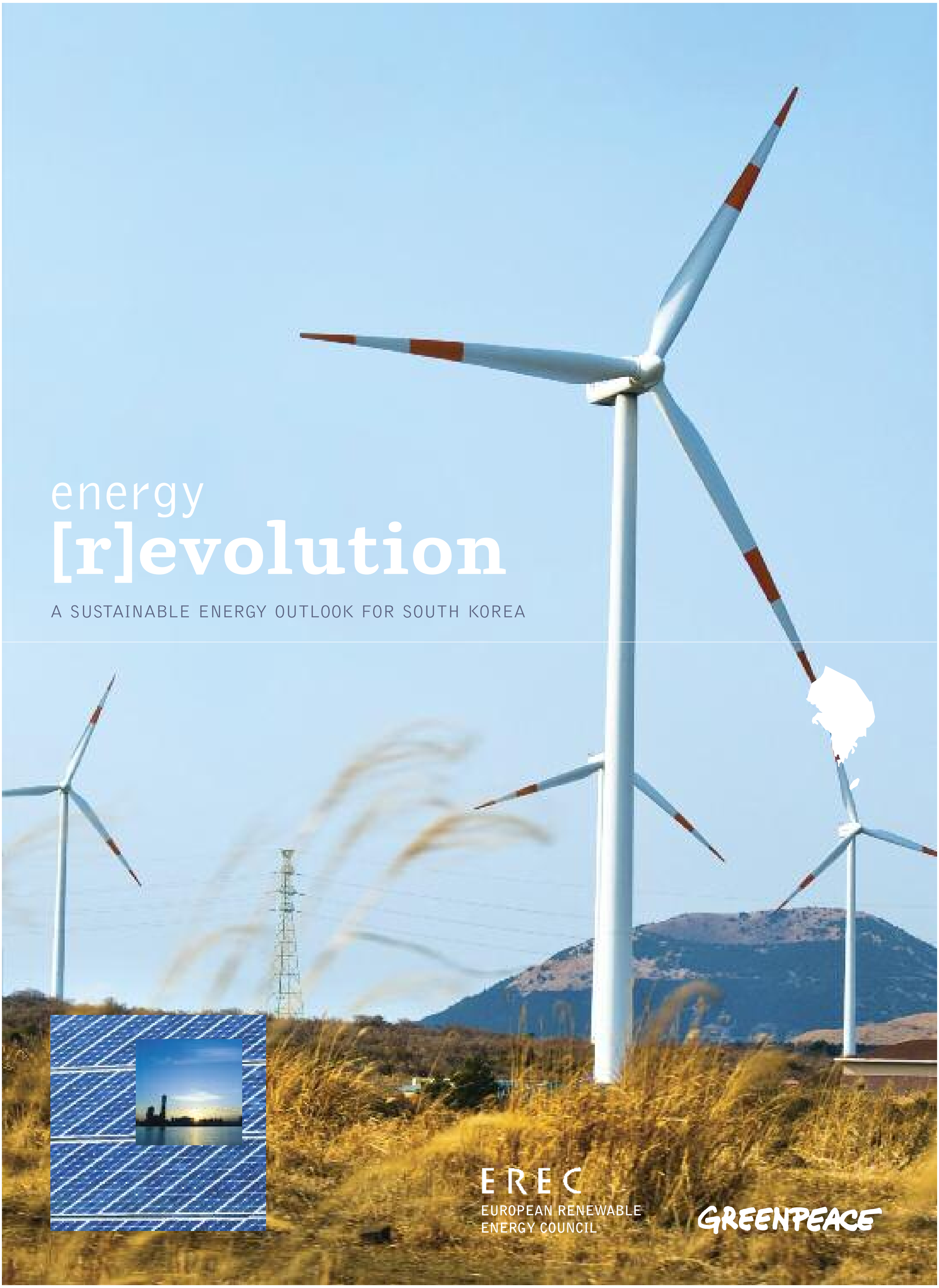

energy [r]evolution

A SUSTAINABLE ENERGY OUTLOOK FOR SOUTH KOREA

EREC
EUROPEAN RENEWABLE
ENERGY COUNCIL

GREENPEACE

report 2012 south korea energy scenario

"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?"**

Greenpeace International, European Renewable Energy Council (EREC)

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partners

image A WOMAN CARRIES HER DAUGHTER AS SHE WALKS THROUGH A FLOODED STREET NEAR BANGPA-IN INDUSTRIAL PARK IN AYUTTHAYA, THAILAND. OVER SEVEN MAJOR INDUSTRIAL PARKS IN BANGKOK AND THOUSANDS OF FACTORIES HAVE BEEN CLOSED IN THE CENTRAL THAI PROVINCE OF AYUTTHAYA AND NONTHABURI WITH MILLIONS OF TONNES OF RICE DAMAGED. THAILAND IS EXPERIENCING THE WORST FLOODING IN OVER 50 YEARS WHICH HAS AFFECTED MORE THAN NINE MILLION PEOPLE.

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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

We sincerely congratulate on the launch of Greenpeace's Report of "Energy [R]evolution – A sustainable Energy Outlook for South Korea".

We are reassured that the outlined scenario of the report covering the energy demand by sector, energy supply by sources, the relevant investment and employment by 2050 will provide and remind of Korean government's energy outlook and policy with a fresh impact. It is inevitable for a developing country like Korea which has poor energy resources but is pursuing the sustainable economic growth and business opportunity to dramatically improve the management of energy demand and to expend the renewable energy.

contents at a glance

image LA DEHESA 50 MW PARABOLIC SOLAR THERMAL POWER PLANT. A WATER RESERVOIR AT LA DEHESA SOLAR POWER PLANT. LA DEHESA, 50 MW PARABOLIC THROUGH SOLAR THERMAL POWER PLANT WITH MOLTEN SALTS STORAGE. COMPLETED IN FEBRUARY 2011, IT IS LOCATED IN LA GAROVILLA AND IT IS OWNED BY RENOVABLES SAMCA. WITH AN ANNUAL PRODUCTION OF 160 MILLION KWH, LA DEHESA WILL BE ABLE TO COVER THE ELECTRICITY NEEDS OF MORE THAN 45,000 HOMES, PREVENTING THE EMISSION OF 160,000 TONNES OF CARBON. THE 220 H PLANT HAS 225,792 MIRRORS ARRANGED IN ROWS AND 672 SOLAR COLLECTORS WHICH OCCUPY A TOTAL LENGTH OF 100KM. BADAJOZ.

With this regards, the Greenpeace's Energy [R]evolution report will be a reference guideline for Korea to come up with a better energy mix composition, implementation and cost-benefit analysis for its Basic National Energy Plan.

'Energy Alternative Forum' has announced its own "2030 Energy Alternative Scenario" in last March 2012, in the same context with the Greenpeace's Energy [R]evolution. In the awake of the Fukushima accident last year, after a series of consultation with and inputs from the various stakeholders and experts through seminars and expert workshops, the Energy Alternative Scenario came up with proposals for Korea's sustainable energy scenario and policy.

The vision of two organizations is identical for the sustainable and peaceful future. So we believe that if the two organizations share each other's expertise and experience to move forward the vision, the Energy [R]evolution and the better future will become realized.

Song Jin Soo
CO-CHAIRMAN OF ENERGY ALTERNATIVE FORUM
CHAIRMAN OF KOREA SOCIETY FOR NEW & RENEWABLE ENERGY
APRIL 2012

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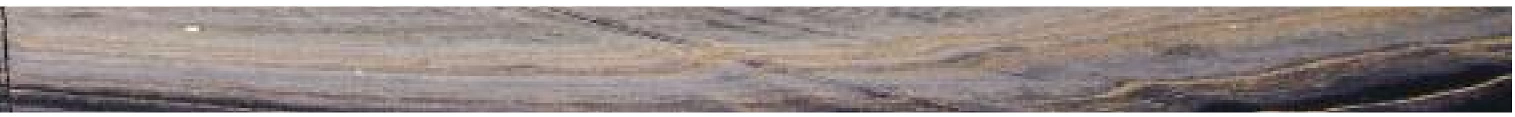

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image FIRST GEOTHERMAL POWER STATION IN GERMANY PRODUCING ELECTRICITY. WORKER IN THE FILTRATION ROOM.

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introduction

"KOREA IS FORTUNATE ENOUGH TO HAVE HUGE RENEWABLE ENERGY RESOURCES AND, WITH THE POLITICAL WILL, COULD BECOME A RENEWABLE ENERGY LEADER."

image GEMASOLAR, A 15 MWE SOLAR-ONLY POWER TOWER PLANT. IT'S 16-HOUR MOLTEN SALT STORAGE SYSTEM CAN DELIVER POWER AROUND THE CLOCK. IT RUNS THE EQUIVALENT OF 6,570 FULL HOURS OUT OF A 8,769 TOTAL. GEMASOLAR IS OWNED BY TORRESOL ENERGY AND HAS BEEN COMPLETED IN MAY 2011.

On 11 March 2011 an enormous earthquake and tsunami hit Japan. It is a day that will be remembered in history, not only for the unimaginable human tragedy, but for the resulting nuclear disaster, the scale of which, after Chernobyl, we were told could never happen again. The nuclear disaster at Japan's Fukushima Daiichi Nuclear Power Plant has had one positive outcome, however, as it will also be seen as a turning point in not only Japan's, but the world's energy policy.

The Fukushima crisis has triggered intensive discussions on the safety of nuclear power, and as a first result, Germany, Switzerland, and Italy choose to end their nuclear programmes and to phase out existing reactors.

The nuclear crisis in the neighbouring country Japan could be turned into a huge opportunity to move towards a sustainable energy future. With an abundance of renewable energy resources and top class technology, South Korea can easily join other countries with a large renewable energy industry, while simultaneously ending its reliance on risky and expensive nuclear technology. It is also well placed to become much more energy efficient, to reduce the costs of energy as well as emissions, and to do its part to address climate change, the biggest challenge of our age.

The solution is the Energy [R]evolution. Only a dynamic shift in how we generate and use energy will make it possible to achieve both the phase out of nuclear and minimize the risk of climate change. Harnessing the renewable resources would not only make a huge contribution to averting runaway climate change, but would also create a thriving green economy.

The Advanced Energy [R]evolution scenario for South Korea is based on a detailed renewable energy resource assessment . However only a fraction of the technical available renewable energy resources are needed to make the Advanced Energy [R]evolution scenario until 2050 a reality.

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.

turning the nuclear crisis into an opportunity

This report, The Advanced Energy [R]evolution—A sustainable Energy Outlook for South Korea, has been created to show the paths we can follow for a clean energy future. The 'reference scenario' is based on the Reference Scenario is based on the 1st National Basic Energy Plan (2008-2030). Both Energy [R]evolution scenarios were calculated by the German Aerospace Center (DLR) with support from local experts.

If South Korea takes the 'Energy [R]evolution' pathway it is possible to achieve a renewable energy future by:

- Phasing out nuclear power generation by 2030
- Generating 14% of electricity from renewable energy by 2020 and over 25% by 2030
- Reducing 30% of CO_2 emissions by 2030

The global market for renewable energy is booming internationally. Between 2005 and 2010, installed capacity of wind power grew by 333% globally, while solar photovoltaic grew by over 700%. As renewable energy is scaled up, we can start phasing out nuclear and fossil fuel, and end the reliance on these risky and dirty forms power. Enhanced efficiency and renewable energy supply can not only meet South Korea's energy demand, but also help minimize the effects of climate change and create green jobs and a sustainable clean future.

the forgotten solution: energy efficiency

The South Korea Energy [R]evolution scenario takes advantage of the enormous potential for the country to become much more energy efficient. Energy efficiency offers some of the simplest, easiest and quickest measures for reducing energy demands, greenhouse gas emissions and cost to end-users. South Korea has extensive potential in maximizing energy efficiency. The Government can introduce policy measures to reduce the electricity consumption across all sectors and – at the same time – trigger innovation and new technology developments. There is no doubt that South Korea's engineering industry could become among the world leader in energy efficiency and it will be a huge asset for the economy.

on the front foot

The Advanced Energy [R]evolution scenario demonstrates that making the necessary transformation in how we use energy is achievable, it provides new opportunities, and creates green and sustainable jobs. We call on South Korea's political leaders to turn the Energy [R]evolution scenario into a reality and to begin the inevitable transition from nuclear/fossil-fuels to renewable energy now, delivering a safe, nuclear-free environment, reduced threat from climate change and a sustainable, prosperous future.

Arthouros Zervos
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ENERGY COUNCIL (EREC)

Sven Teske
CLIMATE & ENERGY UNIT
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SENIOR CLIMATE & ENERGY CAMPAIGNER
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APRIL 2012

executive summary

"NOW IS THE TIME TO COMMIT TO A TRULY SECURE AND SUSTAINABLE ENERGY FUTURE – A FUTURE BUILT ON CLEAN TECHNOLOGIES, ECONOMIC DEVELOPMENT AND THE CREATION OF MILLIONS OF NEW JOBS."

© MICHAEL LOEWA/GP

image WITNESSES FROM FUKUSHIMA, JAPAN, KANAKO NISHIKATA AND HER TWO CHILDREN KAITO AND FUU, VISIT A WIND FARM IN KLENNOW, GERMANY.

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. Japan's major nuclear accident at Fukushima in March 2011 following a tsunami came 25 years after the disastrous explosion in the Chernobyl nuclear power plant in former Soviet Union, showing that nuclear energy is an inherently unsafe source of power.

Recognising the global threats of climate change, the signatories to the 1992 UN Framework Convention on Climate Change (UNFCCC) agreed the Kyoto Protocol in 1997. The Protocol entered into force in early 2005 and its 193 members meet continuously to negotiate further refinement and development of the agreement. Only one major industrialised nation, the United States, has not ratified the protocol. In 2011, Canada announced its intention to withdraw from the protocol. In Copenhagen in 2009, the 195 members of the UNFCCC were supposed to deliver a new climate change agreement towards ambitious and fair emission reductions. Unfortunately the ambition to reach such an agreement failed at this conference. At the 2012 Conference of the Parties in Durban, there was agreement to reach a new agreement by 2015. There is also agreement to adopt a second commitment period at the end of 2012. However, the United Nations Environment Program's examination of the climate action pledges for 2020 shows that there is still a major gap between what the science demands to curb climate change and what the countries plan to do. The proposed mitigation pledges put forward by governments are likely to allow global warming to at least 2.5 to 5 degrees temperature increase above pre-industrial levels.[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.

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

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 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 and is a testament to the inherent attractiveness of renewable technology.

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.

the energy [r]evolution

The climate change imperative demands nothing short of an Energy [R]evolution, 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.

towards a renewable future

Today, renewable energy sources account for 2.2 % of South Korea'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 1.1%, while their contribution to heat supply is around 9%, to a large extent accounted for by traditional uses such as firewood. About 81% of the primary energy supply today still comes from fossil fuels and 16% from nuclear energy . 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 and the nuclear phase-out 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:

1. Exploitation of existing large energy efficiency potentials will ensure that primary energy demand decreases from the current 9,614 PJ/a (2009) to 6,500 PJ/a in 2050, compared to 15,151 PJ/a in the Reference scenario. 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.

2. 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 around 10% and by 2050 to over 65%. More public transport systems also use electricity, as well as there being a greater shift in transporting freight from road to rail.
3. 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 limit the further expansion of CHP.
4. The electricity sector will be the pioneer of renewable energy utilisation. By 2050, around 90% of electricity will be produced from renewable sources. A capacity of around 198,000 MW will produce 475 TWh/a renewable electricity in 2050. A significant share of the fluctuating power generation from wind and solar photovoltaics will be used to supply electricity to vehicle batteries and produce hydrogen or "renewable-methane" 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.
5. In the heat supply sector, the contribution of renewables will increase to 88% by 2050. Fossil fuels and especially inefficient electric heating systems will be increasingly replaced by more efficient modern technologies, in particular biomass, solar collectors and geothermal. Geothermal heat pumps will play a growing part in industrial heat production as well.
6. 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 biofuels 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.
7. By 2050, 58% 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.

future costs

The introduction of renewable technologies under the Energy [R]evolution scenario slightly increases the costs of electricity generation in the South Korea 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 scenarios and by 2050 costs will be 2 resp. 4.2 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 $34 billion per year to more than $117 bn in 2050. The Energy [R]evolution scenario not only complies with South Korea'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 about 50% lower than in the Reference scenario

future investment

It would require US$ 457 billion in investment for the Advanced Energy [R]evolution scenario to become reality (including investments for replacement after the economic lifetime of the plants) - approximately US$ 160 billion annual or US$ 4 billion less than in the Reference scenario (US$ 617 billion). Under the Reference version, the levels of investment in nuclear power plants add up to almost 74% while approximately 20% would be invested in renewable energy and cogeneration until 2050. Under the Advanced scenario, however, South Korea would shift almost 90% of the entire investment towards renewables and cogeneration. Until 2030 the fossil fuel share of power sector investment would be focused mainly on combined heat and power plants. The average annual investment in the power sector under the Advanced Energy [R]evolution scenario between today and 2050 would be approximately US$ 11.4 billion.

Because renewable energy has no fuel costs, however, the fuel cost savings in the basic Energy [R]evolution scenario reach a total of US$ 147 billion, or US$ 3.7 billion per year. The Advanced Energy [R]evolution has even higher fuel cost savings of US$ 191 billion, or US$ 4.8 billion per year.

These renewable energy sources would then go on to produce electricity without any further fuel costs beyond 2050, while the costs for coal and gas will continue to be a burden on national economies.

future employment

Modelled energy sector jobs increase by 2015 under all scenarios. In 2010, there are 59,000 electricity sector jobs. These increase to 78,000 in the Reference scenario, 74,000 in the Energy [R]evolution scenario, and 104,000 in the Advanced scenario.

- In the Reference case, jobs grow by 32% by 2015, and then a further 27% by 2020, to reach 94,000. There is a reduction between 2020 and 2030, but jobs in 2030 are still 67,000, 14% higher than jobs in 2010.
- In the [R]evolution scenario, jobs increase by 25% by 2015, to 74,000. By 2020, jobs are nearly double 2010 levels at 116,000. There is a slight reduction between 2020 and 2030, but jobs are still 89% above 2010 levels at 112,000.

image FIRST GEOTHERMAL POWER STATION IN GERMANY PRODUCING ELECTRICITY. WORKER IN THE FILTRATION ROOM.

- In the Advanced scenario, energy sector jobs increase by 75% between 2010 and 2015, to reach 104,000. By 2020 jobs are nearly two and a half times greater than 2010 levels, at 141,000. There is a reduction in jobs between 2020 and 2030, but 2030 jobs are still 101,000, 71% higher than jobs in 2010.
- Solar PV and wind energy show particularly strong growth, and together account for between 51% and 77% of total energy sector employment by 2020 in all three scenarios.

These calculations do not include the jobs associated with decommissioning nuclear power stations, or jobs in energy efficiency. These are both likely to be significant in the Energy [R]evolution and Advanced scenarios.

Jobs in nuclear decommissioning are likely to maintain the nuclear operations and maintenance workforce at present levels (approximately 6,000 jobs) at least until 2020. 6 GW of nuclear power is phased out in the two Energy [R]evolution scenarios by 2020, with a further 2 GW phased out by 2030 in the [R]evolution scenario (a further 11 GW in the Advanced scenario).

There is a reduction in electricity generation by 2030 of more than 30% in both the Energy [R]evolution scenarios compared to the Reference scenario, which is likely to create a significant number of jobs in the energy efficiency sector, although it is beyond the scope of this work to estimate numbers.

development of CO_2 emissions

While CO_2 emissions in South Korea will increase by 20% in the Reference scenario by 2030 and decrease by 2050 to today's level, under the Advanced Energy [R]evolution scenario they will decrease from 501 million tonnes in 2009 to around 45 million tonnes in 2050 - equal to a 81% emissions reduction compared to the 1990 level. Annual per capita emissions will drop from 10.5 tonne to 1.0 tonnes. 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 28% of total CO_2 in 2050, the power sector will drop to the level of the transport sector emissions.

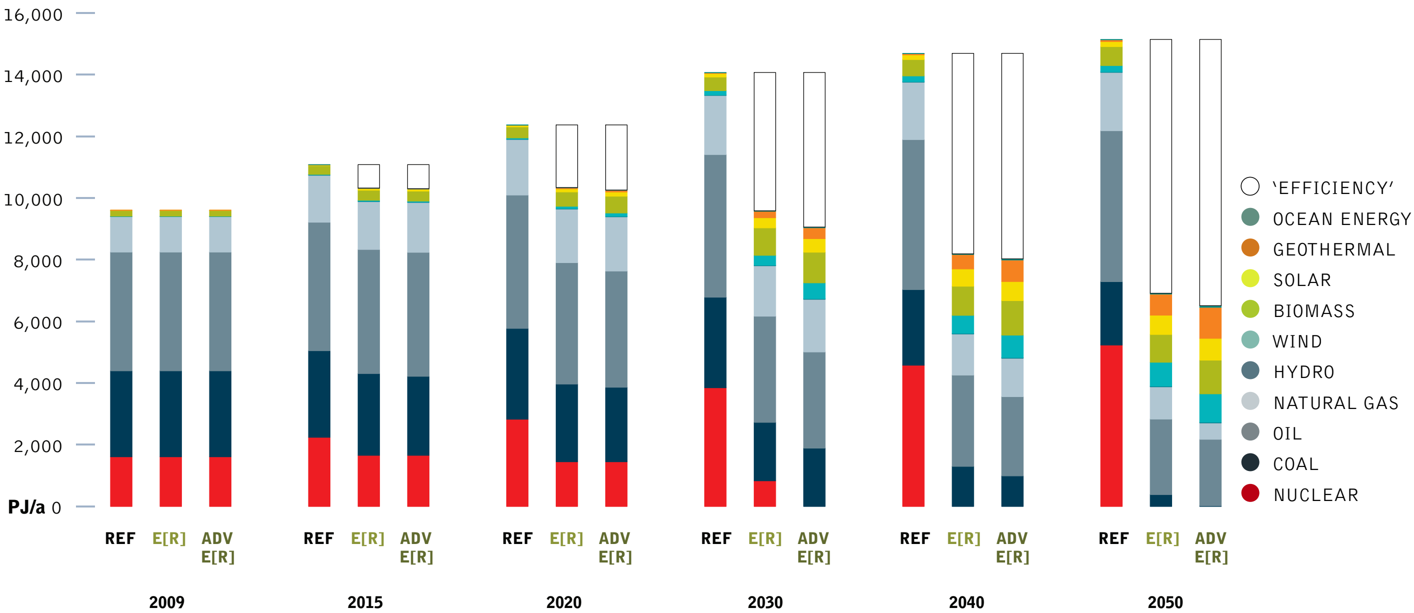
policy changes

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: development of primary energy consumption under the three scenarios

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



climate change and nuclear threats

THE IMPACTS OF CLIMATE CHANGE

NUCLEAR THREATS

1

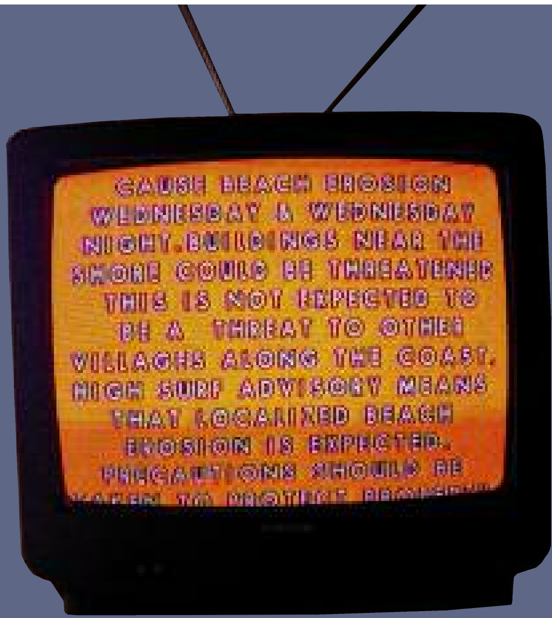


image THE LOCAL ALASKAN TELEVISION STATION BROADCASTS A WARNING FOR HIGH TIDES AND EROSION ALONG THE SEASIDE DURING A 2006 OCTOBER STORM WHICH IMPACTS ON THE VILLAGE OF SHISHMAREF. © GP/ROBERT KNOTH

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

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


© PAUL LANGROCK/ZENIT/GP

The world's power supply has bestowed great benefits on society, but it has also come with high price tag. The world's most rigorous scientific bodies are in agreement on climate change, which is occurring due to a build of carbon dioxide in the atmosphere caused by human activity.

The largest proportion of global fossil fuel use is to generate energy and for transport fuels. We have the evidence that if unchanged, the growth of fossil-fuel based energies will lead to unmanageable impacts on the population of the globe. Climate change threatens all continents, living systems, coastal cities, food systems and natural systems. It will mean more natural disasters like fire and flood, disruption to food growing patterns and damage to property as sea levels rise.

The pursuit of security for electricity supply, while remaining dependent on fossil fuels, is a potential catastrophic spiral towards increasing greenhouse gas emissions and more extreme climate impacts. The need for more fuels drives the industry towards unconventional sources like oil, shale gas and super-coal mines which destroy ecosystems and put water supply in danger. Relying on a fuel that has a fluctuating cost on the global market is also harmful to economies.

The use of nuclear energy as a climate change solution is simply not viable. Apart from being too dangerous and too slow to develop, it is also incredibly expensive. This chapter explains how even if a massive-roll out world-wide of nuclear could occur, the drop in greenhouse gas emissions would still only amount to a tiny proportion of the reductions needed to combat climate change.

1.1 the impacts of climate change

Every day we damage our climate by using fossil fuels (oil, coal and gas) for energy and transport. The resulting changes are likely to destroy the livelihoods of millions of people, especially in the developing world, as well as ecosystems and species, over the coming decades. We therefore need to significantly reduce our greenhouse gas emissions. This makes both environmental and economic sense.

box 1.1: what is the greenhouse effect?

The greenhouse effect is a natural process where the atmosphere traps some of the sun's energy, warming the earth and moderating our climate. Increase in 'greenhouse gases' from human activity has enhanced this effect, artificially raising global temperatures and disrupting our climate. 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.

According to the Intergovernmental Panel on Climate Change, the United Nations forum for established scientific opinion, the world's temperature is expected to increase over the next hundred years by up to 6.4° Celsius if no action is taken to reduce greenhouse gas emissions. This is much faster than anything experienced so far in human history. At more than a 2°C rise, damage to ecosystems and disruption to the climate system increases dramatically. An average global warming of more than 2°C threatens millions of people with an increased risk of hunger, disease, flooding and water shortages.

A certain amount of climate change is now "locked in", based on the amount of carbon dioxide and other greenhouse gases already emitted into the atmosphere since industrialisation. No one knows how much warming is "safe" for life on the plant. However, we know is that the effects of climate change are already being felt in populations and ecosystems. We can already see melting glaciers, disintegrating polar ice, thawing permafrost, dying coral reefs, rising sea levels, changing ecosystems and fatal heat waves that are made more severe by a changed climate.

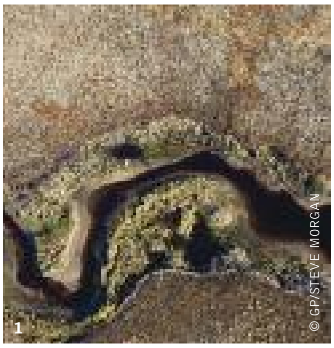
It is not only scientists who are witnessing these changes. From Inuit in the far north to islanders near the equator - people are already struggling with the impacts of climate change. We are already experiencing more extreme weather like flooding and droughts. While not all regional effects of climate change are known, the predictions if we allow current trends to continue are:

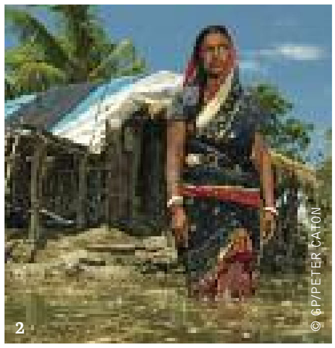
Relatively likely and early effects of small to moderate warming

- 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 which in turn trap more heat in the atmosphere.
- A high risk of more extreme weather events such as heat waves, droughts and floods. Already, the global incidence of drought has doubled over the past 30 years.
- Severe impacts for specific regions. For example, in Europe, river flooding will increase over much of the continent, and there will be substantially greater risk of flooding, erosion and wetland loss in coastal areas.
- Natural systems, including glaciers, coral reefs, mangroves, arctic ecosystems, alpine ecosystems, boreal forests, tropical forests, prairie wetlands and native grasslands, will be severely threatened.
- There will be an increased risk of species extinction and biodiversity losses.
- The greatest impacts will be on the developing countries least able to protect themselves from rising sea levels, spread of disease and declines in agricultural production. Impacts will be more pronounced in many parts of Africa, Asia and the Pacific.
- At all scales of climate change, developing countries will suffer the most.

Longer term catastrophic effects if warming continues

- Unless checked, warming from emissions may trigger the irreversible meltdown of the Greenland ice sheet in the coming decades which would add up to seven meters of sea-level rise over some centuries. Now, new evidence that the rate of ice discharge from parts of the Antarctic mean that the ice is also at risk of meltdown.
- The Atlantic Gulf Stream could slow, shift or shut down, which would having dramatic effects on weather in Europe, and disrupt the global ocean circulation system.
- Catastrophic releases of methane from the oceans could lead to rapid increases in methane in the atmosphere which is a potent heat-trapping gas, and would add to overall global warming.





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.

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.

box 1.2: how the international panel on climate change (IPCC) view risks

The IPCC used the following terms in the Summary Report to indicate the assessed likelihood:

TERM	LIKELIHOOD OF THE OUTCOME
Virtually certain	99-100% probability
Very likely	90-100% probability
Likely	66-100% probability
About as likely as not	33 to 66% probability
Unlikely	0-33% probability
Very unlikely	0-10% probability
Exceptionally unlikely	0-1% probability

Observations with high confidence: (High or very high confidence is associated with findings for which an author team has assigned likelihood).

It is very likely that there has been an overall decrease in the number of cold days and nights, and an overall increase in the number of warm days and nights, on the global scale, i.e., for most land areas with sufficient data.

It is likely that these changes have also occurred at the continental scale in North America, Europe, and Australia.

It is likely that there have been statistically significant increases in the number of heavy precipitation events in more regions than there have been statistically significant decreases, but there are strong regional and sub-regional variations in the trends.

It is likely that there has been an increase in extreme coastal high water related to trends in mean sea level in the late 20th century.

There is evidence that some extremes have changed as a result of anthropogenic influences, including increases in atmospheric concentrations of greenhouse gases. It is likely that anthropogenic influences have led to warming of extreme daily minimum and maximum temperatures on the global scale.

It is likely that there has been an anthropogenic influence on increasing extreme sea levels via mean sea level contributions.

Observations with a range of uncertainty: There is medium confidence of a warming trend in temperature extremes in much of Asia. Confidence in observed trends in temperature extremes in Africa and South America generally varies from low to medium depending on the region.

Globally, in many (but not all) regions with sufficient data there is medium confidence that the length or number of warm spells, including heat waves, has increased since the middle of the 20th century.

There is medium confidence that since the 1950s some regions of the world have experienced more intense and longer droughts, in particular in southern Europe and West Africa, but in some regions droughts have become less frequent, less intense, or shorter, e.g., in central North America and northwestern Australia.

There is medium confidence that anthropogenic influences have contributed to intensification of extreme precipitation on the global scale.

Projections with high confidence: It is virtually certain that increases in the frequency and magnitude of warm daily temperature extremes and decreases in cold extremes will occur through the 21st century on the global scale. It is very likely that the length, frequency and/or intensity of warm spells, including heat waves, will continue to increase over most land areas.

It is likely that the frequency of heavy precipitation or the proportion of total rainfall from heavy falls will increase in the 21st century over many areas of the globe. This is particularly the case in the high latitudes and tropical regions, and in winter in the northern mid-latitudes.

Heavy rainfalls associated with tropical cyclones are likely to increase with continued warming induced by enhanced greenhouse gas concentrations.

Mean tropical cyclone maximum wind speed is likely to increase, although increases may not occur in all ocean basins. It is likely that the global frequency of tropical cyclones will either decrease or remain essentially unchanged.

It is very likely that mean sea level rise will contribute to upward trends in extreme sea levels in the future. There is high confidence that locations currently experiencing adverse impacts such as coastal erosion and inundation will continue to do so in the future due to increasing sea levels, all other contributing factors being equal.

