energy [r]evolution

A SUSTAINABLE ASEAN ENERGY OUTLOOK

GWEC
GLOBAL WIND ENERGY COUNCIL

GREENPEACE

report 1st edition 2013 ASEAN 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**?”

partners

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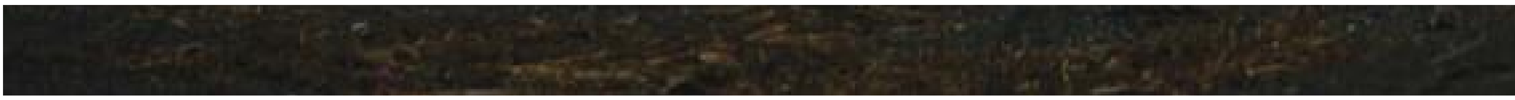

image WIND FARM IN ILOCOS NORTE.

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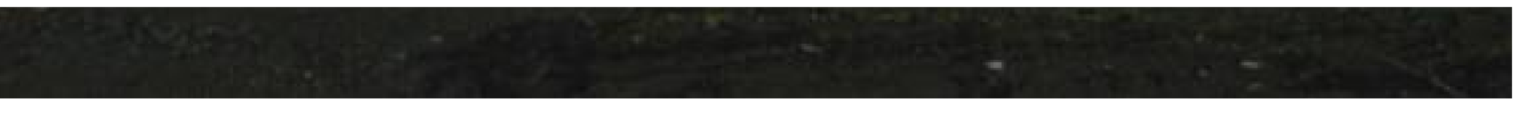

for further information about the global, regional and national scenarios please visit the Energy [R]evolution website: **www.energyblueprint.info/**

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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.


© GP/NICK COBBING

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

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introduction

"NOT LEAST IN TIMES OF TIGHT PUBLIC BUDGETS, CREDIBLE LONG-TERM COMMITMENTS ARE NEEDED. TARGETS HAVE PROVEN TO BE A KEY ELEMENT FOR TRIGGERING THE VITAL INVESTMENTS WHICH ARE NEEDED FOR A TRANSITION TO A SUSTAINABLE ENERGY SYSTEM."

image WIND TURBINE IN NAKHON SI THAMMARAT PROVINCE. PEOPLE OF PAK PHANANG RIVER BASIN OPPOSE ELECTRICITY GENERATING AUTHORITY OF THAILAND'S (EGAT) PLANS TO BUILD A COAL-FIRED POWER PLANT IN THE AREA.

Southeast Asia needs energy – sustainable, clean energy! Renewable energy is the solution to the region's energy needs and it is undeniable that the potential for the 10-member countries of the Association of Southeast Asian Nations (ASEAN) for renewable energy is huge.

Access to sufficient energy is important for making our economies work. But at the same time, the energy sector is one of the main sources of greenhouse gas emissions that put our climate at risk. An overwhelming consensus of scientific opinion has long agreed that climate change is here, caused largely by human activities and that our leaders' inaction will have disastrous consequences. In addition to climate change, other challenges have become equally urgent. Energy demand in the ASEAN region is growing at an unprecedented rate. Uncertainty on the global economy brought on by highly volatile fossil fuel prices, which are continuously rising, has also created a clear incentive for many countries in the region to invest in renewable energy and energy efficiency technologies. While signatories to the United Nations Framework Convention on Climate Change are yet to agree to a fair, ambitious and legally binding global deal, climate change mitigation and adaptation remain high on the political agenda of many countries.

About 28% of the region's total population or approximately 160 million people still remain without access to electricity. Numerous communities, villages and towns are dependent on expensive and imported diesel generators. Currently, much of the ASEAN region's rural energy requirements are met by kerosene lanterns and inefficient smoke stoves which are damaging to health. Other countries that are faced with rapidly growing urban and rural populations have weak, fragile or insufficient grids, thus the proliferation of diesel back-up systems. Increased use of fossil fuels such as oil, coal and gas in the ASEAN region will increase the problem of climate change which is already devastating many lives of poor people. Southeast Asia is a region most vulnerable yet least prepared to deal with the impacts of climate change.

An integrated solution should therefore be implemented across the region to address rising energy demand. This can be realized through a decentralized system owing to the region's geographical conditions and challenges. This in turn should be supplemented by a rural and community-based development approach. The integrated systems will then provide an increasing supply of energy especially for the poor, empower societies and thus create independent communities.

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.

This system can only be successful with the participation of all from the governments and policy makers who need to support this program, to corporations who will provide investments, along with civil society actors who will act as catalysts working alongside communities.

It is under these circumstances that the regional Energy [R]evolution scenario for the ASEAN region is created. The report takes a close look at the possible energy supply strategies for the future and how to develop a sustainable energy and climate policy. Providing modern energy systems that meet basic needs for clean water, health care facilities, cooling and lighting, at the same time preventing the region from doubling or tripling its greenhouse gas emissions from fossil fuels is the main objective of this Energy [R]evolution scenario.

The good news is that renewable energy, combined with the smart use of energy, can deliver over 90% of the ASEAN region's electricity needs by 2050. This is equivalent to over 1,200 GW of installed capacity by 2050. The Greenpeace report "ASEAN Energy [R]evolution" shows that renewable energy is not a dream for the future. It is real, mature and can be deployed on a large scale. Renewable energy technologies produce little or no greenhouse gases and rely on virtually inexhaustible natural elements for their "fuel." Decades of technological progress have seen renewable energy technologies such as wind turbines, solar photovoltaic panels, biomass power plants and solar thermal collectors move steadily into the mainstream. The global market for renewable energy is steadily growing and most technologies are already competitive. For example, the wind power industry has continued its explosive growth in the face of a global recession and a financial crisis, a testament to the inherent attractiveness of renewable energy technology. In 2011, renewable energy investments surged to a record US$ 257 billion, a 17% increase from the previous year despite rapidly falling prices for renewable power equipment. Solar photovoltaic prices dropped by 50% and on-shore wind turbines close to 10% bringing the price of leading renewable power technologies close to grid parity with fossil fuels such as coal and gas.

The renewable energy industry also employs close to 2 million people globally and has become a major feature of national industrial development plans. in the ASEAN region, renewable energy has the potential to deliver over 850,000 jobs to its people by 2020.

However, the window to shift from fossil fuels to renewable is relatively short. Since electricity access is still low in the region, power plants will nevertheless have to be built. A decision to contract a coal-fired power plant today will result in the production of carbon emissions that will last beyond 2050. Whatever plans are made by the ASEAN region's governments and utilities over the next few years will define the energy supply of the region's next generation. Greenpeace believes that this should be the "renewables generation."

This report underscores that the future of renewable energy development in the ASEAN region will depend strongly on the political will of its state governments. By choosing renewable energy, coupled with far-reaching energy efficiency measures, the ASEAN region will be able to contribute in stabilizing global carbon emissions while at the same time achieve economic growth. It's a win-win solution for the climate and the region's right to equitable development. The ASEAN region's people no longer have to literally sit in the dark. Renewable energy can and will have to play a leading role in the region's energy future. For the sake of a sound environment, political stability and thriving economies, now is the time to commit to a truly secure and sustainable energy future – a future built on genuinely clean technologies, economic development and the creation of close to a quarter of a million of new jobs.

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executive summary

"THE SCALE OF THE CHALLENGE REQUIRES A COMPLETE TRANSFORMATION OF THE WAY WE PRODUCE, CONSUME AND DISTRIBUTE ENERGY, WHILE MAINTAINING ECONOMIC GROWTH."

image WORKERS BUILD A WIND TURBINE IN A FACTORY IN PATHUM THANI. THE IMPACTS OF SEA-LEVEL RISE DUE TO CLIMATE CHANGE ARE PREDICTED TO HIT HARD ON COASTAL COUNTRIES IN ASIA, AND CLEAN RENEWABLE ENERGY IS A SOLUTION.

The expert consensus is that a 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.[1] The scale of the challenge requires a complete transformation of the way we produce, consume and distribute energy, while maintaining economic growth. The five key principles behind this Energy [R]evolution will be to:

- Implement renewable solutions, especially through decentralised energy systems and grid expansions
- 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, reduce grid loads and energy losses in distribution. Global investments in 'climate infrastructure' such as smart interactive grids and transmission grids to transport large quantities of offshore wind and concentrated 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 who currently do not have access to electricity.

the energy [r]evolution – key results

Renewable energy sources accounted for 26.7% of the ASEAN region's primary energy demand in 2010. The main sources are bio energy and geothermal followed by hydro. Biomass is almost exclusively "traditional biomass" used for cooking.

Renewables contributed about 14% for electricity generation. About 73% of the primary energy supply today still comes from fossil fuels.

The Energy [R]evolution scenario describes development pathways to a sustainable energy supply, achieving the urgently needed CO_2 reduction target and a fossil fuel phase-out. The results of the Energy [R]evolution scenario which will be achieved through the following measures:

reference
1 IPCC – SPECIAL REPORT RENEWABLES, CHAPTER 1, MAY 2011.

image TEST WINDMILL N90 2500, BUILT BY THE GERMAN COMPANY NORDEX, IN THE HARBOUR OF ROSTOCK. THIS WINDMILL PRODUCES 2.5 MEGA WATT AND IS TESTED UNDER OFFSHORE CONDITIONS. TWO TECHNICIANS WORKING INSIDE THE TURBINE.

- **Curbing energy demand:** The energy demand of the 10 ASEAN countries is projected by combining population development, GDP growth and energy intensity. Under the Reference scenario, total final energy demand increases by 115% from the current 14,819 PJ/a to 31,875 PJ/a in 2050. In the Energy [R]evolution scenario, final energy demand increases at a much lower rate by 23% compared to current consumption and it is expected to reach 18,190 PJ/a by 2050.
- **Controlling power demand:** Under the Energy [R]evolution scenario, due to economic growth, increasing living standards and electrification of the transport sector, electricity demand is exptected to increase in both the industry sector, in the residential and service sectors as well as in the the transport sector. Total electricity demand will rise from 605 TWh/a to 2,275 TWh/a by the year 2050. Compared to the Reference scenario, efficiency measures in the industry, residential and service sectors avoid the generation of about 1,080 TWh/a. This reduction can be achieved in particular by introducing highly efficient electronic devices using the best available technology in all demand sectors.
- **Reducing energy demand for heating and cooling:** Efficiency gains in the building sector are even larger. Under the Energy [R]evolution scenario, demand for heating and climatization is expected to increase until 2030 and remains rather constant afterwards. Compared to the Reference scenario, consumption equivalent to 3,374 PJ/a is avoided through efficiency gains by 2050. As a result of energy-related renovation of the existing stock of residential buildings, the introduction of low energy standards and 'passive climatisation' for new buildings, as well as highly efficient air conditioning systems, enjoyment of the same comfort and energy services will be accompanied by a much lower future energy demand.
- **Electricity generation:** The development of the electricity supply sector is charaterised by a dynamically growing renewable energy market and an increasing share of renewable electricity. This will compensate for the abstinence of nuclear power production in the Energy [R]evolution scenario and reduce the number of fossil fuel-fired power plants required for grid stabilisation. By 2050, 92% of the electricity produced in the ASEAN region will come from renewable energy sources. 'New' renewables – mainly wind, geothermal energy and PV – will contribute 70% to the total electricity generation. Already by 2020 the share of renewable electricity production will be 29% and 60% by 2030. The installed capacity of renewables will reach 427 GW in 2030 and 1,184 GW by 2050.
- **Future costs of electricity generation:** The introduction of renewable technologies under the Energy [R]evolution scenario increase the future costs of electricity generation compared to the Reference scenario until 2020. This difference will be less than 0.8 US$ct/kWh up to 2020, however. Because of high prices for conventional fuels and the lower CO_2 intensity of electricity generation, from 2030 on electricity generation costs will become economically favourable under the Energy [R]evolution scenario and by 2050 costs will be 7.5 US$ct/kWh below those in the Reference version.
- **The future electricity bill:** Under the Reference scenario, the 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$ 96 billion per year to more than US$ 555 billion in 2050, compared to US$ 327 billion in the E[R] scenario. The Energy [R]evolution scenario not only complies with the ASEAN region's CO_2 reduction targets, but also helps to stabilise energy costs and relieve the economic pressure on society. Increasing energy efficiency and shifting energy supply to renewables lead to long term costs for electricity supply that are more than 41% lower than in the Reference scenario.
- **Future investment in power generation:** It would require US$ 2,752 billion in investment for the Energy [R]evolution scenario to become reality - including investments for replacement after the economic lifetime of the plants - approximately US$ 67.1 billion per year or US$ 1,470 billion more than in the Reference scenario (US$ 1,282 billion). Under the Reference version, the levels of investment in conventional power plants add up to almost 59% while approximately 41% would be invested in renewable energy until 2050. Under the Energy [R]evolution scenario, however, the ASEAN region would shift almost 90% of the entire investment towards renewables. Until 2030, the fossil fuel share of power sector investment would be focused mainly on gas power plants.
- **Fuel costs savings:** Because renewable energy has no fuel costs, the fuel cost savings in the Energy [R]evolution scenario reach a total of US$ 2,698 billion up to 2050, or US$ 69.2 billion per year. Total fuel cost savings therefore would cover almost twice the additional investmentss compared to the Reference scenario. 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.
- **Energy supply for heating and cooling:** Today, renewables meet 47% of the ASEAN region's energy demand for heating and cooling, the main contribution coming from the use of biomass. Dedicated support instruments are required toensure a dynamic development in particular for renewable cooling technologies (e.g. solar cooling) and renewable process heat production. In the Energy [R]evolution scenario, renewables provide 52% of the ASEAN region's total heat demand in 2030 and 78% in 2050. Energy efficiency measures help to reduce the currently growing energy demand for heating and cooling by 28 % in 2050 (relative to the reference scenario), in spite of improving living standards and economic growth. In the industry sector solar collectors, geothermal energy (incl. heat pumps) as well as electricity and hydrogen from renewable sources are increasingly substituting for fossil fuel-fired systems. A shift from coal and oil to natural gas in the remaining conventional applications leads to a further reduction of CO_2 emissions.

- **Future investments in the heating and cooling sector:** Renewable heating technologies are extremely variable, from low tech biomass stoves and unglazed solar collectors to very sophisticated enhanced geothermal systems and solar cooling systems. Thus it can only roughly be calculated, that the Energy [R]evolution scenario in total requires around US$ 1,258 billion to be invested in renewable heating technologies until 2050 (including investments for replacement after the economic lifetime of the plants) - approximately US$ 31 billion per year.
- **Future employment in the energy sector:** Energy sector jobs in the ASEAN region are higher in the Energy [R]evolution scenario at every stage in the projection. In 2010, 1.1 million people were employed in the energy sector. Due to strong growth in the renewable energy sector, jobs in the Energy [R]evolution scenario increase by 238 thousand (21%) to 1.4 million in 2015, while jobs in the Reference Scenario fall slightly in the same period. After 2015, jobs in both scenarios fall, reflecting the fact that labour intensity is reduced as prosperity in the region grows, although losses in the Energy [R]evolution scenario are somewhat compensated for by strong growth in renewable energy. In 2020, there are nearly 1.3 million jobs in the Energy [R]evolution scenario, and 1 million in the Reference scenario. In 2030, there are approximately 1.1 million jobs in the Energy [R]evolution scenarios, and 0.9 million jobs in the Reference scenario.
- **Transport:** Due to population increase, GDP growth and higher living standards, energy demand from the transport sector is expected to increase in the Energy [R]evolution scenario by 13% to 4,411 PJ/a in 2050, 480 PJ/a higher than today's levels (3,891 PJ/a). However, in 2050 efficiency measures and mode shifts will save 55% compared to the Reference scenario (9,788 PJ/a). Highly efficient propulsion technology with hybrid, plug-in hybrid and battery-electric power trains will bring large efficiency gains. By 2030, electricity will provide 10% of the transport sector's total energy demand in the Energy [R]evolution, while in 2050 the share will be 27%.
- **Primary energy consumption:** Under the Energy [R]evolution scenario, primary energy demand will increase by 22% from today's 23,227 PJ/a to 28,302 PJ/a. Compared to the Reference scenario, overall primary energy demand will be reduced by 43% in 2050 under the Energy [R]evolution scenario (REF: 49,621 PJ in 2050).
- **Development of CO_2 emissions:** Whilst the ASEAN region's emissions of CO_2 will increase by 144% between 2010 and 2050 under the Reference scenario, under the Energy [R]evolution scenario they will decrease from 1,164 million tonnes in 2010 to 296 million tonnes in 2050. Annual per capita emissions will drop from 2.0 tonne to 0.4 tonne. In spite of the abstinence of nuclear power production and increasing energy demand, CO_2 emissions will decrease in the electricity sector. In the long run efficiency gains and the increased use of renewable in vehicles will reduce emissions also in the transport sector. With a share of 39% of CO_2, the industry sector will be the largest sources of emissions in 2050. By 2050, the ASEAN region's CO_2 emissions are 26% below 1990 levels.

policy changes

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

1. Phase out all subsidies for fossil fuel consumption and production because these subsidies often benefit more affluent segments of society rather than the poor. It will help create a level-playing field where renewable energy technologies can compete with other energy carriers. It is also important to take into account all of the external benefits and costs of all energy technologies so that the so-called "cheapness" of coal will be exposed and the supposed "expensiveness" of RE debunked.
2. Ensure that renewable energy incentives do not shift a disproportionate share of the additional financial cost to the poorest households. Impacts can be minimized by adopting policy support to national development objectives.
3. To help advance electrification and socio-economic objectives, off-grid applications of renewable energy must be prioritized.
4. Guarantee priority access to the grid for renewable power generators
5. Renewable energy policies that are predictable and consistent with emerging but common energy policy frameworks in the region should be harmonized. Such measure sends a strong signal to potential investors about the stability of the support system. The effectiveness of fostering market uptake depends more on design and implementation rather than on specific type of incentive. On the other hand, a feed-in tariff policy in the ASEAN region countries will help boost the renewable energy sector in countries that warrant the financial and technological support from developed countries.
6. Design complementing renewable energy and climate change policies to derive maximum benefit from climate change financing options. These complementary renewable energy and climate policies can be the main vehicles for ASEAN countries NAMAs or nationally appropriate mitigation actions as part of our region's commitment to reduce greenhouse gas. And because renewable energy policies contribute to carbon dioxide emissions reductions that, although voluntary, are measurable, reportable and verifiable, this will provide an additional impetus to the on-going international climate negotiations.
7. Implement efficiency standards for all energy consuming appliances, buildings and vehicles.

climate and energy policy

THE UNFCCC AND THE KYOTO PROTOCOL

INTERNATIONAL ENERGY POLICY

ASEAN CLIMATE PROTECTION AND ENERGY POLICY

RENEWABLE ENERGY TARGETS

POLICY CHANGES IN THE ENERGY SECTOR

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image GREENPEACE DONATES A SOLAR POWER SYSTEM TO A COASTAL VILLAGE IN ACEH, INDONESIA, ONE OF THE WORST HIT AREAS BY THE TSUNAMI IN DECEMBER 2004. IN COOPERATION WITH UPLINK, A LOCAL DEVELOPMENT NGO, GREENPEACE OFFERED ITS EXPERTISE ON ENERGY EFFICIENCY AND RENEWABLE ENERGY AND INSTALL RENEWABLE ENERGY GENERATORS FOR ONE OF THE BADLY HIT VILLAGES BY THE TSUNAMI.

If we do not take urgent and immediate action to protect the climate, the threats from climate change 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.

1.1 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 1.1: 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.[2]

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 an average temperature increase of 2°C 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.

1.2 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.

reference
2 UNEP EMISSIONS GAP REPORT.

image PART-MADE WIND TURBINES FOR AN OFFSHORE WIND FARM AT MIDDELGRUNDEN, CLOSE TO COPENHAGEN, DENMARK

1.3 ASEAN climate protection and energy policy

The region that makes up the 10 countries of the Association of Southeast Asian Nations (ASEAN) lies within the waters of the Pacific Ocean, Indian Ocean, Andaman Sea and South China Sea. It has an extensive coastline measuring approximately 173,000 kilometers. As of 2007, the population stands at 563 million people with an average growth rate of 2% per year, higher than the global average of 1.4%. Because of its extensive coastline, it is particularly vulnerable to the impacts of climate change due to the concentration of people and economic activities in the coastal areas.

According to the Intergovernmental Panel on Climate Change (IPCC) during the past several decades an increasing trend in mean temperature in the region has been observed with 0.1-0.3 C increase per decade recorded between 1951 and 2000. Other observable trends include decreasing rainfall and rising sea levels at 1-3 mm per year, increase in frequency and intensity of extreme weather events, including more heat waves expressed in the increase in the number of hot days and warm nights and decreases in the number of cold days and cold nights. There has also been a significant increase in the number of heavy precipitation events and an increase in the number of tropic cyclones. All these climatic changes were manifest recently with massive flooding, landslides and droughts across the region causing hundreds of thousands worth of damage to property, assets and human life.[3]

Even with these already serious impacts, climate change is projected to intensify even more in the coming decades. Relative to the baseline period of 1961-1990, the projection for Southeast Asia is an increase of 3.77 C in mean surface air temperature by the end of this century under a high emissions scenario. The projected increase in global average sea level of 59 centimeters by 2100, or even higher than 1 meter as suggested most recently by climate experts, could have dire consequences for Southeast Asia. The Asian Development Bank's report[4] outlines a summary of projected climate impacts in the region based on IPCC and other studies:

- Food security will be threatened as climate change is likely to lead to a significant decrease in grain production potential in the region by the end of the century. Due to the combined effect of increasing CO_2 fertilization, thermal stress and water scarcity, rice yields in Asia could decline by 3.8% by 2100.[5] Other studies predict that crop yield in Vietnam and Thailand could decline by 15% and 26% respectively.[6] A decline of crop yield of this magnitude could mean a drop in real gross domestic product of 1.4% on an annual basis by 2080.[7]
- Doubling of CO_2 could lead to the extinction of around 100 to over 2800 plant species in the Indo-Myanmar region.[8]
- Some parts of Southeast Asia already have high risks of mortality and morbidity due to climate change-induced diarrhea and malnutrition. Poor water quality may lead to more water-related infectious diseases as a result of flooding and sea-level rise.
- There will be significant changes in the monthly flow of the Mekong River by 2070-2099 such that there could be an increase by 41% in the basin and by 19% in the delta during maximum flows. This suggests that there could be increased risk to floods during the rainy season. On the other hand, the minimum monthly flow could decline by 24% in the basin and as much as 29% in the delta which has an implication of possible water shortages during the dry season.[9]
- Increase of 13 to 94 million people flooded in coastal areas of South, Southeast and East Asia due to sea level rise even on most conservative emissions scenario. Of this increase, 20% is predicted to be in Indonesia, Philippines, Thailand and Vietnam.[10]

With the region already experiencing and still expected to face such severe climate impacts in the coming decades, the ASEAN region must play a stronger, more significant role in building resilience and taking appropriate mitigation actions to fight climate change.

1.3.1 international and ASEAN climate policy

As the ASEAN region is becoming increasingly aware of the huge costs of climate impacts in the region, it has started to undertake regional cooperation on mitigation and adaptation measures. Climate policies are slowly cascading from the realm of international policy into regional endeavours. ASEAN leaders officially recognized climate change threats to the environment and economic development only in November 2007 through the ASEAN Declaration on Environmental Sustainability during the 13th ASEAN Summit in Singapore.[11] That same month, Indonesia hosted the 13th session of the Conference of Parties (COP) to the United Nations Framework Convention on Climate Change (UNFCCC) which set in place the Bali Roadmap that initiated current talks to conclude a new global climate change deal in Copenhagen by December 2009 during COP15. Unfortunately, signatories to the UNFCCC failed to reach a fair, ambitious and globally binding deal in Copenhagen. Instead, the new deadline for a legally binding global climate deal has been set for 2015.

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ASEAN also agreed to enhance regional cooperation by creating the ASEAN Climate Change Initiative (ACCI). The ACCI is envisioned to be a consultative platform to further strengthen the region's capacity in both mitigation and adaptation efforts through cooperation. For that purpose, an ASEAN Working Group on Climate Change was established to implement the ACCI. The extent of collaboration through the ACCI includes policy and strategy formulation, information sharing, capacity building and technology transfer.[12] One of the strengths of the ACCI is that it is legally grounded on the 2007 ASEAN Charter which is a legally binding agreement. By passing the Charter, the ASEAN region's leaders had indeed indicated their commitment to legal obligations and rights.[13] The new ASEAN Charter also provides for a legal framework for incorporating ASEAN decisions, such as the ACCI and other policies, treaties and conventions, into the national legislation and policy of member countries.[14]

While climate adaptation and building resilience seems to be the priority for Southeast Asia, the region also has an important role to play in contributing to global greenhouse gas mitigation efforts by pursuing a low-carbon development pathway. In 2000, the ASEAN region's GHG emissions reached 5,187 million tons of carbon dioxide, equivalent to 12% of the world's GHG emissions. This translates to a 27% increase in emissions from 1990 levels, faster than the global average. Energy-related emissions contributed 15% to the region's GHG emissions with the fastest growth rate at 83% during 1990-2000.[15]

The debate, however, on mitigating GHG -- particularly CO_2 -- has become a development issue. How much growth can each ASEAN member country pursue given the constraints on the limiting capacity of carbon space in the atmosphere? The key argument is that developed countries had enjoyed these rights with their historically unconstrained industrial growth and have now consumed much of the atmospheric carbon space. This is now limiting the development potential of developing countries such as those in the ASEAN region given that they too have to the right to equitable development. This draws attention to the stark reality that climate change is a wholesale problem that requires a wholesale solution, one that needs the absolute cooperation of each country. The ASEAN region, with its rapid pace of economic and population growth should play an important part of this global solution since the region's carbon emissions are likely to grow further and because a low-carbon development path is possible.

1.3.2 ASEAN energy policy

The ASEAN Plan of Action for Energy Cooperation (APAEC) 2010-2015 is the third of a series of regional energy implementation plans. It covers the energy component of the ASEAN Economic Blueprint 2015 and aims to enhance energy security, accessibility and sustainability for the ASEAN region to accelerate implementation plans of the following program areas:

- ASEAN Power Grid (APG) – Efficient, reliable, and resilient electricity infrastructure are essential for stimulating regional economic growth and development. Electricity access is roughly 66% of the ASEAN population and is accessible through grid power supply, stand-alone and distributed power generation systems. By integrating the national power grids of the member states, electricity trade across borders may be enhanced.
- Trans-ASEAN Gas Pipeline (TAGP) – To achieve long-term security, availability and reliability of energy supply particularly in oil and gas, the establishment of the interconnecting arrangements are emphasized. The TAGP aims to interconnect gas pipeline infrastructure of ASEAN member states and to enable gas to be transported across borders.
- Coal and Clean Coal Technology – This program area aims to promote the development and use of new coal technologies and to facilitate intra-ASEAN coal trade towards enhancing regional energy security needs as well as to cooperate and promote development and utilization of coal.
- Renewable Energy – The objective is to institute and maintain sustainable development on the use of renewable energy technologies. ASEAN has a collective target of 15% total RE power installed capacity by 2015.
- Energy Efficiency and Conservation – Includes capacity building and increased private sector involvement, enhancing public awareness and expanding markets for energy efficient products. ASEAN has an aspirational goal of reducing energy intensity of at least 8% by 2015 from 2005 levels.
- Regional Energy Policy and Planning – Aims to enhance cooperation on regional energy policy analysis and planning towards sustainable development and to effectively manage the implementation of APAEC.
- Civilian Nuclear Energy – The objective of ASEAN is to cooperate on a voluntary and non-binding basis, the sharing and exchange of information and knowledge, technical assistance, networking and training on nuclear energy for power generation.

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image PART-MADE WIND TURBINES FOR AN OFFSHORE WIND FARM AT MIDDELGRUNDEN, CLOSE TO COPENHAGEN, DENMARK

1.3.3 renewable energy policy frameworks in ASEAN 6[16]

Decision makers in most ASEAN countries have fostered deployment of RE technologies in a more concerted manner through policy implementation. The driving forces for this enhanced cooperation are the rising costs of fossil fuel imports, environmental impacts of fossil fuel use and potential effects of climate change.

Countries in the region have put significant effort into setting renewable energy targets and are introducing supportive policy frameworks to attract private sector investment. ASEAN-6 countries have already adopted medium- and long-term targets for renewable energy, with some countries showing much more ambition than others. In this regard, Thailand is leading the pack.[17] Targets are important indications of a country's willingness and determination to tap its renewable energy potential. On the other hand, Indonesia, Singapore and Thailand have announced carbon dioxide emissions reduction targets in support of the Copenhagen Accord.[18]

To ensure appropriate conditions to tap renewable energy potential, an effective system of financial and non-financial incentives must also be in place. Price support systems for renewable energy have recently been introduced in many ASEAN countries. Thailand introduced the adder model of feed-in tariffs (FIT) in 2007, while Indonesia introduced a FIT for geothermal electricity in 2010 and micro-hydro in 2012. Malaysia and the Philippines introduced the FITs in 2011 and 2012 respectively. Tax exemptions for specific renewable energy technologies are also employed in Malaysia, the Philippines and Indonesia. Other incentives include capital costs grant in Thailand and research and development incentives in Singapore.

Non-financial support mechanisms are also in place in Malaysia, Indonesia and Thailand including standard power purchase agreements, preferential arrangements for small generators and information support. Initiatives such as these aid small and independent power producers to enter the market more easily and reduce barriers that are specific to non-liberalized energy markets.

1.3.4 demands for the ASEAN energy sector

Greenpeace and the renewable industry have a clear agenda for changes which need to be made in energy policy to encourage a shift to renewable sources. In order to achieve large-scale diffusion of renewables and be well on the way to low-carbon development, ASEAN should:

- Phase out all subsidies for fossil fuel consumption and production because these subsidies often benefit more affluent segments of society rather than the poor. It will help create a level-playing field where renewable energy technologies can compete with other energy carriers. It is also important to take into account all of the external benefits and costs of all energy technologies so that the so-called "cheapness" of coal will be exposed and the supposed "expensiveness" of RE debunked.
- Ensure that renewable energy incentives do not shift a disproportionate share of the additional financial cost to the poorest households. Impacts can be minimized by adopting policy support to national development objectives.
- To help advance electrification and socio-economic objectives, off-grid applications of renewable energy must be prioritized.
- Guarantee priority access to the grid for renewable power generators
- Renewable energy policies that are predictable and consistent with emerging but common energy policy frameworks in the region should be harmonized. Such measure sends a strong signal to potential investors about the stability of the support system. The effectiveness of fostering market uptake depends more on design and implementation rather than on specific type of incentive. On the other hand, a feed-in tariff policy in the ASEAN region countries will help boost the renewable energy sector in countries that warrant the financial and technological support from developed countries.
- Design complementing renewable energy and climate change policies to derive maximum benefit from climate change financing options. These complementary renewable energy and climate policies can be the main vehicles for ASEAN countries NAMAs or nationally appropriate mitigation actions as part of our region's commitment to reduce greenhouse gas. And because renewable energy policies contribute to carbon dioxide emissions reductions that, although voluntary, are measurable, reportable and verifiable, this will provide an additional impetus to the on-going international climate negotiations.
- Implement efficiency standards for all energy consuming appliances, buildings and vehicles.

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16 ONLY INCLUDES INDONESIA, MALAYSIA, THE PHILIPPINES, SINGAPORE, THAILAND AND VIETNAM SINCE ENERGY DATA ACCESS FOR THE OTHER FOUR COUNTRIES PROVIDE A SUBSTANTIAL CHALLENGE.

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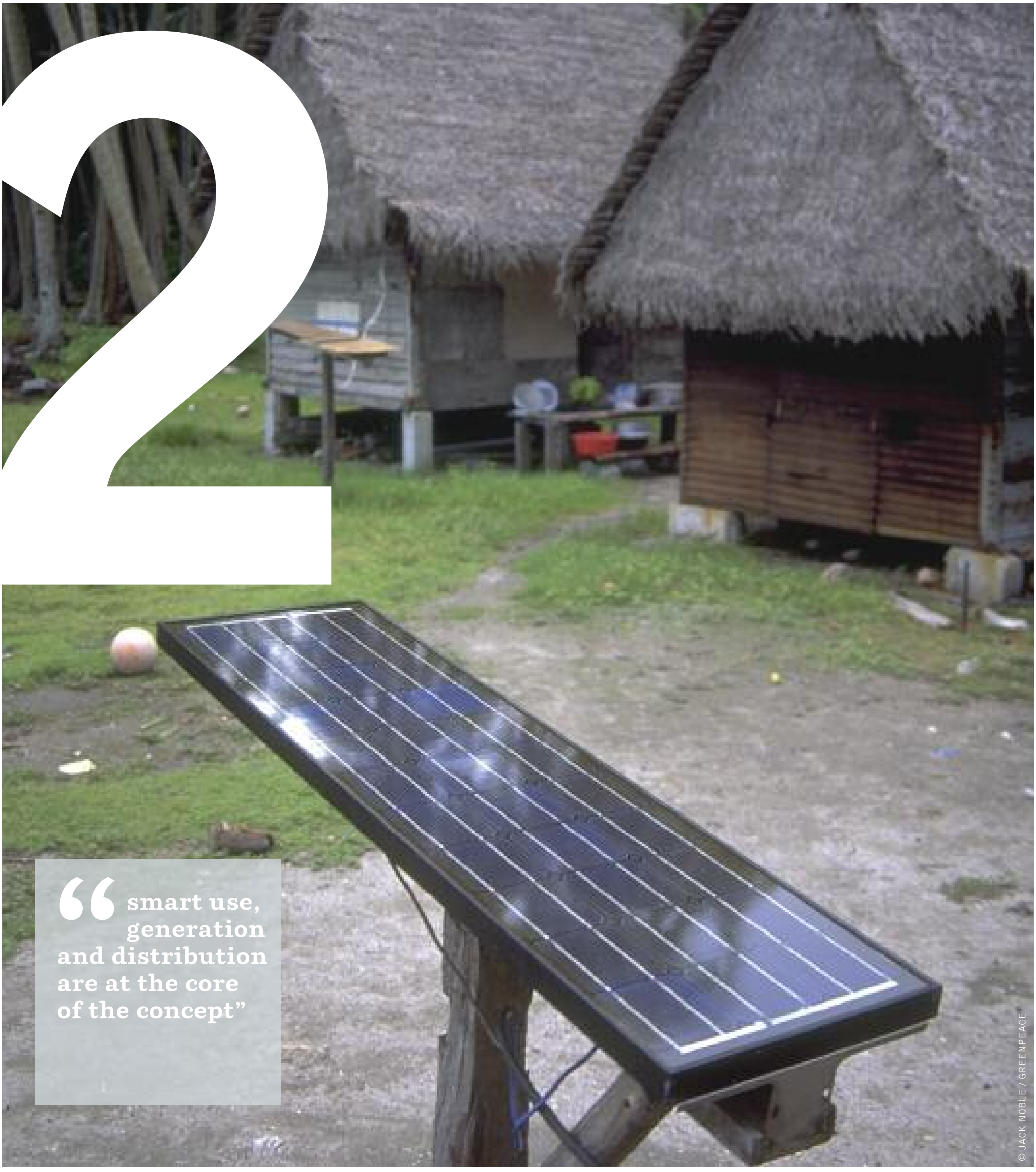
2

the energy [r]evolution concept

2



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

© JACK NOBLE / GREENPEACE

image PHOTOVOLTAIC (SOLAR) PANEL ON TOBI ISLAND, BELAU ISLANDS, PACIFIC. THESE PANELS PRODUCE ALL THE ELECTRICITY USED ON TOBI ISLAND.

The expert consensus is that a 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, while 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°C, above which the impacts become devastating. This chapter explains the basic principles and strategic approach of the Energy [R]evolution concept, which have formed the 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 develop 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 therefore there are changes both to the way that energy is produced and distributed.

2.1 key principles

The Energy [R]evolution can be achieved by adhering to five key principles:

1. **Respect natural limits – phase out fossil fuels by the end of this century** We must learn to respect natural limits. There is only so much carbon that the atmosphere can absorb. Each year we emit 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 global Energy [R]evolution 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 global Energy [R]evolution scenario has a target to achieve energy equity as soon as technically possible. By 2050 the average annual 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]

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

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

Sheikh Zaki Yamani, former Saudi Arabian oil minister

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

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

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

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

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

Step 1: energy efficiency 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 global Energy [R]evolution 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 2.1: centralised generation systems waste more than two thirds of their original energy input

61.5 units LOST THROUGH INEFFICIENT GENERATION AND HEAT WASTAGE

3.5 units LOST THROUGH TRANSMISSION AND DISTRIBUTION

13 units WASTED THROUGH INEFFICIENT END USE

100 units >> ENERGY WITHIN FOSSIL FUEL

38.5 units >> OF ENERGY FED TO NATIONAL GRID

35 units >> OF ENERGY SUPPLIED

22 units OF ENERGY ACTUALLY UTILISED

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

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.

Step 2: the renewable energy [r]evolution Decentralised energy and large scale renewables In order to achieve higher fuel efficiencies and reduce distribution losses, the Energy [R]evolution scenario makes extensive use of Decentralised Energy (DE).This term 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 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.

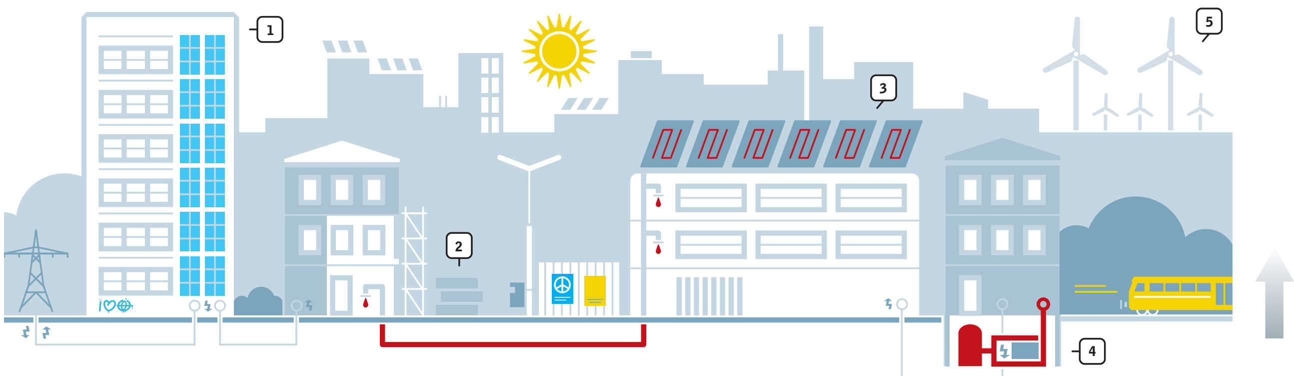
Cogeneration (CHP) The increased use of combined heat and power generation (CHP) will improve the supply system's energy conversion efficiency, whether using natural gas or biomass. In the longer term, a decreasing demand for heat and the large potential for producing heat directly from renewable energy 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 [R]evolution scenario, the majority of electricity will be produced from renewable energy sources. The anticipated growth of electricity use in transport will further promote the effective use of renewable power generation technologies.

figure 2.2: a decentralised energy future

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

city



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

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, other electricity users need to make large efficiency gains. In this study, biomass is primarily committed to stationary applications; the use of biofuels for transport is limited by the availability of sustainably grown biomass and only for heavy duty vehicles, ships and aviation. In contrast to previous versions of Energy [R]evolution scenarios, first generation biofuels are entirely banned now for use in private cars. 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. When combined with 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 [R]evolution scenario will also result in a dramatic change in the business model of energy companies, utilities, fuel suppliers and the manufacturers of energy technologies. Decentralised energy generation and large solar or offshore wind arrays which operate in remote areas, without the need for any fuel, will have a profound impact on the way utilities operate in 2020 and beyond.

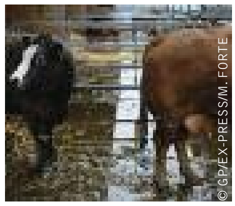
Today's power supply value chain is broken down into clearly defined players but a global renewable power supply will inevitably change this division of roles and responsibilities. Table 2.1 provides an overview of how the value chain would change in a revolutionised energy mix.

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 [R]evolution 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 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.

table 2.1: 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 few 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 liberalisation.
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 - except biomass - will operate without the need of fuel supply.	Grid operation will move towards state controlled grid companies or communities due to liberalisation.
Market player							
Renewable power plant engineering companies	■	■	■		■		
Private & public investors				■			
Grid operator							■

image COWS FROM A FARM WITH A BIOGAS PLANT IN ITTIGEN BERN, SWITZERLAND. THE FARMER PETER WYSS PRODUCES ON HIS FARM WITH A BIOGAS PLANT, GREEN ELECTRICITY WITH DUNG FROM COWS, LIQUID MANURE AND WASTE FROM FOOD PRODUCTION.



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. Moreover, the majority of power plants will not require any fuel supply, so mining and other fuel production companies will lose their strategic importance.

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

Step 3: optimised integration – renewables 24/7 A complete transformation of the energy system will be necessary to accommodate the significantly higher shares of renewable energy expected under the Energy [R]evolution scenario. The grid network of cables and sub-stations that brings electricity to our homes and factories was designed for large, centralised generators running at huge loads, 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 [R]evolution 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'.[22] 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 collection and analysis of a lot of data. Smart grids require software, hardware and data networks capable of delivering data quickly, and 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.

2.3 the new electricity grid

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.

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 2.3, page 27).

reference

22 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 2.2: 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 of a 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 turn 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.

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 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, e.g. 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.

