electricity	48	53	53	57	61	64
RES electricity	7	10	11	13	15	16
Hydrogen	0	0	0	0	0	0
RES share Transport	**2.1%**	**4.0%**	**5.6%**	**6.2%**	**6.7%**	**7.2%**
Industry	**16,149**	**16,054**	**16,022**	**16,190**	**16,373**	**16,581**
Electricity	4,488	4,615	4,653	4,791	4,920	5,057
RES electricity	680	882	965	1,080	1,182	1,278
District heat	708	731	783	912	1,056	1,229
RES district heat	60	82	116	180	212	249
Coal	1,225	1,141	962	716	512	317
Oil products	1,763	1,469	1,421	1,337	1,231	1,117
Gas	6,142	5,793	5,750	5,635	5,518	5,346
Solar	0	9	31	73	109	136
Biomass and waste	1,818	2,274	2,363	2,627	2,905	3,212
Geothermal	5	22	60	99	122	167
Hydrogen	0	0	0	0	0	0
RES share Industry	**15.9%**	**20.4%**	**22.1%**	**25.1%**	**27.7%**	**30.4%**
Other Sectors	**25,035**	**24,800**	**25,978**	**29,043**	**32,114**	**35,184**
Electricity	11,773	12,532	13,409	15,619	17,837	20,055
RES electricity	1,784	2,396	2,781	3,521	4,286	5,068
District heat	93	80	75	77	82	88
RES district heat	8	9	11	15	16	18
Coal	75	57	63	32	37	37
Oil products	3,399	2,687	2,659	2,569	2,471	2,374
Gas	8,729	8,432	8,609	9,175	9,720	10,264
Solar	61	61	108	313	441	584
Biomass and waste	866	873	942	1,139	1,329	1,516
Geothermal	39	79	112	119	198	267
RES share Other Sectors	**11.0%**	**13.8%**	**15.2%**	**17.6%**	**19.5%**	**21.2%**
Total RES	**5,973**	**7,910**	**9,257**	**11,145**	**12,990**	**14,896**
RES share	**8.3%**	**11.0%**	**12.6%**	**14.4%**	**16.0%**	**17.5%**
Non energy use	**7,976**	**7,118**	**7,118**	**7,034**	**6,950**	**6,866**
Oil	7,091	6,311	6,303	6,223	6,143	6,063
Gas	868	790	797	793	789	785
Coal	17	16	17	18	18	19

oecd north america: energy [r]evolution scenario

table 13.26: oecd north america: electricity generation

TWh/a	2007	2015	2020	2030	2040	2050
Power plants	**4,879**	**4,950**	**5,071**	**5,787**	**5,947**	**5,549**
Coal	1,168	877	568	445	91	0
Lignite	1,038	804	499	96	0	0
Gas	859	1,314	1,598	1,629	1,053	92
Oil	111	48	22	11	3	0
Diesel	11	7	4	2	1	0
Nuclear	941	680	410	53	7	0
Biomass	43	61	71	68	56	64
Hydro	645	747	797	831	866	899
Wind	38	276	629	1,220	1,526	1,646
PV	1	31	142	469	761	957
Geothermal	24	62	138	341	538	632
Solar thermal power plants	0	36	173	569	937	1,104
Ocean energy	0	8	19	52	108	156
Combined heat & power production	**342**	**519**	**696**	**853**	**970**	**1,056**
Coal	56	72	59	30	15	0
Lignite	1	1	0	0	0	0
Gas	227	317	422	441	321	264
Oil	19	22	16	0	0	0
Biomass	39	105	185	348	577	708
Geothermal	0	2	14	34	58	84
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	194	235	277	320	353	386
Autoproducers	148	284	419	533	617	670
Total generation	**5,221**	**5,469**	**5,767**	**6,639**	**6,917**	**6,605**
Fossil	3,489	3,462	3,188	2,654	1,483	356
Coal	1,224	949	628	475	105	0
Lignite	1,039	805	499	96	0	0
Gas	1,086	1,631	2,020	2,070	1,374	356
Oil	129	70	38	11	3	0
Diesel	11	7	4	2	1	0
Nuclear	941	680	410	53	7	0
Hydrogen	0	0	0	0	0	0
Renewables	791	1,327	2,168	3,933	5,427	6,249
Hydro	645	747	797	831	866	899
Wind	38	276	629	1,220	1,526	1,646
PV	1	31	142	469	761	957
Biomass	83	166	256	416	633	772
Geothermal	24	64	152	376	596	716
Solar thermal	0	36	173	569	937	1,104
Ocean energy	0	8	19	52	108	156
Distribution losses	363	391	403	420	423	406
Own consumption electricity	332	347	383	421	449	445
Electricity for hydrogen production	0	5	78	140	188	182
Final energy consumption (electricity)	**4,530**	**4,732**	**4,909**	**5,666**	**5,863**	**5,578**
Fluctuating RES (PV, Wind, Ocean)	39	315	790	1,741	2,395	2,759
Share of fluctuating RES	0.7%	5.8%	13.7%	26.2%	34.6%	41.8%
RES share	**15.2%**	**24.3%**	**37.6%**	**59.2%**	**78.5%**	**94.6%**
'Efficiency' savings (compared to Ref.)	**0**	**75**	**335**	**980**	**1,777**	**2,847**

table 13.27: oecd north america: heat supply

PJ/A	2007	2015	2020	2030	2040	2050
District heating plants	**2**	**402**	**1,001**	**2,055**	**2,854**	**2,838**
Fossil fuels	0	0	0	0	0	0
Biomass	2	219	486	903	1,094	943
Solar collectors	0	95	281	670	1,076	1,211
Geothermal	0	88	234	482	684	683
Heat from CHP	**866**	**1,220**	**1,727**	**2,386**	**3,061**	**3,479**
Fossil fuels	686	836	995	997	749	626
Biomass	180	376	643	1,165	1,925	2,337
Geothermal	0	8	88	223	387	517
Fuel cell (hydrogen)	0	0	0	0	0	0
Direct heating[1)]	**21,331**	**19,782**	**18,700**	**16,900**	**14,968**	**13,330**
Fossil fuels	18,855	16,378	14,350	10,433	6,803	4,635
Biomass	2372	2,731	2,931	2,887	2,876	2,597
Solar collectors	61	502	912	2,544	3,525	4,019
Geothermal	44	170	507	1,035	1,764	2,079
Total heat supply[1)]	**22,198**	**21,403**	**21,427**	**21,341**	**20,883**	**19,646**
Fossil fuels	19,540	17,214	15,345	11,431	7,552	5,260
Biomass	2,554	3,326	4,061	4,955	5,894	5,877
Solar collectors	61	597	1,192	3,214	4,601	5,230
Geothermal	44	266	829	1,741	2,835	3,279
Fuel cell (hydrogen)	0	0	0	0	0	0
RES share (including RES electricity)	**12.0%**	**20%**	**28%**	**46%**	**64%**	**73%**
'Efficiency' savings (compared to Ref.)	**0**	**84**	**353**	**1,495**	**3,016**	**5,372**

1) heat from electricity (direct and from electric heat pumps) not included; covered in the model under 'electric appliances'

table 13.28: oecd north america: CO_2 emissions

MILL t/a	2007	2015	2020	2030	2040	2050
Condensation power plants	**2,746**	**2,324**	**1,759**	**1,206**	**519**	**38**
Coal	1,092	820	527	406	79	0
Lignite	1,182	901.0	527.6	100.5	0.0	0.0
Gas	379	564	686	690	437	38
Oil	85	34.6	15.6	7.4	2.1	0.0
Diesel	8.3	5.3	3.2	1.6	0.8	0.0
Combined heat & power production	**164**	**196**	**213**	**199**	**143**	**110**
Coal	51	56	43	19	8	0
Lignite	2	1	0	0	0	0
Gas	100	127	162	180	136	110
Oil	11	12	9	0	0	0
CO_2 emissions electricity & steam generation	**2,911**	**2,520**	**1,973**	**1,405**	**662**	**148**
Coal	1,142	876	570	425	87	0
Lignite	1,184	902	528	100	0	0
Gas	479	691	847	870	573	148
Oil & diesel	104	51	28	9	3	0
CO_2 emissions by sector	**6,686**	**6,094**	**5,223**	**3,655**	**2,024**	**942**
% of 1990 emissions	120%	109%	94%	66%	36%	17%
Industry	611	570	501	382	249	170
Other sectors	752	624	566	410	283	219
Transport	2134	2,056	1,876	1,337	813	431
Electricity & steam generation	2,870	2,444	1,872	1,284	562	62
District heating	319	398	408	243	116	61
Population (Mill.)	449	483	503	537	561	577
CO_2 emissions per capita (t/capita)	**14.9**	**12.6**	**10.4**	**6.8**	**3.6**	**1.6**

table 13.29: oecd north america: installed capacity

GW	2007	2015	2020	2030	2040	2050
Power plants	**1,121**	**1,328**	**1,605**	**2,154**	**2,406**	**2,225**
Coal	183	138	91	69	17	0
Lignite	161	126	80	15	0	0
Gas	362	549	668	683	471	26
Oil	66	33	13	7	3	0
Diesel	21	15	9	5	2	0
Nuclear	115	83	50	6	1	0
Biomass	7	9	10	10	8	9
Hydro	183	211	227	237	248	255
Wind	19	109	241	448	561	605
PV	1	27	120	402	653	821
Geothermal	4	9	20	46	72	85
Solar thermal power plants	0	12	57	173	263	270
Ocean energy	0	8	19	52	108	156
Combined heat & power production	**106**	**157**	**196**	**217**	**199**	**205**
Coal	10	13	11	5	2	0
Lignite	0	0	0	0	0	0
Gas	79	114	144	142	82	63
Oil	10	10	5	0	0	0
Biomass	7	19	34	64	105	127
Geothermal	0	0	2	6	10	14
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	69	81	87	87	74	72
Autoproducers	37	76	109	130	125	132
Total generation	**1,227**	**1,485**	**1,801**	**2,370**	**2,606**	**2,430**
Fossil	892	998	1021	926	578	89
Coal	193	151	102	74	20	0
Lignite	162	126	79	15	0	0
Gas	441	663	812	825	553	89
Oil	75	43	19	7	3	0
Diesel	21	15	9	5	2	0
Nuclear	115	83	49.7	6	0.8	0.0
Hydrogen	0	0	0	0	0	0
Renewables	**221**	**404**	**731**	**1,438**	**2,027**	**2,341**
Hydro	183	211	227	237	248	255
Wind	19	109	240	448	561	605
PV	1	27	120	402	653	821
Biomass	13.7	27	44	74	113	136
Geothermal	4	9	23	52	82	99
Solar thermal	0	13	57	173	263	270
Ocean energy	0	8	19	52	108	156
Fluctuating RES (PV, Wind, Ocean)	20	143	380	903	1,321	1,582
Share of fluctuating RES	1.6%	9.6%	21.1%	38.1%	50.7%	65.1%
RES share	**18.0%**	**27.2%**	**40.6%**	**60.7%**	**77.8%**	**96.4%**

table 13.30: oecd north america: primary energy demand

PJ/A	2007	2015	2020	2030	2040	2050
Total	**115,758**	**109,961**	**105,546**	**96,462**	**82,847**	**70,197**
Fossil	**97,824**	**91,005**	**81,757**	**62,949**	**38,915**	**21,814**
Hard coal	14,252	10,953	7,276	4,997	1,178	180
Lignite	10,671	8,125	4,753	905	0	0
Natural gas	27,435	30,432	32,130	29,523	19,094	8,937
Crude oil	45,466	41,495	37,598	27,523	18,644	12,698
Nuclear	**10,260**	**7,418**	**4,473**	**578**	**76**	**0**
Renewables	**7,674**	**11,537**	**19,317**	**32,935**	**43,855**	**48,383**
Hydro	2,323	2,689	2,869	2,992	3,118	3,235
Wind	136	994	2,264	4,392	5,494	5,926
Solar	64	838	2,326	6,951	10,714	12,649
Biomass	4,647	5,997	9,179	12,403	14,605	14,739
Geothermal	502	992	2,610	6,010	9,536	11,272
Ocean Energy	0	27	68	187	389	562
RES share	**6.6%**	**10.5%**	**18.3%**	**34.2%**	**52.9%**	**68.9%**
'Efficiency' savings (compared to Ref.)	**0**	**4,609**	**11,464**	**26,233**	**42,790**	**59,585**

table 13.31: oecd north america: final energy demand

PJ/a	2007	2015	2020	2030	2040	2050
Total (incl. non-energy use)	**80,323**	**77,924**	**77,264**	**72,915**	**66,087**	**58,260**
Total (energy use)	**72,347**	**70,806**	**70,147**	**65,881**	**59,137**	**51,393**
Transport	**31,163**	**30,336**	**29,993**	**26,558**	**21,335**	**16,564**
Oil products	29,612	28,513	25,999	18,495	11,226	5,912
Natural gas	856	872	859	859	850	836
Biofuels	646	781	2,127	3,336	4,017	4,106
Electricity	48	159	817	3,517	4,748	5,218
RES electricity	7	38	307	2,083	3,725	4,937
Hydrogen	0	12	192	352	494	493
RES share Transport	**2.1%**	**2.7%**	**8.4%**	**21.2%**	**38.1%**	**57.4%**
Industry	**16,149**	**15,895**	**15,120**	**14,379**	**13,561**	**12,225**
Electricity	4,488	4,546	4,293	3,947	3,621	3,215
RES electricity	680	1,103	1,614	2,338	2,841	3,042
District heat	708	925	1,302	2,047	2,708	2,901
RES district heat	60	445	890	1,758	2,558	2,812
Coal	1,225	1,020	704	95	0	0
Oil products	1,763	1,388	1,029	503	144	100
Gas	6,142	5,713	5,229	4,638	3,402	2,317
Solar	0	279	445	943	1,207	1,274
Biomass and waste	1,818	1,993	1,898	1,807	1,772	1,584
Geothermal	5	30	221	399	707	834
Hydrogen	0	0	0	0	0	0
RES share Industry	**15.9%**	**24.2%**	**33.5%**	**50.4%**	**67.0%**	**78.1%**
Other Sectors	**25,035**	**24,575**	**25,033**	**24,944**	**24,240**	**22,605**
Electricity	11,773	12,330	12,560	12,933	12,739	11,647
RES electricity	1,784	2,992	4,723	7,660	9,994	11,020
District heat	93	588	1,247	2,110	2,835	3,041
RES district heat	8	283	852	1,812	2,678	2,947
Coal	75	0	0	0	0	0
Oil products	3,399	2,330	1,799	1,038	631	491
Gas	8,729	7,903	7,311	5,328	3,466	2,411
Solar	61	223	467	1,601	2,318	2,745
Biomass and waste	866	1,098	1,443	1,471	1,493	1,347
Geothermal	39	104	207	463	758	923
RES share Other Sectors	**11.0%**	**19.1%**	**30.7%**	**52.1%**	**71.1%**	**84.0%**
Total RES	**5,973**	**9,372**	**15,265**	**25,880**	**34,455**	**38,037**
RES share	**8.3%**	**13.2%**	**21.8%**	**39.3%**	**58.3%**	**74.0%**
Non energy use	**7,976**	**7,118**	**7,118**	**7,034**	**6,950**	**6,866**
Oil	7,091	6,311	6,303	6,223	6,143	6,063
Gas	868	790	797	793	789	785
Coal	17	16	17	18	18	19

oecd north america: advanced energy [r]evolution scenario

table 13.32: oecd north america: electricity generation

TWh/a	2007	2015	2020	2030	2040	2050
Power plants	**4,879**	**4,949**	**5,071**	**5,992**	**7,063**	**6,865**
Coal	1,168	760	523	132	33	0
Lignite	1,038	697	341	20	0	0
Gas	859	1,282	1,064	876	402	8
Oil	111	54	20	7	4	0
Diesel	11	11	6	2	1	0
Nuclear	941	680	410	53	7	0
Biomass	43	68	100	109	89	1
Hydro	645	756	827	877	939	946
Wind	38	488	1,053	1,756	2,040	2,168
PV	1	42	179	561	1,077	1,158
Geothermal	24	63	195	539	825	789
Solar thermal power plants	0	41	322	976	1,411	1,511
Ocean energy	0	8	32	85	235	284
Combined heat & power production	**342**	**519**	**697**	**854**	**972**	**1,060**
Coal	56	55	41	21	5	0
Lignite	1	0	0	0	0	0
Gas	227	348	438	441	293	140
Oil	19	22	16	4	0	0
Biomass	39	92	187	348	554	682
Geothermal	0	2	15	39	114	217
Hydrogen	0	0	0	0	6	21
CHP by producer						
Main activity producers	194	235	277	319	351	384
Autoproducers	148	284	420	535	621	676
Total generation	**5,221**	**5,468**	**5,768**	**6,845**	**8,035**	**7,925**
Fossil	3,489	3,229	2,448	1,501	738	149
Coal	1,224	815	564	152	38	0
Lignite	1,039	697	341	20	0	0
Gas	1,086	1,630	1,502	1,317	695	148
Oil	129	76	36	10	4	0
Diesel	11	11	6	2	1	0
Nuclear	941	680	410	53	7	0
Hydrogen	0	0	0	0	6	21
Renewables	**791**	**1,560**	**2,909**	**5,291**	**7,284**	**7,756**
Hydro	645	756	827	877	939	946
Wind	38	488	1,053	1,756	2,040	2,168
PV	1	42	179	561	1,077	1,158
Biomass	83	160	287	458	643	683
Geothermal	24	65	209	578	939	1,006
Solar thermal	0	41	322	976	1,,411	1,511
Ocean energy	0	8	32	85	235	284
Distribution losses	363	391	403	420	423	406
Own consumption electricity	332	347	383	421	449	445
Electricity for hydrogen production	0	5	78	139	257	336
Final energy consumption (electricity)	**4,530**	**4,731**	**4,909**	**5,873**	**6,911**	**6,744**
Fluctuating RES (PV, Wind, Ocean)	39	538	1,264	2,402	3,352	3,610
Share of fluctuating RES	0.7%	9.8%	21.9%	35.1%	41.7%	45.5%
RES share	**15.2%**	**28.5%**	**50.4%**	**77.3%**	**90.7%**	**97.9%**
'Efficiency' savings (compared to Ref.)	**0**	**76**	**335**	**976**	**1,753**	**2,827**

table 13.33: oecd north america: heat supply

PJ/A	2007	2015	2020	2030	2040	2050
District heating plants	**6**	**367**	**919**	**2,573**	**3,753**	**3,791**
Fossil fuels	0	0	0	0	0	0
Biomass	6	190	421	1,048	1,245	1,049
Solar collectors	0	92	275	857	1,497	1,708
Geothermal	0	85	225	668	1,011	1,035
Heat from CHP	**861**	**1,211**	**1,756**	**2,428**	**3,288**	**3,991**
Fossil fuels	681	874	1,005	992	673	288
Biomass	180	329	658	1,190	1,842	2,252
Geothermal	0	8	94	245	753	1,387
Fuel cell (hydrogen)	0	0	0	1	19	64
Direct heating[1]	**21,331**	**19,818**	**18,748**	**16,336**	**13,664**	**11,606**
Fossil fuels	18,855	16,599	14,289	9,418	3,915	355
Biomass	2,372	2,615	2,891	2,949	2,617	2,265
Solar collectors	61	426	1,023	2,882	4,831	6,266
Geothermal	44	178	544	1,087	2,301	2,719
Total heat supply[1]	**22,198**	**21,396**	**21,423**	**21,338**	**20,883**	**19,646**
Fossil fuels	19,536	17,472	15,294	10,410	4,589	644
Biomass	2,558	3,134	3,968	5,186	5,704	5,566
Solar collectors	61	518	1,298	3,739	6,328	7,974
Geothermal	44	178	544	1,087	2,301	2,719
Fuel cell (hydrogen)	0	0	0	1	198	321
RES share (including RES electricity)	**12.0%**	**18.3%**	**28.6%**	**51.2%**	**77.9%**	**96.7%**
'Efficiency' savings (compared to Ref.)	**0**	**91**	**358**	**1,498**	**3,016**	**5,372**

1) heat from electricity (direct and from electric heat pumps) not included; covered in the model under 'electric appliances'

table 13.34: oecd north america: CO_2 emissions

MILL t/a	2007	2015	2020	2030	2040	2050
Condensation power plants	**2,746**	**2,098**	**1,320**	**516**	**198**	**4**
Coal	1,092	711	485	119	28	0
Lignite	1,182	781	360	21	0	0
Gas	379	550	456	371	167	4
Oil	85	38	14	5	3	0
Diesel	8	8	5	2	1	0
Combined heat & power production	**164**	**195**	**207**	**194**	**124**	**51**
Coal	51	42	28	13	3	0
Lignite	2	0	0	0	0	0
Gas	100	140	169	179	121	51
Oil	11	14	10	3	0	0
CO_2 emissions electricity & steam generation	**2,910**	**2,284**	**1,527**	**711**	**322**	**55**
Coal	1,142	753	513	132	31	0
Lignite	1,184	781	360	21	0	0
Gas	479	690	627	549	288	55
Oil & diesel	104	60	28	9	4	0
CO_2 emissions by sector	**6,685**	**5,825**	**4,734**	**2,723**	**1,143**	**215**
% of 1990 emissions	120%	105%	185%	49%	21%	4%
Industry	611	578	479	342	150	39
Other sectors	752	635	587	395	191	52
Transport	2,134	2,010	1,878	1,240	507	88
Electricity & steam generation	2,869	2,207	1,425	586	241	14
District heating	318	395	364	160	54	22
Population (Mill.)	449	483	503	537	561	577
CO_2 emissions per capita (t/capita)	**14.9**	**12.1**	**9.4**	**5.1**	**2.0**	**0.4**

table 13.35: oecd north america: installed capacity

GW	2007	2015	2020	2030	2040	2050
Power plants	**1,121**	**1,392**	**1,621**	**2,239**	**2,867**	**2,797**
Coal	183	120	83	21	5	0
Lignite	162	109	54	3	0	0
Gas	362	534	433	355	172	2
Oil	66	40	15	6	4	0
Diesel	21	18	11	5	2	0
Nuclear	115	83	50	6	1	0
Biomass	7	10	14	16	13	0
Hydro	183	213	234	247	265	267
Wind	19	191	401	642	747	797
PV	1	37	151	478	920	980
Geothermal	4	9	29	72	110	106
Solar thermal power plants	0	15	106	295	392	361
Ocean energy	0	8	32	85	235	284
Combined heat & power production	**106**	**160**	**196**	**214**	**202**	**194**
Coal	10	10	8	4	1	0
Lignite	0	0	0	0	0	0
Gas	79	126	150	142	79	30
Oil	10	11	6	1	0	0
Biomass	7	17	34	63	101	123
Geothermal	0	0	3	7	20	37
Hydrogen	0	0	0	0	1	4
CHP by producer						
Main activity producers	69	83	89	87	77	61
Autoproducers	37	76	107	126	125	133
Total generation	**1,227**	**1,552**	**1,817**	**2,453**	**3,069**	**2,991**
Fossil	892	970	764	541	264	32
Coal	193	130	91	25	6	0
Lignite	162	109	54	3	0	0
Gas	441	661	583	497	251	32
Oil	75	51	21	7	4	0
Diesel	21	18	11	5	2	0
Nuclear	114.9	82.8	49.7	6.4	0.8	0.0
Hydrogen	0	0	0	0	1	4
Renewables	**221**	**499**	**1,004**	**1,905**	**2,804**	**2,955**
Hydro	183	213	234	247	265	267
Wind	19	191	401	642	747	797
PV	1	37	151	478	920	980
Biomass	13.7	26	48	79	114	123
Geothermal	4	10	31	79	130	143
Solar thermal	0	15	106	295	392	361
Ocean energy	0	8	32	85	235	284
Fluctuating RES (PV, Wind, Ocean)	20	236	585	1,205	1,902	2,062
Share of fluctuating RES	1.6%	15.2%	32.2%	49.1%	62.0%	68.9%
RES share	**18.0%**	**32.1%**	**55.2%**	**77.7%**	**91.3%**	**98.8%**

table 13.36: oecd north america: primary energy demand

PJ/A	2007	2015	2020	2030	2040	2050
Total	**115,751**	**108,616**	**102,071**	**90,967**	**81,332**	**70,227**
Fossil	**97,810**	**88,222**	**75,190**	**50,060**	**25,231**	**10,316**
Hard coal	14,252	9,649	6,519	1,745	513	134
Lignite	10,671	7,038	3,245	188	0	0
Natural gas	27,426	30,248	27,475	22,128	10,748	2,688
Crude oil	45,461	41,288	37,951	26,000	13,971	7,494
Nuclear	**10,261**	**7,418**	**4,473**	**578**	**76**	**0**
Renewables	**7,680**	**12,976**	**22,408**	**40,329**	**56,024**	**59,912**
Hydro	2,323	2,722	2,977	3,157	3,380	3,406
Wind	136	1,757	3,791	6,322	7,344	7,805
Solar	64	817	3,102	9,272	15,285	17,683
Biomass	4,644	6,641	9,114	12,740	14,364	13,037
Geothermal	502	1,013	3,309	8,533	14,806	16,959
Ocean Energy	0	27	115	306	846	1,022
RES share	**6.6%**	**11.9%**	**22.0%**	**44.3%**	**68.9%**	**85.3%**
'Efficiency' savings (compared to Ref.)	**0**	**5,937**	**14,941**	**31,728**	**44,305**	**59,555**

table 13.37: oecd north america: final energy demand

PJ/a	2007	2015	2020	2030	2040	2050
Total (incl. non-energy use)	**80,323**	**77,927**	**77,304**	**72,508**	**65,271**	**56,838**
Total (energy use)	**72,347**	**70,809**	**70,187**	**65,474**	**58,321**	**49,972**
Transport	**31,163**	**30,336**	**29,993**	**26,158**	**20,335**	**14,764**
Oil products	29,612	27,898	26,068	17,192	7,004	1,177
Natural gas	856	814	758	648	553	392
Biofuels	646	1,454	2,159	3,729	4,154	3,662
Electricity	48	158	816	4,241	7,948	8,624
RES electricity	7	45	412	3,278	7,205	8,440
Hydrogen	0	12	192	349	676	908
RES share Transport	**2.1%**	**5.0%**	**8.9%**	**27.8%**	**58.9%**	**88.0%**
Industry	**16,149**	**15,888**	**15,136**	**14,364**	**13,678**	**12,440**
Electricity	4,488	4,546	4,297	3,954	3,693	3,265
RES electricity	680	1,296	2,168	3,056	3,348	3,196
District heat	708	901	1,442	2,420	3,258	3,723
RES district heat	60	401	970	2,145	3,101	3,700
Coal	1,225	1,039	592	50	0	0
Oil products	1,763	1,532	1,053	491	108	35
Gas	6,142	5,683	5,012	3,948	1,844	482
Solar	0	277	642	1,258	1,667	1,814
Biomass and waste	1,818	1,880	1,866	1,794	1,691	1,502
Geothermal	5	30	232	450	1,116	1,255
Hydrogen	0	0	0	0	301	363
RES share Industry	**15.9%**	**24.5%**	**38.8%**	**60.6%**	**81.9%**	**95.0%**
Other Sectors	**25,035**	**24,585**	**25,057**	**24,951**	**24,308**	**22,768**
Electricity	11,773	12,329	12,560	12,943	12,754	11,668
RES electricity	1,784	3,516	6,336	10,003	11,563	11,419
District heat	93	570	1,065	2,262	3,400	3,677
RES district heat	8	254	717	2,005	3,236	3,654
Coal	75	47	33	22	0	0
Oil products	3,399	2,485	2,026	921	372	192
Gas	8,729	7,810	7,333	5,174	2,254	135
Solar	61	148	381	1,624	3,164	4,553
Biomass and waste	866	1,083	1,429	1,559	1,565	1,374
Geothermal	39	114	230	447	798	1,171
RES share Other Sectors	**11.0%**	**20.8%**	**36.3%**	**62.7%**	**83.6%**	**97.4%**
Total RES	**5,973**	**10,503**	**17,638**	**31,616**	**43,494**	**46,983**
RES share	**8.3%**	**14.8%**	**25.1%**	**48.3%**	**74.6%**	**94.0%**
Non energy use	**7,976**	**7,118**	**7,118**	**7,034**	**6,950**	**6,866**
Oil	7,091	6,311	6,303	6,223	6,143	6,063
Gas	868	790	797	793	789	785
Coal	17	16	17	18	18	19

oecd north america: total new investment by technology

table 13.38: oecd north america: total investment

MILLION $	2007	2011-2020	2021-2030	2007-2030
Reference scenario				
Conventional (fossil & nuclear)	**400,086**	**591,355**	**602,987**	**1,594,428**
Renewables	**186,979**	**379,395**	**394,932**	**961,306**
Biomass	22,265	43,401	43,064	108,731
Hydro	60,917	152,543	161,405	374,865
Wind	52,131	86,489	84,452	223,072
PV	22,041	27,144	35,887	85,072
Geothermal	27,222	47,844	35,519	110,586
Solar thermal power plants	2,364	21,948	32,044	56,356
Ocean energy	38	26	2,561	2,625
Energy [R]evolution				
Conventional (fossil & nuclear)	**400,086**	**454,223**	**319,847**	**1,174,156**
Renewables	**186,979**	**1,503,790**	**1,922,496**	**3,613,265**
Biomass	22,265	88,348	84,486	195,100
Hydro	60,917	268,362	179,670	508,949
Wind	52,131	256,292	290,129	598,553
PV	22,041	261,727	411,808	695,576
Geothermal	27,222	244,098	321,954	593,275
Solar thermal power plants	2,364	313,228	551,189	866,780
Ocean energy	38	71,735	83,260	155,032
Advanced Energy [R]evolution				
Conventional (fossil & nuclear)	**400,086**	**301,907**	**226,504**	**928,496**
Renewables	**186,979**	**2,228,489**	**2,636,796**	**5,052,265**
Biomass	22,265	98,808	87,633	208,707
Hydro	60,917	287,280	190,281	538,478
Wind	52,131	462,662	329,297	844,090
PV	22,041	335,907	476,484	834,432
Geothermal	27,222	346,778	521,340	895,341
Solar thermal power plants	2,364	581,956	898,065	1,482,384
Ocean energy	38	115,098	133,696	248,833

notes

latin america: reference scenario

table 13.39: latin america: electricity generation

TWh/a	2007	2015	2020	2030	2040	2050
Power plants	**998**	**1,226**	**1,357**	**1,682**	**2,022**	**2,380**
Coal	16	73	87	122	173	228
Lignite	6	10	17	28	39	50
Gas	133	214	242	352	472	604
Oil	101	96	89	67	44	21
Diesel	24	13	10	8	7	6
Nuclear	20	26	42	48	54	60
Biomass	26	33	38	49	59	71
Hydro	669	749	809	944	1,069	1,194
Wind	1	7	14	34	54	74
PV	0	1	2	4	10	20
Geothermal	3	4	5	11	17	23
Solar thermal power plants	0	1	2	15	24	29
Ocean energy	0	0	0	0	0	0
Combined heat & power production	**0**	**18**	**39**	**73**	**95**	**100**
Coal	0	4	8	13	15	14
Lignite	0	0	0	0	0	0
Gas	0	14	29	55	71	75
Oil	0	0	0	0	0	0
Biomass	0	0	2	5	9	11
Geothermal	0	0	0	0	0	0
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	0	0	0	0	0	0
Autoproducers	0	18	39	73	95	100
Total generation	**998**	**1,244**	**1,396**	**1,755**	**2,117**	**2,480**
Fossil	280	424	482	645	821	998
Coal	16	78	95	135	188	242
Lignite	6	10	17	28	39	50
Gas	133	227	271	407	543	679
Oil	101	96	89	67	44	21
Diesel	24	13	10	8	7	6
Nuclear	20	26	42	48	54	60
Hydrogen	0	0	0	0	0	0
Renewables	**699**	**794**	**872**	**1,062**	**1,242**	**1,422**
Hydro	669	749	809	944	1,069	1,194
Wind	1	7	14	34	54	74
PV	0	1	2	4	10	20
Biomass	26	33	40	54	68	82
Geothermal	3	4	5	11	17	23
Solar thermal	0	1	2	15	24	29
Ocean energy	0	0	0	0	0	0
Distribution losses	164	195	201	220	234	244
Own consumption electricity	32	49	67	94	126	163
Electricity for hydrogen production	0	0	0	0	0	0
Final energy consumption (electricity)	**806**	**1,004**	**1,134**	**1,448**	**1,765**	**2,083**
Fluctuating RES (PV, Wind, Ocean)	1	8	16	38	64	94
Share of fluctuating RES	0.1%	0.6%	1.1%	2.2%	3.0%	3.8%
RES share	**70.0%**	**63.8%**	**62.5%**	**60.5%**	**58.7%**	**57.3%**

table 13.40: latin america: heat supply

PJ/A	2007	2015	2020	2030	2040	2050
District heating plants	**0**	**7**	**14**	**22**	**24**	**24**
Fossil fuels	0	0	0	0	0	0
Biomass	0	7	14	22	24	24
Solar collectors	0	0	0	0	0	0
Geothermal	0	0	0	0	0	0
Heat from CHP	**0**	**89**	**176**	**274**	**308**	**308**
Fossil fuels	0	87	167	255	280	274
Biomass	0	2	9	19	28	34
Geothermal	0	0	0	0	0	0
Fuel cell (hydrogen)	0	0	0	0	0	0
Direct heating[1)]	**6,105**	**6,596**	**6,970**	**7,680**	**8,422**	**9,149**
Fossil fuels	3,754	4,096	4,352	4,898	5,445	6,005
Biomass	2,345	2,497	2,588	2,750	2,937	3,102
Solar collectors	6	2	18	29	32	38
Geothermal	0	1	12	3	9	4
Total heat supply[1)]	**6,105**	**6,691**	**7,160**	**7,976**	**8,754**	**9,481**
Fossil fuels	3,754	4,183	4,519	5,153	5,725	6,278
Biomass	2,345	2,505	2,610	2,791	2,989	3,161
Solar collectors	6	2	18	29	32	38
Geothermal	0	1	12	3	9	4
Fuel cell ((hydrogen)	0	0	0	0	0	0
RES share (including RES electricity)	**38.5%**	**37.5%**	**36.9%**	**35.4%**	**34.6%**	**33.8%**

1) heat from electricity (direct and from electric heat pumps) not included; covered in the model under 'electric appliances'

table 13.41: latin america: CO_2 emissions

MILL t/a	2007	2015	2020	2030	2040	2050
Condensation power plants	**186**	**238**	**247**	**298**	**353**	**418**
Coal	13	58	66	91	124	159
Lignite	9	11	17	27	36	44
Gas	70	96	97	129	157	196
Oil	63	61	57	44	29	14
Diesel	30.9	12.3	9.2	7.0	5.8	4.7
Combined heat & power production	**0**	11	21	33	39	38
Coal	0	4	6	10	10	9
Lignite	0	0	0	0	0	0
Gas	0	7	14	24	29	29
Oil	0	0	0	0	0	0
CO_2 emissions electricity & steam generation	**186**	**249**	**268**	**331**	**392**	**457**
Coal	13	62	72	100	135	168
Lignite	9	11	17	27	36	44
Gas	70	103	112	153	186	226
Oil & diesel	94	73	66	51	35	19
CO_2 emissions by sector	**1,010**	**1,155**	**1,244**	**1,496**	**1,749**	**2,006**
% of 1990 emissions	167%	191%	206%	248%	290%	332%
Industry	205	228	249	285	313	336
Other sectors	121	141	149	169	188	208
Transport	355	394	433	551	674	796
Electricity & steam generation	186	238	247	298	353	418
District heating	143	154	165	194	221	248
Population (Mill.)	462	503	526	563	588	600
CO_2 emissions per capita (t/capita)	**2.2**	**2.3**	**2.4**	**2.7**	**3.0**	**3.3**

table 13.42: latin america: installed capacity

GW	2007	2015	2020	2030	2040	2050
Power plants	**227**	**277**	**304**	**375**	**454**	**504**
Coal	3	14	16	21	29	35
Lignite	1.1	1.6	2.5	4.1	5.7	7.1
Gas	38	58	64	87	118	121
Oil	26	28	29	29	24	18
Diesel	12.1	6.5	5.0	4.0	4.7	6.0
Nuclear	2.9	4.0	6.0	6.4	7.2	8.6
Biomass	4.1	5.0	5.7	7.1	8.2	9.5
Hydro	138	155	168	197	223	249
Wind	0.5	3.0	5.5	11.9	20.5	28.1
PV	0.0	0.4	1.4	2.9	7.1	14.3
Geothermal	0.5	1.0	1.0	1.5	2.3	3.1
Solar thermal power plants	0.0	0.2	0.6	2.5	3.8	4.5
Ocean energy	0.0	0.0	0.0	0.0	0.0	0.0
Combined heat & power production	**0**	**4**	**9**	**16**	**20**	**21**
Coal	0	1	2	3	4	3
Lignite	0	0	0	0	0	0
Gas	0	3	6	12	14	15
Oil	0	0	0	0	0	0
Biomass	0	0	0	1	2	2
Geothermal	0	0	0	0	0	0
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	0	0	0	0	0	0
Autoproducers	0	4	9	16	20	21
Total generation	**227**	**281**	**313**	**391**	**474**	**524**
Fossil	81	113	124	160	200	205
Coal	3	15	18	25	33	39
Lignite	1	2	3	4	6	7
Gas	38	61	70	99	132	136
Oil	26	28	29	29	24	18
Diesel	12	7	5	4	5	6
Nuclear	2.9	4.0	6.0	6.4	7.2	8.6
Hydrogen	0	0	0	0	0	0
Renewables	**143**	**165**	**183**	**224**	**267**	**311**
Hydro	138	155	168	197	223	249
Wind	0	3	5	12	21	28
PV	0	0	1	3	7	14
Biomass	4.2	5.1	6.2	8.2	10.0	11.7
Geothermal	1	1	1	2	2	3
Solar thermal	0	0	1	3	4	4
Ocean energy	0	0	0	0	0	0
Fluctuating RES (PV, Wind, Ocean)	0.5	3.3	6.9	14.8	27.7	42.4
Share of fluctuating RES	0.2%	1.2%	2.2%	3.8%	5.8%	8.1%
RES share	**63.2%**	**58.5%**	**58.4%**	**57.3%**	**56.3%**	**59.3%**

table 13.43: latin america: primary energy demand

PJ/A	2007	2015	2020	2030	2040	2050
Total	**22,513**	**25,496**	**27,304**	**32,040**	**36,447**	**40,874**
Fossil	**15,705**	**17,622**	**18,729**	**22,027**	**25,190**	**28,376**
Hard coal	811	1,466	1,591	1,927	2,325	2,724
Lignite	81	103	157	243	327	398
Natural gas	4,465	5,337	5,675	7,007	8,132	9,358
Crude oil	10,349	10,716	11,306	12,850	14,407	15,895
Nuclear	**214**	**284**	**458**	**524**	**589**	**655**
Renewables	**6,594**	**7,591**	**8,117**	**9,490**	**10,668**	**11,843**
Hydro	2,409	2,696	2,912	3,398	3,848	4,298
Wind	3	25	50	122	194	266
Solar	6	6	33	97	154	214
Biomass	4,073	4,778	5,030	5,738	6,275	6,803
Geothermal	103	85	92	134	196	261
Ocean Energy	0	0	0	0	0	0
RES share	**28.6%**	**29.1%**	**29.0%**	**28.9%**	**28.5%**	**28.2%**

table 13.44: latin america: final energy demand

PJ/a	2007	2015	2020	2030	2040	2050
Total (incl. non-energy use)	**17,731**	**20,043**	**21,683**	**25,805**	**29,862**	**33,886**
Total (energy use)	**16,276**	**18,494**	**20,092**	**24,172**	**28,187**	**32,170**
Transport	**5,387**	**6,238**	**6,866**	**8,876**	**10,886**	**12,895**
Oil products	4,757	5,233	5,778	7,327	8,949	10,555
Natural gas	238	320	320	441	560	680
Biofuels	382	670	753	1,089	1,347	1,616
Electricity	11	15	15	20	29	45
RES electricity	8	9	9	12	17	26
Hydrogen	0	0	0	0	0	0
RES share Transport	**7.2%**	**10.9%**	**11.1%**	**12.4%**	**12.5%**	**12.7%**
Industry	**6,244**	**6,968**	**7,516**	**8,664**	**9,747**	**10,797**
Electricity	1,356	1,675	1,884	2,428	2,973	3,517
RES electricity	949	1,069	1,177	1,469	1,744	2,017
District heat	0	89	176	274	308	308
RES district heat	0	89	176	274	308	308
Coal	330	455	455	493	531	569
Oil products	1,358	1,357	1,444	1,565	1,686	1,809
Gas	1,387	1,406	1,489	1,685	1,879	2,074
Solar	0	0	0	0	0	0
Biomass and waste	1,814	1,985	2,068	2,219	2,370	2,521
Geothermal	0	0	0	0	0	0
Hydrogen	0	0	0	0	0	0
RES share Industry	**44.2%**	**45.1%**	**45.5%**	**45.7%**	**45.4%**	**44.9%**
Other Sectors	**4,644**	**5,288**	**5,709**	**6,632**	**7,555**	**8,478**
Electricity	1,534	1,926	2,183	2,765	3,353	3,937
RES electricity	1,073	1,230	1,364	1,673	1,967	2,258
District heat	0	0	0	0	0	0
RES district heat	0	0	0	0	0	0
Coal	0	5	14	15	5	4
Oil products	1,221	1,425	1,484	1,613	1,742	1,869
Gas	534	603	668	844	1,025	1,210
Solar	6	2	18	29	32	38
Biomass and waste	1,349	1,326	1,335	1,366	1,394	1,417
Geothermal	0	0	7	2	5	2
RES share Other Sectors	**52.3%**	**48.4%**	**47.7%**	**46.3%**	**45.0%**	**43.8%**
Total RES	**5,581**	**6,381**	**6,907**	**8,132**	**9,183**	**10,202**
RES share	**34.3%**	**34.5%**	**34.4%**	**33.6%**	**32.6%**	**31.7%**
Non energy use	**1,455**	**1,549**	**1,591**	**1,633**	**1,675**	**1,717**
Oil	948	1,009	1,036	1,063	1,091	1,118
Gas	501	533	548	562	577	591
Coal	7	7	7	7	7	8

latin america: energy [r]evolution scenario

table 13.45: latin america: electricity generation

TWh/a	2007	2015	2020	2030	2040	2050
Power plants	**998**	**1,205**	**1,236**	**1,347**	**1,598**	**2,239**
Coal	16	65	61	33	21	6
Lignite	6	2	1	0	0	0
Gas	133	198	128	70	32	24
Oil	101	80	53	13	1	1
Diesel	24	5	2	2	0	0
Nuclear	20	18	18	5	0	0
Biomass	26	47	83	110	145	239
Hydro	669	749	770	785	793	822
Wind	1	30	85	205	422	737
PV	0	3	14	71	90	165
Geothermal	3	7	11	15	20	25
Solar thermal power plants	0	1	10	35	65	195
Ocean energy	0	1	2	4	10	25
Combined heat & power production	**0**	21	85	192	266	335
Coal	0	1	2	2	2	0
Lignite	0	0	0	0	0	0
Gas	0	12	32	55	48	46
Oil	0	0	0	0	0	0
Biomass	0	8	47	122	183	228
Geothermal	0	0	4	12	33	61
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	0	3	10	35	48	60
Autoproducers	0	18	75	157	218	275
Total generation	**998**	**1,226**	**1,321**	**1,539**	**1,864**	**2,574**
Fossil	280	363	278	175	103	77
Coal	16	66	62	35	22	6
Lignite	6	2	1	0	0	0
Gas	133	210	160	125	80	70
Oil	101	80	53	13	1	1
Diesel	24	5	2	2	0	0
Nuclear	20	18	18	5	0	0
Hydrogen	0	0	0	0	0	0
Renewables	**699**	**845**	**1,026**	**1,359**	**1,761**	**2,497**
Hydro	669	749	770	785	793	822
Wind	1	30	85	205	422	737
PV	0	3	14	71	90	165
Biomass	26	55	130	232	328	467
Geothermal	3	7	15	27	53	86
Solar thermal	0	1	10	35	65	195
Ocean energy	0	1	2	4	10	25
Distribution losses	164	195	195	200	210	230
Own consumption electricity	32	49	50	75	105	120
Electricity for hydrogen production	0	0	0	8	11	42
Final energy consumption (electricity)	**806**	**987**	**1,082**	**1,273**	**1,542**	**2,185**
Fluctuating RES (PV, Wind, Ocean)	1	34	101	280	522	927
Share of fluctuating RES	0.1%	2.7%	7.6%	18.2%	28.0%	36.0%
RES share	**70.0%**	**69.0%**	**77.7%**	**88.3%**	**94.5%**	**97.0%**
'Efficiency' savings (compared to Ref.)	**0**	**20**	**62**	**225**	**329**	**388**

table 13.46: latin america: heat supply

PJ/A	2007	2015	2020	2030	2040	2050
District heating plants	**0**	**123**	**209**	**227**	**283**	**358**
Fossil fuels	0	20	23	16	6	0
Biomass	0	86	146	154	178	197
Solar collectors	0	5	19	34	57	89
Geothermal	0	12	21	23	42	72
Heat from CHP	**0**	**109**	**439**	**860**	**1,165**	**1,500**
Fossil fuels	0	64	155	214	182	161
Biomass	0	45	245	545	706	813
Geothermal	0	0	39	101	277	526
Fuel cell (hydrogen)	0	0	0	0	0	0
Direct heating[1)]	**6,105**	**6,539**	**6,442**	**6,351**	**6,338**	**6,037**
Fossil fuels	3,754	3,654	3,062	2,486	1,954	1,350
Biomass	2,345	2,711	2,682	2,733	2,881	2,803
Solar collectors	6	67	452	726	940	1,112
Geothermal	0	108	247	404	562	772
Total heat supply[1)]	**6,105**	**6,771**	**7,090**	**7,437**	**7,786**	**7,894**
Fossil fuels	3,754	3,737	3,240	2,717	2,142	1,511
Biomass	2,345	2,842	3,073	3,432	3,766	3,813
Solar collectors	6	71	471	760	997	1,201
Geothermal	0	121	306	528	881	1,370
Fuel cell (hydrogen)	0	0	0	0	0	0
RES share (including RES electricity)	**38.5%**	**45%**	**54%**	**63%**	**72%**	**81%**
'Efficiency' savings (compared to Ref.)	**0**	**0**	**70**	**538**	**969**	**1,586**