The very likely contribution of mean sea level rise to increased extreme sea levels, coupled with the likely increase in tropical cyclone maximum wind speed, is a specific issue for tropical small island states.

There is high confidence that changes in heat waves, glacial retreat and/or permafrost degradation will affect high mountain phenomena such as slope instabilities, movements of mass, and glacial lake outburst floods. There is also high confidence that changes in heavy precipitation will affect landslides in some regions.

Disaster losses: Economic losses from weather- and climate-related disasters are increasing, but with large inter-annual variability (high confidence).

Measured economic and insured losses from disasters are largest in developed countries. Fatality rates and economic losses as a proportion of GDP are higher in developing countries (high confidence). For example, during the 25-year period from 1979 to 2004 over 95% of deaths from natural disasters occurred in developing countries.

Direct economic losses from tropical cyclones will increase in the absence of additional protection measures (high confidence).

If disasters occur more frequently and/or with greater magnitude, some local areas will become increasingly marginal as places to live or in which to maintain livelihoods. In such cases, migration becomes permanent and could introduce new pressures in areas of relocation. For locations such as atolls, in some cases it is possible that many residents will have to relocate.

source
IPCC SUMMARY REPORT: MANAGING THE RISKS OF EXTREME EVENTS AND DISASTERS TO ADVANCE CLIMATE CHANGE ADAPTATION –KEY FINDINGS FROM THE SUMMARY FOR POLICY MAKERS (SPM), NOVEMBER 2011.

1.2 nuclear threats

Nuclear energy is a relatively minor industry with major problems. Currently covering just one sixteenth of the world's primary energy consumption, that share is set to decline over the coming decades.

The amount of nuclear capacity added during last five years (6,600 MW) was 35 times less than the new wind and solar capacity built in the same period (230,000 MW).[4] Renewable power plants built in just one single year of 2011 are capable of generating as much electricity as 16 large nuclear reactors; the nuclear industry has not matched this level of new capacity in a single year since 1988.

Despite the rhetoric of a 'nuclear renaissance', the industry is struggling with a massive cost increases, construction delays and safety and security problems. Japan's major nuclear accident at Fukushima following a tsunami came 25 years after the disastrous explosion in the Chernobyl nuclear power plant in former Soviet Union, showing that nuclear energy is an inherently unsafe source of power.

Following the Fukushima accident, the German Parliament to shut all nuclear power plants by 2022,[5] including immediate shut down for nearly half of them. On the same day, Germany also passed a set of laws which will further boost renewable energy and energy efficiency technologies. Just two weeks before, 95% of Italian voters made the decision to reject nuclear energy in a referendum. At the start of 2012, over 90% of the Japan's reactors were offline. There have been no significant problems with the electricity supply with only 3 of 54 in operation.

1.2.1 no solution to climate protection

The nuclear industry promises that nuclear energy can contribute to both climate protection and energy security, however their claims need to be reality-checked.

The most recent Energy Technology Perspectives report published by the International Energy Agency,[6] includes a Blue Map scenario for a future energy mix with a large expansion of nuclear power to halve global carbon emissions by the middle of this century. However, the technical assumption is a quadrupling of nuclear capacity between now and 2050, from 2,629 TWh/year in 2010 to 9,857 TWh/year in 2050. In order to achieve this, the report says that on average 32 large reactors (1,000 MWe each) would have to be built every year from now until 2050. This is actually an unrealistic, expensive and hazardous model that would not deliver enough reduction in greenhouse gas emissions to protect the climate. According to the IEA's own scenario, such this massive nuclear expansion would cut carbon emissions by less than 5 %.

More realistic analysis shows:

- The nuclear industry only achieved this scale of development for two years at the peak of a state-driven boom, so forty consecutive years of record growth is not likely. In the peak years of 1984 and 1985, 31 GW of nuclear energy was added to the global mix, but average for the decade was 17 GW. In the past decade, less than three large reactors have been brought on line annually – the global nuclear production can only deliver six units per year.
- The IEA scenario assumes investment costs of $2,100/kWe installed, in line with what the industry has been promising. The reality indicates costs of new plant are three to four times higher (see box).
- Massive expansion of nuclear energy comes with an increase in related hazards. These include the risk of serious reactor accidents like in Fukushima, Japan, the growing stockpiles of deadly high level radioactive waste which will need to be safeguarded for hundreds of thousands of years, and potential proliferation of both nuclear technologies and materials through diversion to military or terrorist use.
- Climate science says that we need to reach a peak of global greenhouse gas emissions in 2015 and a 20 % reduction by 2020. Even if the world's governments decided on strong nuclear expansion now, very few reactors would start generating electricity before 2020 because it typically takes at least ten years from decision to commissioning. Any significant contribution from nuclear power towards reducing emissions would come too late to help save the climate.

1.2.2 nuclear power blocks climate solutions

There are other technologies that can deliver much larger emission reductions, much more quickly, that are cheaper and come without dangerous by-products.

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

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.[8] With limited time, finance and industrial capacity to change our energy sector and greenhouse emissions, choosing to spend nearly $10 trillion on nuclear development would be a fatal mistake. For the reasons explained above, the Energy [R]evolution scenario envisages a nuclear phase-out with existing reactors to 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 worldwide will be finally put into operation. Plans for nuclear expansion would be cancelled.

references
4 PLATTS, DATABASE, JULY 2011.
5 NAME OF LAW – 30 JUNE 2011.
6 'ENERGY TECHNOLOGY PERSPECTIVES 2008 - SCENARIOS & STRATEGIES TO 2050', IEA.
7 PLATTS, 2008; ENERGY BIZ, MAY/JUNE 2008.
8 CALCULATION BASED ON INFORMATIONS OF THE "IEA WORLD ENERGY OUTLOOK 2011".

image YONEZAWA GYMNASIUM IS NOW PROVIDING A SHELTER FOR 504 PEOPLE WHO EITHER LOST THEIR HOMES BY THE TSUNAMI OR LIVE NEAR FUKUSHIMA NUCLEAR POWER STATION. FOR THOSE WHO LOST THEIR HOMES, OR HAVE BEEN EVACUATED DUE TO RADIATION FEARS, THE FUTURE IS UNCERTAIN.

box 1.3: nuclear industry in numbers

TRENDS

27 years	Average age of operating commercial nuclear reactors
465	Number of operating reactors globally as of February 2012
17	All of Germany's power plants to be shut down by 2022
1,400	Number of new large reactors built up to 2050 in IEA "Blue Map" scenario

FUEL AND BY-PRODUCTS

35,000	Tonnes of spent nuclear fuel that would be created from 1,400 light water reactors per year
30,000	Kilograms of plutonium each year required for the IEA "Blue Map" scenario – enough to build 35,000 crude nuclear weapons

COSTS

$7,500 per kWe	Estimated cost for nuclear power, Moody's 2008
$5,200 - $8,000 per kWe	Quotes for projects under preparation in USA[7]
$5,000 per kWe	Latest cost estimate for first French EPR pressurised water reactor being built in Finland, likely to increase for future reactors
$9.8 trillion US	Cost to build 1,400 large reactors in IEA Blue Map Scenario

1.2.3 the dangers of nuclear power

Electricity from nuclear power does produce less carbon dioxide than fossil fuels, however there are multiple threats to people and the environment from its operations. The main risks are for safety of the reaction, nuclear waste disposal and nuclear proliferation. These three risks are detailed below and are the reasons nuclear power has been discounted as a future technology in the Energy [R]evolution Scenario.

1.2.4 safety risks

Several hundred accidents have occurred in the nuclear energy industry since it began, including Windscale (1957), Three Mile Island (1979), Chernobyl (1986), Tokaimura (1999) and Fukushima (2011) Despite the nuclear industry's assurances that a nuclear accident of the Chernobyl scale could never happen again, and earthquake and subsequent tsunami in Japan caused leaks and explosions in four reactors of the Fukushima nuclear power plant. Large areas around the nuclear power plant have been seriously contaminated by radioactive releases from the plant. Areas up to 50 km from the facility have been evacuated, and food and water restrictions apply at distances more than 100 km. The impacts on the lives of hundreds of thousands of people as well as the Japanese economy will be felt for decades to come. The Fukushima disaster proves the inherent safety problems with nuclear energy.

- All existing nuclear reactors need continuous power to cool the reactors and spent nuclear fuel, even after the reactor has shut down. In 2006, the emergency power systems failed at the Swedish Forsmark plant for 20 minutes during a power cut and four of Sweden's ten nuclear power stations had to be shut down. If power had not been restored there could have been a major incident within hours.
- 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 the life of their reactors which were designed to last only 30 years, up to 60 years which posing new risks.
- A series of institutional failures set the stage for the Fukushima Daiichi disaster including a system of industry-led self-regulation, the industry's overconfidence, and its inherently dismissive attitude towards nuclear risks as well as its neglect of scientific evidence. Institutional failures are the main cause of all past nuclear accidents, however, the nuclear industry's risk assessments fail to take those into account.
- Nuclear utilities are reducing safety-related investments and have limited staff numbers, but they are increasing reactor pressure and operational temperature and the burn-up of the fuel. This accelerates ageing and decreases safety margins.

1.2.5 nuclear waste

Despite 50 years of producing radioactive waste, there is no solution for the long term storage and safeguarding of these dangerous materials. Disposal sites of low level radioactive waste have already started leaking after only decades, even though highly radioactive waste needs to be safely contained for hundreds of thousands of years. 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. Power plant developers try 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 a campaign to build new nuclear stations around the world, the industry claims that public acceptability is the main problem with burying radioactive waste rather than technical issues. It cites nuclear dumping proposals in Finland or Sweden but without scientific backing of its claims of safe disposal.

The most hazardous waste is the 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.[9]

The least damaging option for waste already in existence is to store it above ground, in dry storage at the site of origin. However, this option also presents major challenges and threats, as was seen in the Fukushima accident where there was major disruption to the cooling of the spent nuclear fuel. The only real solution is to stop producing the waste.

1.2.6 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 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.

As a result, 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, they are countries also implementing domestic nuclear energy. The tasks of International Atomic Energy Agency (IAEA) and the Nuclear Non-proliferation Treaty (NPT) have an inherent contradiction - 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 former Director General of the International Atomic Energy Agency, Mohamed ElBaradei, 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".[10]

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".[11] 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.

Restricting the production of fissile material to a few 'trusted' countries will not work. Instead, it would create greater security threats through inequity and resentment. 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, which would promote world peace rather than threaten it.

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image NUCLEAR REACTOR IN LIANYUNGANG, CHINA.

figure 1.1: 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 % comes from just seven countries: Canada, Kazakhstan, Australia, Namibia, Russia, Niger and Uzbekistan. Mine workers breathe in radioactive gas which can trigger lung cancers. 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, which has to be enriched to 3 or 5% to be suitable for most nuclear reactors. Enrichment can be done in 16 facilities around the world, where 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 four-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 turns a turbine to generate electricity. This process creates a radioactive 'cocktail' containing 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 two worst accidents to date happened at Chernobyl in the then Soviet Union in 1986 and in Fukushima, Japan in March 2011. A typical nuclear reactor generates enough plutonium every year to create 40 nuclear weapons.

5. reprocessing

Reprocessing means extracting 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 enough for one nuclear bomb. Reprocessing is not the same as recycling: it takes many time more water and millions of litres of radioactive waste are discharged into the sea and air each day. Radioactive material and nuclear waste is moved all around the world by ship, rail, air and road for reprocessing. 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 for 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.

climate and energy policy

THE UNFCCC AND THE KYOTO PROTOCOL

INTERNATIONAL ENERGY POLICY

RENEWABLE ENERGY TARGETS

POLICY CHANGES IN THE ENERGY SECTOR

KOREAN ENERGY AND CLIMATE POLICY

2

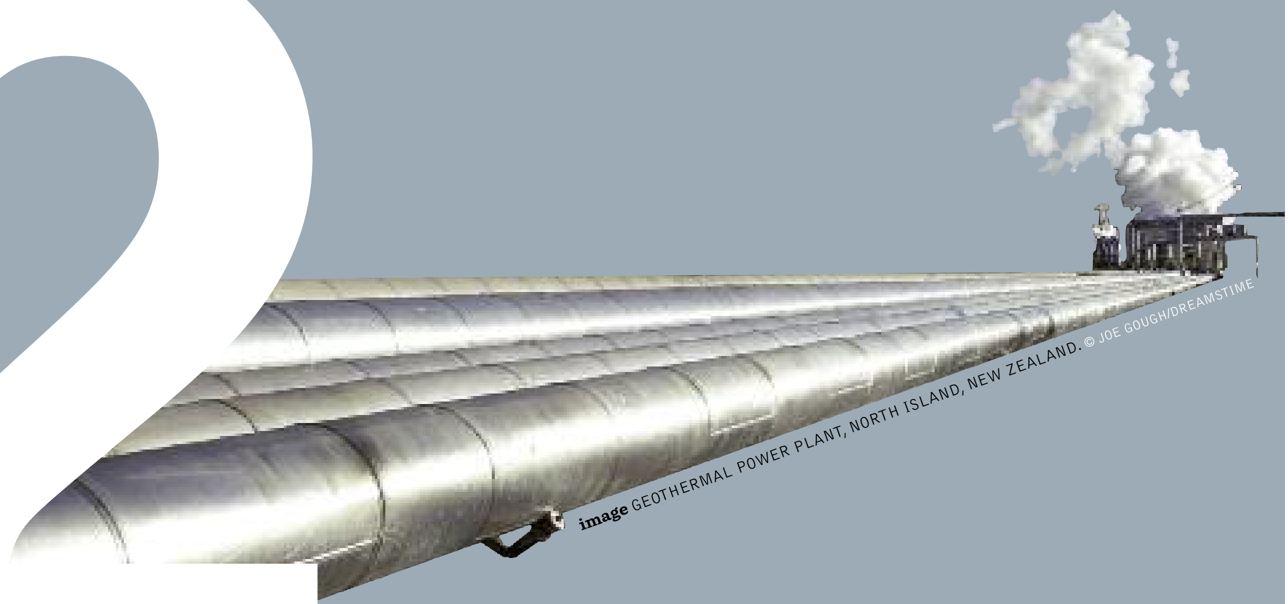

image GEOTHERMAL POWER PLANT, NORTH ISLAND, NEW ZEALAND. © JOE GOUGH/DREAMSTIME

"bridging the gap."

GREENPEACE INTERNATIONAL
CLIMATE CAMPAIGN

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.

If we do not take urgent and immediate action to protect the climate, the threats from climate change outlined in Chapter one could become irreversible.

The goal of climate policy should be to keep the global mean temperature rise to less than 2°C above pre-industrial levels. 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 the end of the next decade at the latest.

The only way forwards is a rapid reduction in the emission of greenhouse gases into the atmosphere.

2.1 the UNFCCC and the kyoto protocol

Recognising the global threats of climate change, the signatories to the 1992 UN Framework Convention on Climate Change (UNFCCC) agreed the Kyoto Protocol in 1997. The Protocol entered into force in early 2005 and its 193 members meet continuously to negotiate further refinement and development of the agreement. Only one major industrialised nation, the United States, has not ratified the protocol. In 2011, Canada announced its intention to withdraw from the protocol.

box 2.1: what does the kyoto protocol do?

The Kyoto Protocol commits 193 countries (signatories) to reduce their greenhouse gas emissions by 5.2% from their 1990 level. The global target period to achieve cuts was 2008-2012. Under the protocol, many countries and regions have adopted regional and national reduction targets. The European Union commitment is for overall reduction of 8%, for example. In order to help reach this target, the EU also created a target to increase its proportion of renewable energy from 6% to 12% by 2010.

In Copenhagen in 2009, the 195 members of the UNFCCC were supposed to deliver a new climate change agreement towards ambitious and fair emission reductions. Unfortunately the ambition to reach such an agreement failed at this conference.

At the 2012 Conference of the Parties in Durban, there was agreement to reach a new agreement by 2015. There is also agreement to adopt a second commitment period at the end of 2012. However, the United Nations Environment Program's examination of the climate action pledges for 2020 shows that there is still a major gap between what the science demands to curb climate change and what the countries plan to do. The proposed mitigation pledges put forward by governments are likely to allow global warming to at least 2.5 to 5 degrees temperature increase above pre-industrial levels.[12]

reference
12 UNEP EMISSIONS GAP REPORT.

This means that the new agreement in 2015, with the Fifth Assessment Report of the IPCC on its heels, should strive for climate action for 2020 that ensures that the world stay as far below 2 degrees as possible. Such an agreement will need to ensure:

- That industrialised countries reduce their emissions on average by at least 40% by 2020, compared to their 1990 level.
- That industrialised countries provide funding of at least $140 billion a year to developing countries under the newly established Green Climate Fund to enable them to adapt to climate change, protect their forests and be part of the energy revolution.
- That developing countries reduce their greenhouse gas emissions by 15 to 30% compared to their projected growth by 2020.

2.2 international energy policy

At present there is a distortion in many energy markets, where renewable energy generators have to compete with old nuclear and fossil fuel power stations but not on a level playing field. This is because consumers and taxpayers have already paid the interest and depreciation on the original investments so the generators are running at a marginal cost. Political action is needed to overcome market distortions so renewable energy technologies can compete on their own merits.

While governments around the world are 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 because there has been decades of massive financial, political and structural support to conventional technologies. Developing renewables will therefore require strong political and economic efforts for example, 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.

2.3 renewable energy targets

A growing number of countries have established targets for renewable energy in order to reduce greenhouse emissions and increase energy security. Targets are usually expressed as installed capacity or as a percentage of energy consumption and they are important catalysts for increasing the share of renewable energy worldwide.

However, in the electricity sector 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 incentive mechanisms such as feed-in tariffs for renewable electricity generation. To get significant increases in the proportion of renewable energy, 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.

Data from the wind and solar power industries show that it is possible to maintain a growth rate of 30 to 35% in the renewable energy sector. In conjunction with the European Photovoltaic Industry Association,[13] the European Solar Thermal Power Industry Association[14] and the Global Wind Energy Council,[15] the European Renewable Energy Council, Greenpeace has documented the development of these clean energy industries in a series of Global Outlook documents from 1990 onwards and predicted growth up to 2020 and 2040.

2.4 policy changes in the energy sector

Greenpeace and the renewable energy industry share 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 $409 billion[16] in subsidies in 2010, 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 supply would not only save taxpayers' money, it would also dramatically reduce the need for renewable energy support.

2.4.1 the most effective way to implement the energy [r]evolution: feed-in laws

To plan and invest in energy infrastructure whether for conventional or renewable energy requires secure policy frameworks over decades.

The key requirements are:

a. Long term security for the investment The investor needs to know if the energy policy will remain stable over the entire investment period (until the generator is paid off). Investors want a "good" return of investment and while there is no universal definition of a good return, it depends to a large extent on the inflation rate of the country. Germany, for example, has an average inflation rate of 2% per year and a minimum return of investment expected by the financial sector is 6% to 7%. Achieving 10 to 15% returns is seen as extremely good and everything above 20% is seen as suspicious.

b. Long-term security for market conditions The investor needs to know, if the electricity or heat from the power plant can be sold to the market for a price which guarantees a "good" return of investment (ROI). If the ROI is high, the financial sector will invest, it is low compare to other investments financial institutions will not invest.

c. Transparent Planning Process A transparent planning process is key for project developers, so they can sell the planned project to investors or utilities. The entire licensing process must be clear and transparent.

d. Access to the grid A fair access to the grid is essential for renewable power plants. If there is no grid connection available or if the costs to access the grid are too high the project will not be build. In order to operate a power plant it is essential for investors to know if the asset can reliably deliver and sell electricity to the grid. If a specific power plant (e.g. a wind farm) does not have priority access to the grid , the operator might have to switch the plant off when there is an over supply from other power plants or due to a bottleneck situation in the grid. This arrangement can add high risk to the project financing and it may not be financed or it will attract a "risk-premium" which will lower the ROI.

references
13 'SOLARGENERATION IV', SEPTEMBER 2009.
14 'GLOBAL CONCENTRATED SOLAR POWER OUTLOOK – WHY RENEWABLES ARE HOT!' MAY, 2009.
15 'GLOBAL WIND ENERGY OUTLOOK 2008', OCTOBER 2008.
16 'IEA WORLD ENERGY OUTLOOK 2011', PARIS NOVEMBER 2011, CHAPTER 14, PAGE 507.

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

box 2.2: example of a sustainable feed-in tariff

The German Feed-in Law ("Erneuerbare Energien Gesetz" = EEG) is among the most effective pieces of legislation to phase in renewable energy technologies. Greenpeace supports this law and encourages other countries to implement a similar effective renewable energy law.

Structure of the German renewable energy Act:

a. Definitions & Purpose Chapter 1 of the law provides a general overview about the purpose, the scope of the applications, specific definitions for all used terms in the law as well as the statutory obligations

b. Regulation of all grid related issues Chapter 2 of the law provides the general provisions of grid connection, technical and operational requirements, how to establish and use grid connection and how the renewable electricity purchase, the transmission and distribution of this electricity must be organised.

c. Regulation how for grid expansion and renewable power management in the grid This part of the law regulates the grid capacity expansion and feed-in management, how to organize the compensation for required grid expansion, the feed-in management and a hardship clause.

d. Regulations for all tariff-related subjects This part provides the general provisions regarding tariffs, the payment claims, how to organize direct sale of renewable electricity, how to calculate the tariffs, details about tariffs paid for electricity from several installations, the degression rate for each technology as well as the commencement and duration of tariff payment and setting of payment claims. There are special provisions regarding tariffs for the different fuel sources (hydropower, landfill gas, sewage treatment gas, Mine gas, biomass, geothermal energy,, wind energy – re-powering, offshore wind energy, solar power, rooftop installations for solar radiation.)

e. Equalisation scheme This part defines how to organise the nationwide equalisation scheme for the payment of all feed-in tariffs. The delivery to transmission system operator, tariffs paid by transmission system operator, the equalisation amongst transmission system operators, the delivery to suppliers, subsequent corrections and advance payments

f. Special regulations for energy intensive industries The part defines the special equalisation scheme for electricity-intensive enterprises and rail operators, the basic principle, the list of sectors which are excluded from the payment of feed-in law costs and how to apply for this exclusion.

g. Transparency Regulations This part established a detailed process how to make the entire process transparent and publicly accessible to minimise corruption, false treatments of consumers, or some scale power plant operators. The regulations provides the basic information principles for installation operators, grid system operators, transmission system operators, utility companies, certification, data to be provided to the Federal Network Agency (the governmental control body for all 800 grid operators in Germany), data to be made public, notification regulations, details for billing.

Another subchapter identifies regulations for the guarantee of origin of the renewable electricity feed into the grid and the prohibition of multiple sales.

h. Legal roles and responsibilities This part identifies the legal protection and official procedure for clearing house and consumer protection, temporary legal protection, use of maritime shipping lanes, tasks of the Federal Network Agency Administrative fines provisions and supervision.

i. Governmental procedures to control and review the law on a regular basis Authorisation to issue ordinances, when and how to commission the progress report (published every second year to capture lessons learned and to change regulation which do not work), transitional provisions, authorisation to issue ordinances and transitional provisions.

2.4.2 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 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[26] underscores the same 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 some criteria have emerged as essential for 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.[27] 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, for example, because the support system is more secure and reliable.

box 2.3: experience of feed-in tariffs

- Feed-in tariffs are seen as the best way forward, especially in developing countries. By 2009 this system has created an incentive for 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 renewable energy. They have the lowest investment risk, highest technology diversity, lowest windfall profits for mature technologies and attract a broad spectrum of investors.[29]
- The main argument against them is the increase in electricity prices for households and industry, because 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 boost development of new renewable energies. The extra costs to consumers' electricity bills are an obstacle for countries with low average incomes. In order to enable technology transfer from Annex 1 countries under the Kyoto Protocol to developing countries, a mix of a feed-in law, international finance and emissions trading could establish a locally-based renewable energy infrastructure and industry with help from the wealthier 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, or wind farms in Denmark and Germany, show how economic benefits can flow to the local community. With careful project planning based on good local knowledge and understanding, projects can achieve local involvement and acceptance. When the community identifies the project rather than the project identifying the community, the result is generally faster bottom-up growth of the renewable energy 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.

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

© LANGROCK/ZENIT/GP

2.5 korean energy and climate policy

2.5.1 climate change & CO_2 emission

The CO_2 emissions in South Korea have been growing fast and are expected to grow much faster than the average for the OECD countries. Korea's GHG emissions accounted for 1.7% of the world total in 2008, making it the 10th-largest emitter in the world with annual CO_2 emission of 509,170 (1000 of metric tonnes) according to the US DOE's Carbon Dioxide Information Analysis Centre (CDIAC). Under the International Energy Agency's (IEA) reference scenario, which assumes that the level of growth in carbon emissions continues from the 2002 level, the Republic of Korea would increase its emissions by close to 35 per cent in 2025, compared to less than 15 per cent for the whole of the OECD countries. In the IEA's low emissions scenario, carbon emissions would grow by slightly less than 25 per cent in 2025, compared to 5 per cent for the whole of the OECD countries. And according to OECD (Jones, 2011), on a per capita basis, Korea's emissions rose by 71.6% over the period 1990 to 2005, far outstripping the OECD average of 2.1%. The growth in GHG emissions per capita can be explained by changes in per capita income, energy intensity and GHG emissions per unit of energy. The large increase in GHG emissions per capita was primarily a result of rapid economic growth, which doubled per capita income. Moreover, Korea has become one of the most energy-intensive economies in the OECD area.

Korea which is given a status as a non-Annex I Party to the Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC), announced the mid-term greenhouse gas reduction target at 4% below 2005 levels (30% of the 2020 BAU levels) in 2009. But the plan faced fierce criticism from the concerned group of NGOs and academics that the 4% reduction target is disappointing and does not meet its historical responsibility for climate change and the country's capability for further reduction, while the industrial sector expressed their concern about the possible negative impact on their international competitiveness.

Low-carbon Green-growth The Korean government has created an institutional framework for a great leap forward toward a green economic power. In 2009, Korea enacted a Framework Act on Low Carbon Green Growth, the first law of its kind in the world, and released a National Strategy for Green Growth and Five-Year Plan for Green Growth.In particular, the Framework Act represents a milestone in the national development strategy and the legal foundation of the nation's green growth policies, approaching green growth in a comprehensive and systematic manner.The National Strategy for Green Growth envisages three main objectives and ten policy directions, based on a consensus between social, business, academic and government stakeholders. The three objectives include mitigation of climate change and the strengthening of the country's energy independence, creation of new growth engines, improvement in the quality of people's lives and enhancement of Korea's international standing. Korea government has been using the green growth discourse to justify its nuclear energy program as one of the viable solutions for the climate mitigation misleading the Koreans to believe that nuclear power is a practical alternative to secure energy and resolve global warming problem. Korean is one of the very few countries who announce that they would accelerate efforts in the nuclear industry after the Fukushima disaster. Korea also ranks the lowest among the OECD countries in terms of the renewable energy percentage of the overall energy. Nuclear energy currently produces 40% of all the electricity currently consumed in Korea.

1st National Basic Energy Plan (2008-2030) In 2008, in order to provide a backbone support for its "Low-carbon Green-growth" initiative in the energy sector, Korean government announced the nation's first 20-year long-term energy plan which is a guideline for other energy-related government plans such as the Basic Plan for Long-term electricity supply and demand. According to the plan, the energy intensity will be decreased from 0.341 to 0.185 by 2030, and the NRE (New & Renewable Energy) will be expanded from 2.4% to 11% of total energy supply by 2030, while reducing the fossil energy ratio (based on the primary energy level), including oil, to 61% by 2030 from 83% at present. At the same time Korean government will invest a lot in the expansion of nuclear power energy indicating that nuclear power has far contributed significantly to the stable supply of cheaper electricity, alleviating the national economy's oil dependence and energy import burden, considering that for the past 25 years, the electricity fare stood at a 11.4% increase although consume prices rose as much as 186%, so to respond to high oil prices and greenhouse gas reduction, the reinforced role of nuclear energy is an avoidable choice. The government plans to increase the nuclear power ratio among total generation facilities up to 41% and 59% of total power generation by 2030.

The government is now working on the 2nd NBEP with aim to announce it by the end of 2012.

table 2.1: south korea: energy consumption related key indicators

ENERGY CONSUMPTION	2006	2020	2030	ANNUAL INCREASE (%) 2006 - 2020	2020 - 2030	2006 - 2030
Total energy consumption (M TOE)	233.4	288.0	300.4	1.5	0.4	1.1
Energy consumption per capita (TOE)	4.83	5.84	6.18	1.4	0.6	1.0
Energy intensity (TOE/k$)	0.347	0.233	0.185	-2.8	-2.3	-2.6
PRIMARY ENERGY CONSUMPTION BY SOURCE (k TOE)						
Coal	56,687 (24.3)	66,836 (23.2)	47,237 (15.7)	1.2	-6.4	-0.8
Oil	101,831 (43.6)	104,313 (36.2)	99,138 (33.0)	0.2	-0.5	-0.1
LNG	32,004 (13.7)	34,275 (11.9)	36,169 (12.0)	0.5	0.5	0.5
Hydro	1,306 (0.6)	2,387 (0.8)	2,392 (0.8)	4.4	0.0	2.6
Nuclear	37,187 (15.9)	63,582 (22.1)	83,420 (27.8)	3.9	2.8	3.4
RE	4,358 (1.9)	16,583 (5.8)	32,062 (10.7)	10.0	6.8	8.7
Total	**233,372 (100)**	**287,976 (100)**	**300,417 (100)**	**1.5**	**0.4**	**1.1**
FINAL ENERGY CONSUMPTION BY SOURCE (k TOE)						
Coal	22,660 (13.1)	20,753 (10.1)	8,193 (3.9)	-0.6	-6.9	-4.2
Oil	97,037 (55.9)	102,876 (50.0)	98,650 (47.6)	0.4	-0.4	0.1
City gas	18,379 (10.6)	27,001 (13.1)	29,720 (14.30)	2.8	1.0	2.0
Electricity	29,990 (17.3)	40,567 (19.7)	44,119 (21.3)	2.2	0.8	1.6
Heat energy	1,425 (0.8)	2,673 (1.3)	3,397 (1.6)	4.6	2.4	3.7
RE	4,092 (2.4)	12,014 (5.8)	23,379 (11.3)	8.0	6.9	7.5
Total	**173,584 (100)**	**205,883 (100)**	**207,459 (100)**	**1.2**	**0.1**	**0.7**

2.5.2 renewable energy

The Republic of Korea has daunting energy challenges. Korea is the world's 10th largest energy consumer, with virtually no domestic traditional energy sources of its own. It imports 97% of its energy resources, and is currently the 2nd largest coal importer and 6th largest oil importer in the world. To reduce its heavy energy dependency on foreign fossil-fuels Korea has embarked on a series of plans and initiatives to promote the domestic development and use of new and renewable energies (NRE).[17]

According to the government's 5th Basic Plan for Long-term Electricity Supply and Demand (2010 ~ 2024) announced in 2010, as of Dec. 2009, the total capacity of NRE has reached to 2,750.9 MW, and the government plans to increase the NRE installation to 19,157.4 MW during the period of 2010-2024 including 8,346.1 MW of constructor's intent + 10,811.3 MW of mandatory construction by RPS, so to generate 54,467 GWh from NRE in 2024, accounting 8.9% of total generation.

According to the National Basic Energy Plan (2008-2030), the government plans to decrease the ratio of fossil energies to the 61% level by 2030 from the present 83% while increasing the ratio of new & renewable energies to 11% from 2.4% and that of nuclear energy to 27.8% from 14.9%.

reference

17 ACCORDING TO THE ACT ON THE PROMOTION OF THE DEVELOPMENT, USE AND DIFFUSION OF NEW AND RENEWABLE ENERGY (ENFORCED IN APRIL 12, 2010), KOREAN GOV'T DEFINED THE TERM "NEW ENERGY AND RENEWABLE ENERGY" WHICH FALL UNDER ANY OF THE FOLLOWING ITEMS: SOLAR, BIO, WIND, WATER, FUEL CELLS, IGCC, OCEAN, WASTE, GEOTHERMAL, HYDRO AND SOURCES OF ENERGY PRESCRIBED BY PRESIDENTIAL DECREE OTHER THAN PETRO, COAL, NUCLEAR AND NATURAL GAS.

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

As for new & renewable energies, in particular, the government plans to achieve the supply scale equivalent to the advanced countries by 2030 through continuous expansion of supply volume and support for technology development. By NRE subsector specifically; 1) the generation capacity of photovoltaic power will grow 44 times; 2) wind energy will grow 37 times; 3) bio energy from 19 times; 4) and geothermal energy will grow 51 times.