2.3.1 hybrid systems

While grid in the developed world supplies 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 use 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 (FTSM), allows projects 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 GEMASOLAR IS A 15 MWE SOLAR-ONLY POWER TOWER PLANT, EMPLOYING MOLTEN SALT TECHNOLOGIES FOR RECEIVING AND STORING ENERGY. IT'S 16 HOUR MOLTEN SALT STORAGE SYSTEM CAN DELIVER POWER AROUND THE CLOCK. IT RUNS AN EQUIVALENT OF 6,570 FULL HOURS OUT OF 8,769 TOTAL. FUENTES DE ANDALUCÍA SEVILLE, SPAIN.

© MARKEL REDONDO/GP

2.3.2 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 dispatchable 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 consist of tens of thousands of generation units such as solar panels, wind turbines and other renewable generation, partly within 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.[23] Figure 2.3 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, a 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.[24] 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.[25] Together, the combination ensures sufficient electricity supply to cover demand.

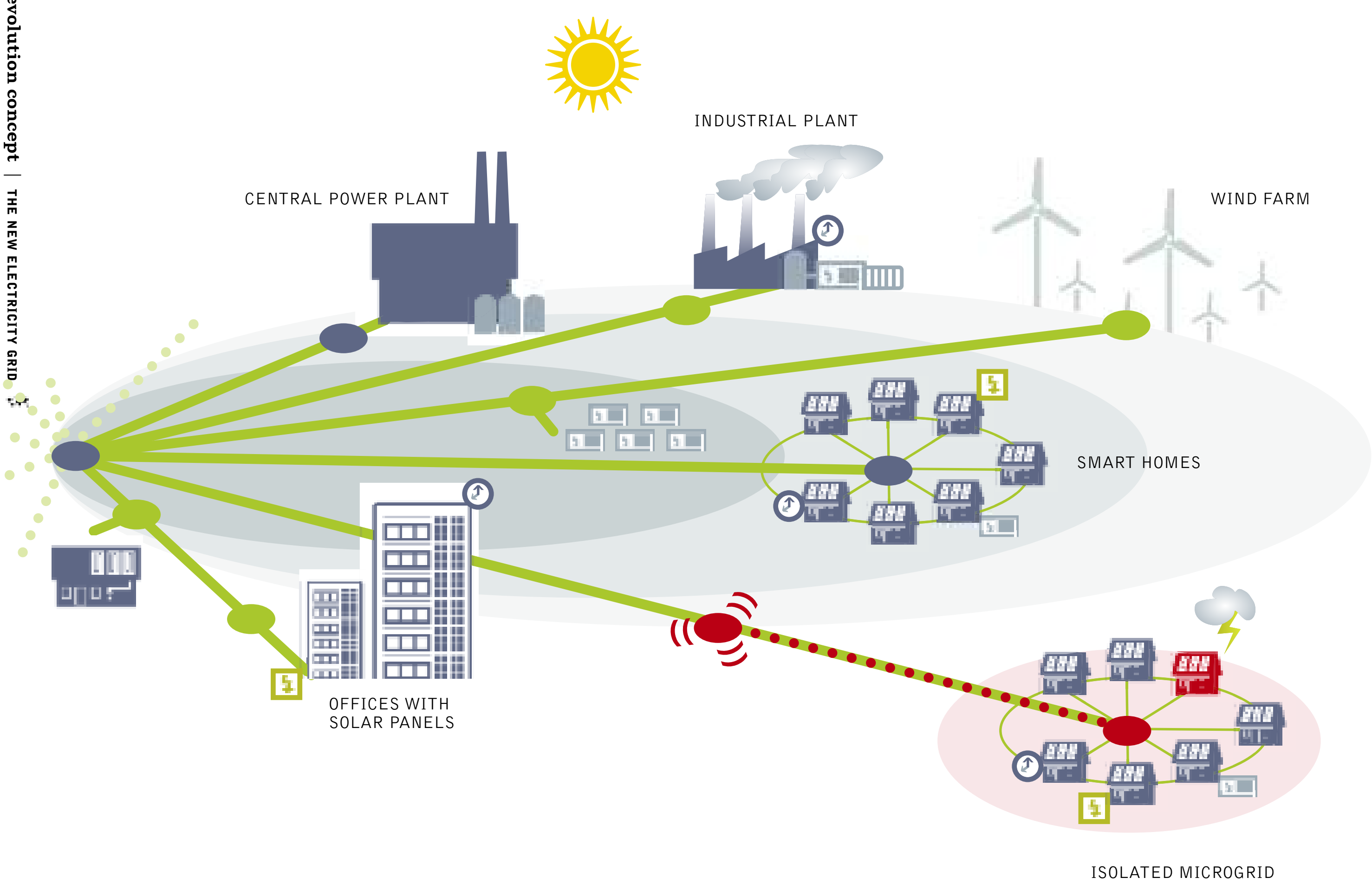
Electricity storage options. Pumped storage is the most established technology for storing energy from a type of hydroelectric power station. Water is pumped from a lower elevation reservoir to a higher elevation during times of low cost, off-peak electricity. During periods of high electrical demand, 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. In 2007, the European Union had 38 GW of pumped storage capacity, representing 5% of total electrical capacity.

references

23 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.
24 SEE ALSO HTTP://WWW.KOMBIKRAFTWERK.DE/INDEX.PHP?ID=27.
25 SEE ALSO HTTP://WWW.SOLARSERVER.DE/SOLARMAGAZIN/ANLAGEJANUAR2008_E.HTML.

figure 2.3: 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 AERIAL VIEW OF THE WORLD'S LARGEST OFFSHORE WINDPARK IN THE NORTH SEA HORNS REV IN ESBJERG, DENMARK.

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

2.3.3 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.[26]

2.3.4 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 a 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 prices 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 2.3: do we need baseload power plants?[27]

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 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, section 2.4 for more). The gas plants and pipelines would then progressively be converted for transporting biogas.

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

figure 2.4: a typical load curve throughout europe, shows electricity use peaking and falling on a daily basis

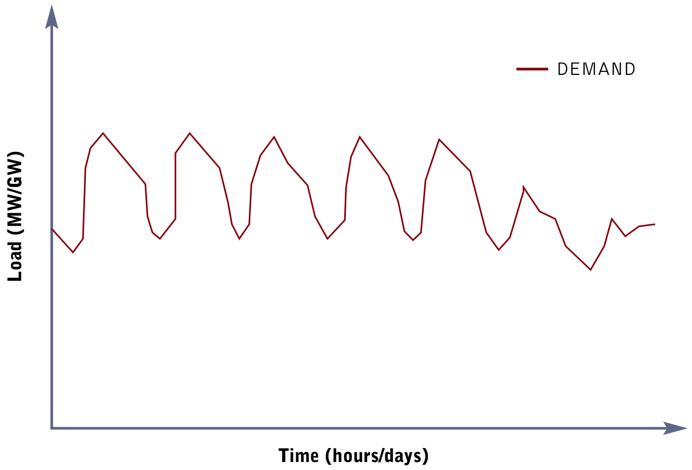
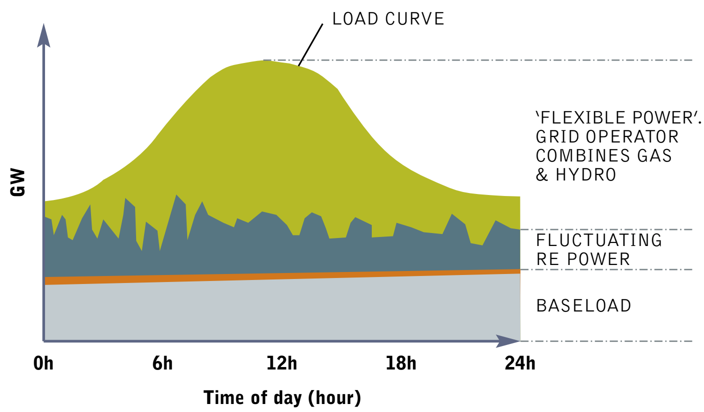


figure 2.5: the evolving approach to grids

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.

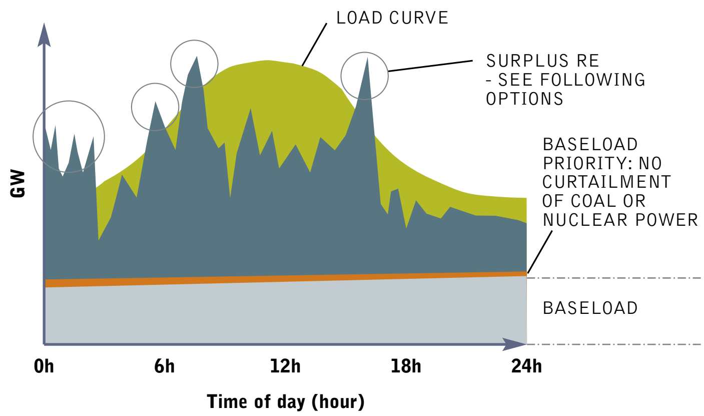


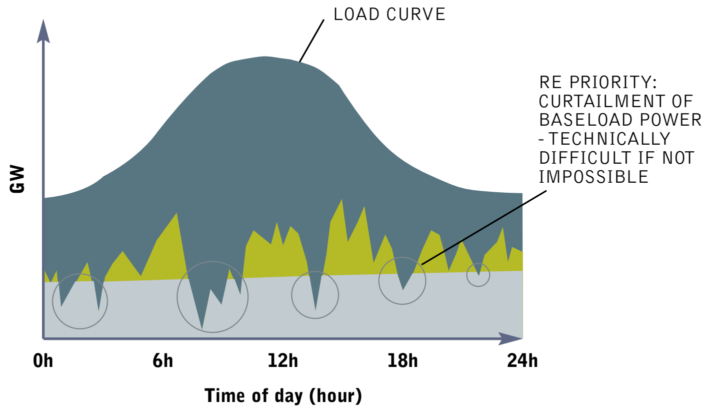
image GREENPEACE OPENS A SOLAR ENERGY WORKSHOP IN BOMA. A MOBILE PHONE GETS CHARGED BY A SOLAR ENERGY POWERED CHARGER.

figure 2.5: 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.

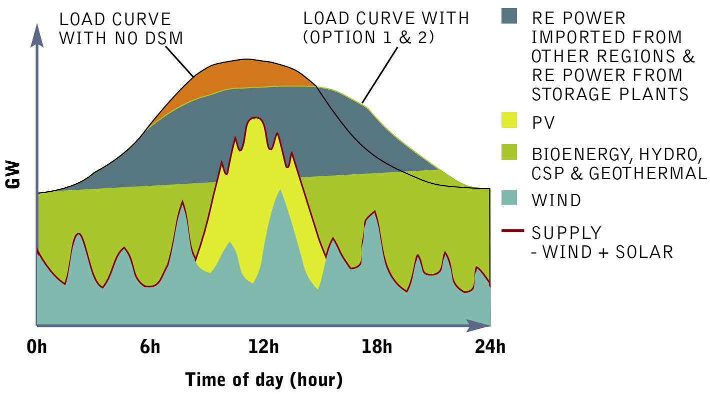
Technically difficult, not a solution.



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-side management (DSM) 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.

2.4 case study: a year after the german nuclear phase out

On 30 May 2011, the German environment minister, Norbert Röttgen, announced the Germany would close its eight oldest nuclear plants and phase out the remaining nine reactors by 2022. The plan is to replace most of the generating capacity of these nine reactors with renewables. The experience so far gives a real example of the steps needed for a global Energy [R]evolution at a national scale.

2.4.1 target and method

The German government expects renewables to generate 35% of German electricity by 2020.[28] The German Federal Environment Agency believes that the phase out would be technically feasible from 2017, requiring only 5 GW of additional combined heat-and-power or combined cycle gas plant (other than those already under construction) to meet peak time demand.[29]

2.4.2 carbon dioxide emissions trends

The German energy ambassador, Dr. Georg Maue, reported to a meeting in the British Parliament in February 2012 that Germany was still on track to meet its CO_2 reduction targets of 40% by 2020 and 80% by 2050 from 1990 levels. Figures for Germany's 2011 greenhouse gas emissions were not available for this report, although the small growth in use of lignite fuels is likely to have increased emissions in the short term.

However, the decision to phase out nuclear energy has renewed the political pressure to deliver a secure climate-friendly energy policy and ensure Germany still meets its greenhouse targets. The Energiewende ('energy transition') measures include €200 billion investment in renewable energy over the next decade, a major push on energy efficiency and an accelerated roll out of infrastructure to support the transition.[30] Germany has also become an advocate for renewables at the European level.[31] In the longer-term, by deploying a large amount of renewable capability Germany should be able to continue reducing its emissions at this accelerated rate and its improved industrial production should make it more viable for other countries to deliver greater and faster emissions reductions.

2.4.3 shortfall from first round of closures

The oldest eight nuclear reactors were closed immediately and based on figures available it looks like the 'shortfall' will be covered by a mix of lower demand, increasing renewable energy supply, and a small part by fossil-fuelled power.

In 2011 only 18% of the country's energy generation came from nuclear.[32] In the previous year, nuclear energy's contribution had already fallen from 22% to 18%, a shortfall covered mostly by renewable electricity which increased from 16% to 20% in the same period, while use of lignite (a greenhouse-intensive fossil fuel) increased from 23% to 25%.

In the first half of 2011, Germany was a net exporter of electricity (Figure 2.9), exporting 29 billion kWh and importing 24 kWh.[33] Complete figures for electricity imports and exports in the second half of 2011 are not yet available, once nuclear reactors were decommissioned, however it is known that Germany exported electricity to France during a cold spell in February 2012.[34]

Inside Germany, the demand for energy is falling.[35] Between 2010 and 2011 energy demand dropped by 5%, because the mild weather reduced demand for gas heating. While the British government is planning for electricity demand in the UK to double by 2050, the German government expects a cut of 25% from 2008 levels.[36] Total energy demand is expected to halve over the same time period.

2.4.4 the renewable energy sector in germany

Germany has successfully increased the share of renewable energy constantly over the last twenty years (see Figures 2.6 and 2.7), and the sector was employing over 350,000 employees by the end of 2011. The back bone of this development has been the Renewable Energy Act (Erneuerbare Energien Gesetz – EEG); a feed-in law which guarantees a fixed tariff per kWh for 20 years. The tariffs are different for each technology and between smaller and larger, to reflect their market penetration rates.

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36 HTTP://WWW.BMU.DE/FILES/ENGLISH/PDF/APPLICATION/PDF/ENERGIEKONZEPT_BUNDESREGIERUNG_EN.PDF (PAGE 5)

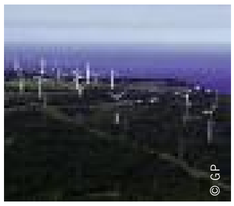
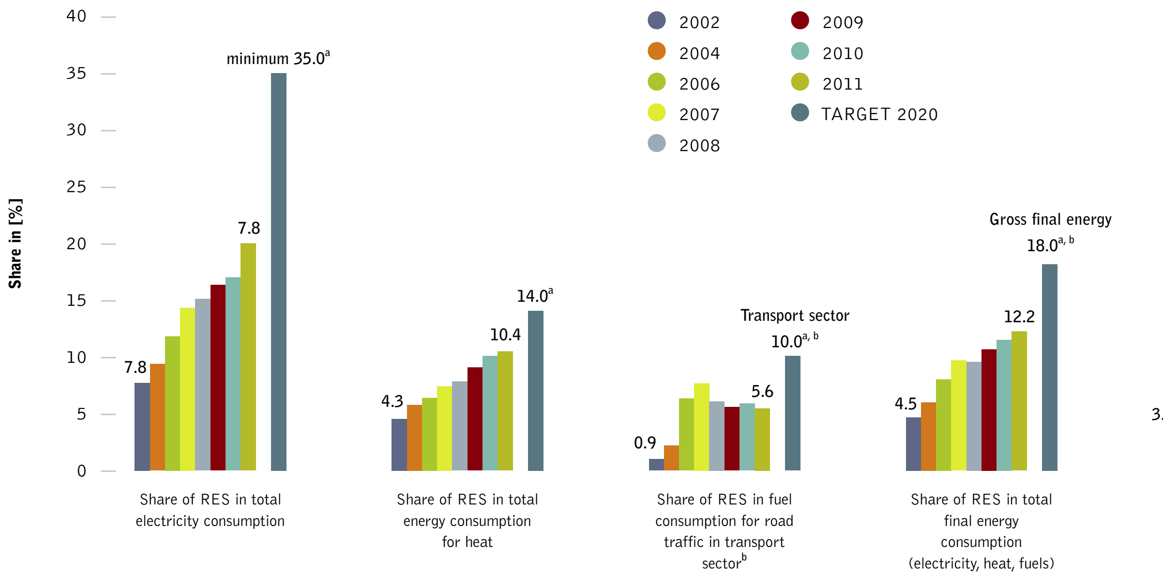


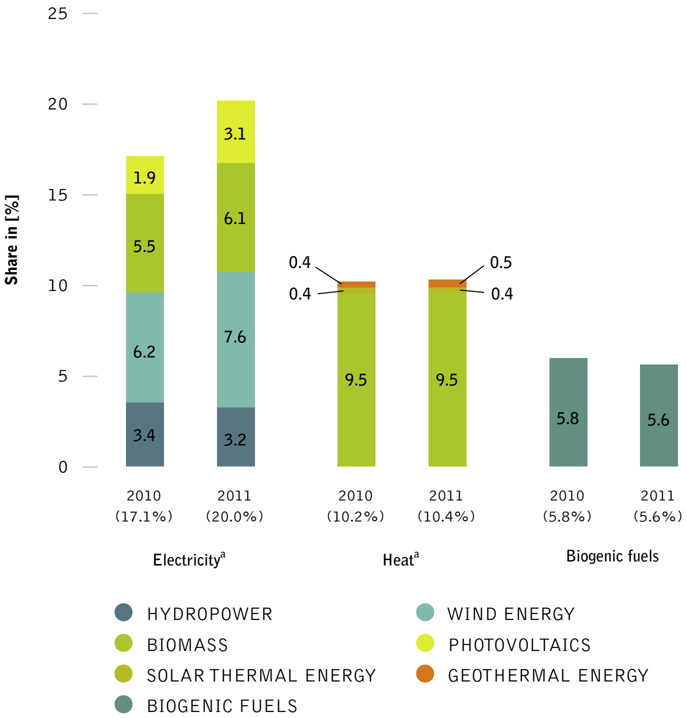
image LE NORDAIS WINDMILL PARK, ONE OF THE MOST IMPORTANT IN AMERICA, LOCATED ON THE GASPÈ PENINSULA IN CAP-CHAT, QUEBEC, CANADA.

figure 2.6: renewable energy sources as a share of energy supply in germany



source
a TARGETS OF THE GERMAN GOVERNMENT, RENEWABLE ENERGY SOURCES ACT (EEG). RENEWABLE ENERGY SOURCES HEAT ACT (EEWärmeG). EU-DIRECTIVE 2009/28/EC.
b TOTAL CONSUMPTION OF ENGINE FUELS, EXCLUDING FUEL IN AIR TRAFFIC.
c CALCULATED USING EFFICIENCY METHOD; SOURCE: WORKING GROUP ON ENERGY BALANCES e.V. (AGEB); RES: RENEWABLE ENERGY SOURCES; SOURCE: BMU-KI III 1 ACCORDING TO WORKING GROUP ON RENEWABLE ENERGY-STATISTICS (AGEE-STAT); AS AT: MARCH 2012; ALL FIGURES PROVISIONAL.

figure 2.7: renewable energy sources in total final energy consumption in germany 2011/2010



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a BIOMASS: SOLID AND LIQUID BIOMASS, BIOGAS, SEWAGE AND LANDFILL GAS, BIOGENIC SHARE OF WASTE; ELECTRICITY FROM GEOTHERMAL ENERGY NOT PRESENTED DUE TO NEGLIBLE QUANTITIES PRODUCED; DEVIATIONS IN THE TOTALS ARE DUE TO ROUNDING; SOURCE: BMU-KI III 1 ACCORDING TO WORKING GROUP ON RENEWABLE ENERGY-STATISTICS (AGEE-STAT); AS AT: MARCH 2012; ALL FIGURES PROVISIONAL.

2.4.5 energy and climate targets

The German government agreed on short, medium and long term – binding - targets for renewable, energy efficiency and greenhouse gas reduction (Table 2.2).

2.4.6 details of the german nuclear phase-out plan

The following figure shows where the nuclear power stations are located and when they will be shut down. The last nuclear reactor will be closed down in 2022.

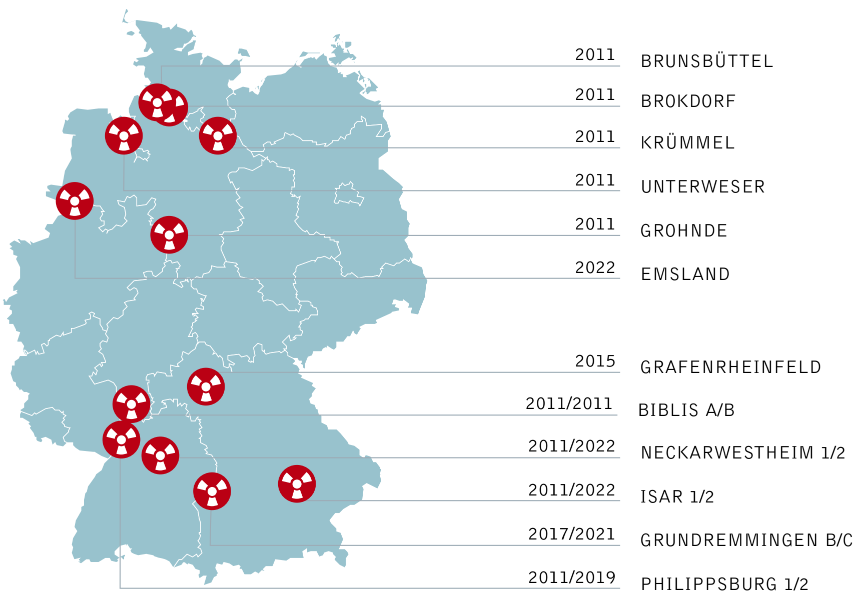
2.4.7 no 'blackouts'

The nuclear industry has implied there would be a "black-out" in winter 2011 - 2012, or that Germany would need to import electricity from neighbouring countries, when the first set of reactors were closed. Neither event happened, and Germany actually remained a net- export of electricity during the first winter. The table below shows the electricity flow over the borders.

table 2.2: german government short, medium and long term binding targets

	CLIMATE	RENEWABLE ENERGIES		EFFICIENCY		
	GREENHOUSE GASES (VS 1990)	SHARE OF ELECTRICITY	OVERALL SHARE (Gross final energy consumption)	PRIMARY ENERGY CONSUMPTION	ENERGY PRODUCTIVITY	BUILDING MODERNISATION
2020	- 40%	35%	18%	-20%		
2030	- 55%	50%	30%	↓	Increase to 2.1% annum	Double the rate 1%-2%
2040	- 70%	65%	45%			
2040	- 85-95%	80%	60%	-50%		

figure 2.8: phase out of nuclear energy



- Seven oldest plants plus Krümmel: immediate decommissioning
- Gradual phasing out of nuclear power by 2022
- Shutdown years: 2015, 2017, 2019, 2021, 2022

source UMWELTBUNDESAMT (UBA) 2012, GERMAN MINISTRY FOR ENVIRONMENT

figure 2.9: electricity imports/exports germany

JANUARY TO NOVEMBER 2011. (VOLUME MEASURE IN MILLION KWH)

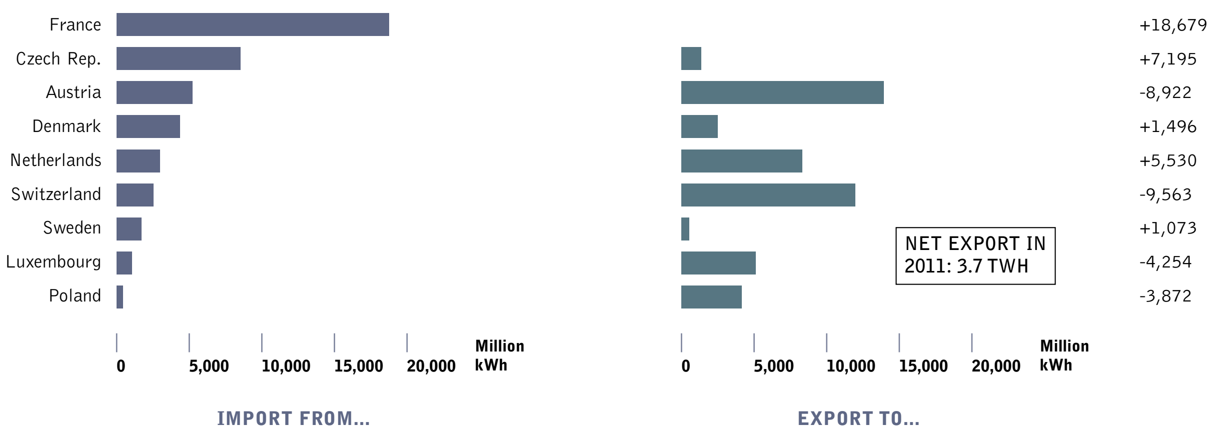


image A COW IN FRONT OF A BIOREACTOR IN THE BIOENERGY VILLAGE OF JUEHNDE. IT IS THE FIRST COMMUNITY IN GERMANY THAT PRODUCES ALL OF ITS ENERGY NEEDED FOR HEATING AND ELECTRICITY, WITH CO_2 NEUTRAL BIOMASS.

2.5 case study: providing smart energy to Bihar, from the "bottom-up"

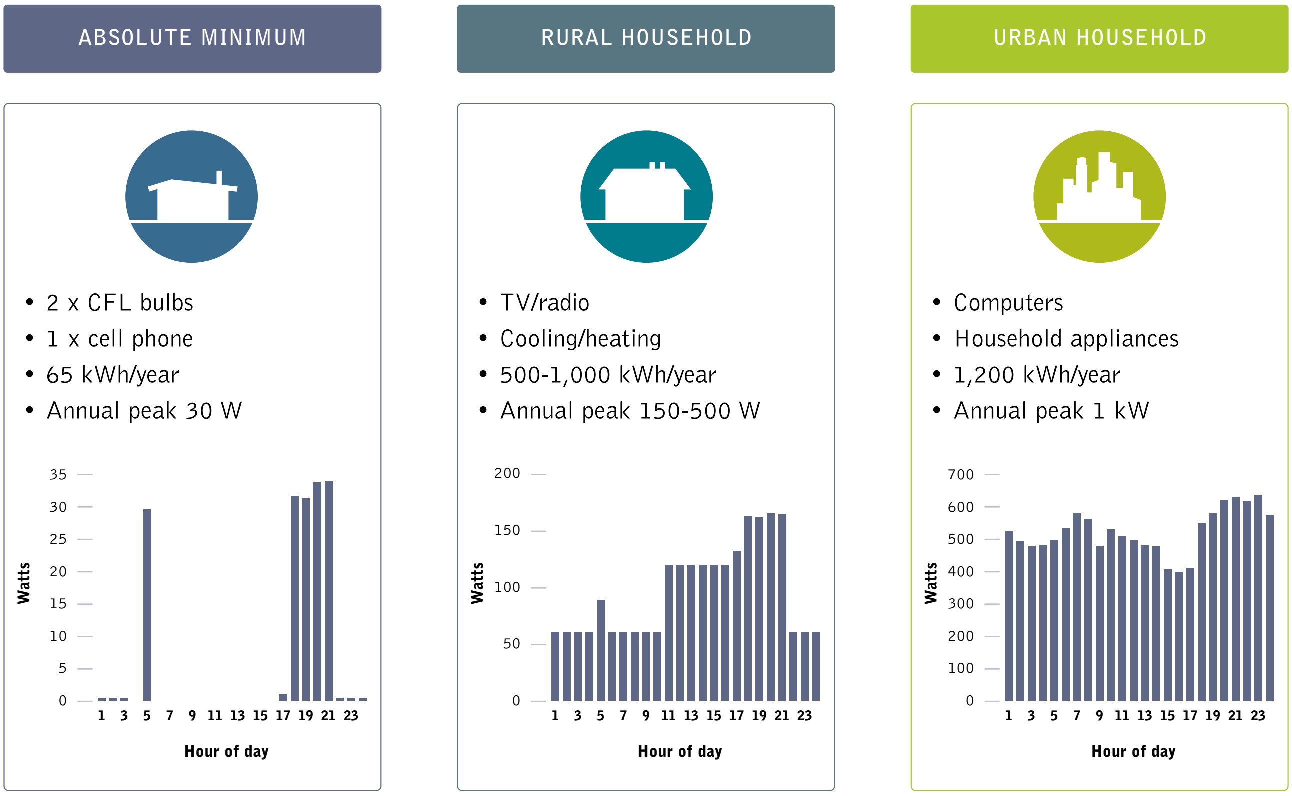
Over one billion people do not have any access to energy services – most of them are living in rural areas, far away from electricity grids. Rural electrification is known to bring economic development to communities, and the premise of an Energy [R]evolution is to strive for more equity, not to entrench disadvantage.

Greenpeace worked with a community in northern India in the state of Bihar to see how a real community could create their own, new electricity services in a sustainable way. The core concept was for communities to be able to organise their own electricity supply step by step, building up a local micro-grid that runs on locally available, renewable resources.

For example, households may start with only a few hours of electricity for lighting each day, but they are on a pathway towards continuous supply. As each community builds the infrastructure, they can connect their smart microgrids with each other. The advantages are that it is faster than waiting for a centralised approach, communities take their electricity supply into their own hands, and investment stays in the region and creates local jobs.

Greenpeace International asked the German/Swedish engineering company energynautics to develop a technical concept. Called *Smart Energy Access*, it proposes a proactive, bottom-up approach to building smart microgrids in developing countries. They are flexible, close to users so reduce transmission losses, help facilitate integration of renewable energy and educe transmission losses by having generation close to demand.

figure 2.10: development of household demand



source
"E[R] CLUSTER FOR A SMART ENERGY ACCESS", GREENPEACE MAY 2012.

2.5.1 methodology

The first step is to **assess the resources** available in the area. In Bihar, these are biomass, hydro and solar PV power.

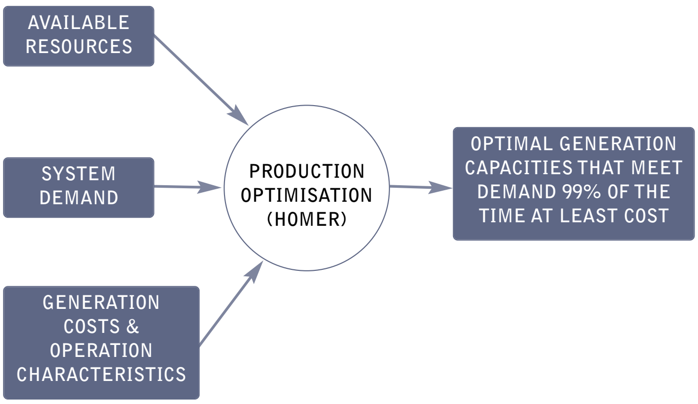
The second step is to **assess the level of electrical demand** for the area, taking into account that the after initial access, demand will almost always grow, following the economic growth electricity allows. For Bihar, demand levels shown in Figure 2.10 were considered.

The third and final step is to design a system which can serve the demand using the resources available in the most economic manner. Key parameters for developing a system are:

- That system design uses standard components and is kept modular so that it can be replicated easily for expansion across the region.
- An appropriate generation mix which can meet demand 99% of the time at the lowest production cost, e.g. using simulation software such as HOMER.[37] (Figure 2.11)
- That electricity can be distributed through a physical network without breaching safe operating limits, and that the quality of the supply is adequate for its use, e.g. using a software model such as PowerFactory[38] which tests system behaviour under different operating conditions. (Figure 2.12)
- A suitable strategy for switching between "grid-connected" and "island" modes, so that the community can connect to the neighbours. There are many options for systems designers by typically for microgrids in rural parts of developing countries, design simplicity and cost efficiency are more valuable than an expensive but sophisticated control system.

The *Smart Energy Access Concept* method can be used to develop roadmap visions and general strategy directions. It must be noted however, that detailed resource assessments, cost evaluations, demand profile forecasts and power system simulations are always required to ensure that a specific microgrid design is viable in a specific location.

figure 2.11: process overview of supply system design by production optimisation

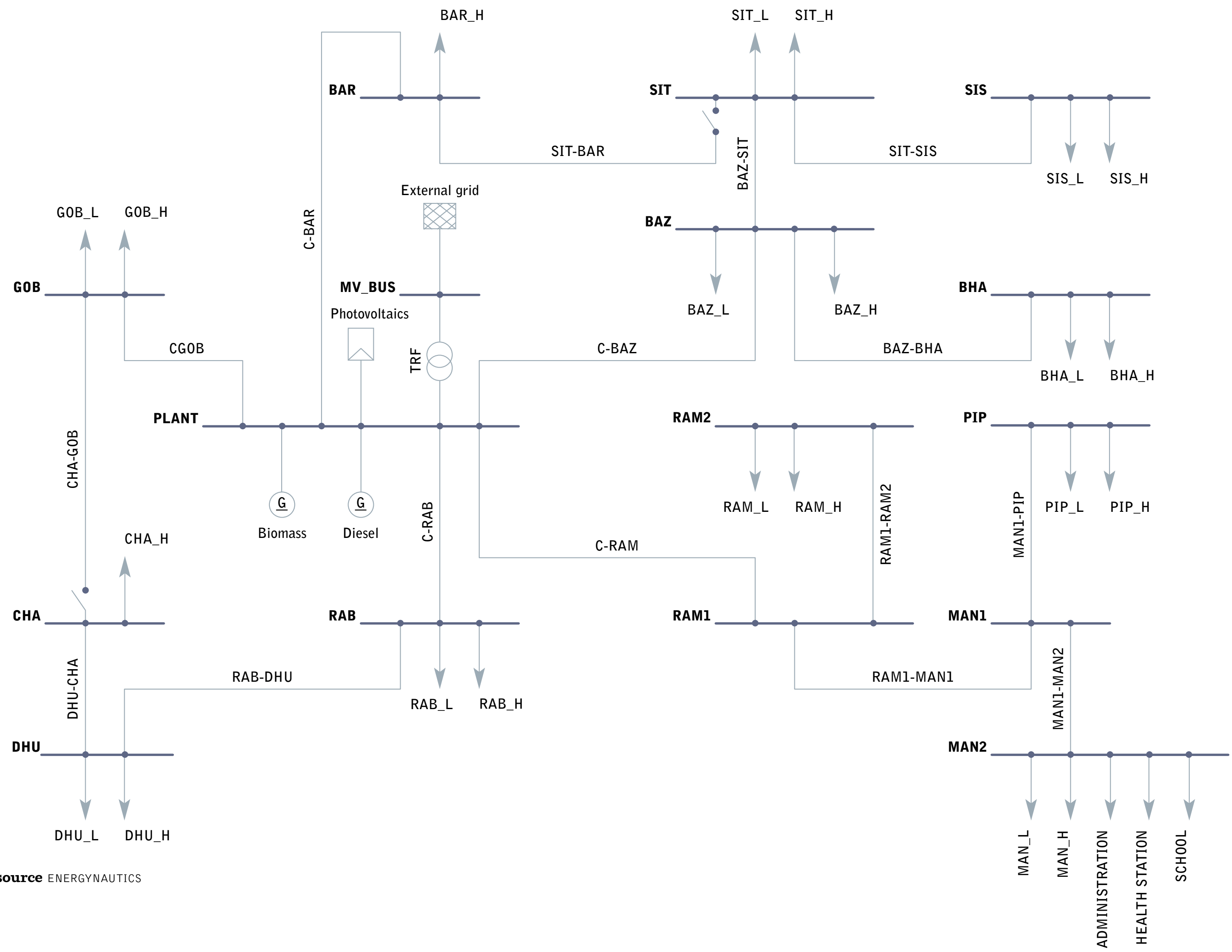


source ENERGYNAUTICS

references
37 HOMER IS AN ENERGY MODELLING SOFTWARE FOR DESIGNING AND ANALYSING HYBRID POWER SYSTEMS. A TRIAL VERSION OF THE SOFTWARE CAN BE DOWNLOADED FOR FREE AT THE WEBSITE: HTTP://WWW.HOMERENERGY.COM/
38 POWERFACTORY IS A POWER SYSTEM SIMULATION SOFTWARE FOR DESIGNING AND ANALYSING POWER SYSTEMS. IT IS A LICENSED PRODUCT DEVELOPED BY DIGSILENT.

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

figure 2.12: screenshot of the PowerFactory grid model.



source ENERGYNAUTICS

box 2.4: philippines: case study for energy efficient lighting

One of the ASEAN countries that transitioned to energy efficient lighting is the Philippines when it began the its Efficient Lighting Market Transformation Project in 2005. The project integrated various energy efficient lighting programmes and practices into standards, labelling programmes and even promotional activities. When the project concluded in 2011, the government was able to achieve 7,366 GWh equivalent of energy savings and 3.98 million tonnes of carbon emissions reductions.

A continued transition to energy efficient lighting in the on-grid residential, commercial, industrial and outdoor sectors for all major lamp types is estimated to save 3.5 terrawatt-hours (TWh) in annual electricity consumption which is about 42.1% of national electricity consumption for lighting. This lighting transition would save more than US$ 760 million annually and avoid 1.7 million tonnes of carbon emissions on an annual basis. On the other hand, off-grid transition to energy efficient lighting could save US$ 270 million annually, equivalent to more than 220 million liters of kerosene, more than 120 million candles and up to 30 million batteries.

2.5.2 implementation

Once an electricity service is available, people generally increase their consumption. A typical pattern for system growth in India is:

- 60kWh per household, covering basic lighting, based on two energy-efficient globes per household for a few hours. In Bihar, this can be provided efficiently with a predominantly biomass-powered system, such as the Husk Power Systems[39], which are already in use in a number of villages.
- 500 kWh per household, provided by a predominantly biomass-diesel system or a biomass-hydro system (if water is available nearby). Such systems can be achieved at costs of around 14-15 INR/kWh, or 9-10 INR/kWh respectively and will cover demand from appliances such as fans, television sets and cellular phones
- 1,200 kWh per year per household – an urban level of electricity consumption – can not be provided by the simple systems described above. Without hydro power solar PV would be required, and where hydro power is available, diesel would need to be included to cover seasonal flows. These systems can be achieved also at costs of 14-15 INR/kWh, or 9-10 INR/kWh respectively.

2.5.3 lessons from the study

When considering bottom-up microgrid developments some key points for the system's expansion are:

Unit Sizes. From 32 kW and 52 kW for biomass husks to 100 kW minimum for an economic micro-hydro system (based on the general flows for the state of Bihar) to a tiny 100-1,000 W for rooftop solar PV. Diesel generators which could operate with biofuels come in all sizes as they are a more conventional product. The system owner would have to decide how best to expand the system in a piecewise fashion.

Connection to the grid. When eventually connected to State or National grid, different arrangements mean the community can be connected or autonomous, depending on the situation. However, expensive and experimental control systems that manage complex transitions would be difficult to implement in a rural area in a developing country which has financial barriers, lower operational capacity, less market flexibility and regulatory considerations. A simplified design concept limits transitions from grid-connected mode to "island mode" when there are central grid blackouts, and back again.

Capacity and number systems. To replicate this type of microgrid design across the entire state of Bihar, a rough approximation based on geographical division indicates that 13,960 villages can be supplied by a non-hydro no wind system and 3,140 villages with a hydro system. It is assumed that there is potential for up to 1,900 systems where wind power may be used, and that a total number of 19,000 villages are appropriate to cover all rural areas in the state of Bihar. With such an expansion strategy, at minimum (corresponding to demand scenario 2) approximately 1,700 MW of biomass, 314 MW of hydro and 114 MW of PV power installations would be required. At the stage when microgrids are fully integrated with the central grid (demand scenario 4), it is expected that at least 4,000 MW of biomass, 785 MW of hydro and 10,000 MW of PV power installations would be required.

Distance to the grid. System costs of the optimal microgrid designs were compared with the cost of extending the grid to determine the break-even grid distance. Calculations show the break-even grid distance for a biomass + solar + hydro + diesel system (with or without wind) is approximately 5 kilometres, while for a biomass + solar + diesel system (with or without wind) is approximately 10 kilometres.

Technology type. The system costs did not vary significantly with the addition of wind power in the generation mix, or with a significant reduction in solar PV installation costs because the costs per installed kilowatt of such systems are already higher than for the other generators. However, when diesel prices increase, the overall system costs also rise, as the cost of energy production from the diesel units increase, but the installation costs are still lower than for solar PV and wind power systems.

The case study in Bihar, India, show how microgrids can function as an off-grid system, incorporate multiple generation sources, adapt to demand growth, and be integrated with the central grid while still separate and operate as an island grid if needed.

reference
39 WWW.HUSKPOWERSYSTEMS.COM

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


© GP/FLAVIO CANNALONGA

box 2.5: indonesia: case study for community-managed micro-hydro system

More than one-third of Indonesia's population lack access to electricity. Having close to 237.5 million people living in its more than 17,000 islands in 2010, this means that more than 8 million people are still devoid of electricity. Among the key barriers to better electricity access are poor grid infrastructure, scattered geographical conditions and remoteness of un-electrified areas.

However, scaleable on-grid and off-grid renewable energy systems -- particularly micro-hydro plants -- are being made available and has brought its benefits for the first time to remote communities in Indonesia, creating income generating opportunities, providing leisure, educational benefits and a window to the outside world. With these schemes, more than 60 micro-hydro plants have been installed so far where more than 54,000 people have benefitted.

An example of this scheme is the Cinta Mekar project in Subang, West Java, a village 150 kilometers from the capital city of Jakarta. Cinta Mekar runs a 120-kiloWatt micro-hydro power plant which is designed to generate a supply of grid-connected electricity. Prior to the project, more than 100 households were without electricity composed mostly of villagers who were poor rice farmers.

