energy

[r]evolution

A SUSTAINABLE USA ENERGY OUTLOOK

GREENPEACE

GWEC
GLOBAL WIND ENERGY COUNCIL

report 3rd edition 2014 USA energy scenario

partners

Greenpeace International, European Renewable Energy Council (EREC)

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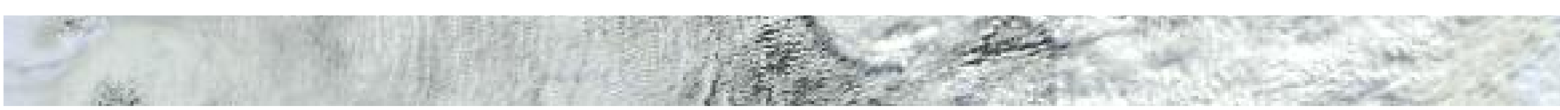

image AS HURRICANE SANDY MOVED NORTH ALONG THE EAST COAST OF THE UNITED STATES, ITS WAVES CHURNED UP SEDIMENTS FROM THE CONTINENTAL SHELF AND LEFT TURBID WATER IN ITS WAKE.

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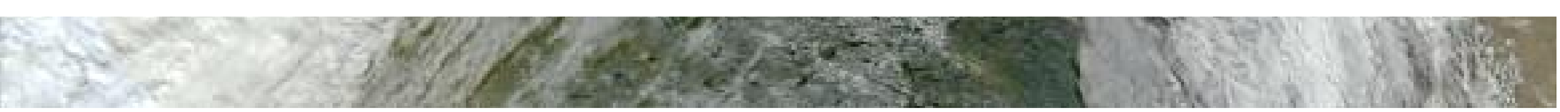

for further information about the global, regional and national scenarios please visit the Energy [R]evolution website: **www.energyblueprint.info/**

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contents

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

list of figures

list of tables

introduction

"WE CAN CHOOSE TO BELIEVE THAT SUPERSTORM SANDY, AND THE MOST SEVERE DROUGHT IN DECADES, AND THE WORST WILDFIRES SOME STATES HAVE EVER SEEN WERE ALL JUST A FREAK COINCIDENCE. OR WE CAN CHOOSE TO BELIEVE IN THE OVERWHELMING JUDGMENT OF SCIENCE – AND ACT BEFORE IT'S TOO LATE." PRESIDENT BARRACK OBAMA-FROM 2013 STATE OF THE UNION.

image ALAMOSA SOLAR GENERATING PLANT, COLORADO. A 30 MEGAWATT CONCENTRATING PHOTOVOLTAIC (CPV) POWER PLANT OWNED BY COGENTRIX ENERGY. IT WAS CALLED THE LARGEST CPV FACILITY IN THE WORLD WHEN IT CAME OPERATIONAL IN MAY 2012

One thing is certain about the Energy (R)evolution – it is happening. In some ways it's happening even more quickly than we proposed in previous scenarios, as Chapter 4 shows. The US scenario aims to wean the economy off dirty fuels as thoroughly and quickly as possible, but also in a way that is technologically, politically, and ecologically realistic.

The driving goal of the Energy [R]evolution is stopping global climate disruption, which is caused primarily by burning coal, oil, and methane gas. But the reasons to modernize our energy system are innumerable.

Our antiquated, fossil fuel-based system hoards resources to deal with incessant inputs, outputs, and undesirable externalities – extraction, transportation, fuel processing, combustion, pollution abatement, and waste processing or storage. In a post-recession world, it has become obvious that we have neglected upkeep of infrastructure that is required for the economy to function. Bridges need maintenance, urban sewer systems are corroded, entire cities like Detroit have been abandoned by industry.

A wide political spectrum worries that the American middle class has fallen in stature. An echelon class of fewer than 1% have benefited from relaxing all manner of safeguards that were supposed to referee self-interest in order for the economy as a whole could prosper. In real terms, wages for the vast majority of Americans have not risen, or have fallen, for the last few decades. For most, the 'jobless recovery' seems almost a numbers game played by politicians and investment bankers.

This report demonstrates that a transition to a renewable energy economy can free resources for economic development. It means more and better jobs, greater energy independence, and it is more democratic as citizens attain more control of their energy demand and supply.