NRE relies heavily on government policies to make such options economically viable. The Government's principal policy drivers for NRE have used a variety of mechanisms to spur such investments.

table 2.2: south korea: renewable energy expansion plan

RE	EXPANSION	CHANGE (2007-2030)
Solar energy	44-fold	80 -> 3,504 MW
Wind power	37-fold	199 -. 7,301 MW
Bio	19-fold	1,874,000 -> 36,487,000 Gcal
Geothermal	51-fold	110 -> 5,606 Gcal

source
1st National Energy Basic Plan (2008-2030).

Such inducements have come mainly in two forms: 1) incentives such as subsidy, low interest loans, tax reductions/exemption, and FIT to power generation companies using NRE, and 2) Renewable Portfolio Standard (RPS) and other mandates requiring the major power generators to source certain percentages of their overall power generation from New and Renewable Energy. Korea introduced the Feed-in-tariffs in 2002 and the total of 345 MW has been subsidized (as of Dec. 2008) through this mechanism, but in April 2009, Korean authorities abruptly decided to phase-out application of the FIT by 2012, and to implement a new Renewable Portfolio Standard (RPS) that will mandate major power utilities generate certain amount of electricity using NRE. Under this new system, power utilities with a combined generation capacity of 500 MW or more (14 companies are subject to this plan) will be required to produce 4% of energy from renewable sources by 2015, increasing to 10% by 2022. According to the government, eligible power sources and technologies for RPS include Solar PVs, Wind, Hydro, Fuel Cell, Marine Energy, geothermal, wastes and its total mandatory volume is as outlined in the following table.

While supporting development of core source technologies for solar energy, the government plans to create initial markets for domestically developed products in linkage with technology development and the one million green home supply projects.

table 2.3: south korea: annual RPS scheme planned

RPS (%)	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
	2.0	2.5	3.0	3.5	4.0	5.0	6.0	7.0	8.0	9.0	10.0

source
Korea RE white paper 2010.

table 2.4: south korea: potential RE resources
(k TOE)

RE		POTENTIAL RESERVES	PRACTICAL RESERVES	TECHNOLOGICAL RESERVES
Solar	Thermal Photovotaic	11,159,495 (thermal/pv)	3,483,910 (thermal/pv)	870,977 585,315
Wind	On-shore Off-shore wind	121,433 172,781	24,293 60,813	8,097 22,264
Hydro		126,273	65,210	20,867
Bio		141,855	11,656	6,171
Geothermal		2,352,347,459	160,131,880	233,793
Ocean	Tidal Current Wave			2,559 288 3,500
Total		2,364,421,296	163,795,362	1,753,831

source
Korea RE white paper 2010.

table 2.5: south korea: RE supply target

(k TOE)

RE	2008	2010	2015	2020	2030	ANNUAL INCREASE (%) 2008 - 2030
Solar thermal	33 (0.5)	40 (0.5)	63 (0.5)	342 (2.0)	1,882 (5.7)	(20.2)
Photovoltai	59 (0.9)	138 (1.8)	313 (2.7)	552 (3.2)	1,364 (4.1)	(15.3)
Wind	106 (1.7)	220 (2.9)	1,084 (9.2)	2,035 (11.6)	4,155 (12.6)	(18.1)
Bio	518 (8.1)	987 (13.0)	2,210 (18.8)	4,211 (24.0)	10,357 (31.4)	(18.1)
Hydro	946 (14.9)	972 (12.8)	1,071 (9.1)	1,165 (6.6)	1,447 (4.4)	(1.9)
Geothermal	9 (0.1)	43 (0.6)	280 (2.4)	544 (3.1)	1,261 (3.8)	(25.5)
Ocean	0 (0.0)	70 (0.9)	393 (3.3)	907 (5.2)	1,540 (4.7)	(49.6)
Waste	4,668 (73.7)	5,097 (67.4)	6,316 (53.8)	7,764 (44.3)	11,021 (33.4)	(4.0)
Total	**6,360**	**7,566**	**11,731**	**17,520**	**33,027**	**(7.8)**
Primary Energy (M TOE)	247	253	270	287	300	(0.9)
RE share	2.58%	2.98%	4.33%	6.08%	11.0%	

source
Korea RE white paper 2010.

table 2.6: south korea: RE generation

(MWh)

RE	2008	2010	2015	2020	2030
Solar thermal	-	-	15,330	391,890	2,046,139
Photovoltaic	202,443	476,709	961,773	1,424,471	1,971,513
Wind	425,297	880,641	4,336,243	8,138,081	16,619,638
Hydro (small)	289,949	393,836	653,552	913,269	1,926,163
Hydro (large)	3,494,833	3,494,833	3,631,991	3,746,289	3,860,587
Wooden	-	62,306	166,396	1,146,446	2,628,920
Biogas	294	3,449	31,372	64,222	161,129
Geothermal	-	70,080	744,600	1,401,600	2,803,200
LFG	597,460	684,853	903,336	1,121,819	1,340,302
Ocean	876	278,102	1,571,488	3,629,361	6,159,599
Total	5,011,152	6,344,809	13,016,081	21,977,446	39,517,190
Share	1.2%	1.5%	2.9%	4.7%	7.7%

source
Korea RE white paper 2010.

In terms of the RE Investment by Korean government, Korea will increase it from 2 trillion KRW in 2008 to 6.5 trillion KRW by 2030, so the accumulation during the period will reach to 111.4 trillion KRW in 2030, for which 99.9 trillion KRW goes to the distribution (diffusion) while the rest of 11.5 trillion KRW for R&D.

As for the investment in FIT, since the government will implement RPS replacing FIT in 2012 and since the feed-in tariff system scaled up in its final year in 2011 for next 30 years, the investment in FIT will increase until 2020 but will dramatically decline nearing 2030.

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.

table 2.7: south korea: government financial support for RE

(100 million KRW)

ITEM	SUPPORT	RE	2008	2010	2015	2020	2030
	Subsidy	Solar thermal	137	236	1,257	2,746	599
		Photovoltaic	869	1,017	1,945	2,525	608
		Wind	144	993	1,777	1,076	-
		Hydro	107	103	97	62	56
		Bio	78	327	102	420	629
		Geothermal	460	1,412	2,761	2,517	2,246
		Ocean	-	-	-	-	-
		Waste	883	1,614	4,144	4,870	3,131
		Sub-total	2,679	5,703	12,083	14,215	7,270
	FIT		1,171	2,462	3,589	2,607	657
	Loan		2,041	2,718	1,699	1,919	1,723
Diffusion			5,891	10,883	17,371	18,741	9,650
R & D			2,000	3,750	5,625	4,063	2,313
Total			**7,890**	**14,663**	**22,996**	**22,803**	**11,963**

source
Korea RE white paper 2010.

Photovoltaic power Since its very first solar power plant was built in 2004, the total capacity of solar power has reached 414.7 MW in 2009.[18] One of the most critical driving factors for the market development of photovoltaic energy has been the feed-in tariff (FIT), incentive structure to encourage the adoption of NRE, introduced in 2006, but the decision was made in 2008 to reduce the rate by up to 30% as a way of encouraging local production. As with wind, the solar FIT scheme will be replaced in 2012 by RPS, and utility companies will be given a separate solar energy production quota of 120 MW in the first year, gradually increasing to 200 MW in 10 years, after rules are enacted. The government plans to put the Photovoltaic energy in the priority for the RPS and will allot a mandatory annual supply: 263 MW in year 2012; 552 MW in 2013, 867 MW in 2014, 1,209 MW in 2015 and 1,577 MW after 2016. The allotment for photovoltaic is to be concentrated in the initial 5 years (1012-2016) in order to bringing up the industry, afterwards the competition among other renewables is to be encouraged without specific allotment after 2017.

Rates now range from KRW 572 (€0.37)/kWh for systems smaller than 30kW to KRW 509 (€0.33)/kWh for those larger than 1MW capacity. Korea, a leading country in the semi-conductor and displays industry, has technological advantages with the strong support from the government, but it is weak in terms of small size of domestic market and lack of core technologies of PV, and the competition with the cheap Chinese PV products and the burden for the governments to subsidize the industry is threatening the growth.

table 2.8: south korea: annual mandatory PV supply for RPS

(MW)

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
New	263	552	867	1,209	1,577	-	-	-	-	-	-

table 2.9: south korea: annual PV allotment (installation) for RPS

(MW)

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
New	200	220	240	260	280	-	-	-	-	-	-
Cumulative	200	420	660	920	1200	1200	1200	1200	1200	1200	1200

sources for 2.8 & 2.9
Korea PV Industry Association.

reference
18 5TH BASIC PLAN FOR LONG-TERM ELECTRICITY SUPPLY AND DEMAND (2010 ~ 2024).

Wind power Korea's total wind power installed capacity was around 350 MW as of 2009. Korea's unique topography is very mountainous and surrounded by the oceans, providing ample amounts of wind resources. Thus, wind power is seen as perhaps the most economically viable long-term renewable energy that will not have to rely on the government's incentives.

With limited land and the public perception and opposition to the noise problems from wind power sites, Korea's focus on wind-power is rapidly shifting from ground applications to offshore applications. Being a peninsula with a well-established shipbuilding industry base, Korea fully supports the shift, and the local companies are actively working to become leading wind power producers or components suppliers. With lack of core technologies on wind turbines and other components, they try to improve their technology levels mostly through acquiring foreign technologies either through mergers and acquisitions (M&A) or through technology licensing agreement.

Wind is currently supported through a FIT of KRW 107.29 (€0.07)/kWh, however this FIT will be replaced by the RPS from 2012 onwards.

The current installed capacity is around 350 MW (as of Dec. 2009) and it is estimated to have potential reserves of 186.5 TWh per annum for on-shore wind energy while it has 460.5 TWh per annum for off-shore, so total 647 TWh per annum. According to the government, Korea aims to be the world's 3rd largest offshore wind power generator. In 2011, the government announced to launch a large scale offshore wind farm project of the capacity of 2.5 GW by 2019 by installing 500 wind turbines.

Ocean energy With ocean on three sides, Korea has an abundant access to marine energy and is aggressively emphasizing such development through on-going R&D projects and pilot construction projects.

Korea's first tidal current power plant was constructed in Uldolkmok in Jindo-gun on the southwest coast of Korea. The first-phase, test-bed project was completed in May 2009. It has 1 MW capacity, currently world's largest in its kind, which can feed electricity into 430 households. When the final-phase project is completed in 2013 as planned, it will have a combined capacity of 90 MW that can meet electricity need of 46,000 households.

The world's largest tidal power plant is constructed in Sihwa off the west coast of Korea with a total power out capacity of 254 MW. Korean government is very ambitious for the development of tidal power industry, and has plans to build several mega-sized tidal power plants including Saemangum (400 MW), Garorim (520 MW), Chonsuman (720 MW), Gwanghwa (812 MW), Incheonman (1,140MW), all along the west coastline that has the biggest tidal potential among Korea's three coasts. The cost of electricity generation from tidal power is identified as the lowest among the competing NRE, so the government is actively pushing the further development of the industry.

table 2.10: south korea: wind power installed capacity
(kW)

	2005	2006	2007	2008	2009	2010
New	30,664	78,941	18,420	108,020	44,338	30,900
Cumulative	98,726	177,677	196,087	304,107	348,445	379,345

source
Korea Wind Power Industry Association.

image A COW IN FRONT 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.

Bio energy The potential reserve of bioenergy in Korea is estimated to be 11,280,000 TOE per annum while the technological potential is around 2,320,000 TOE / year and most of the bioenergy comes from the solid bio-fuels such as co-digestion of organic wastes, wooden-chip and coal briquette. As of 2008, the bioenergy accounts for 7.3% of total RE with 427,000 TOE.

As to the bio-diesel, on the basis of revised Petroleum Business Law, both BD5 and BD20 have been supplied since July 2006 and it aims to supply 600,000 Kl by 2012.

According to the government plan, the bioenergy will reach to account for 30% of total RE supply by 2030. In order to achieve the goal, given the limited domestic resources, Korea plans to invest more in developing overseas resources and to introduce RFS (Renewable Fuel Standards) along with RPS.

table 2.11: south korea: current bio energy diffusion status

(TOE0)

BIO ENERGY		2005	2006	2007	2008
Biogas	Electricity	-	-	-	723
	Heat	43,782	77,390	81,537	44,663
LPG	Electricity	32,399	38,630	66,069	88,794
	Heat	10,229	15,201	42,469	31,196
Bio-diesel		13,401	53,346	95,663	177,642
Wooden-chip		-	5,505	5,742	13,320
Coal briquette		32,298	34,170	35,267	29,186
Forest waste		49,166	50,238	43,411	41,236

source
Korea RE white paper 2010.

table 2.12: south korea: bio-diesel supply plan

(KI/YEAR, %)

	2006	2007	2008	2009	2010	2011	2012
Target (Kl/year)	100,000	100,000	200,000	300,000	400,000	500,000	600,000
BD ratio (%)	0.5	0.5	1.0	1.5	2.0	2.5	3.0

source
Korea RE white paper 2010.

Green Home project In an effort to encourage NRE deployment, the government has initiated a program called 1 million green homes in 2009 to facilitate installing NRE facilities in residential areas such as private houses, multifamily houses and public rental houses. The government will support a certain portion of total installation cost and will focuses on a variety of resources such as PV, solar thermal, biomass, geo-thermal, and small wind. The aim until 2020 is to create a million homes that use one of these technologies.

table 2.13: south korea: green home project scheme

Country / region	South Korea.
Name of programme	1 Million Green Home Project.
Type of incentive	Subsidy.
Eligible technologies	Solar thermal, PV, geothermal, biomass and small wind.
Applicable sectors	Residential sector (home owners need to be on a residential list).
Amount	930,000 KRW/m2
Maximum incentive	50 % of the investment cost of a solar thermal system.
Requirements for system	Collector certification has to comply with requirements set forth by the government.
Requirements for installation	The installer has to be certified by the Korean Energy Management Corporation (KEMCO).
Finance provider	Korean New and Renewable Energy Center (KNREC).
Total funds	KRW 94.3 billion (USD 72 million) for all five technologies in 2009: KRW 33.3 billion (USD 25 million) for solar thermal, geothermal KRW 59 billion (USD 45 million) for photovoltaic The total budget will be set new each year.
Funding source	Public money.
Effective date	1 January 2009.
Expiration date	2020.

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Korea Wind Energy Industry Association, http://www.kweia.or.kr/
Act on the promotion of the development, use and diffusion of new and renewable energy.

3

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

"smart use, generation and distribution are at the core of the concept."

GREENPEACE INTERNATIONAL
CLIMATE CAMPAIGN

The expert consensus is that this fundamental shift in the way we consume and generate energy must begin immediately and be well underway within the next ten years in order to avert the worst impacts of climate change.[19] The scale of the challenge requires a complete transformation of the way we produce, consume and distribute energy, white maintaining economic growth. Nothing short of such a revolution will enable us to limit global warming to a rise in temperature of lower than 2° Celsius, above which the impacts become devastating. This chapter explains the basic principles and strategic approach of the Energy [R]evolution concept, which is basis for the scenario modelling since the very first Energy [R]evolution scenario published in 2005. However, this concept has been constantly improved as technologies develops and new technical and economical possibilities emerge.

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

3.1 key principles

The Energy Revolution 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 almost 30 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.

   The Energy Revolution scenario has a target to reduce energy related CO_2 emissions to a maximum of 3,5 Gigatonnes (Gt) by 2050 and phase out over 80% of fossil fuels by 2050.

2. **Equity and fair access to energy** 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 Revolution scenario has a target to achieve energy equity as soon as technically possible. By 2050 the average per capita emission should be between 0.5 and 1 tonne 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[20] and.

   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 Revolution.

references
19 IPCC – SPECIAL REPORT RENEWABLES, CHAPTER 1, MAY 2011.
20 REN 21, RENEWABLE ENERGY STATUS REPORT 2012, JUNE 2012.

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.

3.2 the "3 step implementation"

In 2009, 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%. About 81% of primary energy supply today still comes from fossil fuels.[21]

Now is the time 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, South Africa and Brazil, are looking to satisfy the growing energy demand created by their expanding economies.

Within this decade, the power sector will decide how new electricity demand will be met, either by fossil and nuclear fuels or by the efficient use of renewable energy. The Energy Revolution scenario puts forwards a policy and technical model for renewable energy and cogeneration combined with energy efficiency to meet the world's needs.

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.

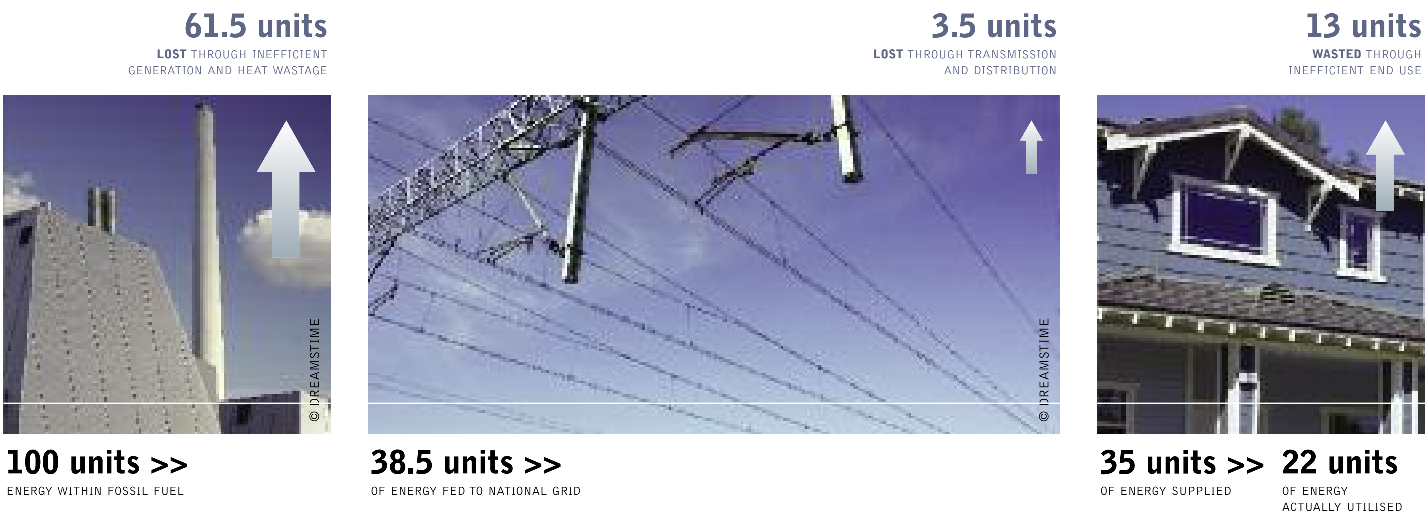
A transition phase is required to build up the necessary infrastructure because it is not possible to switch directly from a large scale fossil and nuclear fuel based energy system to a full renewable energy supply. Whilst remaining firmly committed to the promotion of renewable sources of energy, we appreciate that conventional natural gas, used in appropriately scaled cogeneration plants, is valuable as a transition fuel, and can also 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 valuable means of achieving emissions reductions. The Energy Revolution 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 and Equity The Energy [R]evolution makes an 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.

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 currently use energy in the most inefficient way and can reduce their consumption drastically without the loss of either housing comfort or information and entertainment electronics. The Energy Revolution scenario depends on energy saved in OECD countries to meet 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 towards a fairer worldwide distribution of efficiently-used supply.

A dramatic reduction in primary energy demand compared to the Reference scenario – 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.

figure 3.1: centralised generation systems waste more than two thirds of their original energy input



reference
21 'IEA WORLD ENERGY OUTLOOK 2011, PARIS NOVEMBER 2011.

Step 2: The Renewable Energy Revolution Decentralised energy and large scale renewables In order to achieve higher fuel efficiencies and reduce distribution losses, the Energy Revolution scenario makes extensive use of Decentralised Energy (DE).This terms refers to energy generated at or near the point of use.

Decentralised energy is connected to a local distribution network system, supplying homes and offices, rather than the high voltage transmission system. Because electricity generation is closer to consumers any waste heat from combustion processes can to be piped to nearby buildings, a system known as cogeneration or combined heat and power. This means that for a fuel like gas, all the input energy is used, not just a fraction as with traditional centralised fossil fuel electricity plant.

Decentralised energy 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 for domestic users to provide sustainable, low emission heating. Some consider decentralised energy technologies 'disruptive' because they do not fit the existing electricity market and system. However, with appropriate changes they can grow exponentially with overall benefit and diversification for the energy sector.

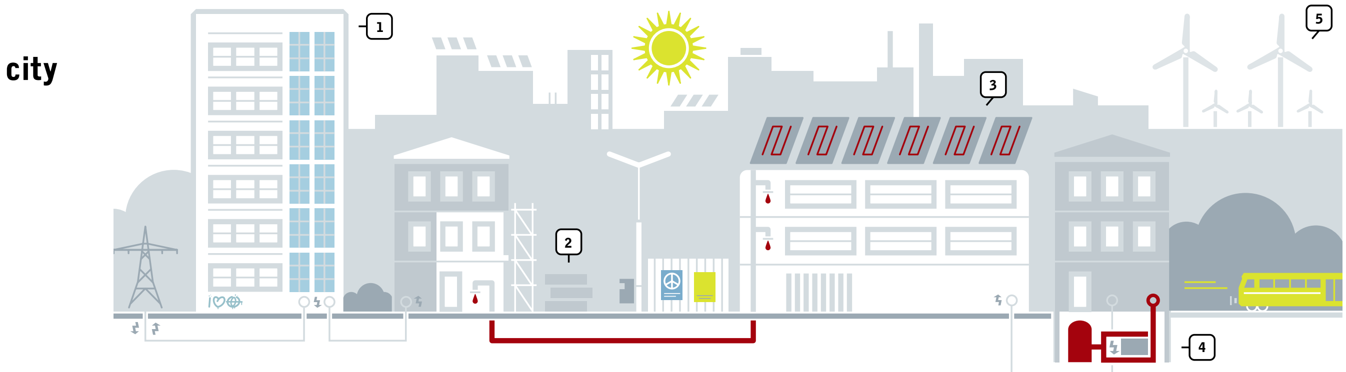
A huge proportion of global energy in 2050 will be produced by decentralised energy sources, although large scale renewable energy supply will still be needed for an energy revolution. Large offshore wind farms and concentrating solar power (CSP) plants in the sunbelt regions of the world will therefore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

Cogeneration (CHP) 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 Revolution 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.

figure 3.2: 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.



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.

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

Renewable heating In the heat supply sector, the contribution of renewable energy 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 and electric cars can seriously enter the transport sector, the other electricity users need to make large efficiency gains. 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 and only for heavy duty vehicles, ships and aviation. In opposite to previous versions of Energy [R]evolution scenarios, biofuels are entirely banned now for the use in private cars.[22] 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, requires a balanced and timely mobilisation of all technologies. 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.

New business model The Energy Revolution 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.

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

The current model is a relatively small number of large power plants that are owned and operated by utilities or their subsidiaries, generating electricity for the population. Under the Energy Revolution scenario, around 60 to 70% of electricity will be made by small but numerous decentralised power plants. Ownership will shift towards more private investors, the manufacturer of renewable energy technologies and EPC

table 3.1: power plant value chain

TASK & MARKET PLAYER	PROJECT DEVELOPMENT	MANUFACTURE OF GEN. EQUIPMENT	INSTALLATION	OWNER OF THE POWER PLANT	OPERATION & MAINTENANCE	FUEL SUPPLY	TRANSMISSION TO THE CUSTOMER
CURRENT SITUATION POWER MARKET	Coal, gas and nuclear power stations are larger than renewables. Average number of power plants needed per 1 GW installed only 1 or 2 projects.			Relatively view power plants owned and sometimes operated by utilities.		A few large multinational oil, gas and coal mining companies dominate: today approx 75-80% of power plants need fuel supply.	Grid operation will move towards state controlled grid companies or communities due to liberalization.
Market player							
Power plant engineering companies	■	■	■				
Utilities				■	■		
Mining companies						■	
Grid operator							■
2020 AND BEYOND POWER MARKET	Renewable power plants are small in capacity, the amount of projects for project development, manufacturers and installation companies per installed 1 GW is bigger by an order of magnitude. In the case of PV it could be up to 500 projects, for onshore wind still 25 to 50 projects.			Many projects will be owned by private households or investment banks in the case of larger projects.		By 2050 almost all power generation technologies - accept biomass - will operate without the need of fuel supply.	Grid operation will move towards state controlled grid companies or communities due to liberalization.
Market player							
Renewable power plant engineering companies	■	■	■		■		
Private & public investors				■			
Grid operator							■

reference
22 SEE CHAPTER 13.

companies (engineering, procurement and construction) away from centralised utilities. In turn, the value chain for power companies will shift towards project development, equipment manufacturing and operation and maintenance.

Simply selling electricity to customers will play a smaller role, as the power companies of the future will deliver a total power plant and the required IT services 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, so mining and other fuel production companies will lose their strategic importance.

The future pattern under the Energy Revolution will see more and more renewable energy companies, such as wind turbine manufacturers 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.

Access to energy in 2012: The International Year of Sustainable Energy for All In December 2010, the United Nations General Assembly declared 2012 the International Year of Sustainable Energy for All, recognizing that "...access to modern affordable energy services in developing countries is essential for the achievement of the internationally agreed development goals, including the Millennium Development Goals, and sustainable development, which would help to reduce poverty and to improve the conditions and standard of living for the majority of the world's population."

box 3.1: about sustainable energy for all

From the IEA Report "Energy for All – financing access for the poor.[23]

The International Energy Agency's World Energy Outlook (WEO) has focused attention on modern energy access for a decade. In a special early excerpt of World Energy Outlook 2011, the IEA tackled the critical issue of financing the delivery of universal access to modern forms of energy. The report recognised that energy access can create a better life for individuals, alleviating poverty and improving health, literacy and equity.

Globally, over 1.3 billion people, more than a quarter of the world's population are without access to electricity and 2.7 billion people are without clean cooking facilities. More than 95% of these people are either in sub-Saharan Africa or developing Asia and 84% are in rural areas. In 2009, the IEA estimates that $9.1 billion was invested globally in extending access to modern energy services and will average $14 billion per year, projected between 2010 and 2030, mostly devoted to new on-grid electricity connections in urban areas. Even with this there will be one billion people without electricity and 2.7 billion people without clean cooking facilities in 2030. To provide universal modern energy access by 2030 the IEA forecasts that annual average investment needs would need to be $48 billion per year, more than five-times the level of 2009, and most in sub-Saharan Africa.

The IEA puts forwards five actions to achieve universal, modern energy access:

1. Adopt a clear and consistent statement that modern energy access is a political priority and that policies and funding will be reoriented accordingly. National governments need to adopt a specific energy access target, allocate funds and define their delivery strategy.
2. Mobilise additional investment in universal access, above the $14 billion per year assumed in our central scenario, of $34 billion per year - equivalent to around 3% of global investment in energy infrastructure over the period to 2030. All sources and forms of investment have their part to play, reflecting the varying risks and returns of particular solutions.
3. Overcome the significant banners to large growth in private sector investment. National governments need to adopt strong governance and regulatory frameworks and invest in internal capacity building. The public sector, including multilateral and bilateral institutions, needs to use its tools to leverage greater private sector investment where the business case is marginal and encourage the development of repeatable business models. When used, public subsidies must be well targeted to reach the poorest.
4. Concentrate a large part of multilateral and bilateral direct funding on those difficult areas of access which do not initially offer an adequate commercial return. Provision of end-user finance is required to overcome the barrier of the initial capitals. Local banks and microfinance arrangements can support the creation of local networks and the necessary capacity in energy sector activity.
5. Collection of robust, regular and comprehensive data to quantify the outstanding challenge and monitor progress towards its elimination. International concern about the issue of energy access is growing.

Discussions at the Energy for All Conference in Oslo, Norway (October 2011) and the COP17 in Durban, South Africa (December 2011) have established the link between energy access, climate change and development which can now be addressed at the United Nations Conference on Sustainable Development (Rio+20) in Rio de Janeiro, Brazil in June 2012. That conference will be the occasion for commitments to specific action to achieve sustainable development, including universal energy access, since as currently the United Nations Millennium Development Goals do not include specific targets in relation to access to electricity or to clean cooking facilities.

reference
23 SPECIAL EXCERPT OF THE WORLD ENERGY OUTLOOK 2011.

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

The General Assembly's Resolution 65/151 called on UN Secretary-General Ban Ki-Moon to organize and coordinate activities during the Year in order to "increase awareness of the importance of addressing energy issues", including access to and sustainability of affordable energy and energy efficiency at local, national, regional and international levels.

In response, the new global initiative, Sustainable Energy for All, launched at the General Assembly in September 2011, along with a High Level Group, is designed to mobilize action from governments, the private sector and civil society globally. The initiative has three inter-linked objectives: universal access to modern energy services, improved rates of energy efficiency, and expanded use of renewable energy sources.

The role of sustainable, clean renewable energy To achieve the dramatic emissions cuts needed to avoid climate change, around 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 Revolution 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, providing 'baseload' power. Until now, renewable energy has been seen as an additional slice of the energy mix and had had adapt to the grid's operating conditions. If the Energy Revolution scenario is to be realised, this will have to change.

Because renewable energy relies mostly on natural resources, which are not available at all times, some critics say this makes it unsuitable for large portions of energy demand. Existing practice in a number of countries has already shown that this is false.

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 current and emerging 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'.[24] Further adaptations to how the grid network operates will allow integration of even larger quantities of renewable capacity.

Changes to the grid required to support decentralised energy Most grids around the world have large power plants in the middle connected by high voltage alternating current (AC) power lines and smaller distribution network carries power to final consumers. The centralised grid model was designed and planned up to 60 years ago, and brought great benefit to cities and rural areas. However the system is very wasteful, with much energy lost in transition. A system based on renewable energy, requiring lots of smaller generators, some with variable amounts of power output will need a new architecture.

The overall concept of a smart grid is one that balances fluctuations in energy demand and supply to share out power effectively among users. New measures to manage demand, forecasting the weather for storage needs, plus advanced communication and control technologies will help deliver electricity effectively.

Technological opportunities Changes to the power system by 2050 will create huge business opportunities for the information, communication and technology (ICT) sector. A smart grid has power supplied from a diverse range of sources and places and it relies on the gathering and analysis of a lot of data. Smart grids require software, hardware and data networks capable of delivering data quickly, and of responding to the information that they contain. Several important ICT players are racing to smarten up energy grids across the globe and hundreds of companies could be involved with smart grids.

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.

3.3 the new electricity grid

All over the developed world, the grids were built with large fossil fuel 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.

In the future power generators will be smaller and distributed throughout the grid, which 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 the large generators of the future are massive wind farms already being built in Europe's North Sea and plans for large areas of concentrating solar mirrors to generate energy in Southern Europe or Northern Africa.

The challenge ahead will require 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 1).

reference

24 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.

box 3.2: definitions and technical terms

The electricity 'grid' is the collective name for all the cables, transformers and infrastructure that transport electricity from power plants to the end users.

Micro grids supply local power needs. Monitoring and control infrastructure are embedded inside distribution networks and use local energy generation resources. An example microgrid would be a combination of solar panels, micro turbines, fuel cells, energy efficiency and information/communication technology to manage the load, for example on an island or small rural town.

Smart grids balance demand out over a region. A 'smart' electricity grid connects decentralised renewable energy sources and cogeneration and distributes power highly efficiently. Advanced types of control and management technologies for the electricity grid can also make it run more efficiently overall. For example, smart electricity meters show real-time use and costs, allowing big energy users to switch off or down on a signal from the grid operator, and avoid high power prices.

Super grids transport large energy loads between regions. This refers to interconnection - typically based on HVDC technology - between countries or areas with large supply and large demand. An example would be the interconnection of all the large renewable based power plants in the North Sea or a connection between Southern Europe and Africa where renewable energy could be exported to bigger cities and towns, from places with large locally available resources.

Baseload is the concept that there must be a minimum, uninterruptible supply of power to the grid at all times, traditionally provided by coal or nuclear power. The Energy [R]evolution challenges this, and instead relies on a variety of 'flexible' energy sources combined over a large area to meet demand. Currently, 'baseload' is part of the business model for nuclear and coal power plants, where the operator can produce electricity around the clock whether or not it is actually needed.

Constrained power refers to when there is a local oversupply of free wind and solar power which has to be shut down, either because it cannot be transferred to other locations (bottlenecks) or because it is competing with inflexible nuclear or coal power that has been given priority access to the grid. Constrained power is also available for storage once the technology is available.