The US$ 225,000 project cost was borne equally by the United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP), private organization PT HIBS and not-for-profit organization called IBEKA (Yayasan Institut Bisnis dan Ekonomi Kerakyatan). UNESCAP and HIBS covered the investment cost including technical assistance and the contractor to build the micro-hdyro power plant while IBEKA contributed towards information dissemination, social preparation and a training facility for the village community. Ownership of the plant is shared equally between PT HIBS and the local community represented by the Mekar Sari Cooperative as a joint venture.

The electricity generated by the plant is sold by the joint venture to state-owned electricity company PLN through a Power Purchase Agreement. The electricity is sold at a tariff of IDR 432 or approximately US$ 0.044 per kWh. Assuming an average production of 100 kW per day, monthly sales revenue from the plant is roughly IDR 25,000,000 or around US$ 2,329. After maintenance costs and forex loss, the net monthly profit shared between HIBS and the Mekar coop is estimated at IDR 10,000,000 or US$ 1,000.

One of the success factors for this project was the involvement of the Mekar community from the planning and development to the implementation stages. Whereas similar projects in other areas normally view communities as sole beneficiaries, the Cinta Mekar project was successful because it had the twin goals of providing electricity as well as empowering communities to engage in investment or production activities and not just simple infrastructure development.

To date, the micro-hydro power plant is providing electricity to all 122 households, enabling the community to generate revenue from the power it sells to the grid, reinvest in village development through educational programs where scholarships have been granted to more than 150 children from the poorest families. The community has also built a clinic and have installed a village telephone to improve communication and information access.

2.6 greenpeace proposal to support a renewable energy cluster

This energy cluster system builds upon Greenpeace's Energy [R]evolution scenario[40] which sets out a global energy pathway that not only phases out dirty and dangerous fossil fuels over time to help cut CO_2 levels, but also brings energy to the 2 billion people on the planet that currently don't have access to energy. The most effective way to ensure financing for the Energy [R]evolution in the power sector is via Feed-in laws.

To plan and invest in an energy infrastructure, whether for conventional or renewable energy, requires secure policy frameworks over decades. The key requirements are:

long term security for the investment The investor needs to know the pattern of evolution of the energy policy 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 on the long term profitability of the activity as well as on the inflation rate of the country and the short term availability of cash throughout the year to sustain operations.

maximize the leverage of scarce financial resources Access to privileged credit facilities, under State guarantee, are one of the possible instruments that can be deployed by governments to maximise the distribution of scarce public and international financial resources, leverage on private investment and incentivize developers to rely on technologies that guarantee long term financial sustainability.

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; if it is low compared to other investments then financial institutions will not invest. Moreover, the supply chain of producers needs to enjoy the same level of favourable market conditions and stability (e.g. agricultural feedstock).

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, transparent and fast.

access to the (micro) 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 built. 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 oversupply 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.

table 2.3: key results for energy [r]evolution village cluster - state of bihar (rural) - employment, environment + fit

	EMPLOYMENT			CO_2 SAVINGS		FIT
SCENARIO	GENERATION Jobs	GRID Jobs	TOTAL Jobs	SPECIFIC t CO_2 /GWh	TOTAL million t CO_2/a	AVERAGE ACCROSS ALL TECHNOLOGIES INR/kWh
Scenario A: Solar + Biomass						
Absolute Minimum (state-wide)	1,778	10	1,788	1,100	0.8	25
Low income demand (state-wide)	5,936	75	6,011		6.7	19
Medium income demand (state-wide)	14,326	153	14,479		13.4	25
Urban households (state-wide)	16,340	447	16,787		32.0	19
Scenario B: Solar + Small Hydro + Biomass						
Absolute Minimum (state-wide)	1,778	10	1,788	1,100	0.8	25
Low income demand (state-wide)	2,782	141	2,922		6.7	11
Medium income demand (state-wide)	11,742	343	12,085		13.4	13
Urban households (state-wide)	15,770	541	16,311		32.0	13
Scenario C: Solar + Wind + Biomass						
Absolute Minimum (state-wide)	1,778	10	1,788	1,100	0.8	25
Low income demand (state-wide)	5,936	75	6,011		6.7	19
Medium income demand (state-wide)	14,326	153	14,479		13.4	25
Urban households (state-wide)	21,470	410	21,880		32.0	21

source
"E[R] CLUSTER FOR A SMART ENERGY ACCESS", GREENPEACE MAY 2012.

reference
40 ENERGY [R]EVOLUTION – A SUSTAINABLE ENERG Y WORLD ENERGY OUTLOOK 2012, GREENPEACE INTERNATIONAL, AMSTERDAM – THE NETHERLANDS, JUNE 2012.

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

2.6.1 a rural feed-in tariff for bihar

In order to help implement the Energy [R]evolution clusters in Bihar, Greenpeace suggests starting a feed-in regulation for the cluster, which will be partly financed by international funds. The international program should add a CO_2 saving premium of 10 Indian Rupee (INR) per kWh for 10 years. This premium should be used to help finance the required power generation as well as the required infrastructure (grids). In the Table 2.2 the CO_2 savings, rough estimation of employment effects as well as the required total funding for the CO_2 premium for the state of Bihar are shown.

2.7 energy [r]evolution cluster jobs

While the employment effect for the operation and maintenance (O&M) for solar photovoltaics (0.4/MW), wind (0.4/MW), hydro (0.2/MW) and bio energy (3.1/MW) are very well documented,[41] the employment effect of grid operations and maintenance are not. Therefore Greenpeace assumed in this calculation that for each 100 GWh one job will be created. This number is based on grid operators in Europe and might be too conservative. However it is believed that the majority of the jobs will be created by the O&M of power generation; grid operation may be part of this work as well.

Due to the high uncertainty of employment effects from grid operation, these numbers are only indicative.

Microgrids can offer reliable and cost competitive electricity services, providing a viable alternative to the conventional topdown approach of extending grid services. The microgrid approach is "smart" because it can facilitate the integration of renewable energies, thereby contributing to national renewable energy (RE) targets. In addition it can reduce transmission losses by having generation close to demand. Being built from modular distributed generation units, it can adequately adjust to demand growth. It can operate both in island mode and grid-connected mode, making operation flexible and can also offer grid support features. This report demonstrates with a case study how this bottom-up approach with microgrids would work. It focuses on development in the state of Bihar in India.

box 2.6: laos as a model for off-grid renewable energy

Despite its impressive economic performance in the past several years, the ASEAN region still faces tremendous energy poverty challenges. Of its more than 560 million people, 28% or 160.3 million have no electricity at all, most of whom live in rural areas with little to no infrastructure to support electricity access. Electrification rates vary from 100% in Singapore to 10% in Myanmar and many poor communities still rely on kerosene for their lighting needs and the collection of wood for cooking purposes.

As less developed member countries of ASEAN continue to build their electricity infrastructure from scratch, it can very well learn from other countries' experience. Laos provides one such example where in 2000, the country had an electrification rate of only 30%. Majority of the population live in rural areas and to supplement its national grid extension efforts, the Laotian government placed emphasis on off-grid renewable energy expansion through public-private partnerships. This program deployed more than 10,000 solar home systems and numerous village mini-grids that utilize solar, small hydro and biomass energy sources were created. Thirteen years after the program was conceived, more than 7 in 10 Laotians have electricity access today.

What are the key lessons that would make similarly-placed countries take a leap towards off-grid renewable energy development? Because more than a quarter of ASEAN population who don't have access to electricity live in rural and remote villages or islands, the case is strong for off-grid renewable energy solutions. Village or community mini-grids offer the opportunity for fast, flexible, expandable and cost-effective energy access. Laos' experience can serve as an indicative study for other governments in the region to develop its off-grid electrification strategy using renewables.

reference

41 INSTITUTE FOR SUSTAINABLE FUTURES (ISF), UNIVERS ITY OF TECHNOLOGY, SYDNEY, AUSTRALIA: JAY RUTOVITZ, ALISON ATHERTON. PLEASE NOTE THAT THIS REPORT HAS BEEN PUBLISHED BEFORE THE NEW EMPLOYMENT ANALYSIS FOR THE ASEAN E[R] IN CHAPTER 6.

Step 1: renewable resource assessment The first step to this approach is to make an assessment of the resources available in the area. In the case of Bihar, these are biomass, hydro and solar PV power. While there are no detailed wind measurements available, there are indications that in some areas wind turbines could operate economically as well.

Step 2: demand projections The second step is to assess the level of electrical demand that will need to be serviced. Once there is access to electricity services, demand will almost always grow, accompanying economic growth. For the case of Bihar the following demand levels were considered, which are characterised by total energy consumption, peak demand and daily load profiles as shown in Figure 2.10.

As the proposed bottom-up electrification approach starts on a per village basis, a set of village demand profiles is generated based on these hypothetical household demand profiles. The village demand profiles also contain assumptions about non-household loads such as a school, health stations or public lighting.

The village-based electricity supply system forms the smallest individual unit of a supply system. Therefore the matching set of generation assets is also determined on a per-village basis.

Step 3: define optimal generation mix The third step in this approach is to design a system which can serve the demand using the resources available in the most economic manner. At this point it is of utmost importance that the system design uses standard components and is kept modular so that it can be replicated easily for expansion across the entire state. In designing such a system, an appropriate generation mix needs to be developed, which can meet demand 99% of the time at the lowest production cost. This can be determined using production simulation software such as HOMER[42], which calculates the optimal generation capacities based on a number of inputs about the installation and operation costs of different types of generation technologies in India.

Step 4: network design Once the optimal supply system design is determined, it is also important to make sure that such a supply system can be distributed through a physical network without breaching safe operating limits, and that the quality of the delivered electricity is adequate for its use. This can be done by modelling the physical system using power system simulation software such as PowerFactory.[43] In this way the behaviour of the electrical system under different operating conditions can be tested, for example in steady-state power flow calculations. Figure 2.12 shows a diagram of the village power system model used in this study.

Step 5: control system considerations The final part of the system design involves the development of a suitable strategy for switching between grid-connected and island modes. Depending on the quality of service required by the loads in the microgrid, the regulations stipulated in the grid code for operation practices, and number of grid support features desired, several different designs could be developed. For microgrids as part of rural electrification efforts in developing countries however, design simplicity and cost efficiency weighs more than the benefits of having an expensive but sophisticated control system. Through the use of microgrids, the gap between rural electrification and universal electrification with grid expansion can be met, while at the same time bringing many additional benefits both for the consumers and grid operators. By developing a system which is modular and constructed using standard components, it makes it easier to replicate it across wide areas with varying geographic characteristics. The method demonstrated in this report can be used to develop roadmap visions and general strategy directions. It must be noted however, that detailed resource assessments, cost evaluations, demand profile forecasts and power system simulations are always required to ensure that a specific microgrid design is viable in a specific location.

table 2.4: village cluster demand overview

DEMAND SCENARIOS				SUPPLY NEEDS
SCENARIO	DEMAND PER DAY kWh/day	TOTAL ANNUAL DEMAND kWh/a	PEAK DEMAND kW peak	TOTAL INSTALLED CAPACITY kW
Absolute Minimum (state-wide)	111	40,514	22	31.5
Low income demand (state-wide)	881	321,563	99.4	106
Medium income demand (state-wide)	1,754	640,117	271	265
Urban households (state-wide)	4,192	1,530,037	554	800

source
"E[R] CLUSTER FOR A SMART ENERGY ACCESS", GREENPEACE MAY 2012.

reference
42 HOMER IS AN ENERGY MODELLING SOFTWARE FOR DESIGNING AND ANALYSING HYBRID POWER SYSTEMS . A TRIAL VERSION OF THE SOFTWARE CAN BE DOWNLOADED FOR FREE AT THE WEBSITE: HTTP://WWW.HOMERENERG Y.COM/
43 POWER FACTORY IS A POWER SYSTEM SIMULATION SOFTWARE FOR DESIGNING AND ANALYSING POWER SYSTEMS. IT IS A LICENSED PRODUCT DEVELOPED BY DIGSILENT.

implementing the energy [r]evolution

RENEWABLE ENERGY PROJECT PLANNING BASICS

RENEWABLE ENERGY FINANCING BASICS

image RAINBOW WARRIOR BESIDE KOH LAN WIND TURBINES, THAILAND.

3.1 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 ten steps from "field to an operating power plant" for renewable energy projects in the current market situation. Those steps are similar for each renewable energy 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 3.1: how does the current renewable energy 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 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 renewable electricity produced can be fed 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 configuration or sites for the technology, 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 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 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 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.

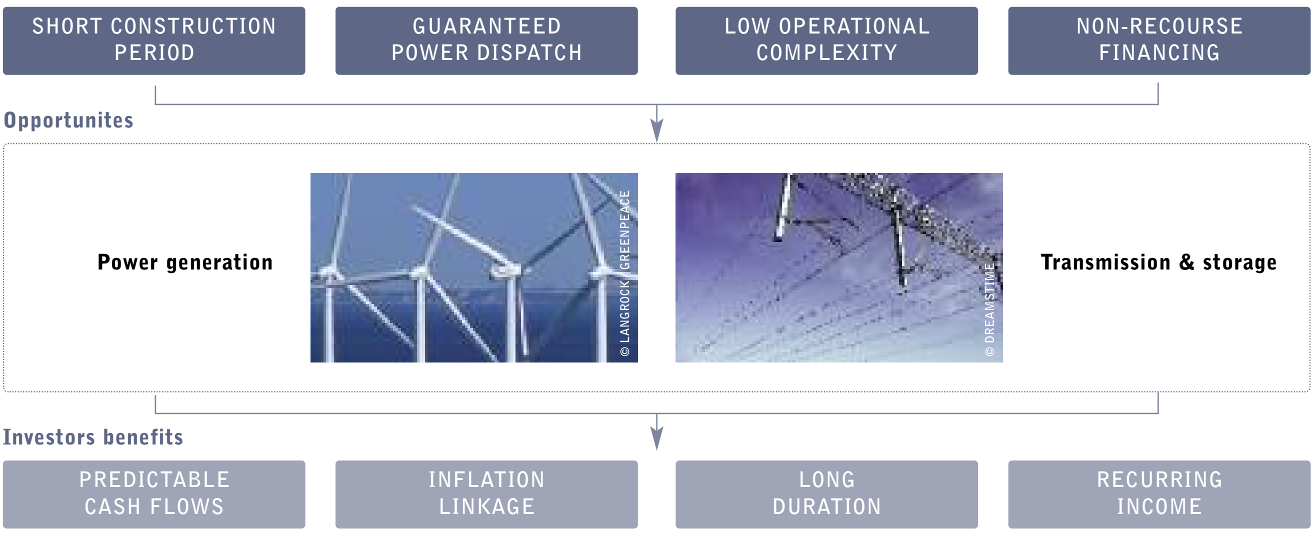
image GEOTHERMAL ACTIVITY NEAR HOLSSELSNALAR CLOSE TO REYKJAVIK, ICELAND.

3.2 renewable energy financing basics

The Swiss RE Private Equity Partners have provided 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 periods 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 ten years to build large conventional power plants.
- The Renewable Energy Directive granted priority of dispatch to renewable energy producers. Under this principle, 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 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 it is 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. 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 2 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 3.1: return characteristics of renewable energies



source
SWISS RE PRIVATE EQUITY PARTNERS.

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 3.2: overview risk factors for renewable energy projects

REGULATORY RISKS	CONSTRUCTION RISKS
FINANCING RISKS	OPERATIONAL RISKS

source
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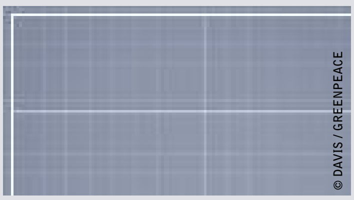
figure 3.3: investment stages of renewable energy projects

RISKS

Higher → Lower

Stage

DEVELOPMENT	CONSTRUCTION	OPERATIONS



- 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.

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.

3.2.1 overcoming barriers to finance and investment for renewable energy

table 3.2: 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. insufficient 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 renewable energy policy and law	Renewable energy targets Feed-in tariffs 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[44] and interviews with renewable energy sector financiers and developers are shown in Figure 3.4.

There are broad categories of common barriers to renewable energy development that are present in many countries, however the nature of the barriers differs significantly. At the local level, political and policy support, grid infrastructure, electricity markets and planning regulations have to be negotiated for new projects.

It is uncertainty of policy that is holding back investment more than an absence of policy support mechanisms. In the short term, investors aren't confident rules will remain unaltered and aren't confident that renewable energy goals will be met in the longer term, let alone increased.

When investors are cautious about taking on these risks, it drives up investment costs and the difficulty in accessing finance is a barrier to renewable energy project developers. Contributing factors 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 are also major barriers to developers, because they are not certain they will be able to sell all the electricity they generate in many countries, during project development.

Both state and private utilities are contributing to blocking renewable energy through their market power and political power, maintaining 'status quo' in the grid, electricity markets for centralised coal and nuclear power and lobbying against pro-renewable and climate protection laws.

The sometimes higher cost of renewable energy relative to competitors is still a barrier, though many are confident that it will be overcome in the coming decades. The Special Report on Renewable Energy Sources and Climate Change Mitigation (SRREN) identifies cost as the most significant barrier to investment[45] and while it 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).

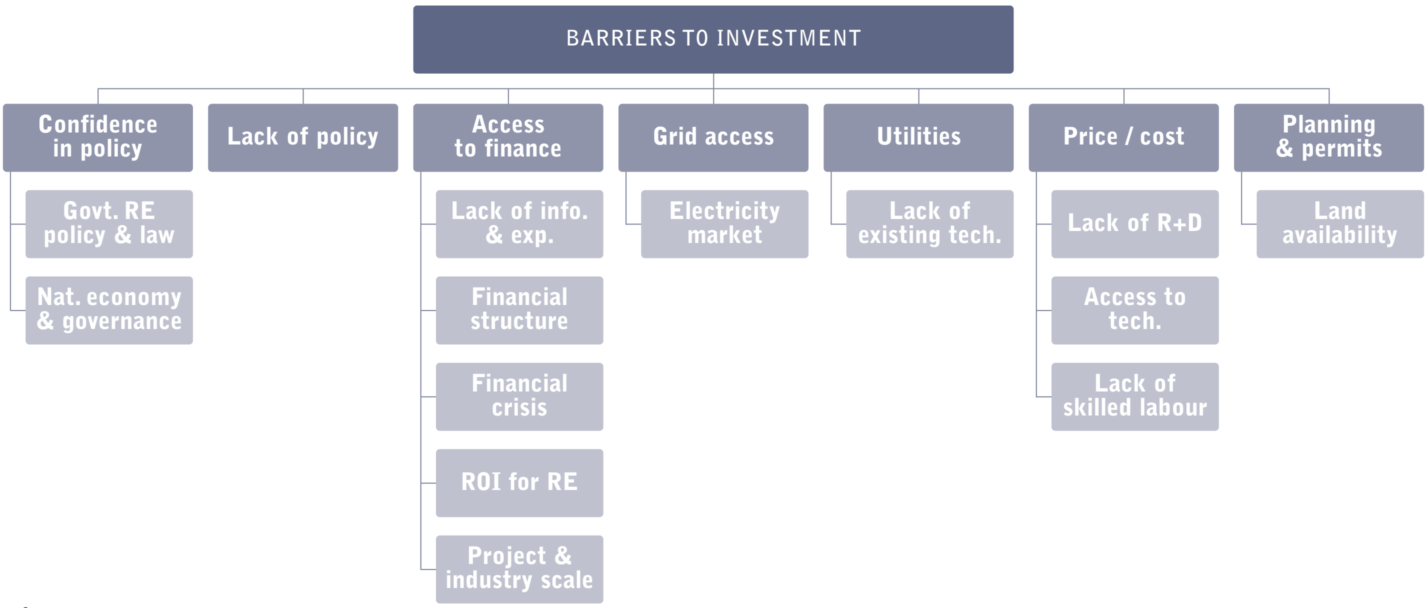
Concerns over planning and permit issues are significant, though vary significantly in their strength and nature depending on the jurisdiction.

3.2.2 how to overcome investment barriers for renewable energy

To see an Energy [R]evolution will require a mix of policy measures, finance, grid, and development. In summary:

- Additional and improved policy support mechanisms for renewable energy are needed in all countries and regions.
- Building confidence in the existing policy mechanisms may be just as important as making them stronger, particularly in the short term.
- Improved policy mechanisms can also lower the cost of finance, particularly by providing longer durations of revenue support and increasing revenue certainty.[46]
- 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 renewable energy technologies directly will require industry development and boosted research and development.
- A smoother pathway for renewable energy needs to be established through planning and permit issues at the local level.
- In accordance to national governance laws, renewable energy policies must be carried out consistent with social reforms. For example, RE policies should be connected to substantive rights of affected communities such as collective ownership of rights to land and resources, right to self-government, right to development and even procedural rights like due process of law. Community plans should be seen as key opportunities to take into account local peoples' own development priorities and initiatives.

figure 3.4: key barriers to renewable energy investment



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45 INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE (IPCC) (2011) SPECIAL REPORT ON RENEWABLE ENERGY SOURCES AND CLIMATE CHANGE MITIGATION (SRREN). 15TH JUNE 2011. CHP. 11, P.24.

46 CLIMATE POLICY INITIATIVE (2011):THE IMPACTS OF POLICY ON THE FINANCING OF RENEWABLE PROJECTS: A CASE STUDY ANALYSIS, 3 OCTOBER 2011.

image 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."

box 3.1: a sustainable energy trade agreement (SETA)

A rapid scale-up and deployment of renewable energy and energy efficiency technology systems could significantly reduce the emissions responsible for global warming. Switching to cleaner and low-carbon transport fuels and technologies also contribute positively toward achieving this goal. However, efforts to increase renewable energy uptake require power producers to keep costs of energy generation as low as possible. Despite the fact that market incentives such as the feed-in tariffs and other tax breaks help, lowering the costs of equipment and services in the ASEAN region used to produce renewable power could also play an essential role in facilitating the scale-up process.

This is where trade policy comes in since it can contribute by lowering barriers to market access for sustainable energy goods and services, particularly renewables. Often, however, trade and domestic sustainable energy policies are designed to restrict access to competitively priced goods and services for sustainable energy producers because while policy makers aim to lower the costs of renewable energy production, they often also seek to promote the domestic manufacturing of renewable energy equipment and the provision of services. This is because the renewable energy sector is viewed as an engine for job creation and rightly so. Other trade and market barriers are also triggered by existing domestic laws and measures linked to investment, government procurement, competition policy and trade facilitation, or in some cases their absence. Diversity of product-related standards and even the absence of standards also hamper trade and diffusion of renewable energy equipment, as well as energy efficient products.

In the region, one of the mechanisms by which trade and investment is facilitated is through the ASEAN Free Trade Area (AFTA) agreed by the 10 member countries. The two primary objectives of the AFTA are i) to increase ASEAN's competitive edge as a production base in the world market through the elimination of tariffs and non-tariff barriers within the region, and ii) attract more foreign direct investment to ASEAN. Moreover, in November 2012, in its determination to beat the global economic slowdown, the heads of states or governments of the member countries and its main trade partners namely Australia, China, India, Korea, Japan and New Zealand officially kicked off negotiations for the Regional Comprehensive Economic Partnership or RCEP. The RCEP sets out the general principles for broadening and deepening the ASEAN's engagement with its free trade agreement (FTA) partners and this milestone signalled the determination and commitment of ASEAN to play the lead and central role in the emerging regional economic architecture.

In order for the ASEAN to fast-track the deployment of renewable energy goods and services in the region, it is imperative for AFTA to start addressing some of these trade-related barriers. Trade in these goods and services are affected by rules and agreements developed in regional and bilateral forums. In some cases, trade in renewable energy goods and services is also affected by negotiating and rule-making forums set up to address climate change issues such as the United Nations Framework Convention on Climate Change or even on issues of energy transit under the International Energy Charter Treaty where ASEAN has an observer status.

To overcome these different factors, it may be worthwhile for ASEAN to consider another fresh methodology that accounts for an integrated view of the renewable energy sector while simultaneously addressing trade-related barriers. A key concept that is now being considered and debated on is the Sustainable Energy Trade Agreement or SETA which is a way of bringing together countries interested in addressing climate change and longer term energy security. There are various possible ways that could be conceived for such an agreement in terms of structure, scope of issues and market barriers to address. One of the advantages of SETA is that it could be a stand-alone pluri-lateral regional agreement outside of the AFTA, which would also be open to other non-ASEAN trade-related partners.

In terms of scope of issues and market barriers to address, other possibilities also exist within a SETA. One phase can address clean energy supply goods and services of solar, wind, small hydro, biomass, geothermal and transport-related biofuels. Another phase could address the scope of energy efficiency products and standards, focusing on priority sectors for greenhouse gas mitigation as identified by the Intergovernmental Panel on Climate Change (IPCC) . These sectors are buildings and construction, transportation and manufacturing. Policy makers may discuss issues on a thematic basis or proceed incrementally on an issue by issue agenda.

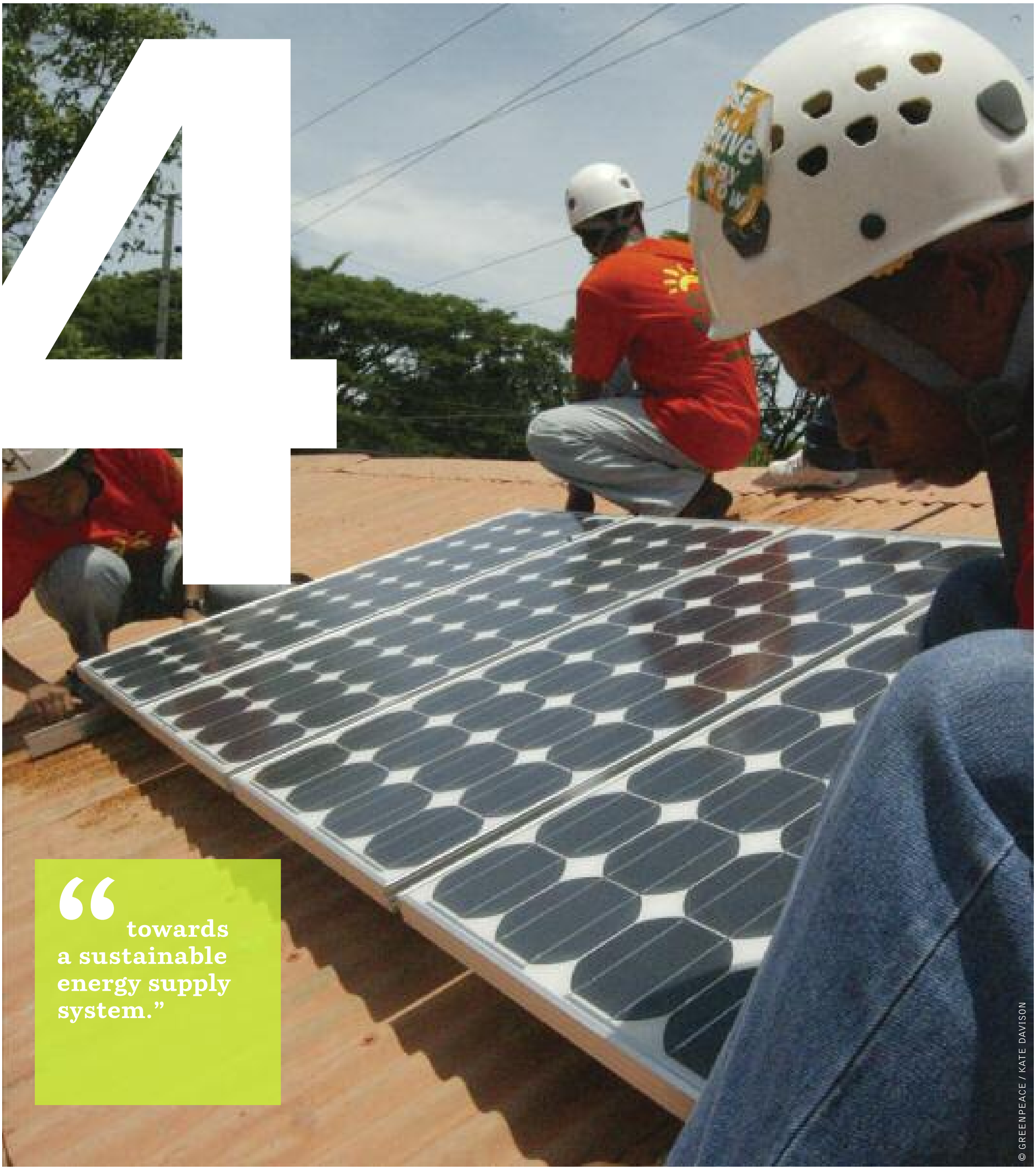
It is worthy to bear in mind however that these approaches has its own set of advantages and disadvantages. But regardless of the approach to be adopted, policy makers should ensure that the "development dimension" is reflected in the modalities, including meaningful provisions on facilitating access to climate-related technologies, technical assistance and capacity building.

The SETA is not a cure-all remedy for all trade-related issues and challenges on renewable energy. But while that is true, a SETA in ASEAN might be able to facilitate innovative approaches to opening up and liberalizing renewable energy goods and services. It is a way to provide a trade climate that is conducive to assessing the linkages between sustainable energy goods and servies where rules and discipline pertaining to renewable energy could be clarified and take shape.

In addition to its catalysing effect on regional trade in a sector of huge importance to global mitigation efforts, such a sustainable energy trade agreement could constructively inform and perhaps even shape the course and direction of future negotiations at the UNFCCC.

scenario for a future energy supply

4



“towards a sustainable energy supply system.”

© GREENPEACE / KATE DAVISON

image TOUR AROUND THE SOUTH EAST OF ASIA TO PROMOTE THE USE OF CLEAN ENERGY.ACTIVISTS SETTING UP SOLAR PANELS AT NEGROS.

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

Moving from principles to action for energy supply that mitigates against climate change 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. In most world regions the transformation from fossil to renewable energies will require additional investment and higher supply costs over about twenty years. However, there will be tremendous economic benefits in the long term, due to much lower consumption of increasingly expensive, rare or imported fuels. Any analysis that seeks to tackle energy and environmental issues therefore needs to look ahead at least half a century.

Scenarios are necessary to describe possible development paths, to give decision-makers a broad overview and indicate how far they can shape the future energy system. Two scenarios are used here to show the wide range of possible pathways in each world region for a future energy supply system:

- **Reference scenario**, reflecting a continuation of current trends and policies.
- The **Energy [R]evolution scenario**, designed to achieve a set of environmental policy targets.

The Reference scenario is based on the Current Policies scenarios published by the International Energy Agency (IEA) in World Energy Outlook 2011 (WEO 2011).[47] It only takes existing international energy and environmental policies into account. Its assumptions include, for example, continuing progress in electricity and gas market reforms, the liberalisation of cross-border energy trade and recent policies designed to combat environmental pollution. The Reference scenario does not include additional policies to reduce greenhouse gas emissions. As the IEA's projections only extend to 2035, they have been extended by extrapolating their key macroeconomic and energy indicators forward to 2050. This provides a baseline for comparison with the Energy [R]evolution scenario.

The global Energy [R]evolution scenario has a key target to reduce worldwide carbon dioxide emissions from energy use down to a level of below 4 Gigatonnes per year by 2050 in order to hold the increase in average global temperature under +2°C. A second objective is the global phasing out of nuclear energy. The Energy [R]evolution scenarios published by Greenpeace in 2007, 2008 and 2010 included 'basic' and 'advanced' scenarios, the less ambitious target was for 10 Gigatonnes CO_2 emissions per year by 2050. However, the 2012 revision only focuses on the more ambitious "advanced" Energy [R]evolution scenario first published in 2010.

This global carbon dioxide emission reduction target translates into a carbon budget for ASEAN countries which forms one of the key assumption for the Energy [R]evolution scenario. To achieve the target, the scenario includes 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 biofuels. The general framework parameters for population and GDP growth remain unchanged from the Reference scenario.

Efficiency in use of electricity and fuels in industry and "other sectors" has been completely re-evaluated compared to earlier versions of the Energy [R]evolution scenarios using a consistent approach based on technical efficiency potentials and energy intensities.

Hydrogen generated by electrolysis and renewable electricity is introduced in this scenario as third renewable fuel in the transport sector after 2025 complementary to biofuels and direct use of renewable electricity. Hydrogen generation can have high energy losses, however the limited potentials of biofuels and probably also battery electric mobility makes it necessary to have a third renewable option. Alternatively, this renewable hydrogen could be converted into synthetic methane or liquid fuels depending of economic benefits (storage costs vs. additional losses) and technology and market development in the transport sector (combustion engines vs. fuel cells).

In all sectors, the latest market development projections of the renewable energy industry[48] have been taken into account. The fast introduction of electric vehicles, combined with the implementation of smart grids and fast expansion of super grids allows a high share of fluctuating renewable power generation (photovoltaic and wind) to be employed. In this scenario, renewable energy would pass 50% within the ASEAN region's energy supply just after 2030.

These scenarios by no means claim to predict the future; they simply describe and compare two 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 truly sustainable.

reference
47 INTERNATIONAL ENERGY AGENCY (IEA), 'WORLD ENERGY OUTLOOK 2011', OECD/IEA 2011.
48 SEE EREC ('RE-THINKING 2050'), GWEC, EPIA ET AL.

4.1 scenario background

The scenarios in this report were jointly commissioned by Greenpeace, the Global Wind Energy Council (GWEC) and the European Renewable Energy Council (EREC) 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.[49] The new energy demand projections were developed from the University of Utrecht, Netherlands, based on an analysis of the future potential for energy efficiency measures in 2012. Finally the Institute for Sustainable Futures (ISF) analysed the employment effects of the Energy [R]evolution and Reference scenarios.

4.1.1 status and future projections for renewable heating technologies

EREC and DLR undertook detailed research about the current renewable heating technology markets, market forecasts, cost projections and state of the technology development. The cost projection as well as the technology option have been used as an input information for this new Energy [R]evolution scenario.

4.2 population development

Future population development is an important factor in energy scenario building because population size affects the size and composition of energy demand, directly and through its impact on economic growth and development.

table 4.1: population development projection

(IN MILLIONS)

	2009	2015	2020	2025	2030	2040	**2050**
ASEAN Region	592	625	654	681	704	738	**756**

4.3 economic growth

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

Although PPP assessments are still relatively imprecise compared to statistics based on national income and product trade and national price indexes, they are considered to provide a better basis for a scenario development.[50] Thus all data on economic development in WEO 2011 refers to purchasing power adjusted GDP. However, as WEO 2011 only covers the time period up to 2035, the projections for 2035-2050 for the Energy [R]evolution scenario are based on our own estimates.

Prospects for GDP growth have decreased considerably since the previous study, due to the financial crisis at the beginning of 2009, although underlying growth trends continue much the same. GDP growth in all regions is expected to slow gradually over the coming decades. World GDP is assumed to grow on average by 3.8% per year over the period 2009-2030, compared to 3.1% from 1971 to 2007, and on average by 3.1% per year over the entire modelling period (2009-2050). China and India are expected to grow faster than other regions, followed by the Middle East, Africa, remaining Non-OECD Asia, and Eastern Europe/Eurasia. The Chinese economy will slow as it becomes more mature, but will nonetheless become the largest in the world in PPP terms early in the 2020s. GDP for the ASEAN countries is assumed to grow by around 3.4% per year over the projection period.

references

49 ENERGY [R]EVOLUTION: A SUSTAINABLE WORLD ENERGY OUTLOOK', GREENPEACE INTERNATIONAL, 2007, 2008 AND 2010.

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

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

table 4.2: gdp development projections

(AVERAGE ANNUAL GROWTH RATES)

REGION	2009-2020	2020-2035	2035-2050	**2009-2050**
World	4.2%	3.2%	2.2%	3.1%
OECD Americas	2.7%	2.3%	1.2%	2.0%
OECD Asia Oceania	2.4%	1.4%	0.5%	1.3%
Eastern Europe/ Eurasia	4.2%	3.2%	1.9%	3.0%
India	7.6%	5.8%	3.1%	5.3%
China	8.2%	4.2%	2.7%	4.7%
Non OECD Asia	5.2%	3.2%	2.6%	3.5%
ASEAN Region	5.6%	3.2%	2.6%	3.5%
Latin America	4.0%	2.8%	2.2%	2.9%
Middle East	4.3%	3.7%	2.8%	3.5%
Africa	4.5%	4.4%	4.2%	4.4%

source 2009-2035: IEA WEO 2011 AND 2035-2050: DLR, PERSONAL COMMUNICATION (2012)

4.4 oil and gas price projections

The recent dramatic fluctuations in global oil prices have resulted in slightly higher forward price projections for fossil fuels. Under the 2004 'high oil and gas price' scenario from the European Commission, for example, an oil price of just US$ 34 per barrel (/bbl) was assumed in 2030. More recent projections of oil prices by 2035 in the IEA's WEO 2011 range from US$2010 97/bbl in the 450 ppm scenario up to US$2010 140/bbl in current policies scenario.

Since the first Energy [R]evolution study was published in 2007, however, the actual price of oil has reached over US$ 100/bbl for the first time, and in July 2008 reached a record high of more than US$ 140/bbl. Although oil prices fell back to US$ 100/bbl in September 2008 and around US$ 80/bbl in April 2010, prices have increased to more than US$ 110/bbl in early 2012. Thus, the projections in the IEA Current Policies 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 slightly higher than the IEA WEO 2011 "Current Policies" case extrapolated forward to 2050 (see Table 4.3).

As the supply of natural gas is limited by the availability of pipeline infrastructure, there is no world market price for gas. In most regions of the world the gas price is directly tied to the price of oil. Gas prices are therefore assumed to increase to US$24-30/GJ by 2050.

table 4.3: development projections for fossil fuel and biomass prices in $ 2010

FOSSIL FUEL	UNIT	2000	2005	2007	2008	2010	2015	2020	2025	2030	2035	2040	2050
Crude oil imports													
Historic prices (from WEO)	barrel	35	51	76	98	78							
WEO "450 ppm scenario"	barrel					78	97	97	97	97	97		
WEO Current policies	barrel					78	106	106	106	135	140		
Energy [R]evolution 2012	barrel					78	112	112	112	152	152	152	152
Natural gas imports													
Historic prices (from WEO)													
United States	GJ	5.07	2.35	3.28		4.64							
Europe	GJ	3.75	4.55	6.37		7.91							
Japan LNG	GJ	6.18	4.58	6.41		11.61							
WEO 2011 "450 ppm scenario"													
United States	GJ					4.64	6.22	6.86	8.44	8.85	8.23		
Europe	GJ					7.91	9.92	10.34	10.34	10.23	9.92		
Japan LNG	GJ					11.61	12.56	12.66	12.66	12.77	12.77		
WEO 2011 Current policies													
United States	GJ					4.64	6.44	7.39	8.12	8.85	9.50		
Europe	GJ					7.91	10.34	11.61	12.56	13.29	13.72		
Japan LNG	GJ					11.61	13.40	14.24	14.98	15.61	16.04		
Energy [R]evolution 2012													
United States	GJ					4.64	8.49	10.84	12.56	14.57	16.45	18.34	24.04
Europe	GJ					7.91	14.22	16.78	18.22	19.54	20.91	22.29	26.37
Japan LNG	GJ					11.61	16.22	19.08	20.63	22.12	23.62	25.12	29.77
OECD steam coal imports													
Historic prices (from WEO)	tonne	42	50	70	122	99							
WEO 2011 "450 ppm scenario"	tonne					99	100	93	83	74	68		
WEO 2011 Current policies	tonne					99	105	109	113	116	118		
Energy [R]evolution 2012	tonne						126.7	139	162.3	171.0	181.3	199.0	206.3
Biomass (solid)													
Energy [R]evolution 2012													
OECD Europe	GJ			7.50		7.80	8.31	9.32	9.72	10.13	10.28	10.43	10.64
OECD Asia Oceania & North America	GJ			3.34		3.44	3.55	3.85	4.10	4.36	4.56	4.76	5.27
Other regions	GJ			2.74		2.84	3.24	3.55	3.80	4.05	4.36	4.66	4.96

source IEA WEO 2009 & 2011 own assumptions and 2035-2050: DLR, Extrapolation (2012).

4.5 cost of CO_2 emissions

The costs 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, and a broad range of future estimates has been made in studies. Other projections have assumed higher CO_2 costs than than those included in this Energy [R]evolution study (75 $US\$_{2010}/tCO_2$)[51], reflecting estimates of the total external costs of CO_2 emissions. The CO_2 cost estimates in the 2010 version of the global Energy [R]evolution were rather conservative (50 $US\$_{2008}/t$). CO_2 costs are applied in Kyoto Protocol Non-Annex B countries only from 2030 on.

table 4.4: assumptions on CO_2 emissions cost development for Annex-B and Non-Annex-B countries of the UNFCCC.
($NZS2010/tCO_2$)

COUNTRIES	2010	2015	2020	2030	2040	2050
Annex-B countries	0	15	25	40	55	75
Non-Annex-B countries	0	0	0	40	55	75

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

Further cost reduction potentials are assumed for fuel power technologies in use today for coal, gas, lignite and oil. Because they are at an advanced stage of market development the potential for cost reductions is limited, and will be achieved mainly through an increase in efficiency.[52]

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 means 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 special report on CCS assesses costs at US$ 15-75 per tonne of captured CO_2[53], while a 2007 US Department of Energy report found installing carbon capture systems to most modern plants resulted in a near doubling of costs.[54] These costs are estimated to increase the price of electricity in a range from 21-91%.[55]

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.[56] 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.[57]

The Intergovernmental Panel on Climate Change (IPCC) estimates a cost range for pipelines of US$ 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 US$ 6 million. The same report estimates that a dedicated interstate pipeline network in North Carolina would cost upwards of US$ 5 billion due to the limited geological sequestration potential in that part of the country.[58] Storage and subsequent monitoring and verification costs are estimated by the IPCC to range from US$ 0.5-8/tCO_2 (for storage) and US$ 0.1-0.3/tCO_2. The overall cost of CCS could therefore be a major barrier to its deployment.[59]

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

Table 4.5 summarises our assumptions on the technical and economic parameters of future fossil-fuelled power plant technologies. Based on estimates from WEO 2010, we assume that further technical innovation will not prevent an increase of future investment costs because raw material costs and technical complexity will continue to increase. Also, improvements in power plant efficiency are outweighed by the expected increase in fossil fuel prices, which would increase electricity generation costs significantly.