1) heat from electricity (direct and from electric heat pumps) not included; covered in the model under 'electric appliances'

table 13.47: latin america: CO_2 emissions

MILL t/a	2007	2015	2020	2030	2040	2050
Condensation power plants	**186**	**198**	**134**	**60**	**26**	**13**
Coal	13	52	46	24	15	4
Lignite	9	2.3	0.5	0.0	0.0	0.0
Gas	70	89	52	25	11	8
Oil	63	50.8	34.0	8.6	0.7	0.7
Diesel	30.9	4.7	1.8	1.7	0.0	0.0
Combined heat & power production	**0**	**7**	**18**	**26**	**23**	**20**
Coal	0	1	1	2	1	0
Lignite	0	0	0	0	0	0
Gas	0	6	16	24	22	20
Oil	0	0	0	0	0	0
CO_2 emissions electricity & steam generation	**186**	**205**	**152**	**86**	**49**	**32**
Coal	13	52	47	26	16	4
Lignite	9	2	1	0	0	0
Gas	70	95	68	50	32	28
Oil & diesel	94	55	36	10	1	1
CO_2 emissions by sector	**1,010**	**1,030**	**901**	**736**	**642**	**312**
% of 1990 emissions	167%	170%	149%	122%	106%	52%
Industry	205	204	178	143	101	70
Other sectors	121	111	91	74	56	42
Transport	355	374	368	343	349	130
Electricity & steam generation	186	199	136	66	35	20
District heating	143	141	128	111	101	50
Population (Mill.)	462	503	526	563	588	600
CO_2 emissions per capita (t/capita)	**2.2**	**2.0**	**1.7**	**1.3**	**1.1**	**0.5**

table 13.48: latin america: installed capacity

GW	2007	2015	2020	2030	2040	2050
Power plants	**227**	**275**	**287**	**342**	**439**	**650**
Coal	3	13	11	6	3	1
Lignite	1.1	0.3	0.1	0.0	0.0	0.0
Gas	38	54	34	17	8	5
Oil	26	23	17	6	1	1
Diesel	12.1	2.5	1.0	1.0	0.0	0.0
Nuclear	2.9	2.7	2.5	0.7	0.0	0.0
Biomass	4.1	7.2	12.6	15.9	20.0	31.9
Hydro	138	155	160	164	165	172
Wind	0.5	12.7	33.3	71.9	160.5	280.2
PV	0.0	1.8	10.0	50.7	64.3	117.9
Geothermal	0.5	1.7	2.1	2.0	2.8	3.4
Solar thermal power plants	0.0	0.4	3.2	5.8	10.3	30.0
Ocean energy	0.0	0.3	0.7	1.3	3.3	8.3
Combined heat & power production	**0**	**5**	**20**	**44**	**59**	**73**
Coal	0	0	0	1	0	0
Lignite	0	0	0	0	0	0
Gas	0	3	8	13	12	11
Oil	0	0	0	0	0	0
Biomass	0	2	11	28	40	50
Geothermal	0	0	1	2	7	12
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	0	1	3	11	15	19
Autoproducers	0	4	16	33	43	54
Total generation	**227**	**280**	**307**	**386**	**497**	**723**
Fossil	81	96	71	43	24	17
Coal	3	13	11	6	4	1
Lignite	1	0	0	0	0	0
Gas	38	57	41	30	20	16
Oil	26	23	17	6	1	1
Diesel	12	3	1	1	0	0
Nuclear	2.9	2.7	2.5	0.7	0.0	0.0
Hydrogen	0	0	0	0	0	0
Renewables	**143**	**181**	**233**	**342**	**473**	**705**
Hydro	138	155	160	164	165	172
Wind	0	13	33	72	160	280
PV	0	2	10	51	64	118
Biomass	4.2	9	23	44	60	82
Geothermal	1	2	3	4	9	16
Solar thermal	0	0	3	6	10	30
Ocean energy	0	0	1	1	3	8
Fluctuating RES (PV, Wind, Ocean)	0.5	14.8	44.0	124.0	228.1	406.4
Share of fluctuating RES	0.2%	5.3%	14.3%	32.1%	45.9%	56.2%
RES share	**63.2%**	**64.7%**	**76.1%**	**88.6%**	**95.2%**	**97.6%**

table 13.49: latin america: primary energy demand

PJ/A	2007	2015	2020	2030	2040	2050
Total	**22,513**	**24,429**	**24,623**	**25,012**	**26,226**	**28,339**
Fossil	**15,705**	**16,146**	**14,262**	**11,972**	**10,553**	**6,310**
Hard coal	811	1,297	1,182	750	543	392
Lignite	81	21	5	0	0	0
Natural gas	4,465	5,429	4,734	4,162	3,633	3,040
Crude oil	10,349	9,399	8,342	7,060	6,376	2,878
Nuclear	**214**	**191**	**191**	**55**	**0**	**0**
Renewables	**6,594**	**8,093**	**10,171**	**12,986**	**15,674**	**22,029**
Hydro	2,409	2,696	2,772	2,826	2,855	2,959
Wind	3	108	306	738	1,519	2,653
Solar	6	84	558	1,142	1,555	2,497
Biomass	4,073	4,946	5,959	7,332	8,003	11,104
Geothermal	103	255	569	934	1,706	2,725
Ocean Energy	0	4	7	14	36	90
RES share	**28.6%**	**32.5%**	**41.3%**	**52.0%**	**59.8%**	**77.7%**
'Efficiency' savings (compared to Ref.)	**0**	**1,099**	**2,925**	**7,293**	**10,599**	**12,972**

table 13.50: latin america: final energy demand

PJ/a	2007	2015	2020	2030	2040	2050
Total (incl. non-energy use)	**17,731**	**19,381**	**19,875**	**20,678**	**21,687**	**22,550**
Total (energy use)	**16,276**	**17,832**	**18,284**	**19,078**	**20,096**	**21,005**
Transport	**5,387**	**5,656**	**5,718**	**5,842**	**5,965**	**6,089**
Oil products	4,757	4,976	4,885	4,527	4,719	1,550
Natural gas	238	297	303	324	201	364
Biofuels	382	362	480	770	606	2,249
Electricity	11	21	49	200	409	1,811
RES electricity	8	15	38	177	386	1,757
Hydrogen	0	0	1	20	30	114
RES share Transport	**7.2%**	**6.7%**	**9.1%**	**16.5%**	**17.1%**	**67.6%**
Industry	**6,244**	**7,033**	**7,314**	**7,626**	**7,840**	**7,878**
Electricity	1,356	1,763	1,984	2,283	2,553	2,729
RES electricity	949	1,216	1,540	2,016	2,411	2,648
District heat	0	136	377	590	814	1,118
RES district heat	0	109	311	485	677	999
Coal	330	393	329	128	29	6
Oil products	1,358	1,013	703	491	130	77
Gas	1,387	1,642	1,622	1,584	1,595	1,174
Solar	0	29	228	369	400	450
Biomass and waste	1,814	1,995	1,969	2,024	2,123	2,056
Geothermal	0	62	103	157	196	268
Hydrogen	0	0	0	0	0	0
RES share Industry	**44.2%**	**48.5%**	**56.8%**	**66.2%**	**74.1%**	**81.5%**
Other Sectors	**4,644**	**5,142**	**5,252**	**5,611**	**6,291**	**7,039**
Electricity	1,534	1,768	1,861	2,099	2,589	3,327
RES electricity	1,073	1,219	1,445	1,854	2,445	3,227
District heat	0	69	212	416	538	635
RES district heat	0	56	175	342	448	568
Coal	0	0	0	0	0	0
Oil products	1,221	1,045	760	557	293	199
Gas	534	581	507	425	455	336
Solar	6	37	224	357	540	662
Biomass and waste	1,349	1,609	1,570	1,554	1,591	1,530
Geothermal	0	32	118	202	284	350
RES share Other Sectors	**52.3%**	**57.4%**	**67.3%**	**76.8%**	**84.4%**	**90.0%**
Total RES	**5,581**	**6,741**	**8,203**	**10,324**	**12,136**	**16,875**
RES share	**34.3%**	**37.8%**	**44.9%**	**54.1%**	**60.4%**	**80.3%**
Non energy use	**1,455**	**1,549**	**1,591**	**1,600**	**1,591**	**1,545**
Oil	948	1,009	1,036	1,042	1,036	1,006
Gas	501	533	548	551	548	532
Coal	7	7	7	7	7	7

latin america: advanced energy [r]evolution scenario

table 13.51: latin america: electricity generation

TWh/a	2007	2015	2020	2030	2040	2050
Power plants	**998**	**1,205**	**1,252**	**1,461**	**1,828**	**2,592**
Coal	16	40	29	15	4	1
Lignite	6	2	1	0	0	0
Gas	133	213	148	95	57	27
Oil	101	80	28	3	1	1
Diesel	24	5	2	2	0	0
Nuclear	20	18	18	5	0	0
Biomass	26	47	83	108	154	228
Hydro	669	749	770	785	793	822
Wind	1	35	114	250	426	799
PV	0	3	28	88	160	270
Geothermal	3	7	11	25	25	53
Solar thermal power plants	0	6	20	80	184	338
Ocean energy	0	1	2	4	25	52
Combined heat & power production	**0**	**21**	**85**	**192**	**266**	**335**
Coal	0	1	2	2	0	0
Lignite	0	0	0	0	0	0
Gas	0	12	32	53	33	23
Oil	0	0	0	0	0	0
Biomass	0	8	47	124	186	232
Geothermal	0	0	4	13	46	80
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	0	3	10	35	48	60
Autoproducers	0	18	75	157	218	275
Total generation	**998**	**1,226**	**1,337**	**1,653**	**2,094**	**2,927**
Fossil	280	353	241	171	95	52
Coal	16	41	30	18	4	1
Lignite	6	2	1	0	0	0
Gas	133	225	180	148	90	50
Oil	101	80	28	3	1	1
Diesel	24	5	2	2	0	0
Nuclear	20	18	18	5	0	0
Hydrogen	0	0	0	0	0	0
Renewables	**699**	**855**	**1,079**	**1,477**	**1,999**	**2,874**
Hydro	669	749	770	785	793	822
Wind	1	35	114	250	426	799
PV	0	3	28	88	160	270
Biomass	26	55	130	232	340	460
Geothermal	3	7	15	38	71	133
Solar thermal	0	6	20	80	184	338
Ocean energy	0	1	2	4	25	52
Distribution losses	164	195	195	200	210	230
Own consumption electricity	32	49	50	75	105	120
Electricity for hydrogen production	0	0	15	38	32	79
Final energy consumption (electricity)	**806**	**987**	**1,083**	**1,356**	**1,751**	**2,502**
Fluctuating RES (PV, Wind, Ocean)	1	39	144	342	611	1,121
Share of fluctuating RES	0.1%	3.1%	10.8%	20.7%	29.2%	38.3%
RES share	**70.0%**	**69.8%**	**80.7%**	**89.4%**	**95.4%**	**98.2%**
'Efficiency' savings (compared to Ref.)	**0**	**20**	**62**	**222**	**317**	**369**

table 13.52: latin america: heat supply

PJ/A	2007	2015	2020	2030	2040	2050
District heating plants	**0**	**123**	**209**	**292**	**536**	**719**
Fossil fuels	0	20	23	20	11	0
Biomass	0	86	146	199	338	396
Solar collectors	0	5	19	44	107	180
Geothermal	0	12	21	29	80	144
Heat from CHP	**0**	**109**	**439**	**885**	**1,233**	**1,594**
Fossil fuels	0	64	155	216	120	71
Biomass	0	45	245	560	714	822
Geothermal	0	0	39	109	400	702
Fuel cell (hydrogen)	0	0	0	0	0	0
Direct heating[1]	**6,105**	**6,539**	**6,442**	**6,261**	**5,970**	**5,471**
Fossil fuels	3,754	3,654	3,062	2,265	1,1115	162
Biomass	2,345	2,711	2,680	2,707	2,747	2,760
Solar collectors	6	67	453	812	1,211	1,430
Geothermal	0	108	247	476	897	1,119
Total heat supply[1]	**6,105**	**6,771**	**7,090**	**7,437**	**7,786**	**7,894**
Fossil fuels	3,754	3,737	3,240	2,502	1,246	232
Biomass	2,345	2,842	3,071	3,466	3,798	3,977
Solar collectors	6	71	471	856	1,319	1,610
Geothermal	0	121	306	614	1,377	1,965
Fuel cell (hydrogen)	0	0	0	0	46	110
RES share (including RES electricity)	**38.5%**	**44.8%**	**54.3%**	**66.4%**	**84.0%**	**97.0%**
'Efficiency' savings (compared to Ref.)	**0**	**0**	**70**	**538**	**969**	**1,586**

1) heat from electricity (direct and from electric heat pumps) not included; covered in the model under 'electric appliances'

table 13.53: latin america: co2 emissions

MILL t/a	2007	2015	2020	2030	2040	2050
Condensation power plants	**186**	**185**	**102**	**50**	23	10
Coal	13	32	22	11	3	1
Lignite	9	2.3	0.5	0.0	0.0	0.0
Gas	70	95	60	35	19	9
Oil	63	50.8	18.0	2.0	0.7	0.7
Diesel	30.9	4.7	1.8	1.7	0.0	0.0
Combined heat & power production	**0**	7	18	26	15	9
Coal	0	1	1	2	0	0
Lignite	0	0	0	0	0	0
Gas	0	6	16	24	15	9
Oil	0	0	0	0	0	0
CO_2 emissions electricity & steam generation	**186**	**192**	**119**	**76**	37	19
Coal	13	32	23	13	3	1
Lignite	9	2	1	0	0	0
Gas	70	102	76	59	34	18
Oil & diesel	94	55	20	4	1	1
CO_2 emissions by sector	**1,010**	**1,016**	**843**	**636**	440	119
% of 1990 emissions	167%	168%	140%	105%	73%	20%
Industry	205	204	179	135	62	9
Other sectors	121	111	90	64	35	17
Transport	355	374	350	292	254	64
Electricity & steam generation	186	186	104	56	28	11
District heating	143	141	121	89	61	19
Population (Mill.)	462	503	526	563	588	600
CO_2 emissions per capita (t/capita)	**2.2**	**2.0**	**1.6**	**1.1**	0.7	0.2

table 13.54: latin america: installed capacity

GW	2007	2015	2020	2030	2040	2050
Power plants	**227**	**278**	**303**	**377**	**519**	**782**
Coal	3	8	5	3	1	0
Lignite	1.1	0.3	0.1	0.0	0.0	0.0
Gas	38	58	39	24	14	5
Oil	26	23	9	1	1	1
Diesel	12.1	2.5	1.0	1.0	0.0	0.0
Nuclear	2.9	2.7	2.5	0.7	0.0	0.0
Biomass	4.1	7.2	12.6	15.6	21.3	30.4
Hydro	138	155	160	164	165	172
Wind	0.5	14.8	44.7	87.7	162.0	304.0
PV	0.0	1.8	20.0	62.9	114.3	192.9
Geothermal	0.5	1.7	2.1	3.4	3.4	7.2
Solar thermal power plants	0.0	2.4	6.5	13.3	29.2	52.0
Ocean energy	0.0	0.3	0.7	1.3	8.3	17.3
Combined heat & power production	**0**	**5**	**20**	**44**	**58**	**72**
Coal	0	0	0	1	0	0
Lignite	0	0	0	0	0	0
Gas	0	3	8	12	8	5
Oil	0	0	0	0	0	0
Biomass	0	2	11	29	41	51
Geothermal	0	0	1	3	9	16
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	0	1	3	11	15	18
Autoproducers	0	4	16	33	43	54
Total generation	**227**	**283**	**323**	**421**	**578**	**854**
Fossil	81	95	62	42	23	11
Coal	3	8	6	3	1	0
Lignite	1	0	0	0	0	0
Gas	38	61	47	36	22	10
Oil	26	23	9	1	1	1
Diesel	12	3	1	1	0	0
Nuclear	2.9	2.7	2.5	0.7	0.0	0.0
Hydrogen	0	0	0	0	0	0
Renewables	**143**	**185**	**258**	**379**	**554**	**842**
Hydro	138	155	160	164	165	172
Wind	0	15	45	88	162	304
PV	0	2	20	63	114	193
Biomass	4.2	9	23	44	62	81
Geothermal	1	2	3	6	13	23
Solar thermal	0	2	6	13	29	52
Ocean energy	0	0	1	1	8	17
Fluctuating RES (PV, Wind, Ocean)	0.5	16.9	65.4	151.9	284.6	514.1
Share of fluctuating RES	0.2%	6.0%	20.2%	36.0%	49.3%	60.2%
RES share	**63.2%**	**65.4%**	**79.9%**	**90.0%**	**96.0%**	**98.7%**

table 13.55: latin america: primary energy demand

PJ/A	2007	2015	2020	2030	2040	2050
Total	**22,513**	**24,377**	**24,494**	**24,996**	**25,910**	**27,311**
Fossil	**15,705**	**16,057**	**13,639**	**10,837**	**7,850**	**3,338**
Hard coal	811	1,065	884	437	297	247
Lignite	81	21	5	0	0	0
Natural gas	4,465	5,600	4,961	4,291	2,716	1,303
Crude oil	10,349	9,372	7,790	6,109	4,837	1,788
Nuclear	**214**	**191**	**191**	**55**	**0**	**0**
Renewables	**6,594**	**8,129**	**10,664**	**14,104**	**18,060**	**23,973**
Hydro	2,409	2,696	2,772	2,826	2,855	2,959
Wind	3	126	410	900	1,534	2,878
Solar	6	102	644	1,461	2,557	3,799
Biomass	4,073	4,946	6,261	7,754	8,517	10,181
Geothermal	103	255	569	1,149	2,508	3,969
Ocean Energy	0	4	7	14	90	187
RES share	**28.6%**	**32.7%**	**43.6%**	**56.5%**	**69.7%**	**87.8%**
'Efficiency' savings (compared to Ref.)	**0**	**1,148**	**3,055**	**7,309**	**10,915**	**14,001**

table 13.56: latin america: final energy demand

PJ/a	2007	2015	2020	2030	2040	2050
Total (incl. non-energy use)	**17,731**	**19,381**	**19,875**	**20,575**	**21,179**	**21,403**
Total (energy use)	**16,276**	**17,832**	**18,284**	**18,975**	**19,588**	**19,858**
Transport	**5,387**	**5,656**	**5,718**	5,725	5,428	5,358
Oil products	4,757	4,976	4,635	3,841	3,430	717
Natural gas	238	297	303	288	145	228
Biofuels	382	362	690	1,011	721	1,482
Electricity	11	21	54	489	1,048	2,719
RES electricity	8	15	43	437	1,000	2,670
Hydrogen	0	0	37	96	85	212
RES share Transport	**7.2%**	**6.7%**	**13.3%**	**26.8%**	**33.2%**	**81.4%**
Industry	**6,244**	**7,033**	**7,314**	**7,632**	**7,881**	**7,668**
Electricity	1,356	1,763	1,984	2,294	2,595	2,801
RES electricity	949	1,230	1,600	2,051	2,477	2,751
District heat	0	136	377	650	1,031	1,418
RES district heat	0	109	311	548	957	1,416
Coal	330	393	329	17	11	2
Oil products	1,358	1,005	687	448	70	8
Gas	1,387	1,650	1,638	1,626	1,002	154
Solar	0	29	228	374	530	669
Biomass and waste	1,814	1,995	1,969	2,050	2,163	1,988
Geothermal	0	62	103	174	428	505
Hydrogen	0	0	0	0	51	122
RES share Industry	**44.2%**	**48.7%**	**57.6%**	**68.1%**	**83.8%**	**97.2%**
Other Sectors	**4,644**	**5,142**	**5,252**	**5,618**	**6,279**	**6,832**
Electricity	1,534	1,768	1,861	2,100	2,590	3,325
RES electricity	1,073	1,234	1,502	1,877	2,473	3,265
District heat	0	69	212	450	638	782
RES district heat	0	56	175	379	592	781
Coal	0	0	0	0	0	0
Oil products	1,221	1,028	724	472	150	26
Gas	534	598	541	356	262	105
Solar	6	37	224	439	682	761
Biomass and waste	1,349	1,609	1,571	1,559	1,614	1,444
Geothermal	0	32	118	244	342	389
RES share Other Sectors	**52.3%**	**57.7%**	**68.4%**	**80.0%**	**90.8%**	**97.2%**
Total RES	**5,581**	**6,770**	**8,564**	**11,228**	**14,107**	**18,450**
RES share	**34.3%**	**38.0%**	**46.8%**	**59.2%**	**72.0%**	**92.9%**
Non energy use	**1,455**	**1,549**	**1,591**	**1,600**	**1,591**	**1,545**
Oil	948	1,009	1,036	1,042	1,043	1,013
Gas	501	533	548	551	548	532
Coal	7	7	7	7	0	0

latin america: total new investment by technology

table 13.57: latin america: total investment

MILLION $	2005-2010	2011-2020	2021-2030	2005-2030
Reference scenario				
Conventional (fossil & nuclear)	**38,125**	**60,851**	**49,285**	**148,260**
Renewables	**90,858**	**154,799**	**186,209**	**431,867**
Biomass	6,149	9,058	10,306	25,513
Hydro	78,289	129,481	152,344	360,113
Wind	1,940	4,019	7,371	13,330
PV	489	2,875	2,106	5,470
Geothermal	3,461	6,344	5,526	15,330
Solar thermal power plants	531	3,023	8,556	12,111
Ocean energy	0	0	0	0
Energy [R]evolution				
Conventional (fossil & nuclear)	**38,125**	**25,089**	**6,112**	**69,327**
Renewables	**90,858**	**277,772**	**268,818**	**637,449**
Biomass	6,149	64,516	68,093	138,758
Hydro	78,289	105,863	76,495	260,646
Wind	1,940	38,641	41,261	81,842
PV	489	22,041	55,685	78,214
Geothermal	3,461	27,499	13,624	44,583
Solar thermal power plants	531	16,692	12,028	29,251
Ocean energy	0	2,521	1,633	4,154
Advanced Energy [R]evolution				
Conventional (fossil & nuclear)	**38,125**	**22,385**	**6,121**	**66,631**
Renewables	**90,858**	**330,249**	**310,051**	**731,158**
Biomass	6,149	64,516	69,457	140,122
Hydro	78,289	105,863	76,495	260,646
Wind	1,940	52,008	45,828	99,776
PV	489	43,132	58,607	102,229
Geothermal	3,461	27,499	26,286	57,245
Solar thermal power plants	531	34,709	31,745	66,985
Ocean energy	0	2,521	1,633	4,154

notes

oecd europe: reference scenario

table 13.58: oecd europe: electricity generation

TWh/a	2007	2015	2020	2030	2040	2050
Power plants	**2,935**	**3,037**	**3,183**	**3,589**	**4,011**	**4,427**
Coal	456	380	382	406	454	518
Lignite	290	280	260	250	240	231
Gas	528	516	624	738	854	966
Oil	57	22	13	11	10	7
Diesel	8	7	6	5	4	3
Nuclear	925	869	743	707	671	635
Biomass	55	68	76	91	115	137
Hydro	498	547	588	633	678	723
Wind	105	301	419	614	790	950
PV	4	32	48	93	140	185
Geothermal	8	12	14	17	21	24
Solar thermal power plants	0	2	8	15	20	27
Ocean energy	1	1	2	9	15	21
Combined heat & power production	**642**	**681**	**731**	**802**	**858**	**924**
Coal	151	152	163	176	182	190
Lignite	81	82	83	83	86	89
Gas	310	333	358	389	418	451
Oil	45	39	32	28	23	20
Biomass	53	74	93	125	148	173
Geothermal	1	1	1	1	2	2
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	451	480	520	570	605	658
Autoproducers	191	201	211	232	253	266
Total generation	**3,576**	**3,717**	**3,914**	**4,391**	**4,869**	**5,351**
Fossil	1,926	1,810	1,921	2,086	2,270	2,474
Coal	608	532	545	582	635	707
Lignite	371	362	343	333	326	320
Gas	838	849	982	1,127	1,272	1,417
Oil	102	61	45	39	33	27
Diesel	8	7	6	5	4	3
Nuclear	925	869	743	707	671	635
Hydrogen	0	0	0	0	0	0
Renewables	**725**	**1,038**	**1,249**	**1,598**	**1,928**	**2,242**
Hydro	498	547	588	633	678	723
Wind	105	301	419	614	790	950
PV	4	32	48	93	140	185
Biomass	108	142	169	216	263	310
Geothermal	10	13	15	19	22	26
Solar thermal	0	2	8	15	20	27
Ocean energy	1	1	2	9	15	21
Distribution losses	229	210	215	228	240	253
Own consumption electricity	289	290	297	314	332	349
Electricity for hydrogen production	0	0	0	0	0	0
Final energy consumption (electricity)	**3,063**	**3,233**	**3,419**	**3,868**	**4,318**	**4,771**
Fluctuating RES (PV, Wind, Ocean)	110	334	469	716	945	1156
Share of fluctuating RES	3.1%	9.0%	12.0%	16.3%	19.4%	21.6%
RES share	**20.3%**	**27.9%**	**31.9%**	**36.4%**	**39.6%**	**41.9%**

table 13.59: oecd europe: heat supply

PJ/A	2007	2015	2020	2030	2040	2050
District heating plants	**1,249**	**1,321**	**1,263**	**1,148**	**1,089**	**971**
Fossil fuels	936	990	947	861	817	728
Biomass	306	324	310	282	267	238
Solar collectors	0	0	0	0	0	0
Geothermal	6	6	6	5	5	4
Heat from CHP	**2,205**	**2,327**	**2,467**	**2,842**	**3,143**	**3,537**
Fossil fuels	1,901	1,995	2,084	2,400	2,647	2,996
Biomass	291	319	371	429	482	525
Geothermal	13	12	12	13	14	15
Fuel cell (hydrogen)	0	0	0	0	0	0
Direct heating[1]	**19,057**	**18,730**	**19,233**	**20,331**	**21,487**	**22,549**
Fossil fuels	16,793	16,105	16,268	16,611	16,967	17,271
Biomass	2,105	2,410	2,678	3,276	3,874	4,469
Solar collectors	56	87	120	201	325	409
Geothermal	102	128	167	243	321	401
Total heat supply[1]	**22,510**	**22,378**	**22,963**	**24,321**	**25,720**	**27,057**
Fossil fuels	19,631	19,091	19,299	19,871	20,431	20,995
Biomass	2,702	3,053	3,359	3,987	4,624	5,232
Solar collectors	56	87	120	201	325	409
Geothermal	121	146	185	261	341	420
Fuel cell ((hydrogen)	0	0	0	0	0	0
RES share (including RES electricity)	**12.8%**	**14.7%**	**16.0%**	**18.3%**	**20.6%**	**22.4%**

1) heat from electricity (direct and from electric heat pumps) not included; covered in the model under 'electric appliances'

table 13.60: oecd europe: CO_2 emissions

MILL t/a	2007	2015	2020	2030	2040	2050
Condensation power plants	**975**	**818**	**804**	**840**	**892**	**933**
Coal	409	310	294	302	338	385
Lignite	306	273	239	222	213	205
Gas	212	213	257	304	331	336
Oil	41	16	10	8	7	5
Diesel	7.5	6.6	5.5	4.4	3.3	2.4
Combined heat & power production	**498**	**451**	**440**	**432**	**442**	**452**
Coal	156	147	152	133	148	154
Lignite	99	75	63	69	74	81
Gas	147	159	175	196	199	203
Oil	95	70	49	34	20	13
CO_2 emissions electricity & steam generation	**1,472**	**1,269**	**1,245**	**1,272**	**1,335**	**1,386**
Coal	565	457	446	435	486	539
Lignite	405	347	302	291	287	286
Gas	359	372	432	499	530	539
Oil & diesel	144	93	65	47	31	20
CO_2 emissions by sector	**4,017**	**3,747**	**3,768**	**3,788**	**3,774**	**3,798**
% of 1990 emissions	100%	93%	94%	94%	94%	94%
Industry	655	589	564	540	513	485
Other sectors	732	704	710	727	739	754
Transport	1002	961	981	1000	1018	1035
Electricity & steam generation	1,310	1,134	1,125	1,162	1,239	1,304
District heating	318	359	388	359	265	220
Population (Mill.)	540	558	566	575	578	575
CO_2 emissions per capita (t/capita)	**7.4**	**6.7**	**6.7**	**6.6**	**6.5**	**6.6**

table 13.61: oecd europe: installed capacity

GW	2007	2015	2020	2030	2040	2050
Power plants	**708**	**832**	**870**	**991**	**1,111**	**1,239**
Coal	93	87	80	74	83	95
Lignite	56.7	60.9	54.4	45.8	42.1	38.5
Gas	126	148	151	180	198	215
Oil	35	20	11	6	6	5
Diesel	8.1	7.0	6.0	5.4	4.7	3.8
Nuclear	130.6	122.3	103.8	98.9	94.2	89.4
Biomass	10.5	12.8	14.2	16.5	20.9	24.9
Hydro	185	206	218	232	249	265
Wind	57.1	137.8	184.7	252.4	292.0	338.6
PV	4.7	28.2	41.1	69.8	108.4	148.0
Geothermal	1.5	2.1	2.5	3.1	3.8	4.4
Solar thermal power plants	0.0	0.7	2.7	4.6	5.7	6.8
Ocean energy	0.2	0.3	0.8	2.0	3.4	4.9
Combined heat & power production	**157**	**185**	**183**	**183**	**193**	**206**
Coal	30	35	34	32	33	35
Lignite	16	19	17	15	16	16
Gas	74	85	86	94	101	108
Oil	28	33	28	18	15	13
Biomass	10	14	17	23	28	33
Geothermal	0	0	0	0	0	0
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	102	119	121	123	130	142
Autoproducers	56	66	62	60	62	63
Total generation	**865**	**1,017**	**1,053**	**1,174**	**1,304**	**1,444**
Fossil	465	492	468	471	499	529
Coal	123	121	114	107	116	130
Lignite	72	79	72	61	58	55
Gas	200	232	237	274	299	323
Oil	63	52	39	24	21	18
Diesel	8	7	6	5	5	4
Nuclear	130.6	122.3	103.8	98.9	94.2	89.4
Hydrogen	0	0	0	0	0	0
Renewables	**269**	**402**	**482**	**604**	**711**	**826**
Hydro	185	206	218	232	249	265
Wind	57	138	185	252	292	339
PV	5	28	41	70	108	148
Biomass	20.6	26.8	31.5	39.6	48.5	57.7
Geothermal	2	2	3	3	4	5
Solar thermal	0	1	3	5	6	7
Ocean energy	0	0	1	2	3	5
Fluctuating RES (PV, Wind, Ocean)	62.0	166.4	226.6	324.2	403.9	491.5
Share of fluctuating RES	7.2%	16.4%	21.5%	27.6%	31.0%	34.0%
RES share	**31.1%**	**39.6%**	**45.7%**	**51.4%**	**54.5%**	**57.2%**

table 13.62: oecd europe: primary energy demand

PJ/A	2007	2015	2020	2030	2040	2050
Total	**77,549**	**75,333**	**75,953**	**79,088**	**81,219**	**82,634**
Fossil	**60,081**	**56,226**	**56,738**	**58,079**	**58,389**	**58,337**
Hard coal	10,723	9,254	8,993	8,656	8,964	9,319
Lignite	3,648	3,130	2,722	2,620	2,589	2,580
Natural gas	19,170	19,104	20,422	22,550	23,766	24,469
Crude oil	26,541	24,737	24,600	24,253	23,070	21,970
Nuclear	**10,096**	**9,480**	**8,105**	**7,713**	**7,320**	**6,927**
Renewables	**7,371**	**9,627**	**11,110**	**13,296**	**15,510**	**17,369**
Hydro	1,791	1,969	2,117	2,279	2,441	2,603
Wind	379	1,084	1,508	2,210	2,844	3,420
Solar	70	210	322	590	901	1,173
Biomass	4,681	5,891	6,649	7,623	8,644	9,399
Geothermal	448	471	505	562	627	700
Ocean Energy	2	3	9	31	53	76
RES share	**9.5%**	**12.7%**	**14.6%**	**16.7%**	**18.9%**	**20.8%**

table 13.63: oecd europe: final energy demand

PJ/a	2007	2015	2020	2030	2040	2050
Total (incl. non-energy use)	**54,868**	**54,676**	**56,242**	**59,352**	**62,446**	**65,567**
Total (energy use)	**49,912**	**50,154**	**51,846**	**55,123**	**58,385**	**61,674**
Transport	**14,575**	**14,528**	**15,072**	**15,449**	**15,826**	**16,203**
Oil products	13,894	13,313	13,597	13,856	14,103	14,326
Natural gas	79	94	105	122	139	156
Biofuels	329	795	1,005	1,047	1,095	1,152
Electricity	274	326	366	424	489	569
RES electricity	56	91	117	154	194	239
Hydrogen	0	0	0	0	0	0
RES share Transport	**2.6%**	**6.1%**	**7.4%**	**7.8%**	**8.1%**	**8.6%**
Industry	**14,411**	**14,105**	**14,281**	**14,758**	**15,215**	**15,702**
Electricity	4,504	4,605	4,773	5,066	5,359	5,652
RES electricity	913	1,286	1,524	1,844	2,122	2,368
District heat	1,662	1,624	1,610	1,647	1,665	1,714
RES district heat	330	314	310	291	276	260
Coal	1,358	1,123	1,047	968	889	810
Oil products	1,874	1,656	1,566	1,427	1,290	1,153
Gas	4,182	4,137	4,193	4,259	4,324	4,390
Solar	5	7	10	21	32	44
Biomass and waste	825	951	1,079	1,365	1,647	1,928
Geothermal	1	2	2	5	8	11
Hydrogen	0	0	0	0	0	0
RES share Industry	**14.4%**	**18.2%**	**20.5%**	**23.9%**	**26.9%**	**29.4%**
Other Sectors	**20,926**	**21,521**	**22,493**	**24,916**	**27,344**	**29,768**
Electricity	6,247	6,706	7,169	8,434	9,696	10,955
RES electricity	1,266	1,873	2,288	3,070	3,839	4,590
District heat	1,634	1,804	1,896	2,103	2,313	2,522
RES district heat	325	349	365	372	384	383
Coal	564	480	442	368	241	161
Oil products	3,516	3,227	3,104	2,854	2,605	2,353
Gas	7,302	7,377	7,720	8,482	9,250	10,012
Solar	51	80	110	180	293	365
Biomass and waste	1,515	1,727	1,897	2,276	2,658	3,038
Geothermal	97	119	155	219	289	362
RES share Other Sectors	**15.5%**	**19.3%**	**21.4%**	**24.6%**	**27.3%**	**29.4%**
Total RES	**5,712**	**7,595**	**8,863**	**10,844**	**12,837**	**14,739**
RES share	**11.4%**	**15.1%**	**17.1%**	**19.7%**	**22.0%**	**23.9%**
Non energy use	**4,955**	**4,522**	**4,396**	**4,229**	**4,061**	**3,894**
Oil	4,361	3,979	3,869	3,721	3,574	3,427
Gas	541	494	480	462	443	425
Coal	54	49	48	46	44	42

oecd europe: energy [r]evolution scenario

table 13.64: oecd europe: electricity generation

TWh/a	2007	2015	2020	2030	2040	2050
Power plants	**2,935**	**2,929**	**2,816**	**2,652**	**2,571**	**2,569**
Coal	456	577	319	129	21	7
Lignite	290	273	187	76	14	0
Gas	528	497	523	529	235	30
Oil	57	26	20	8	0	0
Diesel	8	7	5	3	1	0
Nuclear	925	755	420	155	22	0
Biomass	55	68	79	82	80	72
Hydro	498	340	518	519	520	520
Wind	105	320	564	825	1,114	1,255
PV	4	50	140	239	389	435
Geothermal	8	10	11	20	45	65
Solar thermal power plants	0	5	26	55	96	130
Ocean energy	1	1	3	13	34	55
Combined heat & power production	**642**	**694**	**760**	**820**	**888**	**893**
Coal	151	129	53	2	0	0
Lignite	81	34	26	5	0	0
Gas	310	365	421	452	368	258
Oil	45	32	14	7	0	0
Biomass	53	131	239	330	457	548
Geothermal	1	3	8	24	63	87
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	451	485	520	540	553	525
Autoproducers	191	209	240	280	335	368
Total generation	**3,576**	**3,623**	**3,576**	**3,472**	**3,459**	**3,462**
Fossil	1,926	1,940	1,567	1,211	639	295
Coal	608	706	371	131	21	7
Lignite	371	307	213	81	14	0
Gas	838	862	944	981	603	288
Oil	102	58	34	15	0	0
Diesel	8	7	5	3	1	0
Nuclear	925	755	420	155	22	0
Hydrogen	0	0	0	0	0	0
Renewables	**725**	**928**	**1,588**	**2,107**	**2,798**	**3,167**
Hydro	498	340	518	519	520	520
Wind	105	320	564	825	1,114	1,255
PV	4	50	140	239	389	435
Biomass	108	199	318	412	537	620
Geothermal	10	13	19	44	108	152
Solar thermal	0	5	26	55	96	130
Ocean energy	1	1	3	13	34	55
Distribution losses	229	210	210	210	210	210
Own consumption electricity	289	280	275	270	260	250
Electricity for hydrogen production	0	3	40	64	101	102
Final energy consumption (electricity)	**3,063**	**3,151**	**3,090**	**3,103**	**3,348**	**3,730**
Fluctuating RES (PV, Wind, Ocean)	110	371	707	1,077	1,537	1,745
Share of fluctuating RES	3.1%	10.2%	19.8%	31.0%	44.4%	50.4%
RES share	**20.3%**	**25.6%**	**44.4%**	**60.7%**	**80.9%**	**91.5%**
'Efficiency' savings (compared to Ref.)	**0**	**108**	**367**	**874**	**1,360**	**1,850**

table 13.65: oecd europe: heat supply

PJ/A	2007	2015	2020	2030	2040	2050
District heating plants	**1,249**	**1,545**	**1,730**	**1,836**	**2,215**	**2,509**
Fossil fuels	936	1,066	1,081	716	266	50
Biomass	306	371	432	496	554	577
Solar collectors	0	62	121	422	1,019	1,380
Geothermal	6	46	95	202	376	502
Heat from CHP	**2,205**	**2,486**	**2,779**	**2,998**	**3,232**	**3,382**
Fossil fuels	1,901	1,857	1,708	1,610	1,299	940
Biomass	291	599	1,001	1,170	1,363	1,657
Geothermal	13	31	71	219	569	785
Fuel cell (hydrogen)	0	0	0	0	0	0
Direct heating[1]	**19,057**	**17,430**	**16,899**	**15,784**	**14,763**	**13,955**
Fossil fuels	16,793	14,397	12,976	10,487	7,808	6,548
Biomass	2,105	2,440	2,716	2,626	2,065	1,659
Solar collectors	56	247	582	1,669	3,063	3,443
Geothermal	102	347	624	1,001	1,827	2,305
Total heat supply[1]	**22,510**	**21,461**	**21,407**	**20,618**	**20,210**	**19,846**
Fossil fuels	19,631	17,319	15,765	12,813	9,373	7,538
Biomass	2,702	3,409	4,150	4,291	3,982	3,893
Solar collectors	56	309	703	2,091	4,082	4,823
Geothermal	121	424	790	1,422	2,773	3,591
Fuel cell (hydrogen)	0	0	0	0	0	0
RES share (including RES electricity)	**12.8%**	**19%**	**26%**	**38%**	**54%**	**62%**
'Efficiency' savings (compared to Ref.)	**0**	**917**	**1,555**	**3,703**	**5,510**	**7,211**

1) heat from electricity (direct and from electric heat pumps) not included; covered in the model under 'electric appliances'

table 13.66: oecd europe: CO_2 emissions

MILL t/a	2007	2015	2020	2030	2040	2050
Condensation power plants	**975**	**967**	**652**	**390**	**120**	**16**
Coal	409	471	245	96	15	5
Lignite	306	266.1	171.8	67.5	12.4	0.0
Gas	212	205	215	218	91	10
Oil	41	18.9	14.8	5.9	0.0	0.0
Diesel	7.5	6.6	4.6	2.6	0.8	0.0
Combined heat & power production	**498**	**386**	**294**	**233**	**173**	**112**
Coal	156	125	49	1	0	0
Lignite	99	31	20	4	0	0
Gas	147	175	206	220	173	112
Oil	95	55	20	8	0	0
CO_2 emissions electricity & steam generation	**1,472**	**1,353**	**946**	**623**	**293**	**128**
Coal	565	596	294	97	15	5
Lignite	405	297	192	72	12	0
Gas	359	379	421	438	264	122
Oil & diesel	144	81	39	16	1	0
CO_2 emissions by sector	**4,017**	**3,642**	**2,947**	**2,209**	**1,360**	**850**
% of 1990 emissions	**100%**	**91%**	**73%**	55%	34%	21%
Industry	655	535	450	374	264	204
Other sectors	732	622	565	434	325	273
Transport	1002	943	863	717	477	277
Electricity & steam generation	1,310	1,231	845	528	211	64
District heating	318	312	224	156	82	32
Population (Mill.)	540	558	566	575	578	575
CO_2 emissions per capita (t/capita)	**7.4**	**6.5**	**5.2**	**3.8**	**2.4**	**1.5**

table 13.67: oecd europe: installed capacity

GW	2007	2015	2020	2030	2040	2050
Power plants	**708**	**787**	**896**	**941**	**1,050**	**1,072**
Coal	93	132	67	26	5	2
Lignite	56.7	59	39	14	2	0
Gas	126	124	122	124	78	15
Oil	35	23	17	4	0	0
Diesel	8.1	7	5	3	1	0
Nuclear	130.6	106	59	22	3	0
Biomass	10.5	13	15	15	12	10
Hydro	185	128	192	190	191	191
Wind	57.1	147	249	340	413	448
PV	4.7	44	120	179	301	348
Geothermal	1.5	2	2	4	8	12
Solar thermal power plants	0.0	2	9	17	27	33
Ocean energy	0.2	0	1	3	8	13
Combined heat & power production	**157**	**182**	**176**	**181**	**185**	**180**
Coal	30	29	11	0	0	0
Lignite	16	8	5	1	0	0
Gas	74	93	101	109	88	60
Oil	28	27	12	4	0	0
Biomass	10	25	45	61	85	103
Geothermal	0	1	2	5	13	17
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	102	117	116	117	114	104
Autoproducers	56	65	59	64	71	76
Total generation	**865**	**969**	**1,072**	**1,122**	**1,235**	**1,252**
Fossil	465	502	379	287	174	78
Coal	123	161	78	26	5	2
Lignite	72	67	45	15	2	0
Gas	200	217	223	234	166	75
Oil	63	50	29	9	0	0
Diesel	8	7	5	3	1	0
Nuclear	130.6	106	59	22	3	0
Hydrogen	0	0	0	0	0	0
Renewables	**269**	**361**	**634**	**814**	**1,058**	**1,175**
Hydro	185	128	192	190	191	191
Wind	57	147	249	340	413	448
PV	5	44	120	179	301	348
Biomass	20.6	38	59	76	97	113
Geothermal	2	2	4	8	21	29
Solar thermal	0	2	9	17	27	33
Ocean energy	0	0	1	3	8	13
Fluctuating RES (PV, Wind, Ocean)	62.0	191	370	522	722	809
Share of fluctuating RES	7.2%	19.7%	34.5%	46.5%	58.4%	64.6%
RES share	**31.1%**	**37.3%**	**59.1%**	**72.5%**	**85.6%**	**93.8%**

table 13.68: oecd europe: primary energy demand

PJ/A	2007	2015	2020	2030	2040	2050
Total	**77,549**	**73,275**	**66,798**	**59,172**	**50,812**	**45,390**
Fossil	**60,081**	**54,805**	**47,688**	**38,510**	**25,563**	**17,557**
Hard coal	10,723	9,719	5,967	3,089	1,454	914
Lignite	3,648	2,676	1,726	645	112	0
Natural gas	19,170	18,342	18,488	17,712	12,587	8,961
Crude oil	26,541	24,067	21,507	17,063	11,410	7,682
Nuclear	**10,096**	**8,236**	**4,582**	**1,691**	**240**	**0**
Renewables	**7,371**	**10,234**	**14,528**	**18,971**	**25,010**	**27,833**
Hydro	1,791	1,224	1,865	1,868	1,872	1,872
Wind	379	1,152	2,030	2,970	4,010	4,518
Solar	70	507	1,301	3,150	5,828	6,857
Biomass	4,681	6,626	8,157	8,711	8,643	8,532
Geothermal	448	721	1,163	2,224	4,534	5,856
Ocean Energy	2	4	12	47	122	198
RES share	**9.5%**	**14.0%**	**21.9%**	**32.6%**	**50.5%**	**63.4%**
'Efficiency' savings (compared to Ref.)	**0**	**2,140**	**9,151**	**19,438**	**28,963**	**34,614**

table 13.69: oecd europe: final energy demand

PJ/a	2007	2015	2020	2030	2040	2050
Total (incl. non-energy use)	**54,868**	**53,036**	**51,469**	**48,230**	**44,879**	**42,749**
Total (energy use)	**49,912**	**48,515**	**47,073**	**44,001**	**40,818**	**38,855**
Transport	**14,575**	**14,396**	**13,581**	**12,025**	**9,991**	**8,848**
Oil products	13,894	13,053	11,894	9,879	6,543	3,772
Natural gas	79	109	171	170	169	163
Biofuels	329	808	911	996	1,121	1,158
Electricity	274	419	505	818	1,894	3,480
RES electricity	56	107	224	496	1,532	3,183
Hydrogen	0	7	99	162	264	276
RES share Transport	**2.6%**	**6.4%**	**8.7%**	**13.2%**	**28.7%**	**51.9%**
Industry	**14,411**	**13,487**	**13,192**	**12,769**	**12,362**	**12,095**
Electricity	4,504	4,467	4,355	4,228	4,143	4,068
RES electricity	913	1,145	1,934	2,565	3,352	3,722
District heat	1,662	1,548	1,581	1,774	2,125	2,369
RES district heat	330	464	642	986	1,627	2,121
Coal	1,358	1,001	684	558	250	22
Oil products	1,874	1,419	1,041	571	131	40
Gas	4,182	3,919	3,845	3,425	2,876	2,594
Solar	5	106	262	580	994	1,172
Biomass and waste	825	927	1,166	1,169	995	757
Geothermal	1	100	259	463	846	1,073
Hydrogen	0	0	0	0	0	0
RES share Industry	**14.4%**	**20.3%**	**32.3%**	**45.1%**	**63.2%**	**73.1%**
Other Sectors	**20,926**	**20,632**	**20,299**	**19,207**	**18,465**	**17,911**
Electricity	6,247	6,456	6,266	6,124	6,017	5,879
RES electricity	1,266	1,654	2,783	3,715	4,867	5,378
District heat	1,634	2,233	2,648	2,759	2,986	3,176
RES district heat	325	669	1,074	1,533	2,286	2,843
Coal	564	128	113	58	41	27
Oil products	3,516	3,307	2,887	1,574	745	358
Gas	7,302	6,371	5,918	5,430	4,559	4,177
Solar	51	141	320	1,089	2,069	2,271
Biomass and waste	1,515	1,785	1,853	1,749	1,299	1,086
Geothermal	97	211	296	424	749	937
RES share Other Sectors	**15.5%**	**21.6%**	**31.2%**	**44.3%**	**61.0%**	**69.9%**
Total RES	**5,712**	**8,119**	**11,769**	**15,864**	**21,952**	**25,953**
RES share	**11.4%**	**16.7%**	**25.0%**	**36.1%**	**53.8%**	**66.8%**
Non energy use	**4,955**	**4,522**	**4,396**	**4,229**	**4,061**	**3,894**
Oil	4,361	3,979	3,869	3,721	3,574	3,427
Gas	541	494	480	462	443	425
Coal	54	49	48	46	44	42

oecd europe: advanced energy [r]evolution

table 13.70: oecd europe: electricity generation

TWh/a	2007	2015	2020	2030	2040	2050
Power plants	**2,935**	**2,930**	**2,827**	**2,860**	**3,018**	**3,518**
Coal	456	401	305	29	9	0
Lignite	290	272	172	51	2	0
Gas	528	497	504	478	172	18
Oil	57	26	20	8	0	0
Diesel	8	7	5	3	1	0
Nuclear	925	755	420	118	22	0
Biomass	55	68	71	72	71	69
Hydro	498	517	518	519	520	520
Wind	105	320	564	938	1,186	1,352
PV	4	50	161	294	477	637
Geothermal	8	10	30	144	183	290
Solar thermal power plants	0	6	46	143	265	451
Ocean energy	1	1	10	63	110	181
Combined heat & power production	**642**	**694**	**760**	**820**	**775**	**715**
Coal	151	129	58	3	0	0
Lignite	81	34	21	3	0	0
Gas	310	365	421	428	242	76
Oil	45	32	14	7	0	0
Biomass	53	131	239	340	426	452
Geothermal	1	3	8	39	106	167
Hydrogen	0	0	0	0	1	20
CHP by producer						
Main activity producers	451	485	520	540	525	485
Autoproducers	191	209	240	280	250	230
Total generation	**3,576**	**3,624**	**3,587**	**3,680**	**3,793**	**4,233**
Fossil	1,926	1,763	1,520	1,009	426	94
Coal	608	530	363	32	9	0
Lignite	371	306	193	54	2	0
Gas	838	862	925	906	414	94
Oil	102	58	34	15	0	0
Diesel	8	7	5	3	1	0
Nuclear	925	755	420	118	22	0
Hydrogen	0	0	0	0	1	20
Renewables	**725**	**1,106**	**1,647**	**2,552**	**3,344**	**4,119**
Hydro	498	517	518	519	520	520
Wind	105	320	564	938	1,186	1,352
PV	4	50	161	294	477	637
Biomass	108	199	310	412	497	521
Geothermal	10	13	38	183	289	457
Solar thermal	0	6	46	143	265	451
Ocean energy	1	1	10	63	110	181
Distribution losses	229	210	210	210	210	210
Own consumption electricity	289	280	265	240	200	185
Electricity for hydrogen production	0	3	40	62	146	293
Final energy consumption (electricity)	**3,063**	**3,151**	**3,112**	**3,342**	**3,697**	**4,375**
Fluctuating RES (PV, Wind, Ocean)	110	371	735	1,295	1,773	2,170
Share of fluctuating RES	3.1%	10.2%	20.5%	35.2%	46.7%	51.3%
RES share	**20.3%**	**30.5%**	**45.9%**	**69.4%**	**88.2%**	**97.3%**
'Efficiency' savings (compared to Ref.)	**0**	**108**	**366**	**864**	**1,343**	**1,793**

table 13.71: oecd europe: heat supply

PJ/A	2007	2015	2020	2030	2040	2050
District heating plants	**1,249**	**1,543**	**1,844**	**2,005**	**2,751**	**3,436**
Fossil fuels	936	1,065	1,153	782	330	0
Biomass	306	370	461	541	660	756
Solar collectors	0	62	129	461	1,293	1,993
Geothermal	6	46	101	220	468	687
Heat from CHP	**2,205**	**2,486**	**2,783**	**3,103**	**3,201**	**3,199**
Fossil fuels	1,901	1,857	1,711	1,579	853	273
Biomass	291	599	1,001	1,170	1,392	1,364
Geothermal	13	31	71	353	953	1,501
Fuel cell (hydrogen)	0	0	0	1	4	62
Direct heating[1]	**19,057**	**17,431**	**16,780**	**15,510**	**14,158**	**12,612**
Fossil fuels	16,793	14,392	12,860	9,614	5,763	1,217
Biomass	2,105	2,446	2,709	2,592	2,427	2,285
Solar collectors	56	247	582	2,158	3,295	4,770
Geothermal	102	347	629	1,146	2,700	4,340
Total heat supply[1]	**22,510**	**21,461**	**21,407**	**20,618**	**20,210**	**19,846**
Fossil fuels	19,631	17,314	15,724	11,975	6,919	1,490
Biomass	2,702	3,415	4,171	4,303	4,479	4,405
Solar collectors	56	309	711	2,619	4,588	6,763
Geothermal	121	423	802	1,719	4,121	6,529
Fuel cell (hydrogen)	0	0	0	1	103	660
RES share (including RES electricity)	**12.8%**	**19.3%**	**26.5%**	**41.9%**	**65.7%**	**92.4%**
'Efficiency' savings (compared to Ref.)	**0**	**917**	**1,555**	**3,703**	**5,510**	**7,211**