Even today the United States mines a billion tons of coal each year, most of which is burned at home. Coal has monopolized almost half of US rail capacity, not counting the eventual transportation of toxic coal ash which is the second largest waste stream in the country. The electricity sector is the largest user of freshwater, with a fossil-based system using steam turbines, and coal is the worst culprit.

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, ANNUALLY.

Water impacts are also a dominant concern regarding of oil and gas extraction. Fracking has come to symbolize the wanton abuse by an industry historically unfettered by federal health standards. Parts of the country like West Texas are stricken by drought, and sucked even dryer to get at the fuel, the burning of which is causing climate disruptions like phenomenal lack of rain. Meanwhile, re-injecting their fracking wastes deep into the ground under intense pressures has made neighboring Oklahoma the second most earthquake-prone state.

It is incredibly frustrating that the first President to make climate a rhetorical priority has decided to embrace extreme fossil fuel extraction. The President may accept climate science in theory, but he appears to deny the required time line for action to avoid runaway climate change. Scientists give the global community maybe to the end of the decade to peak global emissions. The great weakness of President Obama's climate policy approach is that it remains insular rather than global, which includes overt support for increasing global supply of fossil fuels.

President Obama's quintessentially pandering energy platform of 'all of the above' has done little, if anything, to forestall climate denier attacks on timid use of administrative authority to help the climate – assuming, optimistically, this is the President's reasoning. His administration has expanded drilling into new parts of the outer-continental shelf, including into ultra-deepwater. As the pristine and fragile Arctic melts, rather than increase emphasis on protection of the ecosystem the President has begun permitting on production drilling for the first time. He has opened public lands to fracking. He has increased subsidized sales of publicly-owned coal. His administration is overseeing an historic rise in development of new terminals for export of coal and methane gas, considering crude oil exports, while his diplomats lobby foreign governments to increase imports. None of this can be justified in exchange for an international commitment to reduce US territorial emissions by 17% below 2005 levels (4% below 1990). Emissions are falling, but most of it is not due to the President's policies. By the time the Obama Climate Plan was announced in his fifth year in office, emissions were already down 12% from 2005. EPA has not yet established pollution limits on existing power plants.

And, yet, the fact that industry is having to rely on more extreme and costly methods to produce their wares is a sign their end is nigh. Already, wind and solar out-compete fossil fuel-produced electricity in some parts of the country, despite federal subsidies that favor fossil fuels by several fold. A precipitous drop in domestic coal demand has made industry invest in exports for their survival, not just to increase profits. But Americans in the Pacific Northwest are rejecting attempts to build export terminals in states that will be shutting down their last coal plants in just a few years. People are onto the fact that coal, oil, and methane gas from anywhere sully the planet everywhere.

The US government needs to view both demand and supply of fossil fuels as a problem. We must abolish all support for dirty energy, whether used domestically or abroad. Legislation like the "End Polluter Welfare Act," introduced by Senator Bernie Sanders (I-VT) and Congressman Keith Ellison (D-MN) is a good start. President Obama banning public financing of coal-fired power plants abroad is another good step. But it's not nearly enough; we need much more action by our leaders.

At the same time, we need American leadership that accepts humility in the face of intransigent domestic politics, instead of pulling other countries down to our level. That means allowing other nations to take climate as seriously as they do trade and negotiate international legally binding commitments. The Paris climate treaty in 2015 cannot be the culmination of efforts to turn climate negotiations into a polluters anonymous meeting, while trade treaties grandfather environmental loopholes lobbied for by carbon-intensive industries.

A day will soon come when the Republican party abandons its climate denier platform, and the President realizes her climate legacy rides on complete embrace of a clean energy economy – these two developments will undoubtedly be mutually reinforcing. In the meantime, other policymakers and citizens across the country can keep moving forward with the US Energy (R)evolution.

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MAY 2014

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 RAILROAD CROSSING SIGN AT ROSCOE WIND FARM, TEXAS. THE 627 WIND MILLS ARE PRODUCING 781 MEGAWATT, WHICH IS ENOUGH ENERGY TO SUPPLY A QUARTER MILLION HOUSEHOLDS IN TEXAS.