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image SATELLITE IMAGE OF JAPAN'S DAI ICHI POWER PLANT SHOWING DAMAGE AFTER THE EARTHQUAKE AND TSUNAMI OF 2011.

table 4.5: development of efficiency and investment costs for selected new power plant technologies

POWER PLANT		2009	2015	2020	2030	2040	2050
Coal-fired condensing power plant	Max. efficiency (%)	45	46	48	50	52	53
	Investment costs (US$2010/kW)	1,436	1,384	1,363	1,330	1,295	1,262
	CO_2 emissions a)(g/kWh)	744	728	697	670	644	632
Lignite-fired condensing power plant	Max. efficiency (%)	41	43	44	44,5	45	45
	Investment costs (US$2010/kW)	1,693	1,614	1,578	1,545	1,511	1,478
	CO_2 emissions a)(g/kWh)	975	929	908	898	888	888
Natural gas combined cycle	Max. efficiency (%)	57	59	61	62	63	64
	Investment costs (US$2010/kW)	777	754	736	701	666	631
	CO_2 emissions a)(g/kWh)	354	342	330	325	320	315

source
WEO 2010, DLR 2010 a)CO_2 emissions refer to power station outputs only; life-cycle emissions are not considered.

4.7 cost projections for renewable energy technologies

The different renewable energy technologies available today all have different technical maturity, costs and development potential. Whereas hydro power has been widely used for decades, other technologies, such as the gasification of biomass or ocean energy, 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 coordination with the grid network. But although in many cases renewable energy technologies are 'distributed' - their output being generated and delivered locally to the consumer – in the future we can also have large-scale applications like offshore wind parks, photovoltaic power plants or concentrating solar power stations.

It is possible to develop a wide spectrum of options to market maturity, using the individual advantages of the different technologies, and linking them with each other, and integrating them step by step into the existing supply structures. This approach will 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 environmental and social costs of conventional power production are not reflected in market prices. It is expected, however that large cost reductions can come from technical advances, manufacturing improvements and large-scale production, unlike conventional technologies. The dynamic trend of cost developments over time plays a crucial role in identifying economically sensible expansion strategies for scenarios spanning several decades.

To identify long-term cost developments, learning curves have been applied to the model calculations to reflect how the cost of a particular technology can change in relation to the cumulative production volumes. For many technologies, the learning factor (or progress ratio) is 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[60], from the analysis of recent technology foresight and road mapping studies, including the European Commission funded NEEDS project (New Energy Externalities Developments for Sustainability)[61] 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 different sectors of the renewable energy industry.

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4.7.1 photovoltaics (PV)

The worldwide photovoltaics (PV) market has been growing at over 40% per annum in recent years and the contribution is starting to make a significant contribution to electricity generation. Photovoltaics are important because of its decentralised / centralised character, its flexibility for use in an urban environment and huge potential for cost reduction. The PV industry has been increasingly exploiting this potential during the last few years, with installation prices more than halving in the last few years. Current development 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 costs reducing by 20% each time the installed capacity doubles, indicating a high rate of technical learning. Assuming a globally installed capacity of 1,500 GW by between 2030 and 2040 in the Energy [R]evolution scenario, and with an electricity output of 2,600 TWh/a, we can expect that generation costs of around US$ 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. Cost data applied in this study is shown in Table 4.6. In the long term, additional costs for the integration into the power supply system of up to 25% of PV investment have been taken into account (estimation for local batteries and load and generation management measures).

4.7.2 concentrating solar power (CSP)

Solar thermal 'concentrating' power stations (CSP) can only use direct sunlight and are therefore dependent on very sunny locations. Southern Europe has a technical potential for this technology which far exceeds local demand. The various solar thermal technologies have 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 10,000C°, which is then used to run a combined gas and steam turbine.

Thermal storage systems are a way for CSP electricity generators to reduce 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 US$ 6-10 cents/kWh can be achieved. This presupposes rapid market introduction in the next few years. CSP investment costs assumed for this study and shown in Table 4.7 include costs for an increasing storage capacity up to 12 hours per day and additional solar fields up to solar multiple 3, achieving a maximum of 6,500 full load hours per year.

table 4.6: photovoltaics (PV) cost assumptions

INCLUDING ADDITIONAL COSTS FOR GRID INTEGRATION OF UP TO 25% OF PV INVESTMENT

SCENARIO	2009	2015	2020	2030	2040	2050
E[R]						
Investment costs (US$/kWp)	3,000	2,300	1,650	1,280	1,040	1,060
O & M costs US$/(kW/a)	43	38	21	15	14	15

O & M = Operation and maintenance.

table 4.7: concentrating solar power (CSP) cost assumptions

INCLUDING COSTS FOR HEAT STORAGE AND ADDITIONAL SOLAR FIELDS

SCENARIO	2009	2015	2020	2030	2040	2050
E[R]						
Investment costs (US$/kWp)	9,300	8,100	6,600	5,750	5,300	4,800
O & M costs US$/(kW/a)	420	330	265	229	211	193

O & M = Operation and maintenance.

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

4.7.3 wind power

Within a short period of time, the dynamic development of wind power has resulted in the establishment of a flourishing global market. In Europe, favorable policy incentives were the early drivers for the global wind market. The boom in demand for wind power technology has nonetheless led to supply constraints. As a consequence, the cost of new systems has increased. The industry is continuously expanding production capacity, however, so it is already resolving the bottlenecks in the supply chain. Taking into account market development projections, learning curve analysis and industry expectations, we assume that investment costs for wind turbines will reduce by 25% for onshore and 50% for offshore installations up to 2050. Additional costs for grid integration of up to 25% of investment has been taken into account also in the cost data for wind power shown in Table 4.9.

4.7.4 biomass

The crucial factor for the economics of using biomass for energy is the cost of the feedstock, which today ranges from a negative 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 has a wide range of applications, is still relatively expensive. In the long term it is expected that using wood gas both in micro CHP units (engines and fuel cells) and in gas-and-steam power plants will have the most favorable electricity production costs. 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 –although its climate benefit is disputed. 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 could 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 4.8: wind power cost assumptions

INCLUDING ADDITIONAL COSTS FOR GRID INTEGRATION OF UP TO 25% OF INVESTMENT

SCENARIO	2009	2015	2020	2030	2040	2050
E[R]						
Wind turbine offshore						
Investment costs (US$/kWp)	6,000	5,100	3,800	3,000	2,700	2,350
O & M costs US$/(kW/a)	230	205	161	131	124	107
Wind turbine onshore						
Investment costs (US$/kWp)	1,800	1,500	1,290	1,280	1,300	1,350
O & M costs US$/(kW/a)	64	55	55	56	59	61

O & M = Operation and maintenance.

table 4.9: biomass cost assumptions

SCENARIO	2009	2015	2020	2030	2040	2050
E[R]						
Biomass power plant						
Investment costs (US$/kWp)	3,350	3,100	3,000	2,800	2,700	2,650
O & M costs US$/(kW/a)	201	185	175	169	162	166
Biomass CHP						
Investment costs (US$/kWp)	5,700	5,050	4,400	3,850	3,550	3,380
O & M costs US$/(kW/a)	397	354	310	270	250	237

O & M = Operation and maintenance.

4.7.5 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 widened potential sites. 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, could make it possible to produce geothermal electricity anywhere. Advanced heat and power cogeneration plants will also improve the economics of geothermal electricity.

A large part of the costs for a geothermal power plant come from deep underground drilling, so further development of innovative drilling technology is expected. Assuming a global average market growth for geothermal power capacity of 15% per year up to 2020, adjusting to 12% up to 2030 and still 7% per year beyond 2030, the result would be a cost reduction potential of more than 60% by 2050:

- for conventional geothermal power (without heat credits), from $ 15 cents/kWh to about $ 9 cents/kWh;
- for EGS, despite the presently high figures (about $ 20-30 cents/kWh), electricity production costs - depending on the credits for heat supply - are expected to come down to around $ 8 cents/kWh in the long term.

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

4.7.6 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 research and development, 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 US$ 25-95 cents/kWh[62], and for initial tidal stream farms in the range of US$ 14-28 cents/kWh. Generation costs of US$ 8-10 cents/kWh are expected by 2030. 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 long 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.[63]

table 4.10: geothermal cost assumptions

SCENARIO	2009	2015	2020	2030	2040	2050
E[R]						
Geothermal power plant						
Investment costs (US$/kWp)	13,500	11,100	9,300	6,400	5,300	4,550
O & M costs US$/(kW/a)	637	538	418	318	297	281

O & M = Operation and maintenance.

table 4.11: ocean energy cost assumptions

SCENARIO	2009	2015	2020	2030	2040	2050
E[R]						
Ocean energy power plant						
Investment costs (US$/kWp)	5,900	4,650	3,300	2,300	1,900	1,700
O & M costs US$/(kW/a)	237	185	132	91	77	68

O & M = Operation and maintenance.

references

62 G.J. DALTON, T. LEWIS (2011): PERFORMANCE AND ECONOMIC FEASIBILITY ANALYSIS OF 5 WAVE ENERGY DEVICES OFF THE WEST COAST OF IRELAND; EWTEC 2011.
63 WWW.NEEDS-PROJECT.ORG.

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.

4.7.7 hydro power

Hydro power 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. There is likely to be some more potential for hydropower with the increasing need for flood control and the maintenance of water supply during dry periods. Sustainable hydropower makes an effort to integrate plants with river ecosystems while reconciling ecology with economically attractive power generation.

table 4.12: hydro power cost assumptions

SCENARIO	2009	2015	2020	2030	2040	2050
E[R]						
Investment costs (US$/kWp)	3,300	3,400	3,500	3,650	3,500	3,900
O & M costs US$/(kW/a)	132	136	141	146	152	156

O & M = Operation and maintenance.

4.7.8 summary of renewable energy cost development

Figure 4.1 summarises the cost trends for renewable power technologies derived from the respective learning curves. It is important to note that the expected cost reduction is not a function of time, but of cumulative capacity (production of units), so dynamic market development is required. Most of the technologies will be able to reduce their specific investment costs to between 30% and 60% of current 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 4.2. Generation costs today are around US$ 8 to 35 cents/kWh for the most important technologies, including photovoltaic. In the long term, costs are expected to converge at around US$ 6 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 4.1: future development of investment costs for renewable energy technologies (NORMALISED TO 2010 COST LEVELS)

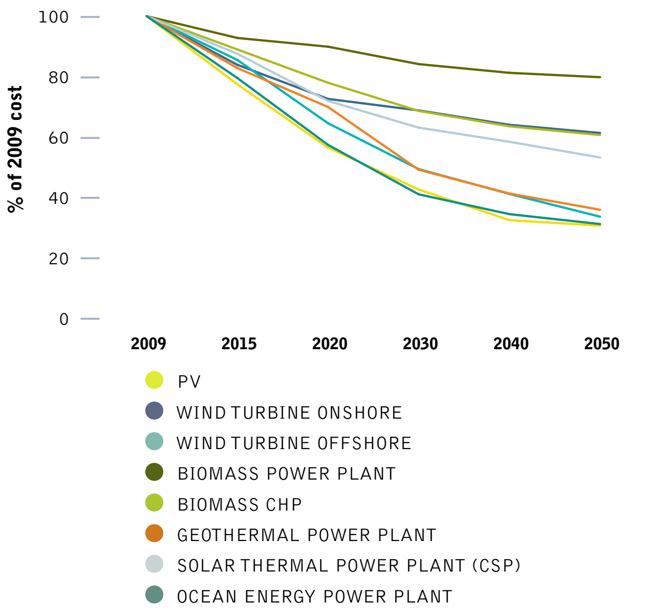
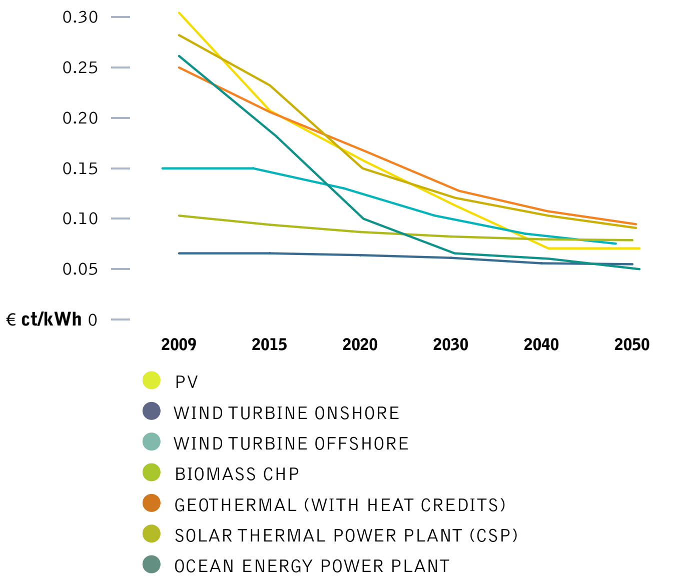


figure 4.2: expected development of electricity generation costs from fossil fuel and renewable options

EXAMPLE FOR OECD EUROPE



4.8 cost projections for renewable heating technologies

Renewable heating has the longest tradition of all renewable technologies. EREC and DLR carried out a survey on costs of renewable heating technologies in Europe, which analyses installation costs of renewable heating technologies, ranging from direct solar collector systems to geothermal and ambient heat applications and biomass technologies. The report shows that some technologies are already mature and compete on the market – especially simple heating systems in the domestic sector. However, more sophisticated technologies, which can provide higher shares of heat demand from renewable sources, are still under development and rather expensive. Market barriers slow down the further implementation and cost reduction of renewable heating systems, especially for heating networks. Nevertheless, significant learning rates can be expected if renewable heating is increasingly implemented as projected in the Energy [R]evolution scenario.

4.8.1 solar thermal technologies

Solar collectors depend on direct solar irradiation, so the yield strongly depends on the location. In very sunny regions even very simple collectors can provide hot water to households at very low cost. In Europe, thermosiphon systems can provide total hot water demand in households at around 400 €/m^2 installation costs. In regions with less sun, where additional space heating is needed, installation cost for pumped systems are twice as high. In these areas, economies of scales can decrease solar heating costs significantly. Large scale solar collector system are known from 250-600 €/m^2, depending on the share of solar energy in the whole heating system and the level of storage required. While those cost assumptions were transferred to all OECD Regions and the Eastern European Economies, a lower cost level for households was assumed in very sunny or developing regions.

4.8.2 deep geothermal applications

Deep geothermal heat from aquifers or reservoirs can be used directly in hydrothermal heating plants to supply heat demand close to the plant or in a district heating network for several different types of heat. Due to the high drilling costs deep geothermal energy is mostly feasibly for large applications in combination with heat networks. It is already economic feasible and has been in use for a long time, where aquifers can be found near the surface, e.g. in the Pacific Island or along the Pacific ring of fire. Also in Europe deep geothermal applications are being developed for heating purposes at investment costs from 500€/kWth (shallow) to 3000 €/kWth (deep), with the costs strongly dependent on the drilling depth. As deep geothermal systems require a high technology level, European cost assumptions were transferred to all regions worldwide.

4.8.3 heat pumps (aerothermal systems)

Heat pumps typically provide hot water or space heat for heating systems with relatively low supply temperature or can serve as a supplement to other heating technologies. They have become increasingly popular for underfloor heating in buildings in Europe. Economies of scale are less important than for deep geothermal, so there is focus on small household applications with investment costs in Europe ranging from 500-1,600 €/kW for ground water systems and from 1,200-3,000 €/kW for ground source or aerothermal systems.

4.8.4 biomass applications

There is broad portfolio of modern technologies for heat production from biomass, ranging from small scale single room stoves to heating or CHP-plants in MW scale. Investments costs in Europe show a similar variety: simple log wood stoves can be obtained from 100 €/kW, more sophisticated automated heating systems that cover the whole heat demand of a building are significantly more expensive. Log wood or pellet boilers range from 400-1,200 €/kW, with large applications being cheaper than small systems. Considering the possible applications of this wide range of technologies especially in the household sector, higher investment costs were assumed for hightech regions of the OECD, the Eastern European Economies and Middle East. Sunny regions with low space heat demand as well as developing regions are covered with very low investment costs. Economy of scales apply to heating plants above 500kW, with investment cost between 400-700 €/kW. Heating plants can deliver process heat or provide whole neighbourhoods with heat. Even if heat networks demand additional investment, there is great potential to use solid biomass for heat generation in both small and large heating centres linked to local heating networks.

Cost reductions expected vary strongly within each technology sector, depending on the maturity of a specific technology. E.g. small wood stoves will not see significant cost reductions, while there is still learning potential for automated pellet heating systems. Cost for simple solar collectors for swimming pools might be already optimised, whereas integration in large systems is neither technological nor economical mature. Table 4.13 shows average development pathways for a variety of heat technology options.

table 4.13: overview over expected investment costs pathways for heating technologies IN $/KW

	2015	2020	2030	2040	2050
Geothermal distict heating*	2,650	2,520	2,250	2,000	1,760
Heat pumps	1,990	1,930	1,810	1,710	1,600
Low tech solar collectors	140	140	140	140	140
Small solar collector systems	1,170	1,120	1,010	890	750
Large solar collector systems	950	910	810	720	610
Solar district heating*	1,080	1,030	920	820	690
Low tech biomass stoves	130	130	130	130	130
Biomass heating systems	930	900	850	800	750
Biomass district heating*	660	640	600	570	530

* WITHOUT NETWORK

image A SATELLITE IMAGE OF EYJAFJALLAJOKULL VOLCANO ERUPTION, ICELAND, 2010.

4.9 assumptions for fossil fuel phase out

More than 80% of the global current energy supply is based on fossil fuels. Oil dominates the entire transport sector; oil and gas make up the heating sector and coal is the most-used fuel for power. Each sector has different renewable energy and energy efficiency technologies combinations which depend on the locally available resources, infrastructure and to some extent, lifestyle. The renewable energy technology pathways use in this scenario are based on currently available "off-the-shelf" technologies, market situations and market projections developed from renewable industry associations such as the Global Wind Energy Council, the European Photovoltaic Industry Association and the European Renewable Energy Council, the DLR and Greenpeace International.

In line with this modeling, the Energy [R]evolution needs to map out a clear pathway to phase-out oil in the short term and gas in the mid to long term. This pathway has been identified on the basis of a detailed analysis of the global conventional oil resources, current infrastructure of those industries, the estimated production capacities of existing oil wells and the investment plans know by end 2011. Those remaining fossil fuel resources between 2012 and 2050 form the oil pathway, so no new deep sea and arctic oil exploration, no oil shale and tar sand mining for two reasons:

- First and foremost, to limit carbon emissions to save the climate.
- Second, financial resources must flow from 2012 onwards in the development of new and larger markets for renewable energy technologies and energy efficiency to avoid "locking-in" new fossil fuel infrastructure.

4.9.1 oil – production decline assumptions

Figure 4.3 shows the remaining production capacities with an annual production decline between 2.5% and 5% and the additional production capacities assuming all new projects planned for 2012 to 2020 will go ahead. Even with new projects, the amount of remaining conventional oil is very limited and therefore a transition towards a low oil demand pattern is essential.

4.9.2 coal – production decline assumptions

While there is an urgent need for a transition away from oil and gas to avoid "locking-in" investments in new production wells, the climate is the clearly limiting factor for the coal resource, not its availability. All existing coal mines – even without new expansions of mines – could produce more coal, but its burning puts the world on a catastrophic climate change pathway.

figure 4.3: global oil production 1950 to 2011 and projection till 2050

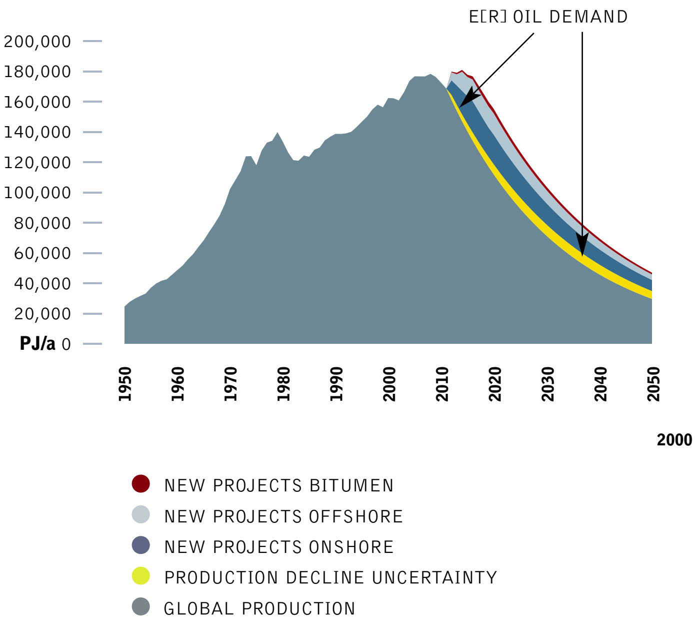
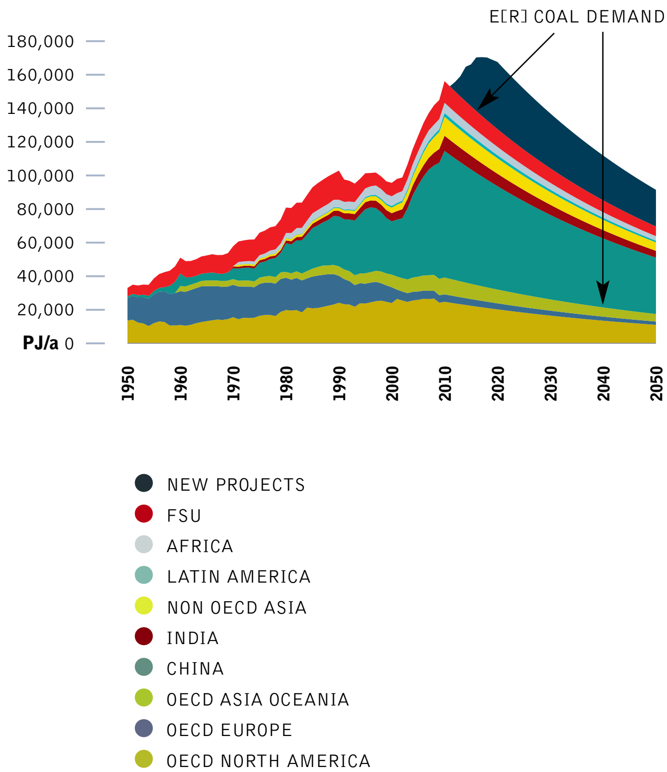


figure 4.4: coal scenario: base decline of 2% per year and new projects



4.10 review: greenpeace scenario projections of the past

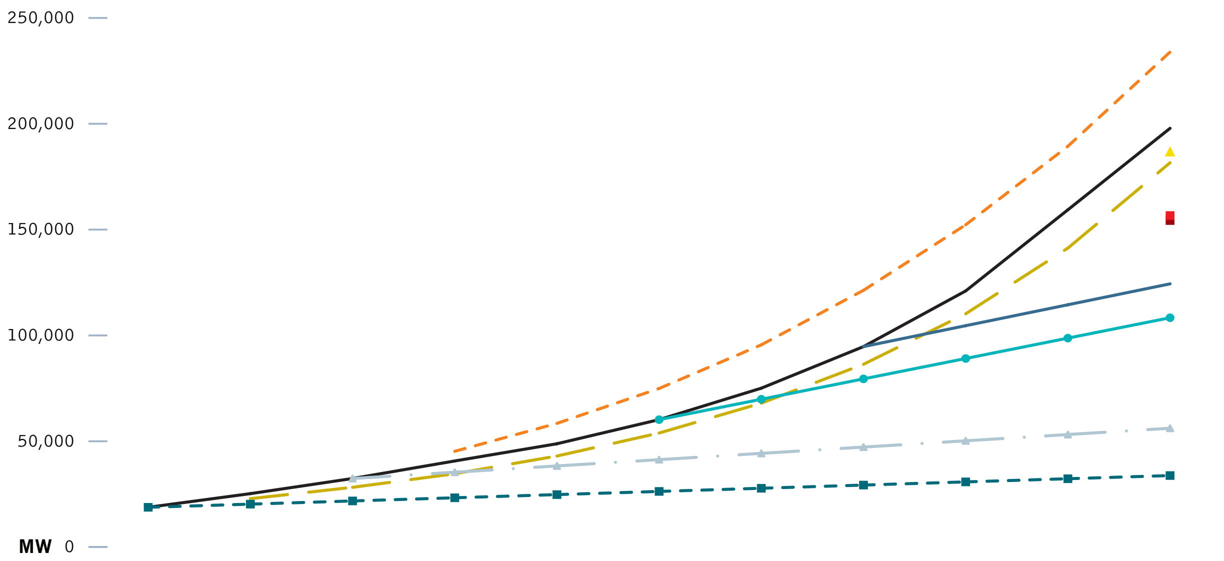
Greenpeace has published numerous projections in cooperation with renewable industry associations and scientific institutions in the past decade. This section provides an overview of the projections between 2000 and 2011 and compares them with real market developments and projections of the IEA World Energy Outlook – our Reference scenario.

4.10.1 the development of the global wind industry

Greenpeace and the European Wind Energy Association published "Windforce 10" for the first time in 1999– a global market projection for wind turbines until 2030. Since then, an updated prognosis has been published every second year. Since 2006 the report has been renamed to "Global Wind Energy Outlook" with a new partner – the Global Wind Energy Council (GWEC) – a new umbrella organisation of all regional wind industry associations. Figure 4.5 shows the projections made each year between 2000 and 2010 compared to the real market data. The graph also includes the first two Energy [R]evolution (ER) editions (published in 2007 and 2008) against the IEA's wind projections published in World Energy Outlook (WEO) 2000, 2002, 2005 and 2007.

The projections from the "Wind force 10" and "Windforce 12" were calculated by BTM consultants, Denmark. The "Windforce 10" (2001 - 2011) projection for the global wind market was actually 10% lower than the actual market development. All following editions were around 10% above or below the real market. In 2006, the new "Global Wind Energy Outlook" had two different scenarios, a moderate and an advanced wind power market projections calculated by GWEC and Greenpeace International. The figures here show only the advanced projections, as the moderate were too low. However, these very projections were the most criticised at the time, being called "over ambitious" or even "impossible".

figure 4.5: wind power: short term prognosis vs real market development - global cumulative capacity



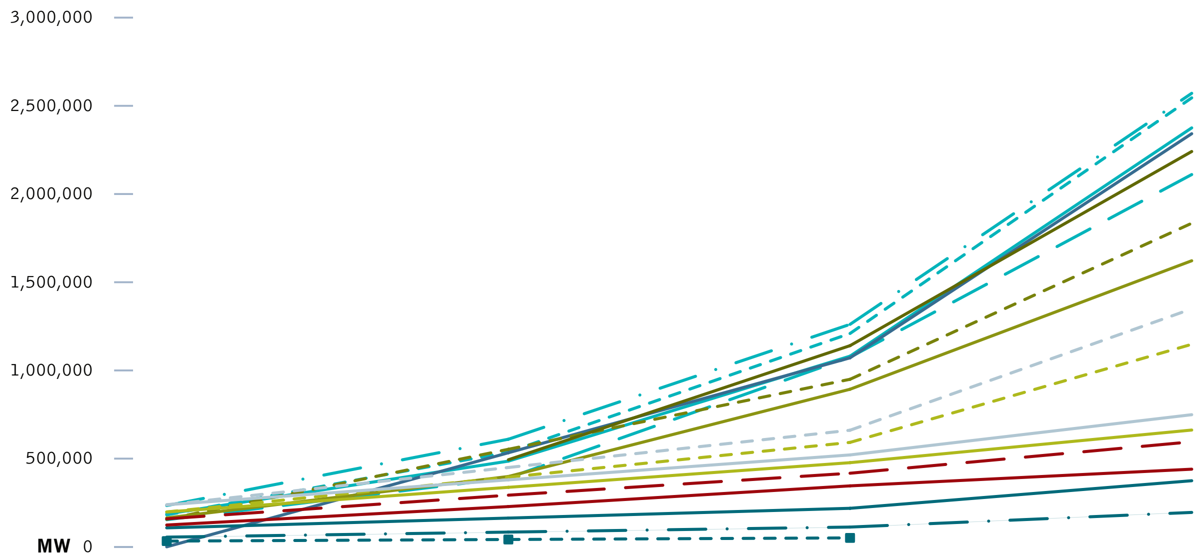
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
REAL	17,400	23,900	31,100	39,431	47,620	59,091	74,052	93,820	120,291	158,864	197,637
WF 10 (1999)		21,510	26,901	33,371	41,781	52,715	66,929	85,407	109,428	140,656	181,252
WF 12 (2002)				44,025	57,306	73,908	94,660	120,600	151,728	189,081	233,905
GWEO 2006 (Advanced)											153,759
GWEO 2008 (Advanced)											186,309
ER 2007											156,149
ER 2008											163,855
ADVANCED ER 2010											
IEA WEO 2000 (REF)	17,400	18,910	20,420	21,930	23,440	24,950	26,460	27,970	29,480	30,990	32,500
IEA WEO 2002 (REF)			31,100	34,088	37,075	40,063	43,050	46,038	49,025	52,013	55,000
IEA WEO 2005 (REF)						59,091	68,781	78,471	88,161	97,851	107,541
IEA WEO 2007 (REF)								93,820	103,767	113,713	123,660

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

In contrast, the IEA "Current Policy" projections seriously under estimated the wind industry's ability to increase manufacturing capacity and reduce costs. In 2000, the IEA published projections of global installed capacity for wind turbines of 32,500 MW for 2010. This capacity had been connected to the grid by early 2003, only two-and-a-half years later. By 2010, the global wind capacity was close to 200,000 MW; around six times more than the IEA's assumption a decade earlier.

Only time will tell if the GPI/DLR/GWEC longer-term projections for the global wind industry will remain close to the real market. However the International Energy Agency's World Energy Outlook projections over the past decade have been constantly increased and keep coming close to our progressive growth rates.

figure 4.6: wind power: long term market projections until 2030



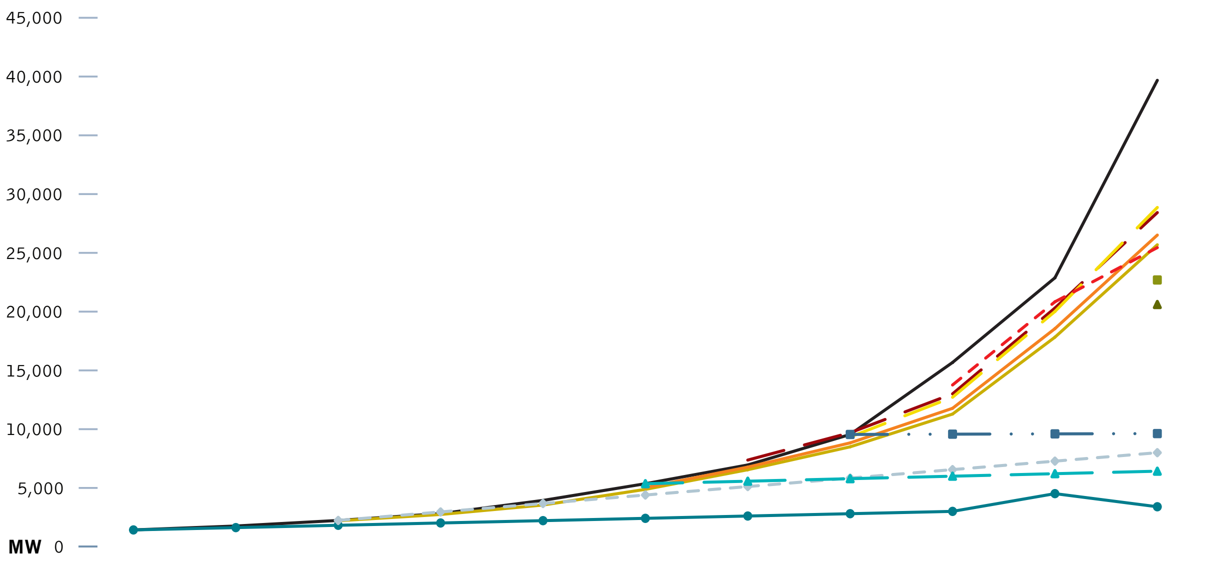
	2010	2015	2020	2030
WF 10 (1999)	181,252	537,059	1,209,466	2,545,232
WF 12 (2002)	233,905	610,000	1,261,157	2,571,000
GWEO 2006 (Advanced)	153,759	391,077	1,074,835	2,110,401
GWEO 2008 (Advanced)	186,309	485,834	1,080,886	2,375,000
GWEO 2008 (Advanced)	0	533,233	1,071,415	2,341,984
E[R] 2007	156,149	552,973	949,796	1,834,286
E[R] 2008	163,855	398,716	893,317	1,621,704
ADVANCED E[R] 2010		493,542	1,140,492	2,241,080
IEA WEO 2000 (REF)	32,500	41,550	50,600	
IEA WEO 2002 (REF)	55,000	83,500	112,000	195,000
IEA WEO 2005 (REF)	107,541	162,954	218,367	374,694
IEA WEO 2007 (REF)	123,660	228,205	345,521	440,117
IEA WEO 2009 (REF)	158,864	292,754	417,198	595,365
IEA WEO 2010 (REF)	197,637	337,319	477,000	662,000
IEA WEO 2010 (450ppm)	197,637	394,819	592,000	1,148,000
IEA WEO 2011 (REF)	238,351	379,676	521,000	749,000
IEA WEO 2011 (450ppm)	238,351	449,676	661,000	1,349,000

4.10.2 the development of the global solar photovoltaic industry

Inspired by the successful work with the European Wind Energy Association (EWEA), Greenpeace began working with the European Photovoltaic Industry Association to publish "Solar Generation 10" – a global market projection for solar photovoltaic technology up to 2020 for the first time in 2001. Since then, six editions have been published and EPIA and Greenpeace have continuously improved the calculation methodology with experts from both organisations.

Figure 4.7 shows the actual projections for each year between 2001 and 2010 compared to the real market data, against the first two Energy [R]evolution editions (published in 2007 and 2008) and the IEA's solar projections published in World Energy Outlook (WEO) 2000, 2002, 2005 and 2007. The IEA did not make specific projections for solar photovoltaic in the first editions analysed in the research, instead the category "Solar/Tidal/Other" are presented in Figure 4.7 and 4.8.

figure 4.7: photovoltaics: short term prognosis vs real market development - global cumulative capacity



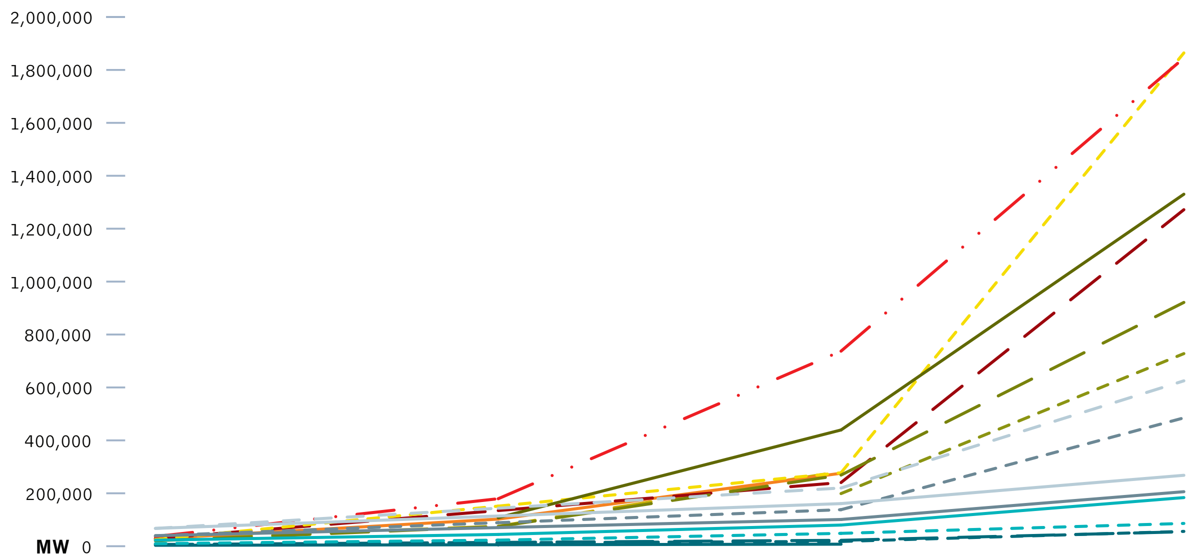
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
REAL	1,428	1,762	2,236	2,818	3,939	5,361	6,956	9,550	15,675	22,878	39,678
SG I 2001			2,205	2,742	3,546	4,879	6,549	8,498	11,285	17,825	25,688
SG II 2004						5,026	6,772	8,833	11,775	18,552	26,512
SG III 2006							7,372	9,698	13,005	20,305	28,428
SG IV 2007 (Advanced)								9,337	12,714	20,014	28,862
SG V 2008 (Advanced)									13,760	20,835	25,447
SG VI 2010 (Advanced)											36,629
ER 2007											22,694
ER 2008											20,606
ADVANCED ER 2010											
IEA WEO 2000 (REF)	1,428	1,625	1,822	2,020	2,217	2,414	2,611	2,808	3,006	4,516	3,400
IEA WEO 2002 (REF)			2,236	2,957	3,677	4,398	5,118	5,839	6,559	7,280	8,000
IEA WEO 2005 (REF)						5,361	5,574	5,787	6,000	6,213	6,425
IEA WEO 2007 (REF)								9550	9,575	9,600	9,625

image SOLON AG PHOTOVOLTAICS FACILITY IN ARNSTEIN OPERATING 1,500 HORIZONTAL AND VERTICAL SOLAR "MOVERS". LARGEST TRACKING SOLAR FACILITY IN THE WORLD. EACH "MOVER" CAN BE BOUGHT AS A PRIVATE INVESTMENT FROM THE S.A.G. SOLARSTROM AG, BAYERN, GERMANY.

In contrast to the wind projections, all the SolarGeneration projections have been too conservative. The total installed capacity in 2010 was close to 40,000 MW about 30% higher than projected in SolarGeneration published ten years earlier. Even SolarGeneration 5, published in 2008, under-estimated the possible market growth of photovoltaic in the advanced scenario. In contrast, the IEA WEO 2000 estimations for 2010 were reached in 2004.

The long-term projections for solar photovoltaic are more difficult than for wind because the costs have dropped significantly faster than projected. For some OECD countries, solar has reached grid parity with fossil fuels in 2012 and other solar technologies, such as concentrated solar power plants (CSP), are also headed in that direction. Therefore, future projections for solar photovoltaic do not just depend on cost improvements, but also on available storage technologies. Grid integration can actually be a bottle-neck to solar that is now expected much earlier than estimated.

figure 4.8: photovoltaic: long term market projections until 2030



	2010	2015	2020	2030
SG I 2001	25,688		207,000	
SG II 2004	26,512	75,600	282,350	
SG III 2006	28,428	102,400	275,700	
SG IV 2007 (Advanced)	28,862	134,752	240,641	1,271,773
SG V 2008 (Advanced)	25,447	151,486	277,524	1,864,219
SG VI 2010 (Advanced)	36,629	179,442	737,173	1,844,937
ER 2007	22,694		198,897	727,816
ER 2008	20,606	74,325	268,789	921,332
ADVANCED ER 2010		107,640	439,269	1,330,243
IEA WEO 2000 (REF)	3,400	5,500	7,600	
IEA WEO 2002 (REF)	8,000	13,000	18,000	56,000
IEA WEO 2005 (REF)	6,425	14,356	22,286	54,625
IEA WEO 2007 (REF)	9,625	22,946	48,547	86,055
IEA WEO 2009 (REF)	22,878	44,452	79,878	183,723
IEA WEO 2010 (REF)	39,678	70,339	101,000	206,000
IEA WEO 2010 (450ppm)	39,678	88,839	138,000	485,000
IEA WEO 2011 (REF)	67,300	114,150	161,000	268,000
IEA WEO 2011 (450ppm)	67,300	143,650	220,000	625,000

4.11 how does the energy [r]evolution scenario compare to other scenarios?

The International Panel on Climate Change (IPCC) published a ground-breaking new "Special Report on Renewables" (SRREN) in May 2011. This report showed the latest and most comprehensive analysis of scientific reports on all renewable energy resources and global scientifically accepted energy scenarios. The Energy [R]evolution was among three scenarios chosen as an indicative scenario for an ambitious renewable energy pathway. The following summarises the IPCC's view.

Four future pathways, the following models were assessed intensively:

- International Energy Agency World Energy Outlook 2009, (IEA WEO 2009)
- Greenpeace Energy [R]evolution 2010, (ER 2010)
- ReMIND-RECIPE
- MiniCam EMF 22

The World Energy Outlook of the International Energy Agency was used as an example baseline scenario (least amount of development of renewable energy) and the other three treated as "mitigation scenarios", to address climate change risks. The four scenarios provide substantial additional information on a number of technical details, represent a range of underlying assumptions and follow different methodologies. They provide different renewable energy deployment paths, including Greenpeace's "optimistic application path for renewable energy assuming that . . . the current high dynamic (increase rates) in the sector can be maintained".