1) heat from electricity (direct and from electric heat pumps) not included; covered in the model under 'electric appliances'

table 13.72: oecd europe: CO_2 emissions

MILL t/a	2007	2015	2020	2030	2040	2050
Condensation power plants	**975**	**823**	**620**	**272**	**76**	**6**
Coal	409	327	235	22	7	0
Lignite	306	265	158	45	2	0
Gas	212	205	207	196	67	6
Oil	41	19	15	6	0	0
Diesel	7.5	7	5	3	1	0
Combined heat & power production	**498**	**386**	**295**	**227**	**114**	**33**
Coal	156	125	53	2	0	0
Lignite	99	31	16	2	0	0
Gas	147	175	206	215	114	33
Oil	95	55	20	8	0	0
CO_2 emissions electricity & steam generation	**1,472**	**1,208**	**915**	**499**	**190**	**39**
Coal	565	452	288	24	7	0
Lignite	405	296	174	48	2	0
Gas	359	379	413	411	180	39
Oil & diesel	144	81	39	17	1	0
CO_2 emissions by sector	**4,017**	**3,488**	**2,908**	**1,931**	**948**	**205**
% of 1990 emissions	100%	87%	72%	48%	24%	5%
Industry	655	535	440	344	195	58
Other sectors	732	625	571	399	244	61
Transport	1002	943	858	633	321	64
Electricity & steam generation	1,310	1,086	814	411	135	18
District heating	318	300	225	145	53	3
Population (Mill.)	540	558	566	575	578	575
CO_2 emissions per capita (t/capita)	**7.4**	**6.3**	**5.1**	**3.4**	**1.6**	**0.4**

table 13.73: oecd europe: installed capacity

GW	2007	2015	2020	2030	2040	2050
Power plants	**708**	**814**	**921**	**1,054**	**1,200**	**1,398**
Coal	93	92	64	6	2	0
Lignite	56.7	59	36	9	0	0
Gas	126	124	124	119	51	9
Oil	35	23	17	4	0	0
Diesel	8.1	7	5	3	1	0
Nuclear	130.6	106	59	17	3	0
Biomass	10.5	13	13	13	11	10
Hydro	185	195	192	190	191	191
Wind	57.1	147	249	386	439	483
PV	4.7	44	138	221	369	510
Geothermal	1.5	2	6	26	33	53
Solar thermal power plants	0.0	2	15	44	74	100
Ocean energy	0.2	0	3	15	26	42
Combined heat & power production	**157**	**182**	**176**	**180**	**158**	**139**
Coal	30	29	12	0	0	0
Lignite	16	8	4	0	0	0
Gas	74	93	101	104	58	18
Oil	28	27	12	4	0	0
Biomass	10	25	45	63	79	84
Geothermal	0	1	2	8	21	33
Hydrogen	0	0	0	0	0	4
CHP by producer						
Main activity producers	102	117	116	116	105	93
Autoproducers	56	65	59	63	53	47
Total generation	**865**	**996**	**1,097**	**1,234**	**1,358**	**1,537**
Fossil	465	461	376	251	112	27
Coal	123	121	76	6	2	0
Lignite	72	67	40	10	0	0
Gas	200	217	226	223	108	27
Oil	63	50	29	9	0	0
Diesel	8	7	5	3	1	0
Nuclear	130.6	106	59	17	3	0
Hydrogen	0	0	0	0	0	4
Renewables	**269**	**428**	**663**	**966**	**1,243**	**1,506**
Hydro	185	195	192	190	191	191
Wind	57	147	249	386	439	483
PV	5	44	138	221	369	510
Biomass	20.6	38	58	76	90	94
Geothermal	2	2	7	34	55	86
Solar thermal	0	2	15	44	74	100
Ocean energy	0	0	3	15	26	42
Fluctuating RES (PV, Wind, Ocean)	62.0	191	390	622	834	1,035
Share of fluctuating RES	7.2%	19.2%	35.6%	50.4%	61.4%	67.3%
RES share	**31.1%**	**43.0%**	**60.4%**	**78.3%**	**91.5%**	**98.0%**

table 13.74: oecd europe: primary energy demand

PJ/A	2007	2015	2020	2030	2040	2050
Total	**77,549**	**72,095**	**66,504**	**59,077**	**50,784**	**46,754**
Fossil	**60,081**	**53,032**	**46,958**	**34,660**	**19,291**	**7,262**
Hard coal	10,723	7,865	5,540	1,644	765	231
Lignite	3,648	2,668	1,566	428	16	0
Natural gas	19,170	18,433	18,533	17,173	9,595	2,613
Crude oil	26,541	24,066	21,319	15,414	8,915	4,418
Nuclear	**10,096**	**8,236**	**4,582**	**1,287**	**240**	**0**
Renewables	**7,371**	**10,827**	**14,964**	**23,130**	**31,252**	**39,492**
Hydro	1,791	1,861	1,865	1,868	1,872	1,872
Wind	379	1,152	2,030	3,377	4,270	4,867
Solar	70	510	1,456	4,192	7,259	10,680
Biomass	4,681	6,579	7,993	8,564	8,841	8,625
Geothermal	448	721	1,584	4,901	8,615	12,797
Ocean Energy	2	4	36	227	396	652
RES share	**9.5%**	**15.0%**	**22.6%**	**39.6%**	**62.4%**	**85.1%**
'Efficiency' savings (compared to Ref.)	**0**	**3,214**	**9,446**	**19,533**	**28,992**	**33,250**

table 13.75: oecd europe: final energy demand

PJ/a	2007	2015	2020	2030	2040	2050
Total (incl. non-energy use)	**54,868**	**53,037**	**51,470**	**47,932**	**43,790**	**41,264**
Total (energy use)	**49,912**	**48,515**	**47,074**	**43,703**	**39,729**	**37,371**
Transport	**14,575**	**14,396**	**13,581**	**11,725**	**8,891**	**7,348**
Oil products	13,894	13,054	11,829	8,712	4,387	887
Natural gas	79	104	166	155	122	10
Biofuels	329	809	908	1,062	1,064	1,121
Electricity	274	422	579	1,639	2,934	4,540
RES electricity	56	129	266	1,137	2,587	4,418
Hydrogen	0	7	99	157	384	790
RES share Transport	**2.6%**	**6.5%**	**9.0%**	**19.7%**	**44.9%**	**85.8%**
Industry	**14,411**	**13,487**	**13,192**	**12,779**	**12,311**	**12,044**
Electricity	4,504	4,467	4,357	4,237	4,184	4,124
RES electricity	913	1,364	2,001	2,939	3,689	4,013
District heat	1,662	1,548	1,696	2,021	2,303	2,602
RES district heat	330	464	686	1,142	1,930	2,552
Coal	1,358	1,001	638	400	281	21
Oil products	1,874	1,419	955	436	108	16
Gas	4,182	3,919	3,853	3,445	2,019	688
Solar	5	106	263	582	1,045	1,462
Biomass and waste	825	927	1,169	1,172	1,145	1,046
Geothermal	1	100	263	485	1,122	1,462
Hydrogen	0	0	0	0	104	624
RES share Industry	**14.4%**	**22.0%**	**33.2%**	**49.5%**	**73.3%**	**92.5%**
Other Sectors	**20,926**	**20,632**	**20,300**	**19,199**	**18,527**	**17,978**
Electricity	6,247	6,456	6,265	6,151	6,035	6,027
RES electricity	1,266	1,971	2,877	4,266	5,321	5,865
District heat	1,634	2,232	2,645	2,764	3,310	3,715
RES district heat	325	669	1,070	1,562	2,773	3,644
Coal	564	203	263	140	0	0
Oil products	3,516	3,306	2,865	1,360	558	68
Gas	7,302	6,300	5,797	4,945	3,507	932
Solar	51	141	319	1,576	2,250	3,308
Biomass and waste	1,515	1,784	1,851	1,752	1,579	1,548
Geothermal	97	211	295	510	1,287	2,380
RES share Other Sectors	**15.5%**	**23.1%**	**31.6%**	**50.4%**	**71.3%**	**93.1%**
Total RES	**5,712**	**8,676**	**12,012**	**18,295**	**26,221**	**34,193**
RES share	**11.4%**	**17.9%**	**25.5%**	**41.9%**	**66.0%**	**91.5%**
Non energy use	**4,955**	**4,522**	**4,396**	**4,229**	**4,061**	**3,894**
Oil	4,361	3,979	3,869	3,721	3,574	3,427
Gas	541	494	480	462	443	425
Coal	54	49	48	46	44	42

oecd europe: total new investment by technology

table 13.76: oecd europe: total investment

MILLION $	2005-2010	2011-2020	2021-2030	2005-2030
Reference scenario				
Conventional (fossil & nuclear)	**174,106**	**184,345**	**84,312**	**442,764**
Renewables	**251,168**	**844,297**	**429,434**	**1,524,899**
Biomass	45,944	62,043	51,847	159,834
Hydro	82,210	230,606	85,610	398,425
Wind	65,576	241,641	137,656	444,873
PV	41,494	253,283	93,874	388,651
Geothermal	13,640	8,280	17,546	39,466
Solar thermal power plants	1,204	45,455	38,098	84,758
Ocean energy	1,101	2,988	4,804	8,893
Energy [R]evolution				
	174,106	**160,718**	**72,082**	**406,906**
Conventional (fossil & nuclear)	**251,168**	**969,733**	**489,757**	**1,710,658**
Renewables	45,944	173,628	84,960	304,532
Biomass	82,210	230,606	85,610	398,425
Hydro	65,576	241,641	137,656	444,873
Wind	41,494	253,283	93,874	388,651
PV	13,640	22,131	44,756	80,527
Geothermal	1,204	45,455	38,098	84,758
Solar thermal power plants	1,101	2,988	4,804	8,893
Ocean energy				
Advanced Energy [R]evolution	**174,106**	**112,971**	**57,306**	**344,383**
	251,168	**934,186**	**873,664**	**2,059,018**
Conventional (fossil & nuclear)	45,944	169,940	90,744	306,629
Renewables	82,210	84,163	85,610	251,982
Biomass	65,576	241,641	185,812	493,030
Hydro	41,494	291,249	125,614	458,356
Wind	13,640	56,380	225,708	295,728
PV	1,204	80,695	132,279	214,178
Geothermal	1,101	10,117	27,898	39,116
Solar thermal power plants				
Ocean energy				

notes

africa: reference scenario

table 13.77: africa: electricity generation

TWh/a	2007	2015	2020	2030	2040	2050
Power plants	**615**	**789**	**877**	**1,168**	**1,458**	**1,751**
Coal	267	284	279	383	483	581
Lignite	0	0	0	0	0	0
Gas	170	289	324	372	420	470
Oil	59	41	42	27	14	5
Diesel	9	7	6	5	4	3
Nuclear	11	11	18	27	36	45
Biomass	1	15	24	42	60	78
Hydro	96	131	161	242	323	404
Wind	1	4	8	24	40	56
PV	0	4	9	33	56	74
Geothermal	1	3	4	8	12	16
Solar thermal power plants	0	0	1	5	10	20
Ocean energy	0	0	0	0	0	0
Combined heat & power production	**0**	**3**	**10**	**32**	**55**	**75**
Coal	0	2	5	20	36	51
Lignite	0	0	0	0	0	0
Gas	0	1	4	10	16	20
Oil	0	0	1	1	1	0
Biomass	0	0	0	1	2	3
Geothermal	0	0	0	0	0	0
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	0	0	0	0	0	0
Autoproducers	0	3	10	32	55	75
Total generation	**615**	**792**	**887**	**1,200**	**1,513**	**1,826**
Fossil	505	624	662	818	974	1,130
Coal	267	286	285	403	519	632
Lignite	0	0	0	0	0	0
Gas	170	290	328	382	436	490
Oil	59	41	43	28	15	5
Diesel	9	7	6	5	4	3
Nuclear	11	11	18	27	36	45
Hydrogen	0	0	0	0	0	0
Renewables	**99**	**157**	**207**	**355**	**503**	**651**
Hydro	96	131	161	242	323	404
Wind	1	4	8	24	40	56
PV	0	4	9	33	56	74
Biomass	1	15	24	43	62	81
Geothermal	1	3	4	8	12	16
Solar thermal	0	0	1	5	10	20
Ocean energy	0	0	0	0	0	0
Distribution losses	68	83	90	111	131	152
Own consumption electricity	46	57	61	75	90	104
Electricity for hydrogen production	0	0	0	0	0	0
Final energy consumption (electricity)	**504**	**656**	**740**	**1,020**	**1,300**	**1,580**
Fluctuating RES (PV, Wind, Ocean)	1	8	17	57	96	130
Share of fluctuating RES	0.2%	1.0%	1.9%	4.8%	6.3%	7.1%
RES share	**16.0%**	**19.8%**	**23.3%**	**29.6%**	**33.2%**	**35.6%**

table 13.78: africa: heat supply

PJ/A	2007	2015	2020	2030	2040	2050
District heating plants	**0**	**0**	**0**	**0**	**0**	**0**
Fossil fuels	0	0	0	0	0	0
Biomass	0	0	0	0	0	0
Solar collectors	0	0	0	0	0	0
Geothermal	0	0	0	0	0	0
Heat from CHP	**0**	**15**	**45**	**120**	**198**	**245**
Fossil fuels	0	15	44	116	190	234
Biomass	0	0	1	4	8	11
Geothermal	0	0	0	0	0	0
Fuel cell (hydrogen)	0	0	0	0	0	0
Direct heating[1]	**10,123**	**10,858**	**11,351**	**12,170**	**13,677**	**15,199**
Fossil fuels	2,559	2,848	2,945	3,351	3,957	4,564
Biomass	7,563	8,002	8,394	8,791	9,674	10,569
Solar collectors	1	7	11	28	47	66
Geothermal	0	0	0	0	0	0
Total heat supply[1]	**10,123**	**10,873**	**11,396**	**12,290**	**13,875**	**15,445**
Fossil fuels	2,559	2,863	2,989	3,467	4,147	4,798
Biomass	7,563	8,003	8,396	8,795	9,682	10,580
Solar collectors	1	7	11	28	47	66
Geothermal	0	0	0	0	0	0
Fuel cell ((hydrogen)	0	0	0	0	0	0
RES share (including RES electricity)	**74.7%**	**73.7%**	**73.8%**	**71.8%**	**70.1%**	**68.9%**

1) heat from electricity (direct and from electric heat pumps) not included; covered in the model under 'electric appliances'

table 13.79: africa: CO_2 emissions

MILL t/a	2007	2015	2020	2030	2040	2050
Condensation power plants	**392**	**451**	**465**	**546**	**601**	**640**
Coal	245	261	256	329	385	432
Lignite	0	0	0	0	0	0
Gas	90	149	168	192	202	201
Oil	39	34	36	21	11	4
Diesel	17	7	6	4	3	2
Combined heat & power production	**0**	**2**	**7**	**19**	**34**	**44**
Coal	0	1	4	14	27	35
Lignite	0	0	0	0	0	0
Gas	0	1	2	4	7	8
Oil	0	0	0	1	0	0
CO_2 emissions electricity & steam generation	**392**	**453**	**472**	**566**	**635**	**684**
Coal	245	262	261	343	412	468
Lignite	0	0	0	0	0	0
Gas	90	150	169	197	209	210
Oil & diesel	56	41	42	26	14	6
CO_2 emissions by sector	**881**	**1,002**	**1,060**	**1,264**	**1,447**	**1,622**
% of 1990 emissions	161%	183%	194%	231%	265%	297%
Industry	116	134	143	173	220	261
Other sectors	114	123	126	142	161	179
Transport	200	219	241	325	408	490
Electricity & steam generation	392	451	465	546	601	640
District heating	59	75	84	78	58	52
Population (Mill.)	965	1,153	1,276	1,524	1,770	1,998
CO_2 emissions per capita (t/capita)	**0.9**	**0.9**	**0.8**	**0.8**	**0.8**	**0.8**

table 13.80: africa: installed capacity

GW	2007	2015	2020	2030	2040	2050
Power plants	**128**	**178**	**200**	**266**	**326**	**382**
Coal	41	53	52	65	82	98
Lignite	0	0	0	0	0	0
Gas	38	62	70	87	96	104
Oil	17	18	18	14	8	3
Diesel	7	5	4	4	4	3
Nuclear	2	2	3	4	5	6
Biomass	0	3	4	7	10	13
Hydro	23	32	40	61	81	101
Wind	1	2	3	8	12	16
PV	0	2	4	15	25	32
Geothermal	0	1	1	1	2	3
Solar thermal power plants	0	0	0	1	1	3
Ocean energy	0	0	0	0	0	0
Combined heat & power production	**0**	**1**	**3**	**7**	**11**	**15**
Coal	0	0	1	4	7	9
Lignite	0	0	0	0	0	0
Gas	0	0	1	2	4	5
Oil	0	0	0	1	0	0
Biomass	0	0	0	0	0	1
Geothermal	0	0	0	0	0	0
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	0	0	0	0	0	0
Autoproducers	0	1	3	7	11	15
Total generation	**128**	**179**	**202**	**273**	**337**	**397**
Fossil	103	138	147	176	200	223
Coal	41	53	53	68	88	108
Lignite	0	0	0	0	0	0
Gas	38	62	71	89	99	109
Oil	17	18	19	14	9	3
Diesel	7	5	4	4	4	3
Nuclear	2	2	3	4	5	6
Hydrogen	0	0	0	0	0	0
Renewables	**24**	**39**	**52**	**93**	**132**	**168**
Hydro	23	32	40	61	81	101
Wind	1	2	3	8	12	16
PV	0	2	4	15	25	32
Biomass	0	3	4	7	10	13
Geothermal	0	1	1	1	2	3
Solar thermal	0	0	0	1	1	3
Ocean energy	0	0	0	0	0	0
Fluctuating RES (PV, Wind, Ocean)	1	4	7	23	37	48
Share of fluctuating RES	0.4%	2.1%	3.5%	8.3%	11.0%	12.1%
RES share	**18.5%**	**21.9%**	**25.8%**	**34.1%**	**39.2%**	**42.3%**

table 13.81: africa: primary energy demand

PJ/A	2007	2015	2020	2030	2040	2050
Total	**26,355**	**29,581**	**31,203**	**35,411**	**39,439**	**43,173**
Fossil	**13,456**	**15,355**	**16,112**	**18,879**	**21,386**	**23,517**
Hard coal	4,330	4,567	4,559	5,483	6,299	6,977
Lignite	0	0	0	0	0	0
Natural gas	3,472	4,894	5,300	5,895	6,240	6,338
Crude oil	5,654	5,894	6,254	7,501	8,847	10,202
Nuclear	**123**	**120**	**196**	**295**	**393**	**491**
Renewables	**12,776**	**14,106**	**14,895**	**16,237**	**17,661**	**19,164**
Hydro	344	472	580	871	1,163	1,454
Wind	4	14	29	86	144	202
Solar	1	22	47	165	284	405
Biomass	12,390	13,522	14,152	14,982	15,909	16,924
Geothermal	37	77	86	132	161	180
Ocean Energy	0	0	0	0	0	0
RES share	**48.4%**	**47.8%**	**47.9%**	**46.0%**	**45.1%**	**45.0%**

table 13.82: africa: final energy demand

PJ/a	2007	2015	2020	2030	2040	2050
Total (incl. non-energy use)	**19,355**	**21,741**	**23,116**	**26,679**	**30,839**	**34,965**
Total (energy use)	**18,782**	**21,113**	**22,488**	**26,009**	**30,127**	**34,212**
Transport	**2,851**	**3,140**	**3,475**	**4,647**	**5,820**	**6,992**
Oil products	2,773	3,032	3,326	4,483	5,635	6,778
Natural gas	61	69	81	85	89	93
Biofuels	0	21	42	50	63	84
Electricity	17	18	27	30	33	36
RES electricity	3	4	6	9	11	13
Hydrogen	0	0	0	0	0	0
RES share Transport	**0.1%**	**0.8%**	**1.4%**	**1.3%**	**1.3%**	**1.4%**
Industry	**3,539**	**4,039**	**4,279**	**5,125**	**6,310**	**7,464**
Electricity	822	1,005	1,089	1,424	1,758	2,093
RES electricity	132	199	254	421	585	746
District heat	0	15	45	120	198	245
RES district heat	0	0	0	0	0	0
Coal	347	369	381	418	493	566
Oil products	603	678	707	796	959	1,121
Gas	693	827	852	985	1,211	1,439
Solar	0	0	0	0	0	0
Biomass and waste	1,074	1,145	1,206	1,383	1,691	1,999
Geothermal	0	0	0	0	0	0
Hydrogen	0	0	0	0	0	0
RES share Industry	**34.1%**	**33.3%**	**34.1%**	**35.2%**	**36.1%**	**36.8%**
Other Sectors	**12,392**	**13,934**	**14,734**	**16,236**	**17,998**	**19,756**
Electricity	977	1,340	1,549	2,219	2,889	3,559
RES electricity	157	266	362	657	960	1,269
District heat	0	0	0	0	0	0
RES district heat	0	0	0	0	0	0
Coal	230	257	252	249	249	248
Oil products	1,058	1,139	1,158	1,309	1,486	1,665
Gas	235	253	296	381	473	567
Solar	1	7	11	28	47	66
Biomass and waste	9,890	10,937	11,468	12,050	12,854	13,651
Geothermal	0	0	0	0	0	0
RES share Other Sectors	**81.1%**	**80.5%**	**80.4%**	**78.4%**	**77.0%**	**75.9%**
Total RES	**11,256**	**12,579**	**13,349**	**14,598**	**16,210**	**17,829**
RES share	**59.9%**	**59.6%**	**59.4%**	**56.1%**	**53.8%**	**52.1%**
Non energy use	**573**	**628**	**628**	**670**	**712**	**754**
Oil	274	301	301	321	341	361
Gas	245	269	269	287	305	323
Coal	53	58	58	62	66	70

africa: energy [r]evolution scenario

table 13.83: africa: electricity generation

TWh/a	2007	2015	2020	2030	2040	2050
Power plants	**615**	**784**	**864**	**1,092**	**1,592**	**2,135**
Coal	267	282	280	275	269	126
Lignite	0	0	0	0	0	0
Gas	170	283	285	285	283	248
Oil	59	41	30	16	10	2
Diesel	9	7	5	4	4	3
Nuclear	11	8	8	0	0	0
Biomass	1	17	19	19	20	20
Hydro	96	128	150	175	190	195
Wind	1	9	31	71	118	153
PV	0	6	29	125	242	415
Geothermal	1	3	4	6	9	11
Solar thermal power plants	0	1	22	110	437	948
Ocean energy	0	0	2	6	10	15
Combined heat & power production	**0**	**10**	**34**	**95**	**142**	**169**
Coal	0	6	17	46	66	74
Lignite	0	0	0	0	0	0
Gas	0	2	9	25	39	47
Oil	0	0	0	0	0	0
Biomass	0	1	5	14	22	27
Geothermal	0	0	3	10	16	21
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	0	2	4	10	17	19
Autoproducers	0	8	30	85	125	150
Total generation	**615**	**794**	**898**	**1,187**	**1,735**	**2,304**
Fossil	505	620	625	651	671	499
Coal	267	287	296	321	335	199
Lignite	0	0	0	0	0	0
Gas	170	285	294	310	322	295
Oil	59	41	30	16	11	2
Diesel	9	7	5	4	4	3
Nuclear	11	8	8	0	0	0
Hydrogen	0	0	0	0	0	0
Renewables	**99**	**165**	**265**	**536**	**1,064**	**1,805**
Hydro	96	128	150	175	190	195
Wind	1	9	31	71	118	153
PV	0	6	29	125	242	415
Biomass	1	18	24	33	42	47
Geothermal	1	3	7	16	25	32
Solar thermal	0	1	22	110	437	948
Ocean energy	0	0	2	6	10	15
Distribution losses	68	83	90	111	133	141
Own consumption electricity	46	57	61	75	90	104
Electricity for hydrogen production	0	0	0	1	3	12
Final energy consumption (electricity)	**504**	**658**	**730**	**940**	**1,196**	**1,490**
Fluctuating RES (PV, Wind, Ocean)	1	15	62	202	370	583
Share of fluctuating RES	0.2%	1.9%	6.9%	17.0%	21.3%	25.3%
RES share	**16.0%**	**20.8%**	**29.5%**	**45.2%**	**61.3%**	**78.3%**
'Efficiency' savings (compared to Ref.)	**0**	**0**	**12**	**87**	**129**	**146**

table 13.84: africa: heat supply

PJ/A	2007	2015	2020	2030	2040	2050
District heating plants	**0**	**0**	**4**	**27**	**89**	**168**
Fossil fuels	0	0	3	16	43	76
Biomass	0	0	1	5	18	34
Solar collectors	0	0	0	3	13	25
Geothermal	0	0	0	3	15	34
Heat from CHP	**0**	**53**	**170**	**406**	**613**	**691**
Fossil fuels	0	44	120	263	390	413
Biomass	0	6	23	51	77	89
Geothermal	0	4	27	92	146	189
Fuel cell (hydrogen)	0	0	0	0	0	0
Direct heating[1]	**10,123**	**10,819**	**11,192**	**11,776**	**12,832**	**13,687**
Fossil fuels	2,559	2,811	2,941	3,003	2,935	2,840
Biomass	7,563	7,802	7,769	7,677	7,800	7,777
Solar collectors	1	172	425	972	1,917	2,833
Geothermal	0	34	57	123	180	238
Total heat supply[1]	**10,123**	**10,872**	**11,365**	**12,209**	**13,534**	**14,547**
Fossil fuels	2,559	2,855	3,063	3,282	3,367	3,328
Biomass	7,563	7,808	7,793	7,734	7,895	7,899
Solar collectors	1	172	425	975	1,931	2,858
Geothermal	0	38	84	218	341	461
Fuel cell (hydrogen)	0	0	0	0	0	0
RES share (including RES electricity)	**74.7%**	**74%**	**73%**	**73%**	**75%**	**77%**
'Efficiency' savings (compared to Ref.)	**0**	**1**	**31**	**81**	**341**	**898**

1) heat from electricity (direct and from electric heat pumps) not included; covered in the model under 'electric appliances'

table 13.85: africa: CO_2 emissions

MILL t/a	2007	2015	2020	2030	2040	2050
Condensation power plants	**392**	**445**	**433**	**399**	**361**	**204**
Coal	245	258	256	236	215	94
Lignite	0	0.0	0.0	0.0	0.0	0.0
Gas	90	146	147	148	136	106
Oil	39	34.3	24.9	12.0	7.9	1.4
Diesel	17	6.6	4.6	3.5	2.9	2.4
Combined heat & power production	**0**	**7**	**19**	**44**	**69**	**74**
Coal	0	5	14	33	50	53
Lignite	0	0	0	0	0	0
Gas	0	1	4	11	18	21
Oil	0	0	0	0	0	0
CO_2 emissions electricity & steam generation	**392**	**452**	**452**	**443**	**430**	**277**
Coal	245	264	270	269	265	146
Lignite	0	0	0	0	0	0
Gas	90	147	152	158	154	127
Oil & diesel	56	41	30	16	11	4
CO_2 emissions by sector	**881**	**1,001**	**1,013**	**1,031**	**1,031**	**880**
% of 1990 emissions	161%	183%	185%	189%	189%	161%
Industry	116	129	138	151	148	135
Other sectors	114	126	135	145	155	160
Transport	200	235	261	294	323	348
Electricity & steam generation	392	447	436	403	373	216
District heating	59	64	43	37	32	21
Population (Mill.)	965	1,153	1,276	1,524	1,770	1,998
CO_2 emissions per capita (t/capita)	**0.9**	**0.9**	**0.8**	**0.7**	**0.6**	**0.4**

table 13.86: africa: installed capacity

GW	2007	2015	2020	2030	2040	2050
Power plants	**128**	**179**	**206**	**281**	**393**	**509**
Coal	41	52	52	55	60	42
Lignite	0	0	0	0	0	0
Gas	38	60	62	66	64	55
Oil	17	18	13	8	6	1
Diesel	7	5	4	3	3	3
Nuclear	2	1	1	0	0	0
Biomass	0	3	3	3	3	3
Hydro	23	31	37	44	48	49
Wind	1	4	12	24	37	44
PV	0	3	14	57	108	180
Geothermal	0	0	1	1	2	2
Solar thermal power plants	0	0	7	17	60	126
Ocean energy	0	0	1	2	3	4
Combined heat & power production	**0**	**3**	**8**	**19**	**30**	**37**
Coal	0	1	4	8	13	16
Lignite	0	0	0	0	0	0
Gas	0	1	2	6	9	11
Oil	0	0	0	0	0	0
Biomass	0	0	1	3	4	5
Geothermal	0	0	1	2	3	4
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	0	0	1	2	4	4
Autoproducers	0	2	7	17	26	32
Total generation	**128**	**182**	**213**	**300**	**423**	**546**
Fossil	103	137	136	147	156	128
Coal	41	53	55	63	73	58
Lignite	0	0	0	0	0	0
Gas	38	61	64	72	74	66
Oil	17	18	13	8	6	1
Diesel	7	5	4	3	3	3
Nuclear	2	1	1	0	0	0
Hydrogen	0	0	0	0	0	0
Renewables	**24**	**43**	**76**	**153**	**267**	**418**
Hydro	23	31	37	44	48	49
Wind	1	4	12	24	37	44
PV	0	3	14	57	108	180
Biomass	0	4	4	6	7	8
Geothermal	0	1	1	3	5	6
Solar thermal	0	0	7	17	60	126
Ocean energy	0	0	1	2	3	4
Fluctuating RES (PV, Wind, Ocean)	1	7	26	82	147	228
Share of fluctuating RES	0.4%	3.9%	12.2%	27.5%	34.8%	41.8%
RES share	**18.5%**	**23.6%**	**35.6%**	**50.9%**	**63.2%**	**76.5%**

table 13.87: africa: primary energy demand

PJ/A	2007	2015	2020	2030	2040	2050
Total	**26,355**	**30,040**	**30,932**	**32,526**	**35,146**	**36,487**
Fossil	**13,456**	**15,143**	**15,494**	**15,612**	**15,454**	**13,538**
Hard coal	4,330	4,214	4,143	3,884	3,628	2,247
Lignite	0	0	0	0	0	0
Natural gas	3,472	4,941	5,302	5,554	5,529	5,028
Crude oil	5,654	5,989	6,049	6,174	6,297	6,263
Nuclear	**123**	**87**	**87**	**0**	**0**	**0**
Renewables	**12,776**	**14,810**	**15,350**	**16,915**	**19,692**	**22,949**
Hydro	344	461	540	630	684	702
Wind	4	32	112	256	425	551
Solar	1	197	609	1,821	4,375	7,765
Biomass	12,390	14,004	13,836	13,629	13,350	12,852
Geothermal	37	115	247	557	822	1,026
Ocean Energy	0	1	7	22	36	54
RES share	**48.4%**	**49.4%**	**49.6%**	**51.8%**	**54.9%**	**61.0%**
'Efficiency' savings (compared to Ref.)	**0**	**0**	**344**	**3,106**	**5,430**	**8,547**

table 13.88: africa: final energy demand

PJ/A	2007	2015	2020	2030	2040	2050
Total (incl. non-energy use)	**19,355**	**21,835**	**22,986**	**25,245**	**27,855**	**30,155**
Total (energy use)	**18,782**	**21,207**	**22,358**	**24,575**	**27,143**	**29,401**
Transport	**2,851**	**3,359**	**3,759**	**4,265**	**4,770**	**5,276**
Oil products	2,773	3,242	3,604	4,057	4,468	4,807
Natural gas	61	70	83	80	77	72
Biofuels	0	23	38	70	92	129
Electricity	17	25	34	56	125	235
RES electricity	3	5	10	25	77	184
Hydrogen	0	0	0	2	9	33
RES share Transport	**0.1%**	**0.8%**	**1.3%**	**2.2%**	**3.6%**	**6.4%**
Industry	**3,539**	**4,026**	**4,283**	**4,852**	**5,411**	**5,809**
Electricity	822	1,005	1,089	1,374	1,608	1,793
RES electricity	132	209	321	620	986	1,405
District heat	0	53	172	429	695	850
RES district heat	0	5	20	103	216	336
Coal	347	372	369	327	219	160
Oil products	603	590	533	459	296	108
Gas	693	799	851	846	872	916
Solar	0	12	62	154	330	404
Biomass and waste	1,074	1,182	1,183	1,186	1,267	1,405
Geothermal	0	12	25	77	124	173
Hydrogen	0	0	0	0	0	0
RES share Industry	**34.1%**	**35.3%**	**37.6%**	**44.1%**	**54.0%**	**64.1%**
Other Sectors	**12,392**	**13,822**	**14,316**	**15,458**	**16,961**	**18,317**
Electricity	977	1,340	1,505	1,956	2,573	3,334
RES electricity	157	279	444	883	1,578	2,612
District heat	0	0	0	0	0	0
RES district heat	0	0	0	0	0	0
Coal	230	257	278	291	315	339
Oil products	1,058	1,109	1,015	925	885	819
Gas	235	351	591	872	1,065	1,208
Solar	1	160	363	818	1,588	2,429
Biomass and waste	9,890	10,584	10,533	10,551	10,479	10,122
Geothermal	0	22	32	46	56	65
RES share Other Sectors	**81.1%**	**79.9%**	**79.4%**	**79.6%**	**80.8%**	**83.1%**
Total RES	**11,256**	**12,493**	**13,030**	**14,534**	**16,798**	**19,290**
RES share	**59.9%**	**58.9%**	**58.3%**	**59.1%**	**61.9%**	**65.6%**
Non energy use	**573**	**628**	**628**	**670**	**712**	**754**
Oil	274	301	301	321	341	361
Gas	245	269	269	287	305	323
Coal	53	58	58	62	66	70

africa: advanced energy [r]evolution scenario

table 13.89: africa: electricity generation

TWh/a	2007	2015	2020	2030	2040	2050
Power plants	**615**	**784**	**866**	**1,103**	**1,654**	**2,321**
Coal	267	282	247	206	81	0
Lignite	0	0	0	0	0	0
Gas	170	283	285	284	188	51
Oil	59	41	30	16	10	2
Diesel	9	7	5	4	4	3
Nuclear	11	8	8	0	0	0
Biomass	1	17	19	19	20	20
Hydro	96	128	150	175	190	195
Wind	1	9	34	84	172	298
PV	0	6	29	125	242	425
Geothermal	1	3	10	40	89	179
Solar thermal power plants	0	1	42	127	606	1,047
Ocean energy	0	0	7	24	51	102
Combined heat & power production	**0**	**10**	**34**	**95**	**142**	**169**
Coal	0	6	17	44	49	38
Lignite	0	0	0	0	0	0
Gas	0	2	9	26	44	57
Oil	0	0	0	0	0	0
Biomass	0	1	5	14	22	27
Geothermal	0	0	3	10	28	46
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	0	2	4	10	17	19
Autoproducers	0	8	30	85	125	150
Total generation	**615**	**794**	**900**	**1,198**	**1,797**	**2,490**
Fossil	505	620	593	580	377	151
Coal	267	287	264	250	131	38
Lignite	0	0	0	0	0	0
Gas	170	285	294	310	232	108
Oil	59	41	30	16	11	2
Diesel	9	7	5	4	4	3
Nuclear	11	8	8	0	0	0
Hydrogen	0	0	0	0	0	0
Renewables	**99**	**165**	**299**	**618**	**1,420**	**2,339**
Hydro	96	128	150	175	190	195
Wind	1	9	34	84	172	298
PV	0	6	29	125	242	425
Biomass	1	18	24	33	42	47
Geothermal	1	3	13	50	117	225
Solar thermal	0	1	42	127	606	1,047
Ocean energy	0	0	7	24	51	102
Distribution losses	68	83	90	111	133	141
Own consumption electricity	46	57	61	75	90	104
Electricity for hydrogen production	0	0	0	1	15	43
Final energy consumption (electricity)	**504**	**658**	**731**	**952**	**1,247**	**1,644**
Fluctuating RES (PV, Wind, Ocean)	1	15	70	233	465	825
Share of fluctuating RES	0.2%	1.9%	7.8%	19.4%	25.9%	33.1%
RES share	**16.0%**	**20.8%**	**33.2%**	**51.6%**	**79.0%**	**93.9%**
'Efficiency' savings (compared to Ref.)	**0**	**0**	**12**	**87**	**129**	**146**

table 13.90: africa: heat supply

PJ/A	2007	2015	2020	2030	2040	2050
District heating plants	**0**	**0**	**6**	**27**	**72**	**109**
Fossil fuels	0	0	0	0	0	0
Biomass	0	0	3	11	22	24
Solar collectors	0	0	2	11	36	63
Geothermal	0	0	1	5	14	22
Heat from CHP	**0**	**53**	**170**	**418**	**675**	**835**
Fossil fuels	0	44	120	275	349	331
Biomass	0	6	23	51	78	89
Geothermal	0	4	27	92	249	416
Fuel cell (hydrogen)	0	0	0	0	0	0
Direct heating[1]	**10,123**	**10,819**	**11,189**	**11,763**	**12,779**	**13,536**
Fossil fuels	2,559	2,811	2,840	2,412	1,838	1,055
Biomass	7,563	7,802	7,762	7,619	7,535	7,216
Solar collectors	1	172	529	1,518	3,028	4,572
Geothermal	0	34	57	215	379	694
Total heat supply[1]	**10,123**	**10,872**	**11,365**	**12,209**	**13,534**	**14,547**
Fossil fuels	2,559	2,855	2,960	2,687	2,187	1,386
Biomass	7,563	7,808	7,789	7,681	7,634	7,328
Solar collectors	1	172	532	1,529	3,064	4,635
Geothermal	0	38	85	312	642	1,131
Fuel cell (hydrogen)	0	0	0	0	7	66
RES share (including RES electricity)	**74.7%**	**73.7%**	**74.0%**	**78.0%**	**83.8%**	**90.4%**
'Efficiency' savings (compared to Ref.)	**0**	**1**	**31**	**81**	**341**	**898**

1) heat from electricity (direct and from electric heat pumps) not included; covered in the model under 'electric appliances'

table 13.91: africa: co2 emissions

MILL t/a	2007	2015	2020	2030	2040	2050
Condensation power plants	**392**	**445**	**404**	**339**	**166**	**25**
Coal	245	258	227	177	65	0
Lignite	0	0	0	0	0	0
Gas	90	146	147	147	90	22
Oil	39	34	25	12	8	1
Diesel	17	7	5	3	3	2
Combined heat & power production	**0**	**7**	**19**	**45**	**59**	**53**
Coal	0	5	14	33	38	28
Lignite	0	0	0	0	0	0
Gas	0	1	4	12	21	25
Oil	0	0	0	0	0	0
CO_2 emissions electricity & steam generation	**392**	**452**	**422**	**384**	**225**	**79**
Coal	245	264	241	210	103	28
Lignite	0	0	0	0	0	0
Gas	90	147	152	159	111	47
Oil & diesel	56	41	30	16	11	4
CO_2 emissions by sector	**881**	**998**	**970**	**889**	**669**	**423**
% of 1990 emissions	161%	183%	178%	163%	123%	77%
Industry	116	129	136	135	116	85
Other sectors	114	126	124	108	85	46
Transport	200	235	260	269	274	247
Electricity & steam generation	392	447	406	345	177	38
District heating	59	61	42	32	18	7
Population (Mill.)	965	1,153	1,276	1,524	1,770	1,998
CO_2 emissions per capita (t/capita)	**0.9**	**0.9**	**0.8**	**0.6**	**0.4**	**0.2**

table 13.92: africa: installed capacity

GW	2007	2015	2020	2030	2040	2050
Power plants	**128**	**179**	**210**	**290**	**409**	**553**
Coal	41	52	46	41	18	0
Lignite	0	0	0	0	0	0
Gas	38	60	62	71	55	27
Oil	17	18	13	8	6	1
Diesel	7	5	4	3	3	3
Nuclear	2	1	1	0	0	0
Biomass	0	3	3	3	3	3
Hydro	23	31	37	44	48	49
Wind	1	4	13	28	54	85
PV	0	3	14	57	108	185
Geothermal	0	0	2	7	16	33
Solar thermal power plants	0	0	14	20	83	140
Ocean energy	0	0	2	8	15	28
Combined heat & power production	**0**	**3**	**8**	**19**	**30**	**36**
Coal	0	1	4	8	10	8
Lignite	0	0	0	0	0	0
Gas	0	1	2	6	10	13
Oil	0	0	0	0	0	0
Biomass	0	0	1	3	4	5
Geothermal	0	0	1	2	6	9
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	0	0	1	2	4	4
Autoproducers	0	2	7	17	26	32
Total generation	**128**	**182**	**218**	**310**	**439**	**589**
Fossil	103	137	130	138	103	52
Coal	41	53	49	49	28	8
Lignite	0	0	0	0	0	0
Gas	38	61	64	77	66	40
Oil	17	18	13	8	6	1
Diesel	7	5	4	3	3	3
Nuclear	2	1	1	0	0	0
Hydrogen	0	0	0	0	0	0
Renewables	**24**	**43**	**86**	**172**	**336**	**537**
Hydro	23	31	37	44	48	49
Wind	1	4	13	28	54	85
PV	0	3	14	57	108	185
Biomass	0	4	4	6	7	8
Geothermal	0	1	2	9	22	42
Solar thermal	0	0	14	20	83	140
Ocean energy	0	0	2	8	15	28
Fluctuating RES (PV, Wind, Ocean)	1	7	29	92	176	298
Share of fluctuating RES	0.4%	3.9%	13.3%	29.8%	40.1%	50.7%
RES share	**18.5%**	**23.6%**	**39.6%**	**55.4%**	**76.6%**	**91.2%**

table 13.93: africa: primary energy demand

PJ/A	2007	2015	2020	2030	2040	2050
Total	**26,355**	**29,979**	**30,787**	**32,129**	**34,019**	**35,805**
Fossil	**13,456**	**15,081**	**14,979**	**13,817**	**10,695**	**7,097**
Hard coal	4,330	4,129	3,597	2,857	1,372	427
Lignite	0	0	0	0	0	0
Natural gas	3,472	4,984	5,381	5,338	3,983	2,456
Crude oil	5,654	5,968	6,000	5,623	5,340	4,214
Nuclear	**123**	**87**	**87**	**0**	**0**	**0**
Renewables	**12,776**	**14,811**	**15,721**	**18,312**	**23,324**	**28,708**
Hydro	344	461	540	630	684	702
Wind	4	32	122	302	619	1,073
Solar	1	197	787	2,436	6,117	9,934
Biomass	12,390	14,005	13,869	13,643	13,265	12,519
Geothermal	37	115	377	1,213	2,456	4,113
Ocean Energy	0	1	25	86	184	367
RES share	**48.4%**	**49.5%**	**51.0%**	**56.8%**	**67.9%**	**79.3%**
'Efficiency' savings (compared to Ref.)	**0**	**0**	**489**	**3,503**	**6,557**	**9,230**

table 13.94: africa: final energy demand

PJ/a	2007	2015	2020	2030	2040	2050
Total (incl. non-energy use)	**19,355**	**21,836**	**23,000**	**24,909**	**27,343**	**29,255**
Total (energy use)	**18,782**	**21,207**	**22,372**	**24,239**	**26,631**	**28,501**
Transport	**2,851**	**3,359**	**3,759**	**3,965**	**4,270**	**4,376**
Oil products	2,773	3,241	3,591	3,716	3,785	3,412
Natural gas	61	71	88	79	57	33
Biofuels	0	23	40	71	94	126
Electricity	17	25	40	97	295	689
RES electricity	3	5	13	50	233	647
Hydrogen	0	0	0	2	38	116
RES share Transport	**0.1%**	**0.8%**	**1.4%**	**3.1%**	**8.4%**	**20.2%**
Industry	**3,539**	**4,026**	**4,284**	**4,859**	**5,463**	**5,919**
Electricity	822	1,005	1,089	1,374	1,608	1,793
RES electricity	132	209	362	708	1,271	1,685
District heat	0	53	174	441	740	935
RES district heat	0	6	49	184	388	567
Coal	347	372	352	239	66	0
Oil products	603	587	527	328	180	43
Gas	693	803	859	874	873	728
Solar	0	12	75	339	730	1,046
Biomass and waste	1,074	1,182	1,184	1,171	1,116	997
Geothermal	0	12	25	94	140	299
Hydrogen	0	0	0	0	9	77
RES share Industry	**34.1%**	**35.3%**	**39.6%**	**51.4%**	**66.9%**	**78.8%**
Other Sectors	**12,392**	**13,822**	**14,329**	**15,415**	**16,897**	**18,207**
Electricity	977	1,340	1,505	1,956	2,573	3,334
RES electricity	157	279	500	1,009	2,033	3,132
District heat	0	0	0	0	0	0
RES district heat	0	0	0	0	0	0
Coal	230	257	172	88	28	5
Oil products	1,058	1,094	987	865	753	269
Gas	235	365	621	628	459	460
Solar	1	160	455	1,179	2,297	3,525
Biomass and waste	9,890	10,586	10,558	10,579	10,549	10,218
Geothermal	0	22	32	121	238	395
RES share Other Sectors	**81.1%**	**79.9%**	**80.6%**	**83.6%**	**89.5%**	**94.9%**
Total RES	**11,256**	**12,496**	**13,293**	**15,506**	**19,129**	**22,819**
RES share	**59.9%**	**58.9%**	**59.4%**	**64.0%**	**71.8%**	**80.1%**
Non energy use	**573**	**628**	**628**	**670**	**712**	**754**
Oil	274	301	301	321	341	361
Gas	245	269	269	287	305	323
Coal	53	58	58	62	66	70

africa: total new investment by technology

table 13.95: africa: total investment

MILLION $	2005-2010	2011-2020	2021-2030	2005-2030
Reference scenario				
Conventional (fossil & nuclear)	**39,780**	**61,064**	**55,812**	**156,656**
Renewables	**27,658**	**74,227**	**113,963**	**215,848**
Biomass	3,105	7,289	10,130	20,524
Hydro	18,751	49,718	74,442	142,911
Wind	997	1,891	5,248	8,137
PV	2,540	8,427	15,434	26,402
Geothermal	2,264	5,207	6,534	14,005
Solar thermal power plants	0	1,696	2,174	3,869
Ocean energy	0	0	0	0
Energy [R]evolution				
Conventional (fossil & nuclear)	**39,780**	**53,940**	**39,351**	**133,071**
Renewables	**27,658**	**144,640**	**178,456**	**350,754**
Biomass	3,105	9,508	8,121	20,734
Hydro	18,751	41,811	31,617	92,179
Wind	997	13,006	13,136	27,139
PV	2,540	29,282	59,492	91,314
Geothermal	2,264	11,281	15,309	28,854
Solar thermal power plants	0	37,520	47,821	85,341
Ocean energy	0	2,233	2,960	5,193
Advanced Energy [R]evolution				
Conventional (fossil & nuclear)	**39,780**	**48,062**	**33,060**	**120,901**
Renewables	**27,658**	**196,052**	**215,718**	**439,428**
Biomass	3,105	9,508	8,121	20,734
Hydro	18,751	41,811	31,617	92,179
Wind	997	14,286	16,455	31,738
PV	2,540	29,282	59,492	91,314
Geothermal	2,264	22,096	56,875	81,235
Solar thermal power plants	0	71,435	30,503	101,938
Ocean energy	0	7,633	12,656	20,289

notes

middle east: reference scenario

table 13.96: middle east: electricity generation

TWh/a	2007	2015	2020	2030	2040	2050
Power plants	**715**	**962**	**1,134**	**1,648**	**2,066**	**2,374**
Coal	38	41	51	111	147	221
Lignite	0	0	0	0	0	0
Gas	404	613	760	1,169	1,515	1,713
Oil	244	256	255	253	252	251
Diesel	5	5	5	5	4	3
Nuclear	0	8	8	10	12	14
Biomass	0	3	4	8	10	13
Hydro	23	32	38	45	52	59
Wind	0	3	7	17	27	37
PV	0	1	1	10	20	30
Geothermal	0	0	0	0	0	0
Solar thermal power plants	0	1	4	21	27	33
Ocean energy	0	0	0	0	0	0
Combined heat & power production	**0**	**3**	**7**	**15**	**25**	**30**
Coal	0	1	0	1	2	2
Lignite	0	0	0	0	0	0
Gas	0	1	3	8	13	15
Oil	0	1	3	5	8	9
Biomass	0	0	1	2	3	4
Geothermal	0	0	0	0	0	0
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	0	0	0	0	0	0
Autoproducers	0	3	7	15	25	30
Total generation	**715**	**965**	**1,141**	**1,663**	**2,091**	**2,404**
Fossil	692	918	1,078	1,551	1,940	2,214
Coal	38	41	52	112	149	223
Lignite	0	0	0	0	0	0
Gas	404	614	763	1,176	1,527	1,728
Oil	244	257	258	258	259	260
Diesel	5	5	5	5	4	3
Nuclear	0	8	8	10	12	14
Hydrogen	0	0	0	0	0	0
Renewables	**23**	**39**	**55**	**102**	**139**	**176**
Hydro	23	32	38	45	52	59
Wind	0	3	7	17	27	37
PV	0	1	1	10	20	30
Biomass	0	3	5	9	13	17
Geothermal	0	0	0	0	0	0
Solar thermal	0	1	4	21	27	33
Ocean energy	0	0	0	0	0	0
Distribution losses	85	94	102	135	146	160
Own consumption electricity	56	80	96	144	180	212
Electricity for hydrogen production	0	0	0	0	0	0
Final energy consumption (electricity)	**573**	**791**	**945**	**1,389**	**1,774**	**2,042**
Fluctuating RES (PV, Wind, Ocean)	0	4	8	27	47	67
Share of fluctuating RES	0.0%	0.4%	0.7%	1.6%	2.2%	2.8%
RES share	**3.2%**	**4.0%**	**4.8%**	**6.1%**	**6.6%**	**7.3%**

table 13.97: middle east: heat supply

PJ/A	2007	2015	2020	2030	2040	2050
District heating plants	**0**	**8**	**9**	**10**	**10**	**11**
Fossil fuels	0	6	6	7	8	8
Biomass	0	2	2	2	2	3
Solar collectors	0	0	0	0	0	0
Geothermal	0	0	0	0	0	0
Heat from CHP	**0**	**19**	**42**	**78**	**116**	**125**
Fossil fuels	0	18	38	68	99	103
Biomass	0	1	4	9	17	22
Geothermal	0	0	0	0	0	0
Fuel cell (hydrogen)	0	0	0	0	0	0
Direct heating[1]	**5,256**	**6,207**	**6,950**	**8,792**	**10,401**	**12,010**
Fossil fuels	5,185	6,125	6,831	8,627	10,217	11,803
Biomass	35	47	48	48	47	46
Solar collectors	36	31	41	62	76	92
Geothermal	0	4	32	56	61	69
Total heat supply[1]	**5,256**	**6,234**	**7,001**	**8,880**	**10,527**	**12,146**
Fossil fuels	5,185	6,149	6,875	8,703	10,324	11,914
Biomass	35	50	53	60	66	70
Solar collectors	36	31	41	62	76	92
Geothermal	0	4	32	56	61	69
Fuel cell ((hydrogen)	0	0	0	0	0	0
RES share (including RES electricity)	**1.4%**	**1.4%**	**1.8%**	**2.0%**	**1.9%**	**1.9%**