Variable power is electricity produced by wind or solar power depending on the weather. Some technologies can make variable power dispatchable, eg by adding heat storage to concentrated solar power.

Dispatchable is a type of power that can be stored and 'dispatched' when needed to areas of high demand, e.g. gas-fired power plants or hydro power plants.

Interconnector is a transmission line that connects different parts of the electricity grid.Load curve is the typical pattern of electricity through the day, which has a predictable peak and trough that can be anticipated from outside temperatures and historical data.

Node is a point of connection in the electricity grid between regions or countries, where there can be local supply feeding into the grid as well.

3.3.1 hybrid systems

While grid in the developed world supply power to nearly 100% of the population, many rural areas in the developing world rely on unreliable grids or polluting electricity, for example from stand-alone diesel generators. This is also very expensive for small communities.

The standard approach of extending the grid used in developed countries is often not economic in rural areas of developing countries where potential electricity is low and there are long distances to existing grid.

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's funding model, the Feed-in Tariff Support Mechanism, discussed in Chapter 2 allows project to be bundled together so the financial package is 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. In terms of project planning, it is essential that the communities themselves are directly involved in the process.

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


© GP/MARKEL REDONDO

3.3.2 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 concept of baseload power towards a mix of flexible and dispatch able renewable power plants. 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.

What is a smart grid? 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 consist 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 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 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 requires a completely new power system architecture, which will need substantial amounts of further work to fully emerge.[25] Figure 1 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. Some features of smart grids could be:

Managing level and timing of demand for electricity. Changes to pricing schemes can give consumers financial incentives to reduce or shut off their supply at periods of peak consumption, as system that 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.

Advances in communications technology. In Italy, for example, 30 million 'smart meters; 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.

Creating Virtual Power Plants (VPP). Virtual power plants interconnect 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.[26] 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 monitors (and anticipates through weather forecasts) when the wind turbines and solar modules will be generating electricity. Biogas and pumped storage units are used to make up the difference, either delivering electricity as needed in order to balance short term fluctuations or temporarily storing it.[27] Together the combination ensures sufficient electricity supply to cover demand.

Electricity storage options. Pumped storage is the most established technology for storing energy from a type of hydroelectric power station . 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.

references

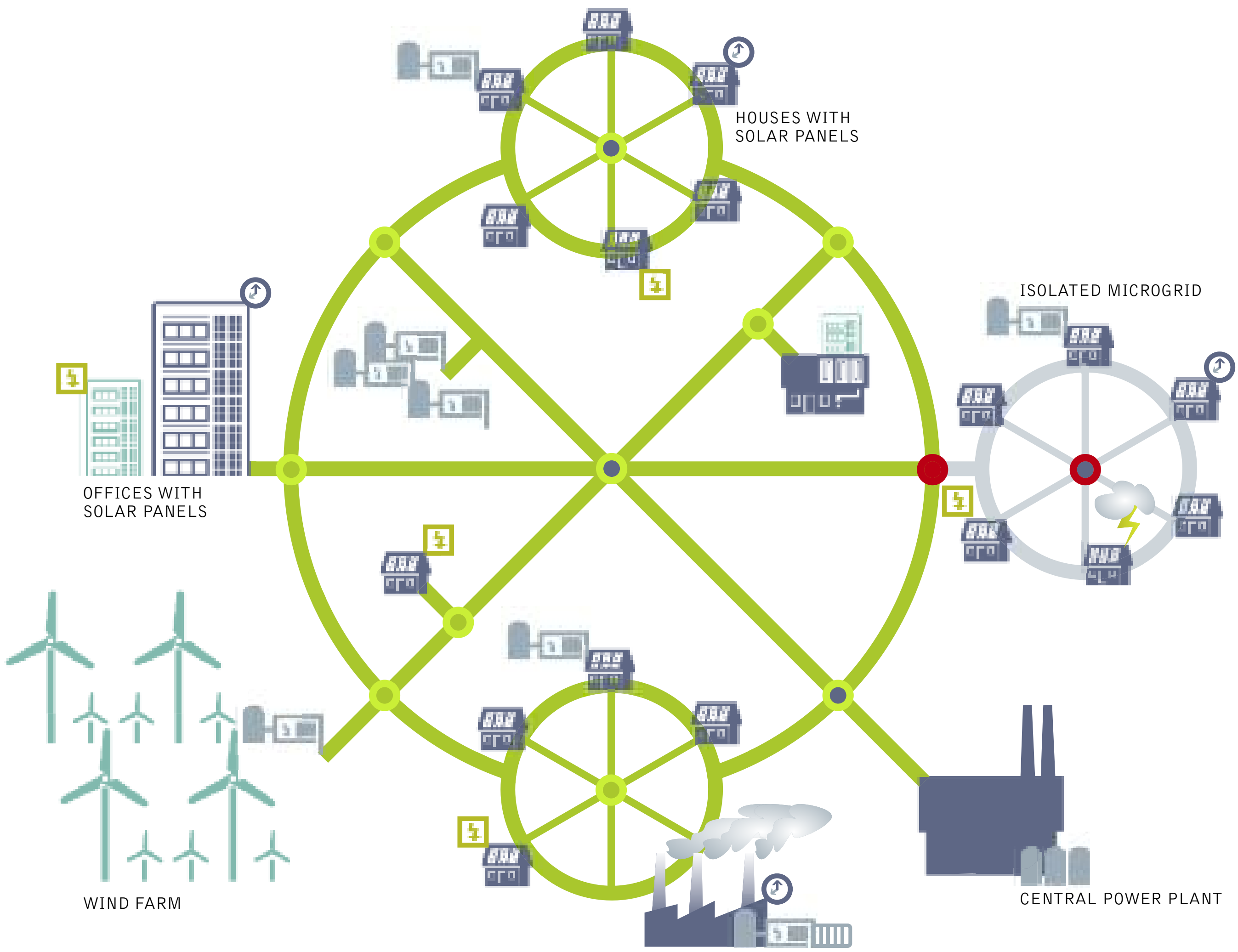
25 SEE ALSO ECOGRID PHASE 1 SUMMARY REPORT, AVAILABLE AT: HTTP://WWW.ENERGINET.DK/NR/RDONLYRES/8B1A4A06-CBA3-41DA-9402-B56C2C288FB0/0/ECOGRIDDK_PHASE1_SUMMARYREPORT.PDF.

26 SEE ALSO HTTP://WWW.KOMBIKRAFTWERK.DE/INDEX.PHP?ID=27.

27 SEE ALSO HTTP://WWW.SOLARSERVER.DE/SOLARMAGAZIN/ANLAGEJANUAR2008_E.HTML.

figure 3.3: 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 GREENPEACE OPENS A SOLAR ENERGY WORKSHOP IN BOMA. A MOBILE PHONE GETS CHARGED BY A SOLAR ENERGY POWERED CHARGER.

In 2007 the European Union had 38 GW of pumped storage capacity, representing 5% of total electrical capacity.

Vehicle-to-Grid. 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 Revolution 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.

3.3.3 the super grid

Greenpeace simulation studies Renewables 24/7 (2010) and Battle of the Grids (2011) have shown that extreme situations with low solar radiation and little wind in many parts of Europe are not frequent, but they can occur. 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.

The Energy [R]evolution scenario assumes 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.[28]

3.3.4 baseload blocks progress

Generally, coal and nuclear plants run as so-called base load, meaning they work most of the time at maximum capacity regardless of how much electricity consumers need. When demand is low the power is wasted. When demand is high additional gas is needed as a backup.

However, coal and nuclear cannot be turned down on windy days so wind turbines will get switched off to prevent overloading the system.

The recent global economic crisis triggered drop in energy demand and revealed system conflict between inflexible base load power, especially nuclear, and variable renewable sources, especially wind power, with wind operators told to shut off their generators. In Northern Spain and Germany, this uncomfortable mix is already exposing the limits of the grid capacity. If Europe continues to support nuclear and coal power alongside a growth in renewables, clashes will occur more and more, creating a bloated, inefficient grid.

Despite the disadvantages stacked against renewable energy it has begun to challenge the profitability of older plants. After construction costs, a wind turbine is generating electricity almost for free and without burning any fuel. Meanwhile, coal and nuclear plants use expensive and highly polluting fuels. Even where nuclear plants are kept running and wind turbines are switched off, conventional energy providers are concerned. Like any commodity, oversupply reduces price across the market. In energy markets, this affects nuclear and coal too. We can expect more intense conflicts over access to the grids over the coming years.

box 3.3: do we need baseload power plants?[29]

Power from some renewable plants, such as wind and solar, varies during the day and week. Some see this as an insurmountable problem, because up until now we have relied on coal or nuclear to provide a fixed amount of power at all times. In current policy-making there is a struggle to determine which type of infrastructure or management we choose and which energy mix to favour as we move away from a polluting, carbon intensive energy system. Some important facts include:

- electricity demand fluctuates in a predictable way.
- smart management can work with big electricity users, so their peak demand moves to a different part of the day, evening out the load on the overall system.
- electricity from renewable sources can be stored and 'dispatched' to where it is needed in a number of ways, using advanced grid technologies.

Wind-rich countries in Europe are already experiencing conflict between renewable and conventional power. In Spain, where a lot of wind and solar is now connected to the grid, gas power is stepping in to bridge the gap between demand and supply. This is because gas plants can be switched off or run at reduced power, for example when there is low electricity demand or high wind production. As we move to a mostly renewable electricity sector, gas plants will be needed as backup for times of high demand and low renewable production. Effectively, a kWh from a wind turbine effectively displaces a kWh from a gas plant, avoiding carbon dioxide emissions. Renewable electricity sources such as thermal solar plants (CSP), geothermal, hydro, biomass and biogas can gradually phase out the need for natural gas. (See Case Studies for more). The gas plants and pipelines would then progressively be converted for transporting biogas.

references
28 GREENPEACE REPORT, 'NORTH SEA ELECTRICITY GRID [R]EVOLUTION', SEPTEMBER 2008.
29 BATTLE OF THE GRIDS, GREENPEACE INTERNATIONAL, FEBRUARY 2011.

figure 3.4: a typical load curve throughout europe, shows electricity use peaking and falling on a daily basis

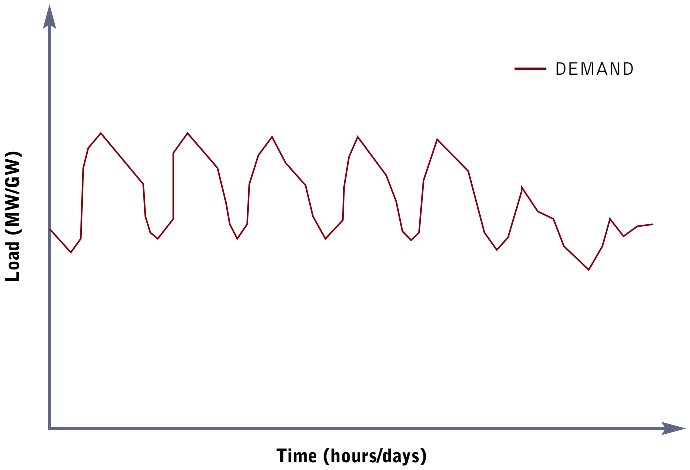
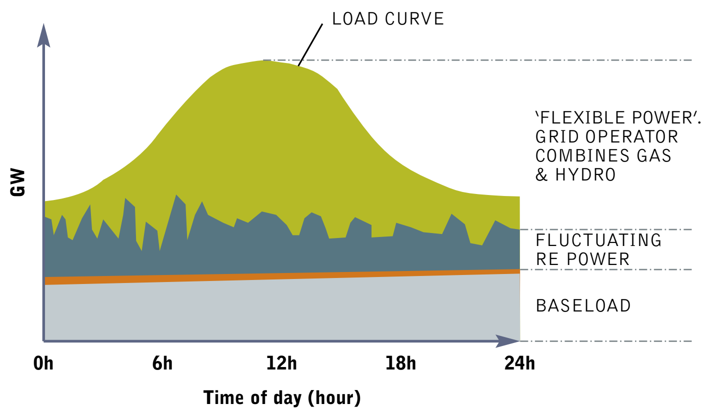


figure 3.6: the evolving approach to grids

Current supply system

- Low shares of fluctuating renewable energy
- The 'base load' power is a solid bar at the bottom of the graph.
- Renewable energy forms a 'variable' layer because sun and wind levels changes throughout the day.
- Gas and hydro power which can be switched on and off in response to demand. This is sustainable using weather forecasting and clever grid management.
- With this arrangement there is room for about 25 percent variable renewable energy.

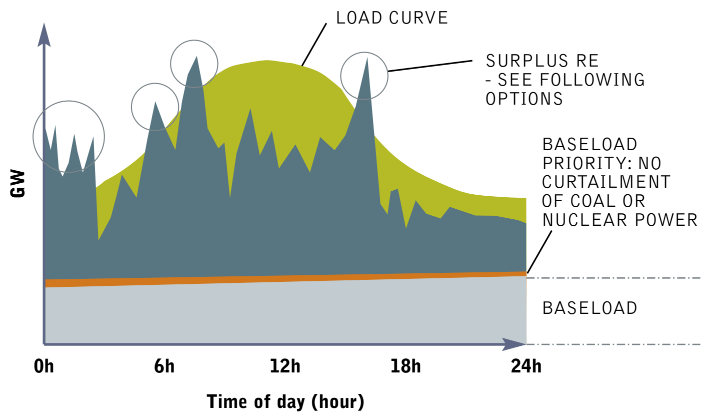
To combat climate change much more than 25 percent renewable electricity is needed.



Supply system with more than 25 percent fluctuating renewable energy > base load priority

- This approach adds renewable energy but gives priority to base load.
- As renewable energy supplies grow they will exceed the demand at some times of the day, creating surplus power.
- To a point, this can be overcome by storing power, moving power between areas, shifting demand during the day or shutting down the renewable generators at peak times.

Does not work when renewables exceed 50 percent of the mix, and can not provide renewable energy as 90- 100% of the mix.



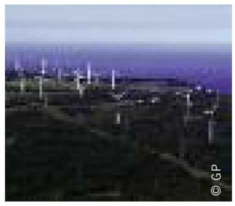


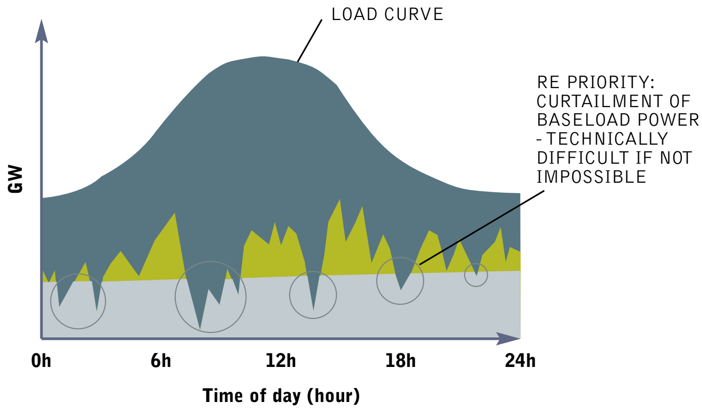
image LE NORDAIS WINDMILL PARK, ONE OF THE MOST IMPORTANT IN AMERICA, LOCATED ON THE GASPÈ PENINSULA IN CAP-CHAT, QUEBEC, CANADA.

figure 3.6: the evolving approach to grids *continued*

Supply system with more than 25 percent fluctuating renewable energy – renewable energy priority

- This approach adds renewables but gives priority to clean energy.
- If renewable energy is given priority to the grid, it "cuts into" the base load power.
- Theoretically, nuclear and coal need to run at reduced capacity or be entirely turned off in peak supply times (very sunny or windy).
- There are technical and safety limitations to the speed, scale and frequency of changes in power output for nuclear and coal-CCS plants.

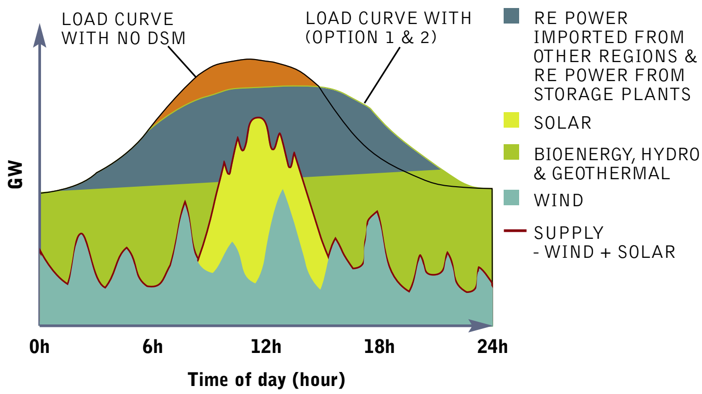
Technically difficult, not a solution.



The solution: an optimised system with over 90% renewable energy supply

- A fully optimised grid, where 100 percent renewables operate with storage, transmission of electricity to other regions, demand management and curtailment only when required.
- Demand management effectively moves the highest peak and 'flattens out' the curve of electricity use over a day.

Works!



One of the key conclusions from Greenpeace research is that in the coming decades, traditional power plants will have less and less space to run in baseload mode. With increasing penetration of variable generation from wind and photovoltaic in the electricity grid, the remaining part of the system will have to run in more 'load following' mode, filling the immediate gap between demand and production. This means the economics of base load plants like nuclear and coal will change fundamentally as more variable generation is introduced to the electricity grid.

4

"investments in renewables are investments in the future."

GREENPEACE INTERNATIONAL
CLIMATE CAMPAIGN

image BIOGAS FACILITY "SCHRADEN BIOGAS" IN GROEDEN NEAR DRESDEN, GERMANY.

image GEOTHERMAL ACTIVITY NEAR HOLSSELSNALAR CLOSE TO REYKJAVIK, ICELAND.

4.1 renewable energy project planning basics

The renewable energy market works significantly different than the coal, gas or nuclear power market. The table below provides an overview of the 10 steps from "field to an operating power plant" for renewable energy projects in the current market situation.

Those steps are similar same for each RE technology, however step 3 and 4 are especially important for wind and solar projects. In developing countries the government and the mostly state owned utilities might directly or indirectly take responsibilities of the project developers. The project developer might also work as a subdivision of a state owned utility.

table 4.1: how does the current RE market work in practice?

STEP	WHAT WILL BE DONE?	WHO?	NEEDED INFORMATION / POLICY AND/OR INVESTMENT FRAMEWORK
Step 1: Site identification	Identify the best locations for RE generators e.g. wind turbines and pay special attention to technical and commercial data, conservation issues and any concerns that local communities may have.	P	Resource analysis to identify possible sites Policy stability in order to make sure that the policy is still in place once Step 10 has been reached. Without a certainty that the produced RE electricity can be feed entirely into the grid to a reliable tariff, the entire process will not start.
Step 2: Securing land under civil law	Secure suitable locations through purchase and lease agreements with land owners.	P	Transparent Planning, efficient authorisation and permitting.
Step 3: Determining site specific potential	Site specific resource analysis (e.g. wind measurement on hub height) from independent experts. This will NOT be done by the project developer as (wind) data from independent experts is a requirement for risk assessments by investors.	P + M	See above.
Step 4: Technical planning/ micrositing	Specialists develop the optimum wind farm configuration or solar panel sites etc, taking a wide range of parameters into consideration in order to achieve the best performance.	P	See above.
Step 5: Permit process	Organise all necessary surveys, put together the required documentation and follow the whole permit process.	P	Transparent Planning, efficient authorisation and permitting.
Step 6: Grid connection planning	Electrical engineers work with grid operators to develop the optimum grid connection concept.	P + U	Priority access to the grid. Certainty that the entire amount of electricity produced can be feed into the grid.
Step 7: Financing	Once the entire RE project design is ready and the estimated annual output (in kWh/a) has been calculated, all permits are processed and the total finance concept (incl. total investment and profit estimation) has been developed, the project developer will contact financial institutions to either apply for a loan and/or sell the entire project.	P + I	Long term power purchase contract. Prior and mandatory access to the grid. Site specific analysis (possible annual output).
Step 8: Construction	Civil engineers organise the entire construction phase. This can be done by the project developer or another. EPC (Engineering, procurement & construction) company – with the financial support from the investor.	P + I	Signed contracts with grid operator. Signed contract with investors.
Step 9: Start of operation	Electrical engineers make sure that the RE power plant will be connected to the power grid.	P + U	Prior access to the grid (to avoid curtailment).
Step 10: Business and operations management	Optimum technical and commercial operation of RE power plants farms throughout their entire operating life – for the owner (e.g. a bank).	P + U + I	Good technology & knowledge (A cost-saving approach and "copy + paste engineering" will be more expensive in the long-term).

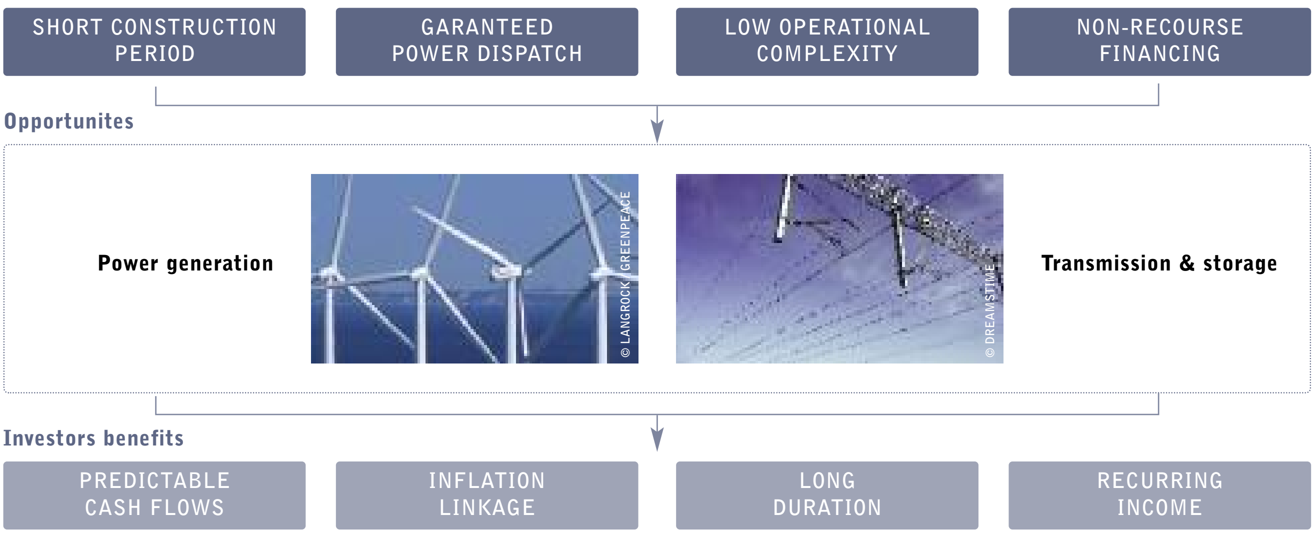
P = Project developer, **M** = Meteorological Experts, **I** = Investor, **U** = utility.

4.2 renewable energy financing basics

The Swiss RE Private Equity Partners have provide an introduction to renewable energy infrastructure investing (September 2011) which describes what makes renewable energy projects different from fossil-fuel based energy assets from a finance perspective:

- Renewable energy projects have short construction period compared to conventional energy generation and other infrastructure assets. Renewable projects have limited ramp-up periods, and construction periods of one to three years, compared to 10 years to build while large conventional power plants.
- In several countries, renewable energy producers have been granted priority of dispatch. Where in place, grid operators are usually obliged to connect renewable power plants to their grid and for retailers or other authorised entities to purchase all renewable electricity produced.
- Renewable projects present relatively low operational complexity compared to other energy generation assets or other infrastructure asset classes. Onshore wind and solar PV projects in particular have well established operational track records. This is obviously less the case for biomass or offshore wind plants.
- Renewable projects are typically have non-recourse financing, through a mix of debt and equity. In contrast to traditional corporate lending, project finance relies on future cash flows for interest and debt repayment, rather than the asset value or the historical financial performance of a company. Project finance debt typically covers 70–90% of the cost of a project, is non-recourse to the investors, and ideally matches the duration of the underlying contractual agreements.
- Renewable power typically has predictable cash flows and they they are not subject to fuel price volatility because the primary energy resource is generally freely available. Contractually guaranteed tariffs, as well as moderate costs of erecting, operating and maintaining renewable generation facilities, allow for high profit margins and predictable cash flows.
- Renewable electricity remuneration mechanisms often include some kind of inflation indexation, although incentive schemes may vary on a case-by-case basis. For example, several tariffs in the EU are indexed to consumer price indices and adjusted on an annual basis (e.g. Spain, Italy). In projects where specific inflation protection is not provided (e.g. Germany), the regulatory framework allows selling power on the spot market, should the power price be higher than the guaranteed tariff.
- Renewable power plants have expected long useful lives (over 20 years). Transmission lines usually have economic lives of over 40 years. Renewable assets are typically underpinned by long-term contracts with utilities and benefit from governmental support and manufacturer warranties.
- Renewable energy projects deliver attractive and stable sources of income, only loosely linked to the economic cycle. Project owners do not have to manage fuel cost volatility and projects generate high operating margins with relatively secure revenues and generally limited market risk.
- The widespread development of renewable power generation will require significant investments in the electricity network. AS discussed in Chapter 3 future networks (smart grids) will have to integrate an ever-increasing, decentralised, fluctuating supply of renewable energy. Furthermore, suppliers and/or distribution companies will be expected to deliver a sophisticated range of services by embedding digital grid devices into power networks.

figure 4.1: return characteristics of renewable energies



source
SWISS RE PRIVATE EQUITY PARTNERS.

image A LARGE SOLAR SYSTEM OF 63M² 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.

Risk assessment and allocation is at the centre of project finance. Accordingly, project structuring and expected return are directly related to the risk profile of the project. The four main risk factors to consider when investing in renewable energy assets are:

- **Regulatory risks** refer to adverse changes in laws and regulations, unfavourable tariff setting and change or breach of contracts. As long as renewable energy relies on government policy dependent tariff schemes, it will remain vulnerable to changes in regulation. However a diversified investment across regulatory jurisdictions, geographies, and technologies can help mitigate those risks.
- **Construction risks** relate to the delayed or costly delivery of an asset, the default of a contracting party, or an engineering/design failure. Construction risks are less prevalent for renewable energy projects because they have relatively simple design, however, construction risks can be mitigated by selecting high-quality and experienced turnkey partners, using proven technologies and established equipment suppliers as well as agreeing on retentions and construction guarantees.
- **Financing risks** refer to the inadequate use of debt in the financial structure of an asset. This comprises the abusive use of leverage, the exposure to interest rate volatility as well as the need to refinance at less favourable terms.
- **Operational risks** include equipment failure, counterparty default and reduced availability of the primary energy source (e.g. wind, heat, radiation). For renewable assets a lower than forecasted resource availability will result in lower revenues and profitability so this risk can damage the business case. For instance, abnormal wind regimes in Northern Europe over the last few years have resulted in some cases in breach of coverage ratios and in the inability of some projects to pay dividends to shareholders.

figure 4.2: overview risk factors for renewable energy projects

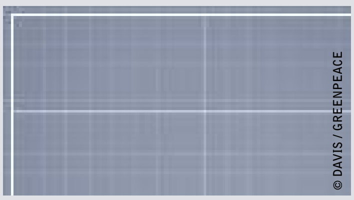
REGULATORY RISKS	CONSTRUCTION RISKS
FINANCING RISKS	OPERATIONAL RISKS

source
SWISS RE PRIVATE EQUITY PARTNERS.

figure 4.3: investment stages of renewable energy projects

RISKS
Higher → Lower

Stage

DEVELOPMENT	CONSTRUCTION	OPERATIONS
 © DAVIS / GREENPEACE	 © DAVIS / GREENPEACE	 © LANGROCK / GREENPEACE
• Site identification • Approval & permitting process • Land procurement • Technical planning	• Financing close • Equipment procurement • Engineering • Construction • Commissioning	• Operations • Maintenance • Refinancing • Refurbishment/Repowering

Strategy

EARLY-STAGE GREENFIELD	LATE-STAGE GREENFIELD	BROWNFIELD

source
SWISS RE PRIVATE EQUITY PARTNERS.

4.2.1 overcoming barriers to finance and investment for renewable energy

table 4.2: categorisation of barriers to renewable energy investment

CATEGORY	SUB-CATEGORY	EXAMPLE BARRIERS
Barriers to finance	Cost barriers	Costs of renewable energy to generate Market failures (e.g. No carbon price) Energy prices Technical barriers Competing technologies (Gas, nuclear, CCS and coal)
	Insufficient information and experience	Overrated risks Lack of experienced investors Lack of experienced project developers Weak finance sectors in some countries
	Financial structure	Up-front investment cost Costs of debt and equity Leverage Risk levels and finance horizon Equity/credit/bond options Security for investment
	Project and industry scale	Relative small industry scale Smaller project scale
	Investor confidence	Confidence in long term policy Confidence in short term policy Confidence in the renewable energy market
Other investment barriers	Government RE policy and law	Feed-in tariffs Renewable energy targets Framework law stability Local content rules
	System integration and infrastructure	Access to grid Energy infrastructure Overall national infrastructure quality Energy market Contracts between generators and users
	Lock in of existing technologies	Subsidies to other technologies Grid lock-in Skills lock-in Lobbying power
	Permitting and planning regulation	Favourability Transparency Public support
	Government economic position and policy	Monetary policy e.g. interest rates Fiscal policy e.g. stimulus and austerity Currency risks Tariffs in international trade
	Skilled human resources	Lack of training courses
	National governance and legal system	Political stability Corruption Robustness of legal system Litigation risks Intellectual property rights Institutional awareness

Despite the relatively strong growth in renewable energies in some countries, there are still many barriers which hinder the rapid uptake of renewable energy needed to achieve the scale of development required. The key barriers to renewable energy investment identified by Greenpeace through a literature review[30] and interviews with renewable energy sector financiers and developers are shown in figure 1.

A number of globally relevant barriers to RE investment can be identified. The broad categories of barriers were present in many countires, however the nature of the barriers differs significantly. Local factors in political and policy support, grid infrastructure, electricity markets and planning regulations and are very important.

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.

Confidence in policy is a crucial barrier and is potentially more important in holding back investment in some regions than an actual absence of policy support mechanisms. In the short term investors aren't confident rules will remain unaltered and in the long term aren't confident medium and long term goals renewable energy goals will be met, let alone increased.

Policy barriers are driving up the cost of finance for RE with investors cautious about taking on these risks. Difficulties in accessing finance at a reasonable cost is a barrier to RE project developers. Factors contributing to this include a lack of information and experience among investors and project developers, involvement of smaller companies and projects and a high proportion of up-front costs.

Grid access and grid infrastructure is an important barrier with RE developers uncertainty they will be able to sell all the electricity they generate in many countries.

Utilities, both state owned and private, are playing a significant blocking role through their market power and political power, maintaining favourable grids, electricity markets for centralised coal and nuclear power and lobbying against RE and climate laws.