The IPCC notes that scenario results are determined partly by assumptions, but also might depend on the underlying modelling architecture and model specific restrictions. The scenarios analysed use different modelling architectures, demand projections and technology portfolios for the supply side. The full results are provided in Table 4.14, but in summary:

- The IEA baseline has a high demand projection with low renewable energy development.
- ReMind-RECIPE, MiniCam EMF 22 scenarios portrays a high demand expectation and significant increase of renewable energy is combined with the possibility to employ CCS and nuclear.
- The ER 2010 relies on and low demand (due to a significant increase of energy efficiency) combined with high renewable energy deployment, no CCS employment and a global nuclear phase-out by 2045.

Both population increase and GDP development are major driving forces on future energy demand and therefore at least indirectly determining the resulting shares of renewable energy. The IPCC analysis shows which models use assumptions based on outside inputs and what results are generated from within the models. All scenarios take a 50% increase of the global population into account on baseline 2009. Regards gross domestic product (GDP), all assume or calculate a significant increase in terms of the GDP. The IEA WEO 2009 and the ER 2010 model uses forecasts of International Monetary Fund (IMF 2009) and the Organisation of Economic Co-Operation and Development (OECD) as inputs to project GSP. The other two scenarios calculate GDP from within their model.

table 4.14: overview of key parameter of the illustrative scenarios based on assumptions that are exogenous to the models respective endogenous model results

CATEGORY		STATUS QUO	BASELINE		CAT III+IV (>450-660PPM)		CAT I+II (<440 PPM)		CAT I+II (<440 PPM)	
SCENARIO NAME			IEA WEO 2009		ReMind		MiniCam		ER 2010	
MODEL					ReMind		EMF 22		MESAP/PlaNet	
	UNIT	2007	2030	2050(1)	2030	2050	2030	2050	2030	2050
Technology pathway										
Renewables			al	all	generec solar	generec solar	generec solar - no ocean energy	>no ocean energy	all	all
CCS			+	+	+	+	+	+	-	-
Nuclear			+	+	+	+	+	+	+	-
Population	billion	6.67	8.31	8.31	8.32	9.19	8.07	8.82	8.31	9.15
GDP/capita	k$$_{2005}$/capita	10.9	17.4	17.4	12.4	18.2	9.7	13.9	17.4	24.3
Input/Indogenous model results										
Energy demand (direct equivalent)	EJ/yr	469	674	674	590	674	608	690	501	466
Energy intensity	MJ/$$_{2005}$	6.5	4.5	4.5	5.7	4.0	7.8	5.6	3.3	1.8
Renewable energy	%	13	14	14	32	48	24	31	39	77
Fossil & industrial CO_2 emissions	Gt CO_2/y	27.4	38.5	38.5	26.6	15.8	29.9	12.4	18.4	3.3
Carbon intensity	kg CO_2/GJ	58.4	57.1	57.1	45.0	23.5	49.2	18.0	36.7	7.1

source
DLR/IEA 2010: IEA World Energy Outlook 2009 does not cover the years 2031 till 2050. As the IEA's projection only covers a time horizon up to 2030 for this scenario exercise, an extrapolation of the scenario has been used which was provided by the German Aerospace Center (DLR) by extrapolating the key macroeconomic and energy indicators of the WEO 2009 forward to 2050 (Publication filed in June 2010 to Energy Policy).

key results of the asean energy [r]evolution scenario

"renewable energy should become the central pillar of our future energy supply"

ANGELA MERKEL
CHANCELLOR OF GERMANY

© LUIS LIWANAG / GREENPEACE

image A HOUSE STAND ALONG THE WIND FARM IN BANGUI, ILOCOS NORTE, IN THE NORTHERN PART OF THE PHILIPPINES.

5.1 energy demand by sector

Combining the projections on population development, GDP growth and energy intensity results in future development pathways for the ASEAN region's final energy demand. These are shown in Figure 5.1 for the Reference and the Energy [R]evolution scenario. Under the Reference scenario, total final energy demand increases by 115% from the current 14,819 PJ/a to 31,875 PJ/a in 2050. In the Energy [R]evolution scenario, final energy demand increases at a much lower rate by 23% compared to current consumption and it is expected to reach 18,190 PJ/a by 2050.

Under the Energy [R]evolution scenario, due to economic growth, increasing living standards and electrification of the transport sector, electricity demand is exptected to increase in both the industry sector, in the residential and service sectors as well as in the the transport sector (see Figure 5.2). Total electricity demand will decrease from 605 TWh/a to 2,275 TWh/a by the year 2050. Compared to the Reference scenario, efficiency measures in the industry, residential and service sectors avoid the generation of about 1,080 TWh/a. This reduction can be achieved in particular by introducing highly efficient electronic devices using the best available technology in all demand sectors.

Efficiency gains in the heating and cooling sector are even larger. Under the Energy [R]evolution scenario, demand for heating and cooling is expected to increase until 2030 and remains rather constant afterwards (see Figure 5.4). Compared to the Reference scenario, consumption equivalent to 3,374 PJ/a is avoided through efficiency gains by 2050. As a result of energy-related renovation of the existing stock of residential buildings, the introduction of low energy standards and 'passive climatisation' for new buildings, as well as highly efficient air conditioning systems, enjoyment of the same comfort and energy services will be accompanied by a much lower future energy demand.

figure 5.1: total final energy demand by sector under the reference scenario and the energy [r]evolution scenario ('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)

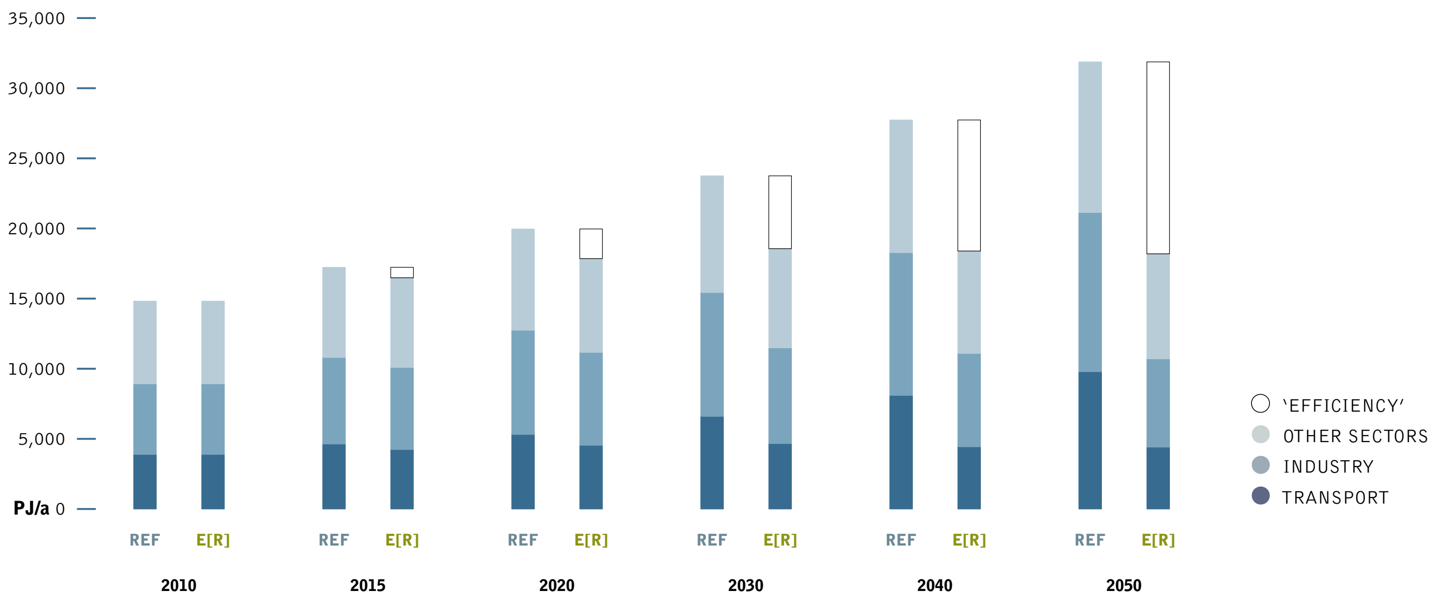


image AT A FACTORY IN PATHUM THANI, THAILAND, A TECHNICIAN CHECKS A DYNAMO FOR USE IN A WIND TURBINE. THE IMPACTS OF SEA-LEVEL RISE DUE TO CLIMATE CHANGE ARE PREDICTED TO HIT HARD ON COASTAL COUNTRIES IN ASIA, AND CLEAN RENEWABLE ENERGY IS A SOLUTION.

image IMPLEMENTING SOLAR POWER IN INDONESIA.

figure 5.2: development of electricity demand by sector in the energy [r]evolution scenario

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

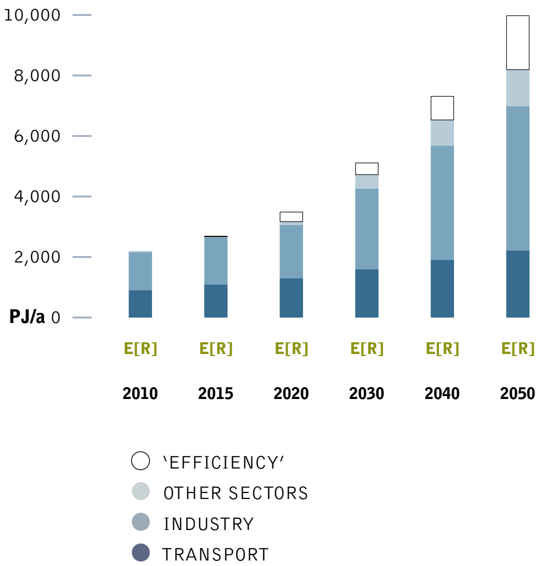


figure 5.4: development of energy demand for heating and cooling by sector in the energy [r]evolution scenario

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

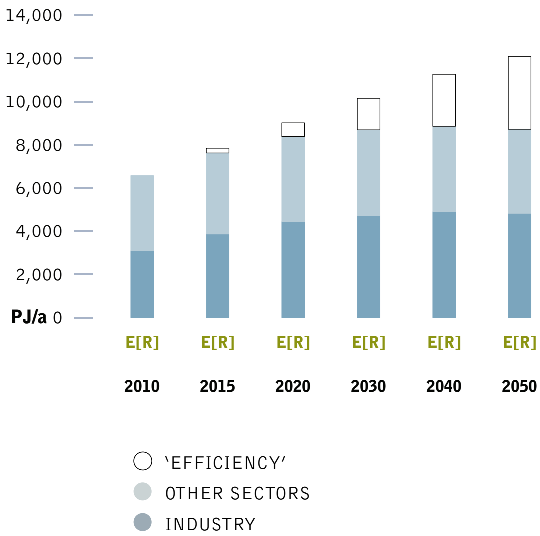
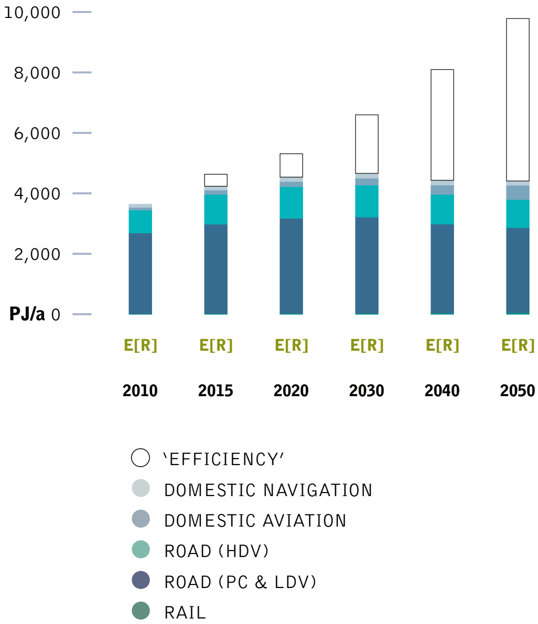


figure 5.3: development of the transport demand by sector in the energy [r]evolution scenario



5.2 electricity generation

The development of the electricity supply sector is charaterised by a dynamically growing renewable energy market and an increasing share of renewable electricity. This will compensate for the abstinence of nuclear power production in the Energy [R]evolution scenario and reduce the number of fossil fuel-fired power plants required for grid stabilisation. By 2050, 92% of the electricity produced in the ASEAN region will come from renewable energy sources. 'New' renewables – mainly wind, geothermal energy and PV – will contribute 70% to the total electricity generation. Alreday by 2020 the share of renewable electricity production will be 29% and 60% by 2030. The installed capacity of renewables will reach 427 GW in 2030 and 1,184 GW by 2050.

Table 5.1 shows the comparative evolution of the different renewable technologies in the ASEAN region over time. Up to 2020 wind and PV will become the main contributors of the growing market share. After 2020, the continuing growth of wind and PV will be complemented by electricity from biomass and geothermal energy. The Energy [R]evolution scenario will lead to a high share of fluctuating power generation sources (photovoltaic, wind and ocean) of 47% by 2030 and 72% by 2050. Therefore the expansion of smart grids, demand side management (DSM) and storage capacity from the increased share of electric vehicles and other storage options will be used for a better grid integration and power generation management.

table 5.1: renewable electricity generation capacity under the reference scenario and the energy [r]evolution scenario

IN GW

		2010	2020	2030	2040	2050
Hydro	REF	21	27	43	64	73
	E[R]	21	23	23	23	23
Biomass	REF	1	4	7	11	15
	E[R]	1	2	7	23	50
Wind	REF	0	15	28	40	50
	E[R]	0	76	208	325	463
Geothermal	REF	3	4	6	7	9
	E[R]	3	4	12	28	53
PV	REF	0	3	7	13	18
	E[R]	0	22	171	385	544
CSP	REF	0	0	0	0	0
	E[R]	0	0	2	6	10
Ocean energy	REF	0	0	0	0	0
	E[R]	0	0	4	17	41
Total	**REF**	**25**	**53**	**91**	**135**	**165**
	E[R]	**25**	**126**	**427**	**807**	**1,184**

figure 5.5: electricity generation structure under the reference scenario and the energy [r]evolution scenario (INCLUDING ELECTRICITY FOR ELECTROMOBILITY, HEAT PUMPS AND HYDROGEN GENERATION)

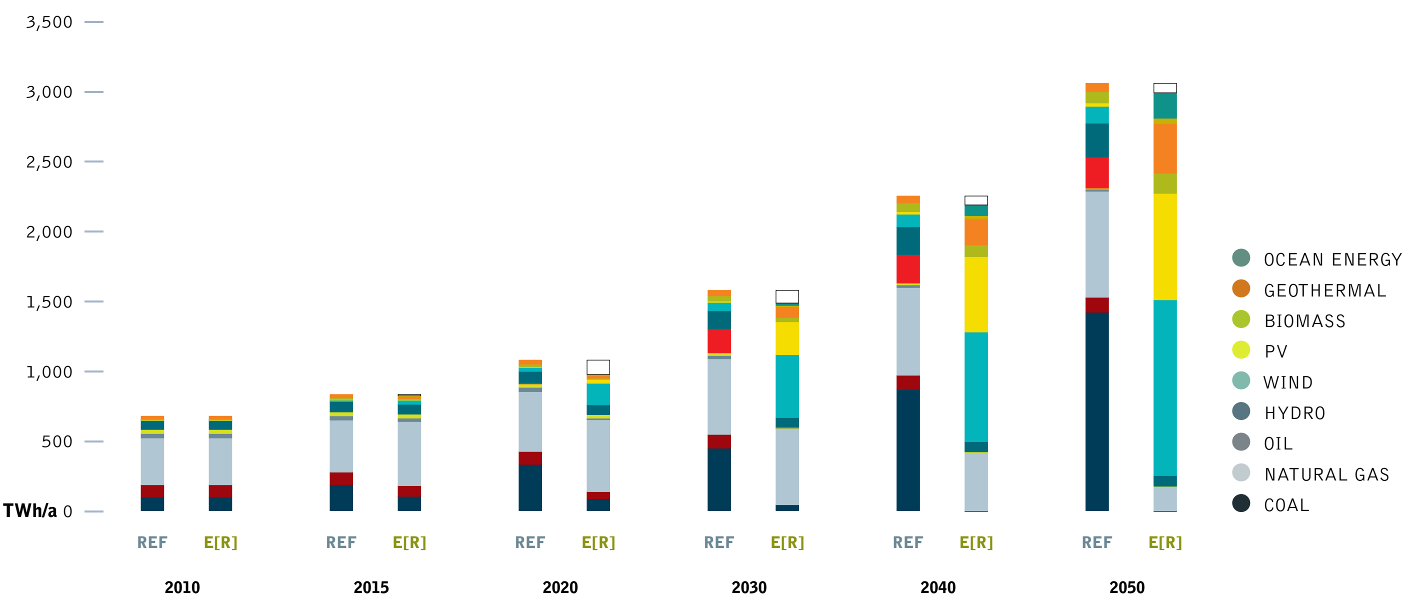


image PHILIPPINES BIGGEST COAL-FIRED POWER STATION, SUAL, IN THE PROVINCE OF PANGASINAN.

image THREE HUNDRED AND FIFTY CHILDREN FROM BANGUI SECONDARY SCHOOLS FORM THE WORDS "R.E. LAW NOW!" BENEATH THE MAJESTIC WIND TURBINES IN BANGUI, ILOCOS NORTE.

5.3 future costs of electricity generation

Figure 5.6 shows that the introduction of renewable technologies under the Energy [R]evolution scenario increase the future costs of electricity generation compared to the Reference scenario until 2020. This difference will be less than 0.8 US$ct/kWh up to 2020, however. Because of high prices for conventional fuels and the lower CO_2 intensity of electricity generation, from 2030 on electricity generation costs will become economically favourable under the Energy [R]evolution scenario and by 2050 costs will be 7.5 US$ct/kWh below those in the Reference version.

Under the Reference scenario, on the other hand, unchecked growth in demand, an increase in fossil fuel prices and the cost of CO_2 emissions result in total electricity supply costs rising from today's US$ 96 billion per year to more than US$ 555 billion in 2050, compared to US$ 327 billion in the Energy [R]evolution scenario.

Figure 5.6 shows that the Energy [R]evolution scenario not only complies with the ASEAN region's CO_2 reduction targets, but also helps to stabilise energy costs and relieve the economic pressure on society. Increasing energy efficiency and shifting energy supply to renewables lead to long term costs for electricity supply that are more than 41% lower than in the Reference scenario.

5.4 future investments in the power sector

It would require US$ 2,752 billion in investment for the Energy [R]evolution scenario to become reality (including investments for replacement after the economic lifetime of the plants) - approximately US$ 67.1 billion per year or US$ 1,470. billion more than in the Reference scenario (US$ 1,282 billion). Under the Reference version, the levels of investment in conventional power plants add up to almost 59% while approximately 41% would be invested in renewable energy until 2050.

Under the Energy [R]evolution scenario, however, the ASEAN region would shift almost 90% of the entire investment towards renewables. Until 2030, the fossil fuel share of power sector investment would be focused mainly on gas power plants.

Because renewable energy has no fuel costs, the fuel cost savings in the Energy [R]evolution scenario reach a total of US$ 2,698 billion up to 2050, or US$ 69.2 billion per year. The total fuel cost savings therefore would cover almost twice the total additional investments compared to the Reference scenario. 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 5.6: total electricity supply costs and specific electricity generation costs under two scenarios

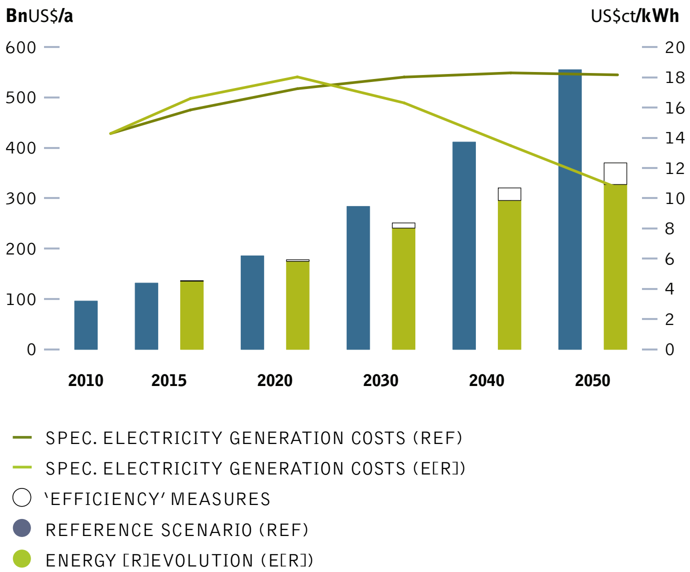
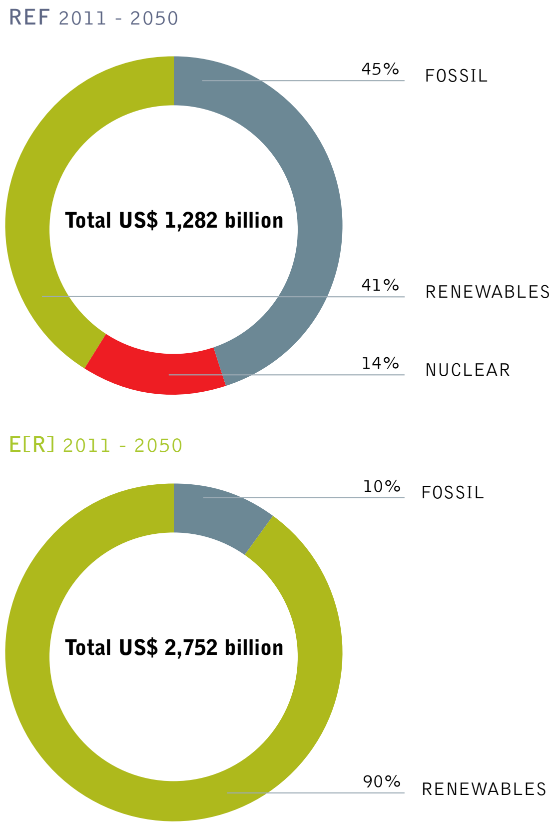


figure 5.7: investment shares - reference scenario versus energy [r]evolution scenario



5.5 energy supply for heating and cooling

Today, renewables meet 47% of the ASEAN region's energy demand for heating and cooling, the main contribution coming from the use of biomass. Dedicated support instruments are required to ensure a dynamic development in particular for renewable cooling technologies (e.g. solar cooling) and renewable process heat production. In the Energy [R]evolution scenario, renewables provide 52% of the ASEAN region's total heat demand in 2030 and 78% in 2050.

- Energy efficiency measures help to reduce the currently growing energy demand for heating and cooling by 28% in 2050 (relative to the reference scenario), in spite of improving living standards and economic growth.
- In the industry sector solar collectors, geothermal energy (incl. heat pumps) as well as electricity and hydrogen from renewable sources are increasingly substituting for fossil fuel-fired systems.
- A shift from coal and oil to natural gas in the remaining conventional applications leads to a further reduction of CO_2 emissions.

Table 5.2 shows the development of the different renewable technologies for heating and cooling in the ASEAN region over time. Up to 2040 biomass will remain the main contributors of the growing market After 2040, the continuing growth of solar collectors (also for solar cooling), a growing share of geothermal and environmental heat as well as heat from renewable hydrogen will reduce the dependence on fossil fuels.

table 5.2: projection of renewable heating and cooling energy supply under the reference and the energy [r]evolution scenario IN PJ/A

		2010	2020	2030	2040	2050
Biomass	REF	3,224	3,292	3,156	3,095	2,945
	E[R]	3,224	3,186	2,749	2,104	1,438
Solar collectors	REF	0	22	45	73	101
	E[R]	0	450	981	1,644	2,271
Geothermal	REF	0	5	8	13	14
	E[R]	0	127	293	517	712
Hydrogen	REF	0	0	0	0	0
	E[R]	0	0	37	101	272
Total	**REF**	**3,224**	**3,319**	**3,210**	**3,182**	**3,059**
	E[R]	**3,224**	**3,763**	**4,060**	**4,366**	**4,694**

figure 5.8: supply structure for heating and cooling under the reference scenario and the energy [r]evolution scenario

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

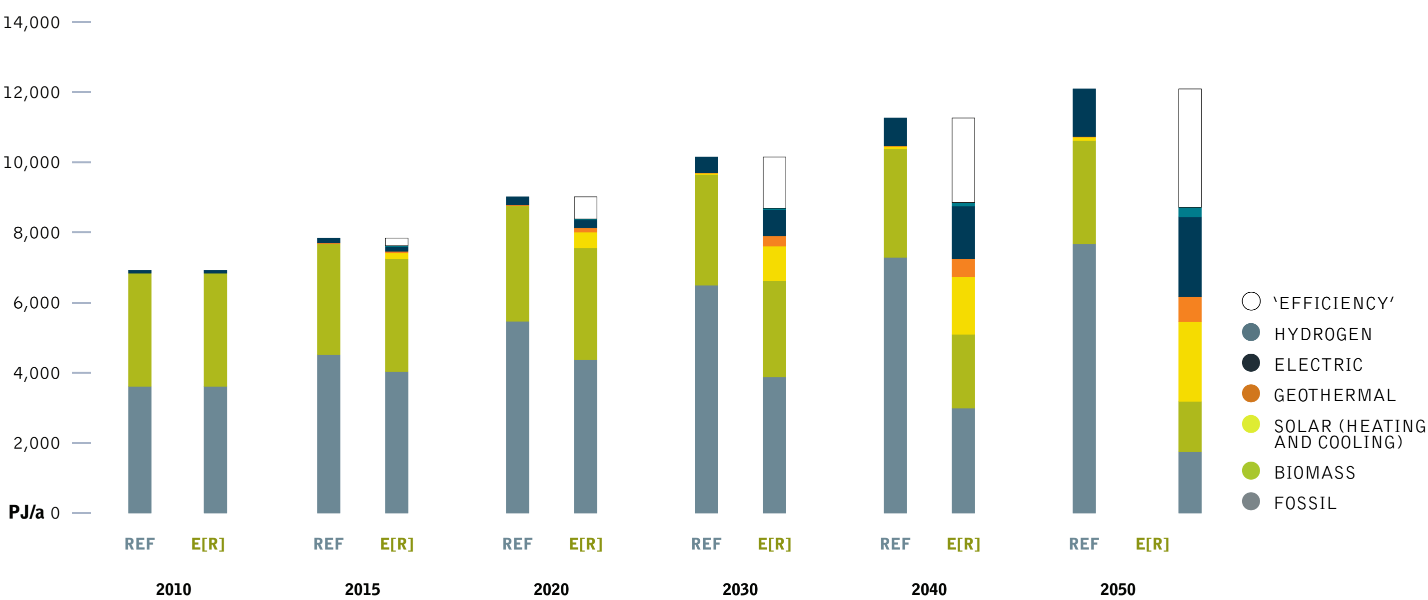


image YOUTH INSTALLING WIND TURBINE, THAILAND.

image SOLAR PANELS INSTALLED AND PAID FOR BY GREENPEACE AT A LOCAL TEMPLE IN THE VILLAGE OF HIN KRUD, THE SITE OF A PLANNED COAL FIRED POWER PLANT IN THE PROVINCE OF PRACHUAB KHIRI KHAN, THAILAND.

5.6 future investment in the heating and cooling sector

Also in the heating and cooling sector the Energy [R]evolution scenario would require a major revision of current investment strategies in heating and cooling technologies. Especially solar thermal, solar cooling and geothermal and heat pump technologies need enourmous increase in installations, if these potentials are to be tapped for the heating and cooling sector. These technologies are practically non-existent in the ASEAN region today. The use of biomass for heating purposes - mostly traditional biomass today - will be substantially reduced in the Energy [R]evolution scenario and be replaced by more effcient and sustainable renewable heating technologies.

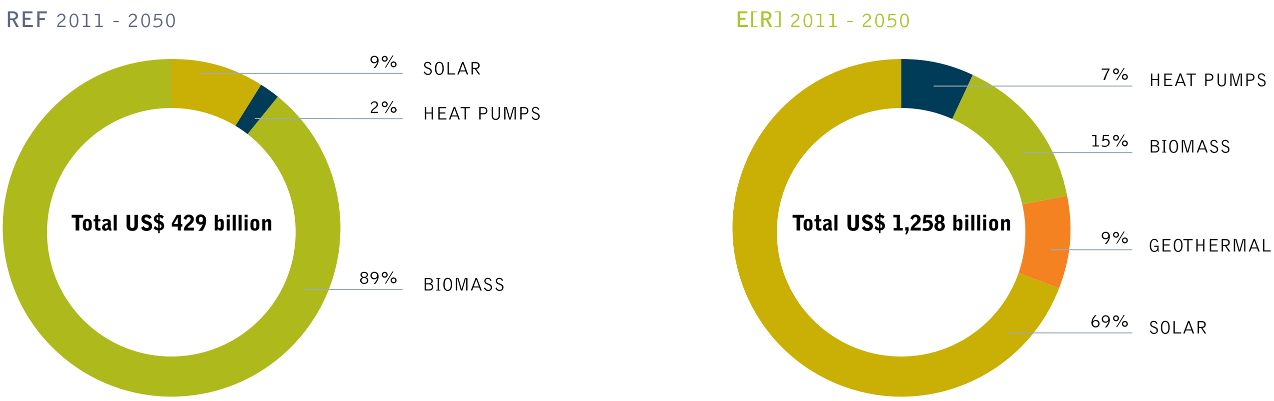
Renewable heating technologies are extremely variable, from low tech biomass stoves and unglazed solar collectors to very sophisticated enhanced geothermal systems and solar cooling systems. Thus it can only roughly be calculated, that the Energy [R]evolution scenario in total requires around US$ 1,258 billion to be invested in renewable heating technologies until 2050 (including investments for replacement after the economic lifetime of the plants) - approximately US$ 31 billion per year.

table 5.3: renewable heating and cooling capacities under the reference scenario and the energy [r]evolution scenario

IN GW

		2010	2020	2030	2040	2050
Biomass	REF	661	713	683	599	502
	E[R]	661	687	586	385	212
Geothermal	REF	0	0	0	0	0
	E[R]	0	6	15	27	35
Solar thermal	REF	0	7	13	22	30
	E[R]	0	138	300	504	695
Heat pumps	REF	0	1	2	2	3
	E[R]	0	7	14	24	36
Total	**REF**	**661**	**721**	**698**	**624**	**534**
	E[R]	**661**	**838**	**916**	**941**	**978**

figure 5.9: investments for renewable heat and cooling technologies under the reference scenario and the energy [r]evolution scenario



5.8 transport

A key target in the ASEAN region is to introduce incentives for people to drive smaller cars. In addition, it is vital to shift transport use to efficient modes like rail, light rail and buses, especially in the expanding large metropolitan areas. Together with rising prices for fossil fuels, these changes reduce the huge growth in car sales projected under the Reference scenario. Due to population increase, GDP growth and higher living standards, energy demand from the transport sector is expected to increase in the Energy [R]evolution scenario by 13% to 4,411 PJ/a in 2050, 480 PJ/a higher than today's levels (3,891 PJ/a). However, in 2050 efficiency measures and mode shifts will save 55% compared to the Reference scenario (9,788 PJ/a).

Highly efficient propulsion technology with hybrid, plug-in hybrid and battery-electric power trains will bring large efficiency gains. By 2030, electricity will provide 10% of the transport sector's total energy demand in the Energy [R]evolution, while in 2050 the share will be 27%.

table 5.4: transport energy demand by mode under the reference scenario and the energy [r]evolution scenario

(WITHOUT ENERGY FOR PIPELINE TRANSPORT) IN PJ/A

		2010	2020	2030	2040	2050
Rail	REF	19	24	28	31	34
	E[R]	19	32	38	47	59
Road	REF	3,429	4,998	6,202	7,568	9,052
	E[R]	3,429	4,193	4,240	3,920	3,742
Domestic aviation	REF	92	164	227	323	493
	E[R]	92	169	227	312	471
Domestic navigation	REF	102	128	145	177	209
	E[R]	102	146	159	155	140
Total	**REF**	**3,642**	**5,314**	**6,602**	**8,099**	**9,788**
	E[R]	**3,642**	**4,540**	**4,663**	**4,435**	**4,411**

figure 5.10: final energy consumption for transport under the reference scenario and the energy [r]evolution scenario

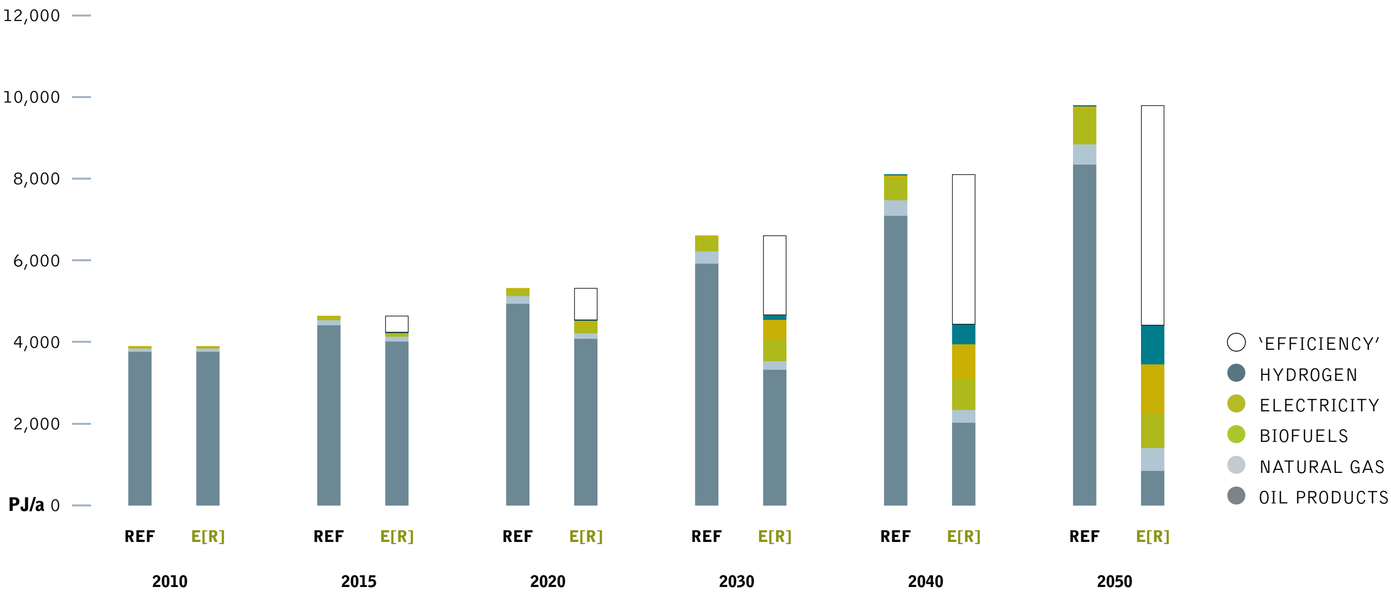


image SOLAR POWER SYSTEMS BEING INSTALLED IN THAILAND.

image A WIND TURBINE INSTALLATION STANDS AT THE WATER'S EDGE ON KOH LAN ISLAND, THAILAND.

5.9 development of CO_2 emissions

Whilst the ASEAN region's emissions of CO_2 will increase by 144% between 2010 and 2050 under the Reference scenario, under the Energy [R]evolution scenario they will decrease from 1,164 million tonnes in 2010 to 296 million tonnes in 2050. Annual per capita emissions will drop from 2.0 t to 0.4 t. In spite of the abstinence of nuclear power production and increasing energy demand, CO_2 emissions will decrease in the electricity sector. In the long run efficiency gains and the increased use of renewable in vehicles will reduce emissions also in the transport sector. With a share of 39% of CO_2, the industry sector will be the largest sources of emissions in 2050. By 2050, the ASEAN region's CO_2 emissions are 26% below 1990 levels.

5.10 primary energy consumption

Under the Energy [R]evolution scenario, primary energy demand will increase by 22% from today's 23,227 PJ/a to 28,302 PJ/a (see Figure 5.12). Compared to the Reference scenario, overall primary energy demand will be reduced by 43% in 2050 under the Energy [R]evolution scenario (REF: 49,621 PJ in 2050).

The Energy [R]evolution version aims to phase out coal and oil as fast as technically and economically possible. This is made possible mainly by replacement of coal power plants with renewables and a fast introduction of very efficient electric vehicles in the transport sector to replace oil combustion engines. This leads to an overall renewable primary energy share of 41% in 2030 and 78% in 2050. In contrast to the REF scenario, no nuclear power plants will be built in the ASEAN region in the Energy [R]evolution scenario.

figure 5.11: development of CO_2 emissions by sector under the energy [r]evolution scenario ('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)

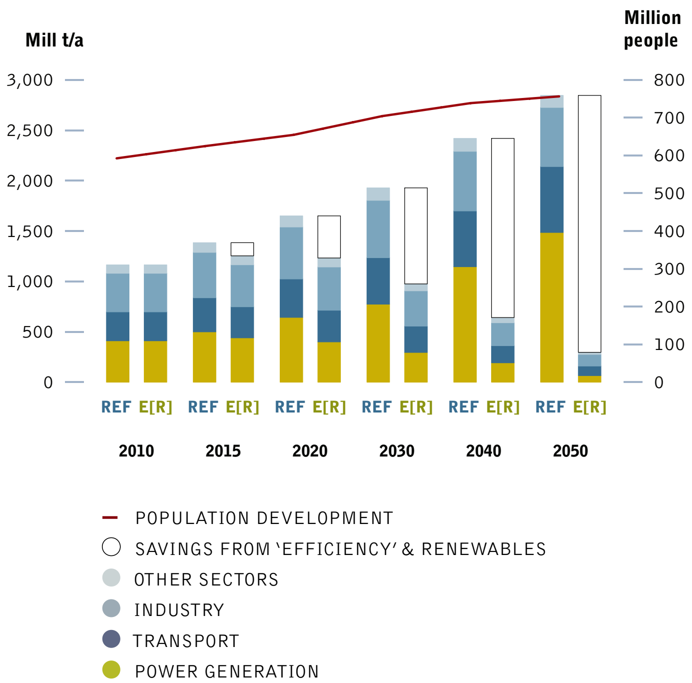


figure 5.12: primary energy consumption under the reference scenario and the energy [r]evolution scenario

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

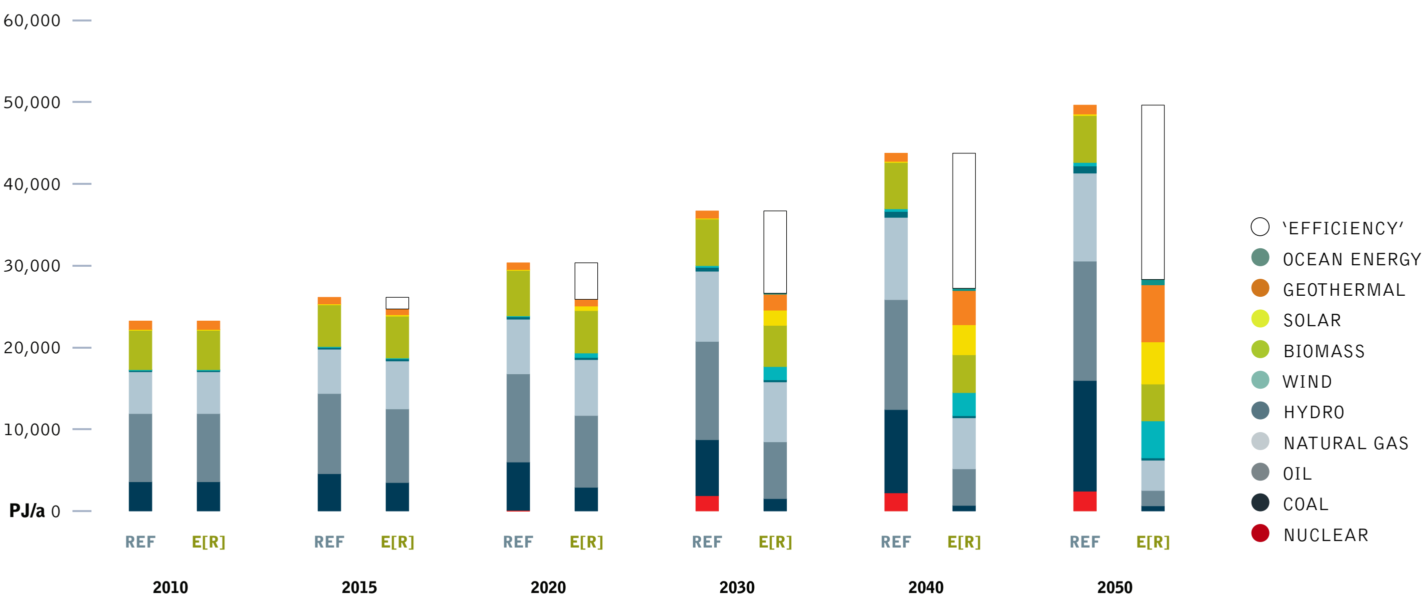


table 5.6: investment costs for electricity generation and fuel cost savings under the energy [r]evolution scenario compared to the reference scenario

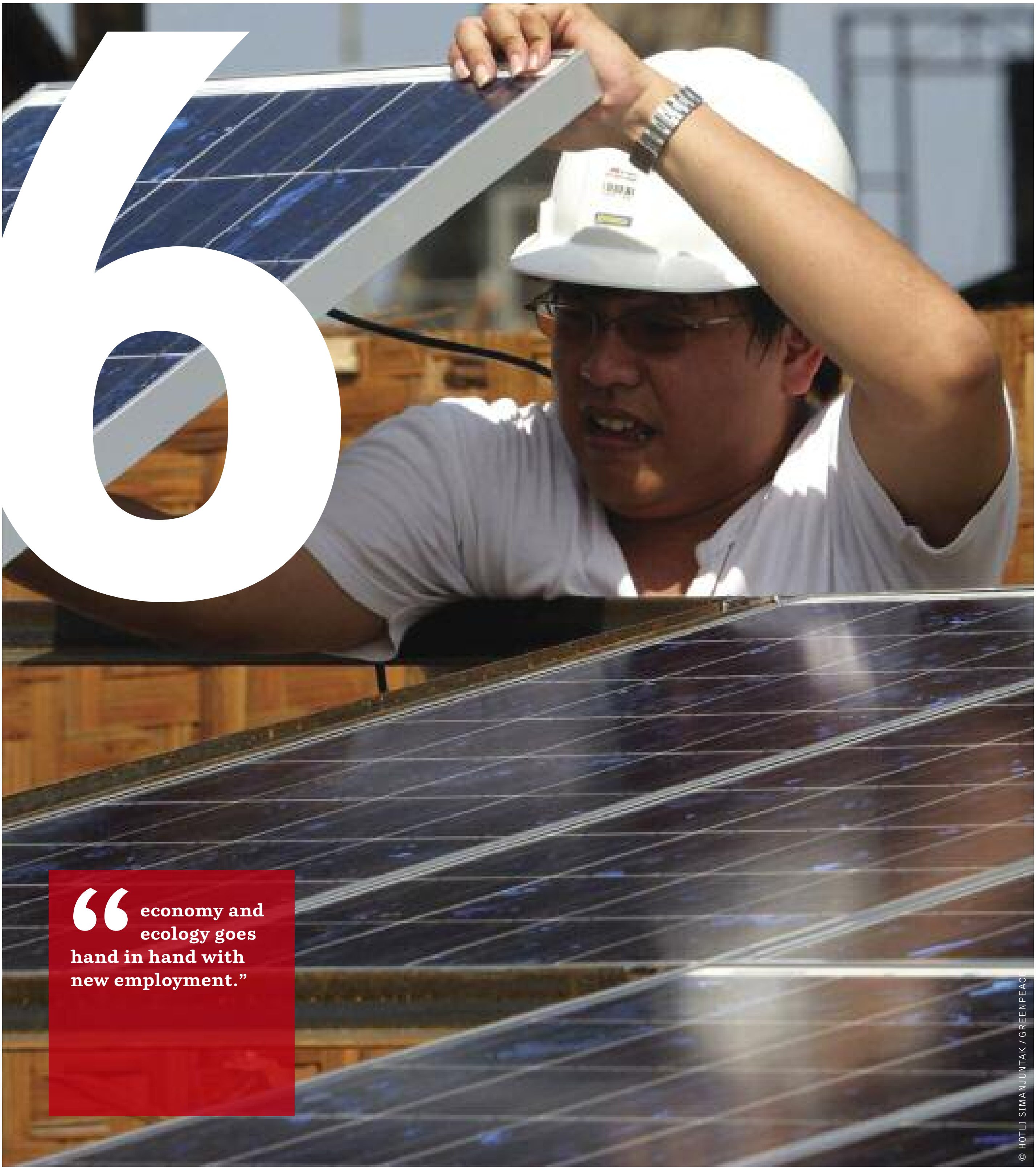
INVESTMENT COSTS		2011 - 2020	2021 - 2030	2031 - 2040	2041 - 2050	2011 - 2050	2011 - 2050 AVERAGE PER ANNUM
DIFFERENCE E[R] VERSUS REF							
Conventional (fossil)	billion US$	57.6	153.8	107.7	171.5	490.6	12.3
Renewables	billion US$	-85.3	-355.8	-587.9	-931.6	-1,960.5	-49.0
Total	billion US$	**-27.7**	**-201.9**	**-480.2**	**-760.1**	**-1,469.9**	**-36.8**

ACCUMULATED FUEL COST SAVINGS							
SAVINGS CUMULATIVE E[R] VERSUS REF							
Fuel oil	billion US$/a	18.2	52.4	54.3	45.8	170.7	4.3
Gas	billion US$/a	-105.7	-97.4	185.2	921.3	903.4	22.6
Hard coal	billion US$/a	59.6	214.0	453.9	760.7	1,488.3	37.2
Lignite	billion US$/a	3.3	12.4	17.8	20.5	54.0	1.3
Nuclear	billion US$/a	0.3	10.4	29.7	40.9	81.3	2.0
Total	billion US$/a	**-24.3**	**192.0**	**740.8**	**1,789.2**	**2,697.7**	**67.4**

table 5.7: accumulated investment costs for heat generation and fuel cost savings under the energy [r]evolution scenario compared to the reference scenario

ACCUMULATED INVESTMENT COSTS							
DIFFERENCE E[R] MINUS REF							
Conventional	billion US$						
Renewable	billion US$	24.0	169.1	329.1	307.3	829.5	20.7
Total	billion US$	**24.0**	**169.1**	**329.1**	**307.3**	**829.5**	**20.7**

employment projections



"economy and ecology goes hand in hand with new employment."