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 decentralized 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

Decentralized energy systems, where power and heat are produced close to the point of final use will avoid the current energy waste in distribution. Investments in 'climate infrastructure' such as smart interactive grids and super grids to transport large quantities of offshore wind and concentrating solar power are essential. Building up clusters of renewable micro grids, especially for people living in remote areas, will be a central tool in providing sustainable electricity to the almost two billion people around who currently don't have access to electricity.

the energy [r]evolution for USA – key results

Renewable energy sources account for 6.6% of USA's primary energy demand in 2011. The main sources are biomass which is mostly used for heating and hydro and wind, used for power generation.

For electricity generation renewables contributed in 2011 about 13% and for heat supply around 10%, the majority from biomass but increasingly from solar thermal collectors and although to a much lower extend - geothermal heat pumps as well. About 93% of the primary energy supply today still comes from fossil fuels.

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 MEGAWATT AND IS TESTED UNDER OFFSHORE CONDITIONS. TWO TECHNICIANS WORKING INSIDE THE TURBINE.

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:

- **Curbing energy demand:** Combining the projections on population development, GDP growth and energy intensity results in future development pathways for North America's final energy demand. Under the Reference scenario, which reflects a continuation of current trends and policies (see chapter 3, page 31), total primary energy demand increases by 11% from the current 95,201 Trillion BTU/a to around 105,800 Trillion BTU/a in 2050. In the Energy [R]evolution scenario, primary energy demand decreases by 40% compared to current consumption and it is expected to reach around 57,500 Trillion BTU/a by 2050.
- **Controlling power demand:** Under the Energy [R]evolution scenario, electricity demand is expected to decrease in both the industry sector as well as in the residential and service sector, but to grow in the transport sector. Total electricity demand will rise from 3,796 TWh/a to 4,153 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 1,930 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 heating demand:** Compared to the Reference scenario, consumption equivalent to around 5,380 Trillion BTU/a is avoided through efficiency gains by 2050. As a result of energy-related renovation of the existing stock of residential buildings, as well as the introduction of low energy standards and 'passive houses' for new buildings, enjoyment of the same comfort and energy services will be accompanied by a much lower future energy demand.
- **Electricity generation:** The development of the electricity supply sector is characterized by a dynamically growing renewable energy market and an increasing share of renewable electricity. This will compensate for the phasing out of nuclear energy and reduce the number of fossil fuel-fired power plants required for grid stabilization. By 2050, 97% of the electricity produced in the USA will come from renewable energy sources. 'New' renewables – mainly wind, solar thermal energy and PV – will contribute 88% of electricity generation. Already by 2020 the share of renewable electricity production will be 37% and 71% by 2030. The installed capacity of renewables will reach 1,366 GW in 2030 and 1,857 GW by 2050.
- **Future costs of electricity generation:** The introduction of renewable technologies under the Energy [R]evolution scenario slightly increases the future costs of electricity generation compared to the Reference scenario. This difference will be only around 0.3 cent/kWh up to 2025, however, if increasing fossil fuel prices are assumed. Because of high costs for conventional fuels and the lower CO_2 intensity of electricity generation, electricity generation costs will become economically favorable under the Energy [R]evolution scenario and by 2050 costs will be 10.5 cents/kWh below those in the Reference version.
- **The future electricity bill:** 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$ 469 billion per year to more than US$ 1,088 billion in 2050. The Energy [R]evolution scenario not only complies with US CO_2 reduction targets but also helps to stabilize energy costs and relieve the economic pressure on society. Increasing energy efficiency and shifting energy supply to renewables leads to long term costs for electricity supply that are 47% lower than in the Reference scenario.
- **Future investment in power generation:** It would require US$ 6,750 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$ 4,080 billion or US$ 102 billion annual more than in the Reference scenario (US$ 2,670 billion). Under the Reference version, the levels of investment in conventional power plants add up to almost 66% while approx. 34% would be invested in renewable energy and cogeneration (CHP) until 2050. Under the Energy [R]evolution scenario, however, USA would shift almost 95% of the entire investment towards renewables and cogeneration. Until 2030, the fossil fuel share of power sector investment would be focused mainly on CHP plants. The average annual investment in the power sector under the Energy [R]evolution scenario between today and 2050 would be approximately US$ 170 billion.
- **Fuel costs savings:** Because non-biomass renewable energy has no fuel costs, however, the fossil fuel cost savings (excluding nuclear) in the Energy [R]evolution scenario reach a total of US$ 6,100 billion up to 2050, or US$ 153 billion per year. The total fuel cost savings therefore would cover 150% of 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.
- **Heating supply:** Today, renewables meet 10% of USA's primary energy demand for heat supply, the main contribution coming from the use of biomass. The lack of district heating networks is a severe structural barrier to the large scale utilization of geothermal and solar thermal energy. Dedicated support instruments are required to ensure a dynamic development. In the Energy [R]evolution scenario, renewables provide 45% of USA's total heat demand in 2030 and 94% in 2050. Energy efficiency measures help to reduce the currently growing energy demand for heating by 28% in 2050 (relative to the Reference scenario), in spite of improving living standards. In the industry sector solar collectors, geothermal energy (incl. heat pumps), and electricity 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 heat sector**: The Energy [R]evolution shows a major revision of current investment strategies in heating technologies is needed. Especially solar and heat pump technologies need enormous increase in installations, if these potentials are to be tapped for the heat sector. Total installed capacity needs to increase by the factor of 70 for solar thermal and by the factor of more than 400 for heat pumps. Capacity of biomass technologies will be lower than in the Reference case but remains a main pillar of heat supply. Renewable heating technologies are extremely variable, from low tech biomass stoves and unglazed solar collectors to very sophisticated enhanced geothermal systems and solar thermal district heating plants with seasonal storage. Thus it can only roughly be calculated, that the Energy [R]evolution scenario in total requires more than US$ 4,300 billion to be invested in renewable heating technologies until 2050 (including investments for replacement after the economic lifetime of the plants) - approximately US$ 108 billion per year.