1) heat from electricity (direct and from electric heat pumps) not included; covered in the model under 'electric appliances'

table 13.98: middle east: CO_2 emissions

MILL t/a	2007	2015	2020	2030	2040	2050
Condensation power plants	**488**	**542**	**615**	**842**	**993**	**1,133**
Coal	36	35	43	86	110	164
Lignite	0	0	0	0	0	0
Gas	240	288	356	548	678	767
Oil	200	206	203	195	194	194
Diesel	13	13	13	13	10	8
Combined heat & power production	**0**	**3**	**5**	**8**	**13**	**13**
Coal	0	1	0	1	2	1
Lignite	0	0	0	0	0	0
Gas	0	0	2	4	6	7
Oil	0	1	2	4	5	5
CO_2 emissions electricity & steam generation	**488**	**544**	**620**	**851**	**1,006**	**1,147**
Coal	36	36	43	87	111	166
Lignite	0	0	0	0	0	0
Gas	240	288	358	552	685	774
Oil & diesel	213	220	218	212	209	207
CO_2 emissions by sector	**1,374**	**1,730**	**1,970**	**2,494**	**2,872**	**3,208**
% of 1990 emissions	234%	294%	335%	424%	488%	546%
Industry	223	279	321	417	514	606
Other sectors	189	210	226	274	303	332
Transport	312	461	539	683	736	774
Electricity & steam generation	488	542	615	842	993	1,133
District heating	162	238	269	278	326	363
Population (Mill.)	202	235	255	293	326	353
CO_2 emissions per capita (t/capita)	**6.8**	**7.4**	**7.7**	**8.5**	**8.8**	**9.1**

table 13.99: middle east: installed capacity

GW	2007	2015	2020	2030	2040	2050
Power plants	**190**	**272**	**290**	**388**	**653**	**1,220**
Coal	5	6	8	17	26	44
Lignite	0	0	0	0	0	0
Gas	107	173	185	265	496	1,008
Oil	63	70	68	62	76	100
Diesel	5	5	5	5	4	3
Nuclear	0	1	1	1	2	2
Biomass	0	1	1	1	1	2
Hydro	10	14	17	20	23	26
Wind	0	1	3	7	10	14
PV	0	0	1	6	11	17
Geothermal	0	0	0	0	0	0
Solar thermal power plants	0	0	1	3	4	5
Ocean energy	0	0	0	0	0	0
Combined heat & power production	**0**	**2**	**3**	**6**	**9**	**10**
Coal	0	0	0	0	0	0
Lignite	0	0	0	0	0	0
Gas	0	0	1	2	3	3
Oil	0	1	2	3	5	6
Biomass	0	0	0	0	1	1
Geothermal	0	0	0	0	0	0
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	0	0	0	0	0	0
Autoproducers	0	2	3	6	9	10
Total generation	**190**	**274**	**294**	**394**	**662**	**1,231**
Fossil	180	256	270	355	610	1,165
Coal	5	7	8	17	26	45
Lignite	0	0	0	0	0	0
Gas	107	173	186	267	499	1,011
Oil	63	71	70	66	81	106
Diesel	5	5	5	5	4	3
Nuclear	0	1	1	1	2	2
Hydrogen	0	0	0	0	0	0
Renewables	**10**	**17**	**23**	**37**	**50**	**64**
Hydro	10	14	17	20	23	26
Wind	0	1	3	7	10	14
PV	0	0	1	6	11	17
Biomass	0	1	1	1	2	3
Geothermal	0	0	0	0	0	0
Solar thermal	0	0	1	3	4	5
Ocean energy	0	0	0	0	0	0
Fluctuating RES (PV, Wind, Ocean)	0	2	3	12	21	31
Share of fluctuating RES	0.0%	0.6%	1.2%	3.2%	3.2%	2.5%
RES share	**5.3%**	**6.0%**	**7.7%**	**9.4%**	**7.6%**	**5.2%**

table 13.100: middle east: primary energy demand

PJ/A	2007	2015	2020	2030	2040	2050
Total	**21,372**	**27,358**	**31,498**	**41,370**	**46,773**	**51,281**
Fossil	**21,202**	**26,971**	**31,009**	**40,563**	**45,725**	**49,998**
Hard coal	435	483	597	1,124	1,443	2,091
Lignite	2	2	2	2	2	2
Natural gas	9,056	11,371	13,431	19,125	23,042	26,034
Crude oil	11,709	15,115	16,980	20,313	21,238	21,871
Nuclear	**0**	**95**	**94**	**114**	**134**	**153**
Renewables	**170**	**291**	**395**	**693**	**914**	**1,131**
Hydro	82	115	137	162	187	212
Wind	1	11	25	61	97	133
Solar	36	40	62	173	246	319
Biomass	52	123	151	258	341	415
Geothermal	0	2	20	38	44	52
Ocean Energy	0	0	0	0	0	0
RES share	**0.8%**	**1.1%**	**1.3%**	**1.7%**	**2.0%**	**2.2%**

table 13.101: middle east: final energy demand

PJ/a	2007	2015	2020	2030	2040	2050
Total (incl. non-energy use)	**15,272**	**20,331**	**23,412**	**30,236**	**34,840**	**38,787**
Total (energy use)	**12,867**	**16,939**	**19,518**	**25,505**	**29,690**	**33,218**
Transport	**4,344**	**6,406**	**7,494**	**9,546**	**10,341**	**10,928**
Oil products	4,307	6,364	7,452	9,417	10,125	10,618
Natural gas	37	41	41	82	124	165
Biofuels	0	0	1	44	89	136
Electricity	1	1	1	2	4	8
RES electricity	0	0	0	0	0	1
Hydrogen	0	0	0	0	0	0
RES share Transport	**0.0%**	**0.0%**	**0.0%**	**0.5%**	**0.9%**	**1.3%**
Industry	**3,847**	**4,835**	**5,612**	**7,494**	**9,375**	**11,227**
Electricity	398	544	670	1,047	1,424	1,800
RES electricity	13	22	32	64	95	132
District heat	0	19	42	78	116	125
RES district heat	0	5	10	19	28	31
Coal	24	54	81	138	195	255
Oil products	1,567	1,863	2,053	2,476	2,900	3,324
Gas	1,849	2,345	2,758	3,749	4,736	5,723
Solar	0	0	0	0	0	0
Biomass and waste	9	9	9	7	4	0
Geothermal	0	0	0	0	0	0
Hydrogen	0	0	0	0	0	0
RES share Industry	**0.6%**	**0.6%**	**0.8%**	**1.1%**	**1.3%**	**1.4%**
Other Sectors	**4,676**	**5,699**	**6,412**	**8,466**	**9,974**	**11,063**
Electricity	1,665	2,304	2,733	3,953	4,958	5,544
RES electricity	53	93	132	243	330	406
District heat	0	8	9	10	10	11
RES district heat	0	2	2	2	2	3
Coal	0	12	15	18	17	21
Oil products	1,295	1,354	1,405	1,613	1,727	1,833
Gas	1,645	1,922	2,126	2,712	3,085	3,455
Solar	36	36	44	62	76	92
Biomass and waste	36	59	59	60	57	55
Geothermal	0	2	20	38	44	52
RES share Other Sectors	**2.7%**	**3.3%**	**4.0%**	**4.8%**	**5.1%**	**5.5%**
Total RES	**147**	**229**	**310**	**540**	**726**	**907**
RES share	**1.1%**	**1.3%**	**1.6%**	**2.1%**	**2.4%**	**2.7%**
Non energy use	**2,405**	**3,391**	**3,894**	**4,731**	**5,150**	**5,568**
Oil	1,277	1,800	2,067	2,511	2,733	2,956
Gas	1,128	1,591	1,827	2,220	2,416	2,613
Coal	0	0	0	0	0	0

middle east: energy [r]evolution scenario

table 13.102: middle east: electricity generation

TWh/a	2007	2015	2020	2030	2040	2050
Power plants	**715**	**849**	**923**	**1,219**	**1,569**	**2,354**
Coal	38	39	33	25	14	1
Lignite	0	0	0	0	0	0
Gas	404	518	521	484	315	51
Oil	244	226	212	131	17	1
Diesel	5	5	4	3	3	1
Nuclear	0	5	5	5	5	0
Biomass	0	2	2	2	2	6
Hydro	23	32	40	45	48	50
Wind	0	10	62	150	210	290
PV	0	1	6	55	230	510
Geothermal	0	1	8	17	23	40
Solar thermal power plants	0	10	30	300	700	1,400
Ocean energy	0	0	1	2	3	5
Combined heat & power production	**0**	**10**	**21**	**33**	**55**	**70**
Coal	0	1	0	0	0	0
Lignite	0	0	0	0	0	0
Gas	0	2	4	6	6	2
Oil	0	2	2	1	0	0
Biomass	0	5	10	16	27	36
Geothermal	0	1	4	10	22	32
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	0	0	0	0	0	0
Autoproducers	0	10	21	33	55	70
Total generation	**715**	**859**	**944**	**1,252**	**1,624**	**2,424**
Fossil	692	792	777	651	354	56
Coal	38	40	34	26	14	1
Lignite	0	0	0	0	0	0
Gas	404	520	525	490	320	53
Oil	244	228	214	132	18	1
Diesel	5	5	4	3	3	1
Nuclear	0	5	5	5	5	0
Hydrogen	0	0	0	0	0	0
Renewables	**23**	**62**	**163**	**597**	**1,265**	**2,368**
Hydro	23	32	40	45	48	50
Wind	0	10	62	150	210	290
PV	0	1	6	55	230	510
Biomass	0	7	12	18	29	42
Geothermal	0	2	12	27	45	71
Solar thermal	0	10	30	300	700	**1,400**
Ocean energy	0	0	1	2	3	5
Distribution losses	85	91	89	91	93	104
Own consumption electricity	56	78	84	97	115	138
Electricity for hydrogen production	0	0	4	9	12	14
Final energy consumption (electricity)	**573**	**689**	**760**	**928**	**1,236**	**1,870**
Fluctuating RES (PV, Wind, Ocean)	0	11	69	207	443	805
Share of fluctuating RES	0.0%	1.3%	7.3%	16.5%	27.3%	33.2%
RES share	**3.2%**	7.3%	17.2%	47.6%	77.9%	97.7%
'Efficiency' savings (compared to Ref.)	**0**	**119**	**214**	**533**	**726**	**754**

table 13.103: middle east: heat supply

PJ/A	2007	2015	2020	2030	2040	2050
District heating plants	**0**	**43**	**109**	**193**	**414**	**637**
Fossil fuels	0	0	0	0	0	0
Biomass	0	0	0	0	0	0
Solar collectors	0	39	98	173	373	574
Geothermal	0	4	11	19	41	64
Heat from CHP	**0**	**70**	**145**	**223**	**375**	**479**
Fossil fuels	0	26	37	33	25	8
Biomass	0	35	70	101	152	187
Geothermal	0	9	38	89	198	284
Fuel cell (hydrogen)	0	0	0	0	0	0
Direct heating[1)]	**5,256**	**6,130**	**6,763**	**7,977**	**8,423**	**9,025**
Fossil fuels	5,185	5,778	5,928	5,931	4,461	1,621
Biomass	35	62	90	156	225	266
Solar collectors	36	187	548	1,437	3,013	5,738
Geothermal	0	103	196	453	724	1,399
Total heat supply[1)]	**5,256**	**6,240**	**7,013**	**8,393**	**9,212**	**10,141**
Fossil fuels	5,185	5,804	5,965	5,964	4,486	1,629
Biomass	35	97	160	257	377	453
Solar collectors	36	223	643	1,610	3,385	6,312
Geothermal	0	116	244	561	964	1,747
Fuel cell (hydrogen)	0	0	0	0	0	0
RES share (including RES electricity)	**1%**	**7%**	**15%**	**29%**	**51%**	**84%**
'Efficiency' savings (compared to Ref.)	**0**	**0**	**0**	**487**	**1,315**	**2,005**

1) heat from electricity (direct and from electric heat pumps) not included; covered in the model under 'electric appliances'

table 13.104: middle east: CO_2 emissions

MILL t/a	2007	2015	2020	2030	2040	2050
Condensation power plants	**488**	**470**	**451**	**356**	**171**	**27**
Coal	36	34	28	20	11	1
Lignite	0	0	0	0	0	0
Gas	240	243	244	227	141	23
Oil	200	182	168	101	13	1
Diesel	13	12	10	8	6	3
Combined heat & power production	**0**	**3**	**4**	**4**	**3**	**1**
Coal	0	1	0	0	0	0
Lignite	0	0	0	0	0	0
Gas	0	1	2	3	3	1
Oil	0	1	2	0	0	0
CO_2 emissions electricity & steam generation	**488**	**474**	**455**	**360**	**174**	**28**
Coal	36	34	28	20	11	1
Lignite	0	0	0	0	0	0
Gas	240	244	247	230	144	24
Oil & diesel	213	195	180	110	20	3
CO_2 emissions by sector	**1,374**	**1,555**	**1,439**	**1,248**	**866**	**387**
% of 1990 emissions	234%	265%	245%	212%	147%	66%
Industry	223	280	272	251	204	98
Other sectors	189	205	202	195	137	41
Transport	312	377	376	357	313	209
Electricity & steam generation	488	470	451	356	171	27
District heating	162	223	138	89	40	12
Population (Mill.)	202	235	255	293	326	353
CO_2 emissions per capita (t/capita)	**6.8**	**6.6**	**5.6**	**4.3**	**2.7**	**1.1**

table 13.105: middle east: installed capacity

GW	2007	2015	2020	2030	2040	2050
Power plants	**190**	**227**	**253**	**325**	**450**	**666**
Coal	5	6	5	5	3	0
Lignite	0	0	0	0	0	0
Gas	107	130	128	121	105	26
Oil	63	62	56	32	5	0
Diesel	5	5	4	3	3	1
Nuclear	0	1	1	1	1	0
Biomass	0	1	0	0	0	1
Hydro	10	14	18	20	21	22
Wind	0	4	25	61	80	110
PV	0	1	3	31	128	283
Geothermal	0	0	1	3	4	6
Solar thermal power plants	0	4	10	48	100	215
Ocean energy	0	0	0	0	1	1
Combined heat & power production	**0**	**3**	**6**	**7**	**11**	**14**
Coal	0	0	0	0	0	0
Lignite	0	0	0	0	0	0
Gas	0	1	1	1	1	0
Oil	0	1	2	0	0	0
Biomass	0	1	2	3	5	7
Geothermal	0	0	1	2	4	6
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	0	0	0	0	0	0
Autoproducers	0	3	6	7	11	14
Total generation	**190**	**230**	**258**	**332**	**461**	**680**
Fossil	180	204	197	163	117	28
Coal	5	6	5	5	3	0
Lignite	0	0	0	0	0	0
Gas	107	130	129	122	106	26
Oil	63	63	58	33	5	0
Diesel	5	5	4	3	3	1
Nuclear	0	1	1	1	1	0
Hydrogen	0	0	0	0	0	0
Renewables	**10**	**25**	**61**	**168**	**343**	**653**
Hydro	10	14	18	20	21	22
Wind	0	4	25	61	80	110
PV	0	1	3	31	128	283
Biomass	0	1	2	3	5	8
Geothermal	0	0	2	5	8	12
Solar thermal	0	4	10	48	100	215
Ocean energy	0	0	0	0	1	1
Fluctuating RES (PV, Wind, Ocean)	0	5	29	92	208	395
Share of fluctuating RES	0.0%	2.2%	11.1%	27.8%	45.2%	58.1%
RES share	**5.3%**	**10.8%**	**23.5%**	**50.5%**	**74.4%**	**95.9%**

table 13.106: middle east: primary energy demand

PJ/A	2007	2015	2020	2030	2040	2050
Total	**21,372**	**25,396**	**26,825**	**28,799**	**28,166**	**28,414**
Fossil	**21,202**	**24,552**	**24,729**	**23,444**	**17,837**	**10,260**
Hard coal	435	435	327	231	127	19
Lignite	2	2	0	0	0	0
Natural gas	9,056	10,808	11,780	12,247	9,287	4,367
Crude oil	11,709	13,307	12,621	10,966	8,423	5,874
Nuclear	**0**	**59**	**59**	**57**	**56**	**0**
Renewables	**170**	**784**	**2,038**	**5,298**	**10,274**	**18,154**
Hydro	82	115	144	162	173	180
Wind	1	36	223	540	756	1,044
Solar	36	274	796	2,888	6,733	13,188
Biomass	52	195	348	645	909	1,005
Geothermal	0	164	522	1,057	1,692	2,719
Ocean Energy	0	0	4	5	11	18
RES share	**0.8%**	**3.1%**	**7.5%**	**17.3%**	**35.3%**	**62.6%**
'Efficiency' savings (compared to Ref.)	**0**	**1,981**	**4,725**	**13,153**	**19,333**	**24,055**

table 13.107: middle east: final energy demand

PJ/A	2007	2015	2020	2030	2040	2050
Total (incl. non-energy use)	**15,272**	**19,174**	**20,484**	**22,585**	**23,806**	**25,031**
Total (energy use)	**12,867**	**15,783**	**16,785**	**18,327**	**19,429**	**20,577**
Transport	**4,344**	**5,315**	**5,404**	**5,436**	**5,332**	**5,290**
Oil products	4,307	5,197	5,175	4,889	4,251	2,782
Natural gas	37	46	63	96	125	154
Biofuels	0	11	53	167	247	212
Electricity	1	61	104	262	679	2,103
RES electricity	0	4	18	125	529	2,055
Hydrogen	0	0	10	22	30	39
RES share Transport	**0.0%**	**0.3%**	**1.3%**	**5.6%**	**15.0%**	**43.6%**
Industry	**3,847**	**5,201**	**5,691**	**6,360**	**6,830**	**7,081**
Electricity	398	585	669	808	953	1,096
RES electricity	13	43	115	385	742	1,071
District heat	0	108	227	361	595	843
RES district heat	0	108	227	361	595	843
Coal	24	18	0	0	0	0
Oil products	1,567	1,686	1,087	757	602	376
Gas	1,849	2,660	3,333	3,411	2,796	1,234
Solar	0	57	205	687	1,366	2,653
Biomass and waste	9	24	51	112	176	184
Geothermal	0	64	119	225	342	696
Hydrogen	0	0	0	0	0	0
RES share Industry	**0.6%**	**5.7%**	**12.6%**	**27.8%**	**47.2%**	**76.9%**
Other Sectors	**4,676**	**5,267**	**5,689**	**6,531**	**7,267**	**8,205**
Electricity	1,665	1,834	1,962	2,271	2,816	3,533
RES electricity	53	133	338	1,082	2,193	3,451
District heat	0	0	15	36	157	220
RES district heat	0	0	15	36	157	220
Coal	0	27	0	0	0	0
Oil products	1,295	1,333	1,207	878	662	236
Gas	1,645	1,842	1,997	2,315	1,572	428
Solar	36	137	365	750	1,647	3,085
Biomass and waste	36	57	66	81	96	133
Geothermal	0	36	78	200	317	570
RES share Other Sectors	**2.7%**	**6.9%**	**15.1%**	**32.9%**	**60.7%**	**90.9%**
Total RES	**147**	**674**	**1,652**	**4,220**	**8,431**	**15,209**
RES share	**1.1%**	**4.3%**	**9.8%**	**23.0%**	**43.4%**	**73.9%**
Non energy use	**2,405**	**3,391**	**3,699**	**4,258**	**4,377**	**4,455**
Oil	1,277	1,800	1,963	2,260	2,323	2,364
Gas	1,128	1,591	1,736	1,998	2,054	2,090
Coal	0	0	0	0	0	0

middle east: advanced energy [r]evolution scenario

table 13.108: middle east: electricity generation

TWh/a	2007	2015	2020	2030	2040	2050
Power plants	**715**	**849**	**939**	**1,294**	**1,862**	**2,696**
Coal	38	107	32	13	0	0
Lignite	0	0	0	0	0	0
Gas	404	450	444	397	305	31
Oil	244	226	212	131	17	1
Diesel	5	5	4	3	3	1
Nuclear	0	5	5	5	5	0
Biomass	0	2	2	2	2	1
Hydro	23	32	40	45	48	50
Wind	0	10	97	180	235	365
PV	0	1	22	84	378	597
Geothermal	0	1	8	24	99	105
Solar thermal power plants	0	10	62	396	737	1,485
Ocean energy	0	0	11	**14**	33	61
Combined heat & power production	**0**	**10**	**21**	**33**	**65**	**90**
Coal	0	1	0	0	0	0
Lignite	0	0	0	0	0	0
Gas	0	2	4	6	7	2
Oil	0	2	2	1	0	0
Biomass	0	5	10	16	31	44
Geothermal	0	1	4	10	26	41
Hydrogen	0	0	0	0	1	4
CHP by producer						
Main activity producers	0	0	0	0	0	0
Autoproducers	0	10	21	33	65	90
Total generation	**715**	**859**	**960**	**1,327**	**1,927**	**2,786**
Fossil	692	792	699	551	332	34
Coal	38	108	32	13	0	0
Lignite	0	0	0	0	0	0
Gas	404	452	448	403	312	32
Oil	244	228	214	132	18	1
Diesel	5	5	4	3	3	1
Nuclear	0	5	5	5	5	0
Hydrogen	0	0	0	0	1	4
Renewables	**23**	**62**	**256**	**771**	**1,590**	**2,748**
Hydro	23	32	40	45	48	50
Wind	0	10	97	180	235	365
PV	0	1	22	84	378	597
Biomass	0	7	12	18	34	45
Geothermal	0	2	12	34	125	145
Solar thermal	0	10	62	396	737	1,485
Ocean energy	0	0	11	14	33	61
Distribution losses	85	91	89	91	93	104
Own consumption electricity	56	78	84	97	109	124
Electricity for hydrogen production	0	0	4	12	32	75
Final energy consumption (electricity)	**573**	**689**	**775**	**1,000**	**1,524**	**2,185**
Fluctuating RES (PV, Wind, Ocean)	0	11	130	278	646	1,023
Share of fluctuating RES	0.0%	1.3%	13.5%	20.9%	33.5%	36.7%
RES share	**3.2%**	**7.3%**	**26.7%**	**58.1%**	**82.5%**	**98.6%**
'Efficiency' savings (compared to Ref.)	**0**	**119**	**214**	**532**	**720**	**745**

table 13.109: middle east: heat supply

PJ/A	2007	2015	2020	2030	2040	2050
District heating plants	**0**	**43**	**109**	**228**	**552**	**781**
Fossil fuels	0	0	0	0	0	0
Biomass	0	0	0	0	0	0
Solar collectors	0	39	98	205	497	703
Geothermal	0	4	11	23	55	78
Heat from CHP	**0**	**70**	**145**	**223**	**442**	**613**
Fossil fuels	0	26	37	33	29	7
Biomass	0	35	70	101	173	227
Geothermal	0	9	38	89	234	365
Fuel cell (hydrogen)	0	0	0	0	6	14
Direct heating[1]	**5,256**	**6,490**	**7,067**	**8,070**	**8,355**	**8,520**
Fossil fuels	5,185	6,122	6,186	5,727	3,813	261
Biomass	35	64	91	159	229	261
Solar collectors	36	194	573	1,622	3,392	6,498
Geothermal	0	109	217	562	921	1,500
Total heat supply[1]	**5,256**	**6,603**	**7,321**	**8,521**	**9,465**	**10,112**
Fossil fuels	5,185	6,148	6,223	5,760	3,842	268
Biomass	35	100	161	259	402	488
Solar collectors	36	233	671	1,827	3,889	7,201
Geothermal	0	123	266	674	1,210	1,942
Fuel cell (hydrogen)	0	0	0	0	121	212
RES share (including RES electricity)	**1.4%**	**6.9%**	**15.0%**	**32.4%**	**59.2%**	**97.3%**
'Efficiency' savings (compared to Ref.)	**0**	**-369**	**-321**	**359**	**1,062**	**2,034**

1) heat from electricity (direct and from electric heat pumps) not included; covered in the model under 'electric appliances'

table 13.110: middle east: CO_2 emissions

MILL t/a	2007	2015	2020	2030	2040	2050
Condensation power plants	**488**	**497**	**414**	**305**	**157**	**17**
Coal	36	92	27	10	0	0
Lignite	0	0.2	0.2	0.0	0.0	0.0
Gas	240	211	208	186	137	14
Oil	200	182.1	168.4	101.3	13.5	0.8
Diesel	13	11.7	10.4	7.8	6.5	2.6
Combined heat & power production	**0**	**3**	**4**	**4**	**3**	**1**
Coal	0	1	0	0	0	0
Lignite	0	0	0	0	0	0
Gas	0	1	2	3	3	1
Oil	0	1	2	0	0	0
CO_2 emissions electricity & steam generation	**488**	**500**	**418**	**309**	**160**	**18**
Coal	36	92	27	10	0	0
Lignite	0	0	0	0	0	0
Gas	240	212	211	189	140	14
Oil & diesel	213	195	180	110	20	3
CO_2 emissions by sector	**1,374**	**1,571**	**1,393**	**1,124**	**677**	**122**
% of 1990 emissions	234%	267%	237%	191%	115%	21%
Industry	223	280	275	252	170	21
Other sectors	189	205	201	178	112	8
Transport	312	377	372	317	214	72
Electricity & steam generation	488	497	414	305	157	17
District heating	162	213	131	72	24	4
Population (Mill.)	202	235	255	293	326	353
CO_2 emissions per capita (t/capita)	**6.8**	**6.7**	**5.5**	**3.8**	**2.1**	**0.3**

table 13.111: middle east: installed capacity

GW	2007	2015	2020	2030	2040	2050
Power plants	**190**	**220**	**270**	**349**	**648**	**873**
Coal	5	17	5	3	0	0
Lignite	0	0.0	0.0	0.0	0.0	0.0
Gas	107	113	109	99	90	16
Oil	63	62	56	32	5	0
Diesel	5	4.5	4.0	3.0	2.5	1.0
Nuclear	0	0.7	0.7	0.7	0.7	0.0
Biomass	0	0.5	0.3	0.2	0.4	0.1
Hydro	10	14	18	20	21	22
Wind	0	4.3	39.6	73.5	89.4	138.8
PV	0	0.8	12.2	46.7	210.0	331.7
Geothermal	0	0.2	1.2	3.7	15.2	16.1
Solar thermal power plants	0	4.0	20.0	62.9	204.7	330.0
Ocean energy	0	0.0	3.1	4.0	9.4	17.4
Combined heat & power production	**0**	**3**	**6**	**7**	**13**	**18**
Coal	0	0	0	0	0	0
Lignite	0	0	0	0	0	0
Gas	0	1	1	1	2	0
Oil	0	1	2	0	0	0
Biomass	0	1	2	3	6	9
Geothermal	0	0	1	2	5	8
Hydrogen	0	0	0	0	0	1
CHP by producer						
Main activity producers	0	0	0	0	0	0
Autoproducers	0	3	6	7	13	18
Total generation	**190**	**223**	**276**	**356**	**661**	**891**
Fossil	180	198	178	139	99	18
Coal	5	17	5	3	0	0
Lignite	0	0	0	0	0	0
Gas	107	113	110	101	91	16
Oil	63	63	58	33	5	0
Diesel	5	5	4	3	3	1
Nuclear	0	0.7	0.7	0.7	0.7	0.0
Hydrogen	0	0	0	0	0	1
Renewables	**10**	**25**	**97**	**216**	**561**	**873**
Hydro	10	14	18	20	21	22
Wind	0	4	40	73	89	139
PV	0	1	12	47	210	332
Biomass	0	1	2	3	6	9
Geothermal	0	0	2	6	20	24
Solar thermal	0	4	20	63	205	330
Ocean energy	0	0	3	4	9	17
Fluctuating RES (PV, Wind, Ocean)	0	5.1	55.0	124.1	308.8	487.9
Share of fluctuating RES	0.0%	2.3%	19.9%	34.9%	46.7%	54.7%
RES share	**5.3%**	**11.1%**	**35.3%**	**60.7%**	**84.9%**	**97.9%**

table 13.112: middle east: primary energy demand

PJ/A	2007	2015	2020	2030	2040	2050
Total	**21,372**	**25,435**	**26,417**	**28,020**	**28,274**	**27,475**
Fossil	**21,202**	**24,593**	**23,989**	**21,632**	**15,251**	**6,300**
Hard coal	435	1,063	407	280	19	13
Lignite	2	2	2	0	0	0
Natural gas	9,056	10,248	11,110	11,252	8,722	2,805
Crude oil	11,709	13,279	12,471	10,101	6,510	3,482
Nuclear	**0**	**59**	**59**	**57**	**56**	**0**
Renewables	**170**	**783**	**2,369**	**6,330**	**12,967**	**21,175**
Hydro	82	115	144	162	173	180
Wind	1	36	349	648	846	1,314
Solar	36	274	974	3,555	7,903	14,696
Biomass	52	194	340	643	908	965
Geothermal	0	164	523	1,272	3,018	3,800
Ocean Energy	0	0	40	50	119	220
RES share	**0.8%**	**3.1%**	**8.9%**	**21.5%**	**44.9%**	**76.3%**
'Efficiency' savings (compared to Ref.)	**0**	**1,942**	**5,132**	**13,932**	**19,225**	**24,994**

table 13.113: middle east: final energy demand

PJ/a	2007	2015	2020	2030	2040	2050
Total (incl. non-energy use)	**15,272**	**19,174**	**20,484**	**22,319**	**23,271**	**23,525**
Total (energy use)	**12,867**	**15,783**	**16,785**	**18,061**	**18,894**	**19,071**
Transport	**4,344**	**5,315**	**5,404**	**5,164**	**4,798**	**4,232**
Oil products	4,307	5,197	5,125	4,346	2,922	952
Natural gas	37	46	57	73	67	61
Biofuels	0	11	55	198	237	177
Electricity	1	61	158	517	1,488	2,840
RES electricity	0	4	42	300	1,227	2,801
Hydrogen	0	0	10	30	84	202
RES share Transport	**0.0%**	**0.3%**	**1.8%**	**10.0%**	**32.0%**	**75.1%**
Industry	**3,847**	**5,201**	**5,692**	**6,362**	**6,857**	**6,891**
Electricity	398	585	669	812	973	1,132
RES electricity	13	43	179	472	803	1,116
District heat	0	108	227	389	754	1,047
RES district heat	0	108	227	389	754	1,047
Coal	24	18	90	153	6	0
Oil products	1,567	1,677	1,049	606	271	73
Gas	1,849	2,669	3,281	3,362	2,614	268
Solar	0	57	205	692	1,526	3,164
Biomass and waste	9	24	51	113	179	180
Geothermal	0	64	119	235	398	794
Hydrogen	0	0	0	0	136	233
RES share Industry	**0.6%**	**5.7%**	**13.7%**	**29.9%**	**55.0%**	**94.8%**
Other Sectors	**4,676**	**5,267**	**5,689**	**6,535**	**7,239**	**7,947**
Electricity	1,665	1,834	1,962	2,272	2,817	3,532
RES electricity	53	133	523	1,320	2,323	3,483
District heat	0	0	15	40	193	281
RES district heat	0	0	15	40	193	281
Coal	0	27	4	0	0	0
Oil products	1,295	1,316	1,155	778	508	24
Gas	1,645	1,858	2,043	2,146	1,324	109
Solar	36	137	368	930	1,867	3,334
Biomass and waste	36	57	63	83	98	130
Geothermal	0	36	79	285	432	537
RES share Other Sectors	**2.7%**	**6.9%**	**18.4%**	**40.7%**	**67.9%**	**97.7%**
Total RES	**147**	**674**	**1,929**	**5,075**	**10,218**	**17,474**
RES share	**1.1%**	**4.3%**	**11.5%**	**28.1%**	**54.1%**	**91.6%**
Non energy use	**2,405**	**3,391**	**3,699**	**4,258**	**4,377**	**4,455**
Oil	1,277	1,800	1,963	2,260	2,323	2,364
Gas	1,128	1,591	1,736	1,998	2,054	2,090
Coal	0	0	0	0	0	0

middle east: total new investment by technology

table 13.114: middle east: total investment

MILLION $	2005-2010	2011-2020	2021-2030	2005-2030
Reference scenario				
Conventional (fossil & nuclear)	**64,223**	**89,756**	**100,150**	**254,129**
Renewables	**11,447**	**31,020**	**35,697**	**78,164**
Biomass	1,017	1,733	1,759	4,510
Hydro	8,502	20,270	13,770	42,543
Wind	769	1,777	3,919	6,465
PV	0	1,384	6,821	8,205
Geothermal	0	0	0	0
Solar thermal power plants	1,159	5,856	9,427	16,442
Ocean energy	0	0	0	0
Energy [R]evolution				
Conventional (fossil & nuclear)	**60,484**	**42,528**	**19,404**	**122,416**
Renewables	**11,447**	**141,294**	**287,337**	**440,079**
Biomass	1,017	8,508	4,564	14,089
Hydro	8,502	22,880	11,063	42,446
Wind	769	28,956	37,692	67,417
PV	0	7,156	37,441	44,597
Geothermal	0	20,899	21,151	42,050
Solar thermal power plants	1,159	51,969	175,077	228,204
Ocean energy	0	926	350	1,276
Advanced Energy [R]evolution				
Conventional (fossil & nuclear)	**60,484**	**30,335**	**16,428**	**107,247**
Renewables	**11,447**	**241,651**	**327,962**	**581,061**
Biomass	1,017	8,494	4,574	14,085
Hydro	8,502	22,880	11,063	42,446
Wind	769	45,304	35,581	81,655
PV	0	26,379	46,991	73,369
Geothermal	0	20,899	29,895	50,795
Solar thermal power plants	1,159	107,511	197,759	306,428
Ocean energy	0	10,184	2,100	12,284

notes

transition economies: reference scenario

table 13.115: transition economies: electricity generation

TWh/a	2007	2015	2020	2030	2040	2050
Power plants	**815**	**977**	**1,111**	**1,460**	**1,812**	**2,163**
Coal	69	76	86	220	318	427
Lignite	82	110	130	170	246	311
Gas	64	109	113	173	233	292
Oil	15	11	8	2	1	0
Diesel	0	0	0	0	0	1
Nuclear	293	328	388	413	438	463
Biomass	0	7	13	24	35	46
Hydro	291	325	350	397	444	491
Wind	0	7	16	44	72	100
PV	0	0	0	0	0	0
Geothermal	0	4	6	11	15	19
Solar thermal power plants	0	0	1	5	9	13
Ocean energy	0	0	0	0	0	0
Combined heat & power production	**870**	**890**	**901**	**916**	**932**	**947**
Coal	162	157	155	152	150	146
Lignite	75	72	69	67	64	59
Gas	598	626	643	668	693	719
Oil	32	30	28	21	15	9
Biomass	2	5	6	8	10	12
Geothermal	0	0	0	0	1	2
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	813	825	830	835	840	845
Autoproducers	57	65	71	81	92	102
Total generation	**1,685**	**1,867**	**2,012**	**2,376**	**2,743**	**3,110**
Fossil	1,098	1,191	1,232	1,474	1,720	1,964
Coal	231	234	241	373	468	573
Lignite	158	182	199	237	310	370
Gas	662	735	756	841	926	1,011
Oil	47	41	36	23	16	9
Diesel	0	0	0	0	0	1
Nuclear	293	328	388	413	438	463
Hydrogen	0	0	0	0	0	0
Renewables	**295**	**348**	**392**	**489**	**586**	**683**
Hydro	291	325	350	397	444	491
Wind	0	7	16	44	72	100
PV	0	0	0	0	0	0
Biomass	2	12	19	32	45	58
Geothermal	0	4	6	11	16	21
Solar thermal	0	0	1	5	9	13
Ocean energy	0	0	0	0	0	0
Distribution losses	190	197	202	220	239	257
Own consumption electricity	291	303	310	338	366	394
Electricity for hydrogen production	0	0	0	1	2	3
Final energy consumption (electricity)	**1,189**	**1,338**	**1,459**	**1,773**	**2,089**	**2,404**
Fluctuating RES (PV, Wind, Ocean)	0	7	16	44	72	100
Share of fluctuating RES	0.0%	0.4%	0.8%	1.9%	2.6%	3.2%
RES share	**17.5%**	**18.6%**	**19.5%**	**20.6%**	**21.3%**	**21.9%**

table 13.116: transition economies: heat supply

PJ/A	2007	2015	2020	2030	2040	2050
District heating plants	**4,865**	**4,491**	**4,404**	**4,367**	**4,259**	**4,047**
Fossil fuels	4,716	4,353	4,269	4,233	4,129	3,923
Biomass	149	137	135	134	130	124
Solar collectors	0	0	0	0	0	0
Geothermal	0	0	0	0	0	0
Heat from CHP	**3,765**	**4,015**	**4,169**	**4,542**	**4,982**	**5,511**
Fossil fuels	3,738	3,967	4,119	4,491	4,925	5,437
Biomass	27	48	50	52	49	54
Geothermal	0	0	0	0	8	20
Fuel cell (hydrogen)	0	0	0	0	0	0
Direct heating[1)]	**10,051**	**10,429**	**10,883**	**12,185**	**13,472**	**14,759**
Fossil fuels	9,603	9,932	10,358	11,537	12,693	13,871
Biomass	442	488	514	630	729	827
Solar collectors	2	4	6	9	13	17
Geothermal	3	4	6	9	38	43
Total heat supply[1)]	**18,682**	**18,935**	**19,457**	**21,094**	**22,713**	**24,317**
Fossil fuels	18,057	18,252	18,746	20,261	21,746	23,231
Biomass	619	674	698	815	908	1,005
Solar collectors	2	4	6	9	13	18
Geothermal	3	5	7	9	45	63
Fuel cell ((hydrogen)	0	0	0	0	0	0
RES share (including RES electricity)	**3.3%**	**3.6%**	**3.7%**	**4.0%**	**4.3%**	**4.5%**