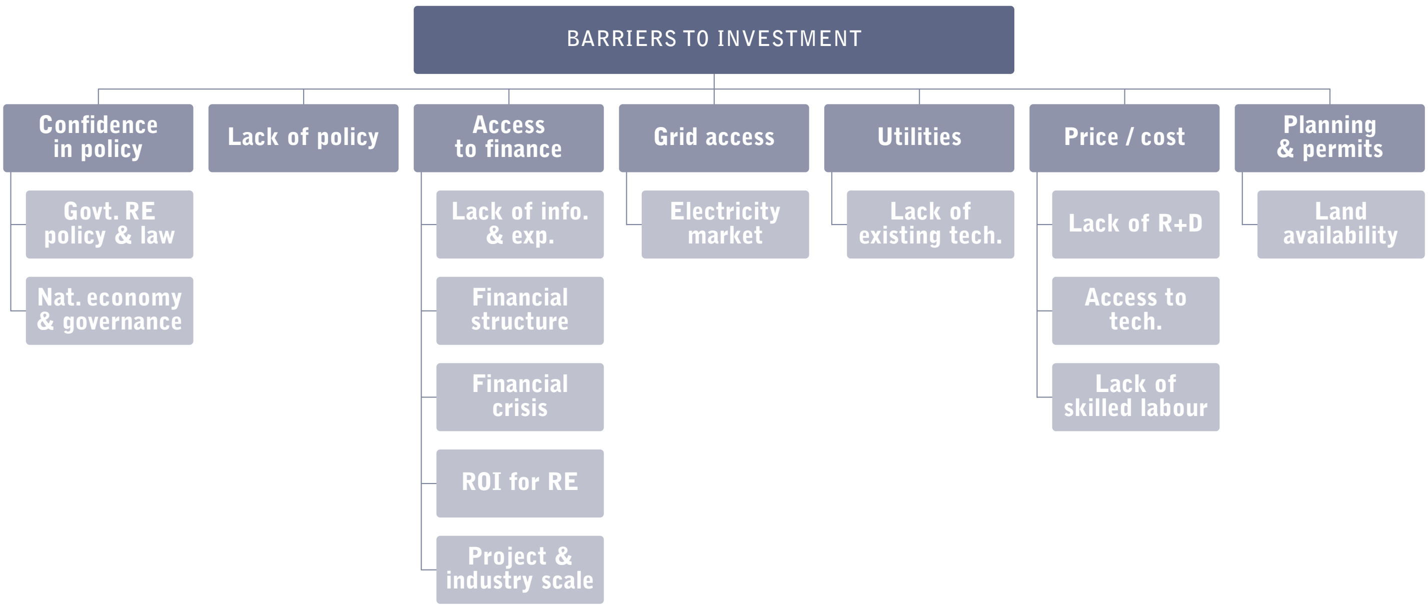
The sometimes higher cost of RE relative to competitors is an overarching barrier, though one many are confident in overcoming in the coming decades. Cost is identified as the most important barrier in the Special Report on Renewable Energy Sources and Climate Change Mitigation (SRREN).[31] While this cost barrier exists, renewable energy will rely on policy intervention by governments in order to be competitive, which creates additional risks for investors. It is important to note though, that in some regions of the world specific renewable technologies are broadly competitive with current market energy prices (e.g. onshore wind in Europe and solar hot water heaters in China).

Concerns over planning and permit issues are significant though vary significantly in their strength and nature.

How to overcome investment barriers for renewable energy:

- Additional and improved RE policy support mechanisms are needed in all countries and regions
- Building confidence in existing policy mechanisms may be as important as increasing their strength, particularly in the short run.
- Improved policy mechanisms can also lower the cost of finance, particularly by providing longer durations of revenue support and increasing revenue certainty.[32]
- Access to finance can be increased by greater involvement of governments and development banks in programs like loan guarantees and green bonds as well as more active private investors.
- Grid access and infrastructure needs to be improved through investment in smart, decentralised grids.
- Lowering the cost of RE technologies directly will require industry development and boosted R&D.
- A smoother pathway for RE through planning and permit issues needs to be established at the local level.

figure 4.4: key barriers to RE investment



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scenarios for a future energy supply

SCENARIO BACKGROUND

PRICE PROJECTIONS FOR FOSSIL FUELS AND BIOMASS

COST OF CO_2 EMISSIONS

COST PROJECTIONS FOR EFFICIENT FOSSIL FUEL GENERATION

COST PROJECTIONS FOR RENEWABLE ENERGY TECHNOLOGIES

5

5

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

“towards a sustainable energy supply system.”

GREENPEACE INTERNATIONAL
CLIMATE CAMPAIGN

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

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 1st National Basic Energy Plan (2008-2030) (see chapter 2)In 2008, in order to provide a backbone support for its "Low-carbon Green-growth" initiative in the energy sector, Korean government announced the nation's first 20-year long-term energy plan which is a guideline for other energy-related government plans such as the Basic Plan for Long-term electricity supply and demand. According to the plan, the energy intensity will be decreased from 0.341 to 0.185 by 2030, and the NRE (New & Renewable Energy) will be expanded from 2.4% to 11% of total energy supply by 2030, while reducing the fossil energy ratio (based on the primary energy level), including oil, to 61% by 2030 from 83% at present. At the same time Korean government will invest a lot in the expansion of nuclear power energy indicating that nuclear power has far contributed significantly to the stable supply of cheaper electricity, alleviating the national economy's oil dependence and energy import burden, considering that for the past 25 years, the electricity fare stood at a 11.4% increase although consume prices rose as much as 186%, so to respond to high oil prices and greenhouse gas reduction, the reinforced role of nuclear energy is an avoidable choice. The government plans to increase the nuclear power ratio among total generation facilities up to 41% and 59% of total power generation by 2030. 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. 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 global market development projections of the renewables industry[33] have been taken into account (see table 5.11 Assumed global average annual growth rates for renewable 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 scenario) - 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 before 2030 (also ten years ahead).

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

National and regional Energy [R]evolution scenarios take the global framework as a basis and adjust them to locally available technology and infrastructure as well as regional (renewable) energy resources and change them according to national socio-economic circumstances.

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.

reference
33 SEE EREC, RE-THINKING 2050, GWEC, EPIA ET AL.

5.1 scenario background

The scenarios in this report were jointly commissioned by Greenpeace and the European Renewable Energy Council from the Systems Analysis group of 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.[34] 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.

The recent dramatic fluctuations in global oil prices have resulted in much 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 oil price increased again and reached US$125 in March 2012 again. However 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 5.1).

table 5.1: development projections for fossil fuel prices in $ 2008

FOSSIL FUEL	UNIT	2000	2005	2007	2008	2010	2015	2020	2025	2030	2035	2040	2050
Crude oil imports													
IEA WEO 2011	barrel					78.10	106.30	118.10	127.30	134.50	140.00		
IEA WEO 2009 "Reference"	barrel	34.30	50.00	75.00	97.19		86.67	100.00	107.50	115.00			
IEA WEO 2007 / ETP 2008	barrel												
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 2008	barrel												
Energy [R]evolution 2010	barrel						110.56	130.00	140.00	150.00		150.00	150.00
Natural gas imports													
IEA WEO 2011													
United States	GJ					4.40	6.10	7.00	7.70	8.40	9.00		
Europe	GJ					7.50	9.80	11.00	11.90	12.60	13.00		
Japan LNG	GJ					11.00	12.70	13.50	14.20	14.80	15.20		
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 2011	tonne					99.20	104.60	109.00	112.80	115.90	118.40		
IEA WEO 2009 "Reference"	tonne	41.22	49.61	69.45		120.59	91.05	104.16	107.12	109.40			
Biomass (solid)													
Energy [R]evolution 2010													
OECD Europe	GJ			7.40		7.70	8.20	9.20		10.00		10.30	10.50
OECD Pacific & North America	GJ			3.30		3.40	3.50	3.80		4.30		4.70	5.20
Other regions	GJ			2.70		2.80	3.20	3.50		4.00		4.60	4.90

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.

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.

5.2 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 2010, 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 5.2: 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

5.3 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.[35]

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,[36] while a recent US Department of Energy report found installing carbon capture systems to most modern plants resulted in a near doubling of costs.[37] These costs are estimated to increase the price of electricity in a range from 21-91%.[38]

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.[39] 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.[40]

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.[41] 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.[42]

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

Table 5.3 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.

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table 5.3: development of efficiency and investment costs for selected power plant technologies

POWER PLANT		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.

5.4 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,[43] from the analysis of recent technology foresight and road mapping studies, including the European Commission funded NEEDS project (New Energy Externalities Developments for Sustainability)[44] 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.

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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.

5.4.1 photovoltaics (PV)

The worldwide photovoltaics (PV) market has been growing at over 35% 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 1,600 GW by between 2030 and 2040 in the basic Energy [R]evolution scenario, and with an electricity output of 2,600 TWh, 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.

5.4.2 concentrating solar power (CSP)

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 1,0000C, 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.

table 5.4: photovoltaics (PV) cost assumptions

SCENARIO	2010	2015	2020	2030	2040	2050
E[R] / ADV E[R]						
Investment costs ($/kWp)	3,013	1,937	1,506	1,219	903	846
O & M costs ($/kW/a)	43	31	19	14	13	13

O & M = Operation and maintenance.

table 5.5: concentrating solar power (CSP) cost assumptions

SCENARIO	2010	2015	2020	2030	2040	2050
E[R] / ADV E[R]						
Investment costs ($/kWp)	9,038	6,620	5,738	5,273	4,949	4,806
O & M costs ($/kW/a)	290	265	240	202	199	198

O & M = Operation and maintenance.

5.4.3 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.

5.4.4 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.

table 5.6: wind power cost assumptions

SCENARIO	2010	2015	2020	2030	2040	2050
E[R] / ADV E[R]						
Wind onshore						
Investment costs ($/kWp)	1,793	1,490	1,291	1,219	1,119	1,076
O & M costs ($/kW/a)	60	57	53	53	56	57
Wind offshore						
Investment costs ($/kWp)	5,523	3,228	2,582	2,224	2,008	1,872
O & M costs ($/kW/a)	199	165	170	131	115	166

O & M = Operation and maintenance.

table 5.7: biomass cost assumptions

SCENARIO	2010	2015	2020	2030	2040	2050
E[R] / ADV E[R]						
Biomass electricity only						
Investment costs ($/kWp)	3,345	3,084	2,912	2,812	2,697	2,640
O & M costs ($/kW/a)	189	181	174	169	168	166
Biomass CHP						
Investment costs ($/kWp)	5,684	5,051	4,419	3,859	3,556	3,379
O & M costs ($/kW/a)	397	354	310	270	250	237

O & M = Operation and maintenance.

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

5.4.5 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:

- 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.

table 5.8: geothermal cost assumptions

SCENARIO	2010	2015	2020	2030	2040	2050
E[R] / ADV E[R]						
Geothermal power plant						
Investment costs ($/kWp)	14,777	12,338	9,325	6,384	5,306	4,563
O & M costs ($/kW/a)	637	563	489	429	402	380

O & M = Operation and maintenance.

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.

5.4.6 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.[45]

table 5.9: ocean energy cost assumptions

SCENARIO	2010	2015	2020	2030	2040	2050
E[R] / ADV E[R]						
Investment costs ($/kWp)	5,909	4,620	3,300	2,295	1,906	1,697
O & M costs ($/kW/a)	237	185	133	102	86	76

O & M = Operation and maintenance.

reference
45 WWW.NEEDS-PROJECT.ORG.

5.4.7 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 5.10: hydro power cost assumptions

SCENARIO	2010	2015	2020	2030	2040	2050
E[R] ADV E[R]						
Investment costs ($/kWp)	3,295	3,400	3,505	3,663	3,795	3,911
O & M costs ($/kW/a)	132	136	141	146	152	156

O & M = Operation and maintenance.

5.4.8 summary of renewable energy cost development

Figure 5.1 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 5.2. Generation costs today are around 10 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 to 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.

figure 5.1: future development of renewable energy investment costs

(NORMALISED TO CURRENT COST LEVELS) FOR RENEWABLE ENERGY TECHNOLOGIES

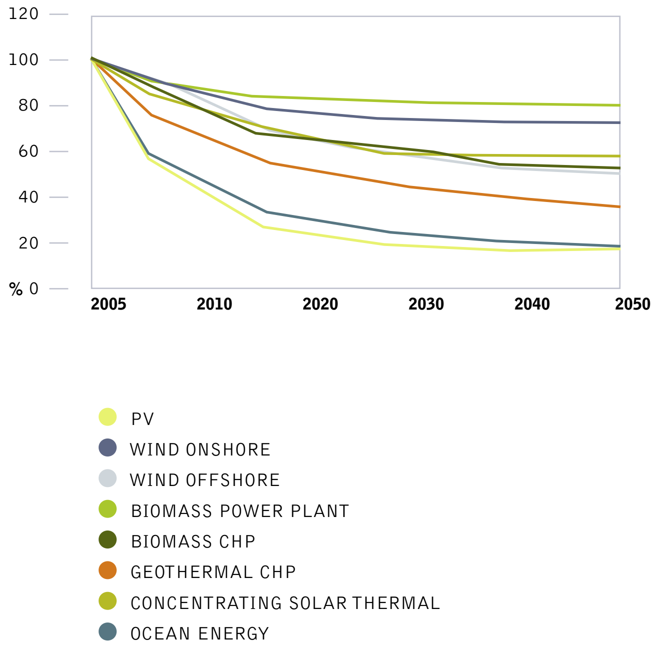
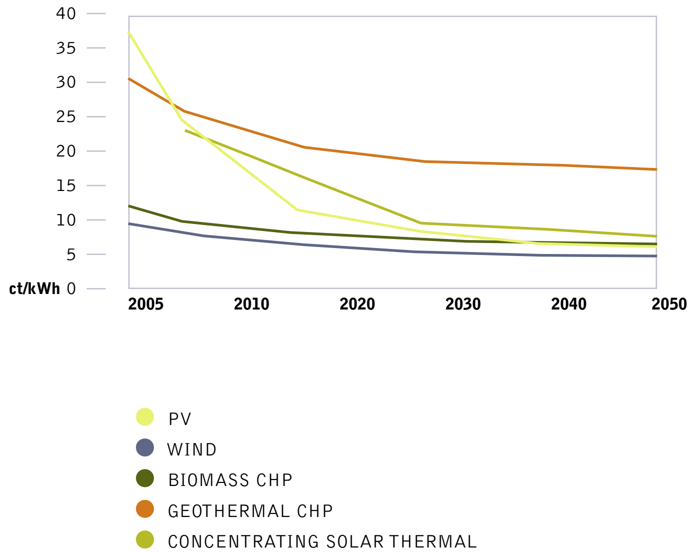


figure 5.2: expected development of electricity generation costs from fossil fuel and renewable options

EXAMPLE FOR OECD NORTH AMERICA



references
46 HERZOG ET AL., 2005; BARKER ET AL., 2007.
47 VAN VUUREN ET AL.; HOURCADE ET AL., 2006.

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.

5.5 assumed growth rates in different scenarios

In scientific literature[46] 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.[47] 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).

table 5.11: assumed global average annual growth rates for renewable technologies

(ENERGY PARAMETER GENERATION)

RE	REF (TWh/a)	E[R] (TWh/a)	ADV E[R] (TWh/a)	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%

key results of the south korea energy [r]evolution scenario

DEVELOPMENT OF ENERGY DEMAND TO 2050

ELECTRICITY GENERATION

FUTURE COSTS OF ELECTRICITY GENERATION

FUTURE INVESTMENT

HEATING AND COOLING SUPPLY

TRANSPORT

DEVELOPMENT OF CO_2 EMISSIONS

PRIMARY ENERGY CONSUMPTION

6

image SOLAR PANEL. © BERND JUERGENS/DREAMSTIME

"the technology is here, all we need is political will."

GREENPEACE INTERNATIONAL
CLIMATE CAMPAIGN

image WIND TURBINES IN JEJU ISLAND.

6.1 development of energy demand to 2050

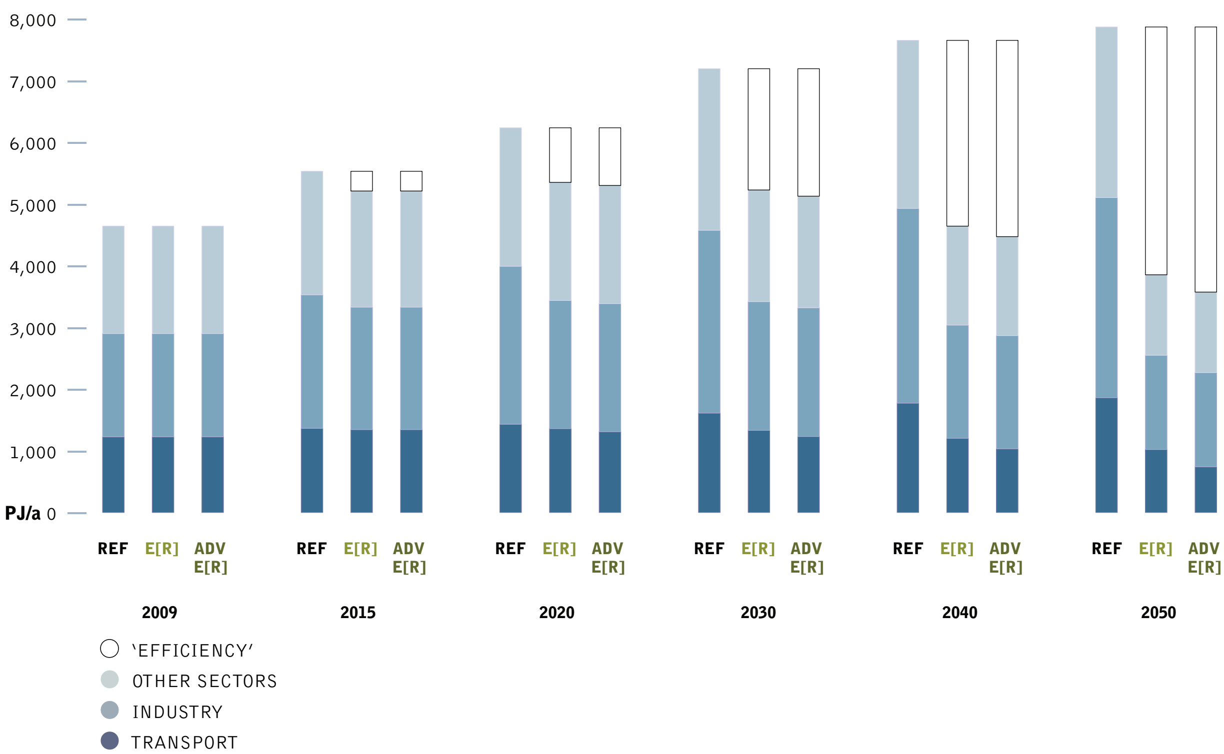
The future development pathways for South Korea's energy demand are shown in Figure 6.1 for the Reference and both Energy [R]evolution scenarios. Under the Reference scenario, total primary energy demand in South Korea increases by 58% from the current 9,614 PJ/a to 15,151 PJ/a in 2050. In the Energy [R]evolution scenario, by contrast, energy demand decreases by 28% and 32% in the Advanced case, compared to current consumption and it is expected by 2050 to reach 6,917 PJ/a and 6,513 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 6.2). The growing use of electric vehicles however, leads to an increased demand reaching a level of 477 TWh/a 2050. Electricity demand in the Energy [R]evolution scenario is still 396 TWh/a lower than in the Reference scenario.

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 Advanced Energy [R]evolution is higher and reaches 486 TWh/a in 2050, still 37% below the Reference case.

figure 6.1: south korea: projection of total final energy demand by sector under three scenarios

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



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 6.3). Compared to the Reference scenario, consumption equivalent to 1,370 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 20% to 1,021 PJ/a by 2050, saving 45% 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 741 PJ/a, 40% lower than in the Reference case.

figure 6.2: south korea: development of electricity demand by sector under both energy [r]evolution scenarios

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

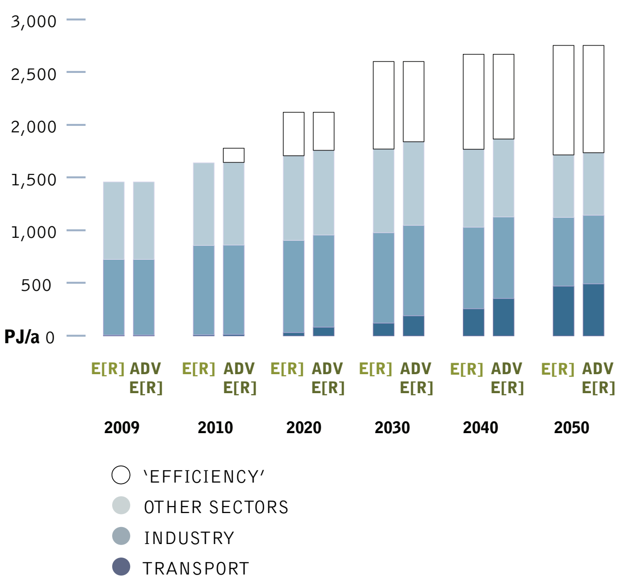
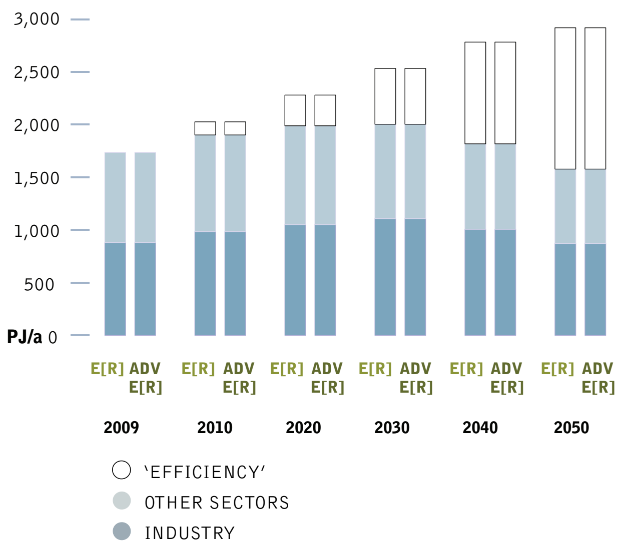


figure 6.3: south korea: development of heat demand by sector under both energy [r]evolution scenarios

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



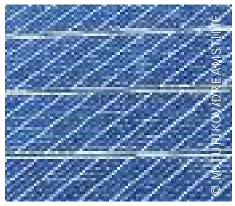


image SOLAR PANELS ON JEJU ISLAND.

6.2 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, 77% of the electricity produced in South Korea will come from renewable energy sources. 'New' renewables – mainly wind, solar thermal energy and PV – will contribute 56% of electricity generation. The installed capacity of renewable energy technologies will grow from the current 3 GW to 164 GW in 2050, increasing renewable capacity by a factor of 55.

The Advanced Energy [R]evolution scenario projects a faster market development with higher annual growth rates achieving a renewable electricity share of 49% by 2030 and 90% by 2050. The installed capacity of renewables will reach 129 GW in 2030 and 198 GW by 2050, 21% 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 6.4 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 electricity 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 41% 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 6.1: south korea: projection of renewable electricity generation capacity under both energy [r]evolution scenarios

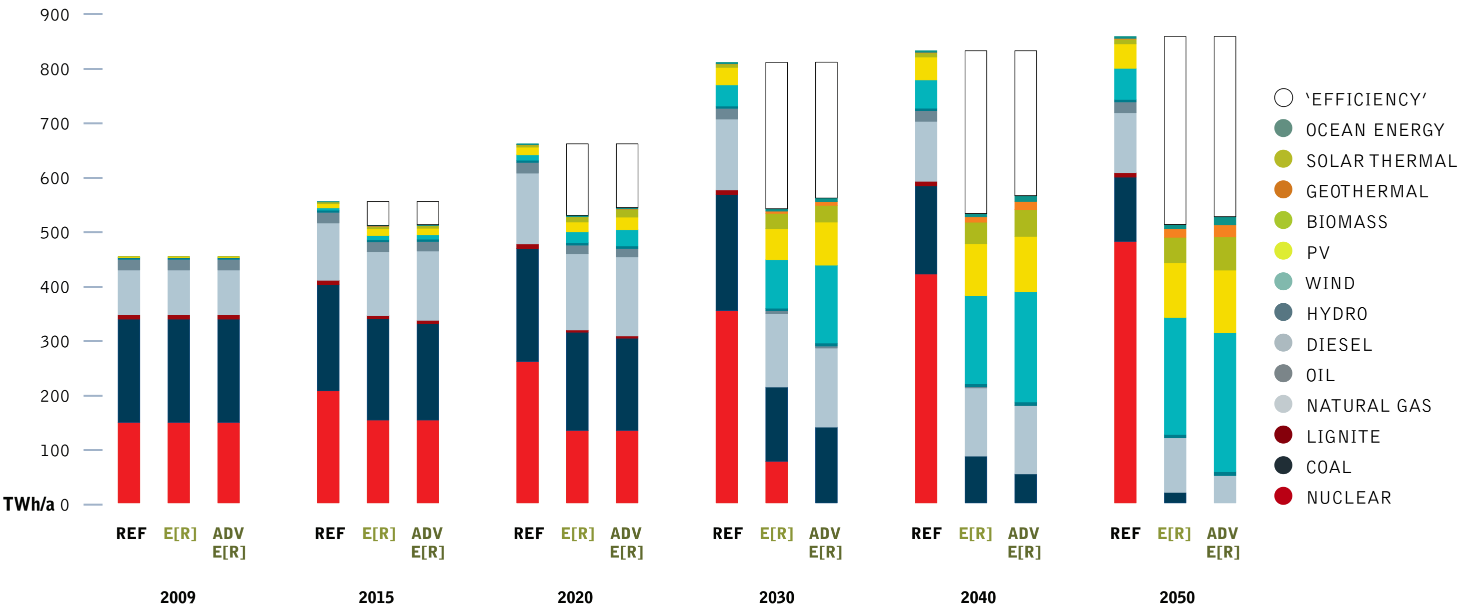
IN GW

		2009	2020	2030	2040	2050
Hydro	E[R]	2	2	2	2	3
	ADV E[R]	2	2	2	3	3
Biomass	E[R]	0	2	5	7	8
	ADV E[R]	0	2	5	8	10
Wind	E[R]	0	7	31	56	72
	ADV E[R]	0	10	54	73	89
Geothermal	E[R]	0	0	1	2	3
	ADV E[R]	0	0	1	2	3
PV	E[R]	1	16	47	73	77
	ADV E[R]	1	20	65	78	88
CSP	E[R]	0	0	0	0	0
	ADV E[R]	0	0	0	0	0
Ocean energy	E[R]	0	1	1	2	2
	ADV E[R]	0	1	2	3	4
Total	**E[R]**	**3**	**28**	**86**	**141**	**164**
	ADV E[R]	**3**	**36**	**129**	**167**	**198**

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 estimated technical potential for wind power (KFEM estimation) is relatively high at 72% in the Advanced version, for geothermal less than 1%, for PV less than 2% and for hydro less than 3% has been used.

figure 6.4: south korea: development of electricity generation structure under three scenarios

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



6.3 future costs of electricity generation

Figure 6.5 shows that the introduction of renewable technologies under the Energy [R]evolution scenario slightly increases the costs of electricity generation in the South Korea 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 scenarios and by 2050 costs will be 2 respective 4.2 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 US$ 34 billion per year to more than US$ 117 billion in 2050. Figure 6.5 shows that the Energy [R]evolution scenario not only complies with South Korea'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 41% by 2030 and 73% 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.

In both Energy [R]evolution scenarios the specific generation costs are almost on the same level until 2030. By 2050, however the Advanced version results in a reduction of 2.2 cents/kWh lower generation costs, mainly because of better economics of scale in renewable power equipment. Due to the faster and earlier expansion of renewable technologies the overall total supply costs in 2030 are US$ 7 billion higher in the Advanced case than in the basic case. However, in 2050 total supply costs are US$ 9 billion lower than in the basic Energy [R]evolution scenario, despite the increased electricity consumption in the transport sector.

figure 6.5: south korea: development of total electricity supply costs & development of specific electricity generation costs under three scenarios

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

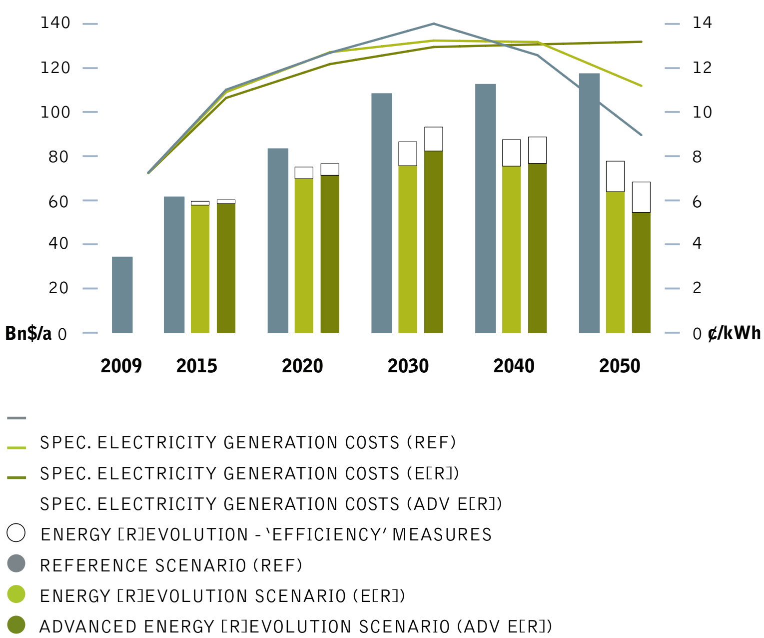


image SUN SETTING OVER SEOUL, SOUTH KOREA. AS SEEN FROM THE NORTH SIDE OF THE HAN RIVER.

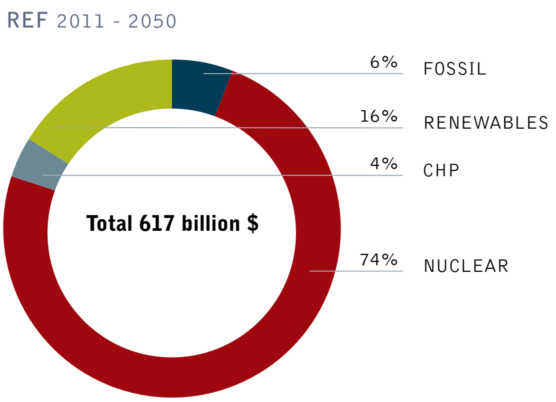
6.4 future investment

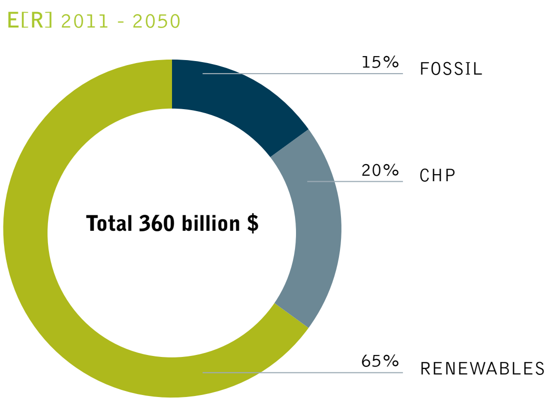
It would require US$ 457 billion in investment for the Advanced Energy [R]evolution scenario to become reality (including investments for replacement after the economic lifetime of the plants) - approximately US$ 160 billion annual or US$ 4 billion less than in the Reference scenario (US$ 617 billion). Under the Reference version, the levels of investment in nuclear power plants add up to almost 74% while approximately 20% would be invested in renewable energy and cogeneration until 2050. Under the Advanced scenario, however, South Korea would shift almost 90% of the entire investment towards renewables and cogeneration. Until 2030 the fossil fuel share of power sector investment would be focused mainly on combined heat and power plants. The average annual investment in the power sector under the Advanced Energy [R]evolution scenario between today and 2050 would be approximately US$ 11.4 billion.

Because renewable energy has no fuel costs, however, the fuel cost savings in the basic Energy [R]evolution scenario reach a total of US$ 147 billion, or US$ 3.7 billion per year. The Advanced Energy [R]evolution has even higher fuel cost savings of US$ 191 billion, or US$ 4.8 billion per year.