- **Future employment in the energy sector:** Energy sector jobs in USA are higher in the Energy [R]evolution scenario at every stage in the projection. In 2015, extremely strong growth in renewable energy in the Energy [R]evolution scenario meant overall energy employment increased by 665,300 (61%), while jobs in the Reference scenario remain static. Jobs in the Energy [R]evolution drop between 2020 and 2030, but remain 414,000 above 2010 levels. Jobs in the Reference scenario are just 27,000 above 2010 levels by 2030. Jobs in the Reference scenario remain relatively contstant over the entire period. In the Energy [R]evolution scenario, energy sector jobs double by 2015, with 0.7 million additional jobs. Jobs drop between 2015 and 2030, but despite this are 38% above 2010 levels. Renewable energy accounts for 61% of energy jobs by 2030, with solar heat having the greatest share (18%), followed by geothermal and heat pump heat and wind.

- **Transport**: A key target in the USA is to introduce incentives for people to drive smaller cars, something almost completely absent today. In addition, it is vital to shift transport use to efficient modes like rail, light rail and buses, especially in the expanding large metropolitan areas. Together with rising prices for fossil fuels, these changes reduce the huge car sales projected under the Reference scenario. Energy demand from the transport sector is reduced by around 18,700 Trillion BTU/a in 2050 (saving 71%) compared to the Reference scenario. Energy demand in the transport sector will therefore decrease between 2011 and 2050 by 71% to 7,480 Trillion BTU/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 12% of the transport sector's total energy demand in the Energy [R]evolution, while in 2050 the share will be 39%.

- **Primary energy consumption**: Compared to the Reference scenario, overall primary energy demand will be reduced by 46% in 2050. Around 87% of the remaining demand will be covered by renewable energy sources. 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 42% in 2030 and 87% in 2050. Nuclear energy is phased out just after 2035.

- **Development of CO_2 emissions:** Whilst USA's emissions of CO_2 will increase by 4% between 2011 and 2050 under the Reference scenario, under the Energy [R]evolution scenario they will decrease from 5,420 million tonnes in 2011 to 188 million tonnes in 2050 Annual per capita emissions will drop from 17.1 tonnes to 0.5 tonnes. In spite of the phasing out of nuclear energy and increasing demand, CO_2 emissions will decrease in the electricity sector. In the long run efficiency gains and the increased use of renewable energy in vehicles will reduce emissions in the transport sector. With a share of 45% of CO_2, the transport sector will be the largest remaining source of emissions in 2050. By 2025, USA's CO_2 emissions are 27% below 1990 levels, by 2030 the reduction is 48%, while by 2050 the total energy related CO_2 reduction reaches 96%.