1) heat from electricity (direct and from electric heat pumps) not included; covered in the model under 'electric appliances'

table 13.117: transition economies: CO_2 emissions

MILL t/a	2007	2015	2020	2030	2040	2050
Condensation power plants	**214**	**274**	**306**	**507**	**659**	**792**
Coal	69	75	84	211	267	318
Lignite	95	126	148	191	279	355
Gas	38	64	67	103	112	118
Oil	10	7	6	1	1	0
Diesel	2.1	1.4	1.4	1.1	1.0	0.9
Combined heat & power production	**846**	**800**	**778**	**755**	**749**	**754**
Coal	236	214	203	189	177	167
Lignite	113	105	100	98	100	105
Gas	447	445	444	445	456	474
Oil	50	36	31	23	15	8
CO_2 emissions electricity & steam generation	**1,060**	**1,074**	**1,084**	**1,263**	**1,408**	**1,546**
Coal	305	290	287	400	444	485
Lignite	209	231	248	290	380	460
Gas	485	509	511	547	568	592
Oil & diesel	62	45	38	25	16	9
CO_2 emissions by sector	**2,650**	**2,721**	**2,814**	**3,145**	**3,344**	**3,564**
% of 1990 emissions	66%	67%	70%	78%	83%	88%
Industry	416	433	439	472	508	542
Other sectors	382	383	397	437	473	512
Transport	274	304	347	406	465	523
Electricity & steam generation	952	977	992	1,173	1,319	1,458
District heating	625	624	638	657	580	530
Population (Mill.)	340	339	337	331	321	311
CO_2 emissions per capita (t/capita)	**7.8**	**8.0**	**8.3**	**9.5**	**10.4**	**11.5**

table 13.118: transition economies: installed capacity

GW	2007	2015	2020	2030	2040	2050
Power plants	**198**	**233**	**253**	**317**	**392**	**463**
Coal	20	21	22	44	61	78
Lignite	24	30	33	34	47	57
Gas	13	22	23	38	55	73
Oil	10	7	5	1	0	0
Diesel	0	0	0	0	0	1
Nuclear	41	45	53	55	58	62
Biomass	0	2	3	5	7	9
Hydro	90	101	108	121	133	144
Wind	0	3	5	15	25	34
PV	0	0	0	0	0	0
Geothermal	0	1	1	2	3	3
Solar thermal power plants	0	0	0	1	2	2
Ocean energy	0	0	0	0	0	0
Combined heat & power production	**214**	**213**	**207**	**205**	**206**	**208**
Coal	46	43	39	31	30	29
Lignite	22	20	18	13	13	12
Gas	126	128	131	147	153	159
Oil	21	21	18	12	8	6
Biomass	0	1	1	1	2	2
Geothermal	0	0	0	0	0	0
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	200	196	189	185	183	183
Autoproducers	14	17	18	20	23	25
Total generation	**412**	**446**	**461**	**522**	**598**	**671**
Fossil	280	293	289	322	369	413
Coal	65	64	61	75	91	107
Lignite	45	50	51	48	60	69
Gas	139	150	154	185	208	232
Oil	31	28	23	13	9	6
Diesel	0	0	0	0	0	1
Nuclear	41	45	53	55	58	62
Hydrogen	0	0	0	0	0	0
Renewables	**91**	**108**	**118**	**145**	**171**	**196**
Hydro	90	101	108	121	133	144
Wind	0	3	5	15	25	34
PV	0	0	0	0	0	0
Biomass	0	3	4	6	8	11
Geothermal	0	1	1	2	3	4
Solar thermal	0	0	0	1	2	2
Ocean energy	0	0	0	0	0	0
Fluctuating RES (PV, Wind, Ocean)	0	3	5	15	25	34
Share of fluctuating RES	0.0%	0.7%	1.1%	2.9%	4.1%	5.1%
RES share	**22.0%**	**24.1%**	**25.7%**	**27.8%**	**28.5%**	**29.2%**

table 13.119: transition economies: primary energy demand

PJ/A	2007	2015	2020	2030	2040	2050
Total	**48,111**	**48,797**	**50,861**	**56,543**	**60,619**	**64,449**
Fossil	**43,054**	**42,911**	**44,037**	**48,840**	**52,071**	**55,098**
Hard coal	7,121	7,173	7,169	8,469	8,994	9,517
Lignite	1,882	2,077	2,231	2,610	3,419	4,148
Natural gas	24,225	23,799	24,226	26,879	28,215	29,478
Crude oil	9,826	9,863	10,411	10,882	11,443	11,955
Nuclear	**3,197**	**3,578**	**4,233**	**4,505**	**4,778**	**5,051**
Renewables	**1,861**	**2,308**	**2,591**	**3,197**	**3,769**	**4,300**
Hydro	1,049	1,170	1,260	1,429	1,598	1,768
Wind	1	25	58	158	259	360
Solar	2	5	8	26	44	63
Biomass	788	991	1,110	1,356	1,561	1,747
Geothermal	21	117	155	228	307	363
Ocean Energy	0	0	0	0	0	0
RES share	**3.8%**	**4.7%**	**5.0%**	**5.6%**	**6.2%**	**6.7%**

table 13.120: transition economies: final energy demand

PJ/a	2007	2015	2020	2030	2040	2050
Total (incl. non-energy use)	**31,889**	**33,313**	**35,133**	**39,180**	**43,220**	**47,252**
Total (energy use)	**28,955**	**30,365**	**32,035**	**35,873**	**39,704**	**43,526**
Transport	**5,853**	**6,489**	**7,201**	**8,248**	**9,295**	**10,341**
Oil products	3,780	4,187	4,786	5,603	6,417	7,223
Natural gas	1,682	1,839	1,907	2,077	2,248	2,418
Biofuels	5	42	71	87	105	128
Electricity	386	422	437	478	519	565
RES electricity	67	79	85	98	111	124
Hydrogen	0	0	0	3	5	7
RES share Transport	**1.2%**	**1.9%**	**2.2%**	**2.3%**	**2.3%**	**2.5%**
Industry	**10,714**	**11,072**	**11,446**	**12,647**	**13,838**	**15,023**
Electricity	2,053	2,345	2,554	3,056	3,559	4,061
RES electricity	359	437	497	629	760	891
District heat	3,955	3,701	3,664	3,759	3,841	3,914
RES district heat	76	71	69	67	68	70
Coal	906	1,166	1,193	1,245	1,295	1,346
Oil products	933	927	957	1,086	1,216	1,347
Gas	2,801	2,854	2,982	3,372	3,765	4,159
Solar	0	0	0	0	0	0
Biomass and waste	66	80	95	128	162	196
Geothermal	0	0	0	0	0	0
Hydrogen	0	0	0	0	0	0
RES share Industry	**4.7%**	**5.3%**	**5.8%**	**6.5%**	**7.2%**	**7.7%**
Other Sectors	**12,388**	**12,804**	**13,387**	**14,978**	**16,570**	**18,162**
Electricity	1,842	2,052	2,261	2,848	3,441	4,028
RES electricity	322	382	440	586	735	884
District heat	3,984	4,084	4,181	4,393	4,612	4,828
RES district heat	77	78	78	79	82	86
Coal	334	338	339	378	378	414
Oil products	1,229	1,095	1,055	979	906	834
Gas	4,521	4,720	5,031	5,776	6,524	7,262
Solar	2	4	6	9	13	17
Biomass and waste	474	507	509	587	666	744
Geothermal	3	4	6	8	29	35
RES share Other Sectors	**7.1%**	**7.6%**	**7.8%**	**8.5%**	**9.2%**	**9.7%**
Total RES	**1,451**	**1,686**	**1,857**	**2,279**	**2,732**	**3,177**
RES share	**5.0%**	**5.6%**	**5.8%**	**6.4%**	**6.9%**	**7.3%**
Non energy use	**2,934**	**2,948**	**3,098**	**3,308**	**3,517**	**3,726**
Oil	1,366	1,373	1,443	1,540	1,638	1,735
Gas	1,477	1,484	1,560	1,665	1,771	1,876
Coal	90	91	95	102	108	115

transition economies: energy [r]evolution scenario

table 13.121: transition economies: electricity generation

TWh/a	2007	2015	2020	2030	2040	2050
Power plants	**815**	**940**	**983**	**1,049**	**1,098**	**1,213**
Coal	69	55	45	36	8	4
Lignite	82	75	42	25	0	0
Gas	64	122	171	168	120	11
Oil	15	12	13	9	3	0
Diesel	0	0	0	0	0	1
Nuclear	293	328	290	150	30	0
Biomass	0	10	11	11	11	9
Hydro	291	325	350	360	370	375
Wind	0	9	38	218	437	665
PV	0	1	3	40	75	95
Geothermal	0	2	3	4	5	6
Solar thermal power plants	0	0	1	8	14	17
Ocean energy	0	2	15	20	25	30
Combined heat & power production	**870**	**891**	**901**	**913**	**924**	**930**
Coal	162	141	107	42	17	0
Lignite	75	66	42	17	0	0
Gas	598	610	592	556	475	387
Oil	32	28	10	1	0	0
Biomass	2	41	137	253	345	422
Geothermal	0	5	14	44	87	121
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	813	825	830	830	830	830
Autoproducers	57	66	71	83	94	100
Total generation	**1,685**	**1,831**	**1,884**	**1,962**	**2,022**	**2,143**
Fossil	1,098	1,108	1,022	854	623	403
Coal	231	195	151	78	25	4
Lignite	158	141	84	42	0	0
Gas	662	732	763	724	595	398
Oil	47	40	24	10	3	0
Diesel	0	0	0	0	0	1
Nuclear	293	328	290	150	30	0
Hydrogen	0	0	0	0	0	0
Renewables	**295**	**395**	**573**	**958**	**1,369**	**1,741**
Hydro	291	325	350	360	370	375
Wind	0	9	38	218	437	665
PV	0	1	3	40	75	95
Biomass	2	51	149	264	356	432
Geothermal	0	7	17	48	92	127
Solar thermal	0	0	1	8	14	17
Ocean energy	0	2	15	20	25	30
Distribution losses	190	197	200	205	210	210
Own consumption electricity	291	297	298	295	280	265
Electricity for hydrogen production	0	0	0	2	8	19
Final energy consumption (electricity)	**1,189**	**1,319**	**1,360**	**1,437**	**1,506**	**1,646**
Fluctuating RES (PV, Wind, Ocean)	0	12	56	278	537	790
Share of fluctuating RES	0.0%	0.6%	3.0%	14.2%	26.6%	36.9%
RES share	**17.5%**	**21.6%**	**30.4%**	**48.8%**	**67.7%**	**81.2%**
'Efficiency' savings (compared to Ref.)	**0**	**26**	**125**	**394**	**713**	**1,012**

table 13.122: transition economies: heat supply

PJ/A	2007	2015	2020	2030	2040	2050
District heating plants	**4,865**	**3,976**	**3,274**	**2,705**	**1,816**	**1,276**
Fossil fuels	4,716	3,220	2,292	1,433	472	89
Biomass	149	596	655	676	545	319
Solar collectors	0	40	98	189	236	293
Geothermal	0	119	229	406	563	574
Heat from CHP	**3,765**	**4,307**	**5,105**	**5,700**	**5,975**	**6,007**
Fossil fuels	3,738	3,746	3,448	3,042	2,644	2,249
Biomass	27	515	1,532	2,262	2,550	2,667
Geothermal	0	46	125	396	781	1,091
Fuel cell (hydrogen)	0	0	0	0	0	0
Direct heating[1)]	**10,051**	**9,853**	**9,834**	**9,659**	**8,725**	**7,934**
Fossil fuels	9,603	8,653	7,172	5,432	3,560	1,553
Biomass	442	691	1,315	1,930	2,123	2,207
Solar collectors	2	193	632	971	1,289	1,716
Geothermal	3	316	715	1,325	1,752	2,458
Total heat supply[1)]	**18,682**	**18,135**	**18,213**	**18,064**	**16,515**	**15,216**
Fossil fuels	18,057	15,619	12,912	9,908	6,676	3,892
Biomass	619	1,802	3,502	4,868	5,218	5,192
Solar collectors	2	232	730	1,160	1,525	2,009
Geothermal	3	482	1,069	2,127	3,096	4,123
Fuel cell (hydrogen)	0	0	0	0	0	0
RES share (including RES electricity)	**3.3%**	**14%**	**29%**	**45%**	**60%**	**74%**
'Efficiency' savings (compared to Ref.)	**0**	**799**	**1,244**	**3,031**	**6,198**	**9,101**

1) heat from electricity (direct and from electric heat pumps) not included; covered in the model under 'electric appliances'

table 13.123: transition economies: CO_2 emissions

MILL t/a	2007	2015	2020	2030	2040	2050
Condensation power plants	**214**	**222**	**203**	**169**	**67**	**9**
Coal	69	54	43	34	7	3
Lignite	95	86.0	47.9	28.1	0.0	0.0
Gas	38	72	102	99	57	5
Oil	10	8.0	9.0	6.0	1.7	0.0
Diesel	2.1	1.4	1.4	1.1	1.0	0.9
Combined heat & power production	**846**	**749**	**621**	**452**	**338**	**259**
Coal	236	190	139	53	20	0
Lignite	113	96	60	24	0	0
Gas	447	434	411	374	318	259
Oil	50	30	11	1	0	0
CO_2 emissions electricity & steam generation	**1,060**	**971**	**825**	**621**	**405**	**268**
Coal	305	244	183	87	27	3
Lignite	209	182	108	53	0	0
Gas	485	506	512	473	375	264
Oil & diesel	62	39	22	8	3	1
CO_2 emissions by sector	**2,650**	**2,382**	**1,931**	**1,440**	**928**	**532**
% of 1990 emissions	66%	59%	48%	36%	23%	13%
Industry	416	365	292	217	159	99
Other sectors	382	340	269	205	138	62
Transport	274	295	274	228	172	106
Electricity & steam generation	952	887	749	553	340	214
District heating	625	495	346	238	119	51
Population (Mill.)	340	339	337	331	321	311
CO_2 emissions per capita (t/capita)	**7.8**	**7.0**	**5.7**	**4.4**	**2.9**	**1.7**

table 13.124: transition economies: installed capacity

GW	2007	2015	2020	2030	2040	2050
Power plants	**198**	**223**	**235**	**311**	**394**	**461**
Coal	20	15	11	7	2	1
Lignite	24	21	11	5	0	0
Gas	13	25	35	37	34	8
Oil	10	8	8	5	2	0
Diesel	0	0	0	0	0	1
Nuclear	41	45	40	20	4	0
Biomass	0	2	2	2	2	2
Hydro	90	101	108	110	111	110
Wind	0	4	12	74	149	227
PV	0	1	3	42	79	100
Geothermal	0	0	1	1	1	1
Solar thermal power plants	0	0	0	2	3	3
Ocean energy	0	1	4	6	7	9
Combined heat & power production	**214**	**213**	**206**	**196**	**204**	**202**
Coal	46	39	27	11	5	0
Lignite	22	18	11	4	0	0
Gas	126	125	121	122	117	100
Oil	21	19	7	1	0	0
Biomass	0	12	38	50	64	78
Geothermal	0	1	3	9	17	24
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	200	198	190	178	184	181
Autoproducers	14	16	16	18	20	21
Total generation	**412**	**436**	**441**	**507**	**597**	**663**
Fossil	280	270	230	192	160	109
Coal	65	54	38	18	7	1
Lignite	45	39	21	9	0	0
Gas	139	149	155	159	151	107
Oil	31	27	15	5	2	0
Diesel	0	0	0	0	0	1
Nuclear	41	45	40	20	4	0
Hydrogen	0	0	0	0	0	0
Renewables	**91**	**122**	**171**	**295**	**433**	**554**
Hydro	90	101	108	110	111	110
Wind	0	4	12	74	149	227
PV	0	1	3	42	79	100
Biomass	0	14	40	52	66	80
Geothermal	0	1	3	10	18	25
Solar thermal	0	0	0	2	3	3
Ocean energy	0	1	4	6	7	9
Fluctuating RES (PV, Wind, Ocean)	0	5	19	122	235	335
Share of fluctuating RES	0.0%	1.2%	4.4%	24.1%	39.4%	50.5%
RES share	**22.0%**	**27.9%**	**38.8%**	**58.2%**	**72.5%**	**83.6%**

table 13.125: transition economies: primary energy demand

PJ/A	2007	2015	2020	2030	2040	2050
Total	**48,111**	**46,648**	**45,481**	**42,832**	**37,624**	**33,756**
Fossil	**43,054**	**38,370**	**33,310**	**27,029**	**19,275**	**12,906**
Hard coal	7,121	5,552	3,973	2,285	1,279	740
Lignite	1,882	1,640	971	474	0	0
Natural gas	24,225	22,235	21,091	18,716	13,644	8,809
Crude oil	9,826	8,942	7,275	5,554	4,351	3,357
Nuclear	**3,197**	**3,578**	**3,164**	**1,636**	**327**	**0**
Renewables	**1,861**	**4,701**	**9,008**	**14,166**	**18,021**	**20,850**
Hydro	1,049	1,170	1,260	1,296	1,332	1,350
Wind	1	32	137	785	1,573	2,394
Solar	2	235	744	1,333	1,846	2,412
Biomass	788	2,665	5,448	7,780	8,654	8,752
Geothermal	21	591	1,364	2,901	4,526	5,834
Ocean Energy	0	7	54	72	90	108
RES share	**3.8%**	**10.1%**	**19.7%**	**33.0%**	**47.8%**	**61.8%**
'Efficiency' savings (compared to Ref.)	**0**	**2,058**	**5,164**	**13,440**	**22,652**	**30,246**

table 13.126: transition economies: final energy demand

PJ/A	2007	2015	2020	2030	2040	2050
Total (incl. non-energy use)	**31,889**	**32,013**	**31,891**	**31,284**	**29,171**	**27,267**
Total (energy use)	**28,955**	**29,066**	**28,793**	**27,977**	**25,654**	**23,541**
Transport	**5,853**	**6,278**	**6,025**	**5,464**	**4,813**	**4,137**
Oil products	3,780	4,067	3,779	3,130	2,357	1,435
Natural gas	1,682	1,738	1,656	1,424	1,090	806
Biofuels	5	26	58	219	355	364
Electricity	386	447	531	687	990	1,482
RES electricity	67	96	161	335	670	1,203
Hydrogen	0	0	0	5	21	50
RES share Transport	**1.2%**	**1.9%**	**3.6%**	**10.2%**	**21.6%**	**38.9%**
Industry	**10,714**	**10,581**	**10,349**	**9,909**	**9,083**	**8,164**
Electricity	2,053	2,240	2,301	2,329	2,260	2,221
RES electricity	359	483	699	1,137	1,531	1,803
District heat	3,955	3,705	3,599	3,525	3,288	2,978
RES district heat	76	603	1,190	1,743	2,106	2,142
Coal	906	911	649	328	184	65
Oil products	933	631	281	30	23	17
Gas	2,801	2,712	2,487	2,151	1,439	751
Solar	0	50	138	262	353	465
Biomass and waste	66	255	733	1,042	1,136	1,086
Geothermal	0	76	161	242	400	581
Hydrogen	0	0	0	0	0	0
RES share Industry	**4.7%**	**13.9%**	**28.2%**	**44.7%**	**60.8%**	**74.4%**
Other Sectors	**12,388**	**12,207**	**12,418**	**12,604**	**11,758**	**11,240**
Electricity	1,842	2,062	2,063	2,157	2,173	2,224
RES electricity	322	444	627	1,053	1,471	1,806
District heat	3,984	3,850	4,088	4,258	3,993	3,892
RES district heat	77	627	1,352	2,106	2,557	2,799
Coal	334	355	60	0	0	0
Oil products	1,229	935	494	260	122	108
Gas	4,521	4,123	3,971	3,233	2,210	892
Solar	2	143	493	709	937	1,251
Biomass and waste	474	575	814	1,151	1,277	1,421
Geothermal	3	165	435	837	1,047	1,452
RES share Other Sectors	**7.1%**	**16.0%**	**30.0%**	**46.5%**	**62.0%**	**77.7%**
Total RES	**1,451**	**3,543**	**6,862**	**10,839**	**13,853**	**16,414**
RES share	**5.0%**	**12.2%**	**23.8%**	**38.7%**	**54.0%**	**69.7%**
Non energy use	**2,934**	**2,948**	**3,098**	**3,308**	**3,517**	**3,726**
Oil	1,366	1,373	1,443	1,540	1,638	1,735
Gas	1,477	1,484	1,560	1,665	1,771	1,876
Coal	90	91	95	102	108	115

transition economies: advanced energy [r]evolution scenario

table 13.127: transition economies: electricity generation

TWh/a	2007	2015	2020	2030	2040	2050
Power plants	**815**	**940**	**993**	**1,092**	**1,263**	**1,558**
Coal	69	54	38	13	5	0
Lignite	82	75	38	10	0	0
Gas	64	122	163	158	44	8
Oil	15	12	13	9	2	0
Diesel	0	0	0	0	0	1
Nuclear	293	328	290	150	30	0
Biomass	0	10	11	10	10	10
Hydro	291	325	350	360	375	380
Wind	0	9	67	293	614	948
PV	0	1	3	45	115	135
Geothermal	0	3	3	3	4	5
Solar thermal power plants	0	0	1	8	22	27
Ocean energy	0	2	15	32	42	44
Combined heat & power production	**870**	**891**	**891**	**888**	**884**	**880**
Coal	162	142	106	25	0	0
Lignite	75	66	41	16	0	0
Gas	598	610	585	541	351	160
Oil	32	28	10	1	0	0
Biomass	2	41	136	254	386	477
Geothermal	0	4	14	51	148	243
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	813	825	820	805	790	780
Autoproducers	57	66	71	83	94	100
Total generation	**1,685**	**1,831**	**1,885**	**1,980**	**2,147**	**2,438**
Fossil	1,098	1,108	995	774	402	169
Coal	231	195	144	38	5	0
Lignite	158	141	79	26	0	0
Gas	662	732	748	699	395	168
Oil	47	40	24	10	2	0
Diesel	0	0	0	0	0	1
Nuclear	293	328	290	150	30	0
Hydrogen	0	0	0	0	0	0
Renewables	**295**	**395**	**600**	**1,056**	**1,716**	**2,269**
Hydro	291	325	350	360	375	380
Wind	0	9	67	293	614	948
PV	0	1	3	45	115	135
Biomass	2	51	147	264	396	487
Geothermal	0	7	17	54	152	248
Solar thermal	0	0	1	8	22	27
Ocean energy	0	2	15	32	42	44
Distribution losses	190	197	200	205	210	210
Own consumption electricity	291	297	298	295	280	265
Electricity for hydrogen production	0	0	0	6	43	92
Final energy consumption (electricity)	**1,189**	**1,319**	**1,360**	**1,450**	**1,597**	**1,867**
Fluctuating RES (PV, Wind, Ocean)	0	12	85	370	771	1,127
Share of fluctuating RES	0.0%	0.6%	4.5%	18.7%	35.9%	46.2%
RES share	**17.5%**	**21.6%**	**31.8%**	**53.3%**	**79.9%**	**93.1%**
'Efficiency' savings (compared to Ref.)	**0**	**26**	**125**	**394**	**708**	**1,008**

table 13.128: transition economies: heat supply

PJ/A	2007	2015	2020	2030	2040	2050
District heating plants	**4,865**	**3,976**	**3,327**	**3,212**	2,662	1,909
Fossil fuels	4,716	3,221	2,262	1,670	692	95
Biomass	149	596	699	803	692	420
Solar collectors	0	40	100	225	346	439
Geothermal	0	119	266	514	932	954
Heat from CHP	**3,765**	**4,306**	**5,052**	**5,611**	6,139	6,247
Fossil fuels	3,738	3,753	3,414	2,883	1,953	1,036
Biomass	27	515	1,515	2,272	2,856	3,027
Geothermal	0	38	123	457	1,330	2,184
Fuel cell (hydrogen)	0	0	0	0	0	0
Direct heating[1)]	**10,051**	**9,854**	**9,834**	**9,240**	7,643	6,709
Fossil fuels	9,603	8,653	7,172	4,560	2,083	466
Biomass	442	691	1,315	1,919	1,739	1,582
Solar collectors	2	193	632	1,396	1,768	1,872
Geothermal	3	316	715	1,366	2,054	2,789
Total heat supply[1)]	**18,682**	**18,135**	**18,213**	**18,064**	16,515	15,216
Fossil fuels	18,057	15,627	12,848	9,113	4,728	1,598
Biomass	619	1,803	3,528	4,994	5,287	5,028
Solar collectors	2	233	731	1,620	2,114	2,311
Geothermal	3	473	1,105	2,337	4,315	5,927
Fuel cell (hydrogen)	0	0	0	0	71	351
RES share (including RES electricity)	**3.3%**	**13.8%**	**29.5%**	**49.6%**	71.3%	89.3%
'Efficiency' savings (compared to Ref.)	**0**	**799**	**1,244**	**3,031**	6,198	9,101

1) heat from electricity (direct and from electric heat pumps) not included; covered in the model under 'electric appliances'

table 13.129: transition economies: CO_2 emissions

MILL t/a	2007	2015	2020	2030	2040	2050
Condensation power plants	**214**	**221**	**187**	**125**	**27**	**4**
Coal	69	53	37	13	4	0
Lignite	95	86.0	43.3	11.3	0.0	0.0
Gas	38	72	97	93	21	3
Oil	10	8.0	9.1	6.0	1.0	0.0
Diesel	2.1	1.4	1.4	1.1	1.0	0.9
Combined heat & power production	**846**	**751**	**615**	**420**	**241**	**118**
Coal	236	192	138	31	0	0
Lignite	113	96	59	24	0	0
Gas	447	434	407	364	241	118
Oil	50	30	11	1	0	0
CO_2 emissions electricity & steam generation	**1,060**	**972**	**802**	**545**	**269**	**122**
Coal	305	245	175	44	4	0
Lignite	209	182	103	35	0	0
Gas	485	506	503	458	262	121
Oil & diesel	62	39	22	8	2	1
CO_2 emissions by sector	**2,650**	**2,382**	**1,906**	**1,303**	**664**	**258**
% of 1990 emissions	66%	59%	47%	32%	16%	6%
Industry	416	367	292	205	146	69
Other sectors	382	340	269	161	61	24
Transport	274	295	278	224	145	65
Electricity & steam generation	952	886	727	477	206	72
District heating	625	495	339	236	106	28
Population (Mill.)	340	339	337	331	321	311
CO_2 emissions per capita (t/capita)	**7.8**	**7.0**	**5.6**	**3.9**	**2.1**	**0.8**

table 13.130: transition economies: installed capacity

GW	2007	2015	2020	2030	2040	2050
Power plants	**198**	**223**	**240**	**335**	**481**	**604**
Coal	20	15	10	3	1	0
Lignite	24	21	10	2	0	0
Gas	13	25	33	35	13	5
Oil	10	8	8	5	1	0
Diesel	0	0	0	0	0	1
Nuclear	41	45	40	20	4	0
Biomass	0	2	2	2	2	2
Hydro	90	101	108	110	112	112
Wind	0	4	21	100	209	323
PV	0	1	3	47	121	142
Geothermal	0	1	1	1	1	1
Solar thermal power plants	0	0	0	2	4	5
Ocean energy	0	1	4	9	12	13
Combined heat & power production	**214**	**214**	**203**	**190**	**187**	**185**
Coal	46	39	27	6	0	0
Lignite	22	18	10	4	0	0
Gas	126	125	119	119	86	48
Oil	21	19	7	1	0	0
Biomass	0	12	38	50	72	89
Geothermal	0	1	3	10	30	49
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	200	198	188	172	168	164
Autoproducers	14	16	16	18	20	21
Total generation	**412**	**436**	**444**	**525**	**668**	**789**
Fossil	280	269	224	174	101	54
Coal	65	54	36	9	1	0
Lignite	45	39	20	6	0	0
Gas	139	149	152	154	99	53
Oil	31	27	15	5	1	0
Diesel	0	0	0	0	0	1
Nuclear	41	45	40	20	4	0
Hydrogen	0	0	0	0	0	0
Renewables	**91**	**122**	**180**	**330**	**563**	**735**
Hydro	90	101	108	110	112	112
Wind	0	4	21	100	209	323
PV	0	1	3	47	121	142
Biomass	0	14	40	52	74	90
Geothermal	0	1	3	11	30	50
Solar thermal	0	0	0	2	4	5
Ocean energy	0	1	4	9	12	13
Fluctuating RES (PV, Wind, Ocean)	0	5	28	156	342	478
Share of fluctuating RES	0.0%	1.2%	6.4%	29.8%	51.2%	60.6%
RES share	**22.0%**	**27.9%**	**40.6%**	**63.0%**	**84.2%**	**93.2%**

table 13.131: transition economies: primary energy demand

PJ/A	2007	2015	2020	2030	2040	2050
Total	**48,111**	**46,538**	**45,170**	**42,283**	**37,495**	**34,710**
Fossil	**43,054**	**38,268**	**32,843**	**25,160**	**15,007**	**8,276**
Hard coal	7,121	5,335	3,586	1,382	571	327
Lignite	1,882	1,640	924	315	0	0
Natural gas	24,225	22,351	21,011	17,990	10,555	5,248
Crude oil	9,826	8,942	7,323	5,472	3,881	2,701
Nuclear	**3,197**	**3,578**	**3,164**	**1,636**	**327**	**0**
Renewables	**1,861**	**4,692**	**9,163**	**15,487**	**22,161**	**26,434**
Hydro	1,049	1,170	1,260	1,296	1,350	1,368
Wind	1	32	241	1,055	2,210	3,413
Solar	2	235	746	1,811	2,607	2,894
Biomass	788	2,664	5,462	7,973	8,981	8,936
Geothermal	21	584	1,400	3,237	6,862	9,664
Ocean Energy	0	7	54	115	151	158
RES share	**3.8%**	**10.1%**	**20.2%**	**36.5%**	**59.1%**	**76.1%**
'Efficiency' savings (compared to Ref.)	**0**	**2,168**	**5,476**	**13,989**	**22,780**	**29,292**

table 13.132: transition economies: final energy demand

PJ/a	2007	2015	2020	2030	2040	2050
Total (incl. non-energy use)	**31,889**	**32,013**	**31,891**	**31,185**	**28,870**	**26,864**
Total (energy use)	**28,955**	**29,066**	**28,793**	**27,877**	**25,353**	**23,138**
Transport	**5,853**	**6,278**	**6,025**	**5,364**	**4,513**	**3,737**
Oil products	3,780	4,067	3,827	3,078	1,990	886
Natural gas	1,682	1,738	1,607	1,324	888	492
Biofuels	5	26	59	214	327	342
Electricity	386	447	533	733	1,194	1,767
RES electricity	67	96	170	391	954	1,645
Hydrogen	0	0	0	16	113	249
RES share Transport	**1.2%**	**1.9%**	**3.8%**	**11.4%**	**30.4%**	**59.4%**
Industry	**10,714**	**10,580**	**10,349**	**9,908**	**9,081**	**8,163**
Electricity	2,053	2,240	2,301	2,329	2,277	2,235
RES electricity	359	483	733	1,243	1,819	2,080
District heat	3,955	3,704	3,599	3,529	3,301	3,046
RES district heat	76	603	1,220	1,804	2,450	2,771
Coal	906	911	649	246	74	0
Oil products	933	631	281	26	15	7
Gas	2,801	2,713	2,487	2,089	1,442	397
Solar	0	50	138	328	443	520
Biomass and waste	66	255	733	1,118	1,008	887
Geothermal	0	76	161	242	445	702
Hydrogen	0	0	0	0	75	370
RES share Industry	**4.7%**	**13.9%**	**28.8%**	**47.8%**	**68.5%**	**89.5%**
Other Sectors	**12,388**	**12,207**	**12,418**	**12,605**	**11,759**	**11,238**
Electricity	1,842	2,062	2,063	2,158	2,175	2,227
RES electricity	322	444	657	1,151	1,738	2,073
District heat	3,984	3,850	4,088	4,640	4,921	4,647
RES district heat	77	627	1,386	2,373	3,652	4,227
Coal	334	355	60	0	0	0
Oil products	1,229	935	486	225	65	31
Gas	4,521	4,123	3,979	2,484	914	313
Solar	2	143	493	1,068	1,324	1,352
Biomass and waste	474	575	814	1,155	1,075	1,024
Geothermal	3	165	435	876	1,284	1,645
RES share Other Sectors	**7.1%**	**16.0%**	**30.5%**	**52.5%**	**77.2%**	**91.8%**
Total RES	**1,451**	**3,543**	**6,999**	**11,971**	**16,670**	**19,843**
RES share	**5.0%**	**12.2%**	**24.3%**	**42.9%**	**65.8%**	**85.8%**
Non energy use	**2,934**	**2,948**	**3,098**	**3,308**	**3,517**	**3,726**
Oil	1,366	1,373	1,443	1,540	1,638	1,735
Gas	1,477	1,484	1,560	1,665	1,771	1,876
Coal	90	91	95	102	108	115

transition economies: total new investment by technology

table 13.33: transition economies: total investment

MILLION $	2005-2010	2011-2020	2021-2030	2005-2030
Reference scenario				
Conventional (fossil & nuclear)	**129,596**	**165,562**	**139,958**	**435,116**
Renewables	**37,631**	**106,279**	**117,534**	**261,445**
Biomass	4,271	7,954	8,434	20,658
Hydro	28,195	84,941	86,824	199,959
Wind	1,763	3,855	10,821	16,439
PV	10	9	12	30
Geothermal	3,394	8,492	7,624	19,510
Solar thermal power plants	0	1,028	3,820	4,848
Ocean energy	0	0	0	0
Energy [R]evolution				
Conventional (fossil & nuclear)	**129,596**	**85,078**	**41,415**	**256,089**
Renewables	**37,631**	**310,580**	**277,057**	**625,268**
Biomass	4,271	157,232	43,245	204,747
Hydro	28,195	84,941	52,709	165,844
Wind	1,763	12,652	65,834	80,249
PV	10	7,136	53,137	60,282
Geothermal	3,394	32,416	51,919	87,728
Solar thermal power plants	0	1,696	6,715	8,411
Ocean energy	0	14,508	3,499	18,007
Advanced Energy [R]evolution				
Conventional (fossil & nuclear)	**129,596**	**82,805**	**39,277**	**251,678**
Renewables	**37,631**	**319,147**	**321,992**	**678,771**
Biomass	4,271	155,546	45,306	205,122
Hydro	28,195	84,941	52,709	165,844
Wind	1,763	22,968	82,909	107,639
PV	10	7,136	60,317	67,462
Geothermal	3,394	32,354	62,139	97,887
Solar thermal power plants	0	1,696	6,715	8,411
Ocean energy	0	14,508	11,898	26,406

notes

india: reference scenario

table 13.134: india: electricity generation

TWh/a	2007	2015	2020	2030	2040	2050
Power plants	**814**	**1,255**	**1,601**	**2,652**	**3,705**	**4,757**
Coal	540	762	1,005	1,784	2,547	3,295
Lignite	19	31	42	66	107	164
Gas	68	150	189	299	409	519
Oil	33	36	36	33	30	27
Diesel	0	0	0	0	0	0
Nuclear	17	52	73	106	139	172
Biomass	2	6	10	29	48	67
Hydro	124	172	188	251	314	377
Wind	12	45	56	72	88	104
PV	0	1	2	11	19	27
Geothermal	0	0	0	1	2	3
Solar thermal power plants	0	0	0	0	1	2
Ocean energy	0	0	0	0	0	0
Combined heat & power production	**0**	**21**	**45**	**84**	**123**	**162**
Coal	0	21	45	84	123	162
Lignite	0	0	0	0	0	0
Gas	0	0	0	0	0	0
Oil	0	0	0	0	0	0
Biomass	0	0	0	0	0	0
Geothermal	0	0	0	0	0	0
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	0	0	0	0	0	0
Autoproducers	0	21	45	84	123	162
Total generation	**814**	**1,276**	**1,647**	**2,736**	**3,827**	**4,918**
Fossil	660	1,000	1,318	2,266	3,216	4,166
Coal	540	783	1,050	1,868	2,670	3,457
Lignite	19	31	42	66	107	164
Gas	68	150	189	299	409	519
Oil	33	36	36	33	30	27
Diesel	0	0	0	0	0	0
Nuclear	17	52	73	106	139	172
Hydrogen	0	0	0	0	0	0
Renewables	**137**	**224**	**256**	**364**	**472**	**580**
Hydro	124	172	188	251	314	377
Wind	12	45	56	72	88	104
PV	0	1	2	11	19	27
Biomass	2	6	10	29	48	67
Geothermal	0	0	0	1	2	3
Solar thermal	0	0	0	0	1	2
Ocean energy	0	0	0	0	0	0
Distribution losses	198	299	376	584	781	966
Own consumption electricity	54	84	112	195	289	395
Electricity for hydrogen production	0	0	0	0	0	0
Final energy consumption (electricity)	**567**	**900**	**1,168**	**1,974**	**2,781**	**3,589**
Fluctuating RES (PV, Wind, Ocean)	12	46	58	83	107	131
Share of fluctuating RES	1.4%	3.6%	3.5%	3.0%	2.8%	2.7%
RES share	**16.9%**	**17.6%**	**15.5%**	**13.3%**	**12.3%**	**11.8%**

table 13.135: india: heat supply

PJ/A	2007	2015	2020	2030	2040	2050
District heating plants	**0**	**6**	**11**	**16**	**20**	**25**
Fossil fuels	0	6	10	15	18	20
Biomass	0	0	0	1	2	4
Solar collectors	0	0	0	0	0	0
Geothermal	0	0	0	0	0	0
Heat from CHP	**0**	**117**	**215**	**315**	**398**	**497**
Fossil fuels	0	117	215	315	398	497
Biomass	0	0	0	0	0	0
Geothermal	0	0	0	0	0	0
Fuel cell (hydrogen)	0	0	0	0	0	0
Direct heating[1]	**8,699**	**10,380**	**11,417**	**14,047**	**16,838**	**19,767**
Fossil fuels	3,452	4,736	5,717	8,337	11,018	13,770
Biomass	5,240	5,628	5,659	5,628	5,694	5,824
Solar collectors	6	16	23	42	59	78
Geothermal	0	1	18	41	68	96
Total heat supply[1]	**8,699**	**10,503**	**11,643**	**14,378**	**17,257**	**20,289**
Fossil fuels	3,452	4,859	5,942	8,667	11,434	14,287
Biomass	5,240	5,628	5,659	5,629	5,696	5,828
Solar collectors	6	16	23	42	59	78
Geothermal	0	1	18	41	68	96
Fuel cell ((hydrogen)	0	0	0	0	0	0
RES share (including RES electricity)	**60.3%**	**53.7%**	**49.0%**	**39.7%**	**33.7%**	**29.6%**

1) heat from electricity (direct and from electric heat pumps) not included; covered in the model under 'electric appliances'

table 13.136: india: CO_2 emissions

MILL t/a	2007	2015	2020	2030	2040	2050
Condensation power plants	**785**	**981**	**1,193**	**1,882**	**2,268**	**2,538**
Coal	692	842	1,028	1,659	1,988	2,206
Lignite	28	38	48	63	99	145
Gas	34	69	86	133	159	169
Oil	30	31	31	26	22	18
Diesel	0.0	0.0	0.0	0.0	0.0	0.0
Combined heat & power production	**0**	**22**	**42**	**63**	**83**	**105**
Coal	0	22	42	63	83	105
Lignite	0	0	0	0	0	0
Gas	0	0	0	0	0	0
Oil	0	0	0	0	0	0
CO_2 emissions electricity & steam generation	**785**	**1,003**	**1,235**	**1,945**	**2,351**	**2,643**
Coal	692	865	1,070	1,722	2,071	2,312
Lignite	28	38	48	63	99	145
Gas	34	69	86	133	159	169
Oil & diesel	30	31	31	26	22	18
CO_2 emissions by sector	**1,307**	**1,728**	**2,133**	**3,395**	**4,308**	**5,110**
% of 1990 emissions	222%	293%	362%	576%	731%	868%
Industry	224	351	451	694	927	1,156
Other sectors	135	162	179	221	263	305
Transport	119	173	237	491	745	997
Electricity & steam generation	785	981	1,193	1,882	2,268	2,538
District heating	44	62	73	106	105	114
Population (Mill.)	1,164	1,294	1,367	1,485	1,565	1,614
CO_2 emissions per capita (t/capita)	**1.1**	**1.3**	**1.6**	**2.3**	**2.8**	**3.2**

table 13.137: india: installed capacity

GW	2007	2015	2020	2030	2040	2050
Power plants	**152**	**257**	**323**	**550**	**753**	**950**
Coal	78	133	175	336	471	599
Lignite	3	4	6	10	16	25
Gas	17	32	41	65	89	113
Oil	6	8	8	8	7	7
Diesel	0	0	0	0	0	0
Nuclear	4	8	11	14	18	23
Biomass	0	1	2	5	7	10
Hydro	36	51	56	78	98	117
Wind	8	20	23	29	36	42
PV	0	1	1	6	10	14
Geothermal	0	0	0	0	0	0
Solar thermal power plants	0	0	0	0	0	0
Ocean energy	0	0	0	0	0	0
Combined heat & power production	**0**	**5**	**10**	**18**	**25**	**32**
Coal	0	5	10	18	25	32
Lignite	0	0	0	0	0	0
Gas	0	0	0	0	0	0
Oil	0	0	0	0	0	0
Biomass	0	0	0	0	0	0
Geothermal	0	0	0	0	0	0
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	0	0	0	0	0	0
Autoproducers	0	5	10	18	25	32
Total generation	**152**	**262**	**333**	**568**	**777**	**982**
Fossil	104	182	240	436	608	776
Coal	78	137	185	353	496	631
Lignite	3	4	6	10	16	25
Gas	17	32	41	65	89	113
Oil	6	8	8	8	7	7
Diesel	0	0	0	0	0	0
Nuclear	4	8	11	14	18	23
Hydrogen	0	0	0	0	0	0
Renewables	**44**	**72**	**82**	**118**	**151**	**183**
Hydro	36	51	56	78	98	117
Wind	8	20	23	29	36	42
PV	0	1	1	6	10	14
Biomass	0	1	2	5	7	10
Geothermal	0	0	0	0	0	0
Solar thermal	0	0	0	0	0	0
Ocean energy	0	0	0	0	0	0
Fluctuating RES (PV, Wind, Ocean)	8	20	24	35	46	56
Share of fluctuating RES	5.0%	7.8%	7.2%	6.2%	5.9%	5.7%
RES share	**28.9%**	**27.6%**	**24.6%**	**20.8%**	**19.4%**	**18.7%**

table 13.138: india: primary energy demand

PJ/A	2007	2015	2020	2030	2040	2050
Total	**25,159**	**32,059**	**37,722**	**54,403**	**66,773**	**77,761**
Fossil	**17,710**	**23,409**	**28,476**	**43,843**	**55,277**	**65,390**
Hard coal	9,870	12,547	15,416	24,312	30,386	35,399
Lignite	255	346	433	569	890	1,310
Natural gas	1,397	2,805	3,350	4,731	5,491	6,227
Crude oil	6,187	7,711	9,277	14,230	18,510	22,455
Nuclear	**183**	**567**	**796**	**1,156**	**1,516**	**1,876**
Renewables	**7,267**	**8,083**	**8,450**	**9,404**	**9,979**	**10,495**
Hydro	446	619	677	904	1,130	1,357
Wind	42	162	202	259	317	374
Solar	6	20	31	82	131	182
Biomass	6,773	7,281	7,525	8,097	8,292	8,425
Geothermal	0	1	15	62	109	156
Ocean Energy	0	0	0	0	0	0
RES share	**28.8%**	**25.2%**	**22.4%**	**17.3%**	**14.9%**	**13.5%**

table 13.139: india: final energy demand

PJ/a	2007	2015	2020	2030	2040	2050
Total (incl. non-energy use)	**16,449**	**21,309**	**24,912**	**35,271**	**45,614**	**55,977**
Total (energy use)	**14,818**	**18,839**	**22,107**	**31,838**	**41,553**	**51,288**
Transport	**1,708**	**2,554**	**3,559**	**7,327**	**11,095**	**14,863**
Oil products	1,608	2,345	3,224	6,699	10,166	13,619
Natural gas	52	69	92	162	231	300
Biofuels	6	84	167	335	507	692
Electricity	42	56	75	131	191	252
RES electricity	7	10	12	17	24	30
Hydrogen	0	0	0	0	0	0
RES share Transport	**0.7%**	**3.7%**	**5.0%**	**4.8%**	**4.8%**	**4.9%**
Industry	**4,778**	**6,733**	**8,256**	**12,336**	**16,403**	**20,490**
Electricity	924	1,549	2,052	3,475	4,899	6,322
RES electricity	156	272	319	462	604	746
District heat	0	117	215	315	398	497
RES district heat	0	2	6	17	41	97
Coal	1,319	2,131	2,825	4,898	6,977	9,062
Oil products	867	1,054	1,171	1,344	1,516	1,688
Gas	499	696	816	1,029	1,243	1,457
Solar	0	3	7	14	21	29
Biomass and waste	1,168	1,181	1,171	1,260	1,348	1,436
Geothermal	0	0	0	0	0	0
Hydrogen	0	0	0	0	0	0
RES share Industry	**27.7%**	**21.7%**	**18.2%**	**14.2%**	**12.3%**	**11.3%**
Other Sectors	**8,332**	**9,552**	**10,292**	**12,175**	**14,054**	**15,934**
Electricity	1,074	1,633	2,079	3,500	4,923	6,345
RES electricity	181	287	323	466	607	748
District heat	0	0	0	0	0	0
RES district heat	0	0	0	0	0	0
Coal	431	505	520	563	603	641
Oil products	1,236	1,464	1,633	2,054	2,475	2,896
Gas	35	84	126	252	378	504
Solar	6	13	16	28	38	49
Biomass and waste	5,550	5,853	5,903	5,743	5,579	5,416
Geothermal	0	1	15	37	59	84
RES share Other Sectors	**68.9%**	**64.4%**	**60.8%**	**51.5%**	**44.7%**	**39.5%**
Total RES	**7,074**	**7,706**	**7,940**	**8,380**	**8,829**	**9,326**
RES share	**47.7%**	**40.9%**	**35.9%**	**26.3%**	**21.2%**	**18.2%**
Non energy use	**1,631**	**2,470**	**2,805**	**3,433**	**4,061**	**4,689**
Oil	1,265	1,915	2,175	2,662	3,149	3,636
Gas	366	555	630	771	912	1,053
Coal	0	0	0	0	0	0

india: energy [r]evolution scenario

table 13.140: india: electricity generation

TWh/a	2007	2015	2020	2030	2040	2050
Power plants	**814**	**1,225**	**1,594**	**2,387**	**3,042**	**3,788**
Coal	540	752	925	1,175	1,161	966
Lignite	19	18	13	8	4	0
Gas	68	147	188	439	538	531
Oil	33	26	12	3	0	0
Diesel	0	0	0	0	0	0
Nuclear	17	52	53	43	24	0
Biomass	2	7	15	27	41	48
Hydro	124	154	189	195	201	204
Wind	12	65	170	320	456	645
PV	0	3	13	81	195	490
Geothermal	0	0	4	9	19	25
Solar thermal power plants	0	0	10	80	389	854
Ocean energy	0	1	3	7	14	25
Combined heat & power production	**0**	**30**	**60**	**150**	**370**	**670**
Coal	0	13	21	31	59	87
Lignite	0	0	0	0	0	0
Gas	0	6	10	22	52	114
Oil	0	0	0	0	0	0
Biomass	0	11	24	75	185	335
Geothermal	0	0	5	23	74	134
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	0	0	0	0	0	0
Autoproducers	0	30	60	150	370	670
Total generation	**814**	**1,255**	**1,654**	**2,537**	**3,412**	**4,458**
Fossil	660	962	1,168	1,677	1,815	1,698
Coal	540	765	946	1,205	1,221	1,053
Lignite	19	18	13	8	4	0
Gas	68	153	198	461	590	645
Oil	33	26	12	3	0	0
Diesel	0	0	0	0	0	0
Nuclear	17	52	53	43	24	0
Hydrogen	0	0	0	0	0	0
Renewables	**137**	**241**	**433**	**817**	**1,574**	**2,760**
Hydro	124	154	189	195	201	204
Wind	12	65	170	320	456	645
PV	0	3	13	81	195	490
Biomass	2	18	39	102	226	383
Geothermal	0	0	9	32	93	159
Solar thermal	0	0	10	80	389	854
Ocean energy	0	1	3	7	14	25
Distribution losses	198	299	376	550	650	720
Own consumption electricity	54	84	112	170	240	295
Electricity for hydrogen production	0	0	0	0	10	28
Final energy consumption (electricity)	**567**	**879**	**1,175**	**1,831**	**2,531**	**3,439**
Fluctuating RES (PV, Wind, Ocean)	12	69	186	408	665	1,160
Share of fluctuating RES	1.4%	5.5%	11.3%	16.1%	19.5%	26.0%
RES share	**16.9%**	**19.2%**	**26.2%**	**32.2%**	**46.1%**	**61.9%**
'Efficiency' savings (compared to Ref.)	**0**	**28**	**34**	**313**	**527**	**615**

table 13.141: india: heat supply

PJ/A	2007	2015	2020	2030	2040	2050
District heating plants	**0**	**12**	**44**	**123**	**361**	**711**
Fossil fuels	0	0	0	0	0	0
Biomass	0	10	35	86	162	142
Solar collectors	0	2	9	31	159	441
Geothermal	0	0	0	6	40	128
Heat from CHP	**0**	**166**	**305**	**681**	**1,626**	**2,855**
Fossil fuels	0	108	148	197	360	618
Biomass	0	58	114	281	600	1,031
Geothermal	0	0	43	203	666	1,206
Fuel cell (hydrogen)	0	0	0	0	0	0
Direct heating[1]	**8,699**	**9,825**	**10,573**	**11,631**	**11,946**	**11,612**
Fossil fuels	3,452	4,307	4,696	5,009	4,630	3,786
Biomass	5,240	5,385	5,193	4,654	4,193	3,443
Solar collectors	6	117	593	1,646	2,467	3,236
Geothermal	0	16	91	322	657	1,148
Total heat supply[1]	**8,699**	**10,003**	**10,922**	**12,434**	**13,933**	**15,179**
Fossil fuels	3,452	4,415	4,844	5,206	4,990	4,404
Biomass	5,240	5,453	5,342	5,021	4,955	4,616
Solar collectors	6	119	602	1,677	2,626	3,677
Geothermal	0	16	135	530	1,362	2,482
Fuel cell (hydrogen)	0	0	0	0	0	0
RES share (including RES electricity)	**60.3%**	**56%**	**56%**	**58%**	**64%**	**71%**
'Efficiency' savings (compared to Ref.)	**0**	**500**	**721**	**1,944**	**3,324**	**5,110**