These renewable energy sources would then go on to produce electricity without any further fuel costs beyond 2050, while the costs for coal and gas will continue to be a burden on national economies.

figure 6.6: south korea: investment shares - reference versus energy [r]evolution scenarios





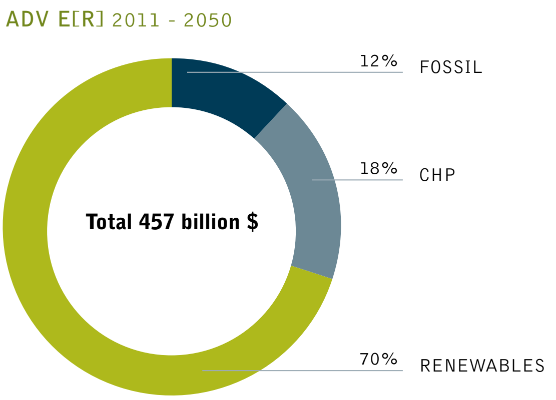


figure 6.7: south korea: change in cummulative power plant investment in both energy [r]evolution scenarios

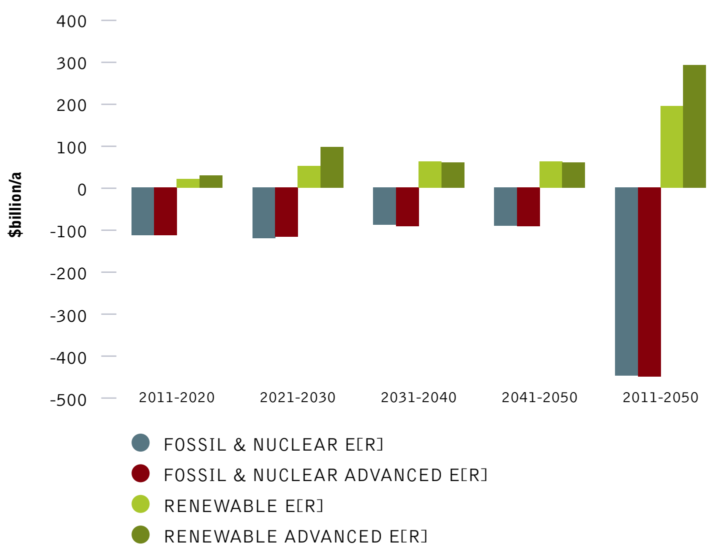


table 6.2: south korea: fuel cost and investment costs under three scenarios

INVESTMENT COST	DOLLARS	2011 - 2020	2021 - 2030	2031 - 2040	2041 - 2050	2011 - 2050	2011 - 2050 AVERAGE P/A
DIFFERENCE E[R] VERSUS REF							
Conventional (fossil & nuclear)	billion $	-113	-120	-92	-92	-445	-11.1
Renewables (incl. CHP)	billion $	18	49	60	60	188	4.7
Total	billion $	**-94**	**-71**	**-32**	**-32**	**-257**	**-6.4**
DIFFERENCE ADV E[R] VERSUS REF							
Conventional (fossil & nuclear)	billion $	-113	-118	-94	-94	-447	-11.2
Renewables (incl. CHP)	billion $	28	96	58	58	286	7.2
Total	billion $	**-86**	**-23**	**-36**	**-36**	**-161**	**-4.0**
CUMULATED FUEL COST SAVINGS							
SAVINGS E[R] CUMULATED IN $							
Fuel oil	billion $/a	3.1	15.3	27.6	31.1	77	1.9
Gas	billion $/a	-8.1	-12.2	-12.0	-0.4	-33	-0.8
Hard coal	billion $/a	4.8	20.4	34.9	39.0	99	2.5
Lignite	billion $/a	0.2	0.8	1.0	1.1	3	0.1
Total		**0.1**	**24.3**	**51.5**	**70.7**	**147**	**3.7**
SAVINGS ADV E[R] CUMULATED IN $							
Fuel oil	billion $/a	3.1	16.6	29.2	31.4	80	2.0
Gas	billion $/a	-13.7	-16.7	-13.5	30.1	-14	-0.3
Hard coal	billion $/a	7.7	22	41.1	50.5	121	3.0
Lignite	billion $/a	0.2	0.9	1.0	1.0	3	0.1
Total		**-2.6**	**22.8**	**57.8**	**112.9**	**191**	**4.8**

image A WIND TURBINE IN SOUTH KOREA.

6.5 heating and cooling supply

Renewables currently provide 9% of South Korea'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 71% of South Korea's total heating and cooling demand in 2050.

- Energy efficiency measures can decrease the current demand for heat supply by 8%, 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 88% by 2050.

6.6 transport

In the transport sector, it is assumed under the Energy [R]evolution scenario that an energy demand reduction of 840 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 roaby 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 9% of the transport sector's total energy demand in the Energy [R]evolution, while in the Advanced case the share will be 16% in 2030 and 67% by 2050.

figure 6.8: south korea: development of heat supply structure under three scenarios

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

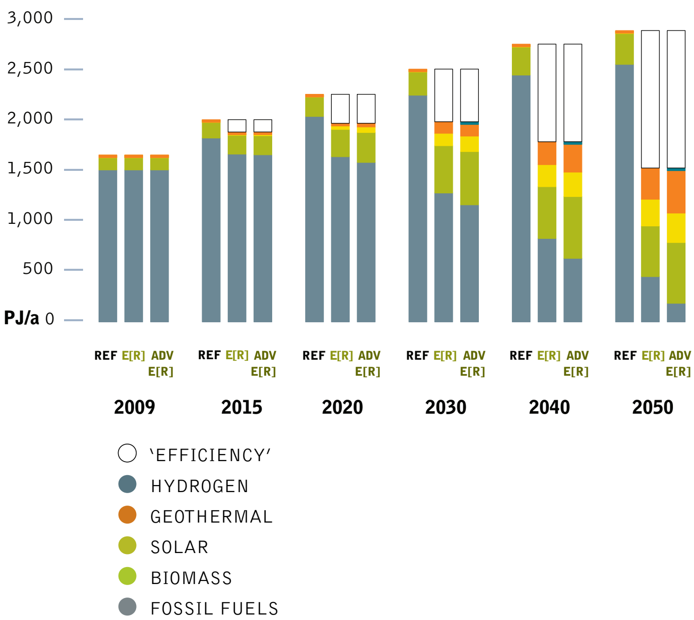
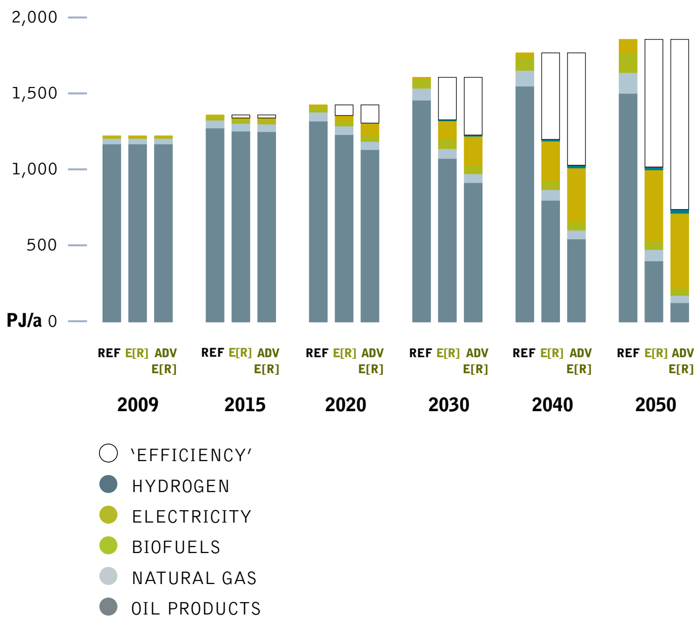


figure 6.9: south korea: transport under three scenarios

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



6.7 development of CO_2 emissions

Whilst the South Korea's emissions of CO_2 will decrease by 5% under the Reference scenario, under the Energy [R]evolution scenario they will decrease from 501 million tonnes in 2009 to 120 million tonnes in 2050. Annual per capita emissions will fall from 10.5 tonnes to 2.6 tonnes. 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 36% 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 7.1 tonnes per capita by 2030 and 0.9 tonnes by 2050. By 2050, South Korea's CO_2 emissions are 19% of 1990 levels.

6.8 primary energy consumption

Taking into account the above assumptions, the resulting primary energy consumption under the Energy [R]evolution scenario is shown in Figure 6.11). Compared to the Reference scenario, overall energy demand will be reduced by 54% in 2050. Around 44% 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 58% in 2050. Nuclear energy is phased out in the basic Energy [R]evolution scenario after 2035 and in the Advanced Energy [R]evolution after 2025.

figure 6.10: south korea: development of CO_2 emissions by sector under both energy [r]evolution scenarios

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

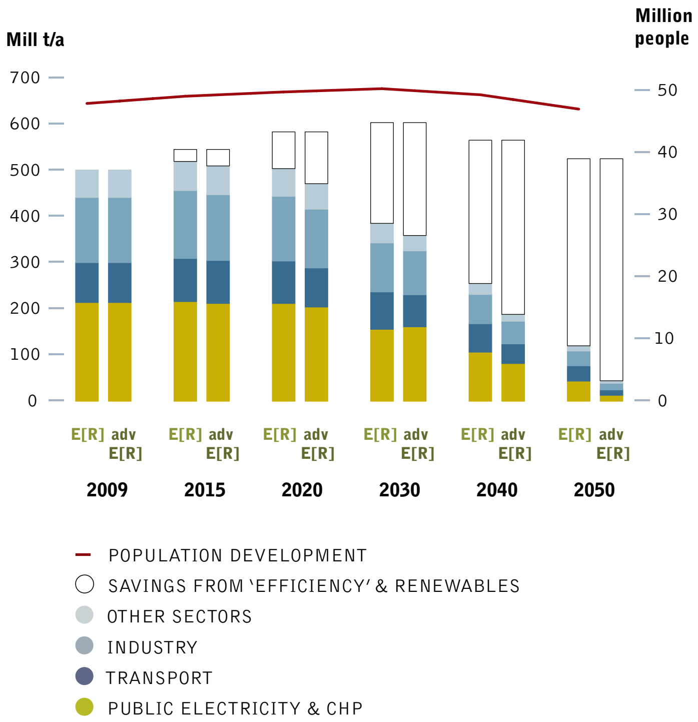
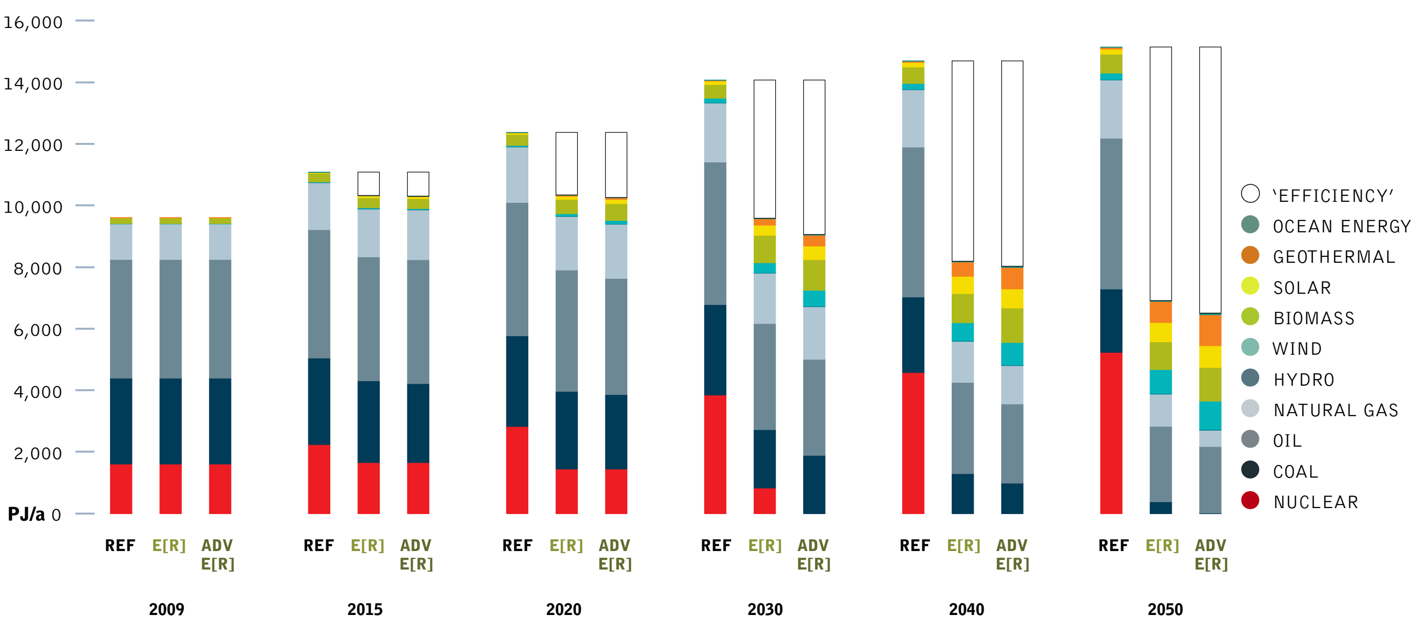


figure 6.11: development of primary energy consumption under the three scenarios

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



7

image PRODUCING WIND ROTORS FOR OFFSHORE WIND ENERGY IN RINGKOBING, DENMARK.
© PAUL LANGROCK/ZENIT/GP

“economy and ecology goes hand in hand with new employment.”

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7.1 future employment

Modelled energy sector jobs increase by 2015 under all scenarios. In 2010, there are 59,000 electricity sector jobs. These increase to 78,000 in the Reference scenario, 74,000 in the Energy [R]evolution scenario, and 104,000 in the Advanced scenario. Figure 7.1 shows the increase in job numbers under both Energy [R]evolution scenarios and the Reference case for each technology up to 2030, with details given in Table 7.1.

- In the Reference case, jobs grow by 32% by 2015, and then a further 27% by 2020, to reach 94,000. There is a reduction between 2020 and 2030, but jobs in 2030 are still 67,000, 14% higher than jobs in 2010.
- In the [R]evolution scenario, jobs increase by 25% by 2015, to 74,000. By 2020, jobs are nearly double 2010 levels at 116,000. There is a slight reduction between 2020 and 2030, but jobs are still 89% above 2010 levels at 112,000.
- In the Advanced scenario, energy sector jobs increase by 75% between 2010 and 2015, to reach 104,000. By 2020 jobs are nearly two and a half times greater than 2010 levels, at 141,000. There is a reduction in jobs between 2020 and 2030, but 2030 jobs are still 101,000, 71% higher than jobs in 2010.
- Solar PV and wind energy show particularly strong growth, and together account for between 51% and 77% of total energy sector employment by 2020 in all three scenarios.

These calculations do not include the jobs associated with decommissioning nuclear power stations, or jobs in energy efficiency. These are both likely to be significant in the Energy [R]evolution and Advanced scenarios.

Jobs in nuclear decommissioning are likely to maintain the nuclear operations and maintenance workforce at present levels (approximately 6,000 jobs) at least until 2020. 6 GW of nuclear power is phased out in the two Energy [R]evolution scenarios by 2020, with a further 2 GW phased out by 2030 in the [R]evolution scenario (a further 11 GW in the Advanced scenario).

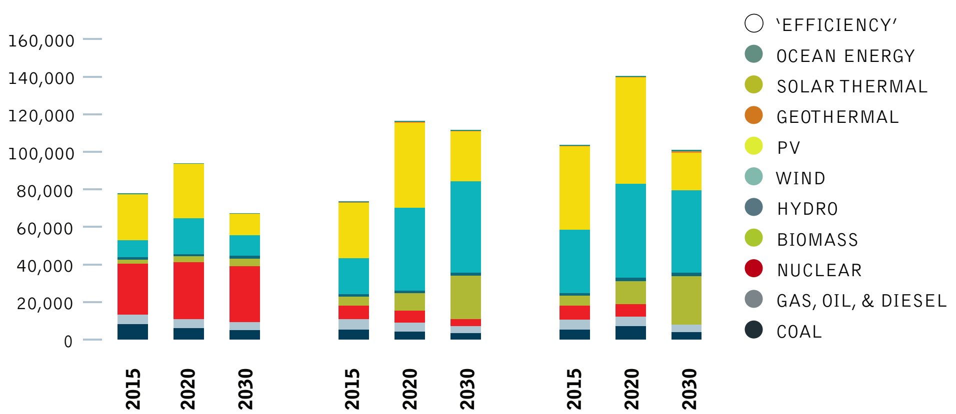
There is a reduction in electricity generation by 2030 of more than 30% in both the Energy [R]evolution scenarios compared to the Reference scenario, which is likely to create a significant number of jobs in the energy efficiency sector, although it is beyond the scope of this work to estimate numbers.

Job numbers in the Reference scenario are dominated by the nuclear, PV and wind industries. The nuclear sector accounts for nearly 50% of electricity sector employment in 2010, mainly because of construction work on new reactors. Numbers of jobs in the nuclear industry remain relatively constant to 2030, at around 29,000. Jobs in solar PV grow strongly until 2020, reaching 29,000, and then fall back to 11,000 by 2030. Employment in coal, oil and gas falls slightly over the same period, from 12,000 in 2010 to 9,000 in 2030.

The [R]evolution scenario shows considerable growth across the renewable sector, with 82,000 new jobs by 2020 which are maintained until 2030. Solar PV accounts for 45,000 and wind 44,000 jobs in 2020. By 2030, wind is the largest sector, accounting for 48,000 jobs. followed by PV and then bioenergy. There are significant reductions in jobs in the nuclear industry, although these are exceeded by the job creation in the renewable sector. By 2030 there are 112,000 electricity sector jobs, 89% above 2010 levels.

The Advanced Energy [R]evolution scenario shows even stronger growth at 2015 and 2020, mainly concentrated in solar PV and wind energy. Solar PV accounts for 43% of electricity sector employment in 2015 (45,000 jobs), and wind for 33% (34,000 jobs). Both sectors continue to grow strongly to 2020. Wind energy jobs fall back slightly to 44,000 jobs by 2030, while PV declines to 20,000 jobs by 2030; this is offset somewhat by the increase in bioenergy jobs. At 2030 there are 101,000 energy sector jobs, 71% above 2010 levels.

figure 7.1: south korea: electricity sector jobs under three scenarios, by technology



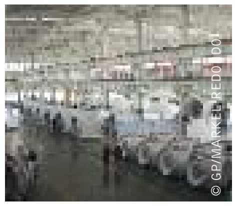


image WORKERS AT GANSU JINFENG WIND POWER EQUIPMENT CO. LTD. IN JIUQUAN, GANSU PROVINCE, CHINA.

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table 7.1: south korea: energy sector jobs under three scenarios

(THOUSAND JOBS)

TECHNOLOGY	2010	REF 2015	REF 2020	REF 2030	E[R] 2015	E[R] 2020	E[R] 2030	ADV E[R] 2015	ADV E[R] 2020	ADV E[R] 2030
Coal	7.0	8.1	6.1	5.0	5.4	4.3	3.4	5.2	7.3	4.0
Gas, oil & diesel	5.2	5.3	4.9	4.3	5.4	4.8	3.9	5.6	5.0	4.0
Nuclear	28	27	30	30	7.3	6.3	3.6	7.3	6.3	-
Renewables	19	37	53	28	55	101	101	86	122	93
Total jobs	**59**	**78**	**94**	**67**	**74**	**116**	**112**	**104**	**141**	**101**

7.2 methodology overview

Greenpeace engaged the Australian-based Institute for Sustainable Futures (ISF) to model the employment effects of the 2009 and 2010 global energy scenarios, published as "Working for the climate – Renewable Energy & The Green Job [R]evolution".[48] The modelling methodology was updated and published in 2010.[49]

The model calculates indicative numbers for jobs that would either be created or lost under the two Energy [R]evolution and the Reference scenarios, with the aim of showing the effect on employment if the world re-invents its energy mix to dramatically cut carbon emissions. The Reference ('business as usual') scenario and both the [R]evolution scenarios were constructed for Greenpeace and the European Renewable Energy Council by the German Aerospace Center (DLR).

To calculate how many jobs will either be lost or created under the three scenarios requires a series of assumptions or calculations. These are summarised below.

- Installed electrical capacity and generation by technology for each year, from the two Energy [R]evolution scenarios and the Reference scenario modelled by DLR.
- "Employment factors" for each technology, which give the number of jobs per unit of electrical capacity. These are key inputs to the analysis. Employment factors from OECD data are used when local factors are not available.
- Decline factors, or learning adjustment rates, which are used to reduce the employment factors by a specific percentage each year. Employment per unit of capacity reduces as technologies mature.
- The percentage of manufacturing for each technology which occurs within South Korea, and whether there are any technology exports to the rest of the world.
- The percentage of coal and gas which originates within South Korea.

Only direct employment is included, namely jobs in construction, manufacturing, operations and maintenance, and fuel supply associated with electricity generation. Employment numbers are indicative only, as a large number of assumptions are required to make calculations However, within the limits of data availability, the figures presented are indicative of employment levels under the three scenarios.

The calculation of energy supply jobs is summarised below:

table 7.2: methodology to calculate employment

JOBS = MANUFACTURING JOBS + CONSTRUCTION JOBS + OPERATIONS & MAINTENANCE (O&M) JOBS + FUEL SUPPLY JOBS, WHERE:

MANUFACTURING JOBS	=	MW INSTALLED & EXPORTED PER YEAR	×	MANUFACTURING EMPLOYMENT FACTOR	×	% OF LOCAL MANUFACTURING
CONSTRUCTION JOBS	=	MW INSTALLED PER YEAR	×	CONSTRUCTION EMPLOYMENT FACTOR		
OPERATION & MAINTENANCE JOBS	=	CUMULATIVE CAPACITY	×	O&M EMPLOYMENT FACTOR		
FUEL SUPPLY JOBS	=	ELECTRICITY GENERATION	×	FUEL EMPLOYMENT FACTOR	×	% OF LOCAL FUEL

JOBS IN REGION 2010	=	**JOBS (AS ABOVE)**
JOBS IN REGION 2020	=	**JOBS (AS ABOVE)** × TECHNOLOGY DECLINE FACTOR$^{\text{(years after start)}}$
JOBS IN REGION 2030	=	**JOBS (AS ABOVE)** × TECHNOLOGY DECLINE FACTOR$^{\text{(years after start)}}$

references
48 GREENPEACE INTERNATIONAL AND EUROPEAN RENEWABLE ENERGY COUNCIL WORKING FOR THE CLIMATE. (2009).
49 RUTOVITZ, J. & USHER, J. METHODOLOGY FOR CALCULATING ENERGY SECTOR JOBS. PREPARED FOR GREENPEACE INTERNATIONAL BY THE INSTITUTE FOR SUSTAINABLE FUTURES, UNIVERSITY OF TECHNOLOGY, SYDNEY. (2010).

7.2.1 employment factors

Electricity sector employment is calculated by using employment factors, which give the jobs created per unit of capacity (MW) or per unit of generation (GWh). Local factors are used for operations and maintenance in coal, gas, and hydro, for solar PV manufacturing, and for coal mining. Data on the number of employees at existing power stations in South Korea was used to derive operations and maintenance factors where possible. The data is shown in Appendix 7.1, and the derived local factors are compared to OECD factors below in Table 7.3.

In other cases OECD employment factors from the global analysis have been used (see Rutovitz and Usher, 2010[50] for a full explanation). The OECD factor for solar PV has been updated using more recent data from the European Photovoltaic Industry Association and Greenpeace.[51]

7.2.2 manufacturing and technology export

South Korea is assumed to manufacture all components for domestic deployment of energy technologies, and to export PV technology proportional to world uptake of PV. There is a government target for South Korea to capture 15% of the world market for solar PV and wind energy by 2015.[52] 2010 production of solar PV was equal to 12% of the world total,[53] and the Korean PV industry produced 10% of world sales, up from 0.6% in 2004.[54] The South Korean wind industry produced only 2.3% of world sales, up from 1.6% in 2004.[55] On this basis it is assumed that South Korea will be responsible for 10% of world PV production, but no net exports have been assumed for wind energy.

World production of PV is taken as the moderate scenario from the European Photovoltaic Industry Association (EPIA)[56] projection in the Reference scenario, and as the policy driven EPIA scenario in the both Energy [R]evolution scenarios. The projection only extends to 2015, after which production is assumed to remain constant. This results in total South Korean PV module production of 2.4 MW from 2015 onwards in the Reference scenario, and of 4.4 MW in the Energy [R]evolution scenarios. Domestic installation is subtracted from production to calculate exports.

7.2.3 coal and gas

Production of coal in South Korea was equal to 1.4% of consumption in 2010, and has been falling 9% per year on average since 1990.[57] For calculation of employment, it is assumed that all coal is imported by 2020. Domestic production of gas in Korea was 1.4% of consumption,[58] and is assumed to stay at this level for calculation of employment.

table 7.3: south korea: local employment factors compared to OECD factors

TECHNOLOGY	SECTOR	UNIT	OECD FACTOR	LOCAL FACTOR
Nuclear	Operations & maintenance	Jobs/MW	0.32[a]	0.40[b]
Coal	Operations & maintenance	Jobs/MW	0.10[a]	0.19[b]
Hydro	Operations & maintenance	Jobs/MW	0.22[a]	0.62[b]
Gas & oil	Operations & maintenance	Jobs/MW	0.05[a]	0.17[b]
Solar PV	Manufacturing	Job years/MW	7.0[d]	3.1[e]
Coal	Mining	Jobs/GWh	0.5[a]	0.73[c]

notes

a Factors from Institute analysis (Rutovitz and Usher, 2010).[2]
b These have been derived from the employment at South Korean power stations in 2009 or 2010 where employment data is available, using the weighted average for each technology. The data for individual power stations came from company annual reports or sustainability reports, and is shown in Appendix 7.1.
c The local factor for coal mining has been calculated from 2009 employment in coal mining of 3630,[4] production of 1.7 MTCE and use in electricity generation of 71.1 MTCE,[5] and generation from coal of 208,864 GWh.[6]
d The OECD factor for manufacturing has been updated using the EPIA and Greenpeace (2011).[3] The overall figure of 33 jobs per MW was allocated to manufacturing and construction using the proportions from EPIA and Greenpeace (2008).[7]
e Employment per MW in solar PV manufacturing is taken from the employment in PV manufacturing (8906 persons)[8] divided by the PV module production in 2010 (2908 MW).[8]

references

50 RUTOVITZ, J. & USHER, J. METHODOLOGY FOR CALCULATING ENERGY SECTOR JOBS. PREPARED FOR GREENPEACE INTERNATIONAL BY THE INSTITUTE FOR SUSTAINABLE FUTURES, UNIVERSITY OF TECHNOLOGY, SYDNEY. (2010).
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58 INTERNATIONAL ENERGY AGENCY NATURAL GAS IN KOREA, REPUBLIC OF IN 2009. (2012).

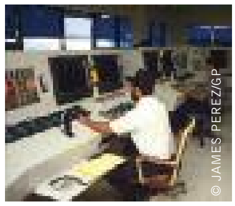

image CONTROL ROOM OF LUZ SOLAR POWER PLANT, CALIFORNIA, USA.

appendix 7.1 employment by power station and calculation of local factors

table 7.4: south korea: factors for nuclear, coal, gas, oil and diesel, and hydro operations and maintenance

TECHNOLOGY & POWER STATION	COMPANY	NO. OF EMPLOYEES	CAPACITY MW	LOCAL FACTORS JOBS/MW
Nuclear				
Gori	KHNP	1,971[a]	3,137[b]	0.63
Yeonggwang	KHNP	1,308[a]	5,900[b]	0.22
Wolseong	KHNP	1,568[a]	2,779[b]	0.56
Uljin	KHNP	1,443[a]	5,900[b]	0.24
WEIGHTED FACTOR				0.36
Coal				
Dangjin	EWP	652[c]	4,000[d]	0.16
Hadong	KOSPO	703[e]	3,000[f]	0.23
WEIGHTED FACTOR				0.19
Gas, oil, & diesel				
Youngnam	KOSPO	165[g]	400[h]	0.41
Sinincheon	KOSPO	237[g]	1,800[h]	0.13
Busan	KOSPO	209[g]	1,800[h]	0.12
Ilsan	EWP	206[i]	900[j]	0.23
Ulsan	EWP	514[i]	3,000[j]	0.17
FACTOR				0.17
Hydro				
All KHNP hydro	KHNP	331[a]	537[b]	0.62

sources
- **a** KOREA HYDRO AND NUCLEAR POWER (KHNP) 2011 SUSTAINABILITY REPORT. P.13 - 14
- **b** KOREA ELECTRIC POWER COMPANY (KEPCO) 2011 ANNUAL REPORT. P.111
- **c** KOREA EAST-WEST POWER CO (EWP) 2010 SUSTAINABILITY REPORT. P.46
- **d** KOREA EAST-WEST POWER CO (EWP) 2010 SUSTAINABILITY REPORT. P.11
- **e** KOREA SOUTHERN POWER CO (KOSPO) 2008 SUSTAINABILITY REPORT. P.63
- **f** KOREA SOUTHERN POWER CO (KOSPO) 2008 SUSTAINABILITY REPORT. P.8
- **g** KOREA SOUTHERN POWER CO (KOSPO) 2008 SUSTAINABILITY REPORT. P.63
- **h** KOREA SOUTHERN POWER CO (KOSPO) 2008 SUSTAINABILITY REPORT. P.8
- **i** KOREA EAST-WEST POWER CO (EWP) 2010 SUSTAINABILITY REPORT. P.46
- **j** KOREA EAST-WEST POWER CO (EWP) 2010 SUSTAINABILITY REPORT. P.11

8

8

IN NORTH AMERICA ALONE WE COULD SHUT DOWN 16 DIRTY POWERPLANTS BY CHANGING TO CFLS AND LEDS. IN EUROPE WE COULD SHUT DOWN 11.

“the bright future for renewable energy is already underway.”

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

The bright future for renewable energy is already underway. This analysis of the global power plant market shows that since the late 1990s, wind and solar installations grew faster than any other power plant technology across the world - about 430,000 MW total installed capacity between 2000 and 2010. However it is too early to claim the end of the fossil fuel based power generation, as at the same time more than 475,000 MW new coal power plants, with embedded cumulative emissions of over 55 billion tonnes CO_2 over their technical lifetime.

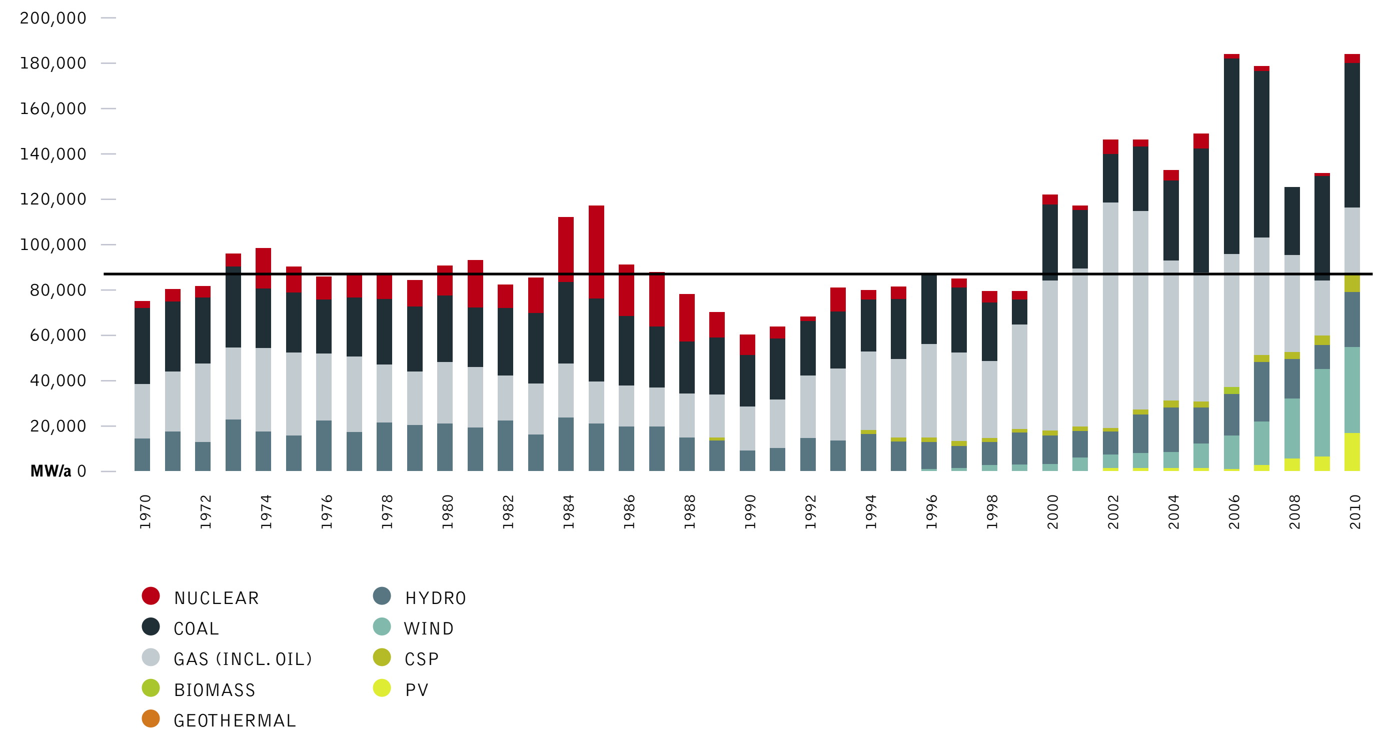
The global market volume of renewable energies in 2010 was on average, as much as the total global energy market volume each year between 1970 and 2000. The window of opportunity for renewables to both dominates new installations replacing old plants in OECD countries, as well as ongoing electrification in developing countries, closes within the next years. Good renewable energy policies and legally binding CO_2 reduction targets are urgently needed.