© HOTLI SIMANJUNTAK / GREENPEACE

image IMPLEMENTING SOLAR POWER, INDONESIA.

6.1 methodology to calculate jobs

Greenpeace International and the European Renewable Energy Council have published four global Energy [R]evolution scenarios. These compare a low-carbon Energy [R]evolution scenario to a Reference scenario based on the International Energy Agency (IEA) "business as usual" projections (from the World Energy Outlook series, for example International Energy Agency, 2007, 2011). The Institute for Sustainable Futures (ISF) analysed the employment effects of the 2008 and 2012 Energy [R]evolution global scenarios. The methodology used in the 2012 global analysis is used to calculate energy sector employment for the ASEAN region region's Energy [R]evolution and Reference scenario.

Employment is projected for the ASEAN region for both scenarios at 2015, 2020, and 2030 by using a series of employment multipliers and the projected electrical generation, electrical capacity, heat collector capacity, and primary consumption of coal, gas and biomass (excluding gas used for transport). The results of the energy scenarios are used as inputs to the employment modelling.

Only direct employment is included, namely jobs in construction, manufacturing, operations and maintenance, and fuel supply associated with electricity generation and direct heat provision. Indirect jobs and induced jobs are not included in the calculations. Indirect jobs generally include jobs in secondary industries that supply the primary industry sector, for example, catering and accommodation. Induced jobs are those resulting from spending wages earned in the primary industries. Energy efficiency jobs are also excluded, despite the fact that the Energy [R]evolution includes significant development of efficiency, as the uncertainties in estimation are too great.

A detailed description of the methodology is given in Rutovitz and Harris, 2012a.

6.2 overview

Inputs for energy generation and demand for each scenario include:

- The amount of electrical and heating capacity that will be installed each year for each technology.
- The primary energy demand for coal, gas, and biomass fuels in the electricity and heating sectors.
- The amount of electricity generated per year from nuclear, oil, and diesel.

Inputs for each technology include:

- "Employment factors", or the number of jobs per unit of capacity, separated into manufacturing, construction, operation and maintenance, and per unit of primary energy for fuel supply.
- For the 2020 and 2030 calculations, a 'decline factor' for each technology that reduces the employment factors by a certain percentage per year to reflect the employment per unit reduction as technology efficiencies improve.
- The percentage of local manufacturing and domestic fuel production in each region, in order to calculate the number of manufacturing and fuel production jobs in the region.
- The percentage of world trade which originates in the region for coal and gas fuels, and renewable traded components.

table 6.1: methodology overview

MANUFACTURING (FOR LOCAL USE)	=	MW INSTALLED PER YEAR IN REGION	×	MANUFACTURING EMPLOYMENT FACTOR	×	REGIONAL JOB MULTIPLIER FOR YEAR	×	% OF LOCAL MANUFACTURING
MANUFACTURING (FOR EXPORT)	=	MW EXPORTED PER YEAR	×	MANUFACTURING EMPLOYMENT FACTOR	×	REGIONAL JOB MULTIPLIER FOR YEAR		
CONSTRUCTION	=	MW INSTALLED PER YEAR	×	CONSTRUCTION EMPLOYMENT FACTOR	×	REGIONAL JOB MULTIPLIER FOR YEAR		
OPERATION & MAINTENANCE	=	CUMULATIVE CAPACITY	×	O&M EMPLOYMENT FACTOR	×	REGIONAL JOB MULTIPLIER FOR YEAR		
FUEL SUPPLY (NUCLEAR)	=	ELECTRICITY GENERATION	×	FUEL EMPLOYMENT FACTOR	×	REGIONAL JOB MULTIPLIER FOR YEAR		
FUEL SUPPLY (COAL, GAS & BIOMASS)	=	PRIMARY ENERGY DEMAND + EXPORTS	×	FUEL EMPLOYMENT FACTOR	×	REGIONAL JOB MULTIPLIER FOR YEAR	×	% OF LOCAL PRODUCTION
HEAT SUPPLY	=	MW INSTALLED PER YEAR	×	EMPLOYMENT FACTOR FOR HEAT	×	REGIONAL JOB MULTIPLIER FOR YEART		

JOBS	=	**MANUFACTURING**	+	**CONSTRUCTION**	+	**OPERATION & MAINTENANCE (O&M)**	+	**FUEL SUPPLY**	+	**FUEL SUPPLY**
EMPLOYMENT FACTOR AT 2020 OR 2030	=	**2010 EMPLOYMENT FACTOR** × TECHNOLOGY DECLINE FACTOR(NUMBER OF YEARS AFTER 2010)								

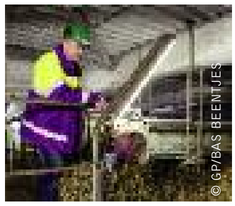


image THROUGH BURNING OF WOOD CHIPS THE POWER PLANT GENERATES ELECTRICITY, ENERGY OR HEAT. HERE WE SEE THE STOCK OF WOOD CHIPS WITH A CAPACITY OF 1000 M^3 ON WHICH THE PLANT CAN RUN, UNMANNED, FOR ABOUT FOUR DAYS. LELYSTAD, THE NETHERLANDS.

- A "regional job multiplier", which is used to adjust Organisation for Economic Co-operation and Development (OECD) employment factors. The regional multiplier indicates how labour-intensive economic activity is in the ASEAN region compared to the OECD, and is used to adjust the employment factors to reflect the fact that more employment will tend to be created per project in economies which are more labour intensive. It would be preferable to use local factors, but very little employment data is available for the ASEAN region.

The electrical capacity increase and energy use figures from each scenario are multiplied by the employment factors for each of the technologies, and the proportion of fuel or manufacturing occurring locally. The calculation is summarised in Table 6.1.

6.3 limitations

Employment numbers are indicative only, as a large number of assumptions are required to make calculations. Quantitative data on present employment based on actual surveys is difficult to obtain, so it is not possible to calibrate the methodology against time series data, or even against current data in many regions. There are also some significant areas of employment that are not included, including replacement of generating plant, and energy efficiency jobs. However, within the limits of data availability, the figures presented are indicative of employment levels in the electricity and heat sectors under the two scenarios.

Insufficient data means it was not possible to include a comprehensive assessment for the heat supply sector. Only a partial estimate of the jobs in heat supply is included, as biomass, gas, and coal jobs in this sector include only fuel supply jobs where heat is supplied directly (that is, not via a combined heat and power plant), while jobs in heat from geothermal and solar collectors primarily include manufacturing and installation.

6.4 employment factors

The employment factors used in the 2013 ASEAN region analysis are shown in Table 1, with the main source given in the notes. Local factors are only used for coal mining employment. All other factors are the OECD factors from the 2012 global analysis (Rutovitz & Harris, 2012a). A regional multiplier is also used, so employment factors other than coal fuel are all increased by between 3.2 in 2010, 2.6 in 2020, and 1.8 in 2030.

6.5 regional adjustment factor

The available employment factors are for OECD countries or regions, and need adjustment for differing stages of economic development. Broadly, the lower the cost of labour in a country, the greater the number of workers that will be employed to produce a unit of any particular output, be it manufacturing, construction or agriculture. This is because when labour costs are low, labour is relatively affordable compared to mechanised means of production. Low average labour costs are closely associated with low GDP per capita, a key indicator of economic development.

This means that changes to levels of production in any given sector of the economy are likely to have a greater impact on jobs in countries with lower GDP per person. Ideally, employment factors would be derived for all the countries within the ASEAN region. In practice, data for developing countries is extremely limited. Instead, the derived OECD employment factors are multiplied by a proxy regional adjustment factor. It is important to derive these job multipliers from a relatively complete data set with global coverage. The best available proxy factor is average labour productivity, measured as GDP (or value added) per worker.

Job multipliers are expected to change over the study period (2010 to 2030), as the differences in labour productivity alter with regional economic growth. Fortunately regional economic growth is a key input to the energy scenarios, as it is the major determinant of projected changes in energy consumption. We therefore use the projected change in GDP per capita derived from GDP growth and population growth figures from 2011 World Energy Outlook (International Energy Agency, 2011) to adjust the regional job multipliers over time.

Regional multipliers for the ASEAN region of 3.2 in 2010, 2.7 in 2015, and 1.8 in 2030 have been derived for this study. These are somewhat higher than the regional multipliers derived for the whole of the Non-OECD Asia region, which were 3, 2, 3, and 1.4 respectively (Rutovitz & Harris, 2012a). These multipliers have been applied to all employment other than coal mining, where a local factor for Indonesia is used.

The regional multiplier is calculated as the ratio of labour productivity in the ASEAN region to the labour productivity in the OECD. Economy wide average labour productivity, calculated as average GDP per engaged worker, is derived from the International Labour Organisation Key Indicators of the Labour Market (KILM) database (ILO, 2010). This database holds labour productivity data for seven of the ten countries in the ASEAN region: Indonesia, Viet Nam, Thailand, Singapore, Philippines, Malaysia, and Cambodia.

Labour productivity in the ASEAN region, excluding the agricultural sector, was calculated as $15,704 per worker compared to $49,606 for the OECD as a whole, giving a regional multiplier of 3.2 for 2010.

Labour productivity is projected for 2015 and 2030 using the growth rates for GDP per capita. For 2010 to 2017, GDP growth for the ASEAN region is taken from the IMF economic outlook database, and the projected growth rate for Non-OECD Asia from the World Energy Outlook (WEO) 2011 is used for the period 2017 – 2030 (International Energy Agency, 2011; International Monetary Fund, 2013). All GDP growth rates for the OECD are taken from the WEO 2011.

table 6.2: employment factors used in the 2012 analysis for the ASEAN region

FUEL	CONSTRUCTION TIMES *Years*	CONSTRUCTION /INSTALLATION *Job years/MW*	MANUFACTURING *Jobs years/MW*	OPERATION & MAINTENANCE *Jobs/MW*	FUEL – PRIMARY ENERGY DEMAND *Jobs/PJ*	
Coal	5	7.7	3.5	0.1	3.7	Note 1
Gas	2	1.7	1.0	0.1	21.9	Note 2
Nuclear	10	13.7	1.3	0.3	0.0009 jobs/GWh	Note 3
Biomass	2	14.0	2.9	1.5	0.3	Note 4
Hydro-large	2	6.0	1.5	0.3		Note 6
Wind onshore	2	2.5	6.1	0.2		Note 7
Wind offshore	4	7.1	10.7	0.2		Note 8
PV	1	10.9	6.9	0.3		Note 9
Geothermal	2	6.8	3.9	0.4		Note 10
Solar thermal	2	8.9	4.0	0.5		Note 12
Ocean	2	9.0	1.0	0.3		Note 13
Geothermal - heat	3.0 jobs/ MW (construction and manufacturing)					Note 14
Solar - heat	7.4 jobs/ MW (construction and manufacturing)					Note 15
Combined Heat and Power	CHP technologies use the factor for the technology, i.e. coal, gas, biomass, geothermal, etc., increased by a factor of 1.5 for O&M only.					
Oil and diesel	Use the employment factors for gas					

notes on employment factors

1. **Coal:** Jobs per PJ fuel have been derived using 2010 employment and production data from three of the major Indonesian coal companies, together accounting for 78% of Indonesian coal production (PT Adaro Indonesia, 2010; PT Indo Tambangraya Megah (ITM), 2010; PT Kaltim Prima Coal, 2010). Tonnes have been converted to PJ using total Indonesian production for 2009 (Coalportal.com, 2011) and IEA data for energy production from Indonesian coal (International Energy Agency, 2011). This may underestimate employment per PJ, as these are the largest producers, and are therefore likely to have higher productivity per worker, but unfortunately no other data is available. Indonesia accounted for 85% of the ASEAN region coal production, and the proportion has been gradually rising. Construction, manufacturing and operations and maintenance factors are from the JEDI model (National Renewable Energy Laboratory, 2011a).

2. **Gas, oil and diesel:** Installation and manufacturing factors are from the JEDI model (National Renewable Energy Laboratory, 2011b). O&M factor is an average of the figure from the 2010 report, the JEDI model (National Renewable Energy Laboratory, 2011b), a US study (National Commission on Energy Policy, 2009) and ISF research (Rutovitz & Harris, 2012b). Fuel factor per PJ is the weighted average of US, Canadian, and Russian employment in gas production, derived from US and Canadian information (America's Natural Gas Alliance, 2008; IHS Global Insight (Canada) Ltd, 2009; Zubov, 2012).

3. **Nuclear:** The construction factor is the average of two studies from the UK and one from the US (Cogent Sector Skills Council, 2010, 2011; National Commission on Energy Policy, 2009). The manufacturing factor is the average of the two UK reports, while the O&M factor is the average of values from all three studies and ISF research (Rutovitz & Harris, 2012b).The fuel factor was derived by ISF in 2009 (Rutovitz & Atherton, 2009).

4. **Bioenergy:** Employment factors for construction, manufacturing, and O&M use the average values of several European and US studies (Kjaer, 2006; Moreno & López, 2008; Thornley, 2006; Thornley et al., 2009; Thornley, Rogers, & Huang, 2008; Tourkolias & Mirasgedis, 2011). Fuel employment per PJ primary energy is derived from five European studies (Domac, Richards, & Risovic, 2005; EPRI, 2001; Hillring, 2002; Thornley, 2006; Upham & Speakman, 2007; Valente, Spinelli, & Hillring, 2011).

5. **Hydro – large:** Construction and manufacturing factors are from a US study (Navigant Consulting, 2009). O&M factor is an average of data from the US study (Navigant Consulting, 2009) and ISF research (Rutovitz & Harris, 2012b; Rutovitz & Ison, 2011; Rutovitz, 2010).

6. **Wind – onshore:** The installation factor used is from the European Wind Energy Association (EWEA) (European Wind Energy Association, 2009), and is the same factor used in previous analyses. The manufacturing factor is derived using the employment per MW in turbine manufacture at Vestas from 2007 – 2011 (Vestas, 2011), adjusted for total manufacturing using the ratio used by the EWEA (European Wind Energy Association, 2009). For further detail see Rutovitz & Harris, 2012a.

7. **Wind offshore:** All factors are from a German report (Price Waterhouse Coopers, 2012).

8. **Solar PV:** The Solar PV installation employment factor is the average of five estimates in Germany and the US, while manufacturing is taken from the JEDI model (National Renewable Energy Laboratory, 2010a), a Greek study (Tourkolias & Mirasgedis, 2011), a Korean national report (Korea Energy Management Corporation (KEMCO) & New and Renewable Energy Center (NREC), 2012), and ISF research for Japan (Rutovitz & Ison, 2011).

9. **Geothermal:** The construction and installation, and operations and maintenance factors are derived from a study conducted by Sinclair Knight Merz (SKM) (2005). The O&M factors are the weighted averages from employment data reported for thirteen power stations totalling 1050 MW in the US, Canada, Greece and Australia (some of them hypothetical). The manufacturing factor is derived from a US study (Geothermal Energy Association, 2010).

10. **Solar thermal power:** The OECD Europe figure is used for the EU27, and is higher than the overall OECD factors of 8.9 job years/MW (construction) and 0.5 jobs/MW (O&M). Overall OECD figures were derived from a weighted average of 19 reported power plants (3223 MW), while the OECD Europe figure includes only European data (951 MW). The manufacturing factor is unchanged from the 2010 analysis (European Renewable Energy Council, 2008, page 16). Construction and O&M jobs were derived from a weighted average of 19 reported power plants (3223 MW) in the US, Spain, and Australia (Rutovitz & Harris, 2012a). The manufacturing factor comes from the European Renewable Energy Council, 2008, page 16.

11. **Ocean:** The construction factor used in this study is a combined projection for wave and tidal power derived from data for offshore wind power (Batten & Bahaj, 2007). A study of a particular wave power technology, Wave Dragon, provided the O&M factor (Soerensen, 2008).

12. **Geothermal and heat pumps:** One overall factor has been used for jobs per MW installed, from the Energy Information Administration (USA) (EIA) annual reporting (US Energy Information Administration, 2010), adjusted to include installation using data from WaterFurnace (WaterFurnace, 2009)

13. **Solar thermal heating:** One overall factor has been used for jobs per MW installed, as this was the only data available on any large scale. This may underestimate jobs, as it may not include O&M. The global figure is derived from the IEA heating and cooling program report (International Energy Agency Solar Heating and Cooling Program, 2011).

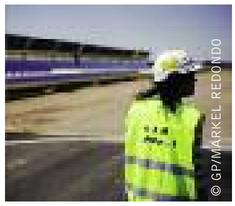


image A WORKER SURVEYS THE EQUIPMENT AT ANDASOL 1 SOLAR POWER STATION, WHICH IS EUROPE'S FIRST COMMERCIAL PARABOLIC TROUGH SOLAR POWER PLANT. ANDASOL 1 WILL SUPPLY UP TO 200,000 PEOPLE WITH CLIMATE-FRIENDLY ELECTRICITY AND SAVE ABOUT 149,000 TONNES OF CARBON DIOXIDE PER YEAR COMPARED WITH A MODERN COAL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

6.6 coal, gas and renewable technology trade

It is assumed that all manufacturing for energy technologies other than wind and PV occurs within the ASEAN region, but that only 30% of manufacturing for wind and 50% of manufacturing for PV occurs within the region. This allows for such items as support frames and wind turbine towers, which are generally locally manufactured. There is already a significant manufacturing base for PV in the region, so the proportion of local manufacturing is assumed to be greater.

Indonesia is the fifth largest coal producer in the world, and exports between 70% and 80% of production (BP, 2012). Between 2000 and 2011, an average of 85% of Indonesian exports became regional exports. The amount of regional export of coal in the Reference scenario has been calculated from the WEO 2011 projection for Indonesian exports (International Energy Agency, 2011).

Net regional trade is assumed to reduce significantly in the Energy [R]evolution scenario, as the region's overall coal consumption is reduced. The reductions were calculated precisely for the global Energy [R]evolution scenario, and it is assumed that exports from the ASEAN region are reduced proportionately to the reduction in exports from the Non-OECD Asia region.

The coal exports calculated for each scenario by year are show in Table 6.3.

6.7 adjustment for learning rates – decline factors

Employment factors are adjusted to take into account the reduction in employment per unit of electrical capacity as technologies and production techniques mature. The learning rates assumed have a significant effect on the outcome of the analysis, and are given in Table 6.4. These decline rates are calculated directly from the cost data used in the Energy [R]evolution modelling for the ASEAN region.

table 6.4: technology cost decline factors

	ANNUAL DECLINE IN JOB FACTORS		
	2010-2015	2015-2020	2020-30
Coal	0.3%	0.3%	0.5%
Lignite	0.4%	0.4%	0.4%
Gas	0.5%	0.5%	1.0%
Oil	0.4%	0.4%	0.8%
Diesel	0.0%	0.0%	0.0%
Nuclear	0.0%	0.0%	0.0%
Biomass	1.6%	1.1%	0.7%
Hydro-large	-0.6%	-0.6%	-0.9%
Wind onshore	1.6%	2.2%	0.2%
Wind offshore	6.4%	8.9%	3.9%
PV	12.0%	4.6%	2.2%
Geothermal power	3.5%	5.4%	7.3%
Solar thermal power	5.6%	5.1%	2.8%
Ocean	4.8%	6.5%	7.0%
Coal CHP	0.3%	0.3%	0.5%
Lignite CHP	0.3%	0.3%	0.5%
Gas CHP	0.9%	1.0%	1.0%
Oil CHP	0.4%	0.4%	0.8%
Biomass CHP	2.0%	2.2%	2.2%
Geothermal CHP	2.6%	3.2%	4.5%
Geothermal - heat	0.0%	0.2%	0.9%
Solar thermal heat	0.0%	0.9%	1.8%

table 6.3: PJ coal exports from the ASEAN region in both scenarios

REFERENCE (PJ COAL EXPORTS)				[R]EVOLUTION (PJ COAL EXPORTS)			
2010	2015	2020	2030	2010	2015	2020	2030
5,074	6,654	8,234	9,877	5,051	2,887	464	172

6.8 future employment in the energy sector

Energy sector jobs in the ASEAN region are higher in the Energy [R]evolution scenario at every stage in the projection. By 2015, jobs in the Energy [R]evolution scenario have increased by 0.2 million, while jobs in the Reference scenario fall slightly. After 2015, jobs in both scenarios fall, reflecting the fact that labour intensity is reduced as prosperity in the region grows. Strong growth in renewable energy in the Energy [R]evolution scenario compensate for some of the job losses.

- By 2015, strong growth in the renewable energy sector increases jobs in the Energy [R]evolution scenario by 21%, to 1.4 million.
- In 2020, there are nearly 1.3 million jobs in the Energy [R]evolution scenario, and 1.0 million in the Reference scenario.
- In 2030, there are approximately 1.1 million jobs in the Energy [R]evolution scenarios, and 0.9 million jobs in the Reference scenario.

Figure 6.1 shows the change in job numbers under both scenarios for each technology between 2010 and 2030. Jobs in the Reference scenario fall by 18% between 2010 and 2030, with job losses in most tenchnology sectors.

In the Energy [R]evolution scenario, jobs fall by 4% by 2030. Extremely strong growth in renewable energy reduces overall energy sector employment losses compared to the Reference scenario. Renewable energy accounts for 72% of energy jobs by 2030, with biomass having the greatest share (25%), followed by solar PV and then solar heating.

figure 6.1: employment in the energy sector under the reference and energy [r]evolution scenarios

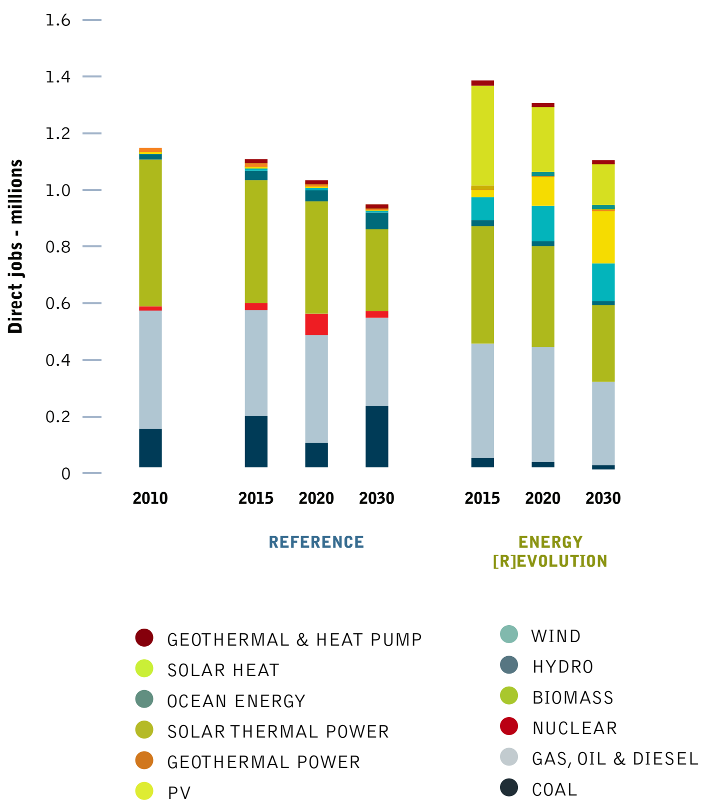


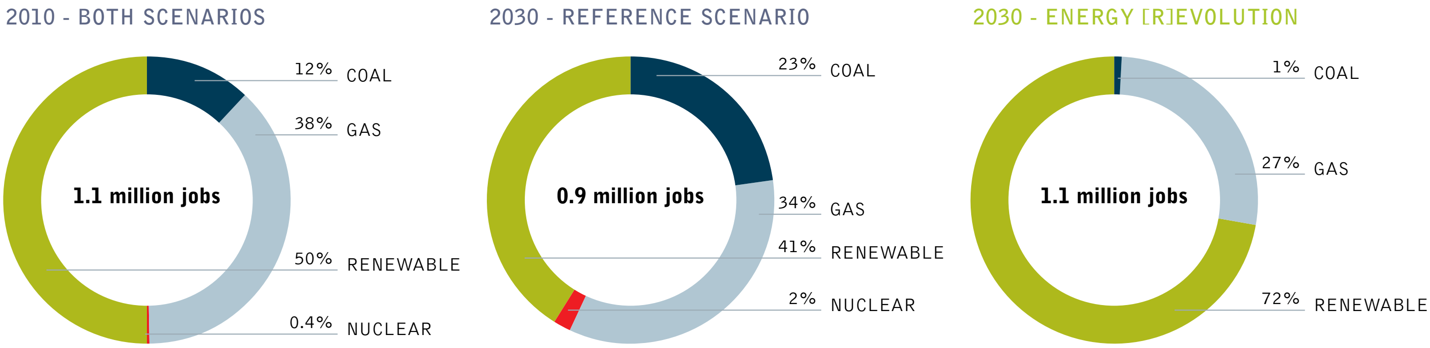
image WIND ENERGY PARK NEAR DAHME. WIND TURBINE IN THE SNOW OPERATED BY VESTAS.

table 6.5: total employment in the energy sector THOUSAND JOBS

		REFERENCE			ENERGY [R]EVOLUTION		
	2010	2015	2020	2030	2015	2020	2030
Coal	136	181	87	216	33	18	7
Gas, oil & diesel	427	373	380	313	404	406	295
Nuclear	5	26	76	23			
Renewable	560	508	471	377	929	862	782
Total Jobs (thousands)	**1,128**	**1,088**	**1,013**	**928**	**1,366**	**1,287**	**1,085**
Construction and installation	113	171	120	163	372	349	332
Manufacturing	49	70	51	66	150	145	128
Operations and maintenance	62	75	87	103	68	93	147
Fuel supply (domestic)	885	748	725	563	765	698	478
Coal and gas export	19	24	30	34	11	2	1
Total Jobs (thousands)	**1,128**	**1,088**	**1,013**	**928**	**1,366**	**1,287**	**1,085**

note
numbers may not add up due to rounding

figure 6.2: employment in the energy sector by technology in 2010 and 2030



box 6.1: green is gold

The Philippine report "Green is Gold: How Renewable Energy can save us money and generate jobs" released in January 2012 shows how investing in renewable energy can generate tens of thousands of jobs among other equally economical and climate-friendly benefits.

In the Philippines, the country stands to benefit from the creation of tens of thousands of jobs. Solar entrepreneurs explained that for each 10-MW plant in the country, they hire 1000 people during construction for 6 months and 100 people full time. A representative 8-MW run of river hydro plant employs 1000 people during construction and 30 people in permanent full time jobs. The manufacturing company SunPower had 4,130 employees in the Philippines. One geothermal company alone already hired 2,582 employees and reported a turnover of almost US$ 465 million.

Seven proposed biomass projects could generate roughly 78,000 jobs to construct power plants; 3400-4000 jobs for plant operation; 7000 in the feedstock supply chain; and additional employment for the farmers producing agricultural wastes. Moreover, these calculations are limited to direct jobs. If indirect jobs are included, the job numbers increase by 50-100%, while including direct, indirect and induced jobs could increase job numbers by 100-350%.

Renewables ensure our security of supply, help cope with rising demand, and provide decarbonized energy. We all need electricity. It is vital to power our lives, run our hospitals and schools and we need it for every aspect of our lives. But we need it to be clean and sustainable. Embracing the Energy [R]evolution and harnessing renewables show that it can bring us wealth, cost savings and employment.

table 6.6: employment in the energy sector by technology, two scenarios THOUSAND JOBS

		REFERENCE			ENERGY [R]EVOLUTION		
By sector	2010	2015	2020	2030	2015	2020	2030
Construction and installation	113	162	115	158	97	168	215
Manufacturing	49	66	49	64	54	82	87
Operations and maintenance	62	75	87	103	68	93	147
Fuel supply (domestic)	885	748	725	563	765	698	478
Coal and gas export	19	24	30	34	10.6	1.7	0.6
Solar and geothermal heat	-	12	7.4	5.6	371	243	158
Total jobs (thousands)	**1,128**	**1,088**	**1,013**	**928**	**1,366**	**1,287**	**1,085**
By technology							
Coal	136	181	87	216	33	18	7
Gas, oil & diesel	427	373	380	313	404	406	295
Nuclear	4.7	26	76	23	-	-	-
Renewable	560	508	471	377	929	862	782
Biomass	*518*	*434*	*396*	*289*	*414*	*356*	271
Hydro	*28*	*33*	*39*	*59*	*22*	*17*	14
Wind	*4.7*	*16*	*17*	*15*	*81*	*125*	133
PV	*1.8*	*6.3*	*7.0*	*6.3*	*34*	*111*	189
Geothermal power	*6.7*	*6.3*	*4.7*	*1.9*	*5.9*	*5.7*	10.9
Solar thermal power	-	-	-	-	*0.9*	*1.5*	3.5
Ocean	-	-	-	-	-	*1.9*	3.9
Solar - heat	-	*12*	*6.9*	*5.4*	*352*	*232*	149
Geothermal & heat pump	-	*0.9*	*0.5*	*0.3*	*19*	*12*	9.2
Total jobs (thousands)	**1,128**	**1,088**	**1,013**	**928**	**1,366**	**1,286**	**1,085**

note
numbers may not add up due to rounding

image WORKERS OUTSIDE GEOTHERMAL POWER PLANT IN KAWERAU, NEW ZEALAND.

6.9 employment in the renewable heating sector

Employment in the renewable heat sector includes jobs in installation, manufacturing, and fuel supply. However, this analysis includes only jobs associated with fuel supply in the biomass sector, and jobs in installation and manucturing for direct heat from solar, geothermal and heat pumps. It will therefore be an underestimate of jobs in this sector.

6.9.1 employment in solar heating

In the Energy [R]evolution scenario, solar heating would provide 12% of total heat supply by 2030, and would employ approximately 149,000 people. Growth is much more modest in the Reference Scenario, with solar heating providing 0.5% of heat supply, and employing only 5,000 people.

6.9.2 employment in geothermal and heat pump heating

In the Energy [R]evolution scenario, geothermal and heat pump heating would provide 4% of total heat supply by 2030, and employ approximately 9,200 people. Growth is much more modest in the Reference Scenario, with geothermal and heat pump heating providing 0.1% of heat supply, and only employing about 300 people.

6.9.3 employment in biomass heat (fuel supply only)

In the Energy [R]evolution scenario, biomass heat would provide 35% of total heat supply by 2030, and would employ approximately 127,000 people. Growth is even stronger in the Reference Scenario, with biomass heat providing 33% of heat supply, and employing about 146,000 people.

table 6.7: solar heating: capacity, heat supplied and direct jobs

		REFERENCE			ENERGY [R]EVOLUTION		
Energy	UNIT	2015	2020	2030	2015	2020	2030
Installed capacity	GW	3.9	6.6	13.3	50	138	300
Heat supplied	PJ	13	22	45	161	450	981
Share of total supply	%	0.2%	0.3%	0.5%	2.2%	6%	12%
Annual increase in capacity	MW	774	550	684	23,717	17,592	15,166
Employment							
Direct jobs in installation and manufacture	jobs	12,000	7,000	5,000	352,000	232,000	149,000

table 6.8: geothermal and heat pump heating: capacity, heat supplied and direct jobs

		REFERENCE			ENERGY [R]EVOLUTION		
Energy	UNIT	2015	2020	2030	2015	2020	2030
Installed capacity	GW	0.6	0.9	1.6	5.0	13.2	29.8
Heat supplied	PJ	3	5	8	46	127	293
Share of total supply	%	neg	0.1%	0.1%	0.6%	1.6%	3.7%
Annual increase in capacity	MW	111	69	56	2,316	1,640	1,742
Employment							
Direct jobs in installation and manufacture	jobs	900	500	300	18,500	11,600	9,200

table 6.9: biomass heat: direct jobs in fuel supply

		REFERENCE			ENERGY [R]EVOLUTION		
Energy	UNIT	2015	2020	2030	2015	2020	2030
Heat supplied	PJ	3,167	3,292	3,156	3,220	3,186	2,749
Share of total supply	%	41%	37%	33%	43%	39%	35%
Employment							
Direct jobs in fuel supply	jobs	252,000	219,000	146,000	256,000	212,000	127,000

6.9.4 employment in hydro

Hydro accounted for 10% of the ASEAN region's electricity generation in 2010, and provided 33,000 jobs.

In the Reference scenario, jobs increase to 59,000 by 2030. Generation nearly doubles in the same period, although the contribution to total generation falls slightly to 8%.

In the Energy [R]evolution generation the amount of hydro capacity and generation is static until 2030. Jobs fall to 22,000 by 2015, and then to 14,000 by 2030. The reason for the reduction in jobs is the general increase in prosperity in the region, which is reflected in lower labour intensity.

6.9.5 employment in biomass

Electricity generation and heat from biomass grows strongly in both scenarios, increasing nearly seven fold in the Reference scenario and six fold in the Energy [R]evolution scenario. Biomass is a significant employer, with 434,000 jobs in the Reference scenario in 2015, and 414,000 in the Energy [R]evolution scenario.

Biomass employment falls over the study period as increasing prosperity reduces labour intensity. Jobs remain significant at 2030 however, with biomass providing 289,000 jobs in the Reference scenario, and 271,000 in Energy [R]evolution scenario.

Jobs in heating from biomass fuels are included here.

table 6.10: hydro: capacity, generation and direct jobs

		REFERENCE			ENERGY [R]EVOLUTION		
Energy	UNIT	2015	2020	2030	2015	2020	2030
Installed capacity	GW	23.2	26.8	43.1	22.2	23.2	23.4
Total generation	TWh	73.0	81.0	129.0	70.0	70.0	70.0
Share of total supply	%	9%	8%	8%	9%	7%	5%
Annual increase in capacity	MW	688	1,009	2,126	189	20	12
Employment							
Direct jobs in construction, manufacture, operation and maintenance	jobs	33,000	39,000	59,000	22,000	17,000	14,000

table 6.11: biomass: capacity, generation and direct jobs

		REFERENCE			ENERGY [R]EVOLUTION		
Energy	UNIT	2015	2020	2030	2015	2020	2030
Installed electrical capacity	GW	2.9	4.2	7.1	1.2	1.6	6.6
Total generation	TWh	10.4	18.0	37.0	6.3	8.4	30.8
Share of total supply	%	1.3%	1.7%	2.3%	0.8%	0.9%	2.1%
Annual increase in capacity	MW	248	239	378	87	160	1,001
Employment							
Direct jobs in construction, manufacture, operation and maintenance	jobs	21,000	22,000	25,000	8,000	11,000	38,000
Direct jobs in fuel supply (includes biomass for heat)	jobs	413,000	375,000	264,000	406,000	345,000	233,000
Total biomass jobs	jobs	**434,000**	**397,000**	**289,000**	**414,000**	**356,000**	**271,000**

image TESTING THE SCOTRENEWABLES TIDAL TURBINE OFF KIRWALL IN THE ORKNEY ISLANDS.

6.9.6 employment in geothermal power

In the Energy [R]evolution scenario, geothermal power would provide 5% of total electricity generation by 2030, and employ approximately 11,000 people.

While installed capacity grows gradually in the Reference scenario, by 2030 geothermal power provides only 2% of generation, and employs approximately 2,000 people.

Employment in geothermal energy is nearly 6 times higher in the Energy [R]evolution scenario at 2030, although output is only double that in the Reference scenario. This is because the sector is going through a significant expansion at 2030, with 10 times greater installations per year.

6.9.7 employment in wind energy

In the Energy [R]evolution scenario, wind energy would provide 30% of total electricity generation by 2030, and would employ approximately 133,000 people. Growth is more modest in the Reference Scenario, with wind energy providing 4% of generation, and employing approximately 15,000 people.

6.9.8 employment in solar photovoltaics

Growth in PV in the Energy [R]evolution scenario results in 189,000 jobs by 2030, with PV supplying 16% of electricity. In the Reference scenario, the share of electricity from solar photovoltaics grows only marginally, to 0.6% by 2030, and employment stays virtually stable at around 6,000 people.

table 6.12: geothermal power: capacity, generation and direct jobs

		REFERENCE			ENERGY [R]EVOLUTION		
Energy	UNIT	2015	2020	2030	2015	2020	2030
Installed capacity	GW	3.6	4.4	5.9	3.0	3.8	11.6
Total generation	TWh	24	29	39	20	25	78
Share of total supply	%	3%	3%	2%	2%	3%	5%
Annual increase in capacity	MW	0.1	0.1	0.1	0.1	0.2	1.5
Employment							
Direct jobs in construction, manufacture, operation and maintenance	jobs	6,000	5,000	2,000	6,000	6,000	11,000

table 6.13: wind energy: capacity, generation and direct jobs

		REFERENCE			ENERGY [R]EVOLUTION		
Energy	UNIT	2015	2020	2030	2015	2020	2030
Installed capacity	GW	8	15	28	15	76	208
Total generation	TWh	15	30	60	30	154	450
Share of total supply	%	2%	3%	4%	4%	16%	30%
Annual increase in capacity	MW	2.3	1.3	1.1	7.9	11.8	12.1
Employment							
Direct jobs in construction, manufacture, operation and maintenance	jobs	16,000	17,000	15,000	81,000	125,000	133,000

table 6.14: solar photovoltaics: capacity, generation and direct jobs

		REFERENCE			ENERGY [R]EVOLUTION		
Energy	UNIT	2015	2020	2030	2015	2020	2030
Installed capacity	GW	2	3	7	4	22	171
Total generation	TWh	2	4	10	5	28	235
Share of total supply	%	0.2%	0.4%	0.6%	0.6%	2.9%	15.8%
Annual increase in capacity	MW	0.2	0.3	0.5	1.6	7.3	18.7
Employment							
Direct jobs in construction, manufacture, operation and maintenance	jobs	6,000	7,000	6,000	34,000	111,000	189,000

6.9.9 employment in coal

Jobs in the coal sector fluctuate in the Reference scenario, and are 19% above 2010 in 2030. Jobs increase sharply from 136,000 in 2010 to 181,000 in 2015, fall to 87,000 in 2020 and then reach 216,000 by 2030. Employment numbers follow the planned construction of coal fired power stations.