1) heat from electricity (direct and from electric heat pumps) not included; covered in the model under 'electric appliances'

table 13.142: india: CO_2 emissions

MILL t/a	2007	2015	2020	2030	2040	2050
Condensation power plants	**785**	**943**	**1,057**	**1,168**	**1,058**	**766**
Coal	692	831	946	963	857	599
Lignite	28	22.6	14.8	7.6	3.7	0.0
Gas	34	67	86	196	198	167
Oil	30	22.5	10.2	2.4	0.0	0.0
Diesel	0.0	0.0	0.0	0.0	0.0	0.0
Combined heat & power production	**0**	**18**	**25**	**32**	**61**	**101**
Coal	0	14	20	23	40	57
Lignite	0	0	0	0	0	0
Gas	0	4	5	10	21	45
Oil	0	0	0	0	0	0
CO_2 emissions electricity & steam generation	**785**	**961**	**1,081**	**1,201**	**1,120**	**867**
Coal	692	845	965	986	897	655
Lignite	28	23	15	8	4	0
Gas	34	71	91	205	218	212
Oil & diesel	30	23	10	2	0	0
CO_2 emissions by sector	**1,307**	**1,626**	**1,807**	**2,035**	**1,944**	**1,620**
% of 1990 emissions	222%	276%	307%	345%	330%	275%
Industry	224	309	346	377	360	329
Other sectors	135	149	139	111	93	65
Transport	119	167	203	315	395	438
Electricity & steam generation	785	943	1,057	1,168	1,058	766
District heating	44	58	62	62	38	22
Population (Mill.)	1,164	1,294	1,367	1,485	1,565	1,614
CO_2 emissions per capita (t/capita)	**1.1**	**1.3**	**1.3**	**1.4**	**1.2**	**1.0**

table 13.143: india: installed capacity

GW	2007	2015	2020	2030	2040	2050
Power plants	**152**	**256**	**355**	**564**	**735**	**973**
Coal	78	131	161	214	211	176
Lignite	3	2	2	1	1	0
Gas	17	31	41	95	117	115
Oil	6	6	3	1	0	0
Diesel	0	0	0	0	0	0
Nuclear	4	8	8	6	3	0
Biomass	0	1	3	5	6	7
Hydro	36	46	56	57	57	57
Wind	8	29	69	128	172	230
PV	0	1	7	41	99	245
Geothermal	0	0	1	1	3	4
Solar thermal power plants	0	0	3	13	62	131
Ocean energy	0	0	1	2	4	7
Combined heat & power production	**0**	**7**	**13**	**31**	**76**	**138**
Coal	0	3	5	6	12	19
Lignite	0	0	0	0	0	0
Gas	0	2	2	5	12	26
Oil	0	0	0	0	0	0
Biomass	0	2	5	16	37	66
Geothermal	0	0	1	5	15	27
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	0	0	0	0	0	0
Autoproducers	0	7	13	31	76	138
Total generation	**152**	**263**	**368**	**595**	**811**	**1,111**
Fossil	104	175	214	322	353	336
Coal	78	134	166	219	223	195
Lignite	3	2	2	1	1	0
Gas	17	33	43	101	129	141
Oil	6	6	3	1	0	0
Diesel	0	0	0	0	0	0
Nuclear	4	8	8	6	3	0
Hydrogen	0	0	0	0	0	0
Renewables	**44**	**80**	**146**	**268**	**455**	**775**
Hydro	36	46	56	57	57	57
Wind	8	29	69	128	172	230
PV	0	1	7	41	99	245
Biomass	0	4	8	21	44	73
Geothermal	0	0	2	6	18	31
Solar thermal	0	0	3	13	62	131
Ocean energy	0	0	1	2	4	7
Fluctuating RES (PV, Wind, Ocean)	8	30	77	171	275	483
Share of fluctuating RES	5.0%	11.5%	21.0%	28.8%	33.9%	43.4%
RES share	**28.9%**	**30.3%**	**39.8%**	**45.0%**	**56.1%**	**69.7%**

table 13.144: india: primary energy demand

PJ/A	2007	2015	2020	2030	2040	2050
Total	**25,159**	**30,708**	**34,896**	**42,657**	**47,587**	**51,626**
Fossil	**17,710**	**22,121**	**24,742**	**29,297**	**29,088**	**26,218**
Hard coal	9,870	11,736	12,911	12,711	11,333	8,285
Lignite	255	203	133	69	33	0
Natural gas	1,397	3,037	4,115	7,274	7,508	7,612
Crude oil	6,187	7,145	7,583	9,244	10,214	10,321
Nuclear	**183**	**567**	**576**	**467**	**260**	**0**
Renewables	**7,267**	**8,019**	**9,578**	**12,893**	**18,238**	**25,408**
Hydro	446	554	679	702	724	734
Wind	42	234	610	1,152	1,642	2,322
Solar	6	129	686	2,256	4,728	8,515
Biomass	6,773	7,076	7,223	7,458	7,676	7,927
Geothermal	0	22	367	1,299	3,419	5,819
Ocean Energy	0	4	12	25	50	90
RES share	**28.8%**	**26.1%**	**27.5%**	**30.3%**	**38.4%**	**49.3%**
'Efficiency' savings (compared to Ref.)	**0**	**1,358**	**2,872**	**11,845**	**19,335**	**26,331**

table 13.145: india: final energy demand

PJ/A	2007	2015	2020	2030	2040	2050
Total (incl. non-energy use)	**16,449**	**20,437**	**23,295**	**29,259**	**34,547**	**39,869**
Total (energy use)	**14,818**	**17,967**	**20,490**	**25,826**	**30,486**	**35,180**
Transport	**1,708**	**2,454**	**3,159**	**5,417**	**7,047**	**8,677**
Oil products	1,608	2,275	2,771	4,295	5,411	5,989
Natural gas	52	51	64	106	97	122
Biofuels	6	44	102	274	324	561
Electricity	42	84	222	742	1,190	1,929
RES electricity	7	16	58	239	549	1,194
Hydrogen	0	0	0	0	25	76
RES share Transport	**0.7%**	**2.5%**	**5.1%**	**9.5%**	**12.5%**	**20.8%**
Industry	**4,778**	**6,336**	**7,529**	**9,558**	**11,905**	**14,139**
Electricity	924	1,542	2,003	2,793	3,791	4,905
RES electricity	156	296	524	899	1,749	3,037
District heat	0	170	326	733	1,829	3,212
RES district heat	0	170	326	733	1,829	3,212
Coal	1,319	1,826	1,890	1,880	1,451	979
Oil products	867	964	999	869	669	319
Gas	499	682	1,076	1,733	1,976	2,008
Solar	0	37	214	574	929	1,248
Biomass and waste	1,168	1,115	964	764	804	769
Geothermal	0	1	56	212	456	698
Hydrogen	0	0	0	0	0	0
RES share Industry	**27.7%**	**25.5%**	**27.7%**	**33.3%**	**48.4%**	**63.4%**
Other Sectors	**8,332**	**9,177**	**9,803**	**10,851**	**11,534**	**12,364**
Electricity	1,074	1,538	2,006	3,056	4,132	5,547
RES electricity	181	295	525	984	1,906	3,435
District heat	0	0	6	32	64	186
RES district heat	0	0	6	32	64	186
Coal	431	471	438	248	196	153
Oil products	1,236	1,218	982	741	562	243
Gas	35	239	430	580	586	593
Solar	6	79	379	1,072	1,538	1,988
Biomass and waste	5,550	5,616	5,527	5,035	4,299	3,281
Geothermal	0	15	34	87	156	373
RES share Other Sectors	**68.9%**	**65.5%**	**66.0%**	**66.4%**	**69.0%**	**74.9%**
Total RES	**7,074**	**7,685**	**8,716**	**10,906**	**14,615**	**20,029**
RES share	**47.7%**	**42.8%**	**42.5%**	**42.2%**	**47.9%**	**56.9%**
Non energy use	**1,631**	**2,470**	**2,805**	**3,433**	**4,061**	**4,689**
Oil	1,265	1,915	2,175	2,662	3,149	3,636
Gas	366	555	630	771	912	1,053
Coal	0	0	0	0	0	0

india: advanced energy [r]evolution scenario

table 13.146: india: electricity generation

TWh/a	2007	2015	2020	2030	2040	2050
Power plants	**814**	**1,225**	**1,595**	**2,441**	**3,186**	**4,392**
Coal	540	747	629	467	118	0
Lignite	19	18	13	8	4	0
Gas	68	147	250	349	326	202
Oil	33	26	12	3	0	0
Diesel	0	0	0	0	0	0
Nuclear	17	52	53	43	24	0
Biomass	2	7	15	27	41	48
Hydro	124	154	189	195	201	204
Wind	12	65	229	525	763	969
PV	0	3	58	218	469	963
Geothermal	0	5	49	214	349	406
Solar thermal power plants	0	0	75	315	781	1,402
Ocean energy	0	1	23	76	110	197
Combined heat & power production	**0**	**30**	**60**	**150**	**370**	**670**
Coal	0	13	21	30	48	74
Lignite	0	0	0	0	0	0
Gas	0	6	10	23	56	101
Oil	0	0	0	0	0	0
Biomass	0	11	24	75	185	335
Geothermal	0	0	5	23	81	161
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	0	0	0	0	0	0
Autoproducers	0	30	60	150	370	670
Total generation	**814**	**1,255**	**1,655**	**2,591**	**3,556**	**5,062**
Fossil	660	957	935	880	552	377
Coal	540	760	650	497	166	74
Lignite	19	18	13	8	4	0
Gas	68	153	260	372	382	303
Oil	33	26	12	3	0	0
Diesel	0	0	0	0	0	0
Nuclear	17	52	53	43	24	0
Hydrogen	0	0	0	0	0	0
Renewables	**137**	**246**	**667**	**1,668**	**2,980**	**4,685**
Hydro	124	154	189	195	201	204
Wind	12	65	229	525	763	969
PV	0	3	58	218	469	963
Biomass	2	18	39	102	226	383
Geothermal	0	5	54	237	430	567
Solar thermal	0	0	75	315	781	1,402
Ocean energy	0	1	23	76	110	197
Distribution losses	198	299	376	540	630	690
Own consumption electricity	54	84	112	170	230	280
Electricity for hydrogen production	0	0	0	0	19	70
Final energy consumption (electricity)	**567**	**879**	**1,176**	**1,895**	**2,696**	**4,047**
Fluctuating RES (PV, Wind, Ocean)	12	69	310	819	1,342	2,129
Share of fluctuating RES	1.4%	5.5%	18.7%	31.6%	37.7%	42.1%
RES share	**16.9%**	**19.6%**	**40.3%**	**64.4%**	**83.8%**	**92.6%**
'Efficiency' savings (compared to Ref.)	**0**	**28**	**34**	**312**	**526**	**607**

table 13.147: india: heat supply

PJ/A	2007	2015	2020	2030	2040	2050
District heating plants	**0**	**12**	**47**	**137**	**420**	**873**
Fossil fuels	0	0	0	0	0	0
Biomass	0	10	37	96	189	175
Solar collectors	0	2	9	34	185	541
Geothermal	0	0	0	7	46	157
Heat from CHP	**0**	**166**	**305**	**681**	**1,669**	**3,014**
Fossil fuels	0	108	148	197	336	536
Biomass	0	58	114	281	600	1,031
Geothermal	0	0	43	203	733	1,447
Fuel cell (hydrogen)	0	0	0	0	0	0
Direct heating[1]	**8,699**	**9,825**	**10,571**	**11,617**	**11,822**	**10,694**
Fossil fuels	3,452	4,308	4,534	4,329	3,331	1,170
Biomass	5,240	5,385	5,353	4,962	4,405	3,489
Solar collectors	6	117	593	1,978	3,085	4,207
Geothermal	0	16	91	348	1,002	1,828
Total heat supply[1]	**8,699**	**10,003**	**10,922**	**12,434**	**13,933**	**15,179**
Fossil fuels	3,452	4,416	4,682	4,526	3,667	1,706
Biomass	5,240	5,453	5,504	5,339	5,194	4,695
Solar collectors	6	119	602	2,012	3,270	4,748
Geothermal	0	16	135	558	1,780	3,432
Fuel cell (hydrogen)	0	0	0	0	22	598
RES share (including RES electricity)	**60.3%**	**55.9%**	**57.1%**	**63.6%**	**73.7%**	**88.5%**
'Efficiency' savings (compared to Ref.)		**500**	**721**	**1,944**	**3,324**	**5,110**

1) heat from electricity (direct and from electric heat pumps) not included; covered in the model under 'electric appliances'

table 13.148: india: CO_2 emissions

MILL t/a	2007	2015	2020	2030	2040	2050
Condensation power plants	**785**	**938**	**783**	**549**	**211**	**64**
Coal	692	826	643	383	87	0
Lignite	28	23	15	8	4	0
Gas	34	67	114	156	120	64
Oil	30	23	10	2	0	0
Diesel	0.0	0	0	0	0	0
Combined heat & power production	**0**	**18**	**25**	**32**	**55**	**87**
Coal	0	14	20	22	33	48
Lignite	0	0	0	0	0	0
Gas	0	4	5	10	22	39
Oil	0	0	0	0	0	0
CO_2 emissions electricity & steam generation	**785**	**956**	**807**	**581**	**266**	**151**
Coal	692	840	663	405	120	48
Lignite	28	23	15	8	4	0
Gas	34	71	119	166	142	103
Oil & diesel	30	23	10	2	0	0
CO_2 emissions by sector	**1,307**	**1,620**	**1,524**	**1,332**	**927**	**499**
% of 1990 emissions	222%	275%	259%	226%	157%	85%
Industry	224	309	336	353	297	186
Other sectors	135	149	139	90	60	15
Transport	119	167	203	297	339	226
Electricity & steam generation	785	938	783	549	211	64
District heating	44	57	64	43	20	8
Population (Mill.)	1,164	1,294	1,367	1,485	1,565	1,614
CO_2 emissions per capita (t/capita)	**1.1**	**1.3**	**1.1**	**0.9**	**0.6**	**0.3**

table 13.149: india: installed capacity

GW	2007	2015	2020	2030	2040	2050
Power plants	**152**	**256**	**397**	**658**	**914**	**1,304**
Coal	78	130	110	85	26	0
Lignite	3	2	2	1	1	0
Gas	17	31	54	76	86	78
Oil	6	6	3	1	0	0
Diesel	0	0	0	0	0	0
Nuclear	4	8	8	6	3	0
Biomass	0	1	3	5	6	7
Hydro	36	46	56	57	57	57
Wind	8	29	93	210	288	346
PV	0	1	30	111	237	482
Geothermal	0	1	8	33	54	62
Solar thermal power plants	0	0	24	53	124	216
Ocean energy	0	0	7	22	31	56
Combined heat & power production	**0**	**7**	**13**	**31**	**76**	**138**
Coal	0	3	5	5	10	16
Lignite	0	0	0	0	0	0
Gas	0	2	2	5	13	23
Oil	0	0	0	0	0	0
Biomass	0	2	5	16	37	66
Geothermal	0	0	1	5	16	32
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	0	0	0	0	0	0
Autoproducers	0	7	13	31	76	138
Total generation	**152**	**263**	**411**	**690**	**990**	**1,442**
Fossil	104	174	176	174	135	117
Coal	78	133	114	90	36	16
Lignite	3	2	2	1	1	0
Gas	17	33	57	81	99	101
Oil	6	6	3	1	0	0
Diesel	0	0	0	0	0	0
Nuclear	4	8	8	6	3	0
Hydrogen	0	0	0	0	0	0
Renewables	**44**	**81**	**227**	**510**	**851**	**1,325**
Hydro	36	46	56	57	57	57
Wind	8	29	93	210	288	346
PV	0	1	30	111	237	482
Biomass	0	4	8	21	44	73
Geothermal	0	1	9	38	70	95
Solar thermal	0	0	24	53	124	216
Ocean energy	0	0	7	22	31	56
Fluctuating RES (PV, Wind, Ocean)	8	30	130	343	556	884
Share of fluctuating RES	5.0%	11.5%	31.7%	49.8%	56.2%	61.3%
RES share	**28.9%**	**30.6%**	**55.3%**	**74.0%**	**86.0%**	**91.9%**

table 13.150: india: primary energy demand

PJ/A	2007	2015	2020	2030	2040	2050
Total	**25,159**	**30,737**	**34,056**	**42,979**	**49,214**	**54,671**
Fossil	**17,710**	**22,026**	**21,854**	**21,309**	**17,159**	**12,078**
Hard coal	9,870	11,611	9,675	6,557	2,803	851
Lignite	255	203	133	69	33	0
Natural gas	1,397	3,082	4,498	5,854	5,050	4,075
Crude oil	6,187	7,130	7,548	8,829	9,273	7,152
Nuclear	**183**	**567**	**576**	**467**	**260**	**0**
Renewables	**7,267**	**8,144**	**11,626**	**21,202**	**31,795**	**42,593**
Hydro	446	554	679	702	724	734
Wind	42	234	824	1,890	2,747	3,488
Solar	6	129	1,081	3,931	7,770	13,262
Biomass	6,773	7,072	7,401	7,835	7,998	7,948
Geothermal	0	150	1,558	6,571	12,161	16,451
Ocean Energy	0	4	83	274	396	709
RES share	**28.8%**	**26.5%**	**34.2%**	**49.4%**	**64.6%**	**77.9%**
'Efficiency' savings (compared to Ref.)	**0**	**1,329**	**3,712**	**11,523**	**17,708**	**23,286**

table 13.151: india: final energy demand

PJ/a	2007	2015	2020	2030	2040	2050
Total (incl. non-energy use)	**16,449**	**20,437**	**23,295**	**29,271**	**34,366**	**38,496**
Total (energy use)	**14,818**	**17,967**	**20,490**	**25,838**	**30,304**	**33,807**
Transport	**1,708**	**2,454**	**3,159**	**5,417**	**6,847**	**7,277**
Oil products	1,608	2,275	2,769	4,061	4,641	3,055
Natural gas	52	51	64	90	93	101
Biofuels	6	44	103	295	318	344
Electricity	42	84	223	971	1,746	3,589
RES electricity	7	16	90	625	1,463	3,321
Hydrogen	0	0	0	0	49	188
RES share Transport	**0.7%**	2.5%	6.1%	17.0%	26.6%	52.8%
Industry	**4,778**	**6,336**	**7,529**	**9,562**	**11,933**	**14,211**
Electricity	924	1,542	2,003	2,794	3,795	4,935
RES electricity	156	302	807	1,798	3,180	4,568
District heat	0	170	328	743	1,913	3,463
RES district heat	0	170	328	743	1,913	3,463
Coal	1,319	1,827	1,916	1,937	1,308	267
Oil products	867	961	992	854	651	295
Gas	499	684	866	1,227	1,219	925
Solar	0	37	214	630	1,235	1,795
Biomass and waste	1,168	1,115	1,155	1,143	1,074	845
Geothermal	0	1	56	233	714	1,313
Hydrogen	0	0	0	0	24	374
RES share Industry	**27.7%**	**25.6%**	**34.0%**	**47.6%**	**68.2%**	**86.8%**
Other Sectors	**8,332**	**9,177**	**9,803**	**10,860**	**11,524**	**12,319**
Electricity	1,074	1,538	2,006	3,056	4,132	5,547
RES electricity	181	301	808	1,967	3,463	5,134
District heat	0	0	6	36	77	241
RES district heat	0	0	6	36	77	241
Coal	431	471	438	192	127	15
Oil products	1,236	1,207	959	617	465	95
Gas	35	250	453	454	246	123
Solar	6	79	379	1,348	1,850	2,412
Biomass and waste	5,550	5,616	5,527	5,065	4,387	3,478
Geothermal	0	15	34	92	240	408
RES share Other Sectors	**68.9%**	**65.5%**	**68.9%**	**78.3%**	**86.9%**	**94.8%**
Total RES	**7,074**	**7,697**	**9,506**	**13,976**	**19,976**	**27,842**
RES share	**47.7%**	**42.8%**	**46.4%**	**54.1%**	**65.9%**	**82.4%**
Non energy use	**1,631**	**2,470**	**2,805**	**3,433**	**4,061**	**4,689**
Oil	1,265	1,915	2,175	2,662	3,149	3,636
Gas	366	555	630	771	912	1,053
Coal	0	0	0	0	0	0

india: total new investment by technology

table 13.152: india: total investment

MILLION $	2005-2010	2011-2020	2021-2030	2005-2030
Reference scenario				
Conventional (fossil & nuclear)	**70,244**	**164,259**	**253,877**	**488,380**
Renewables	**55,635**	**77,430**	**112,166**	**245,231**
Biomass	1,010	3,911	8,047	12,967
Hydro	40,716	55,456	81,435	177,608
Wind	13,259	16,035	14,963	44,257
PV	650	2,028	6,472	9,150
Geothermal	0	0	1,249	1,249
Solar thermal power plants	0	0	0	0
Ocean energy	0	0	0	0
Energy [R]evolution				
Conventional (fossil & nuclear)	**70,218**	**127,429**	**124,971**	**322,617**
Renewables	**55,635**	**208,189**	**260,230**	**524,054**
Biomass	1,010	28,445	41,805	71,259
Hydro	40,716	56,360	16,015	113,091
Wind	13,259	71,588	69,866	154,713
PV	650	14,984	47,312	62,946
Geothermal	0	16,122	36,222	52,344
Solar thermal power plants	0	17,170	46,491	63,661
Ocean energy	0	3,520	2,520	6,040
Advanced Energy [R]evolution				
Conventional (fossil & nuclear)	**70,244**	**88,604**	**23,885**	**182,733**
Renewables	**55,635**	**482,235**	**702,578**	**1,240,448**
Biomass	1,010	28,445	41,805	71,259
Hydro	40,716	56,360	16,015	113,091
Wind	13,259	99,210	129,580	242,049
PV	650	63,733	111,364	175,747
Geothermal	0	85,596	236,104	321,700
Solar thermal power plants	0	127,225	130,617	257,841
Ocean energy	0	21,666	37,094	58,760

notes

developing asia: reference scenario

table 13.153: developing asia: electricity generation

TWh/a	2007	2015	2020	2030	2040	2050
Power plants	**934**	**1,295**	**1,573**	**2,448**	**3,088**	**3,623**
Coal	159	376	488	991	1,261	1,428
Lignite	94	108	116	124	132	140
Gas	358	420	517	734	950	1,165
Oil	119	75	68	53	38	23
Diesel	2	3	4	4	4	4
Nuclear	44	65	65	70	75	80
Biomass	8	24	40	70	101	130
Hydro	132	194	225	276	327	378
Wind	1	2	12	52	92	132
PV	0	1	5	26	47	68
Geothermal	17	27	33	47	61	75
Solar thermal power plants	0	0	0	0	0	0
Ocean energy	0	0	0	0	0	0
Combined heat & power production	**44**	**50**	**56**	**65**	**76**	**98**
Coal	34	38	42	49	57	74
Lignite	4	5	6	6	7	7
Gas	3	3	4	4	5	7
Oil	3	4	4	5	6	7
Biomass	0	0	0	1	1	3
Geothermal	0	0	0	0	0	0
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	7	9	10	11	12	13
Autoproducers	38	41	46	54	64	85
Total generation	**978**	**1,344**	**1,629**	**2,513**	**3,164**	**3,721**
Fossil	777	1,031	1,249	1,971	2,460	2,855
Coal	194	413	530	1,041	1,318	1,502
Lignite	98	113	122	130	139	147
Gas	361	423	521	738	955	1,172
Oil	122	79	73	58	44	30
Diesel	2	3	4	4	4	4
Nuclear	44	65	65	70	75	80
Hydrogen	0	0	0	0	0	0
Renewables	**158**	**248**	**315**	**472**	**629**	**786**
Hydro	132	194	225	276	327	378
Wind	1	2	12	52	92	132
PV	0	1	5	26	47	68
Biomass	8	24	40	71	102	133
Geothermal	17	27	33	47	61	75
Solar thermal	0	0	0	0	0	0
Ocean energy	0	0	0	0	0	0
Distribution losses	81	117	132	183	234	286
Own consumption electricity	48	69	78	108	138	168
Electricity for hydrogen production	0	0	0	0	0	0
Final energy consumption (electricity)	**847**	**1,155**	**1,415**	**2,216**	**2,784**	**3,259**
Fluctuating RES (PV, Wind, Ocean)	1	3	17	78	139	200
Share of fluctuating RES	0.1%	0.2%	1.0%	3.1%	4.4%	5.4%
RES share	**16.1%**	**18.5%**	**19.3%**	**18.8%**	**19.9%**	**21.1%**

table 13.154: developing asia: heat supply

PJ/A	2007	2015	2020	2030	2040	2050
District heating plants	**18**	**59**	**110**	**158**	**196**	**226**
Fossil fuels	18	59	110	158	196	226
Biomass	0	0	0	0	0	0
Solar collectors	0	0	0	0	0	0
Geothermal	0	0	0	0	0	0
Heat from CHP	**259**	**252**	**257**	**285**	**310**	**376**
Fossil fuels	259	252	256	282	305	367
Biomass	0	0	1	2	5	9
Geothermal	0	0	0	0	0	0
Fuel cell (hydrogen)	0	0	0	0	0	0
Direct heating[1]	**10,559**	**11,712**	**12,579**	**14,620**	**16,817**	**18,659**
Fossil fuels	5,286	6,681	7,312	9,062	10,548	11,736
Biomass	5,269	5,025	5,241	5,491	6,153	6,753
Solar collectors	4	6	24	64	110	160
Geothermal	0	1	2	4	6	10
Total heat supply[1]	**10,836**	**12,022**	**12,946**	**15,063**	**17,323**	**19,261**
Fossil fuels	5,563	6,991	7,678	9,502	11,048	12,329
Biomass	5,269	5,025	5,242	5,493	6,158	6,762
Solar collectors	4	6	24	64	110	160
Geothermal	0	1	2	4	6	10
Fuel cell ((hydrogen)	0	0	0	0	0	0
RES share (including RES electricity)	**48.7%**	**41.8%**	**40.7%**	**36.9%**	**36.2%**	**36.0%**

1) heat from electricity (direct and from electric heat pumps) not included; covered in the model under 'electric appliances'

table 13.155: developing asia: CO_2 emissions

MILL t/a	2007	2015	2020	2030	2040	2050
Condensation power plants	**524**	**708**	**841**	**1,297**	**1,572**	**1,709**
Coal	154	331	419	790	982	1,063
Lignite	106	114	119	118	123	127
Gas	177	197	243	344	435	500
Oil	58	64	58	41	29	16
Diesel	29	3	3	3	3	3
Combined heat & power production	**45**	**45**	**47**	**54**	**60**	**74**
Coal	31	32	34	39	43	53
Lignite	8	6	6	7	7	8
Gas	3	2	2	2	2	3
Oil	4	4	5	6	8	11
CO_2 emissions electricity & steam generation	**569**	**753**	**889**	**1,351**	**1,632**	**1,783**
Coal	184	363	453	829	1,025	1,116
Lignite	114	120	125	125	130	135
Gas	180	199	244	346	437	503
Oil & diesel	91	71	66	51	40	30
CO_2 emissions by sector	**1,488**	**1,853**	**2,129**	**2,916**	**3,448**	**3,846**
% of 1990 emissions	216%	269%	308%	423%	500%	557%
Industry	411	484	525	618	684	734
Other sectors	137	183	194	237	279	320
Transport	319	358	422	601	779	957
Electricity & steam generation	536	720	854	1,311	1,588	1,726
District heating	85	108	135	148	118	109
Population (Mill.)	1,011	1,131	1,203	1,333	1,439	1,516
CO_2 emissions per capita (t/capita)	**1.5**	**1.6**	**1.8**	**2.2**	**2.4**	**2.5**

table 13.156: developing asia: installed capacity

GW	2007	2015	2020	2030	2040	2050
Power plants	**229**	**306**	**360**	**550**	**671**	**758**
Coal	26	56	71	144	184	208
Lignite	15	16	17	18	19	20
Gas	92	112	134	208	244	265
Oil	40	39	35	26	22	15
Diesel	2	2	3	3	4	4
Nuclear	6	8	7	9	10	11
Biomass	1	3	5	11	16	20
Hydro	44	65	76	93	110	127
Wind	0	1	4	17	29	39
PV	0	1	3	14	26	38
Geothermal	3	4	5	7	9	11
Solar thermal power plants	0	0	0	0	0	0
Ocean energy	0	0	0	0	0	0
Combined heat & power production	**10**	**14**	**15**	**15**	**17**	**22**
Coal	7	9	9	9	11	14
Lignite	1	1	1	1	1	1
Gas	1	1	1	1	1	2
Oil	2	3	4	3	4	5
Biomass	0	0	0	0	0	1
Geothermal	0	0	0	0	0	0
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	1	2	2	2	2	2
Autoproducers	9	12	12	13	15	20
Total generation	**240**	**320**	**374**	**565**	**688**	**780**
Fossil	185	238	274	414	488	533
Coal	33	64	80	154	194	222
Lignite	16	17	18	19	20	22
Gas	92	113	135	209	245	266
Oil	42	42	39	29	25	20
Diesel	2	2	3	3	4	4
Nuclear	6	8	7	9	10	11
Hydrogen	0	0	0	0	0	0
Renewables	**48**	**74**	**93**	**142**	**190**	**236**
Hydro	44	65	76	93	110	127
Wind	0	1	4	17	29	39
PV	0	1	3	14	26	38
Biomass	1	3	5	11	16	21
Geothermal	3	4	5	7	9	11
Solar thermal	0	0	0	0	0	0
Ocean energy	0	0	0	0	0	0
Fluctuating RES (PV, Wind, Ocean)	0	2	7	31	55	76
Share of fluctuating RES	0.1%	0.6%	1.8%	5.5%	7.9%	9.8%
RES share	**20.2%**	**23.1%**	**24.8%**	**25.1%**	**27.6%**	**30.2%**

table 13.157: developing asia: primary energy demand

PJ/A	2007	2015	2020	2030	2040	2050
Total	**31,903**	**37,421**	**41,810**	**53,745**	**62,690**	**69,233**
Fossil	**22,958**	**27,488**	**31,198**	**41,783**	**49,520**	**55,021**
Hard coal	4,798	7,208	8,415	13,005	15,479	16,688
Lignite	1,026	1,080	1,126	1,122	1,170	1,214
Natural gas	6,998	7,935	9,241	12,216	14,557	16,020
Crude oil	10,136	11,265	12,416	15,440	18,315	21,099
Nuclear	**476**	**709**	**709**	**764**	**818**	**873**
Renewables	**8,469**	**9,224**	**9,903**	**11,199**	**12,352**	**13,340**
Hydro	476	698	810	994	1,177	1,361
Wind	2	7	43	187	331	475
Solar	4	10	42	158	280	405
Biomass	7,366	7,818	8,293	9,080	9,742	10,248
Geothermal	621	690	715	780	821	851
Ocean Energy	0	0	0	0	0	0
RES share	**26.6%**	**24.7%**	**23.7%**	**20.8%**	**19.7%**	**19.3%**

table 13.158: developing asia: final energy demand

PJ/a	2007	2015	2020	2030	2040	2050
Total (incl. non-energy use)	**23,620**	**27,568**	**30,702**	**38,945**	**45,839**	**52,040**
Total (energy use)	**21,242**	**24,888**	**27,813**	**35,679**	**42,196**	**48,021**
Transport	**4,468**	**5,150**	**6,071**	**8,709**	**11,346**	**13,984**
Oil products	4,372	4,870	5,753	8,211	10,662	13,098
Natural gas	82	134	134	172	210	249
Biofuels	7	134	172	310	454	612
Electricity	8	12	12	16	20	25
RES electricity	1	2	2	3	4	5
Hydrogen	0	0	0	0	0	0
RES share Transport	**0.2%**	**2.6%**	**2.9%**	**3.6%**	**4.0%**	**4.4%**
Industry	**7,234**	**9,077**	**10,341**	**13,232**	**15,046**	**16,156**
Electricity	1,374	2,010	2,471	3,711	4,323	4,600
RES electricity	222	371	478	697	859	971
District heat	240	264	305	360	406	486
RES district heat	0	0	0	0	0	0
Coal	2,356	2,846	3,056	3,520	3,819	3,977
Oil products	1,137	1,196	1,240	1,356	1,414	1,427
Gas	1,345	1,771	2,064	2,749	3,291	3,685
Solar	0	0	6	15	27	39
Biomass and waste	782	989	1,197	1,518	1,763	1,934
Geothermal	0	0	1	3	5	7
Hydrogen	0	0	0	0	0	0
RES share Industry	**13.9%**	**15.0%**	**16.3%**	**16.9%**	**17.6%**	**18.3%**
Other Sectors	**9,541**	**10,662**	**11,401**	**13,739**	**15,804**	**17,881**
Electricity	1,667	2,135	2,613	4,250	5,678	7,106
RES electricity	269	394	505	798	1,129	1,501
District heat	36	40	55	74	91	106
RES district heat	0	0	0	0	0	0
Coal	191	201	236	332	420	505
Oil products	1,275	1,814	1,846	2,059	2,260	2,463
Gas	395	476	553	867	1,173	1,477
Solar	4	6	18	49	83	121
Biomass and waste	5,973	5,990	6,081	6,108	6,098	6,103
Geothermal	0	0	0	0	0	0
RES share Other Sectors	**65.5%**	**59.9%**	**57.9%**	**50.6%**	**46.3%**	**43.2%**
Total RES	**7,258**	**7,886**	**8,461**	**9,501**	**10,423**	**11,294**
RES share	**34.2%**	**31.7%**	**30.4%**	**26.6%**	**24.7%**	**23.5%**
Non energy use	**2,378**	**2,680**	**2,889**	**3,266**	**3,643**	**4,019**
Oil	1,823	2,054	2,215	2,503	2,792	3,081
Gas	534	602	649	733	818	902
Coal	21	24	26	29	32	36

developing asia: energy [r]evolution scenario

table 13.159: developing asia: electricity generation

TWh/a	2007	2015	2020	2030	2040	2050
Power plants	**934**	**1,294**	**1,451**	**1,838**	**2,098**	**2,345**
Coal	159	288	310	348	178	69
Lignite	94	83	62	28	6	0
Gas	358	515	534	544	513	463
Oil	119	77	72	59	28	9
Diesel	2	3	3	2	2	1
Nuclear	44	65	60	40	12	0
Biomass	8	19	28	38	53	74
Hydro	132	180	210	240	263	286
Wind	1	29	99	320	569	685
PV	0	4	19	106	255	415
Geothermal	17	29	40	60	91	113
Solar thermal power plants	0	2	11	45	110	194
Ocean energy	0	0	3	8	18	35
Combined heat & power production	**44**	**50**	**75**	**149**	**209**	**250**
Coal	34	33	40	55	44	23
Lignite	4	5	3	2	0	0
Gas	3	5	11	37	82	122
Oil	3	2	2	1	0	0
Biomass	0	5	12	33	49	59
Geothermal	0	1	7	21	34	47
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	7	9	10	11	12	15
Autoproducers	38	41	65	138	197	235
Total generation	**978**	**1,344**	**1,525**	**1,987**	**2,307**	**2,595**
Fossil	777	1,011	1,036	1,076	853	687
Coal	194	321	350	403	222	92
Lignite	98	88	65	30	6	0
Gas	361	520	545	581	595	585
Oil	122	79	74	60	29	9
Diesel	2	3	3	2	2	1
Nuclear	44	65	60	40	12	0
Hydrogen	0	0	0	0	0	0
Renewables	**158**	**269**	**429**	**871**	**1,442**	**1,908**
Hydro	132	180	210	240	263	286
Wind	1	29	99	320	569	685
PV	0	4	19	106	255	415
Biomass	8	24	40	71	102	133
Geothermal	17	30	47	81	125	160
Solar thermal	0	2	11	45	110	194
Ocean energy	0	0	3	8	18	35
Distribution losses	81	117	125	160	205	235
Own consumption electricity	48	69	78	105	125	143
Electricity for hydrogen production	0	0	0	1	8	22
Final energy consumption (electricity)	**847**	**1,139**	**1,319**	**1,721**	**1,967**	**2,171**
Fluctuating RES (PV, Wind, Ocean)	1	33	121	434	842	1,135
Share of fluctuating RES	0.1%	2.5%	7.9%	21.8%	36.5%	43.7%
RES share	**16.1%**	**20.0%**	**28.1%**	**43.8%**	**62.5%**	**73.5%**
'Efficiency' savings (compared to Ref.)	**0**	**22**	**128**	**590**	**975**	**1,329**

table 13.160: developing asia: heat supply

PJ/A	2007	2015	2020	2030	2040	2050
District heating plants	**18**	**53**	**97**	**165**	**431**	**948**
Fossil fuels	18	11	8	8	4	0
Biomass	0	20	45	79	207	446
Solar collectors	0	11	21	36	108	247
Geothermal	0	11	23	41	112	256
Heat from CHP	**259**	**264**	**366**	**676**	**941**	**1,104**
Fossil fuels	259	224	249	352	444	473
Biomass	0	28	57	135	189	212
Geothermal	0	13	60	188	308	419
Fuel cell (hydrogen)	0	0	0	0	0	0
Direct heating[1]	**10,559**	**11,251**	**11,803**	**12,625**	**13,331**	**13,643**
Fossil fuels	5,286	6,032	5,839	5,511	5,031	3,963
Biomass	5,269	4,925	5,094	5,011	4,704	4,064
Solar collectors	4	214	646	1,549	2,309	3,378
Geothermal	0	80	224	554	1,287	2,238
Total heat supply[1]	**10,836**	**11,569**	**12,266**	**13,466**	**14,704**	**15,695**
Fossil fuels	5,563	6,267	6,096	5,872	5,479	4,436
Biomass	5,269	4,973	5,196	5,225	5,100	4,722
Solar collectors	4	225	667	1,585	2,417	3,624
Geothermal	0	104	307	784	1,707	2,913
Fuel cell (hydrogen)	0	0	0	0	0	0
RES share (including RES electricity)	**48.7%**	**46%**	**50%**	**56%**	**63%**	**72%**
'Efficiency' savings (compared to Ref.)	**0**	**454**	**680**	**1,597**	**2,619**	**3,566**

1) heat from electricity (direct and from electric heat pumps) not included; covered in the model under 'electric appliances'

table 13.161: developing asia: CO_2 emissions

MILL t/a	2007	2015	2020	2030	2040	2050
Condensation power plants	**524**	**650**	**643**	**606**	**402**	**257**
Coal	154	253	266	278	138	52
Lignite	106	87	64	27	6	0
Gas	177	242	250	255	235	199
Oil	58	65	60	45	21	6
Diesel	29	3	2	2	1	1
Combined heat & power production	**45**	**40**	**43**	**58**	**66**	**66**
Coal	31	29	32	39	29	15
Lignite	8	6	3	1	0	0
Gas	3	3	6	16	36	51
Oil	4	3	2	2	0	0
CO_2 emissions electricity & steam generation	**569**	**690**	**686**	**665**	**467**	**323**
Coal	184	282	298	317	168	66
Lignite	114	93	67	28	6	0
Gas	180	244	256	271	271	250
Oil & diesel	91	70	65	49	23	7
CO_2 emissions by sector	**1,488**	**1,714**	**1,686**	**1,660**	**1,385**	**1,085**
% of 1990 emissions	216%	248%	244%	241%	201%	157%
Industry	411	433	427	402	355	253
Other sectors	137	163	144	127	108	83
Transport	319	358	402	467	475	466
Electricity & steam generation	536	661	652	609	405	261
District heating	85	99	62	55	43	22
Population (Mill.)	1,011	1,131	1,203	1,333	1,439	1,516
CO_2 emissions per capita (t/capita)	**1.5**	**1.5**	**1.4**	**1.2**	**1.0**	**0.7**

table 13.162: developing asia: installed capacity

GW	2007	2015	2020	2030	2040	2050
Power plants	**229**	**327**	**367**	**512**	**644**	**731**
Coal	26	43	45	51	40	23
Lignite	15	12	9	4	1	0
Gas	92	138	138	154	131	105
Oil	40	39	37	28	16	6
Diesel	2	2	2	2	1	1
Nuclear	6	8	6	5	2	0
Biomass	1	2	4	6	8	11
Hydro	44	60	71	81	89	96
Wind	0	15	33	103	178	201
PV	0	3	11	59	142	231
Geothermal	3	4	6	9	14	17
Solar thermal power plants	0	1	4	8	17	30
Ocean energy	0	0	1	3	5	10
Combined heat & power production	**10**	**13**	**17**	**31**	**44**	**53**
Coal	7	8	8	10	9	5
Lignite	1	1	1	0	0	0
Gas	1	1	3	9	19	28
Oil	2	2	2	1	0	0
Biomass	0	1	2	6	9	11
Geothermal	0	0	1	4	7	9
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	1	2	2	2	2	3
Autoproducers	9	11	15	29	42	50
Total generation	**240**	**340**	**384**	**542**	**688**	**784**
Fossil	185	246	245	259	218	168
Coal	33	50	54	61	48	28
Lignite	16	13	10	4	1	0
Gas	92	139	141	163	151	133
Oil	42	41	38	29	16	6
Diesel	2	2	2	2	1	1
Nuclear	6	8	6	5	2	0
Hydrogen	0	0	0	0	0	0
Renewables	**48**	**86**	**133**	**278**	**468**	**616**
Hydro	44	60	71	81	89	96
Wind	0	15	33	103	178	201
PV	0	3	11	59	142	231
Biomass	1	3	6	12	17	22
Geothermal	3	4	7	13	20	26
Solar thermal	0	1	4	8	17	30
Ocean energy	0	0	1	3	5	10
Fluctuating RES (PV, Wind, Ocean)	0	18	45	165	325	442
Share of fluctuating RES	0.1%	5.2%	11.7%	30.3%	47.2%	56.3%
RES share	**20.2%**	**25.4%**	**34.6%**	**51.3%**	**68.1%**	**78.6%**

table 13.163: developing asia: primary energy demand

PJ/A	2007	2015	2020	2030	2040	2050
Total	**31,903**	**36,651**	**38,829**	**42,238**	**42,602**	**42,702**
Fossil	**22,958**	**26,454**	**26,927**	**27,255**	**24,329**	**20,912**
Hard coal	4,798	5,911	5,800	5,246	3,092	1,005
Lignite	1,026	838	602	250	50	0
Natural gas	6,998	8,953	9,323	9,875	9,988	9,382
Crude oil	10,136	10,752	11,201	11,884	11,199	10,525
Nuclear	**476**	**709**	**655**	**436**	**131**	**0**
Renewables	**8,469**	**9,488**	**11,248**	**14,547**	**18,142**	**21,790**
Hydro	476	648	756	864	947	1,030
Wind	2	104	356	1,152	2,048	2,466
Solar	4	245	775	2,129	3,731	5,817
Biomass	7,366	7,609	8,003	8,128	7,724	7,315
Geothermal	621	881	1,347	2,245	3,627	5,037
Ocean Energy	0	1	11	29	65	126
RES share	**26.6%**	**26.0%**	**29.0%**	**34.4%**	**42.6%**	**50.9%**
'Efficiency' savings (compared to Ref.)	**0**	**922**	**2,966**	**11,457**	**20,036**	**26,559**

table 13.164: developing asia: final energy demand

PJ/A	2007	2015	2020	2030	2040	2050
Total (incl. non-energy use)	**23,620**	**26,799**	**28,940**	**32,619**	**34,455**	**35,804**
Total (energy use)	**21,242**	**24,119**	**26,051**	**29,353**	**30,813**	**31,785**
Transport	**4,468**	**5,100**	**5,821**	**7,004**	**7,530**	**8,016**
Oil products	4,372	4,866	5,481	6,378	6,485	6,442
Natural gas	82	132	128	137	137	45
Biofuels	7	66	86	130	296	576
Electricity	8	36	126	357	592	894
RES electricity	1	7	35	157	370	657
Hydrogen	0	0	0	1	21	60
RES share Transport	**0.2%**	**1.4%**	**2.1%**	**4.1%**	**9.0%**	**15.9%**
Industry	**7,234**	**8,537**	**9,142**	**9,935**	**10,361**	**10,574**
Electricity	1,374	1,959	2,159	2,421	2,650	2,846
RES electricity	222	392	607	1,061	1,656	2,093
District heat	240	266	390	714	980	1,285
RES district heat	0	114	252	630	927	1,253
Coal	2,356	2,481	2,267	1,620	1,111	155
Oil products	1,137	1,116	1,094	1,036	673	382
Gas	1,345	1,652	1,821	2,169	2,521	2,684
Solar	0	89	191	468	754	1,275
Biomass and waste	782	922	1,056	1,136	1,015	911
Geothermal	0	51	165	371	657	1,036
Hydrogen	0	0	0	0	0	0
RES share Industry	**13.9%**	**18.4%**	**24.8%**	**36.9%**	**48.4%**	**62.1%**
Other Sectors	**9,541**	**10,482**	**11,088**	**12,415**	**12,922**	**13,195**
Electricity	1,667	2,105	2,463	3,417	3,839	4,074
RES electricity	269	421	693	1,498	2,400	2,996
District heat	36	45	64	111	366	729
RES district heat	0	19	42	98	346	711
Coal	191	173	137	74	63	49
Oil products	1,275	1,480	1,233	994	719	375
Gas	395	607	658	762	813	868
Solar	4	125	455	1,081	1,555	2,103
Biomass and waste	5,973	5,919	6,019	5,823	4,996	3,926
Geothermal	0	28	58	152	570	1,072
RES share Other Sectors	**65.5%**	**62.1%**	**65.5%**	**69.7%**	**76.4%**	**81.9%**
Total RES	**7,258**	**8,153**	**9,659**	**12,606**	**15,556**	**18,652**
RES share	**34.2%**	**33.8%**	**37.1%**	**42.9%**	**50.5%**	**58.7%**
Non energy use	**2,378**	**2,680**	**2,889**	**3,266**	**3,643**	**4,019**
Oil	1,823	2,054	2,215	2,503	2,792	3,081
Gas	534	602	649	733	818	902
Coal	21	24	26	29	32	36

developing asia: advanced energy [r]evolution scenario

table 13.165: developing asia: electricity generation

TWh/a	2007	2015	2020	2030	2040	2050
Power plants	**934**	**1,294**	**1,451**	**1,881**	**2,454**	**3,298**
Coal	159	288	301	136	5	0
Lignite	94	83	52	22	4	0
Gas	358	515	534	486	403	50
Oil	119	77	72	59	28	9
Diesel	2	3	3	2	2	1
Nuclear	44	65	60	40	12	0
Biomass	8	19	28	29	30	30
Hydro	132	180	210	240	263	286
Wind	1	29	106	402	680	988
PV	0	4	22	143	309	746
Geothermal	17	29	40	148	291	359
Solar thermal power plants	0	2	16	122	310	598
Ocean energy	0	0	7	52	117	232
Combined heat & power production	**44**	**50**	**75**	**149**	**209**	**250**
Coal	34	33	40	48	31	5
Lignite	4	5	3	2	0	0
Gas	3	5	11	44	92	136
Oil	3	2	2	1	0	0
Biomass	0	5	12	33	52	63
Geothermal	0	1	7	21	34	47
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	7	9	10	11	12	15
Autoproducers	38	41	65	138	197	235
Total generation	**978**	**1,344**	**1,525**	**2,030**	**2,663**	**3,548**
Fossil	777	1,011	1,017	800	565	199
Coal	194	321	341	184	36	4
Lignite	98	88	55	24	4	0
Gas	361	520	545	530	495	185
Oil	122	79	74	60	29	9
Diesel	2	3	3	2	2	1
Nuclear	44	65	60	40	12	0
Hydrogen	0	0	0	0	0	0
Renewables	**158**	**269**	**448**	**1,190**	**2,086**	**3,349**
Hydro	132	180	210	240	263	286
Wind	1	29	106	402	680	988
PV	0	4	22	143	309	746
Biomass	8	24	40	62	82	93
Geothermal	17	30	47	169	325	406
Solar thermal	0	2	16	122	310	598
Ocean energy	0	0	7	52	117	232
Distribution losses	81	117	125	160	205	235
Own consumption electricity	48	69	78	105	125	143
Electricity for hydrogen production	0	0	0	7	72	151
Final energy consumption (electricity)	**847**	**1,139**	**1,319**	**1,757**	**2,259**	**2,995**
Fluctuating RES (PV, Wind, Ocean)	1	33	135	597	1,106	1,966
Share of fluctuating RES	0.1%	2.5%	8.9%	29.4%	41.5%	55.4%
RES share	**16.1%**	**20.0%**	**29.4%**	**58.6%**	**78.3%**	**94.4%**
'Efficiency' savings (compared to Ref.)	**0**	**22**	**128**	**581**	**942**	**1,274**

table 13.166: developing asia: heat supply

PJ/A	2007	2015	2020	2030	2040	2050
District heating plants	**18**	**53**	**97**	**208**	**528**	**1,153**
Fossil fuels	18	11	8	7	3	0
Biomass	0	20	45	100	253	542
Solar collectors	0	11	21	48	132	300
Geothermal	0	11	23	53	140	311
Heat from CHP	**259**	**264**	**366**	**686**	**948**	**1,107**
Fossil fuels	259	224	249	363	435	462
Biomass	0	28	57	135	205	227
Geothermal	0	13	60	188	308	419
Fuel cell (hydrogen)	0	0	0	0	0	0
Direct heating[1]	**10,559**	**11,252**	**11,803**	**12,572**	**13,157**	**12,874**
Fossil fuels	5,286	6,031	5,838	5,328	4,048	1,858
Biomass	5,269	4,927	5,096	4,978	4,601	3,972
Solar collectors	4	214	645	1,551	2,651	3,860
Geothermal	0	80	224	715	1,857	3,185
Total heat supply[1]	**10,836**	**11,569**	**12,266**	**13,466**	**14,704**	**15,695**
Fossil fuels	5,563	6,265	6,095	5,698	4,486	2,319
Biomass	5,269	4,975	5,198	5,213	5,059	4,741
Solar collectors	4	225	667	1,599	2,783	4,160
Geothermal	0	104	307	956	2,304	3,915
Fuel cell (hydrogen)	0	0	0	0	71	561
RES share (including RES electricity)	**48.7%**	**45.8%**	**50.3%**	**57.7%**	**69.4%**	**85.0%**
'Efficiency' savings (compared to Ref.)	**0**	**454**	**680**	**1,597**	**2,619**	**3,566**