This briefing provides an overview of the global annual power plant market of the past 40 years and a vision of its potential growth over the next 40 years, powered by renewable energy. Between 1970 and 1990, OECD[59] countries that electrified their economies mainly with coal, gas and hydro power plants dominated the global power plant market. The power sector, at this time, was in the hands of state-owned utilities with regional or nationwide supply monopolies. The nuclear industry had a relatively short period of steady growth between 1970 and the mid 1980s - with a peak in 1985, one year before the Chernobyl accident - while the following years were in decline, with no sign of a 'nuclear renaissance', despite the rhetoric.

Between 1990 and 2000, the global power plant industry went through a series of changes. While OECD countries began to liberalise their electricity markets, electricity demand did not match previous growth, so fewer new power plants were built. Capital-intensive projects with long payback times, such as coal and nuclear power plants, were unable to get sufficient financial support. The decade of gas power plants started.

Economies of developing countries, especially in Asia, started growing during the 1990s, and a new wave of power plant projects began. Similarly to the US and Europe, most of the new markets in the 'tiger states' of Southeast Asia partly deregulated their power sectors. A large number of new power plants in this region were built from Independent Power Producer (IPP`s), who sell the electricity mainly to state-owned utilities. The dominating new built power plant technology in liberalised power markets are gas power plants. However, over the last decade, China focused on the development of new coal power plants. Excluding China, the global power plant market has seen a phase-out of coal since the late 1990s; the growth is in gas power plants and renewables particularly wind.

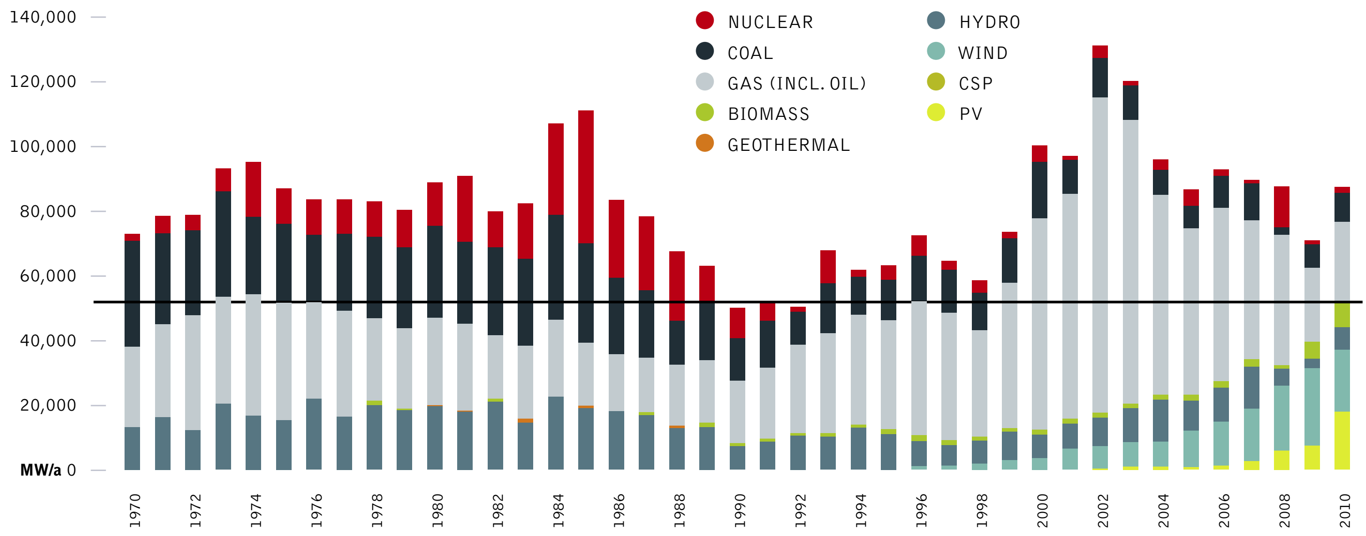
figure 8.1: global power plant market 1970-2010



source
Platts, IEA, Breyer, Teske.

reference
59 ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT.

figure 8.2: global power plant market 1970-2010, excluding china



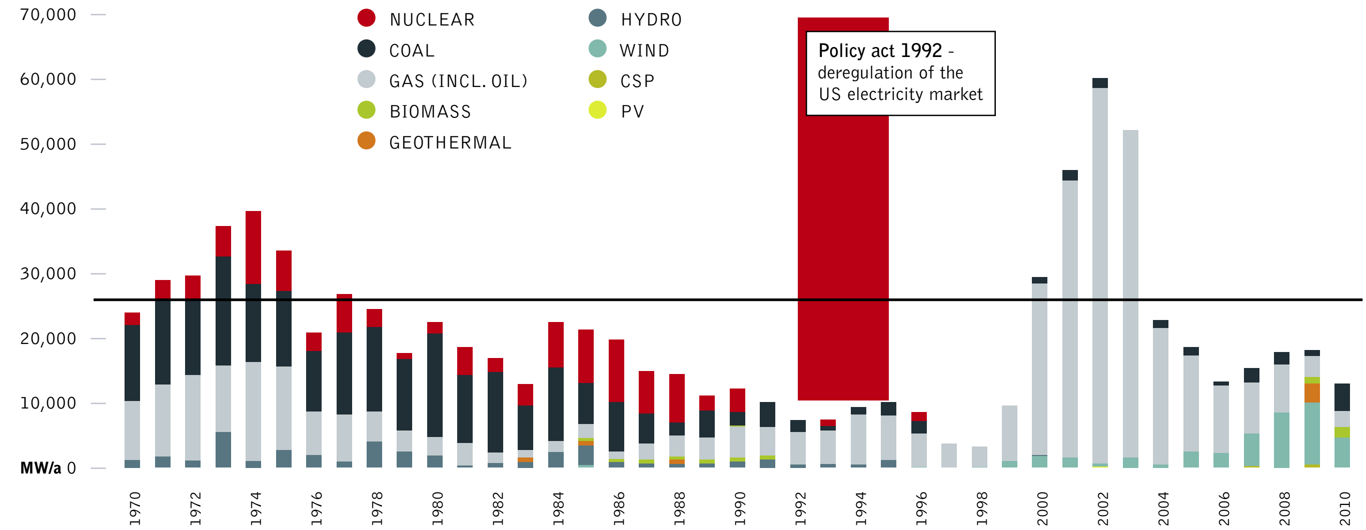
source
Platts, IEA, Breyer, Teske.

8.1 power plant markets in the us, europe and china

Electricity market liberalisation has a great influence on the chosen power plant technology. While the power sector in the US and Europe moved towards deregulated markets, which favour mainly gas power plants, China added a large amount of coal until 2009, with the first signs for a change in favour of renewables in 2009 and 2010.

USA: The liberalisation of the power sector in the US started with the Energy Policy Act 1992, and became a game changer for the entire power sector. While the US in 2010 is still far away from a fully liberalised electricity market, the effect on the chosen power plant technology has changed from coal and nuclear towards gas and wind. Since 2005, a growing number of wind power plants make up an increasing share of the new installed capacities as a result of mainly state based RE support programmes. Over the past year, solar photovoltaic plays a growing role with a project pipeline of 22,000 MW (Photon 4-2011, page 12).

figure 8.3: usa: power plant market 1970-2010



source
Platts, IEA, Breyer, Teske.

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

Europe: About five years after the US began deregulating the power sector, the European Community started a similar process. Once again, the effect on the power plant market was the same. Investors backed fewer new power plants and extended the lifetime of the existing ones. New coal and nuclear power plants have seen a market share of well below 10% since than.

The growing share of renewables, especially wind and solar photovoltaic, are due to a legally-binding target for renewables and the associated renewable energy feed-in laws which are in force in several member states of the EU 27 since the late 1990s. Overall, new installed power plant capacity jumped to a record high, due to the repowering needs of the aged power plant fleet in Europe.

figure 8.4: europe (eu 27): power plant market 1970-2010

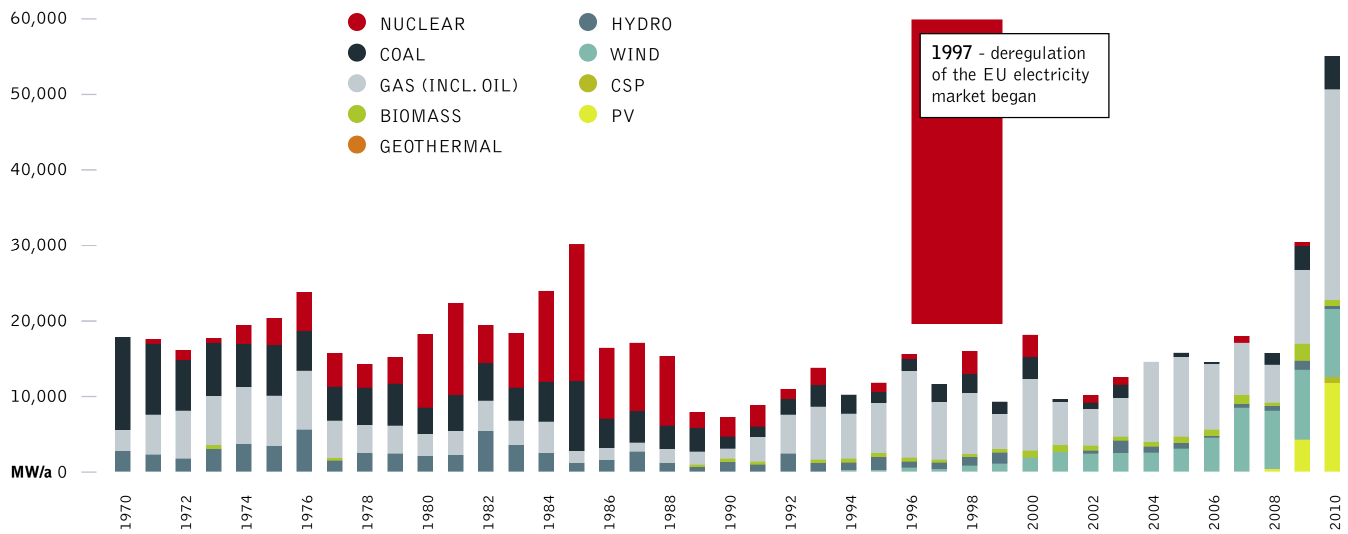
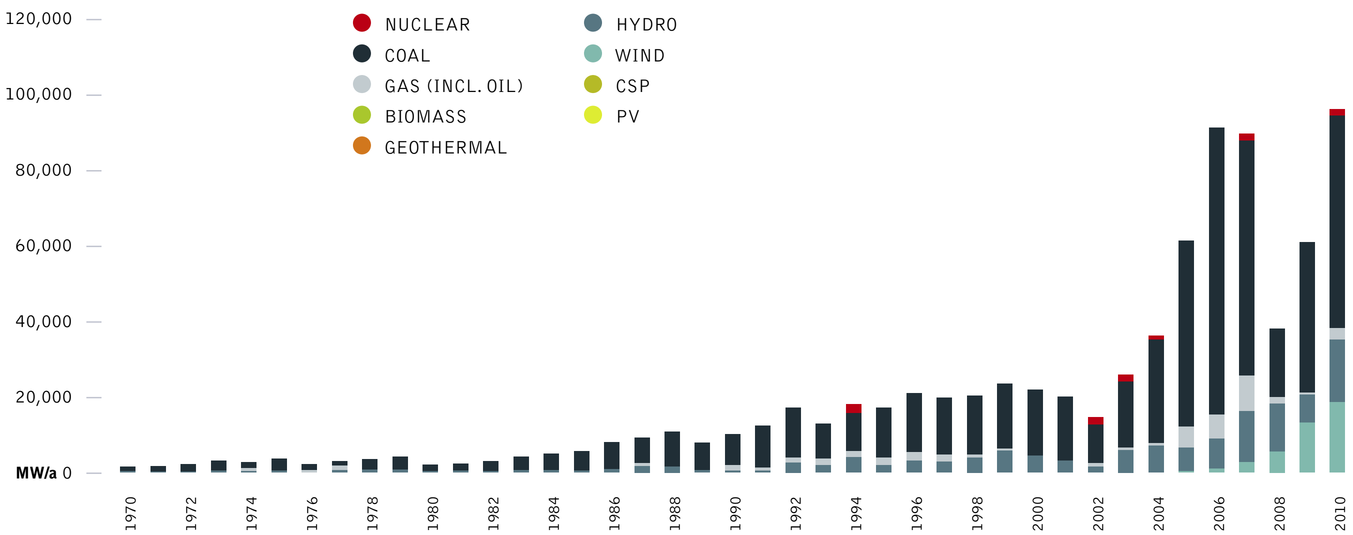


figure 8.5: china: power plant market 1970-2010



source
Platts, IEA, Breyer, Teske.

China: The steady economic growth in China since the late 1990s, and the growing power demand, led to an explosion of the coal power plant market, especially after 2002. In 2006 the market hit the peak year for new coal power plants: 88% of the newly installed coal power plants worldwide were built in China. At the same time, China is trying to take its dirtiest plants offline, within 2006~2010, total 76,825MW of small coal power plants were phased out under the "11th Five Year" programme. While coal still dominates the new added capacity, wind power is rapidly growing as well. Since 2003 the wind market doubled each year and was over 18,000 MW[60] by 2010, 49% of the global wind market. However, coal still dominates the power plant market with over 55 GW of new installed capacities in 2010 alone. The Chinese government aims to increase investments into renewable energy capacity, and during 2009, about US$ 25.1 billion (RMB162.7 billion) went to wind and hydro power plants which represents 44% of the overall investment in new power plants, for the first time larger than that of coal (RMB 149.2billion), and in 2010 the figure was US$26 billion (RMB168 billion) – 4.8% more in the total investment mix compared with the previous year 2009.

8.2 the global market shares in the power plant market: renewables gaining ground

Since the year 2000, the wind power market gained a growing market share within the global power plant market. At this time only a handful of countries, namely Germany, Denmark and Spain, dominated the wind market, but the wind industry now has projects in over 70 countries around the world. Following the example of the wind industry, the solar photovoltaic industry experienced an equal growth since 2005. Between 2000 and 2010, 26% of all new power plants worldwide were renewables – mainly wind – and 42% gas power plants. So, two-thirds of all new power plants installed globally are gas power plants and renewables, with close to one-third as coal. Nuclear remains irrelevant on a global scale with just 2% of the global market share. About 430,000 MW of new renewable energy capacity has been installed over the last decade, while 475,000 MW of new coal, with embedded cumulative emissions of more than 55 bn tonnes CO_2 over their technical lifetime, came online – 78% or 375,000 MW in China.

The energy revolution towards renewables and gas, away from coal and nuclear, has started on a global level already. This picture is even clearer, when we look into the global market shares excluding China, the only country with a massive expansion of coal. About 28% of all new power plants have been renewables and 60% have been gas power plants (88% in total). Coal gained a market share of only 10% globally, excluding China. Between 2000 and 2010, China has added over 350,000 MW of new coal capacity: twice as much as the entire coal capacity of the EU. However China has recently kick-started its wind market, and solar photovoltaics is expected to follow in the years to come.

reference

60 WHILE THE OFFICIAL STATISTIC OF THE GLOBAL AND CHINESE WIND INDUSTRY ASSOCIATIONS (GWEC/CREIA) ADDS UP TO 18,900 MW FOR 2010, THE NATIONAL ENERGY BUREAU SPEAKS ABOUT 13,999 MW. DIFFERENCES BETWEEN SOURCES AS DUE TO THE TIME OF GRID CONNECTION, AS SOME TURBINES HAVE BEEN INSTALLED IN THE LAST MONTHS OF 2010, BUT HAVE BEEN CONNECTED TO THE GRID IN 2011.

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

figure 8.6: south korea: power plant market 1970-2010

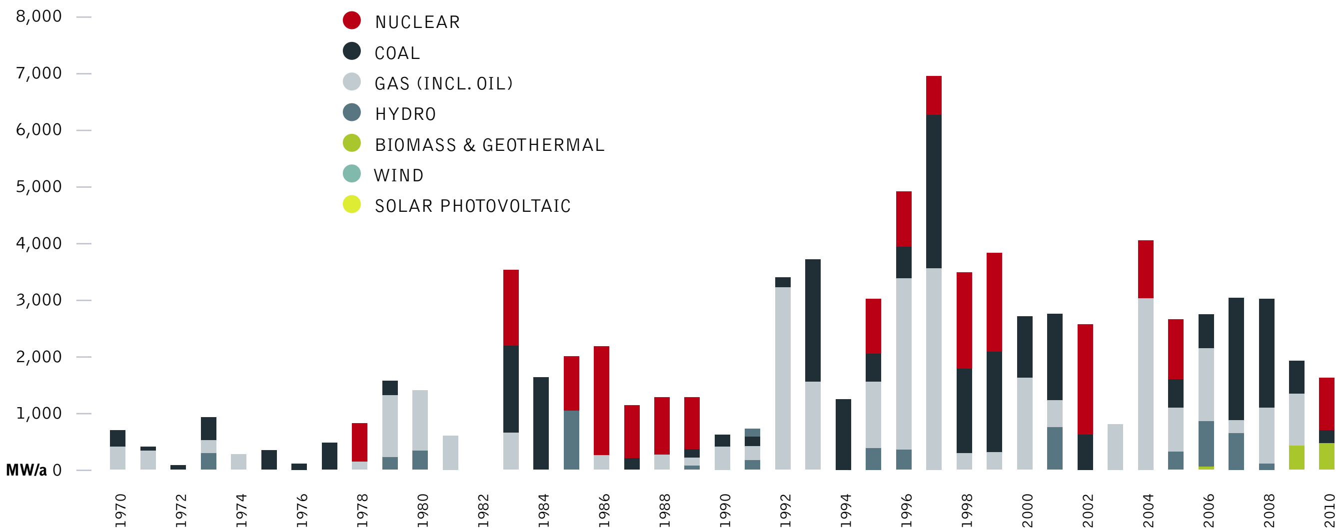


figure 8.7: south korea: new build power plants - market shares 2000-2010

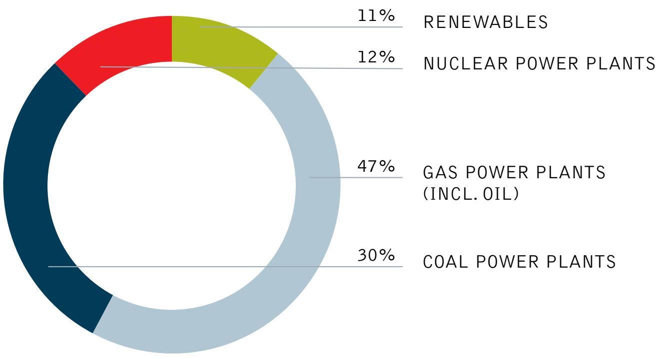
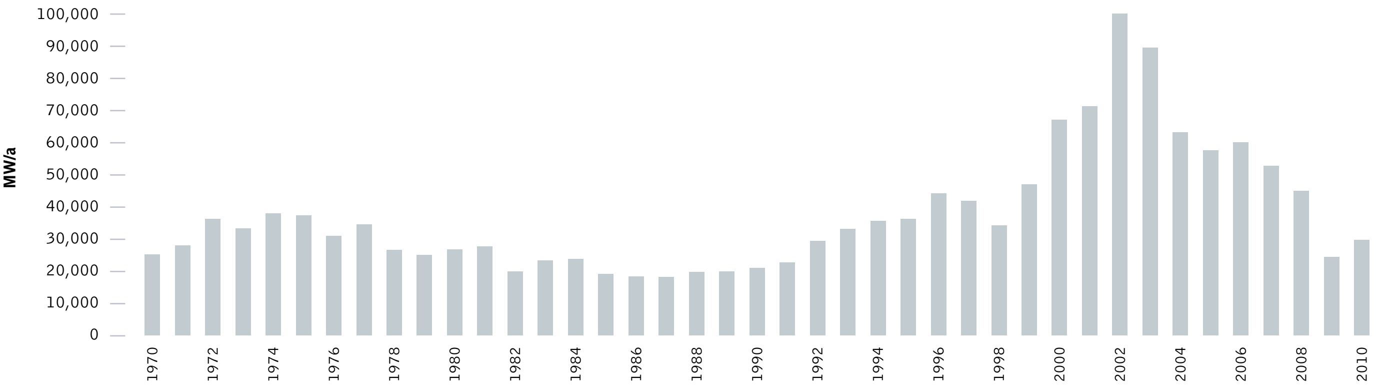


figure 8.8: historic developments of the global power plant market, by technology

GLOBAL ANNUAL GAS POWER PLANT MARKET (INCL. OIL) 1970-2010



GLOBAL ANNUAL COAL POWER PLANT MARKET 1970-2010

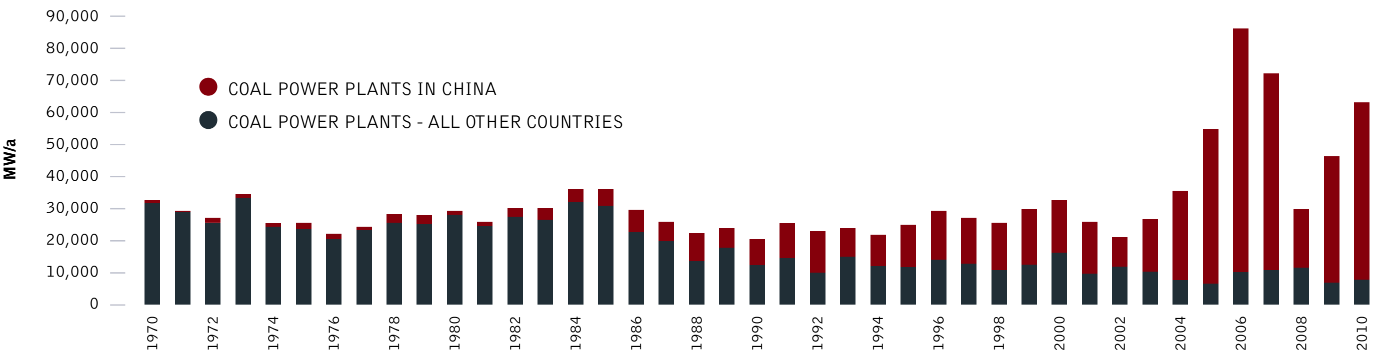


image GARIEP DAM, FREE STATE, SOUTH AFRICA.

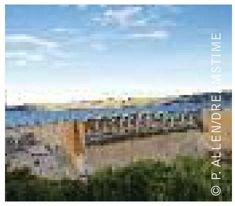
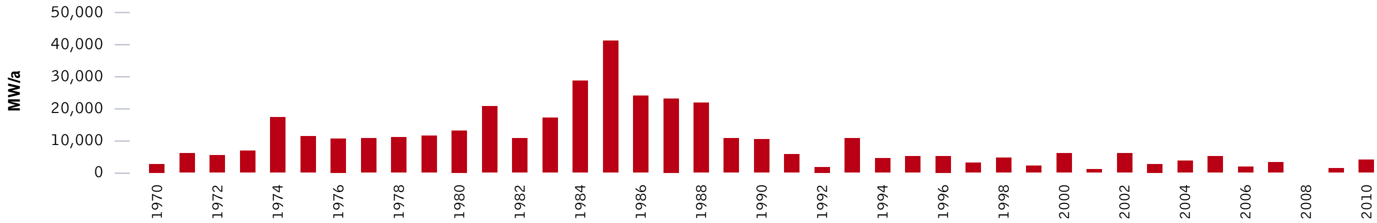
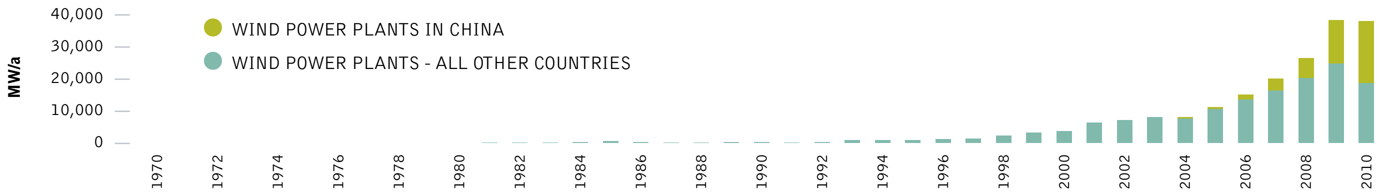


figure 8.8: historic developments of the global power plant market, by technology *continued*

GLOBAL ANNUAL NUCLEAR POWER PLANT MARKET 1970-2010



GLOBAL ANNUAL WIND POWER MARKET 1970-2010



GLOBAL ANNUAL SOLAR PHOTOVOLTAIC MARKET 1970-2010

glossary & appendix

GLOSSARY OF COMMONLY USED TERMS AND ABBREVIATIONS

DEFINITION OF SECTORS

9

“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.

image OFFSHORE WINDFARM, MIDDELGRUNDEN, COPENHAGEN, DENMARK.

9.1 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

table 9.1: conversion factors - fossil fuels

FUEL				
Coal	23.03	MJ/kg	1 cubic	0.0283 m^3
Lignite	8.45	MJ/kg	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

table 9.2: 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

9.2 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, domestic aviation and 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.

south korea: reference scenario

table 9.3: south korea: electricity generation

TWh/a	2009	2015	2020	2030	2040	2050
Power plants	**417**	**509**	**611**	**754**	**770**	**790**
Coal	187	192	205	210	159	115
Lignite	7.2	8.0	8.0	8.0	8.0	8.0
Gas	55	70	92	87	62	58
Oil	15	14	14	14	14	14
Diesel	0	0	0	0	0	0
Nuclear	148	206	259	353	420	480
Biomass	0.5	2.4	3.6	4.4	4.6	4.1
Hydro	2.8	3.8	3.9	4.1	4.3	4.5
Wind	0.7	4.0	10	39	52	57
PV	0.6	8.0	14	32	42	45
Geothermal	0	0	0.2	0.6	1.0	1.5
Solar thermal power plants	0	0	0	0	0	0
Ocean energy	0	0.9	1.4	2.4	3.0	3.5
Combined heat & power production	**35**	**44**	**48**	**54**	**60**	**66**
Coal	2.8	2.9	2.9	2.9	2.8	2.5
Lignite	0.6	0.3	0.3	0.3	0.3	0.3
Gas	27	35	38	43	48	52
Oil	4.7	5.5	5.7	5.9	6.0	6.0
Biomass	0.2	0.6	0.9	1.8	2.9	4.4
Geothermal	0	0	0	0	0	0
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	14	20	23	29	33	38
Autoproducers	21	24	24	26	27	28
Total generation	**452**	**553**	**659**	**808**	**830**	**856**
Fossil	299	328	366	371	300	256
Coal	190	195	208	213	162	118
Lignite	7.8	8.3	8.3	8.3	8.3	8.3
Gas	82	105	130	130	110	110
Oil	20	20	20	20	20	20
Diesel	0	0	0	0	0	0
Nuclear	148	206	259	353	420	480
Hydrogen	0	0	0	0	0	0
Renewables	**4.8**	**20**	**34**	**84**	**110**	**120**
Hydro	2.8	3.8	3.9	4.1	4.3	4.5
Wind	0.7	4.0	10	39	52	57
PV	0.6	8.0	14	32	42	45
Biomass	0.7	3.0	4.5	6.2	7.5	8.5
Geothermal	0	0	0.2	0.6	1.0	1.5
Solar thermal	0	0	0	0	0	0
Ocean energy	0	0.9	1.4	2.4	3.0	3.5
Distribution losses	17	21	25	31	32	33
Own consumption electricity	29	37	44	54	56	58
Electricity for hydrogen production	0	0	0	0	0	0
Final energy consumption (electricity)	**406**	**495**	**589**	**723**	**742**	**766**
Fluctuating RES (PV, Wind, Ocean)	1	13	25	73	97	106
Share of fluctuating RES	0.3%	2.3%	3.9%	9.1%	11.7%	12.3%
RES share	**1.1%**	**3.6%**	**5.2%**	**10.4%**	**13.2%**	**14.0%**

table 9.4: south korea: heat supply

PJ/a	2009	2015	2020	2030	2040	2050
District heating plants	**121**	**120**	**135**	**148**	**165**	**166**
Fossil fuels	46	46	52	57	63	64
Biomass	75	74	84	92	102	103
Solar collectors	0	0	0	0	0	0
Geothermal	0	0	0	0	0	0
Heat from CHP	**172**	**187**	**207**	**220**	**221**	**225**
Fossil fuels	168	181	199	209	209	210
Biomass	4	6	8	11	12	15
Geothermal	0	0	0	0	0	0
Fuel cell (hydrogen)	0	0	0	0	0	0
Direct heating[1]	**1,371**	**1,708**	**1,926**	**2,151**	**2,383**	**2,513**
Fossil fuels	1,301	1,606	1,797	1,994	2,188	2,293
Biomass	67	100	126	153	190	214
Solar collectors	1	1	1	1	2	2
Geothermal[2]	1	1	2	2	3	4
Total heat supply[1]	**1,664**	**2,016**	**2,269**	**2,520**	**2,769**	**2,904**
Fossil fuels	1,515	1,833	2,048	2,260	2,460	2,567
Biomass	146	181	218	257	304	332
Solar collectors	1	1	1	1	2	2
Geothermal[2]	1	1	2	2	3	4
Fuel cell ((hydrogen)	0	0	0	0	0	0
RES share (including RES electricity)	**9.0%**	**9.1%**	**9.7%**	**10.3%**	**11.1%**	**11.6%**