Coal sector employment in the Energy [R]evolution scenario falls dramatically over the period, reflecting a reduction in coal generation between 2010 and 2030 from 27% to only 3% of total electricity supply.

Coal jobs in both scenarios include coal used for heat supply.

6.9.10 employment in gas, oil & diesel

Jobs in the gas sector follow similar paths in the Reference Scenario and the Energy [R]evolution scenario. In the Reference Scenario gas employment is projected to fall 13% by 2015, increase slightly to 2020, and then fall to 313,000 in 2030, 27% below 2010 levels. Electricity generation from gas increases by 48% from 2010 to 2030.

In the Energy [R]evolution scenario, more gas sector jobs are maintained until 2020. Employment falls 5% by 2015, remains stable until 2020, and then falls to 295,000 in 2030, 31% below 2010 levels. Electricity generation from gas increases by 40% from 2010 to 2030. Gas jobs in both scenarios include gas used for heat supply.

6.9.11 employment in nuclear energy

In the Reference scenario, nuclear capacity comes on line in 2016. Employment increases from 4,700 in 2010 to 25,700 in 2015, peaks at 75,900 in 2020, and falls back to 23,000 by 2030. The peak in employment reflects the maximum construction period. In the Energy [R]evolution, this sector is not developed at all, and employment is phased out by 2015.

table 6.15: fossil fuels: capacity, generation and direct jobs

Employment in the energy sector - fossil fuels and nuclear	UNIT	REFERENCE 2015	REFERENCE 2020	REFERENCE 2030	ENERGY [R]EVOLUTION 2015	ENERGY [R]EVOLUTION 2020	ENERGY [R]EVOLUTION 2030
coal	jobs	181,000	87,000	216,000	33,000	18,000	7,000
gas, oil & diesel	jobs	373,000	380,000	313,000	404,000	406,000	295,000
nuclear energy	jobs	25,700	75,900	23,000	-	-	-
COAL							
Energy							
Installed capacity	GW	45	66	84	29	21	7
Total generation	TWh	276	423	545	179	136	43
Share of total supply	%	33%	39%	35%	22%	14%	3%
Annual increase in capacity	MW	3.4	2.6	6.8	-1.8	-2.0	-0.6
GAS, OIL & DIESEL							
Energy							
Installed capacity	GW	104	125	153	121	139	191
Total generation	TWh	430	483	583	511	550	553
Share of total supply	%	52%	45%	37%	62%	57%	37%
Annual increase in capacity	MW	3.6	2.3	1.2	2.8	4.0	5.2
NUCLEAR ENERGY							
Energy							
Installed capacity	GW	-	1	22	-	-	-
Total generation	TWh	-	8	172	-	-	-
Share of total supply	%	-	1%	11%	-	-	-
Annual increase in capacity	MW	0.2	0.4	0	-	-	-

note
"neg" = negligible

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

EIA Energy Information Administration (USA)
EWEA European Wind Energy Association
GWh Gigawatt hour
IEA International Energy Agency
ISF Institute for Sustainable Futures
MW Megawatt
O&M Operations and Maintenance
OECD Organisation for Economic Co-operation and Development
PV Photovoltaic
TWh Terawatt hour
WEO World Energy Outlook

the silent revolution
– past and current market developments

THE POWER PLANT MARKET 1970 TO 2012

POWER PLANT MARKETS IN THE US, EUROPE AND CHINA

GLOBAL MARKET SHARES IN THE POWER PLANT MARKET: RENEWABLE GAINING GROUND

THE GLOBAL RENEWABLE ENERGY MARKET IN 2012

7

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

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technology A MAN WALKS IN SOLAR FARM. THAILAND HAS GREAT POTENTIAL IN PRODUCING SOLAR POWER. GOVERNMENT PROMOTION OF RENEWABLE ENERGY SUPPORTS THESE CLEANER TECHNOLOGIES. THE THAI GOVERNMENT HAS ALSO SET A NATIONAL AGENDA FOR RENEWABLE ENERGY, WHICH AIMS FOR 25% OF THE COUNTRY’S ENERGY PORTFOLIO TO COME FROM RENEWABLE SOURCES BY 2022.

image THE SAN GORGONIO PASS WIND FARM IS LOCATED IN THE COACHELLA VALLEY NEAR PALM SPRINGS, ON THE EASTERN SLOPE OF THE PASS IN RIVERSIDE COUNTY, JUST EAST OF WHITE WATER. DEVELOPMENT BEGUN IN THE 1980S, THE SAN GORGONIO PASS IS ONE OF THE WINDIEST PLACES IN SOUTHERN CALIFORNIA. THE PROJECT HAS MORE THAN 4,000 INDIVIDUAL TURBINES AND POWERS PALM SPRINGS AND THE REST OF THE DESERT VALLEY.

7.1 the power plant market 1970 to 2012

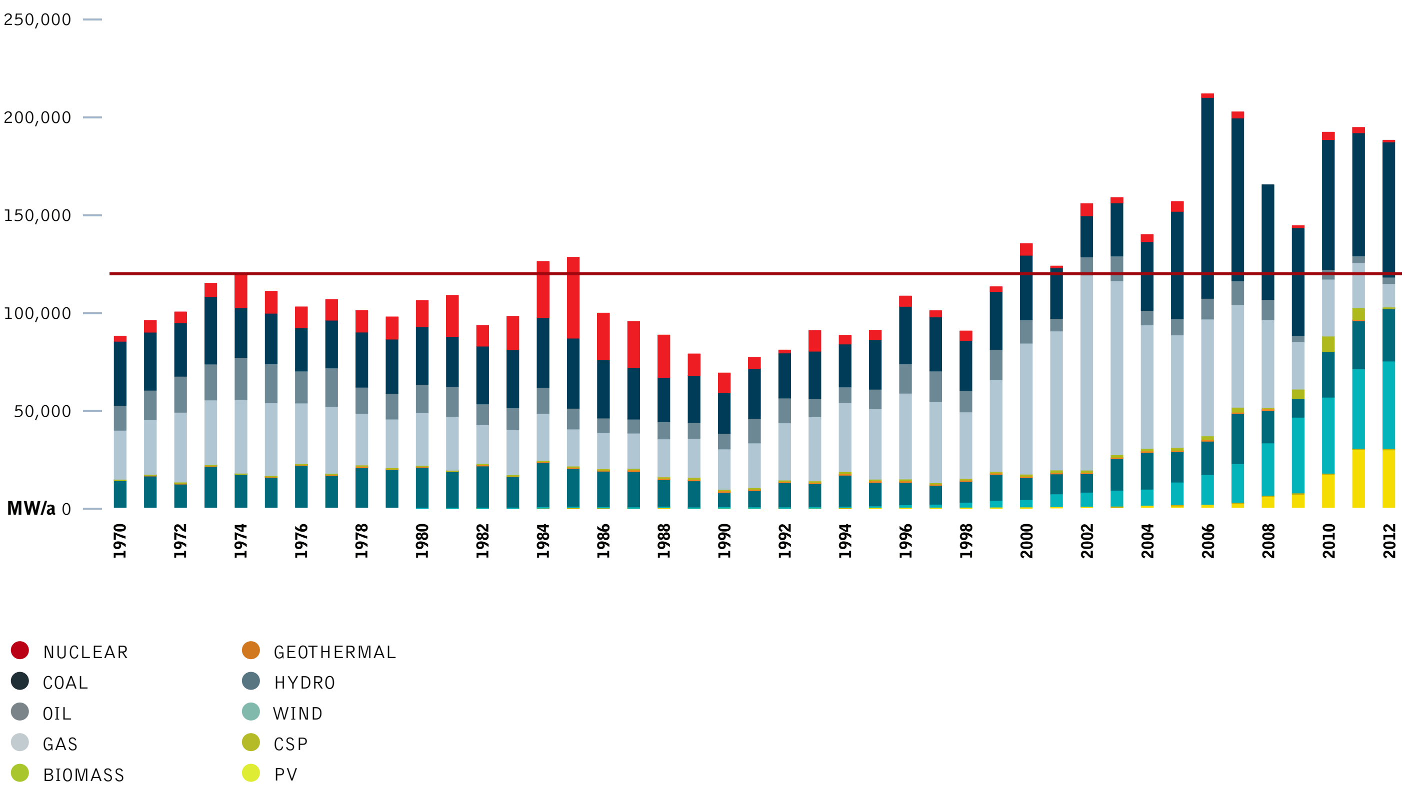
A new analysis of the global power plant market shows that since the late 1990s, renewable energy especially wind and solar photovoltaic installations grew faster than any other power plant technology across the world – over 630,000 MW total new installed capacities between 2000 and 2012. However, it is too early to claim the end of the fossil fuel based power generation, because more than 695,000 MW of new coal power plants were built with embedded cumulative emissions of 78 billion tonnes CO_2 over their technical lifetime.

The global market volume of renewable energies in 2012 was on average, as much as the total global energy market volume each year between 1970 and 2000. There is a window of opportunity for new renewable energy installations to replace old plants in OECD countries and for electrification in developing countries. However, the window will closes within the next years without good renewable energy policies and legally binding CO_2 reduction targets.

Between 1970 and 1990, the global power plant market was dominated by OECD[64] countries that electrified their economies mainly with coal, gas and hydro power plants. The power sector 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 - and went into decline in following years, with no recent signs of growth.

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.

figure 7.1: global power plant market 1970-2010



source Platts, REN21, EWEA, GWEC, EPIA, National Statistics, IEA, Breyer, Teske.

reference
64 ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT.

The economies of developing countries, especially in Asia, started growing during the 1990s, triggering a new wave of power plant projects. Similarly to the US and Europe, most of the new markets in the ASEAN region of Southeast Asia partly deregulated their power sectors. A large number of new power plants in this region were built from Independent Power Producer (IPPs), who sell the electricity mainly to state-owned utilities. The majority of new power plant technology in liberalised power markets is fuelled by gas, except for in China which focused on building new coal power plants. Excluding China, the rest of the global power plant market has seen a significant decline of new coal power plant projects since the late 1990s with growing gas and renewable generation, particularly wind.

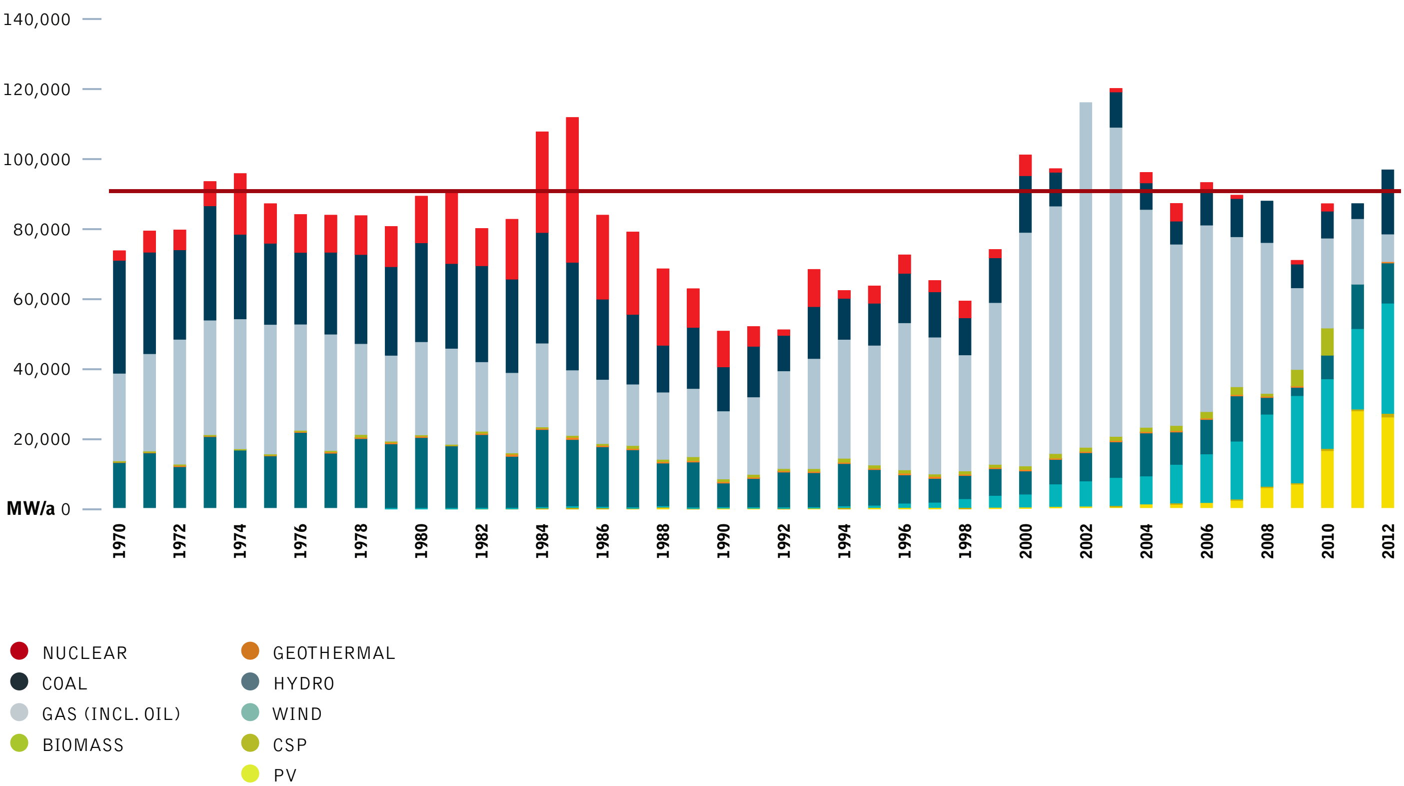
7.2 power plant markets in the US, Europe and China

The graphs show how much electricity market liberalisation influences the choice of power plant technology. While the US and European power sectors 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 renewable energy in 2009 and 2010.

US: Liberalisation of the US power sector started with the Energy Policy Act 1992, and became a game changer for the whole sector. While the US in 2010 is still far away from a fully liberalised electricity market, the effect has been a shift from coal and nuclear towards gas and wind. Since 2005 wind power plants make up an increasing share of the new installed capacities as a result of mainly state-based renewable energy support programmes. However until end 2012, USA renewable energy policy has been very insecure therefore market volumes especially for solar and wind power fluctuate significantly. 2012 was a particular good year both for solar photovoltaic and onshore wind.

Europe: About five years after the US began deregulating the power sector, the European Community started a similar process with similar effect on the power plant market. 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 then. The growing share of renewables, especially wind and solar photovoltaic, are due to a legally-binding target and the associated feed-in laws which have been 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 be the aged power plant fleet in Europe needed re-powering.

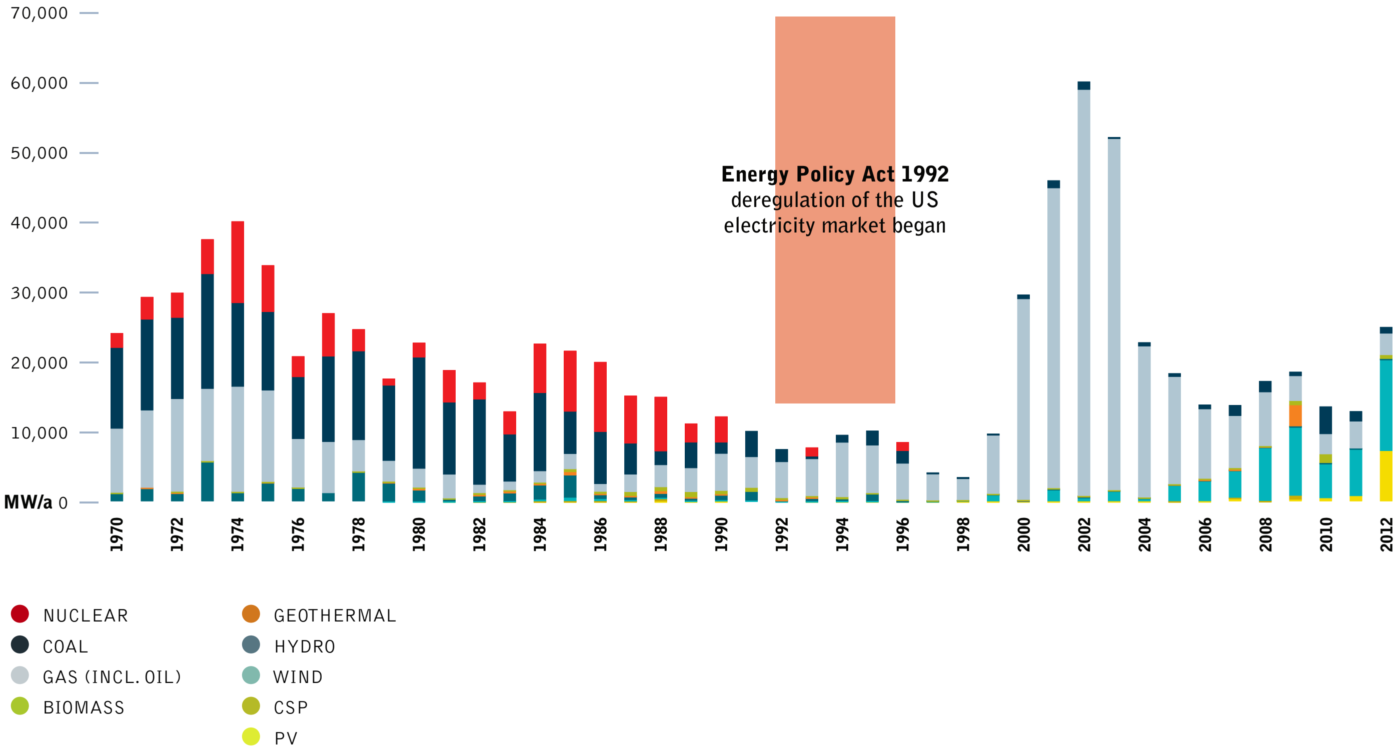
figure 7.2: global power plant market 1970-2012, excluding china



source Platts, REN21, EWEA, GWEC, EPIA, National Statistics, IEA, Breyer, Teske.

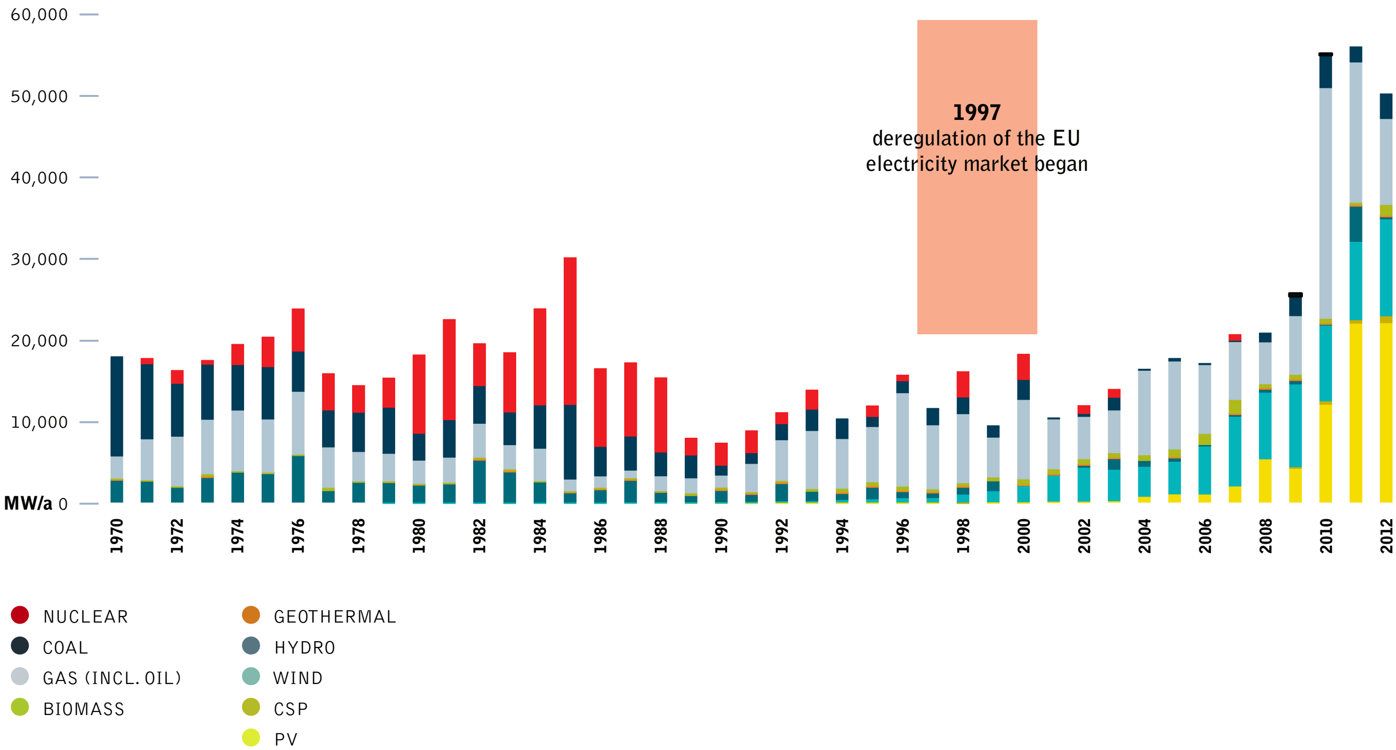
image NESJAVELLIR GEOTHERMAL PLANT GENERATES ELECTRICITY AND HOT WATER BY UTILIZING GEOTHERMAL WATER AND STEAM. IT IS THE SECOND LARGEST GEOTHERMAL POWER STATION IN ICELAND. THE STATION PRODUCES APPROXIMATELY 120MW OF ELECTRICAL POWER, AND DELIVERS AROUND 1,800 LITRES (480 US GAL) OF HOT WATER PER SECOND, SERVICING THE HOT WATER NEEDS OF THE GREATER REYKJAVIK AREA. THE FACILITY IS LOCATED 177 M (581 FT) ABOVE SEA LEVEL IN THE SOUTHWESTERN PART OF THE COUNTRY, NEAR THE HENGILL VOLCANO.

figure 7.3: usa: annual power plant market 1970-2012



source Platts, REN21, EWEA, GWEC, EPIA, National Statistics, IEA, Breyer, Teske.

figure 7.4: europe (eu27): annual power plant market 1970-2012



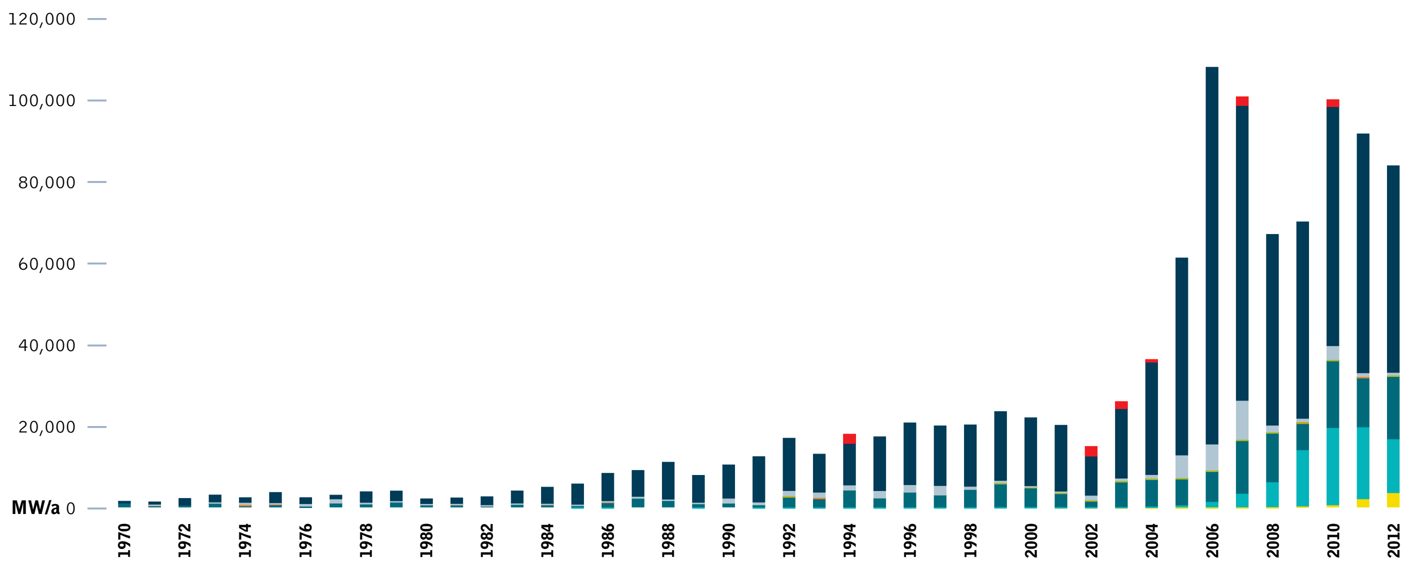
source Platts, REN21, EWEA, GWEC, EPIA, National Statistics, IEA, Breyer, Teske.

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, between 2006 and 2010, a total of 76,825 MW of small coal power plants were phased out under the 11th Five Year Programme. While coal still dominates the new added capacity with an annual new installed capacity of around 50 GW each year between 2005 and 2012, wind power is rapidly growing as well. Since 2003 the wind market doubled each year to a record high of about 18,000 MW[65] by 2010, 49% of the global wind market. The following years 2011 and 2012 the market was smaller at 17.6 GW and 13.2 GW. Since 2012, a new policy for grid connected solar photovoltaic is in force and market growth is expected to follow the development of the wind industry between 2003 and 2010.

7.3 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. Initially only a handful of countries, namely Germany, Denmark and Spain, dominated the wind market, by the end of 2012 however the wind industry is present in 79 countries around the world. Following the example of the wind industry, the solar photovoltaic industry experienced an equal growth since 2005. Between 2000 and 2012, 29% of all new power plants worldwide were renewable-powered – mainly wind – and 37% run on gas. So, two-thirds of all new power plants installed globally are gas power plants and renewable, with close to one-third as coal. Nuclear remains irrelevant on a global scale with just 1.7% of the global market share.

figure 7.5: china: annual power plant market 1970-2012



NUCLEAR
COAL
GAS (INCL. OIL)
BIOMASS
GEOTHERMAL
HYDRO
WIND
CSP
PV

source Platts, REN21, EWEA, GWEC, EPIA, National Statistics, IEA, Breyer, Teske.

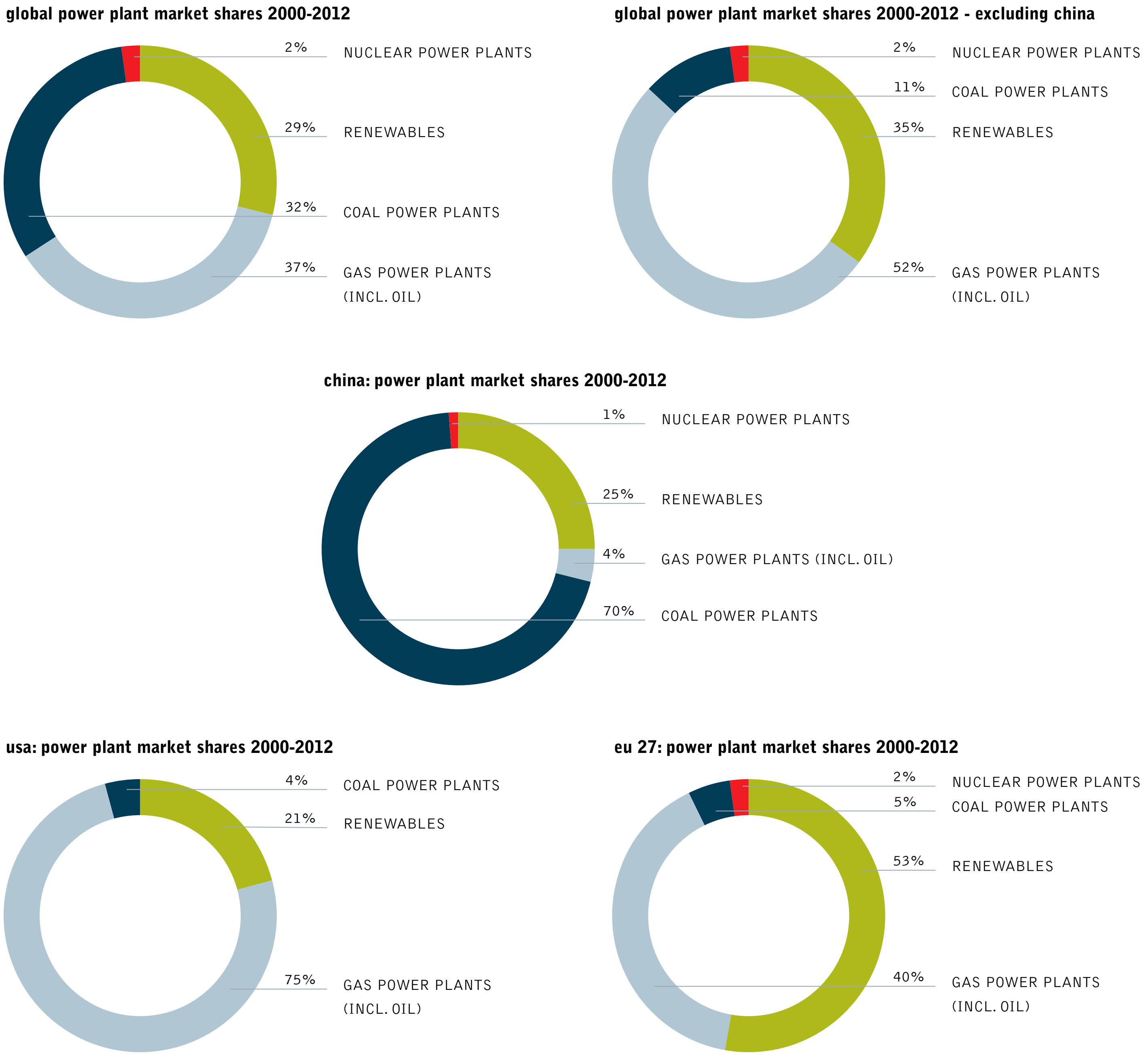
reference
65 WHILE THE OFFICIAL STATISTIC OF THE GLOBAL AND CHINESE WIND INDUSTRY ASSOCIATIONS (GWEC/CREIA) ADDS UP TO 18,900 MW FOR 2010, THE NATIONAL ENERGY BUREAU SPEAKS ABOUT 13,999 MW. DIFFERENCES BETWEEN SOURCES AS DUE TO THE TIME OF GRID CONNECTION, AS SOME TURBINES HAVE BEEN INSTALLED IN THE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

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

About 633,000 MW of new renewable energy capacity has been installed over the last decade, while 695,000 MW of new coal, with embedded cumulative emissions of more than 78 billion tonnes CO_2 over their technical lifetime, came online – 81% or 563,000 MW in China.

The energy revolution has started on a global level already. This picture is even clearer when we look into the global market shares but exclude China, the country with where the majority of coal expansion takes place. About 35% of all *new* power plants since 2000 have been renewables and 52% have been gas power plants (87% in total). Coal gained a market share of only 11% globally, if China is excluded in this calculation. Between 2000 and 2012, China has added over 560,000 MW of new coal capacity: four times the entire coal capacity of the EU! However, China has also recently kick-started its wind market, and solar photovoltaics is expected to follow in the years to come.

figure 7.6: power plant market shares



source PLATTS, IEA, BREYER, TESKE.

7.4 the global renewable energy market in 2012

The renewable energy sector has been growing substantially over the last 10 years. In 2011, the increases in the installation rates of both wind and solar power were particularly impressive. The total amount of renewable energy installed worldwide is reliably tracked by the Renewable Energy Policy Network for the 21st Century (REN21). Its latest global status report (2013) shows how the technologies have grown. The following text has been taken from the Renewables 2013 – Global Status Report– published in June 2013 with the permit of REN 21 and is a shortened version of the executive summary.

7.3.1 continued renewable energy capacity growth

Global demand for renewable energy continued to rise during 2011 and 2012, supplying an estimated 19% of global final energy consumption in 2011 (the latest year for which data are available), with a little less than half from traditional biomass. Useful heat energy from modern renewable sources accounted for an estimated 4.1% of total final energy use, hydropower made up about 3.7%, and an estimated 1.8% was provided by wind, solar, geothermal, biomass power, and biofuels.

Total renewable power capacity worldwide exceeded 1,470 GW in 2012, up about 8.5% from 2011. Hydropower rose 3% to an estimated 990 GW, while other renewables grew 21.5% to exceed 480 GW. Globally, wind power accounted for about 39% of renewable power capacity added in 2012, followed by hydropower and solar PV, each accounting for approximately 26%. Renewables made up just over half of total net additions to electric generating capacity from all sources in 2012. By year's end, they comprised more than 26% of global generating capacity and supplied an estimated 21.7% of global electricity, with 16.5% of electricity provided by hydropower. Industrial, commercial and residential consumers are increasingly becoming producers of renewable power in a growing number of countries.

Demand continued to rise in the heating and cooling sector, which offers an immense, yet mostly untapped, potential for renewable energy deployment. Already, heat from modern biomass, solar, and geothermal sources represents a significant portion of the energy derived from renewables, and the sector is slowly evolving as countries begin to enact support policies. Trends in the sector include the use of larger systems, increasing use of combined heat and power (CHP), the feeding of renewable heat and cooling into district schemes, and the growing use of modern renewable heat for industrial purposes. After years of rapid growth, biodiesel production continued to expand in 2012 but at a much slower rate; fuel ethanol production peaked in 2010 and has since declined. Small but growing quantities of gaseous biofuels are being used to fuel vehicles, and there are limited but increasing initiatives to link electric transport systems with renewable energy. Most technologies continued to see expansion in manufacturing and global demand during 2012. However, uncertain policy environments and declining policy support affected investment climates in a number of established markets, slowing momentum in Europe, China and India.

Solar PV and onshore wind power experienced continued price reductions due to economies of scale and technology advances, but also due to a production surplus of modules and turbines. Combined with the international economic crisis and ongoing tensions in international trade, these developments have created new challenges for some renewable industries and equipment manufacturers, leading to industry consolidation. However, they also have opened up new opportunities and pushed companies to explore new markets. Subsequently, renewables are becoming more affordable for a broader range of consumers in developed and developing countries alike. Renewables are picking up speed across Asia, Latin America, the Middle East, and Africa, with new investment in all technologies. The Middle East-North Africa region (MENA) and South Africa, in particular, witnessed the launch of ambitious new targets in 2012, and the emergence of policy frameworks and renewables deployment. Markets, manufacturing, and investment shifted increasingly towards developing countries during 2012.

The top countries for renewable power capacity at year's end were China, the United States, Brazil, Canada and Germany; the top countries for non-hydro capacity were China, the United States and Germany, followed by Spain, Italy and India. By region, the BRICS nations accounted for 36% of total global renewable power capacity and almost 27% of non-hydro renewable capacity. The EU had the most non-hydro capacity at the end of 2012, with approximately 44% of the global total. Renewables represent a rapidly growing share of energy supply in a growing number of countries and regions:

- In China, wind power generation increased more than generation from coal and passed nuclear power output for the first time.
- In the European Union, renewables accounted for almost 70% of additions to electric capacity in 2012, mostly from solar PV and wind power. In 2011 (the latest data available), renewables met 20.6% of the region's electricity consumption and 13.4% of gross final energy consumption.
- In Germany, renewables accounted for 22.9% of electricity consumption (up from 20.5% in 2011), 10.4% of national heat use, and 12.6% of total final energy demand.
- The United States added more capacity from wind power than any other technology, and all renewables made up about half of total electric capacity additions during the year.
- Wind and solar power are achieving high levels of penetration in countries like Denmark and Italy, which in 2012 generated 30% of electricity with wind and 5.6% with solar PV, respectively.

As their shares of variable wind and solar power increase, a number of countries (including Denmark, Germany and Spain) have begun to enact policies and measures to successfully transform their energy systems to accommodate even larger shares. Impacts of all of these developments on jobs in the renewable energy sector have varied by country and technology, but, globally, the number of people working in renewable industries has continued to rise. An estimated 5.7 million people worldwide work directly or indirectly in the sector.

image SOLON AG PHOTOVOLTAICS FACILITY IN ARNSTEIN OPERATING 1,500 HORIZONTAL AND VERTICAL SOLAR "MOVERS". LARGEST TRACKING SOLAR FACILITY IN THE WORLD. EACH "MOVER" CAN BE BOUGHT AS A PRIVATE INVESTMENT FROM THE S.A.G. SOLARSTROM AG, BAYERN, GERMANY.

7.3.2 an evolving policy landscape

At least 138 countries had renewable energy targets by the end of 2012. As of early 2013, renewable energy support policies were identified in 127 countries, more than two-thirds of which are developing countries or emerging economies. The rate of adoption of new policies and targets has remained slow relative to the early to mid-2000s. As the sector has matured, revisions to historic policies have become increasingly common. In response to rapidly changing market conditions for renewable technologies, tight national budgets, and the broader impacts of the global economic crisis, some countries undertook extensive revisions to existing laws, some of which were imposed retroactively. Others increased support for renewables, and several countries around the world adopted ambitious new targets.

Most policies to support renewable energy target the power sector, with Feed-in tariffs (FITs) and renewable portfolio standards (RPS) used most frequently. During 2012, FIT policies were enacted in five countries, all in Africa and the Middle East; the majority of FIT-related changes involved reduced support. New RPS policies were enacted in two countries. An increasing number of countries turned to public competitive bidding, or tendering, to deploy renewables.

In the heating and cooling sector, promotion policies and targets continued to be adopted at a slower rate than in the power sector, although their adoption is increasing steadily. As of early 2013, 20 countries had specific renewable heating targets in place while at least 19 countries and states mandated the use of renewable heat technologies. Renewable heating and cooling are also supported through building codes and other measures. Biofuel blend mandates were identified at the national level in 27 countries and in 27 states/provinces. Despite increasing pressure in major markets such as Europe and the United States, due to growing debate over the overall sustainability of first generation biofuels, regulatory policies promoting the use of biofuels existed in at least 49 countries as of early 2013.

Thousands of cities and towns around the world have developed their own plans and policies to advance renewable energy, and momentum accelerated in 2012. To achieve ambitious targets, local governments adopted a range of measures, including: FITs or technology-specific capacity targets; fiscal incentives to support renewable energy deployment; and new building codes and standards, including solar heat mandates. Others developed renewable district heating and cooling systems; promoted the use of renewably-powered electric transport; formed consortia to fund projects; or advanced advocacy and information sharing. Several cities are working with their national governments to promote renewable energy, while others have begun to organize from the bottom up. In Europe, 1,116 new cities and towns joined the Covenant of Mayors in 2012, committing to a 20% $CO2$ reduction target and plans for climate mitigation, energy efficiency, and renewable energy.

7.3.3 investment trends

Global new investment in renewable power and fuels was US$ 244 billion in 2012, down 12% from the previous year's record. The total was still the second highest ever and 8% above the 2010 level. If the unreported investments in hydropower projects larger than 50 MW and in solar hot water collectors are included, total new investment in renewable energy exceeded US$ 285 billion.

The decline in investment—after several years of growth—resulted from uncertainty about support policies in major developed economies, especially in Europe (down 36%) and the United States (down 35%). Nonetheless, considering only net additions to electric generating capacity (excluding replacement plants) in 2012, global investment in renewable power was ahead of fossil fuels for the third consecutive year.

The year 2012 saw the most dramatic shift yet in the balance of investment activity between developed and developing economies. Outlays in developing countries reached US$ 112 billion, representing 46% of the world total; this was up from 34% in 2011, and continued an unbroken eight-year growth trend. By contrast, investment in developed economies fell 29% to US$ 132 billion, the lowest level since 2009. The shift was driven by reductions in subsidies for solar and wind project development in Europe and the United States; increased investor interest in emerging markets with rising power demand and attractive renewable energy resources; and falling technology costs of wind and solar PV. Europe and China accounted for 60% of global investment in 2012.

Solar power was the leading sector by far in terms of money committed in 2012, receiving 57% of total new investment in renewable energy (96% of which went to solar PV). Even so, the USD 140.4 billion for solar was down 11% from 2011 levels, due to a slump in financing of CSP projects in Spain and the United States, as well as sharply lower PV system prices. Solar was followed by wind power (USD 80.3 billion) and hydropower projects larger than 50 MW (estimated at USD 33 billion).