1) heat from electricity (direct and from electric heat pumps) not included; covered in the model under 'electric appliances'

table 13.167: developing asia: CO_2 emissions

MILL t/a	2007	2015	2020	2030	2040	2050
Condensation power plants	**524**	**650**	**625**	**404**	**215**	**28**
Coal	154	253	258	109	4	0
Lignite	106	87	53	21	4	0
Gas	177	242	250	228	185	21
Oil	58	65	60	45	21	6
Diesel	29	3	2	2	1	1
Combined heat & power production	**45**	**40**	**43**	**59**	**61**	**60**
Coal	31	29	32	35	21	3
Lignite	8	6	3	2	0	0
Gas	3	3	6	20	40	57
Oil	4	3	2	2	0	0
CO_2 emissions electricity & steam generation	**569**	**690**	**668**	**463**	**276**	**88**
Coal	184	282	290	144	25	3
Lignite	114	93	57	23	4	0
Gas	180	244	256	248	225	78
Oil & diesel	91	70	65	49	23	7
CO_2 emissions by sector	**1,488**	**1,709**	**1,667**	**1,409**	**973**	**428**
% of 1990 emissions	216%	248%	242%	204%	141%	62%
Industry	411	433	426	385	297	156
Other sectors	137	163	144	129	76	39
Transport	319	358	402	437	355	193
Electricity & steam generation	536	661	634	409	218	31
District heating	85	95	62	48	27	7
Population (Mill.)	1,011	1,131	1,203	1,333	1,439	1,516
CO_2 emissions per capita (t/capita)	**1.5**	**1.5**	**1.4**	**1.1**	**0.7**	**0.3**

table 13.168: developing asia: installed capacity

GW	2007	2015	2020	2030	2040	2050
Power plants	**229**	**327**	**371**	**549**	**743**	**1,055**
Coal	26	43	44	20	1	0
Lignite	15	12	8	3	1	0
Gas	92	138	138	138	119	33
Oil	40	39	37	28	16	6
Diesel	2	2	2	2	1	1
Nuclear	6	8	6	5	2	0
Biomass	1	2	4	4	5	4
Hydro	44	60	71	81	89	96
Wind	0	15	35	130	213	291
PV	0	3	13	79	172	414
Geothermal	3	4	6	22	43	54
Solar thermal power plants	0	1	5	20	49	92
Ocean energy	0	0	2	16	33	64
Combined heat & power production	**10**	**13**	**17**	**31**	**44**	**53**
Coal	7	8	8	9	6	1
Lignite	1	1	1	0	0	0
Gas	1	1	3	11	21	31
Oil	2	2	2	1	0	0
Biomass	0	1	2	6	10	12
Geothermal	0	0	1	4	7	9
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	1	2	2	2	2	3
Autoproducers	9	11	15	29	42	50
Total generation	**240**	**340**	**388**	**580**	**787**	**1,109**
Fossil	185	246	242	212	166	72
Coal	33	50	52	29	7	1
Lignite	16	13	8	4	1	0
Gas	92	139	141	148	140	64
Oil	42	41	38	29	16	6
Diesel	2	2	2	2	1	1
Nuclear	6	8	6	5	2	0
Hydrogen	0	0	0	0	0	0
Renewables	**48**	**86**	**140**	**363**	**620**	**1,037**
Hydro	44	60	71	81	89	96
Wind	0	15	35	130	213	291
PV	0	3	13	79	172	414
Biomass	1	3	6	11	14	17
Geothermal	3	4	7	26	50	63
Solar thermal	0	1	5	20	49	92
Ocean energy	0	0	2	16	33	64
Fluctuating RES (PV, Wind, Ocean)	0	18	50	225	418	769
Share of fluctuating RES	0.1%	5.2%	13.0%	38.8%	53.0%	69.4%
RES share	**20.2%**	**25.4%**	**36.0%**	**62.6%**	**78.7%**	**93.5%**

table 13.169: developing asia: primary energy demand

PJ/A	2007	2015	2020	2030	2040	2050
Total	**31,903**	**36,596**	**38,666**	**41,536**	**42,228**	**40,639**
Fossil	**22,958**	**26,408**	**26,708**	**24,177**	**18,986**	**10,789**
Hard coal	4,798	5,812	5,607	3,551	1,044	217
Lignite	1,026	838	510	205	33	0
Natural gas	6,998	9,025	9,436	9,554	8,817	4,368
Crude oil	10,136	10,733	11,155	10,867	9,092	6,204
Nuclear	**476**	**709**	**655**	**436**	**131**	**0**
Renewables	**8,469**	**9,479**	**11,303**	**16,923**	**23,111**	**29,851**
Hydro	476	648	756	864	947	1,030
Wind	2	104	382	1,447	2,448	3,557
Solar	4	245	803	2,553	5,011	8,998
Biomass	7,366	7,601	7,990	8,030	7,503	6,826
Geothermal	621	881	1,347	3,841	6,781	8,605
Ocean Energy	0	1	25	187	421	835
RES share	**26.6%**	**26.0%**	**29.2%**	**40.7%**	**54.7%**	**73.4%**
'Efficiency' savings (compared to Ref.)	**0**	**977**	**3,129**	**12,159**	**20,411**	**28,621**

table 13.170: developing asia: final energy demand

PJ/a	2007	2015	2020	2030	2040	2050
Total (incl. non-energy use)	**23,620**	**26,799**	**28,940**	**32,326**	**33,773**	**34,215**
Total (energy use)	**21,242**	**24,119**	**26,051**	**29,060**	**30,130**	**30,196**
Transport	**4,468**	**5,100**	**5,821**	**6,704**	**6,830**	**6,416**
Oil products	4,372	4,866	5,481	5,971	4,832	2,657
Natural gas	82	132	128	130	122	35
Biofuels	7	66	86	127	271	441
Electricity	8	36	126	457	1,417	2,873
RES electricity	1	7	37	268	1,110	2,712
Hydrogen	0	0	0	19	188	409
RES share Transport	**0.2%**	**1.4%**	**2.1%**	**6.1%**	**22.4%**	55.2%
Industry	**7,234**	**8,537**	**9,142**	**9,940**	**10,369**	**10,579**
Electricity	1,374	1,959	2,159	2,430	2,684	2,943
RES electricity	222	392	634	1,425	2,103	2,778
District heat	240	266	390	766	1,080	1,486
RES district heat	0	113	252	667	1,035	1,457
Coal	2,356	2,481	2,267	1,563	742	152
Oil products	1,137	1,108	1,078	765	406	93
Gas	1,345	1,659	1,837	2,350	2,534	1,447
Solar	0	89	191	470	933	1,482
Biomass and waste	782	922	1,056	1,143	1,030	920
Geothermal	0	51	165	452	882	1,466
Hydrogen	0	0	0	0	77	590
RES share Industry	**13.9%**	**18.4%**	**25.1%**	**41.8%**	**58.3%**	**81.9%**
Other Sectors	**9,541**	**10,482**	**11,088**	**12,417**	**12,932**	**13,201**
Electricity	1,667	2,105	2,463	3,440	3,927	4,178
RES electricity	269	421	723	2,016	3,076	3,943
District heat	36	45	64	111	367	732
RES district heat	0	19	42	97	352	718
Coal	191	173	137	394	0	0
Oil products	1,275	1,469	1,205	690	588	213
Gas	395	623	692	681	519	368
Solar	4	125	454	1,081	1,718	2,378
Biomass and waste	5,973	5,915	6,015	5,821	5,019	3,944
Geothermal	0	28	58	199	793	1,388
RES share Other Sectors	**65.5%**	**62.1%**	**65.8%**	**74.2%**	**84.7%**	**93.7%**
Total RES	**7,258**	**8,148**	**9,714**	**13,778**	**18,530**	**24,570**
RES share	**34.2%**	**33.8%**	**37.3%**	**47.4%**	**61.5%**	**81.4%**
Non energy use	**2,378**	**2,680**	**2,889**	**3,266**	**3,643**	**4,019**
Oil	1,823	2,054	2,215	2,503	2,792	3,081
Gas	534	602	649	733	818	902
Coal	21	24	26	29	32	36

developing asia: total new investment by technology

table 13.71: developing asia: total investment

MILLION $	2005-2010	2011-2020	2021-2030	2005-2030
Reference scenario				
Conventional (fossil & nuclear)	**73,623**	**123,768**	**182,538**	**379,929**
Renewables	**65,080**	**135,730**	**143,146**	**343,957**
Biomass	3,244	9,307	17,201	29,752
Hydro	45,042	88,047	71,231	204,320
Wind	501	3,528	12,912	16,940
PV	1,023	5,831	16,098	22,953
Geothermal	15,271	29,017	25,704	69,992
Solar thermal power plants	0	0	0	0
Ocean energy	0	0	0	0
Energy [R]evolution				
Conventional (fossil & nuclear)	**73,623**	**89,036**	**63,293**	**225,952**
Renewables	**65,080**	**229,087**	**288,353**	**582,521**
Biomass	3,244	14,139	21,542	38,925
Hydro	45,042	73,684	49,863	168,590
Wind	501	40,024	72,979	113,504
PV	1,023	24,702	65,710	91,436
Geothermal	15,271	54,251	56,350	125,872
Solar thermal power plants	0	18,973	18,234	37,207
Ocean energy	0	3,313	3,674	6,987
Advanced Energy [R]evolution				
Conventional (fossil & nuclear)	**73,623**	**87,518**	**39,358**	**200,499**
Renewables	**65,080**	**248,196**	**524,250**	**837,526**
Biomass	3,244	14,141	18,190	35,574
Hydro	45,042	73,684	49,863	168,590
Wind	501	42,680	97,924	141,105
PV	1,023	28,355	91,391	120,769
Geothermal	15,271	54,251	162,781	232,303
Solar thermal power plants	0	27,452	70,009	97,461
Ocean energy	0	7,633	34,090	41,723

notes

china: reference scenario

table 13.172: china: electricity generation

TWh/a	2007	2015	2020	2030	2040	2050
Power plants	**3,231**	**5,366**	**6,364**	**8,355**	**9,996**	**11,367**
Coal	2,576	4,180	4,875	6,352	7,478	8,329
Lignite	0	0	0	0	0	0
Gas	63	74	86	99	118	151
Oil	34	44	41	32	23	14
Diesel	0	0	0	0	0	0
Nuclear	62	227	322	487	652	817
Biomass	2	4	7	59	110	149
Hydro	485	734	848	1,046	1,244	1,442
Wind	9	98	168	225	282	339
PV	0	5	16	50	84	118
Geothermal	0	0	0	1	2	4
Solar thermal power plants	0	0	1	2	3	4
Ocean energy	0	0	0	0	0	0
Combined heat & power production	**88**	**256**	**328**	**492**	**657**	**822**
Coal	84	200	232	274	320	369
Lignite	0	0	0	0	0	0
Gas	4	51	82	166	244	308
Oil	0	0	0	0	0	0
Biomass	0	5	12	50	89	140
Geothermal	0	1	2	3	4	4
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	0	35	56	117	179	241
Autoproducers	88	221	272	375	478	581
Total generation	**3,319**	**5,622**	**6,692**	**8,847**	**10,653**	**12,188**
Fossil	2,760	4,548	5,316	6,924	8,183	9,171
Coal	2,659	4,379	5,107	6,627	7,798	8,698
Lignite	0	0	0	0	0	0
Gas	67	125	168	265	362	459
Oil	34	44	41	32	23	14
Diesel	0	0	0	0	0	0
Nuclear	62	227	322	487	652	817
Hydrogen	0	0	0	0	0	0
Renewables	**496**	**847**	**1,054**	**1,436**	**1,818**	**2,200**
Hydro	485	734	848	1,046	1,244	1,442
Wind	9	98	168	225	282	339
PV	0	5	16	50	84	118
Biomass	2	9	19	109	199	289
Geothermal	0	1	2	4	6	8
Solar thermal	0	0	1	2	3	4
Ocean energy	0	0	0	0	0	0
Distribution losses	201	301	356	450	544	638
Own consumption electricity	397	594	702	887	1,072	1,258
Electricity for hydrogen production	0	0	0	0	0	0
Final energy consumption (electricity)	**2,717**	**4,723**	**5,627**	**7,499**	**9,020**	**10,268**
Fluctuating RES (PV, Wind, Ocean)	9	103	184	275	366	457
Share of fluctuating RES	0.3%	1.8%	2.7%	3.1%	3.4%	3.7%
RES share	**15.0%**	**15.1%**	**15.8%**	**16.2%**	**17.1%**	**18.1%**

table 13.173: china: heat supply

PJ/A	2007	2015	2020	2030	2040	2050
District heating plants	**2,576**	**2,658**	**2,728**	**2,795**	**2,915**	**2,938**
Fossil fuels	2,561	2,578	2,583	2,515	2,594	2,584
Biomass	15	80	145	279	321	353
Solar collectors	0	0	0	0	0	0
Geothermal	0	0	0	0	0	0
Heat from CHP	**704**	**1,530**	**1,735**	**2,040**	**2,340**	**2,705**
Fossil fuels	704	1,490	1,636	1,781	1,957	2,164
Biomass	0	33	84	236	351	502
Geothermal	0	7	15	22	31	39
Fuel cell (hydrogen)	0	0	0	0	0	0
Direct heating[1]	**24,350**	**29,791**	**31,226**	**34,186**	**36,716**	**38,054**
Fossil fuels	17,817	22,980	24,610	27,842	30,722	32,476
Biomass	6,351	6,555	6,244	5,661	4,997	4,263
Solar collectors	182	256	373	684	997	1,315
Geothermal	0	0	0	0	0	0
Total heat supply[1]	**27,629**	**33,980**	**35,689**	**39,021**	**41,971**	**43,697**
Fossil fuels	21,081	27,049	28,828	32,138	35,273	37,224
Biomass	6,366	6,667	6,473	6,176	5,669	5,118
Solar collectors	182	256	373	684	997	1,315
Geothermal	0	7	15	23	32	40
Fuel cell ((hydrogen)	0	0	0	0	0	0
RES share (including RES electricity)	**23.7%**	**20.4%**	**19.2%**	**17.6%**	**16.0%**	**14.8%**

1) heat from electricity (direct and from electric heat pumps) not included; covered in the model under 'electric appliances'

table 13.174: china: CO_2 emissions

MILL t/a	2007	2015	2020	2030	2040	2050
Condensation power plants	**2,734**	**4,362**	**5,048**	**6,141**	**6,106**	**5,866**
Coal	2,675	4,297	4,977	6,077	6,047	5,809
Lignite	0	0	0	0	0	0
Gas	38	35	40	42	44	48
Oil	21	31	30	22	16	9
Diesel	0	0	0	0	0	0
Combined heat & power production	**136**	**277**	**295**	**306**	**334**	**368**
Coal	132	240	242	224	227	244
Lignite	0	0	0	0	0	0
Gas	4	37	52	83	107	124
Oil	0	0	0	0	0	0
CO_2 emissions electricity & steam generation	**2,870**	**4,639**	**5,342**	**6,447**	**6,441**	**6,234**
Coal	2,807	4,537	5,220	6,301	6,274	6,053
Lignite	0	0	0	0	0	0
Gas	42	71	93	124	151	172
Oil & diesel	21	31	30	22	16	9
CO_2 emissions by sector	**5,852**	**8,449**	**9,449**	**11,409**	**12,095**	**12,460**
% of 1990 emissions	261%	377%	421%	508%	539%	555%
Industry	1,523	2,019	2,060	2,147	2,227	2,215
Other sectors	541	697	757	841	922	998
Transport	413	683	846	1,394	1,849	2,301
Electricity & steam generation	2,734	4,405	5,106	6,233	6,216	5,991
District heating	641	645	680	793	882	955
Population (Mill.)	1,336	1,403	1,439	1,471	1,464	1,426
CO_2 emissions per capita (t/capita)	**4.4**	**6.0**	**6.6**	**7.8**	**8.3**	**8.7**

table 13.175: china: installed capacity

GW	2007	2015	2020	2030	2040	2050
Power plants	**686**	**1,132**	**1,348**	**1,762**	**2,069**	**2,309**
Coal	482	774	903	1,187	1,398	1,557
Lignite	0	0	0	0	0	0
Gas	24	41	46	50	50	56
Oil	20	21	19	16	12	7
Diesel	0	0	0	0	0	0
Nuclear	8	28	40	60	80	101
Biomass	1	1	1	11	21	29
Hydro	145	220	255	316	355	379
Wind	6	44	74	95	107	117
PV	0	3	9	26	44	62
Geothermal	0	0	0	0	0	1
Solar thermal power plants	0	0	0	0	0	1
Ocean energy	0	0	0	0	0	0
Combined heat & power production	**22**	**73**	**97**	**153**	**197**	**228**
Coal	21	54	64	77	91	106
Lignite	0	0	0	0	0	0
Gas	1	18	31	68	92	101
Oil	0	0	0	0	0	0
Biomass	0	1	2	7	13	20
Geothermal	0	0	0	0	1	1
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	0	17	28	60	85	100
Autoproducers	22	56	69	94	112	129
Total generation	**708**	**1,205**	**1,444**	**1,916**	**2,266**	**2,537**
Fossil	548	908	1,063	1,398	1,643	1,827
Coal	503	828	966	1,265	1,489	1,663
Lignite	0	0	0	0	0	0
Gas	25	59	78	118	142	156
Oil	20	21	19	16	12	7
Diesel	0	0	0	0	0	0
Nuclear	8	28	40	60	80	101
Hydrogen	0	0	0	0	0	0
Renewables	**152**	**269**	**342**	**457**	**543**	**610**
Hydro	145	220	255	316	355	379
Wind	6	44	74	95	107	117
PV	0	3	9	26	44	62
Biomass	1	2	3	19	34	49
Geothermal	0	0	0	1	1	1
Solar thermal	0	0	0	0	0	1
Ocean energy	0	0	0	0	0	0
Fluctuating RES (PV, Wind, Ocean)	6	47	83	121	151	179
Share of fluctuating RES	0.8%	3.9%	5.7%	6.3%	6.7%	7.1%
RES share	**21.5%**	**22.3%**	**23.6%**	**23.9%**	**23.9%**	**24.0%**

table 13.176: china: primary energy demand

PJ/A	2007	2015	2020	2030	2040	2050
Total	**83,922**	**117,168**	**130,483**	**158,146**	**172,864**	**183,886**
Fossil	**73,016**	**103,141**	**114,673**	**138,311**	**149,423**	**157,109**
Hard coal	55,333	77,483	84,900	97,048	97,745	95,527
Lignite	0	0	0	0	0	0
Natural gas	2,716	4,983	6,155	8,456	10,916	12,953
Crude oil	14,966	20,675	23,618	32,807	40,762	48,629
Nuclear	**678**	**2,476**	**3,513**	**5,313**	**7,113**	**8,913**
Renewables	**10,228**	**11,550**	**12,297**	**14,523**	**16,328**	**17,864**
Hydro	1,747	2,642	3,053	3,766	4,478	5,191
Wind	32	353	605	810	1,015	1,220
Solar	182	274	434	871	1,310	1,754
Biomass	8,267	8,247	8,148	8,960	9,358	9,481
Geothermal	0	33	58	116	166	217
Ocean Energy	0	0	0	0	0	0
RES share	**12.2%**	**9.8%**	**9.4%**	**9.2%**	**9.4%**	**9.7%**

table 13.177: china: final energy demand

PJ/a	2007	2015	2020	2030	2040	2050
Total (incl. non-energy use)	**53,694**	**73,865**	**81,498**	**100,196**	**115,970**	**129,442**
Total (energy use)	**49,186**	**67,250**	**74,380**	**92,157**	**107,010**	**119,561**
Transport	**5,882**	**9,965**	**12,351**	**20,389**	**27,130**	**33,871**
Oil products	5,734	9,408	11,622	19,212	25,479	31,714
Natural gas	3	102	152	196	260	323
Biofuels	46	201	289	528	779	1,064
Electricity	99	254	288	453	611	770
RES electricity	15	38	45	74	104	139
Hydrogen	0	0	0	0	0	1
RES share Transport	**1.0%**	**2.4%**	**2.7%**	**2.9%**	**3.3%**	**3.6%**
Industry	**25,008**	**35,379**	**38,390**	**45,439**	**50,889**	**54,023**
Electricity	6,738	11,933	14,068	18,421	21,520	23,634
RES electricity	1,008	1,798	2,216	2,990	3,672	4,266
District heat	2,551	3,125	3,253	3,498	3,816	4,092
RES district heat	15	90	167	316	379	443
Coal	10,524	14,399	14,788	15,812	16,564	16,523
Oil products	1,691	2,015	2,033	2,144	2,219	2,189
Gas	3,505	3,820	4,075	4,625	5,092	5,298
Solar	0	3	7	14	22	27
Biomass and waste	0	84	168	925	1,656	2,260
Geothermal	0	0	0	0	0	0
Hydrogen	0	0	0	0	0	0
RES share Industry	**4.1%**	**5.6%**	**6.7%**	**9.3%**	**11.3%**	**13.0%**
Other Sectors	**18,295**	**21,906**	**23,639**	**26,329**	**28,992**	**31,667**
Electricity	2,946	4,815	5,903	8,122	10,341	12,560
RES electricity	441	725	930	1,318	1,765	2,267
District heat	697	1,023	1,167	1,290	1,388	1,496
RES district heat	4	29	60	117	138	162
Coal	2,634	3,067	3,049	2,794	2,537	2,273
Oil products	2,830	3,774	4,286	5,086	5,886	6,688
Gas	863	1,342	1,765	2,733	3,701	4,670
Solar	182	253	366	669	975	1,287
Biomass and waste	8,143	7,632	7,104	5,635	4,164	2,693
Geothermal	0	0	0	0	0	0
RES share Other Sectors	**47.9%**	**39.4%**	**35.8%**	**29.4%**	**24.3%**	**20.2%**
Total RES	**9,853**	**10,854**	**11,351**	**12,586**	**13,654**	**14,609**
RES share	**20.0%**	**16.1%**	**15.3%**	**13.7%**	**12.8%**	**12.2%**
Non energy use	**4,509**	**6,615**	**7,118**	**8,039**	**8,960**	**9,881**
Oil	3,104	4,555	4,900	5,535	6,169	6,803
Gas	359	527	567	640	713	787
Coal	1,045	1,534	1,650	1,864	2,078	2,291

china: energy [r]evolution scenario

table 13.178: china: electricity generation

TWh/a	2007	2015	2020	2030	2040	2050
Power plants	**3,231**	**5,079**	**5,758**	**6,505**	**6,823**	**7,249**
Coal	2,576	3,912	4,067	3,651	2,598	1,660
Lignite	0	0	0	0	0	0
Gas	63	74	96	151	195	220
Oil	34	50	45	25	10	0
Diesel	0	0	0	0	0	0
Nuclear	62	105	250	187	146	0
Biomass	2	18	28	58	93	127
Hydro	485	752	850	1,050	1,290	1,510
Wind	9	155	370	954	1,357	1,568
PV	0	5	22	195	420	820
Geothermal	0	0	1	12	29	58
Solar thermal power plants	0	8	28	220	620	1,025
Ocean energy	0	0	1	2	65	260
Combined heat & power production	**88**	**299**	**484**	**975**	**1,529**	**1,990**
Coal	84	190	275	485	660	764
Lignite	0	0	0	0	0	0
Gas	4	81	139	310	490	616
Oil	0	0	0	0	0	0
Biomass	0	27	67	172	347	503
Geothermal	0	1	3	8	33	107
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	0	64	184	535	934	1,223
Autoproducers	88	236	300	440	595	767
Total generation	**3,319**	**5,378**	**6,242**	**7,480**	**8,352**	**9,238**
Fossil	2,760	4,307	4,622	4,622	3,952	3,261
Coal	2,659	4,102	4,342	4,136	3,257	2,425
Lignite	0	0	0	0	0	0
Gas	67	155	235	461	685	836
Oil	34	50	45	25	10	0
Diesel	0	0	0	0	0	0
Nuclear	62	105	250	187	146	0
Hydrogen	0	0	0	0	0	0
Renewables	**496**	**966**	**1,370**	**2,671**	**4,254**	**5,978**
Hydro	485	752	850	1,050	1,290	1,510
Wind	9	155	370	954	1,357	1,568
PV	0	5	22	195	420	820
Biomass	2	45	95	230	440	630
Geothermal	0	1	4	20	62	165
Solar thermal	0	8	28	220	620	1,025
Ocean energy	0	0	1	2	65	260
Distribution losses	201	301	356	450	472	492
Own consumption electricity	397	594	702	887	958	998
Electricity for hydrogen production	0	0	1	16	39	75
Final energy consumption (electricity)	**2,717**	**4,479**	**5,176**	**6,127**	**6,895**	**7,693**
Fluctuating RES (PV, Wind, Ocean)	9	160	393	1,151	1,842	2,648
Share of fluctuating RES	0.3%	3.0%	6.3%	15.4%	22.1%	28.7%
RES share	**15.0%**	**18.0%**	**21.9%**	**35.7%**	**50.9%**	**64.7%**
'Efficiency' savings (compared to Ref.)	**0**	**266**	**572**	**1,696**	**2,663**	**3,562**

table 13.179: china: heat supply

PJ/A	2007	2015	2020	2030	2040	2050
District heating plants	**2,576**	**2,695**	**2,540**	**1,956**	**1,342**	**675**
Fossil fuels	2,561	2,566	2,248	1,393	666	13
Biomass	15	108	152	196	148	88
Solar collectors	0	19	114	196	215	236
Geothermal	0	3	25	172	313	337
Heat from CHP	**704**	**1,806**	**2,653**	**4,317**	**5,772**	**7,131**
Fossil fuels	704	1,628	2,263	3,539	4,287	4,556
Biomass	0	167	365	709	1,191	1,613
Geothermal	0	11	25	70	293	962
Fuel cell (hydrogen)	0	0	0	0	0	0
Direct heating[1]	**24,350**	**28,303**	**29,211**	**28,248**	**26,089**	**23,113**
Fossil fuels	17,817	20,980	21,232	18,413	12,755	6,175
Biomass	6,351	6,886	7,085	7,426	6,960	6,050
Solar collectors	182	386	719	1,995	4,426	6,912
Geothermal	0	52	175	415	1,949	3,976
Total heat supply[1]	**27,629**	**32,805**	**34,404**	**34,522**	**33,203**	**30,919**
Fossil fuels	21,081	25,174	25,743	23,345	17,708	10,744
Biomass	6,366	7,161	7,602	8,330	8,299	7,751
Solar collectors	182	405	833	2,190	4,641	7,148
Geothermal	0	65	225	656	2,555	5,276
Fuel cell (hydrogen)	0	0	0	0	0	0
RES share (including RES electricity)	**23.7%**	**23%**	**25%**	**32%**	**47%**	**65%**
'Efficiency' savings (compared to Ref.)	**0**	**1,175**	**1,285**	**4,499**	**8,768**	**12,778**

1) heat from electricity (direct and from electric heat pumps) not included; covered in the model under 'electric appliances'

table 13.180: china: CO_2 emissions

MILL t/a	2007	2015	2020	2030	2040	2050
Condensation power plants	**2,734**	**4,091**	**4,230**	**3,075**	**1,917**	**1,099**
Coal	2,675	4,022	4,152	2,994	1,838	1,029
Lignite	0	0.0	0.0	0.0	0.0	0.0
Gas	38	35	45	63	73	69
Oil	21	34.7	33.0	17.3	6.8	0.0
Diesel	0	0.0	0.0	0.0	0.0	0.0
Combined heat & power production	**136**	**292**	**399**	**604**	**722**	**766**
Coal	132	233	307	436	495	511
Lignite	0	0	0	0	0	0
Gas	4	59	93	168	227	255
Oil	0	0	0	0	0	0
CO_2 emissions electricity & steam generation	**2,870**	**4,383**	**4,630**	**3,678**	**2,640**	**1,864**
Coal	2,807	4,255	4,459	3,430	2,333	1,540
Lignite	0	0	0	0	0	0
Gas	42	94	138	231	300	324
Oil & diesel	21	35	33	17	7	0
CO_2 emissions by sector	**5,852**	**7,830**	**8,033**	**6,557**	**4,779**	**3,209**
% of 1990 emissions	261%	349%	358%	292%	213%	143%
Industry	1,523	1,853	1,848	1,571	1,095	553
Other sectors	541	603	570	475	319	184
Transport	413	593	645	705	774	818
Electricity & steam generation	2,734	4,168	4,421	3,474	2,411	1,598
District heating	641	613	549	333	179	58
Population (Mill.)	1,336	1,403	1,439	1,471	1,464	1,426
CO_2 emissions per capita (t/capita)	**4.4**	**5.6**	**5.6**	**4.5**	**3.3**	**2.3**

table 13.181: china: installed capacity

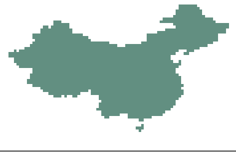
GW	2007	2015	2020	2030	2040	2050
Power plants	**686**	**1,108**	**1,302**	**1,667**	**1,859**	**2,046**
Coal	482	724	753	682	509	346
Lignite	0	0	0	0	0	0
Gas	24	41	52	75	81	67
Oil	20	24	21	13	5	0
Diesel	0	0	0	0	0	0
Nuclear	8	13	31	23	18	0
Biomass	1	4	6	11	18	24
Hydro	145	225	256	317	369	397
Wind	6	70	163	403	516	541
PV	0	3	11	103	221	432
Geothermal	0	0	0	2	5	10
Solar thermal power plants	0	3	9	37	98	155
Ocean energy	0	0	0	1	19	74
Combined heat & power production	**22**	**90**	**162**	**350**	**511**	**584**
Coal	21	55	88	163	224	250
Lignite	0	0	0	0	0	0
Gas	1	30	63	161	233	246
Oil	0	0	0	0	0	0
Biomass	0	5	10	25	49	72
Geothermal	0	0	1	1	5	16
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	0	32	91	249	383	424
Autoproducers	22	59	72	102	128	159
Total generation	**708**	**1,198**	**1,465**	**2,017**	**2,370**	**2,629**
Fossil	548	875	977	1,095	1,052	909
Coal	503	780	841	846	733	596
Lignite	0	0	0	0	0	0
Gas	25	71	115	236	315	313
Oil	20	24	21	13	5	0
Diesel	0	0	0	0	0	0
Nuclear	8	13	31	23	18	0
Hydrogen	0	0	0	0	0	0
Renewables	**152**	**310**	**456**	**899**	**1,300**	**1,721**
Hydro	145	225	256	317	369	397
Wind	6	70	163	403	516	541
PV	0	3	11	103	221	432
Biomass	1	9	16	36	67	96
Geothermal	0	0	1	3	10	25
Solar thermal	0	3	9	37	98	155
Ocean energy	0	0	0	1	19	74
Fluctuating RES (PV, Wind, Ocean)	6	73	175	506	756	1,047
Share of fluctuating RES	0.8%	6.1%	11.9%	25.1%	31.9%	39.8%
RES share	**21.5%**	**25.9%**	**31.2%**	**44.6%**	**54.8%**	**65.4%**

table 13.182: china: primary energy demand

PJ/A	2007	2015	2020	2030	2040	2050
Total	**83,922**	**109,735**	**116,798**	**110,674**	**104,584**	**100,191**
Fossil	**73,016**	**95,652**	**98,333**	**84,490**	**67,780**	**52,735**
Hard coal	55,333	70,581	71,158	56,068	38,309	23,173
Lignite	0	0	0	0	0	0
Natural gas	2,716	6,075	7,317	8,899	10,500	10,580
Crude oil	14,966	18,996	19,858	19,523	18,971	18,981
Nuclear	**678**	**1,145**	**2,727**	**2,040**	**1,593**	**0**
Renewables	**10,228**	**12,937**	**15,738**	**24,144**	**35,211**	**47,457**
Hydro	1,747	2,707	3,060	3,780	4,644	5,436
Wind	32	558	1,332	3,434	4,885	5,645
Solar	182	451	1,011	3,684	8,385	13,790
Biomass	8,267	9,131	10,025	12,108	13,351	13,848
Geothermal	0	90	306	1,130	3,712	7,802
Ocean Energy	0	0	4	7	234	936
RES share	**12.2%**	**11.8%**	**13.5%**	**21.8%**	**33.7%**	**47.4%**
'Efficiency' savings (compared to Ref.)	**0**	**7,455**	**13,692**	**47,423**	**68,139**	**83,472**

table 13.183: china: final energy demand

PJ/A	2007	2015	2020	2030	2040	2050
Total (incl. non-energy use)	**53,694**	**70,170**	**75,259**	**79,821**	**81,940**	**82,799**
Total (energy use)	**49,186**	**63,555**	**68,141**	**71,782**	**72,980**	**72,918**
Transport	**5,882**	**8,775**	**9,992**	**12,054**	**14,270**	**17,096**
Oil products	5,734	8,224	8,952	9,775	10,737	11,343
Natural gas	3	12	16	20	25	27
Biofuels	46	206	300	600	857	1,205
Electricity	99	333	721	1,618	2,547	4,320
RES electricity	15	60	158	578	1,297	2,796
Hydrogen	0	0	3	41	104	202
RES share Transport	**1.0%**	**3.0%**	**4.6%**	**9.9%**	**15.5%**	**24.2%**
Industry	**25,008**	**33,512**	**35,561**	**36,067**	**34,718**	**31,864**
Electricity	6,738	10,974	12,279	13,722	14,406	14,145
RES electricity	1,008	1,972	2,694	4,900	7,337	9,153
District heat	2,551	3,367	3,647	4,099	4,282	4,569
RES district heat	15	149	343	737	1,202	1,906
Coal	10,524	12,846	12,942	11,038	6,505	1,195
Oil products	1,691	1,950	1,959	1,379	774	193
Gas	3,505	4,062	4,180	3,935	4,017	3,541
Solar	0	71	148	547	2,049	3,639
Biomass and waste	0	221	302	1,113	1,646	2,497
Geothermal	0	21	105	233	1,039	2,085
Hydrogen	0	0	0	0	0	0
RES share Industry	**4.1%**	**7.3%**	**10.1%**	**20.9%**	**38.2%**	**60.5%**
Other Sectors	**18,295**	**21,268**	**22,588**	**23,661**	**23,992**	**23,957**
Electricity	2,946	4,815	5,633	6,716	7,869	9,228
RES electricity	441	865	1,236	2,398	4,008	5,971
District heat	697	1,091	1,497	2,118	2,771	3,175
RES district heat	4	48	141	381	778	1,325
Coal	2,634	2,414	2,038	1,856	1,398	479
Oil products	2,830	3,333	3,293	2,296	961	398
Gas	863	1,378	1,537	1,587	1,386	1,285
Solar	182	315	570	1,447	2,377	3,273
Biomass and waste	8,143	7,893	7,958	7,486	6,430	4,514
Geothermal	0	28	62	155	800	1,604
RES share Other Sectors	**47.9%**	**43.0%**	**44.1%**	**50.2%**	**60.0%**	**69.7%**
Total RES	**9,853**	**11,848**	**14,017**	**20,591**	**29,872**	**40,098**
RES share	**20.0%**	**18.6%**	**20.6%**	**28.7%**	**40.9%**	**55.0%**
Non energy use	**4,509**	**6,615**	**7,118**	**8,039**	**8,960**	**9,881**
Oil	3,104	4,555	4,900	5,535	6,169	6,803
Gas	359	527	567	640	713	787
Coal	1,045	1,534	1,650	1,864	2,078	2,291



china: advanced energy [r]evolution scenario

table 13.184: china: electricity generation

TWh/a	2007	2015	2020	2030	2040	2050
Power plants	**3,231**	**5,079**	**5,779**	**6,520**	**7,374**	**8,510**
Coal	2,576	3,914	3,942	2,897	1,326	43
Lignite	0	0	0	0	0	0
Gas	63	74	106	155	143	50
Oil	34	50	45	25	10	0
Diesel	0	0	0	0	0	0
Nuclear	62	105	250	187	146	0
Biomass	2	18	28	63	94	127
Hydro	485	752	850	1,050	1,290	1,510
Wind	9	155	445	1,215	1,713	2,039
PV	0	5	42	295	1,114	1,525
Geothermal	0	0	3	96	313	697
Solar thermal power plants	0	6	65	502	1,115	1,858
Ocean energy	0	0	2	35	110	660
Combined heat & power production	**88**	**299**	**484**	**975**	**1,329**	**1,680**
Coal	84	190	275	365	314	272
Lignite	0	0	0	0	0	0
Gas	4	81	139	401	558	693
Oil	0	0	0	0	0	0
Biomass	0	27	67	172	362	505
Geothermal	0	1	3	37	95	211
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	0	64	184	535	734	913
Autoproducers	88	236	300	440	595	767
Total generation	**3,319**	**5,378**	**6,263**	**7,495**	**8,703**	**10,190**
Fossil	2,760	4,309	4,508	3,843	2,351	1,058
Coal	2,659	4,104	4,218	3,262	1,640	315
Lignite	0	0	0	0	0	0
Gas	67	155	245	556	701	743
Oil	34	50	45	25	10	0
Diesel	0	0	0	0	0	0
Nuclear	62	105	250	187	146	0
Hydrogen	0	0	0	0	0	0
Renewables	**496**	**964**	**1,505**	**3,465**	**6,206**	**9,132**
Hydro	485	752	850	1,050	1,290	1,510
Wind	9	155	445	1,215	1,713	2,039
PV	0	5	42	295	1,114	1,525
Biomass	2	45	95	235	456	632
Geothermal	0	1	6	133	408	908
Solar thermal	0	6	65	502	1,115	1,858
Ocean energy	0	0	2	35	110	660
Distribution losses	201	301	356	395	430	459
Own consumption electricity	397	594	702	790	810	820
Electricity for hydrogen production	0	0	1	26	56	154
Final energy consumption (electricity)	**2,717**	**4,479**	**5,197**	**6,284**	**7,419**	**8,748**
Fluctuating RES (PV, Wind, Ocean)	9	160	489	1,545	2,937	4,224
Share of fluctuating RES	0.3%	3.0%	7.8%	20.6%	33.7%	41.5%
RES share	**15.0%**	**17.9%**	**24.0%**	**46.2%**	**71.3%**	**89.6%**
'Efficiency' savings (compared to Ref.)	**0**	**266**	**572**	**1,694**	**2,642**	**3,500**

table 13.185: china: heat supply

PJ/A	2007	2015	2020	2030	2040	2050
District heating plants	**2,576**	**2,695**	**2,540**	**1,467**	**2,131**	**2,116**
Fossil fuels	2,561	2,566	2,248	1,044	1,037	42
Biomass	15	108	152	147	234	275
Solar collectors	0	19	114	147	362	741
Geothermal	0	3	25	129	497	1,058
Heat from CHP	**704**	**1,806**	**2,653**	**4,436**	**5,270**	**6,653**
Fossil fuels	704	1,628	2,263	3,398	3,183	3,138
Biomass	0	167	365	709	1,236	1,618
Geothermal	0	11	25	329	851	1,896
Fuel cell (hydrogen)	0	0	0	0	0	0
Direct heating[1)]	**24,350**	**28,303**	**29,211**	**28,620**	**25,736**	**21,475**
Fossil fuels	17,817	20,980	21,228	18,713	8,745	811
Biomass	6,351	6,886	7,085	7,268	7,585	6,616
Solar collectors	182	386	719	2,167	6,154	8,708
Geothermal	0	52	179	472	3,251	5,340
Total heat supply[1)]	**27,629**	**32,805**	**34,404**	**34,522**	**33,203**	**30,919**
Fossil fuels	21,081	25,174	25,739	23,156	12,965	3,992
Biomass	6,366	7,161	7,603	8,123	9,055	8,510
Solar collectors	182	405	833	2,313	6,517	9,449
Geothermal	0	65	229	930	4,600	8,294
Fuel cell (hydrogen)	0	0	0	0	66	675
RES share (including RES electricity)	**23.7%**	**23.3%**	**25.2%**	**32.9%**	**60.9%**	**86.9%**
'Efficiency' savings (compared to Ref.)	**0**	**1,175**	**1,285**	**4,499**	**8,768**	**12,778**

1) heat from electricity (direct and from electric heat pumps) not included; covered in the model under 'electric appliances'

table 13.186: china: CO_2 emissions

MILL t/a	2007	2015	2020	2030	2040	2050
Condensation power plants	**2,734**	**4,093**	**4,108**	**2,458**	**998**	**43**
Coal	2,675	4,024	4,025	2,376	938	27
Lignite	0	0.0	0.0	0.0	0.0	0.0
Gas	38	35	50	65	53	16
Oil	21	34.7	33.0	17.3	6.8	0.0
Diesel	0	0.0	0.0	0.0	0.0	0.0
Combined heat & power production	**136**	**292**	**399**	**542**	**485**	**465**
Coal	132	233	307	318	224	177
Lignite	0	0	0	0	0	0
Gas	4	59	93	223	261	287
Oil	0	0	0	0	0	0
CO_2 emissions electricity & steam generation	**2,870**	**4,385**	**4,507**	**3,000**	**1,483**	**507**
Coal	2,807	4,257	4,332	2,694	1,162	204
Lignite	0	0	0	0	0	0
Gas	42	94	142	288	314	303
Oil & diesel	21	35	33	17	7	0
CO_2 emissions by sector	**5,852**	**7,813**	**7,875**	**5,744**	**2,948**	**925**
% of 1990 emissions	261%	348%	351%	256%	131%	41%
Industry	1,523	1,853	1,848	1,642	809	274
Other sectors	541	602	569	452	225	61
Transport	413	593	640	620	499	311
Electricity & steam generation	2,734	4,170	4,299	2,796	1,260	257
District heating	641	595	520	234	154	21
Population (Mill.)	1,336	1,403	1,439	1,471	1,464	1,426
CO_2 emissions per capita (t/capita)	**4.4**	**5.6**	**5.5**	**3.9**	**2.0**	**0.6**

table 13.187: china: installed capacity

GW	2007	2015	2020	2030	2040	2050
Power plants	**686**	**1,107**	**1,341**	**1,762**	**2,223**	**2,548**
Coal	482	725	730	542	260	12
Lignite	0	0	0	0	0	0
Gas	24	41	57	77	60	30
Oil	20	24	21	13	5	0
Diesel	0	0	0	0	0	0
Nuclear	8	13	31	23	18	0
Biomass	1	4	6	12	14	18
Hydro	145	225	256	317	369	397
Wind	6	70	196	513	651	703
PV	0	3	22	155	586	803
Geothermal	0	0	0	16	52	115
Solar thermal power plants	0	2	21	84	177	282
Ocean energy	0	0	1	10	31	189
Combined heat & power production	**22**	**90**	**162**	**373**	**433**	**467**
Coal	21	55	88	117	92	81
Lignite	0	0	0	0	0	0
Gas	1	30	63	226	276	282
Oil	0	0	0	0	0	0
Biomass	0	5	10	25	51	72
Geothermal	0	0	1	6	14	32
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	0	32	91	271	305	309
Autoproducers	22	59	72	102	128	158
Total generation	**708**	**1,197**	**1,503**	**2,134**	**2,656**	**3,015**
Fossil	548	875	960	974	692	405
Coal	503	780	818	658	352	94
Lignite	0	0	0	0	0	0
Gas	25	71	120	303	335	311
Oil	20	24	21	13	5	0
Diesel	0	0	0	0	0	0
Nuclear	8	13	31	23	18	0
Hydrogen	0	0	0	0	0	0
Renewables	**152**	**309**	**513**	**1,138**	**1,946**	**2,610**
Hydro	145	225	256	317	369	397
Wind	6	70	196	513	651	703
PV	0	3	22	155	586	803
Biomass	1	9	16	37	66	90
Geothermal	0	0	1	21	66	147
Solar thermal	0	2	21	84	177	282
Ocean energy	0	0	1	10	31	189
Fluctuating RES (PV, Wind, Ocean)	6	73	219	678	1,269	1,694
Share of fluctuating RES	0.8%	6.1%	14.6%	31.8%	47.8%	56.2%
RES share	**21.5%**	**25.8%**	**34.1%**	**53.3%**	**73.3%**	**86.6%**

table 13.188: china: primary energy demand

PJ/A	2007	2015	2020	2030	2040	2050
Total	**83,922**	**108,851**	**115,083**	**107,859**	**104,763**	**107,104**
Fossil	**73,016**	**94,771**	**96,058**	**76,267**	**47,821**	**24,601**
Hard coal	55,333	68,488	67,216	46,211	20,753	5,027
Lignite	0	0	0	0	0	0
Natural gas	2,716	7,331	9,160	11,949	12,190	8,061
Crude oil	14,966	18,952	19,683	18,107	14,878	11,513
Nuclear	**678**	**1,145**	**2,727**	**2,040**	**1,593**	**0**
Renewables	**10,228**	**12,934**	**16,297**	**29,551**	**55,349**	**82,502**
Hydro	1,747	2,707	3,060	3,780	4,644	5,436
Wind	32	558	1,602	4,374	6,167	7,340
Solar	182	444	1,218	5,183	14,541	21,628
Biomass	8,267	9,131	10,033	11,681	14,401	14,763
Geothermal	0	93	377	4,408	15,200	30,960
Ocean Energy	0	0	7	126	396	2,376
RES share	**12.2%**	**11.9%**	**14.1%**	**27.4%**	**52.8%**	**77.0%**
'Efficiency' savings (compared to Ref.)	**0**	**8,340**	**15,407**	**50,239**	**67,960**	**76,664**

table 13.189: china: final energy demand

PJ/a	2007	2015	2020	2030	2040	2050
Total (incl. non-energy use)	**53,694**	**70,170**	**75,259**	**79,214**	**79,866**	**78,514**
Total (energy use)	**49,186**	**63,555**	**68,141**	**71,175**	**70,906**	**68,633**
Transport	**5,882**	**8,775**	**9,992**	**11,454**	**12,170**	**12,796**
Oil products	5,734	8,225	8,874	8,598	6,922	4,302
Natural gas	3	11	15	16	15	14
Biofuels	46	206	305	595	823	1,113
Electricity	99	333	795	2,178	4,263	6,951
RES electricity	15	60	191	1,007	3,040	6,230
Hydrogen	0	0	4	66	147	416
RES share Transport	**1.0%**	**3.0%**	**5.0%**	**14.3%**	**32.6%**	**60.3%**
Industry	**25,008**	**33,512**	**35,561**	**36,062**	**34,750**	**31,920**
Electricity	6,738	10,974	12,280	13,729	14,480	14,301
RES electricity	1,008	1,968	2,951	6,347	10,326	12,816
District heat	2,551	3,367	3,647	3,731	4,565	5,259
RES district heat	15	149	343	830	2,045	3,773
Coal	10,524	12,847	12,938	11,813	3,848	72
Oil products	1,691	1,942	1,942	1,344	756	160
Gas	3,505	4,069	4,197	3,950	3,516	775
Solar	0	71	148	545	3,494	4,907
Biomass and waste	0	221	302	665	1,894	2,706
Geothermal	0	21	107	284	2,126	3,029
Hydrogen	0	0	0	0	71	710
RES share Industry	**4.1%**	**7.3%**	**10.8%**	**24.0%**	**57.4%**	**87.3%**
Other Sectors	**18,295**	**21,268**	**22,588**	**23,659**	**23,987**	**23,917**
Electricity	2,946	4,815	5,633	6,716	7,869	9,294
RES electricity	441	863	1,354	3,105	5,611	8,329
District heat	697	1,091	1,497	2,119	2,774	3,440
RES district heat	4	48	141	472	1,243	2,468
Coal	2,634	2,414	2,038	1,822	824	0
Oil products	2,830	3,298	3,216	2,145	749	153
Gas	863	1,413	1,614	1,427	959	214
Solar	182	315	570	1,621	2,660	3,801
Biomass and waste	8,143	7,893	7,958	7,654	7,210	5,212
Geothermal	0	28	62	155	941	1,802
RES share Other Sectors	**47.9%**	**43.0%**	**44.6%**	**55.0%**	**73.6%**	**90.4%**
Total RES	**9,853**	**11,843**	**14,433**	**23,311**	**41,568**	**57,195**
RES share	**20.0%**	**18.6%**	**21.2%**	**32.8%**	**58.6%**	**83.3%**
Non energy use	**4,509**	**6,615**	**7,118**	**8,039**	**8,960**	**9,881**
Oil	3,104	4,555	4,900	5,535	6,169	6,803
Gas	359	527	567	640	713	787
Coal	1,045	1,534	1,650	1,864	2,078	2,291

china: total new investment by technology

table 13.190: china: total investment

MILLION $	2005-2010	2011-2020	2021-2030	2005-2030
Reference scenario				
Conventional (fossil & nuclear)	**443,185**	**651,642**	**594,423**	**1,689,250**
Renewables	**221,228**	**381,480**	**360,425**	**963,133**
Biomass	1,695	7,463	42,522	51,680
Hydro	180,411	291,724	244,298	716,433
Wind	33,653	60,833	44,483	138,970
PV	4,387	16,536	25,698	46,621
Geothermal	1,081	3,228	3,374	7,684
Solar thermal power plants	0	1,696	50	1,745
Ocean energy	0	0	0	0
Energy [R]evolution				
Conventional (fossil & nuclear)	**443,185**	**528,449**	**294,099**	**1,265,733**
Renewables	**221,228**	**594,053**	**855,428**	**1,670,709**
Biomass	1,695	53,136	61,806	116,638
Hydro	180,411	293,003	246,134	719,548
Wind	33,653	168,390	271,694	473,737
PV	4,387	22,708	125,820	152,915
Geothermal	1,081	6,706	21,758	29,545
Solar thermal power plants	0	49,185	127,515	176,700
Ocean energy	0	926	700	1,626
Advanced Energy [R]evolution				
Conventional (fossil & nuclear)	**443,185**	**505,186**	**236,795**	**1,185,167**
Renewables	**221,228**	**720,949**	**1,323,677**	**2,265,854**
Biomass	1,695	53,136	64,107	118,939
Hydro	180,411	293,003	246,134	719,548
Wind	33,653	205,998	351,521	591,172
PV	4,387	45,714	182,747	232,847
Geothermal	1,081	9,745	166,756	177,582
Solar thermal power plants	0	111,502	289,316	400,819
Ocean energy	0	1,852	23,096	24,948

notes

oecd pacific: reference scenario

table 13.191: oecd pacific: electricity generation

TWh/a	2007	2015	2020	2030	2040	2050
Power plants	**1,798**	**1,960**	**2,056**	**2,244**	**2,406**	**2,547**
Coal	492	588	601	610	632	631
Lignite	128	130	130	130	131	133
Gas	440	428	457	460	463	466
Oil	174	76	47	42	39	36
Diesel	5	5	5	5	4	3
Nuclear	407	540	595	706	787	868
Biomass	24	30	34	42	50	58
Hydro	116	131	134	141	148	155
Wind	7	17	28	62	86	110
PV	0	2	5	10	20	30
Geothermal	6	9	10	12	13	15
Solar thermal power plants	0	4	9	23	32	41
Ocean energy	0	1	1	1	1	1
Combined heat & power production	**53**	**61**	**65**	**71**	**75**	**79**
Coal	3	4	5	6	6	6
Lignite	5	5	3	2	0	0
Gas	38	41	45	49	53	57
Oil	5	7	7	8	8	8
Biomass	2	3	4	5	6	7
Geothermal	0	0	1	1	2	2
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	22	25	26	27	28	29
Autoproducers	31	36	39	44	47	50
Total generation	**1,851**	**2,021**	**2,121**	**2,315**	**2,481**	**2,626**
Fossil	1,289	1,284	1,300	1,312	1,336	1,339
Coal	495	592	606	616	638	636
Lignite	133	135	133	132	131	133
Gas	478	469	502	509	516	523
Oil	179	83	54	50	47	44
Diesel	5	5	5	5	4	3
Nuclear	407	540	595	706	787	868
Hydrogen	0	0	0	0	0	0
Renewables	**155**	**197**	**226**	**297**	**358**	**419**
Hydro	116	131	134	141	148	155
Wind	7	17	28	62	86	110
PV	0	2	5	10	20	30
Biomass	26	33	38	47	56	65
Geothermal	7	9	11	13	15	17
Solar thermal	0	4	9	23	32	41
Ocean energy	0	1	1	1	1	1
Distribution losses	87	92	97	102	107	113
Own consumption electricity	110	117	124	130	137	143
Electricity for hydrogen production	0	0	0	0	0	0
Final energy consumption (electricity)	**1,654**	**1,812**	**1,900**	**2,082**	**2,237**	**2,370**
Fluctuating RES (PV, Wind, Ocean)	7	20	34	73	107	141
Share of fluctuating RES	0.4%	1.0%	1.6%	3.2%	4.3%	5.4%
RES share	**8.4%**	**9.7%**	**10.7%**	**12.8%**	**14.4%**	**16.0%**

table 13.192: oecd pacific: heat supply

PJ/A	2007	2015	2020	2030	2040	2050
District heating plants	**143**	**121**	**158**	**193**	**223**	**260**
Fossil fuels	90	78	101	122	138	157
Biomass	53	42	55	68	78	91
Solar collectors	0	0	1	2	2	4
Geothermal	0	0	1	2	4	8
Heat from CHP	**274**	**299**	**311**	**301**	**299**	**293**
Fossil fuels	269	288	295	278	267	250
Biomass	4	7	11	14	17	21
Geothermal	1	4	6	8	15	22
Fuel cell (hydrogen)	0	0	0	0	0	0
Direct heating[1]	**7,215**	**7,073**	**7,120**	**7,397**	**7,647**	**7,926**
Fossil fuels	6,836	6,495	6,417	6,343	6,286	6,213
Biomass	330	441	477	692	905	1,134
Solar collectors	30	52	87	121	158	206
Geothermal	19	85	140	240	298	373
Total heat supply[1]	**7,632**	**7,492**	**7,589**	**7,891**	**8,168**	**8,478**
Fossil fuels	7,196	6,861	6,813	6,743	6,690	6,620
Biomass	387	489	543	774	1,000	1,246
Solar collectors	30	52	88	123	160	210
Geothermal	19	90	146	251	317	402
Fuel cell ((hydrogen)	0	0	0	0	0	0
RES share (including RES electricity)	**5.7%**	**8.4%**	**10.2%**	**14.5%**	**18.1%**	**21.9%**