1) including cooling. 2) including heat pumps

table 9.5: south korea: CO_2 emissions

MILL t/a	2009	2015	2020	2030	2040	2050
Condensation power plants	**210**	**213**	**228**	**222**	**164**	**124**
Coal	171	169	176	172	124	86
Lignite	7	8	8	8	7	7
Gas	21	27	35	33	24	22
Oil	10	10	10	9	9	9
Diesel	0	0	0	0	0	0
Combined heat & power production	**22**	**28**	**28**	**28**	**28**	**27**
Coal	6	5	4	3	2	2
Lignite	2	1	1	1	1	1
Gas	10	17	19	21	22	22
Oil	4	5	4	4	4	3
CO_2 emissions power generation (incl. CHP public)	**231**	**241**	**256**	**250**	**192**	**152**
Coal	178	174	180	175	126	87
Lignite	9	9	9	8	8	8
Gas	31	44	54	54	45	44
Oil & diesel	14	15	14	13	13	13
CO_2 emissions by sector	**501**	**546**	**584**	**604**	**566**	**526**
% of 1990 emissions	210%	228%	244%	253%	237%	220%
Industry	66	87	98	110	119	123
Other sectors	60	67	72	75	78	78
Transport	86	95	99	110	118	116
Power generation (incl. CHP public)	214	223	239	235	179	139
Other conversion	75	74	77	75	73	69
Population (Mill.)	48.0	49.1	49.8	50.3	49.4	47.1
CO_2 emissions per capita (t/capita)	**10.5**	**11.1**	**11.7**	**12.0**	**11.5**	**11.2**

table 9.6: south korea: installed capacity

GW	2009	2015	2020	2030	2040	2050
Power plants	**65**	**82**	**100**	**133**	**141**	**145**
Coal	23	23	25	26	20	15
Lignite	0.9	1.0	1.0	1.0	1.0	1.0
Gas	15	15	18	17	12	11
Oil	5.6	5.9	5.8	5.7	5.6	5.7
Diesel	0	0	0	0	0	0
Nuclear	18	25	31	42	50	57
Biomass	0.1	0.3	0.5	0.6	0.6	0.6
Hydro	1.6	1.7	1.7	1.8	1.9	2.0
Wind	0.4	2.0	3.8	12	16	17
PV	0.5	7.2	12	26	32	35
Geothermal	0	0	0.03	0.1	0.1	0.2
Solar thermal power plants	0	0	0	0	0	0
Ocean energy	0	0.3	0.4	0.7	0.9	1.0
Combined heat & power production	**8.1**	**9.7**	**10.6**	**12.3**	**13.7**	**14.7**
Coal	0.7	0.7	0.7	0.7	0.7	0.6
Lignite	0.14	0.06	0.06	0.06	0.06	0.07
Gas	5.8	7.3	8.0	9.8	11	12
Oil	1.4	1.6	1.6	1.4	1.4	1.3
Biomass	0.0	0.1	0.2	0.3	0.5	0.8
Geothermal	0	0	0	0	0	0
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	4.1	5.4	6.2	7.3	8.3	9.1
Autoproducers	4.0	4.3	4.4	5.0	5.4	5.6
Total generation	**73**	**91**	**110**	**146**	**154**	**160**
Fossil	53	55	61	61	52	46
Coal	24	24	26	27	21	15
Lignite	1.0	1.0	1.0	1.0	1.0	1.0
Gas	21	23	26	26	23	23
Oil	7.0	7.4	7.3	7.1	7.0	7.0
Diesel	0	0	0	0	0	0
Nuclear	18	25	31	42	50	57
Hydrogen	0	0	0	0	0	0
Renewables	**2.6**	**12**	**19**	**42**	**52**	**56**
Hydro	1.6	1.7	1.7	1.8	1.9	2.0
Wind	0.4	2.0	3.8	12	16	17
PV	0.5	7.2	12	26	32	35
Biomass	0.1	0.4	0.7	0.9	1.2	1.3
Geothermal	0	0	0.03	0.1	0.1	0.2
Solar thermal	0	0	0	0	0	0
Ocean energy	0	0.3	0.4	0.7	0.9	1.0
Fluctuating RES (PV, Wind, Ocean)	0.9	9.4	16.4	39	49	53
Share of fluctuating RES	1.3%	10.4%	14.9%	27.0%	31.9%	33.0%
RES share	**3.6%**	**12.7%**	**17.1%**	**28.9%**	**34.0%**	**35.2%**

table 9.7: south korea: primary energy demand

PJ/a	2009	2015	2020	2030	2040	2050
Total	**9,614**	**11,090**	**12,378**	**14,078**	**14,700**	**15,151**
Fossil	**7,792**	**8,500**	**9,075**	**9,481**	**9,181**	**8,844**
Hard coal	2,708	2,731	2,868	2,860	2,379	1,984
Lignite	80	78	78	77	74	71
Natural gas	1,151	1,523	1,803	1,917	1,862	1,893
Crude oil	3,853	4,168	4,326	4,628	4,866	4,896
Nuclear	**1,612**	**2,244**	**2,830**	**3,852**	**4,583**	**5,237**
Renewables	**210**	**346**	**472**	**746**	**936**	**1,070**
Hydro	10	14	14	15	15	16
Wind	2	14	36	140	187	205
Solar	3	30	52	117	153	164
Biomass	193	284	357	442	532	615
Geothermal	1	1	8	23	38	57
Ocean Energy	0	3	5	9	11	13
RES share	**2.2%**	**3.1%**	**3.8%**	**5.3%**	**6.4%**	**7.1%**

table 9.8: south korea: final energy demand

PJ/a	2009	2015	2020	2030	2040	2050
Total (incl. non-energy use)	**6,189**	**7,172**	**7,926**	**8,986**	**9,555**	**9,887**
Total (energy use)	**4,639**	**5,528**	**6,232**	**7,189**	**7,649**	**7,866**
Transport	**1,226**	**1,363**	**1,430**	**1,611**	**1,772**	**1,861**
Oil products	1,172	1,277	1,323	1,460	1,553	1,505
Natural gas	37	52	59	79	104	138
Biofuels	9	25	38	59	86	131
Electricity	8	9	10	12	29	87
RES electricity	0	0	0	1	4	12
Hydrogen	0	0	0	0	0	0
RES share Transport	**0.7%**	**1.9%**	**2.7%**	**3.8%**	**5.1%**	**7.7%**
Industry	**1,673**	**2,164**	**2,560**	**2,961**	**3,154**	**3,242**
Electricity	718	918	1,099	1,278	1,303	1,316
RES electricity	8	33	57	133	172	185
District heat	211	215	243	263	274	277
RES district heat	29	58	67	75	82	85
Coal	203	293	347	405	457	484
Oil products	211	309	361	421	463	479
Gas	266	341	404	476	520	540
Solar	0	0	0	0	0	0
Biomass and waste	64	88	107	119	138	145
Geothermal	0	0	0	0	0	0
Hydrogen	0	0	0	0	0	0
RES share Industry	**6.0%**	**8.3%**	**9.0%**	**11.0%**	**12.5%**	**12.8%**
Other Sectors	**1,741**	**2,000**	**2,243**	**2,618**	**2,722**	**2,763**
Electricity	735	854	1,014	1,313	1,339	1,353
RES electricity	8	30	52	137	177	190
District heat	78	88	95	100	106	108
RES district heat	16	33	35	37	40	40
Coal	37	26	23	21	21	23
Oil products	365	446	477	502	525	524
Gas	503	549	586	612	639	645
Solar	1	1	1	1	2	2
Biomass and waste	20	35	46	66	88	107
Geothermal	1	1	1	2	2	3
RES share Other Sectors	**2.7%**	**5.0%**	**6.1%**	**9.3%**	**11.4%**	**12.3%**
Total RES	**156**	**305**	**405**	**631**	**792**	**898**
RES share	**3.4%**	**5.5%**	**6.5%**	**8.8%**	**10.4%**	**11.4%**
Non energy use	**1,549**	**1,644**	**1,693**	**1,796**	**1,906**	**2,022**
Oil	1,534	1,626	1,674	1,776	1,885	1,999
Gas	0	0	0	0	0	0
Coal	16	18	19	20	21	22

south korea: energy [r]evolution scenario

table 9.9: south korea: electricity generation

TWh/a	2009	2015	2020	2030	2040	2050
Power plants	**417**	**465**	**477**	**473**	**451**	**421**
Coal	187	183	178	136	86	19
Lignite	7.2	6.0	4.0	0	0	0
Gas	55	82	101	98	87	63
Oil	15	13	11	1.0	0	0
Diesel	0	0	0	0	0	0
Nuclear	148	152	133	76	0	0
Biomass	0.5	3.7	4.6	4.9	5.0	5.0
Hydro	2.8	4.0	4.3	4.9	5.5	6.1
Wind	0.7	8.0	20	89	162	215
PV	0.6	12	18	57	95	100
Geothermal	0	0.1	0.3	1.7	3.9	5.2
Solar thermal power plants	0	0	0	0	0	0
Ocean energy	0	1.4	2.4	4.4	6.0	7.5
Combined heat & power production	**35**	**45**	**51**	**67**	**80**	**90**
Coal	2.8	2.8	2.6	0	0	0
Lignite	0.6	0.3	0	0	0	0
Gas	27	35	39	37	38	37
Oil	4.7	5.2	4.8	3.7	2.0	0
Biomass	0.2	1.3	4.9	23	35	42
Geothermal	0	0.1	0.2	2.3	6.1	11
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	14	20	23	29	33	38
Autoproducers	21	25	28	38	47	52
Total generation	**452**	**510**	**528**	**540**	**531**	**511**
Fossil	299	327	340	276	213	119
Coal	190	186	180	136	86	19
Lignite	7.8	6.3	4.0	0	0	0
Gas	82	117	140	135	125	100
Oil	20	18	16	4.7	2.0	0
Diesel	0	0	0	0	0	0
Nuclear	148	152	133	76	0	0
Hydrogen	0	0	0	0	0	0
Renewables	**4.8**	**31**	**55**	**187**	**318**	**392**
Hydro	2.8	4.0	4.3	4.9	5.5	6.1
Wind	0.7	8.0	20	89	162	215
PV	0.6	12	18	57	95	100
Biomass	0.7	5.0	10	28	40	47
Geothermal	0	0.2	0.5	4.0	10	16
Solar thermal	0	0	0	0	0	0
Ocean energy	0	1.4	2.4	4.4	6.0	7.5
Distribution losses	17	20	21	23	21	20
Own consumption electricity	29	33	32	23	14	6.8
Electricity for hydrogen production	0	0	0	2	4	7
Final energy consumption (electricity)	**406**	**456**	**475**	**492**	**492**	**477**
Fluctuating RES (PV, Wind, Ocean)	1	21	40	150	263	323
Share of fluctuating RES	0.3%	4.2%	7.7%	27.9%	49.5%	63.1%
RES share	**1.1%**	**6.0%**	**10.4%**	**34.7%**	**59.9%**	**76.6%**
'Efficiency' savings (compared to Ref.)	**0**	**39**	**121**	**261**	**314**	**396**

table 9.10: south korea: heat supply

PJ/a	2009	2015	2020	2030	2040	2050
District heating plants	**121**	**131**	**139**	**158**	**188**	**173**
Fossil fuels	46	47	43	27	15	3
Biomass	75	82	90	106	124	109
Solar collectors	0	1	5	19	34	43
Geothermal	0	0	1	6	15	17
Heat from CHP	**172**	**192**	**233**	**352**	**372**	**396**
Fossil fuels	168	179	192	156	143	120
Biomass	4	12	39	175	175	179
Geothermal	0	1	2	21	55	97
Fuel cell (hydrogen)	0	0	0	0	0	0
Direct heating[1]	**1,371**	**1,570**	**1,608**	**1,486**	**1,236**	**965**
Fossil fuels	1,301	1,447	1,412	1,102	674	328
Biomass	67	106	143	191	218	217
Solar collectors	1	12	32	105	186	223
Geothermal[2]	1	5	21	89	159	197
Total heat supply[1]	**1,664**	**1,893**	**1,980**	**1,995**	**1,796**	**1,534**
Fossil fuels	1,515	1,673	1,647	1,285	832	452
Biomass	146	200	272	471	516	504
Solar collectors	1	14	37	124	220	266
Geothermal[2]	1	6	24	115	228	311
Fuel cell (hydrogen)	0	0	0	0	0	0
RES share (including RES electricity)	**9.0%**	**11.6%**	**16.8%**	**35.6%**	**53.7%**	**70.5%**
'Efficiency' savings (compared to Ref.)	**0**	**123**	**289**	**525**	**973**	**1,370**

1) including cooling. 2) including heat pumps

table 9.11: south korea: CO_2 emissions

MILL t/a	2009	2015	2020	2030	2040	2050
Condensation power plants	**210**	**207**	**203**	**149**	**100**	**38**
Coal	171	161	153	111	67	14
Lignite	7	6	4	0	0	0
Gas	21	31	39	37	33	24
Oil	10	8	7	1	0	0
Diesel	0	0	0	0	0	0
Combined heat & power production	**22**	**28**	**27**	**21**	**19**	**15**
Coal	6	5	4	0	0	0
Lignite	2	1	0	0	0	0
Gas	10	18	20	19	17	15
Oil	4	5	3	2	1	0
CO_2 emissions power generation (incl. CHP public)	**231**	**234**	**229**	**170**	**119**	**53**
Coal	178	166	156	111	67	14
Lignite	9	7	4	0	0	0
Gas	31	49	59	56	51	39
Oil & diesel	14	13	11	3	1	0
CO_2 emissions by sector	**501**	**520**	**504**	**386**	**255**	**120**
% of 1990 emissions	210%	218%	211%	161%	107%	50%
Industry	66	77	74	59	38	21
Other sectors	60	63	60	42	24	11
Transport	86	93	92	81	62	33
Power generation (incl. CHP public)	214	216	212	156	106	44
Other conversion	75	71	66	47	25	11
Population (Mill.)	48.0	49	50	50	49	47
CO_2 emissions per capita (t/capita)	**10.5**	**10.6**	**10.1**	**7.7**	**5.2**	**2.6**

table 9.12: south korea: installed capacity

GW	2009	2015	2020	2030	2040	2050
Power plants	**65**	**82**	**90**	**131**	**170**	**181**
Coal	23	22	22	19	14	5.5
Lignite	0.9	0.7	0.5	0	0	0
Gas	15	18	20	21	21	20
Oil	5.6	5.3	4.8	0.5	0	0
Diesel	0	0	0	0	0	0
Nuclear	18	18	16	9.1	0	0
Biomass	0.1	0.5	0.6	0.7	0.7	0.8
Hydro	1.6	1.8	1.9	2.2	2.4	2.7
Wind	0.4	3.9	7.4	31	56	72
PV	0.5	11	16	47	73	77
Geothermal	0	0	0.04	0.2	0.5	0.7
Solar thermal power plants	0	0	0	0	0	0
Ocean energy	0	0.4	0.7	1.3	1.7	2.1
Combined heat & power production	**8.1**	**9.8**	**11**	**13**	**15**	**17**
Coal	0.7	0.7	0.6	0.03	0	0
Lignite	0.14	0	0	0	0	0
Gas	5.8	7.3	8.1	8.0	8.2	7.9
Oil	1.4	1.4	1.2	0.8	0.4	0
Biomass	0.0	0.3	1.2	4.1	5.8	7.0
Geothermal	0	0	0.03	0.4	1.0	1.8
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	4.1	5.3	6.1	6.4	6.9	7.4
Autoproducers	4.0	4.5	5.0	6.9	8.5	9.3
Total generation	**73**	**92**	**101**	**144**	**185**	**197**
Fossil	53	56	58	49	44	33
Coal	24	23	23	19	14	5.5
Lignite	1.0	0.8	0.5	0	0	0
Gas	21	25	28	29	30	28
Oil	7.0	6.7	5.9	1.3	0.4	0
Diesel	0	0	0	0	0	0
Nuclear	18	18	16	9.1	0	0
Hydrogen	0	0	0	0	0	0
Renewables	**2.6**	**18**	**28**	**86**	**141**	**164**
Hydro	1.6	1.8	1.9	2.2	2.4	2.7
Wind	0.4	3.9	7.4	31	56	72
PV	0.5	11	16	47	73	77
Biomass	0.1	0.8	1.8	4.8	6.5	7.8
Geothermal	0	0	0.07	0.6	1.6	2.5
Solar thermal	0	0	0	0	0	0
Ocean energy	0	0.4	0.7	1.3	1.7	2.1
Fluctuating RES (PV, Wind, Ocean)	0.9	15	24	79	130	151
Share of fluctuating RES	1.3%	16.6%	23.5%	54.7%	70.4%	76.6%
RES share	**3.6%**	**19.4%**	**27.2%**	**59.9%**	**76.1%**	**83.2%**

table 9.13: south korea: primary energy demand

PJ/a	2009	2015	2020	2030	2040	2050
Total	**9,614**	**10,330**	**10,347**	**9,592**	**8,195**	**6,917**
Fossil	**7,792**	**8,231**	**8,198**	**6,975**	**5,596**	**3,882**
Hard coal	2,708	2,593	2,484	1,895	1,300	386
Lignite	80	60	36	0	0	0
Natural gas	1,151	1,553	1,740	1,636	1,334	1,047
Crude oil	3,853	4,025	3,938	3,444	2,962	2,450
Nuclear	**1,612**	**1,659**	**1,451**	**833**	**0**	**0**
Renewables	**210**	**440**	**698**	**1,784**	**2,599**	**3,035**
Hydro	10	14	15	18	20	22
Wind	2	29	72	320	583	774
Solar	3	57	102	329	562	626
Biomass	193	324	466	891	945	901
Geothermal	1	11	33	210	468	684
Ocean Energy	0	5	9	16	22	27
RES share	**2.2%**	**4.3%**	**6.7%**	**18.6%**	**31.7%**	**43.9%**
'Efficiency' savings (compared to Ref.)	**0**	**760**	**2,031**	**4,486**	**6,505**	**8,234**

table 9.14: south korea: final energy demand

PJ/a	2009	2015	2020	2030	2040	2050
Total (incl. non-energy use)	**6,189**	**6,852**	**7,041**	**7,021**	**6,545**	**5,872**
Total (energy use)	**4,639**	**5,208**	**5,347**	**5,224**	**4,639**	**3,851**
Transport	**1,226**	**1,343**	**1,360**	**1,331**	**1,202**	**1,021**
Oil products	1,172	1,257	1,234	1,077	801	402
Natural gas	37	51	57	65	71	75
Biofuels	9	26	37	61	61	51
Electricity	8	10	32	122	258	473
RES electricity	0	1	3	42	155	362
Hydrogen	0	0	0	6	11	19
RES share Transport	**0.7%**	**1.9%**	**3.0%**	**7.9%**	**18.5%**	**41.9%**
Industry	**1,673**	**1,984**	**2,075**	**2,086**	**1,834**	**1,527**
Electricity	718	848	874	858	773	651
RES electricity	8	51	91	298	463	499
District heat	211	225	250	331	352	353
RES district heat	29	69	93	215	257	282
Coal	203	252	239	142	35	0
Oil products	211	247	237	164	73	5
Gas	266	310	334	396	349	228
Solar	0	10	23	45	71	85
Biomass and waste	64	92	112	127	132	131
Geothermal	0	1	5	23	50	72
Hydrogen	0	0	0	0	0	0
RES share Industry	**6.0%**	**11.2%**	**15.6%**	**33.9%**	**53.0%**	**70.1%**
Other Sectors	**1,741**	**1,880**	**1,913**	**1,808**	**1,602**	**1,303**
Electricity	735	784	804	793	739	593
RES electricity	8	47	83	275	443	454
District heat	78	93	117	172	201	209
RES district heat	16	39	55	120	158	178
Coal	37	14	0	0	0	0
Oil products	365	419	390	236	112	16
Gas	503	526	522	402	235	141
Solar	1	3	9	60	115	138
Biomass and waste	20	39	61	103	127	123
Geothermal	1	3	10	43	73	84
RES share Other Sectors	**2.7%**	**6.9%**	**11.4%**	**33.2%**	**57.1%**	**75.0%**
Total RES	**156**	**378**	**583**	**1,413**	**2,111**	**2,475**
RES share	**3.4%**	**7.3%**	**10.9%**	**27.1%**	**45.5%**	**64.3%**
Non energy use	**1,549**	**1,644**	**1,693**	**1,796**	**1,906**	**2,022**
Oil	1,534	1,626	1,674	1,776	1,885	1,999
Gas	0	0	0	0	0	0
Coal	16	18	19	20	21	22

south korea: advanced energy [r]evolution scenario

table 9.15: south korea: electricity generation

TWh/a	2009	2015	2020	2030	2040	2050
Power plants	**417**	**466**	**490**	**491**	**481**	**433**
Coal	187	174	167	139	53	0
Lignite	7.2	6.0	4.0	0	0	0
Gas	55	92	106	107	93	25
Oil	15	13	11	0	0	0
Diesel	0	0	0	0	0	0
Nuclear	148	152	133	0	0	0
Biomass	0.5	3.7	9.2	6.0	6.0	6.0
Hydro	2.8	4.0	4.3	5.5	6.1	7.0
Wind	0.7	8.0	30	143	202	255
PV	0.6	12	23	79	102	115
Geothermal	0	0.1	0.3	4.6	7.4	9.9
Solar thermal power plants	0	0	0	0	0	0
Ocean energy	0	1.4	2.4	6.4	11	15
Combined heat & power production	**35**	**45**	**52**	**69**	**84**	**95**
Coal	2.8	2.8	2.6	0	0	0
Lignite	0.6	0.3	0	0	0	0
Gas	27	35	39	38	32	25
Oil	4.7	5.2	4.8	3.7	0.8	0
Biomass	0.2	1.3	5.3	25	43	55
Geothermal	0	0.1	0.2	2.4	7.6	12
Hydrogen	0	0	0	0.3	1.2	2.1
CHP by producer						
Main activity producers	14	20	23	29	33	38
Autoproducers	21	25	29	40	51	57
Total generation	**452**	**511**	**542**	**560**	**565**	**527**
Fossil	299	328	334	288	179	50
Coal	190	177	169	139	53	0
Lignite	7.8	6.3	4.0	0	0	0
Gas	82	127	145	145	125	50
Oil	20	18	16	3.7	0.8	0
Diesel	0	0	0	0	0	0
Nuclear	148	152	133	0	0	0
Hydrogen	0	0	0	0.3	1.2	2.1
Renewables	**4.8**	**31**	**75**	**272**	**385**	**475**
Hydro	2.8	4.0	4.3	5.5	6.1	7.0
Wind	0.7	8.0	30	143	202	255
PV	0.6	12	23	79	102	115
Biomass	0.7	5.0	15	31	49	61
Geothermal	0	0.2	0.5	7.0	15	22
Solar thermal	0	0	0	0	0	0
Ocean energy	0	1.4	2.4	6.4	11	15
Distribution losses	17	20	21	23	21	20
Own consumption electricity	29	33	32	21	12	3.8
Electricity for hydrogen production	0	0	0	4	11	17
Final energy consumption (electricity)	**406**	**457**	**489**	**512**	**521**	**486**
Fluctuating RES (PV, Wind, Ocean)	1	21	55	228	315	385
Share of fluctuating RES	0.3%	4.2%	10.2%	40.8%	55.7%	73.0%
RES share	**1.1%**	**6.0%**	**13.8%**	**48.5%**	**68.1%**	**90.1%**
'Efficiency' savings (compared to Ref.)	**0**	**39**	**121**	**261**	**314**	**396**

table 9.16: south korea: heat supply

PJ/a	2009	2015	2020	2030	2040	2050
District heating plants	**121**	**131**	**140**	**150**	**188**	**166**
Fossil fuels	46	47	44	28	15	3
Biomass	75	82	91	99	123	104
Solar collectors	0	1	5	18	34	41
Geothermal	0	0	1	6	15	17
Heat from CHP	**172**	**192**	**241**	**373**	**414**	**432**
Fossil fuels	168	179	193	156	117	82
Biomass	4	12	45	194	225	243
Geothermal	0	1	2	22	69	99
Fuel cell (hydrogen)	0	0	0	1	4	6
Direct heating1)	**1,371**	**1,571**	**1,599**	**1,472**	**1,194**	**937**
Fossil fuels	1,301	1,440	1,353	984	501	100
Biomass	67	105	162	237	268	257
Solar collectors	1	16	51	137	209	252
Geothermal2)	1	10	34	114	210	315
Hydrogen	0	0	0	0	6	12
Total heat supply1)	**1,664**	**1,893**	**1,980**	**1,995**	**1,796**	**1,534**
Fossil fuels	1,515	1,666	1,590	1,167	634	186
Biomass	146	199	298	531	616	605
Solar collectors	1	17	56	154	243	294
Geothermal2)	1	11	37	142	294	431
Fuel cell (hydrogen)	0	0	0	1	10	19
RES share (including RES electricity)	**9.0%**	**12.0%**	**19.7%**	**41.5%**	**64.6%**	**87.8%**
'Efficiency' savings (compared to Ref.)	**0**	**123**	**288**	**525**	**972**	**1,370**

1) including cooling. 2) including heat pumps

table 9.17: south korea: co_2 emissions

MILL t/a	2009	2015	2020	2030	2040	2050
Condensation power plants	**210**	**203**	**195**	**155**	**77**	**9**
Coal	171	153	143	114	41	0
Lignite	7	6	4	0	0	0
Gas	21	35	40	41	36	9
Oil	10	8	7	0	0	0
Diesel	0	0	0	0	0	0
Combined heat & power production	**22**	**28**	**27**	**21**	**15**	**10**
Coal	6	5	3	0	0	0
Lignite	2	1	0	0	0	0
Gas	10	18	20	19	15	10
Oil	4	5	3	2	0	0
CO_2 emissions power generation (incl. CHP public)	**231**	**230**	**222**	**175**	**92**	**20**
Coal	178	158	147	114	41	0
Lignite	9	7	4	0	0	0
Gas	31	53	61	60	50	20
Oil & diesel	14	13	11	2	0	0
CO_2 emissions by sector	**501**	**510**	**472**	**359**	**188**	**44**
% of 1990 emissions	210%	213%	197%	150%	79%	19%
Industry	66	77	74	57	31	10
Other sectors	60	63	55	33	15	6
Transport	86	93	85	69	43	12
Power generation (incl. CHP public)	214	212	204	161	82	13
Other conversion	75	66	53	39	18	4
Population (Mill.)	48.0	49	50	50	49	47
CO_2 emissions per capita (t/capita)	**10.5**	**10.4**	**9.5**	**7.1**	**3.8**	**0.9**

table 9.18: south korea: installed capacity

GW	2009	2015	2020	2030	2040	2050
Power plants	**65**	**83**	**98**	**169**	**195**	**207**
Coal	23	21	21	22	13	0
Lignite	0.9	0.7	0.5	0	0	0
Gas	15	20	21	23	23	21
Oil	5.6	5.7	5.5	0	0	0
Diesel	0	0	0	0	0	0
Nuclear	18	18	16	0	0	0
Biomass	0.1	0.5	1.2	0.8	0.9	1.0
Hydro	1.6	1.8	1.9	2.4	2.7	3.1
Wind	0.4	3.9	10	54	73	89
PV	0.5	11	20	65	78	88
Geothermal	0	0.02	0.04	0.6	1.0	1.3
Solar thermal power plants	0	0	0	0	0	0
Ocean energy	0	0.4	0.7	1.8	3.0	4.3
Combined heat & power production	**8.1**	**9.8**	**11**	**14**	**16**	**17**
Coal	0.7	0.7	0.6	0	0	0
Lignite	0.14	0	0	0	0	0
Gas	5.8	7.4	8.3	8.2	7.1	5.7
Oil	1.4	1.4	1.2	0.8	0.2	0
Biomass	0.0	0.3	1.2	4.4	7.3	9.3
Geothermal	0	0.01	0.03	0.4	1.3	2.1
Hydrogen	0	0	0	0.1	0.2	0.4
CHP by producer						
Main activity producers	4.1	5.4	6.2	6.6	6.9	7.4
Autoproducers	4.0	4.5	5.2	7.3	9.2	10
Total generation	**73**	**93**	**110**	**183**	**211**	**225**
Fossil	53	57	58	54	43	26
Coal	24	22	21	22	13	0
Lignite	1.0	0.8	0.5	0	0	0
Gas	21	27	29	31	30	26
Oil	7.0	7.1	6.6	0.8	0.2	0
Diesel	0	0	0	0	0	0
Nuclear	18	18	16	0	0	0
Hydrogen	0	0	0	0.1	0.2	0.4
Renewables	**2.6**	**18**	**36**	**129**	**167**	**198**
Hydro	1.6	1.8	1.9	2.4	2.7	3.1
Wind	0.4	3.9	10	54	73	89
PV	0.5	11	20	65	78	88
Biomass	0.1	0.8	2.5	5.2	8.1	10
Geothermal	0	0.03	0.07	1.0	2.3	3.4
Solar thermal	0	0	0	0	0	0
Ocean energy	0	0.4	0.7	1.8	3.0	4.3
Fluctuating RES (PV, Wind, Ocean)	0.9	15	31	120	154	181
Share of fluctuating RES	1.3%	16.3%	28.4%	65.8%	73.1%	80.7%
RES share	**3.6%**	**19.1%**	**32.5%**	**70.5%**	**79.3%**	**88.1%**

table 9.19: south korea: primary energy demand

PJ/a	2009	2015	2020	2030	2040	2050
Total	**9,614**	**10,310**	**10,265**	**9,064**	**8,033**	**6,513**
Fossil	**7,792**	**8,202**	**7,946**	**6,720**	**4,808**	**2,711**
Hard coal	2,708	2,503	2,381	1,892	992	22
Lignite	80	60	36	0	0	0
Natural gas	1,151	1,617	1,759	1,708	1,246	532
Crude oil	3,853	4,022	3,770	3,121	2,570	2,157
Nuclear	**1,612**	**1,659**	**1,451**	**0**	**0**	**0**
Renewables	**210**	**448**	**869**	**2,344**	**3,224**	**3,803**
Hydro	10	14	15	20	22	25
Wind	2	29	108	515	727	918
Solar	3	61	139	441	621	708
Biomass	193	324	544	993	1,119	1,092
Geothermal	1	14	54	352	698	1,006
Ocean Energy	0	5	9	23	38	54
RES share	**2.2%**	**4.3%**	**8.5%**	**25.9%**	**40.1%**	**58.4%**
'Efficiency' savings (compared to Ref.)	**0**	**780**	**2,113**	**5,015**	**6,667**	**8,637**

table 9.20: south korea: final energy demand

PJ/a	2009	2015	2020	2030	2040	2050
Total (incl. non-energy use)	**6,189**	**6,852**	**6,991**	**6,921**	**6,375**	**5,592**
Total (energy use)	**4,639**	**5,208**	**5,297**	**5,124**	**4,469**	**3,571**
Transport	**1,226**	**1,343**	**1,310**	**1,231**	**1,032**	**741**
Oil products	1,172	1,253	1,135	917	547	127
Natural gas	37	51	54	59	58	48
Biofuels	9	25	37	56	55	47
Electricity	8	14	83	191	355	494
RES electricity	0	1	11	93	242	445
Hydrogen	0	0	0	8	17	25
RES share Transport	**0.7%**	**2.0%**	**3.7%**	**12.4%**	**29.9%**	**69.4%**
Industry	**1,673**	**1,984**	**2,075**	**2,086**	**1,834**	**1,527**
Electricity	718	848	874	858	773	651
RES electricity	8	51	120	416	527	587
District heat	211	225	250	337	370	374
RES district heat	29	69	93	222	290	322
Coal	203	252	237	113	0	0
Oil products	211	247	237	157	57	5
Gas	266	310	335	407	325	78
Solar	0	10	23	51	83	102
Biomass and waste	64	92	113	130	139	141
Geothermal	0	1	6	32	81	162
Hydrogen	0	0	0	0	7	13
RES share Industry	**6.0%**	**11.2%**	**17.1%**	**40.8%**	**61.3%**	**86.9%**
Other Sectors	**1,741**	**1,880**	**1,913**	**1,808**	**1,602**	**1,303**
Electricity	735	784	804	793	739	593
RES electricity	8	47	111	385	503	534
District heat	78	93	126	192	229	227
RES district heat	16	39	60	134	189	203
Coal	37	8	0	0	0	0
Oil products	365	420	336	114	28	16
Gas	503	522	507	400	191	49
Solar	1	7	28	86	136	150
Biomass and waste	20	39	85	156	180	162
Geothermal	1	6	29	68	100	**108**
RES share Other Sectors	**2.7%**	**7.4%**	**16.3%**	**45.8%**	**69.1%**	**88.7%**
Total RES	**156**	**386**	**716**	**1,831**	**2,540**	**2,997**
RES share	**3.4%**	**7.4%**	**13.5%**	**35.7%**	**56.8%**	**83.9%**
Non energy use	**1,549**	**1,644**	**1,693**	**1,796**	**1,906**	**2,022**
Oil	1,534	1,626	1,674	1,776	1,885	1,999
Gas	0	0	0	0	0	0
Coal	16	18	19	20	21	22

south korea: total new investment by technology

table 9.21: south korea: total investment

MILLION $	2005-2010	2011-2020	2021-2030	2031-2040	2041-2050	2011-2050	2011-2050 AVERAGE PER YEAR
Reference scenario							
Conventional (fossil & nuclear)	**31,879**	**153,655**	**134,903**	**101,892**	**122,556**	**513,007**	**12,825**
Renewables	**8,164**	**28,793**	**27,712**	**25,912**	**21,874**	**104,291**	**2,607**
Biomass	524	2,068	1,213	2,488	1,522	7,290	182
Hydro	435	1,529	1,610	1,675	957	5,770	144
Wind	932	2,067	2,218	2,352	2,405	9,043	226
PV	6,272	20,890	21,270	18,004	15,231	75,394	1,885
Geothermal	0	341	542	420	808	2,111	53
Solar thermal power plants							
Ocean energy		1,898	859	974	952	4,683	117
Energy [R]evolution							
Conventional (fossil & nuclear)	**31,879**	**40,904**	**14,574**	**10,107**	**2,508**	**68,093**	**1,702**
Renewables	**8,164**	**47,090**	**76,908**	**86,041**	**81,781**	**291,821**	**7,296**
Biomass	524	7,060	12,355	11,901	14,651	45,967	1,149
Hydro	435	2,142	2,256	2,346	1,485	8,229	206
Wind	932	4,504	11,684	17,989	21,318	55,495	1,387
PV	6,272	29,255	43,641	43,639	32,489	149,025	3,726
Geothermal	0	923	5,266	8,189	9,714	24,091	602
Solar thermal power plants							
Ocean energy		3,207	1,706	1,977	2,124	9,013	225
Advanced Energy [R]evolution							
Conventional (fossil & nuclear)	**31,879**	**40,555**	**16,480**	**8,195**	**643**	**65,873**	**1,647**
Renewables	**8,164**	**56,327**	**123,445**	**83,524**	**127,421**	**390,717**	**9,768**
Biomass	524	9,143	13,226	17,777	17,785	57,932	1,448
Hydro	435	2,142	3,143	2,429	1,799	9,513	238
Wind	932	4,504	32,920	14,605	42,140	94,168	2,354
PV	6,272	36,408	61,634	34,426	50,931	183,399	4,585
Geothermal	0	923	9,234	10,629	10,885	31,670	792
Solar thermal power plants							
Ocean energy		3,207	3,289	3,658	3,881	14,034	351

notes

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 AN ICEBERG 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** WIND TURBINES ON JEJU ISLAND © M.TUPIKOV/DREAMSTIME, © M.TUPIKOV/DREAMSTIME, © L.WALLER/ISTOCK.