7.3.4 rural renewable energy

The year 2012 saw improved access to modern energy services through the use of renewables. Rural use of renewable electricity has increased with greater affordability, improved knowledge about local renewable resources, and more sophisticated technology applications. Attention to mini-grids has risen in parallel with price reductions in solar, wind, inverter, gasification and metering technologies. Technological progress also advanced the use of renewables in the rural heating and cooking sectors. Rural renewable energy markets show significant diversity, with the levels of electrification, access to clean cookstoves, financing models, actors, and support policies varying greatly among countries and regions.

table 7.1: 2013 selected indicators

		2010	2011	2012
Investment in new renewable capacity (annual)[a]	billion USD	227	279	244
Renewable power capacity (total, not including hydro)	GW	315	395	480
Renewable power capacity (total, including hydro)	GW	1,250	1,355	1,470
Hydropower capacity (total)[b]	GW	935	960	990
Biopower generation	GWh	313	335	350
Solar PV capacity (total)	GW	40	71	100
Concentrating solar thermal power (total)	GW	1.1	1.6	2.5
Wind power capacity (total)	GW	198	238	283
Solar how water capacity (total)[c]	GW	195	223	255
Ethanol production (annual)	billion litres	85	84.2	83.1
Biodiesel production (annual)	billion litres	18.5	22.4	22.5
Countries with policy targets	#	109	118	139
States/provinces/countries with feed-in policies	#	88	94	99
States/provinces/countries with RPS/quota policies	#	72	74	76
States/provinces/countries with biofuel mandates[d]	#	71	72	76

notes

a INVESTMENT DATA ARE FROM BLOOMBERG NEW ENERGY FINANCE AND INCLUDE BIOMASS, GEOTHERMAL, AND WIND GENERATION PROJECTS OF MORE THAN 1 MW; ALL HYDRO PROJECTS OF BETWEEN 1 AND 50 MW; ALL SOLAR POWER PROJECTS, WITH THOSE LESS THAN 1 MW ESTIMATED SEPARATELY AND REFERRED TO AS SMALL-SCALE PROJECTS OR SMALL DISTRIBUTED CAPACITY; ALL OCEAN ENERGY PROJECTS; AND ALL B BIOFUEL PROJECTS WITH AN ANNUAL PRODUCTION CAPACITY OF 1 MILLION LITRES OR MORE.

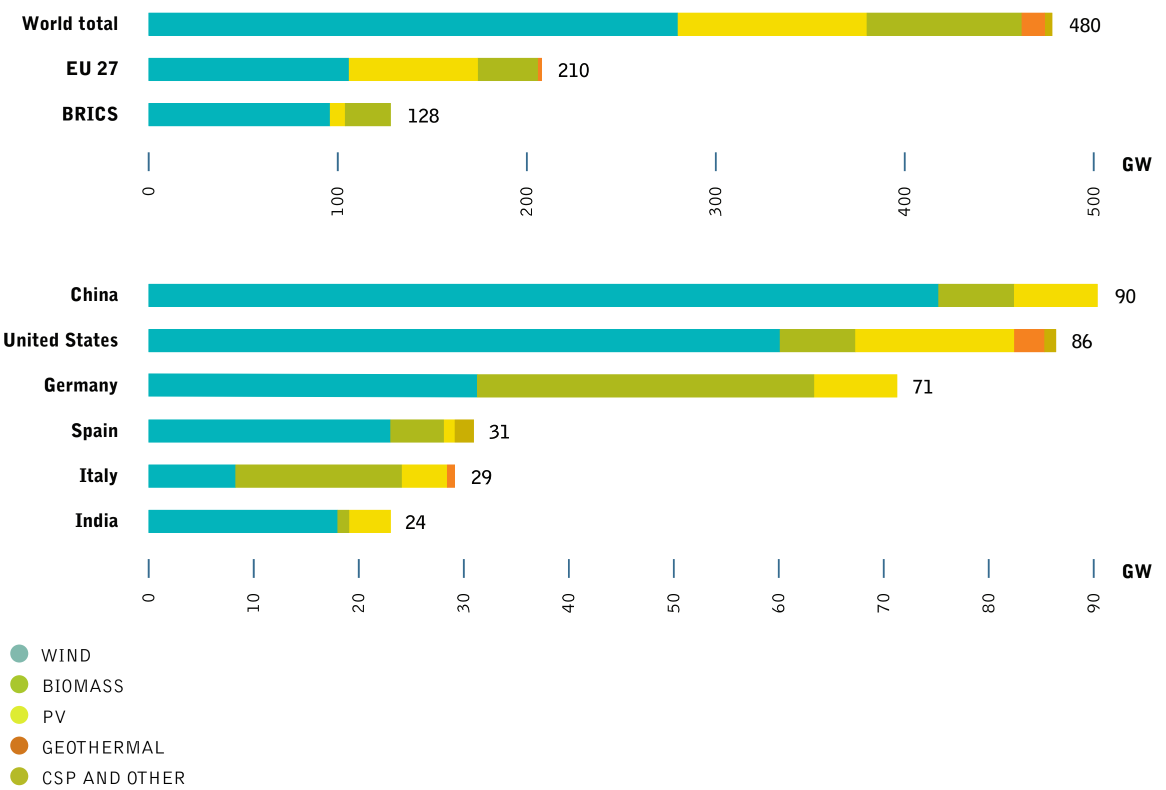
b HYDROPOWER DATA DO NOT INCLUDE PUMPED STORAGE-CAPACITY. FOR MORE INFORMATION, SEE NOTE ON REPORTING AND ACCOUNT ON PAGE XX.

c SOLAR HOT WATER CAPACITY DATA INCLUDE GLAZED WATER COLLECTORS ONLY.

d BIOFUEL POLICIES INCLUDE POLICES LISTED BOTH UNDER THE BIOFUELS OBLIGATION/MANDATE COLUMN IN TABLE 3 (RENEWABLE ENERGY SUPPORT POLICIES) AND IN REFERENCE TABLE R15 (NATIONAL AND STATE/PROVINCIAL BIOFUEL BLEND MANDATES).

NOTE NUMBERS ARE ROUNDED. RENEWABLE POWER CAPACITY (INCLUDING AND NOT INCLUDING HYDROPOWER) AND HYDROPOWER CAPACITY DATA ARE ROUNDED TO NEAREST 5 GW; OTHER CAPACITY NUMBERS ARE ROUNDED TO NEAREST 1 GW EXCEPT FOR VERY SMALL NUMBERS AND BIOFUELS, WHICH ARE ROUNDED TO ONE DECIMAL POINT.

figure 7.7: renewable power capacities in world, eu 27, BRICS, and top six countries, 2012 NOT INCLUDING HYDROPOWER



source REN2.

glossary & appendix

GLOSSARY OF COMMONLY USED TERMS AND ABBREVIATIONS

DEFINITION OF SECTORS

ASEAN: SCENARIO RESULTS DATA

> "because we use such inefficient lighting, 80 coal fired power plants are running day and night to produce the energy that is wasted."

© LUIS LIWANAG / GREENPEACE)

image WIND TURBINES ALONG THE COASTLINE OF BANGUI, ILOCOS NORTE, IN THE NORTHERN PART OF THE PHILIPPINES.

8.1 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 (Kilojoule) = 1,000 Joules
MJ (Megajoule) = 1 million Joules
GJ (Gigajoule) = 1 billion Joules
PJ (Petajoule) = 10^{15} Joules
EJ (Exajoule) = 10^{18} Joules

W Watt, measure of electrical capacity:
kW (Kilowatt) = 1,000 watts
MW (Megawatt) = 1 million watts
GW (Gigawatt) = 1 billion watts
TW (Terawatt) = 1^{12} watts

kWh Kilowatt-hour, measure of electrical output:
kWh (Kilowatt-hour) = 1,000 watt-hours
TWh (Terawatt-hour) = 10^{12} watt-hours

t Tonnes, measure of weight:
t = 1 tonne
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

8.2 definition of sectors

The definition of different sectors follows the sectorial break down of the IEA World Energy Outlook series.

All definitions below are from the IEA Key World Energy Statistics.

Industry sector: Consumption in the industry sector includes the following subsectors (energy used for transport by industry is not included -> see under "Transport")

- Iron and steel industry
- Chemical industry
- Non-metallic mineral products e.g. glass, ceramic, cement etc.
- Transport equipment
- Machinery
- Mining
- Food and tobacco
- Paper, pulp and print
- Wood and wood products (other than pulp and paper)
- Construction
- Textile and Leather

Transport sector: The Transport sector includes all fuels from transport such as road, railway, aviation, domestic navigation. Fuel used for ocean, coastal 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.

ASEAN: scenario results data

image THE ABBOT OF THONGCHAI THAMMACHAK TEMPLE AT THE CEREMONY FOR THE HAND-OVER OF A SOLAR INSTALLATION OF 2 KILOWATTS PROVIDED BY GREENPEACE.

ASEAN: reference scenario

table 8.3: ASEAN: electricity generation

TWh/a	2010	2015	2020	2030	2040	2050
Power plants	**675**	**830**	**1,076**	**1,574**	**2,248**	**3,052**
Coal	97	184	330	447	866	1,418
Lignite	88	92	93	98	102	107
Gas	334	371	427	540	625	756
of which from H_2	0	0	0	0	0	0
Oil	31	30	30	23	19	16
Diesel	29	28	25	19	13	7
Nuclear	0	0	8	172	203	222
Biomass	5	10	18	37	63	80
Hydro	70	73	81	129	199	242
Wind	0	15	30	60	90	120
including offshore	0	0	0	4	14	24
PV	0	2	4	10	18	25
Geothermal	19	24	29	39	49	60
Solar thermal power plants	0	0	0	0	0	0
Ocean energy	0	0	0	0	0	0
Combined heat & power plants	**1**	**1**	**1**	**1**	**2**	**3**
Coal	0	0	0	0	0	0
Lignite	0	0	0	0	0	0
Gas	0	1	1	1	2	2
of which from H_2	0	0	0	0	0	0
Oil	0	0	0	0	0	0
Biomass	0	0	0	0	0	0
Geothermal	0	0	0	0	0	0
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	0	0	0	0	0	0
Autoproducers	1	1	1	1	2	3
Total generation	**676**	**831**	**1,076**	**1,575**	**2,249**	**3,055**
Fossil	581	706	906	1,128	1,627	2,306
Coal	97	184	330	447	866	1,418
Lignite	88	92	93	98	102	107
Gas	335	372	428	541	627	758
Oil	31	30	30	23	19	16
Diesel	29	28	25	19	13	7
Nuclear	0	0	8	172	203	222
Hydrogen	0	0	0	0	0	0
Renewables	**95**	**125**	**162**	**275**	**419**	**527**
Hydro	70	73	81	129	199	242
Wind	0	15	30	60	90	120
PV	0	2	4	10	18	25
Biomass (& renewable waste)	5	10	18	37	63	80
Geothermal	19	24	29	39	49	60
Solar thermal	0	0	0	0	0	0
Ocean energy	0	0	0	0	0	0
Distribution losses	57	68	87	121	164	207
Own consumption electricity	26	32	43	65	96	133
Electricity for hydrogen production	0	0	0	0	0	0
Final energy consumption (electricity)	**605**	**745**	**967**	**1,418**	**2,030**	**2,770**
Fluctuating RES (PV, Wind, Ocean)	0	17	34	70	108	145
Share of fluctuating RES	0%	2%	3.2%	4.4%	4.8%	4.7%
RES share (domestic generation)	**14.1%**	**15.0%**	**15.1%**	**17.5%**	**18.6%**	**17.3%**

table 8.4: ASEAN: energy supply for heating and cooling

PJ/a	2010	2015	2020	2030	2040	2050
District heating	**0**	**0**	**0**	**0**	**0**	**0**
Fossil fuels	0	0	0	0	0	0
Biomass	0	0	0	0	0	0
Solar collectors	0	0	0	0	0	0
Geothermal	0	0	0	0	0	0
Heat from CHP	**0**	**2**	**4**	**6**	**8**	**11**
Fossil fuels	0	2	4	5	8	10
Biomass	0	0	0	0	0	1
Geothermal	0	0	0	0	0	0
Hydrogen	0	0	0	0	0	0
Direct heating and cooling	**6,921**	**7,837**	**9,011**	**10,144**	**11,254**	**12,080**
Fossil fuels	3,615	4,518	5,466	6,492	7,284	7,668
Biomass	3,224	3,167	3,292	3,156	3,095	2,944
Solar collectors	0	13	22	45	73	101
Geothermal	0	0	0	0	0	0
Heat pumps[1)]	0	3	5	8	13	14
Electric direct heating[2)]	82	136	226	442	789	1,355
Hydrogen	0	0	0	0	0	0
Total energy supply for heating and cooling	**6,921**	**7,839**	**9,015**	**10,150**	**11,262**	**12,091**
Fossil fuels	3,615	4,520	5,469	6,497	7,292	7,678
Biomass	3,224	3,167	3,292	3,156	3,095	2,945
Solar collectors	0	13	22	45	73	101
Geothermal	0	0	0	0	0	0
Heat pumps[1)]	0	3	5	8	13	14
Electric direct heating[2)]	82	136	226	442	789	1,355
Hydrogen	0	0	0	0	0	0
RES share (including RES electricity)	**46.7%**	**40.9%**	**37.2%**	**32.4%**	**29.6%**	**27.3%**

1) heat from ambient energy and electricity use; 2) heat from direct electric heating

table 8.5: ASEAN: CO_2 emissions

MILL t/a	2010	2015	2020	2030	2040	2050
Condensation power plants	**411**	**499**	**643**	**774**	**1,146**	**1,485**
Hard Coal (incl. non-renewable waste)	100	176	300	387	725	1,055
Lignite	110	105	100	101	104	109
Gas	154	174	200	253	293	305
Oil	22	23	24	18	14	12
Diesel	24	21	19	14	10	5
Combined heat & power production	**0**	**0**	**1**	**1**	**1**	**1**
Hard Coal (incl. non-renewable waste)	0	0	0	0	0	0
Lignite	0	0	0	0	0	0
Gas	0	0	1	1	1	1
Oil	0	0	0	0	0	0
CO_2 emissions power and CHP plants	**411**	**500**	**644**	**775**	**1,147**	**1,487**
Hard Coal (incl. non-renewable waste)	100	176	300	387	725	1,055
Lignite	110	105	100	101	104	109
Gas	155	174	200	254	294	306
Oil & diesel	46	44	43	32	24	17
CO_2 emissions by sector	**1,164**	**1,384**	**1,650**	**1,928**	**2,419**	**2,846**
% of 1990 emissions	292%	347%	413%	483%	606%	713%
Industry[1)]	273	332	387	438	467	479
Other sectors[1)]	84	96	110	124	128	120
Transport	287	338	381	461	554	654
Power generation[2)]	411	499	643	774	1,146	1,485
District heating & other conversion[3)]	110	119	129	131	124	107
Population (Mill.)	592	625	654	704	738	756
CO_2 emissions per capita (t/capita)	**2.0**	**2.2**	**2.5**	**2.7**	**3.3**	**3.8**

1) including CHP autoproducers. 2) including CHP public 3) district heating, refineries, coal transformation, gas transport

table 8.6: ASEAN: installed capacity

GW	2010	2015	2020	2030	2040	2050
Power plants	**152**	**199**	**256**	**358**	**488**	**636**
Coal	17	30	52	69	133	218
Lignite	15	15	14	15	16	17
Gas	71	91	112	143	165	199
Oil	12	13	13	10	8	6
Diesel	11	12	10	8	5	3
Nuclear	0	0	1	22	26	28
Biomass	1	3	4	7	11	15
Hydro	21	23	27	43	64	73
Wind	0	8	15	28	40	50
of which wind offshore	0	0	0	1	4	7
PV	0	2	3	7	13	18
Geothermal	3	4	4	6	7	9
Solar thermal power plants	0	0	0	0	0	0
Ocean energy	0	0	0	0	0	0
Combined heat & power production	**0**	**0**	**0**	**0**	**0**	**1**
Coal	0	0	0	0	0	0
Lignite	0	0	0	0	0	0
Gas (incl. H_2)	0	0	0	0	0	1
Oil	0	0	0	0	0	0
Biomass	0	0	0	0	0	0
Geothermal	0	0	0	0	0	0
Hydrogen (fuel cells)	0	0	0	0	0	0
CHP by producer						
Main activity producers	0	0	0	0	0	0
Autoproducers	0	0	0	0	0	1
Total generation	**152**	**199**	**256**	**359**	**488**	**637**
Fossil	127	160	202	245	327	444
Coal	17	30	52	69	133	218
Lignite	15	15	14	15	16	17
Gas	71	92	113	144	165	200
Oil	12	13	13	10	8	6
Diesel	11	12	10	8	5	3
Nuclear	0	0	1	22	26	28
Hydrogen (fuel cells, gas power plants, gas CHP)	0	0	0	0	0	0
Renewables	**25**	**39**	**53**	**91**	**135**	**165**
Hydro	21	23	27	43	64	73
Wind	0	8	15	28	40	50
PV	0	2	3	7	13	18
Biomass	1	3	4	7	11	15
Geothermal	3	4	4	6	7	9
Solar thermal	0	0	0	0	0	0
Ocean energy	0	0	0	0	0	0
Fluctuating RES (PV, Wind, Ocean)	0	9	18	35	52	68
Share of fluctuating RES	0.2%	4.6%	7.0%	9.9%	10.7%	10.7%
RES share (domestic generation)	**16.7%**	**19.5%**	**20.8%**	**25.5%**	**27.7%**	**25.9%**

table 8.7: ASEAN: primary energy demand

PJ/a	2010	2015	2020	2030	2040	2050
Total	**23,227**	**26,123**	**30,342**	**36,686**	**43,742**	**49,621**
Fossil	**17,022**	**19,780**	**23,363**	**27,443**	**33,686**	**38,887**
Hard coal	1,945	2,932	4,302	5,144	8,469	11,816
Lignite	1,630	1,628	1,596	1,702	1,715	1,712
Natural gas	5,114	5,420	6,683	8,583	10,063	10,764
Crude oil	8,333	9,800	10,783	12,015	13,439	14,594
Nuclear	**0**	**0**	**84**	**1,871**	**2,215**	**2,422**
Renewables	**6,205**	**6,343**	**6,894**	**7,372**	**7,841**	**8,313**
Hydro	253	263	292	464	716	871
Wind	0	54	108	216	324	432
Solar	0	20	37	81	138	191
Biomass	4,921	5,193	5,630	5,720	5,667	5,728
Geothermal/ambient heat	1,031	813	828	890	995	1,090
Ocean energy	0	0	0	0	0	0
RES share	**26.7%**	**24.3%**	**22.7%**	**20.1%**	**17.9%**	**16.7%**

table 8.8: ASEAN: final energy demand

PJ/a	2010	2015	2020	2030	2040	2050
Total (incl. non-energy use)	**16,795**	**19,240**	**22,050**	**26,057**	**30,203**	**34,456**
Total (energy use)	**14,819**	**17,228**	**19,963**	**23,751**	**27,733**	**31,875**
Transport	**3,891**	**4,635**	**5,314**	**6,602**	**8,099**	**9,788**
Oil products	3,769	4,416	4,943	5,926	7,094	8,350
Natural gas	78	123	189	299	383	497
Biofuels	37	84	168	354	572	848
Electricity	8	11	14	23	50	93
RES electricity	1	2	2	4	9	16
Hydrogen	0	0	0	0	0	0
RES share Transport	**1.0%**	**1.9%**	**3.2%**	**5.4%**	**7.2%**	**8.8%**
Industry	**5,035**	**6,169**	**7,430**	**8,826**	**10,176**	**11,353**
Electricity	902	1,128	1,423	1,882	2,441	3,088
RES electricity	127	169	214	329	455	533
District heat	0	2	3	4	6	7
RES district heat	0	0	0	0	0	0
Hard coal + lignite	1,431	1,598	1,635	1,624	1,314	1,071
Oil products	1,076	1,193	1,430	1,607	1,918	2,094
Gas	845	1,456	2,063	2,733	3,347	3,756
Solar	0	0	0	0	0	0
Biomass and waste	781	792	876	975	1,150	1,337
Geothermal	0	0	0	0	0	0
Hydrogen	0	0	0	0	0	0
RES share Industry	**18.0%**	**15.6%**	**14.7%**	**14.8%**	**15.8%**	**16.5%**
Other Sectors	**5,893**	**6,424**	**7,219**	**8,323**	**9,458**	**10,734**
Electricity	1,269	1,544	2,043	3,199	4,816	6,791
RES electricity	178	232	308	559	898	1,172
District heat	0	0	1	1	3	4
RES district heat	0	0	0	0	0	0
Hard coal + lignite	67	105	111	122	121	111
Oil products	1,021	1,112	1,251	1,309	1,258	1,075
Gas	15	43	91	232	375	475
Solar	0	13	22	45	73	101
Biomass	3,522	3,606	3,695	3,408	2,803	2,166
Geothermal	0	2	3	6	10	10
Hydrogen	0	0	0	0	0	0
RES share Other Sectors	**62.8%**	**60.0%**	**55.8%**	**48.3%**	**40.0%**	**32.1%**
Total RES	**4,646**	**4,901**	**5,290**	**5,681**	**5,971**	**6,182**
RES share	**31.4%**	**28.4%**	**26.5%**	**23.9%**	**21.5%**	**19.4%**
Non energy use	**1,976**	**2,011**	**2,087**	**2,306**	**2,469**	**2,581**
Oil	1,694	1,721	1,775	1,939	2,051	2,098
Gas	278	282	303	357	407	471
Coal	4	9	9	10	11	12

ASEAN: energy [r]evolution scenario

table 8.9: ASEAN: electricity generation

TWh/a	2010	2015	2020	2030	2040	2050
Power plants	**675**	**819**	**969**	**1,470**	**2,172**	**3,015**
Coal	97	102	85	43	0	0
Lignite	88	77	51	0	0	0
Gas	334	457	512	537	417	215
of which from H_2	0	0	0	0	8	54
Oil	31	25	11	4	0	0
Diesel	29	28	25	4	1	1
Nuclear	0	0	0	0	0	0
Biomass	5	5	6	24	73	133
Hydro	70	70	70	70	72	76
Wind	0	30	154	450	784	1,257
including offshore	0	0	0	45	246	641
PV	0	5	28	235	539	761
Geothermal	19	20	25	78	186	352
Solar thermal power plants	0	0	1	8	24	40
Ocean energy	0	0	0	18	76	182
Combined heat & power plants	**1**	**2**	**5**	**15**	**24**	**30**
Coal	0	0	0	0	0	0
Lignite	0	0	0	0	0	0
Gas	0	1	2	8	12	15
of which from H_2	0	0	0	0	1	2
Oil	0	0	0	0	0	0
Biomass	0	1	2	6	10	11
Geothermal	0	0	0	0	1	2
Hydrogen	0	0	0	0	1	2
CHP by producer						
Main activity producers	0	0	0	0	0	0
Autoproducers	1	2	5	15	24	30
Total generation	**676**	**822**	**974**	**1,485**	**2,196**	**3,045**
Fossil	581	690	687	596	421	175
Coal	97	102	85	43	0	0
Lignite	88	77	51	0	0	0
Gas	335	458	514	545	421	174
Oil	31	25	11	4	0	0
Diesel	29	28	25	4	1	1
Nuclear	0	0	0	0	0	0
Hydrogen	0	0	0	1	10	58
Renewables	**95**	**132**	**287**	**889**	**1,764**	**2,813**
Hydro	70	70	70	70	72	76
Wind	0	30	154	450	784	1,257
PV	0	5	28	235	539	761
Biomass (& renewable waste)	5	6	8	31	83	144
Geothermal	19	20	25	78	187	353
Solar thermal	0	0	1	8	24	40
Ocean energy	0	0	0	18	76	182
Distribution losses	57	57	63	75	83	93
Own consumption electricity	26	38	46	60	74	94
Electricity for hydrogen production	0	0	5	62	256	612
Final energy consumption (electricity)	**605**	**743**	**879**	**1,311**	**1,813**	**2,275**
Fluctuating RES (PV, Wind, Ocean)	0	35	182	703	1,399	2,199
Share of fluctuating RES	0%	4.3%	18.7%	47.3%	63.7%	72.2%
RES share (domestic generation)	**14.1%**	**16.0%**	**29.5%**	**59.9%**	**80.3%**	**92.4%**
'Efficiency' savings (compared to Ref.)	**0**	**5**	**113**	**229**	**437**	**804**

table 8.10: ASEAN: energy supply for heating and cooling

PJ/a	2010	2015	2020	2030	2040	2050
District heating	**0**	**0**	**0**	**0**	**0**	**0**
Fossil fuels	0	0	0	0	0	0
Biomass	0	0	0	0	0	0
Solar collectors	0	0	0	0	0	0
Geothermal	0	0	0	0	0	0
Heat from CHP	**0**	**11**	**24**	**82**	**136**	**169**
Fossil fuels	0	4	9	29	46	52
Biomass	0	7	15	48	73	81
Geothermal	0	0	0	3	8	15
Hydrogen	0	0	0	3	9	21
Direct heating and cooling	**6,921**	**7,608**	**8,358**	**8,609**	**8,718**	**8,548**
Fossil fuels	3,615	4,033	4,365	3,852	2,948	1,697
Biomass	3,224	3,213	3,171	2,701	2,031	1,357
Solar collectors	0	161	450	981	1,644	2,271
Geothermal	0	19	66	165	292	383
Heat pumps[1]	0	27	60	125	217	315
Electricit direct heating[2]	82	155	246	750	1,494	2,274
Hydrogen	0	0	0	34	93	251
Total energy supply for heating and cooling	**6,921**	**7,619**	**8,383**	**8,691**	**8,854**	**8,717**
Fossil fuels	3,615	4,036	4,374	3,881	2,994	1,749
Biomass	3,224	3,220	3,186	2,749	2,104	1,438
Solar collectors	0	161	450	981	1,644	2,271
Geothermal	0	19	67	168	300	398
Heat pumps[1]	0	27	60	125	217	315
Electricit direct heating[2]	82	155	246	750	1,494	2,274
Hydrogen	0	0	0	37	101	272
RES share (including RES electricity)	**46.7%**	**45.4%**	**45.9%**	**51.9%**	**62.8%**	**77.8%**
'Efficiency' savings (compared to Ref.)	**0**	**220**	**632**	**1,459**	**2,408**	**3,374**

1) heat from ambient energy and electricity use; 2) heat from direct electric heating

table 8.11: ASEAN: CO_2 emissions

MILL t/a	2010	2015	2020	2030	2040	2050
Condensation power plants	**411**	**440**	**400**	**295**	**192**	**65**
Hard Coal (incl. non-renewable waste)	100	98	77	37	0	0
Lignite	110	88	55	0	0	0
Gas	154	214	239	252	192	65
Oil	22	19	9	3	0	0
Diesel	24	21	19	3	1	0
Combined heat & power production	**0**	**1**	**1**	**4**	**6**	**7**
Hard Coal (incl. non-renewable waste)	0	0	0	0	0	0
Lignite	0	0	0	0	0	0
Gas	0	1	1	4	6	7
Oil	0	0	0	0	0	0
CO_2 emissions power and CHP plants	**411**	**441**	**401**	**299**	**199**	**72**
Hard Coal (incl. non-renewable waste)	100	98	77	37	0	0
Lignite	110	88	55	0	0	0
Gas	155	215	240	256	198	72
Oil & diesel	46	41	28	6	1	0
CO_2 emissions by sector	**1,164**	**1,254**	**1,232**	**975**	**641**	**296**
% of 1990 emissions	292%	314%	309%	244%	161%	74.3%
Industry[1]	273	299	313	260	172	93
Other sectors[1]	84	89	89	69	52	21
Transport	287	308	314	261	170	95
Power generation[2]	411	440	400	295	192	65
District heating & other conversion[3]	110	117	116	90	55	22
Population (Mill.)	592	625	654	704	738	756
CO_2 emissions per capita (t/capita)	**2.0**	**2.0**	**1.9**	**1.4**	**0.9**	**0.4**
'Efficiency' savings (compared to Ref.)	**0**	**130**	**418**	**953**	**1,777**	**2,549**

1) including CHP autoproducers. 2) including CHP public 3) district heating, refineries, coal transformation, gas transport

table 8.12: ASEAN: installed capacity

GW	2010	2015	2020	2030	2040	2050
Power plants	**152**	**195**	**286**	**621**	**1,031**	**1,413**
Coal	17	17	13	7	0	0
Lignite	15	12	8	0	0	0
Gas	71	98	123	185	226	231
Oil	12	10	5	2	0	0
Diesel	11	12	10	2	0	0
Nuclear	0	0	0	0	0	0
Biomass	1	1	1	5	21	48
Hydro	21	22	23	23	23	23
Wind	0	15	76	208	325	463
of which wind offshore	0	0	0	15	75	183
PV	0	4	22	171	385	544
Geothermal	3	3	4	12	28	53
Solar thermal power plants	0	0	0	2	6	10
Ocean energy	0	0	0	4	17	41
Combined heat & power production	**0**	**1**	**1**	**3**	**5**	**7**
Coal	0	0	0	0	0	0
Lignite	0	0	0	0	0	0
Gas (incl. H_2)	0	0	1	2	3	4
Oil	0	0	0	0	0	0
Biomass	0	0	0	1	2	2
Geothermal	0	0	0	0	0	0
Hydrogen (fuel cells)	0	0	0	0	0	1
CHP by producer						
Main activity producers	0	0	0	0	0	0
Autoproducers	0	1	1	3	5	7
Total generation	**152**	**195**	**287**	**625**	**1,037**	**1,420**
Fossil	127	150	160	197	224	177
Coal	17	17	13	7	0	0
Lignite	15	12	8	0	0	0
Gas	71	99	124	187	224	176
Oil	12	10	5	2	0	0
Diesel	11	12	10	2	0	0
Nuclear	0	0	0	0	0	0
Hydrogen (fuel cells, gas power plants, gas CHP)	0	0	0	0	5	59
Renewables	**25**	**45**	**126**	**427**	**807**	**1,184**
Hydro	21	22	23	23	23	23
Wind	0	15	76	208	325	463
PV	0	4	22	171	385	544
Biomass	1	1	2	7	23	50
Geothermal	3	3	4	12	28	53
Solar thermal	0	0	0	2	6	10
Ocean energy	0	0	0	4	17	41
Fluctuating RES (PV, Wind, Ocean)	0	19	97	384	728	1,049
Share of fluctuating RES	0.2%	9.7%	34.0%	61.4%	70.2%	73.9%
RES share (domestic generation)	**16.7%**	**23.3%**	**44.1%**	**68.4%**	**77.9%**	**83.4%**

table 8.13: ASEAN: primary energy demand

PJ/a	2010	2015	2020	2030	2040	2050
Total	**23,227**	**24,696**	**25,873**	**26,618**	**27,221**	**28,302**
Fossil	**17,022**	**18,341**	**18,506**	**15,779**	**11,389**	**6,211**
Hard coal	1,945	2,063	1,853	1,228	678	627
Lignite	1,630	1,412	1,040	285	0	0
Natural gas	5,114	5,864	6,833	7,326	6,237	3,707
Crude oil	8,333	9,003	8,779	6,941	4,474	1,876
Nuclear	**0**	**0**	**0**	**0**	**0**	**0**
Renewables	**6,205**	**6,355**	**7,367**	**10,839**	**15,832**	**22,091**
Hydro	253	252	252	252	259	274
Wind	0	108	555	1,620	2,823	4,526
Solar	0	180	555	1,855	3,669	5,153
Biomass	4,921	5,110	5,185	5,043	4,627	4,506
Geothermal/ambient heat	1,031	705	820	2,006	4,180	6,977
Ocean energy	0	0	0	63	274	655
RES share	**26.7%**	**25.8%**	**28.6%**	**40.9%**	**58.3%**	**78.1%**
'Efficiency' savings (compared to Ref.)	**0**	**1,428**	**4,469**	**10,068**	**16,521**	**21,319**

table 8.14: ASEAN: final energy demand

PJ/a	2010	2015	2020	2030	2040	2050
Total (incl. non-energy use)	**16,795**	**18,396**	**19,730**	**20,405**	**20,119**	**19,738**
Total (energy use)	**14,819**	**16,485**	**17,852**	**18,560**	**18,391**	**18,190**
Transport	**3,891**	**4,238**	**4,540**	**4,663**	**4,435**	**4,411**
Oil products	3,769	4,017	4,085	3,326	2,029	850
Natural gas	78	120	136	212	314	561
Biofuels	37	77	200	549	764	846
Electricity	8	24	106	461	843	1,202
RES electricity	1	4	31	276	677	1,110
Hydrogen	0	0	13	115	485	953
RES share Transport	**1.0%**	**1.9%**	**5.2%**	**19.2%**	**41.3%**	**64.3%**
Industry	**5,035**	**5,852**	**6,623**	**6,826**	**6,654**	**6,296**
Electricity	902	1,090	1,297	1,592	1,906	2,216
RES electricity	127	174	382	953	1,531	2,046
District heat	0	1	1	9	24	40
RES district heat	0	0	0	0	0	0
Hard coal + lignite	1,431	1,557	1,464	934	284	0
Oil products	1,076	1,081	1,061	821	481	60
Gas	845	1,111	1,561	1,882	1,922	1,534
Solar	0	68	155	335	589	766
Biomass and waste	781	913	985	982	930	854
Geothermal	0	33	97	233	417	562
Hydrogen	0	0	0	38	100	264
RES share Industry	**18.0%**	**20.3%**	**24.5%**	**37.0%**	**53.3%**	**71.0%**
Other Sectors	**5,893**	**6,394**	**6,690**	**7,071**	**7,302**	**7,483**
Electricity	1,269	1,562	1,761	2,666	3,777	4,771
RES electricity	178	250	519	1,596	3,035	4,407
District heat	0	10	23	73	112	129
RES district heat	0	0	0	0	0	0
Hard coal + lignite	67	44	28	0	0	0
Oil products	1,021	1,108	1,117	833	550	92
Gas	15	22	36	61	111	168
Solar	0	94	295	646	1,054	1,505
Biomass	3,522	3,550	3,420	2,769	1,663	761
Geothermal	0	5	11	22	34	56
Hydrogen	0	0	0	0	0	0
RES share Other Sectors	**62.8%**	**61.0%**	**63.4%**	**71.2%**	**79.2%**	**89.9%**
Total RES	**4,646**	**5,167**	**6,099**	**8,453**	**11,167**	**14,038**
RES share	**31.4%**	**31.3%**	**34.2%**	**45.5%**	**60.7%**	**77.2%**
Non energy use	**1,976**	**1,911**	**1,878**	**1,845**	**1,729**	**1,548**
Oil	1,694	1,548	1,484	1,439	1,175	805
Gas	278	344	338	240	173	124
Coal	4	19	56	166	380	619

ASEAN: investment & employment

table 8.15: ASEAN: total investment in power sector

MILLION US$	2011-2020	2021-2030	2031-2040	2041-2050	2011-2050	2011-2050 AVERAGE PER YEAR
Reference scenario						
Conventional (fossil & nuclear)	**94,820**	**165,566**	**138,371**	**172,573**	**571,329**	**14,283**
Renewables	**71,433**	**92,977**	**134,227**	**97,283**	**395,920**	**9,898**
Biomass	8,690	7,290	16,732	12,998	45,709	1,143
Hydro	22,297	52,519	68,040	35,389	178,245	4,456
Wind	15,654	14,233	27,394	26,349	83,629	2,091
PV	4,137	3,765	6,954	7,015	21,871	547
Geothermal	20,655	15,170	15,107	15,533	66,465	1,662
Solar thermal power plants	0	0	0	0	0	0
Ocean energy	0	0	0	0	0	0
Energy [R]evolution						
Conventional (fossil & nuclear)	**51,308**	**49,398**	**57,069**	**43,049**	**200,824**	**5,021**
Renewables	**134,366**	**359,004**	**574,840**	**796,894**	**1,865,104**	**46,628**
Biomass	1,445	10,277	33,468	63,159	108,349	2,709
Hydro	12,846	8,784	8,121	8,309	38,060	952
Wind	78,810	142,245	229,190	336,661	786,907	19,673
PV	24,989	133,817	189,608	234,475	582,891	14,572
Geothermal	14,455	48,977	77,077	101,974	242,484	6,062
Solar thermal power plants	1,820	7,139	16,749	18,876	44,584	1,115
Ocean energy	0	7,765	20,626	33,439	61,831	1,546

table 8.16: ASEAN: total investment in renewable heating only

(EXCLUDING INVESTMENTS IN FOSSIL FUELS)

MILLION US$	2011-2020	2021-2030	2031-2040	2041-2050	2011-2050	2011-2050 AVERAGE PER YEAR
Reference scenario						
Renewables	**252,941**	**25,844**	**23,938**	**20,957**	**323,680**	**8,092**
Biomass	245,795	19,718	11,004	10,985	287,502	7,188
Geothermal	0	0	0	0	0	0
Solar	5,801	5,182	10,571	9,068	30,621	766
Heat pumps	1,345	945	2,363	905	5,557	139
Energy [R]evolution scenario						
Renewables	**271,086**	**153,548**	**272,456**	**253,043**	**950,133**	**23,753**
Biomass	137,172	9,538	0	0	146,710	3,668
Geothermal	12,047	16,311	28,631	24,647	81,635	2,041
Solar	111,454	117,171	221,504	204,435	654,563	16,364
Heat pumps	10,414	10,528	22,321	23,961	67,224	1,681

table 8.17: ASEAN: total employment

THOUSAND JOBS		REFERENCE			ENERGY [R]EVOLUTION		
	2010	2015	2020	2030	2015	2020	2030
By sector							
Construction and installation	113	162	115	158	97	168	215
Manufacturing	49	66	49	64	54	82	87
Operations and maintenance	62	75	87	103	68	93	147
Fuel supply (domestic)	885	748	725	563	765	698	478
Coal and gas export	19	24	30	34	10.6	1.7	0.6
Solar and geothermal heat	-	12	7.4	5.6	371	243	158
Total jobs	**1,128**	**1,088**	**1,013**	**928**	**1,366**	**1,287**	**1,085**
By technology							
Coal	136	181	87	216	33	18	7
Gas, oil & diesel	427	373	380	313	404	406	295
Nuclear	4.7	26	76	23	-	-	-
Total renewables	**560**	**508**	**471**	**377**	**929**	**862**	**782**
Biomass	518	434	396	289	414	356	271
Hydro	28	33	39	59	22	17	14
Wind	4.7	16	17	15	81	125	133
PV	1.8	6.3	7.0	6.3	34	111	189
Geothermal power	6.7	6.3	4.7	1.9	5.9	5.7	10.9
Solar thermal power	-	-	-	-	0.9	1.5	3.5
Ocean	-	-	-	-	-	1.9	3.9
Solar - heat	-	12	6.9	5.4	352	232	149
Geothermal & heat pump	-	0.9	0.5	0.3	19	12	9.2
Total jobs	**1,128**	**1,088**	**1,013**	**928**	**1,366**	**1,286**	**1,085**

note
numbers may not add up due to rounding

ASEAN: transport

table 8.18: ASEAN: final energy consumption transport in

PJ/a	2010	2015	2020	2030	2040	2050
Reference scenario						
Road	**3,631**	**4,349**	**4,998**	**6,202**	**7,568**	**9,052**
Fossil fuels	3,517	4,139	4,637	5,539	6,579	7,632
Liquid biofuels	37	84	168	354	572	848
Natural gas	78	123	189	299	383	497
Hydrogen	0	0	0	0	0	0
Electricity	0	2	4	10	34	75
Rail	**20**	**23**	**24**	**28**	**31**	**34**
Fossil fuels	12	14	14	15	15	16
Biofuels	0	0	0	0	0	0
Electricity	8	8	9	13	16	18
Navigation	**121**	**124**	**128**	**145**	**177**	**209**
Fossil fuels	121	124	128	145	177	209
Biofuels	0	0	0	0	0	0
Aviation	**120**	**139**	**164**	**227**	**323**	**493**
Fossil fuels	120	139	164	227	323	493
Biofuels	0	0	0	0	0	0
Total	**3,891**	**4,635**	**5,314**	**6,602**	**8,099**	**9,788**
Fossil fuels	3,769	4,416	4,943	5,926	7,094	8,350
Biofuels (incl. biogas)	37	84	168	354	572	848
Natural gas	78	123	189	299	383	497
Hydrogen	0	0	0	0	0	0
Electricity	8	11	14	23	50	93
Total RES	**38**	**86**	**172**	**367**	**612**	**934**
RES share	**1.0%**	**1.9%**	**3.2%**	**5.4%**	**7.2%**	**8.8%**
Energy [R]evolution						
Road	**3,631**	**3,939**	**4,193**	**4,240**	**3,920**	**3,742**
Fossil fuels	3,517	3,730	3,755	2,951	1,666	540
Liquid biofuels	37	76	198	520	644	540
Natural gas	78	120	136	212	314	561
Hydrogen	0	0	13	115	485	953
Electricity	0	13	92	441	811	1,148
Rail	**20**	**29**	**32**	**38**	**47**	**59**
Fossil fuels	12	17	18	17	13	5
Biofuels	0	1	0	2	3	1
Electricity	8	11	14	19	31	53
Navigation	**121**	**127**	**146**	**159**	**155**	**140**
Fossil fuels	121	127	144	147	116	70
Biofuels	0	0	1	12	40	70
Aviation	**120**	**143**	**169**	**227**	**312**	**471**
Fossil fuels	120	143	168	211	234	235
Biofuels	0	0	1	16	78	235
Total	**3,891**	**4,238**	**4,540**	**4,663**	**4,435**	**4,411**
Fossil fuels	3,769	4,017	4,085	3,326	2,029	850
Biofuels (incl. biogas)	37	77	200	549	764	846
Natural gas	78	120	136	212	314	561
Hydrogen	0	0	13	115	485	953
Electricity	8	24	106	461	843	1,202
Total RES	**38**	**81**	**235**	**894**	**1,831**	**2,836**
RES share	**1.0%**	**1.9%**	**5.2%**	**19.2%**	**41.3%**	**64.3%**

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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GWEC

The Global Wind Energy Council (GWEC) is the voice of the global wind energy sector. GWEC works at highest international political level to create better policy environment for wind power. GWEC's mission is to ensure that wind power established itself as the answer to today's energy challenges, producing substantial environmental and economic benefits. GWEC is a member based organisation that represents the entire wind energy sector. The members of GWEC represent over 1,500 companies, organisations and institutions in more than 70 countries, including manufacturers, developers, component suppliers, research institutes, national wind and renewables associations, electricity providers, finance and insurance companies.

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