1) heat from electricity (direct and from electric heat pumps) not included; covered in the model under 'electric appliances'

table 13.193: oecd pacific: CO_2 emissions

MILL t/a	2007	2015	2020	2030	2040	2050
Condensation power plants	**914**	**892**	**886**	**865**	**837**	**794**
Coal	471	518	529	510	504	469
Lignite	146	139	133	130	122	118
Gas	170	176	184	189	179	177
Oil	120	53	32	29	27	25
Diesel	6.3	6.5	6.5	6.5	5.2	3.9
Combined heat & power production	**39**	**41**	**41**	**39**	**36**	**34**
Coal	6	6	6	6	6	4
Lignite	6	6	3	2	0	0
Gas	16	19	22	23	25	25
Oil	12	11	10	8	6	5
CO_2 emissions electricity & steam generation	**953**	**933**	**926**	**904**	**874**	**828**
Coal	477	524	536	516	509	474
Lignite	152	144	137	132	122	118
Gas	186	195	206	212	204	202
Oil & diesel	138	70	48	43	38	33
CO_2 emissions by sector	**2,144**	**2,070**	**2,039**	**1,984**	**1,911**	**1,822**
% of 1990 emissions	136%	132%	130%	126%	121%	116%
Industry	342	334	328	304	282	259
Other sectors	253	249	247	252	257	263
Transport	412	409	394	366	337	309
Electricity & steam generation	928	909	902	881	853	808
District heating	209	169	169	182	181	182
Population (Mill.)	200	202	201	197	190	180
CO_2 emissions per capita (t/capita)	**10.7**	**10.2**	**10.1**	**10.1**	**10.1**	**10.1**

table 13.194: oecd pacific: installed capacity

GW	2007	2015	2020	2030	2040	2050
Power plants	**394**	**439**	**451**	**482**	**564**	**673**
Coal	79	89	92	91	104	115
Lignite	20	19	19	19	22	27
Gas	91	117	128	138	174	233
Oil	59	50	35	23	20	18
Diesel	5	5	5	5	4	3
Nuclear	64	74	80	94	112	134
Biomass	4	5	5	7	8	9
Hydro	68	69	70	72	71	70
Wind	4	6	10	19	27	34
PV	0	1	4	7	14	21
Geothermal	1	1	2	2	2	2
Solar thermal power plants	0	2	3	4	5	6
Ocean energy	0	0	0	0	0	0
Combined heat & power production	**12**	**14**	**14**	**16**	**17**	**18**
Coal	1	1	2	2	2	2
Lignite	3	3	2	0	0	0
Gas	7	8	8	10	12	13
Oil	1	2	2	2	2	2
Biomass	0	1	1	1	1	1
Geothermal	0	0	0	0	0	0
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	7	8	7	7	8	8
Autoproducers	6	6	7	8	9	10
Total generation	**406**	**453**	**465**	**497**	**581**	**690**
Fossil	265	293	291	291	339	412
Coal	79	90	94	93	106	117
Lignite	23	21	20	19	22	27
Gas	98	124	136	149	186	246
Oil	60	52	36	25	22	20
Diesel	5	5	5	5	4	3
Nuclear	64	74	80	94	112	134
Hydrogen	0	0	0	0	0	0
Renewables	**77**	**86**	**94**	**112**	**129**	**145**
Hydro	68	69	70	72	71	70
Wind	4	6	10	19	27	34
PV	0	1	4	7	14	21
Biomass	4	6	6	8	9	10
Geothermal	1	1	2	2	2	3
Solar thermal	0	2	3	4	5	6
Ocean energy	0	0	0	0	0	0
Fluctuating RES (PV, Wind, Ocean)	4	8	13	27	41	56
Share of fluctuating RES	1.0%	1.7%	2.9%	5.4%	7.1%	8.1%
RES share	**19.0%**	**18.9%**	**20.2%**	**22.6%**	**22.2%**	**21.0%**

table 13.195: oecd pacific: primary energy demand

PJ/A	2007	2015	2020	2030	2040	2050
Total	**37,588**	**38,567**	**39,228**	**40,421**	**40,650**	**40,793**
Fossil	**31,650**	**30,710**	**30,505**	**29,787**	**28,515**	**27,115**
Hard coal	9,285	10,149	10,211	9,808	9,568	9,033
Lignite	1,367	1,300	1,230	1,185	1,097	1,064
Natural gas	5,912	5,630	5,943	6,281	6,335	6,467
Crude oil	15,086	13,632	13,121	12,513	11,515	10,552
Nuclear	**4,437**	**5,891**	**6,491**	**7,702**	**8,585**	**9,469**
Renewables	**1,500**	**1,967**	**2,232**	**2,932**	**3,549**	**4,208**
Hydro	416	472	482	508	533	558
Wind	24	61	101	223	310	396
Solar	30	74	138	242	347	466
Biomass	778	1,052	1,153	1,530	1,873	2,222
Geothermal	253	304	355	426	483	563
Ocean Energy	0	4	4	4	4	4
RES share	**4.0%**	**5.1%**	**5.7%**	**7.3%**	**8.7%**	**10.3%**

table 13.196: oecd pacific: final energy demand

PJ/a	2007	2015	2020	2030	2040	2050
Total (incl. non-energy use)	**24,127**	**24,211**	**24,392**	**24,883**	**25,287**	**25,612**
Total (energy use)	**20,707**	**21,155**	**21,336**	**21,869**	**22,315**	**22,682**
Transport	5,836	5,903	5,694	5,317	4,940	**4,564**
Oil products	5,699	5,652	5,432	5,044	4,653	4,260
Natural gas	41	67	67	67	67	67
Biofuels	8	42	42	43	45	47
Electricity	88	143	153	163	175	189
RES electricity	7	14	16	21	25	30
Hydrogen	0	0	0	0	0	1
RES share Transport	**0.3%**	**0.9%**	**1.0%**	**1.2%**	**1.4%**	**1.7%**
Industry	**7,323**	**7,486**	**7,620**	**7,851**	**8,085**	**8,320**
Electricity	2,337	2,606	2,696	2,872	3,043	3,214
RES electricity	196	254	287	369	439	513
District heat	309	308	315	329	351	376
RES district heat	74	65	77	88	102	121
Coal	1,158	1,484	1,422	1,274	1,153	1,011
Oil products	1,723	1,540	1,492	1,359	1,227	1,096
Gas	1,469	1,035	1,090	1,127	1,162	1,196
Solar	0	12	36	49	63	86
Biomass and waste	322	455	503	710	913	1,113
Geothermal	6	45	67	130	172	227
Hydrogen	0	0	0	0	0	0
RES share Industry	**8.2%**	**11.1%**	**12.7%**	**17.1%**	**20.9%**	**24.8%**
Other Sectors	**7,548**	**7,765**	**8,022**	**8,700**	**9,290**	**9,798**
Electricity	3,529	3,774	3,992	4,459	4,836	5,129
RES electricity	296	368	425	572	698	818
District heat	102	100	142	151	156	162
RES district heat	25	21	35	41	45	52
Coal	76	103	101	53	12	7
Oil products	2,000	1,882	1,812	1,781	1,755	1,709
Gas	1,710	1,750	1,792	1,988	2,186	2,361
Solar	30	40	51	72	95	120
Biomass and waste	88	92	90	131	174	218
Geothermal	13	24	41	64	76	93
RES share Other Sectors	**6.0%**	**7.0%**	**8.0%**	**10.1%**	**11.7%**	**13.3%**
Total RES	**1,064**	**1,432**	**1,671**	**2,289**	**2,847**	**3,438**
RES share	**5.1%**	**6.8%**	**7.8%**	**10.5%**	**12.8%**	**15.2%**
Non energy use	**3,420**	**3,056**	**3,056**	**3,014**	**2,973**	**2,931**
Oil	3,324	2,970	2,970	2,930	2,889	2,848
Gas	64	57	57	56	55	55
Coal	32	29	29	29	28	28

oecd pacific: [r]evolution scenario

table 13.197: oecd pacific: electricity generation

TWh/a	2007	2015	2020	2030	2040	2050
Power plants	**1,798**	**1,939**	**1,946**	**1,953**	**1,956**	**1,963**
Coal	492	505	518	459	329	60
Lignite	128	117	85	39	7	0
Gas	440	528	562	603	581	367
Oil	174	122	86	64	20	2
Diesel	5	3	2	1	0	0
Nuclear	407	430	303	164	45	0
Biomass	24	30	37	41	55	58
Hydro	116	135	155	170	185	195
Wind	7	38	120	256	465	830
PV	0	18	50	100	170	295
Geothermal	6	11	15	18	21	34
Solar thermal power plants	0	3	10	25	40	50
Ocean energy	0	0	3	14	37	72
Combined heat & power production	**53**	**73**	**94**	**124**	**167**	**226**
Coal	3	3	2	0	0	0
Lignite	5	6	4	0	0	0
Gas	38	52	68	77	69	53
Oil	5	5	4	1	0	0
Biomass	2	6	13	39	85	147
Geothermal	0	1	3	6	13	26
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	22	29	37	49	71	113
Autoproducers	31	44	57	75	96	113
Total generation	**1,851**	**2,012**	**2,040**	**2,077**	**2,123**	**2,189**
Fossil	1,289	1,340	1,331	1,244	1,007	482
Coal	495	507	520	459	329	60
Lignite	133	123	89	39	7	0
Gas	478	580	630	680	650	420
Oil	179	127	90	65	21	2
Diesel	5	3	2	1	0	0
Nuclear	407	430	303	164	45	0
Hydrogen	0	0	0	0	0	0
Renewables	**155**	**242**	**406**	**669**	**1,071**	**1,707**
Hydro	116	135	155	170	185	195
Wind	7	38	120	256	465	830
PV	0	18	50	100	170	295
Biomass	26	36	50	80	140	205
Geothermal	7	12	18	24	34	60
Solar thermal	0	3	10	25	40	50
Ocean energy	0	0	3	14	37	72
Distribution losses	87	93	94	92	87	81
Own consumption electricity	110	122	123	119	111	103
Electricity for hydrogen production	0	0	2	6	11	11
Final energy consumption (electricity)	**1,654**	**1,797**	**1,821**	**1,860**	**1,915**	**1,994**
Fluctuating RES (PV, Wind, Ocean)	7	56	173	370	672	1,197
Share of fluctuating RES	0.4%	2.8%	8.5%	17.8%	31.6%	54.7%
RES share	**8.4%**	**12.0%**	**19.9%**	**32.2%**	**50.4%**	**78.0%**
'Efficiency' savings (compared to Ref.)	**0**	**19**	**107**	**314**	**541**	**763**

table 13.198: oecd pacific: heat supply

PJ/A	2007	2015	2020	2030	2040	2050
District heating plants	**143**	**142**	**180**	**310**	**294**	**220**
Fossil fuels	90	89	106	159	126	66
Biomass	53	52	71	136	138	109
Solar collectors	0	0	1	9	15	19
Geothermal	0	0	2	6	15	26
Heat from CHP	**274**	**335**	**413**	**467**	**619**	**847**
Fossil fuels	269	311	346	300	266	193
Biomass	4	12	37	108	236	422
Geothermal	1	12	30	58	117	233
Fuel cell (hydrogen)	0	0	0	0	0	0
Direct heating[1]	**7,215**	**6,868**	**6,658**	**6,396**	**6,061**	**5,682**
Fossil fuels	6,836	6,030	5,374	4,183	2,897	1,506
Biomass	330	565	697	1,006	1,291	1,361
Solar collectors	30	107	230	575	1,024	1,778
Geothermal	19	166	357	633	849	1,036
Total heat supply[1]	**7,632**	**7,344**	**7,251**	**7,173**	**6,974**	**6,749**
Fossil fuels	7,196	6,430	5,826	4,641	3,289	1,765
Biomass	387	629	805	1,251	1,665	1,892
Solar collectors	30	107	231	584	1,038	1,797
Geothermal	19	179	389	697	981	1,295
Fuel cell (hydrogen)	0	0	0	0	0	0
RES share (including RES electricity)	**5.7%**	**12%**	**20%**	**35%**	**53%**	**74%**
'Efficiency' savings (compared to Ref.)	**0**	**148**	**338**	**718**	**1,194**	**1,730**

1) heat from electricity (direct and from electric heat pumps) not included; covered in the model under 'electric appliances'

table 13.199: oecd pacific: CO_2 emissions

MILL t/a	2007	2015	2020	2030	2040	2050
Condensation power plants	**914**	**875**	**832**	**716**	**509**	**185**
Coal	471	445	456	384	263	44
Lignite	146	125	87	39	7	0
Gas	170	217	227	248	225	139
Oil	120	84	60	44	14	1
Diesel	6.3	4	3	1	0	0
Combined heat & power production	**39**	**43**	**45**	**37**	**32**	**24**
Coal	6	5	3	0	0	0
Lignite	6	6	4	0	0	0
Gas	16	24	33	35	32	24
Oil	12	8	5	1	0	0
CO_2 emissions electricity & steam generation	**953**	**917**	**877**	**753**	**541**	**209**
Coal	477	449	459	384	263	44
Lignite	152	131	91	39	7	0
Gas	186	241	259	283	257	163
Oil & diesel	138	96	67	47	15	1
CO_2 emissions by sector	**2,144**	**1,980**	**1,749**	**1,389**	**924**	**385**
% of 1990 emissions	136%	126%	111%	88%	59%	24%
Industry	342	314	278	209	140	107
Other sectors	253	218	185	129	81	18
Transport	412	371	325	244	141	50
Electricity & steam generation	928	892	850	731	523	196
District heating	209	185	112	76	39	14
Population (Mill.)	200	202	201	197	190	180
CO_2 emissions per capita (t/capita)	**10.7**	**9.8**	**8.7**	**7.0**	**4.9**	**2.1**

table 13.200: oecd pacific: installed capacity

GW	2007	2015	2020	2030	2040	2050
Power plants	**394**	**473**	**506**	**561**	**668**	**802**
Coal	79	76	79	92	73	20
Lignite	20	17	12	6	1	0
Gas	91	132	139	151	194	183
Oil	59	80	64	35	11	1
Diesel	5	3	2	1	0	0
Nuclear	64	59	41	22	6	0
Biomass	4	6	6	7	9	8
Hydro	68	71	81	87	89	89
Wind	4	14	41	79	144	257
PV	0	13	36	71	121	211
Geothermal	1	2	2	3	3	5
Solar thermal power plants	0	1	3	4	6	8
Ocean energy	0	0	1	4	11	21
Combined heat & power production	**12**	**16**	**19**	**24**	**32**	**41**
Coal	1	1	0	0	0	0
Lignite	3	3	2	0	0	0
Gas	7	10	13	16	15	12
Oil	1	1	1	0	0	0
Biomass	0	1	2	7	14	25
Geothermal	0	0	1	1	2	4
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	7	8	9	11	15	22
Autoproducers	6	8	10	13	17	19
Total generation	**406**	**489**	**524**	**585**	**700**	**843**
Fossil	265	323	311	300	294	216
Coal	79	77	79	92	73	20
Lignite	23	20	14	6	1	0
Gas	98	142	151	167	209	195
Oil	60	82	64	35	11	1
Diesel	5	3	2	1	0	0
Nuclear	64	59	41	22	6	0
Hydrogen	0	0	0	0	0	0
Renewables	**77**	**107**	**173**	**263**	**399**	**627**
Hydro	68	71	81	87	89	89
Wind	4	14	41	79	144	257
PV	0	13	36	71	121	211
Biomass	4	6	8	14	23	33
Geothermal	1	2	3	4	5	9
Solar thermal	0	1	3	4	6	8
Ocean energy	0	0	1	4	11	21
Fluctuating RES (PV, Wind, Ocean)	4	26	77	155	276	488
Share of fluctuating RES	1.0%	5.4%	14.7%	26.4%	39.4%	57.9%
RES share	**19.0%**	**21.9%**	**32.9%**	**44.9%**	**57.0%**	**74.4%**

table 13.201: oecd pacific: primary energy demand

PJ/A	2007	2015	2020	2030	2040	2050
Total	**37,588**	**36,448**	**34,355**	**31,111**	**26,731**	**22,417**
Fossil	**31,650**	**28,934**	**26,750**	**22,372**	**16,121**	**8,530**
Hard coal	9,285	7,495	6,654	4,859	3,081	604
Lignite	1,367	1,181	821	351	59	0
Natural gas	5,912	6,918	7,626	8,396	7,680	4,671
Crude oil	15,086	13,340	11,650	8,765	5,301	3,255
Nuclear	**4,437**	**4,691**	**3,305**	**1,789**	**491**	**0**
Renewables	**1,500**	**2,823**	**4,299**	**6,950**	**10,120**	**13,887**
Hydro	416	486	558	612	666	702
Wind	24	137	432	922	1,674	2,988
Solar	30	182	447	1,034	1,794	3,039
Biomass	778	1,577	2,163	3,338	4,476	4,849
Geothermal	253	440	688	993	1,376	2,050
Ocean Energy	0	0	11	50	133	259
RES share	**4.0%**	**7.7%**	**12.5%**	**22.3%**	**37.9%**	**61.9%**
'Efficiency' savings (compared to Ref.)	**0**	**2,120**	**4,873**	**9,310**	**13,918**	**18,376**

table 13.202: oecd pacific: final energy demand

PJ/a	2007	2015	2020	2030	2040	2050
Total (incl. non-energy use)	**24,127**	**23,584**	**22,790**	**21,574**	**20,061**	**18,622**
Total (energy use)	**20,707**	**20,527**	**19,887**	**18,861**	**17,535**	**16,278**
Transport	**5,836**	**5,608**	**5,239**	**4,679**	**4,051**	**3,514**
Oil products	5,699	5,121	4,462	3,326	1,874	602
Natural gas	41	70	94	110	125	142
Biofuels	8	257	426	734	1,062	1,162
Electricity	88	160	251	493	963	1,579
RES electricity	7	19	50	159	486	1,231
Hydrogen	0	0	5	16	28	30
RES share Transport	**0.3%**	**4.9%**	**9.1%**	**19.2%**	**38.5%**	**68.8%**
Industry	**7,323**	**7,544**	**7,379**	**7,015**	**6,517**	**5,993**
Electricity	2,337	2,678	2,650	2,569	2,401	2,182
RES electricity	196	322	527	828	1,211	1,702
District heat	309	353	401	462	515	559
RES district heat	74	89	132	213	301	426
Coal	1,158	1,014	625	214	5	0
Oil products	1,723	1,553	1,343	816	239	139
Gas	1,469	1,420	1,678	1,929	1,888	1,517
Solar	0	12	39	149	246	321
Biomass and waste	322	470	560	691	931	945
Geothermal	6	45	84	184	293	329
Hydrogen	0	0	0	0	0	0
RES share Industry	**8.2%**	**12.4%**	**18.2%**	**29.4%**	**45.8%**	**62.1%**
Other Sectors	**7,548**	**7,375**	**7,269**	**7,168**	**6,966**	**6,771**
Electricity	3,529	3,633	3,655	3,632	3,530	3,416
RES electricity	296	437	728	1,170	1,780	2,664
District heat	102	111	176	295	377	485
RES district heat	25	28	58	136	221	370
Coal	76	57	0	0	1	0
Oil products	2,000	1,771	1,454	833	383	197
Gas	1,710	1,406	1,323	1,160	903	33
Solar	30	95	191	426	778	1,457
Biomass and waste	88	228	300	524	610	649
Geothermal	13	74	170	298	384	535
RES share Other Sectors	**6.0%**	**11.7%**	**19.9%**	**35.6%**	**54.2%**	**83.8%**
Total RES	**1,064**	**2,076**	**3,267**	**5,517**	**8,316**	**11,814**
RES share	**5.1%**	**10.1%**	**16.4%**	**29.2%**	**47.4%**	**72.6%**
Non energy use	**3,420**	**3,056**	**2,904**	**2,713**	**2,527**	**2,345**
Oil	3,324	2,970	2,822	2,637	2,456	2,279
Gas	64	57	54	51	47	44
Coal	32	29	27	26	24	22

oecd pacific: advanced energy [r]evolution scenario

table 13.203: oecd pacific: electricity generation

TWh/a	2007	2015	2020	2030	2040	2050
Power plants	**1,798**	**1,946**	**1,932**	**1,960**	**2,031**	**2,089**
Coal	492	650	530	450	48	0
Lignite	128	45	14	3	0	0
Gas	440	450	552	596	589	32
Oil	174	122	85	63	20	1
Diesel	5	3	2	1	0	0
Nuclear	407	430	303	164	45	0
Biomass	24	34	34	42	49	47
Hydro	116	135	155	170	185	195
Wind	7	45	140	229	652	915
PV	0	18	50	100	170	390
Geothermal	6	11	17	41	58	84
Solar thermal power plants	0	3	40	65	130	295
Ocean energy	0	0	10	35	85	130
Combined heat & power production	**53**	**73**	**109**	**142**	**180**	**233**
Coal	3	3	2	0	0	0
Lignite	5	6	4	0	0	0
Gas	38	52	78	84	61	9
Oil	5	5	5	2	0	0
Biomass	2	6	16	48	96	173
Geothermal	0	1	4	9	22	51
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	22	29	37	49	71	113
Autoproducers	31	44	72	93	109	120
Total generation	**1,851**	**2,019**	**2,041**	**2,102**	**2,211**	**2,322**
Fossil	1,289	1,336	1,272	1,199	719	42
Coal	495	653	532	450	48	0
Lignite	133	51	18	3	0	0
Gas	478	502	630	680	650	41
Oil	179	127	90	65	21	1
Diesel	5	3	2	1	0	0
Nuclear	407	430	303	164	45	0
Hydrogen	0	0	0	0	0	0
Renewables	**155**	**253**	**466**	**739**	**1,447**	**2,280**
Hydro	116	135	155	170	185	195
Wind	7	45	140	229	652	915
PV	0	18	50	100	170	390
Biomass	26	40	50	90	145	220
Geothermal	7	12	21	50	80	135
Solar thermal	0	3	40	65	130	295
Ocean energy	0	0	10	35	85	130
Distribution losses	87	93	94	92	87	81
Own consumption electricity	110	122	123	119	105	93
Electricity for hydrogen production	0	0	3	9	10	10
Final energy consumption (electricity)	**1,654**	**1,804**	**1,821**	**1,882**	**2,008**	**2,139**
Fluctuating RES (PV, Wind, Ocean)	7	63	200	364	907	1,435
Share of fluctuating RES	0.4%	3.1%	9.8%	17.3%	41.0%	61.8%
RES share	**8.4%**	**12.5%**	**22.8%**	**35.2%**	**65.5%**	**98.2%**
'Efficiency' savings (compared to Ref.)	**0**	**19**	**107**	**311**	**532**	**745**

table 13.204: oecd pacific: heat supply

PJ/A	2007	2015	2020	2030	2040	2050
District heating plants	**143**	**142**	**181**	**346**	**429**	**404**
Fossil fuels	90	89	106	97	17	0
Biomass	53	52	71	156	223	194
Solar collectors	0	0	1	69	150	161
Geothermal	0	0	2	24	39	48
Heat from CHP	**274**	**335**	**480**	**551**	**701**	**994**
Fossil fuels	269	311	407	340	233	34
Biomass	4	12	42	133	266	504
Geothermal	1	12	32	77	202	456
Fuel cell (hydrogen)	0	0	0	0	0	0
Direct heating[1)]	**7,215**	**6,868**	**6,590**	**6,277**	**5,724**	**5,159**
Fossil fuels	6,836	6,030	5,321	3,778	2,324	227
Biomass	330	565	645	1,028	1,035	1,475
Solar collectors	30	107	268	807	1,394	2,166
Geothermal	19	166	356	664	971	1,290
Total heat supply[1)]	**7,632**	**7,344**	**7,251**	**7,173**	**6,974**	**6,749**
Fossil fuels	7,196	6,430	5,834	4,215	2,574	261
Biomass	387	629	758	1,317	1,524	2,173
Solar collectors	30	107	269	876	1,544	2,328
Geothermal	19	179	390	765	1,212	1,795
Fuel cell (hydrogen)	0	0	0	0	121	193
RES share (including RES electricity)	**5.7%**	**12.5%**	**19.5%**	**41.2%**	**62.5%**	**96.1%**
'Efficiency' savings (compared to Ref.)	**0**	**148**	**338**	**718**	**1,194**	**1,730**

1) heat from electricity (direct and from electric heat pumps) not included; covered in the model under 'electric appliances'

table 13.205: oecd pacific: CO_2 emissions

MILL t/a	2007	2015	2020	2030	2040	2050
Condensation power plants	**914**	**894**	**765**	**670**	**281**	**13**
Coal	471	573	467	377	38	0
Lignite	146	48	14	3	0	0
Gas	170	185	223	245	228	12
Oil	120	84	59	44	14	1
Diesel	6.3	4	3	1	0	0
Combined heat & power production	**39**	**43**	**52**	**41**	**29**	**4**
Coal	6	5	4	0	0	0
Lignite	6	6	4	0	0	0
Gas	16	24	38	40	28	4
Oil	12	8	7	2	0	0
CO_2 emissions electricity & steam generation	**953**	**937**	**817**	**712**	**309**	**17**
Coal	477	577	470	377	38	0
Lignite	152	54	18	3	0	0
Gas	186	209	260	285	257	16
Oil & diesel	138	96	68	47	15	1
CO_2 emissions by sector	**2,144**	**1,988**	**1,671**	**1,286**	**616**	**74**
% of 1990 emissions	136%	126%	106%	82%	39%	5%
Industry	342	314	270	183	107	16
Other sectors	253	218	182	117	67	9
Transport	412	370	326	238	129	31
Electricity & steam generation	928	911	782	686	292	15
District heating	209	175	111	62	21	2
Population (Mill.)	200	202	201	197	190	180
CO_2 emissions per capita (t/capita)	**10.7**	**9.8**	**8.3**	**6.5**	**3.2**	**0.4**

table 13.206: oecd pacific: installed capacity

GW	2007	2015	2020	2030	2040	2050
Power plants	**394**	**469**	**512**	**560**	**690**	**790**
Coal	79	98	81	90	11	0
Lignite	20	7	2	0	0	0
Gas	91	113	136	149	173	17
Oil	59	80	63	34	11	0
Diesel	5	3	2	1	0	0
Nuclear	64	59	41	22	6	0
Biomass	4	6	5	7	7	7
Hydro	68	71	81	87	89	89
Wind	4	16	48	71	202	283
PV	0	13	36	71	121	279
Geothermal	1	2	3	6	9	13
Solar thermal power plants	0	1	13	11	36	66
Ocean energy	0	0	3	10	24	37
Combined heat & power production	**12**	**16**	**21**	**27**	**33**	**39**
Coal	1	1	1	0	0	0
Lignite	3	3	2	0	0	0
Gas	7	10	14	17	13	2
Oil	1	1	1	0	0	0
Biomass	0	1	3	8	16	29
Geothermal	0	0	1	1	4	8
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	7	8	9	11	14	20
Autoproducers	6	8	12	16	19	19
Total generation	**406**	**484**	**534**	**587**	**723**	**829**
Fossil	265	315	301	293	208	19
Coal	79	99	81	90	11	0
Lignite	23	9	4	0	0	0
Gas	98	122	150	166	187	19
Oil	60	82	64	35	11	0
Diesel	5	3	2	1	0	0
Nuclear	64	59	41	22	6	0
Hydrogen	0	0	0	0	0	0
Renewables	**77**	**110**	**191**	**273**	**509**	**810**
Hydro	68	71	81	87	89	89
Wind	4	16	48	71	202	283
PV	0	13	36	71	121	279
Biomass	4	7	8	15	23	35
Geothermal	1	2	3	8	13	21
Solar thermal	0	1	13	11	36	66
Ocean energy	0	0	3	10	24	37
Fluctuating RES (PV, Wind, Ocean)	4	29	86	152	348	599
Share of fluctuating RES	1.0%	6.0%	16.1%	25.9%	48.1%	72.3%
RES share	**19.0%**	**22.8%**	**35.9%**	**46.4%**	**70.3%**	**97.7%**

table 13.207: oecd pacific: primary energy demand

PJ/A	2007	2015	2020	2030	2040	2050
Total	**37,588**	**36,059**	**33,596**	**30,911**	**25,455**	**21,299**
Fossil	**31,650**	**28,498**	**25,729**	**21,097**	**12,516**	**3,500**
Hard coal	9,285	7,969	5,691	4,118	437	27
Lignite	1,367	489	165	27	0	0
Natural gas	5,912	6,749	8,272	8,536	7,167	667
Crude oil	15,086	13,291	11,600	8,416	4,912	2,805
Nuclear	**4,437**	**4,691**	**3,305**	**1,789**	**491**	**0**
Renewables	**1,500**	**2,869**	**4,562**	**8,024**	**12,449**	**17,799**
Hydro	416	486	558	612	666	702
Wind	24	162	504	824	2,347	3,294
Solar	30	182	593	1,470	2,624	4,794
Biomass	778	1,598	2,116	3,493	4,234	4,969
Geothermal	253	440	755	1,499	2,272	3,573
Ocean Energy	0	0	36	126	306	468
RES share	**4.0%**	**8.0%**	**13.6%**	**26.0%**	**48.9%**	**83.6%**
'Efficiency' savings (compared to Ref.)	**0**	**2,509**	**5,632**	**9,510**	**15,195**	**19,494**

table 13.208: oecd pacific: final energy demand

PJ/a	2007	2015	2020	2030	2040	2050
Total (incl. non-energy use)	**24,127**	**23,584**	**22,783**	**21,573**	**19,940**	**18,274**
Total (energy use)	**20,707**	**20,527**	**19,880**	**18,860**	**17,414**	**15,930**
Transport	**5,836**	**5,608**	**5,239**	**4,679**	**3,930**	**3,163**
Oil products	5,699	5,104	4,484	3,254	1,758	402
Natural gas	41	63	68	77	67	58
Biofuels	8	257	427	759	990	913
Electricity	88	184	251	565	1,087	1,762
RES electricity	7	23	57	199	712	1,730
Hydrogen	0	0	8	24	27	27
RES share Transport	**0.3%**	**5.0%**	**9.3%**	**20.6%**	**43.8%**	**84.4%**
Industry	**7,323**	**7,544**	**7,403**	**7,040**	**6,546**	**6,030**
Electricity	2,337	2,678	2,650	2,577	2,430	2,241
RES electricity	196	336	605	906	1,591	2,200
District heat	309	353	468	558	649	739
RES district heat	74	89	155	346	551	724
Coal	1,158	1,014	342	0	0	0
Oil products	1,723	1,546	1,326	786	237	86
Gas	1,469	1,427	1,898	1,792	1,335	162
Solar	0	12	77	298	444	597
Biomass and waste	322	470	558	827	951	1,493
Geothermal	6	45	84	202	371	505
Hydrogen	0	0	0	0	130	207
RES share Industry	**8.2%**	**12.6%**	**20.0%**	**36.6%**	**61.0%**	**94.9%**
Other Sectors	**7,548**	**7,375**	**7,238**	**7,141**	**6,938**	**6,737**
Electricity	3,529	3,633	3,655	3,634	3,533	3,420
RES electricity	296	455	834	1,277	2,313	3,358
District heat	102	111	176	317	455	628
RES district heat	25	28	58	197	386	614
Coal	76	57	0	0	0	4
Oil products	2,000	1,750	1,393	614	119	18
Gas	1,710	1,427	1,356	1,235	996	106
Solar	30	95	191	508	950	1,569
Biomass and waste	88	228	299	531	490	442
Geothermal	13	74	170	302	395	551
RES share Other Sectors	**6.0%**	**11.9%**	**21.4%**	**39.4%**	**65.3%**	**97.0%**
Total RES	**1,064**	**2,112**	**3,517**	**6,360**	**10,245**	**14,926**
RES share	**5.1%**	**10.3%**	**17.7%**	**33.7%**	**58.8%**	**93.7%**
Non energy use	**3,420**	**3,056**	**2,904**	**2,713**	**2,527**	**2,345**
Oil	3,324	2,970	2,822	2,637	2,456	2,279
Gas	64	57	54	51	47	44
Coal	32	29	27	26	24	22

oecd pacific: total new investment by technology

table 13.209: oecd pacific: total investment

MILLION $	2005-2010	2011-2020	2021-2030	2005-2030
Reference scenario				
Conventional (fossil & nuclear)	**217,584**	**239,174**	**233,012**	**689,770**
Renewables	**29,641**	**57,070**	**42,563**	**129,274**
Biomass	5,924	9,122	9,365	24,411
Hydro	9,843	16,984	10,287	37,115
Wind	4,895	5,298	11,493	21,686
PV	256	8,438	4,948	13,642
Geothermal	1,294	6,422	2,178	9,893
Solar thermal power plants	6,815	10,033	4,292	21,140
Ocean energy	613	773	0	1,386
Energy [R]evolution				
Conventional (fossil & nuclear)	**209,968**	**180,219**	**157,162**	**547,348**
Renewables	**29,641**	**211,392**	**145,400**	**386,433**
Biomass	5,924	16,884	21,454	44,262
Hydro	9,843	35,694	13,321	58,858
Wind	4,895	44,088	43,079	92,062
PV	256	84,953	48,799	134,008
Geothermal	1,294	15,479	6,708	23,481
Solar thermal power plants	6,815	11,516	4,341	22,673
Ocean energy	613	2,777	7,699	11,089
Advanced Energy [R]evolution				
Conventional (fossil & nuclear)	**209,968**	**195,884**	**161,466**	**567,319**
Renewables	**29,641**	**280,497**	**149,858**	**459,995**
Biomass	5,924	17,437	26,144	49,505
Hydro	9,843	35,694	13,321	58,858
Wind	4,895	52,329	27,404	84,628
PV	256	84,953	48,799	134,008
Geothermal	1,294	18,436	16,693	36,423
Solar thermal power plants	6,815	62,389	0	69,204
Ocean energy	613	9,258	17,497	27,368

notes

2005 – 2010: 5 years of energy [r]evolution scenarios – 5 years of development

Since Greenpeace published the first Energy [R]evolution scenario in May 2005 (covering the EU-25 countries) during a seven month long ship tour from Poland all the way down to Egypt, the project has developed significantly. That very first scenario was launched on board the ship with the support of former EREC Policy Director Oliver Schäfer. This was the beginning of a long lasting and fruitful collaboration between Greenpeace International and the European Renewable Energy Council. The German Space Agency's Institute for Technical Thermodynamics, under Dr. Wolfram Krewitt´s leadership, was the scientific research institute behind all the analysis which supports the scenario. Between 2005 and 2009 these three very different stakeholders have managed to put together over 30 scenarios for countries from all continents of the world and published two editions of the Global Energy [R]evolution. It has since become a well respected blueprint for progress towards an alternative energy future. The work has been translated into over 15 different languages, including Chinese, Japanese, Arabic, Hebrew, Spanish, Thai and Russian.

The concept of the Energy [R]evolution scenario has been under constant development from the beginning. Now, for example, we are able to calculate the employment effects in parallel with the scenario development. The program MESAP/PlaNet has also been developed by software company seven2one, providing many features to make the project more sophisticated. For the 2010 edition we have developed a specific standard report tool which provides us with a "ready to print" executive summary for each region or country. This allows our calculations to interact between all the world regions, resulting in the global scenario opening up like a cascade. All these new developments have enabled us to provide ever improving quality, faster development times and more user friendly outputs. Over the past few years an experienced team of 20 scientists from all regions of the world has been formed in order to review the regional and/or country specific scenarios and to make sure that they are appropriate to the specific geographical area.

In some cases the Energy [R]evolution Scenarios have been the first ever long term energy scenario produced for a particular country, for example the Turkish scenario published in 2009. Since the first Global Energy [R]evolution scenario published in January 2007, we have organised side events at every single UNFCCC climate conference, countless energy conferences and panel debates. Over 200 presentations in more than 30 languages always had one message in common: "The Energy Revolution is possible; it is needed and will pay for itself in benefits for future generations!" Many high level meetings have taken place, for example on 15th July 2009, when the Chilean President Michelle Bachelet attended our launch event for the Energy [R]evolution in Chile.

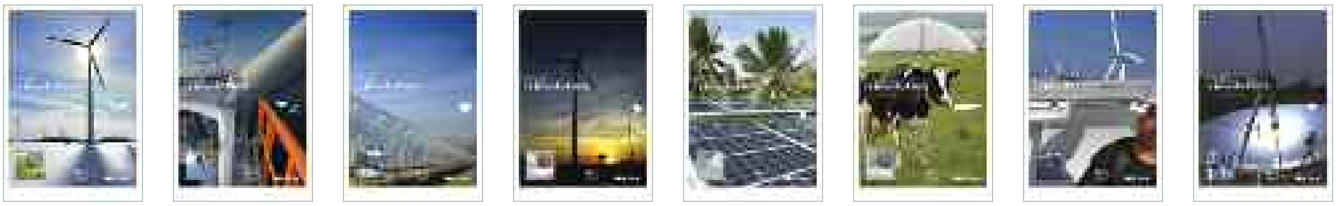
The Energy [R]evolution work is a cornerstone of the Greenpeace climate and energy work worldwide and we would like to thank all the stakeholders who have been involved. Unfortunately, in October 2009, Dr Wolfram Krewitt from DLR passed away far too early and left a huge gap for everybody. His energy and dedication helped to make the project a true success story. Arthouros Zervos and Christine Lins from EREC have been involved in this work from the very beginning and Sven Teske from Greenpeace International has led the project since its first beginnings in late 2004. The well received layout of all the Energy [R]evolution series has been produced – also from the very beginning – by Tania Dunster and Jens Christiansen from "onehemisphere" in Sweden, and with enormous passion, especially in the final phase as the reports have gone to print. Finally, all the Global Energy [R]evolution Scenarios have been reported in a number of scientific and peer review journals such as Energy Policy.

Listed here is a selection of milestones from the progress of the Energy [R]evolution story between 2005 and June 2010.

June 2005: First Energy [R]evolution Scenario for EU 25 presented in Luxembourg for members of the EU´s Environmental Council.
July – August 2005: National Energy [R]evolution scenarios for France, Poland and Hungary launched during an "Energy [R]evolution" ship tour with a sailing vessel across Europe.
January 2007: First Global Energy [R]evolution Scenario published parallel in Brussels and Berlin.
April 2007: Launch of the Turkish translation from the Global Scenario.
July 2007: Launch of Futu[r]e Investment – an analysis of the needed global investment pathway for the Energy [R]evolution scenarios.
November 2007: Launch of the Energy [R]evolution for Indonesia in Jakarta/Indonesia.
January 2008: Launch of the Energy [R]evolution for New Zealand in Wellington/NZ.
March 2008: Launch of the Energy [R]evolution for Brazil in Rio de Janeiro/Brazil.
March 2008: launch of the Energy [R]evolution for China in Beijing/China.
June 2008: Launch of the Energy [R]evolution for Japan in Aoi Mori & Tokyo/Japan.
June 2008: Launch of the Energy [R]evolution for Australia in Canberra/Australia .
August 2008: Launch of the Energy [R]evolution for the Philippines in Manila/Philippines.
August 2008: Launch of the Energy [R]evolution for the Mexico in Mexico City/Mexico.
October 2008: Launch of the second edition of the Global Energy [R]evolution Report.
December 2008: Launch of the Energy [R]evolution for the EU-27 in Brussels/Belgium.
December 2008: Launch of a concept for specific feed in-tariff mechanism to implement the Global Energy [R]evolution Report in developing countries at a COP13 side event in Poznan/Poland.
March 2009: Launch of the Energy [R]evolution for the USA in Washington/USA.
March 2009: Launch of the Energy [R]evolution for India in Delhi/India.
April 2009: Launch of the Energy [R]evolution for Russia in Mosko/Russia.
May 2009: Launch of the Energy [R]evolution for Canada in Ottawa/Canada.
June 2009: Launch of the Energy [R]evolution for Greece in Athens/Greece.
June 2009: Launch of the Energy [R]evolution for Italy in Rome/Italy.
July 2009: Launch of the Energy [R]evolution for Chile in Santiago/Chile.
July 2009: Launch of the Energy [R]evolution for Argentina in Buenos Aires/Argentina.
September 2009: Launch of the first detailed Job Analysis "Working for the Climate" – based on the global Energy [R]evolution report in Sydney/Australia.
October 2009: Launch of the Energy [R]evolution for South Africa in Johannesburg/SA.
November 2009: Launch of the Energy [R]evolution for Turkey in Istanbul/Turkey.
November 2009: Launch of "Renewable 24/7" a detailed analysis for the needed grid infrastructure in order to implement the Energy [R]evolution for Europe with 90% renewable power in Berlin/Germany.

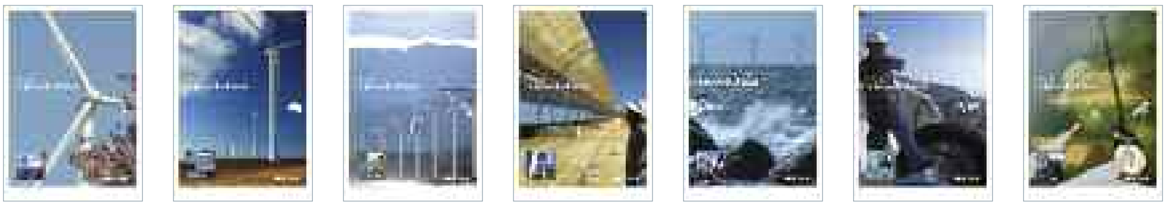
2005

2007



2007

2008



2009

2009

GREENPEACE

Greenpeace is a global organisation that uses non-violent direct action to tackle the most crucial threats to our planet's biodiversity and environment. Greenpeace is a non-profit organisation, present in 40 countries across Europe, the Americas, Africa, Asia and the Pacific. It speaks for 2.8 million supporters worldwide, and inspires many millions more to take action every day. To maintain its independence, Greenpeace does not accept donations from governments or corporations but relies on contributions from individual supporters and foundation grants.

Greenpeace has been campaigning against environmental degradation since 1971 when a small boat of volunteers and journalists sailed into Amchitka, an area west of Alaska, where the US Government was conducting underground nuclear tests. This tradition of 'bearing witness' in a non-violent manner continues today, and ships are an important part of all its campaign work.

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EREC

european renewable energy council - [EREC]
Created in April 2000, the European Renewable Energy Council (EREC) is the umbrella organisation of the European renewable energy industry, trade and research associations active in the sectors of bioenergy, geothermal, ocean, small hydro power, solar electricity, solar thermal and wind energy. EREC thus represents the European renewable energy industry with an annual turnover of €70 billion and employing 550,000 people.

EREC is composed of the following non-profit associations and federations: AEBIOM (European Biomass Association); EGEC (European Geothermal Energy Council); EPIA (European Photovoltaic Industry Association); ESHA (European Small Hydro power Association); ESTIF (European Solar Thermal Industry Federation); EUBIA (European Biomass Industry Association); EWEA (European Wind Energy Association); EUREC Agency (European Association of Renewable Energy Research Centers); EREF (European Renewable Energies Federation); EU-OEA (European Ocean Energy Association); ESTELA (European Solar Thermal Electricity Association).

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image ICE MELTING ON A BERG ON THE GREENLANDIC COAST. GREENPEACE AND AN INDEPENDENT NASA-FUNDED SCIENTIST COMPLETED MEASUREMENTS OF MELT LAKES ON THE GREENLAND ICE SHEET THAT SHOW ITS VULNERABILITY TO WARMING TEMPERATURES. **front cover images** INDUSTRY CLIMBERS CONTROL THE ROTOR BLADES OF A WIND POWER STATION IN LETSCHIEN, GERMANY. © PAUL LANGROCK/ZENIT/GREENPEACE. © GREENPEACE/STEVE MORGAN. © GREENPEACE/MARKEL REDONDO.