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. Abolish all subsidies, including any policies which confer a financial benefit, to fossil fuels and nuclear energy.
2. Internalize the currently socialized cost of industrial climate pollution, such as through a federal carbon fee.
3. Mandate strict efficiency standards for all energy consuming appliances, buildings and vehicles.
4. Establish legally binding targets for renewable energy and combined heat and power generation.
5. Reform the electricity markets by guaranteeing priority access to the grid for renewable power generators.
6. Provide defined and stable returns for investors, for example by feed-in tariff schemes.
7. Implement better labeling and disclosure mechanisms to provide more environmental product information.
8. Increase research and development budgets for renewable energy and energy efficiency.

climate and energy policy

THE UNFCCC AND THE KYOTO PROTOCOL

INTERNATIONAL ENERGY POLICY

USA CLIMATE PROTECTION AND ENERGY POLICY

RENEWABLE ENERGY TARGETS

POLICY CHANGES IN THE ENERGY SECTOR

"No nation can stand alone. We share nothing so completely as our planet."

SECRETARY OF STATE JOHN KERRY
FROM FIRST SPEECH AS SECRETARY OF STATE 21 FEBRUARY 2013

image DROUGHT-FUELED RIM FIRE BURNING IN CENTRAL CALIFORNIA, NEAR YOSEMITE NATIONAL PARK. STARTED ON AUGUST 17, 2013, THE FAST-MOVING FIRE HAD ALREADY CHARRED MORE THAN 100,000 ACRES (40,000 HECTARES) BY AUGUST 23, DESPITE THE EFFORTS OF MORE THAN 2,000 FIREFIGHTERS. HUNDREDS OF PEOPLE WERE FORCED TO EVACUATE THEIR HOMES, AND ROADS IN THE AREA WERE CLOSED.

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 United Nations Framework Convention on Climate Change (UNFCCC)

In recognition of the global threats of climate change, world governments negotiated the United Nations Framework Convention on Climate Change (UNFCCC) in 1992, committing to preventing dangerous climate change. Five years later the convention was strengthened with a Kyoto Protocol that included binding emission caps for industrialized countries.

In Copenhagen 2009, members of the UNFCCC were expected to arrive at a new binding agreement with new emission reduction commitments. Unfortunately, these expectations were not met. Countries did, however, announce voluntary emission reduction pledges for 2020.

An evaluation of the climate pledges for 2020 by the United Nations Environment Program (UNEP) shows that the targets are woefully inadequate to keep temperature increase below catastrophic warming of 2°C or more – a target governments have committed to. Instead the targets put us on a path towards 2.5°C to 5°C warming, which would have devastating consequences for humanity.[2]

In 2012 governments decided to give it another try, and to negotiate a new comprehensive climate agreement by 2015. This is our chance to get it right and learn from past mistakes. The new agreement must ensure broad participation of all major emitters, apply a fair sharing of effort, provide finance and support for the vulnerable and catalyse faster emission cuts before 2020 and beyond, so that warming can be kept as far below 2°C as possible.

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:

- Industrialized countries increase the ambition of their 2020 targets adopted in Cancun, to close the gap between current commitments and what science demands for avoiding surpassing 2°C.
- Developed countries capitalize the Green Climate Fund, making good on their agreement to provide $100 billion per year, and work hard at home to generate political support for significantly more finance to help developing countries adapt to climate impacts, protect their forests and be part of the energy revolution.
- Developed and developing countries alike announce ambitious post-2020 commitments (i.e., 2025) as soon as possible, with the intention they be enshrined in a 2015 Paris Treaty that is internationally legally binding.

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 liberalizing their electricity markets, the increasing competitiveness of renewable energy should lead to higher demand. Without political support, however, renewable energy remains at a disadvantage, marginalized 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 USA climate protection and energy policy

Janet L. Sawin, Ph.D., Sunna Research,
with additions from Kyle Ash, Greenpeace USA

1.3.1 federal policies

In June of 2013, President Obama gave a climate speech at Georgetown University where he announced a 'climate plan'. Obama announcing a climate plan came with the realization that action by Congress seems a lost cause for the rest of his presidency. Climate denialism remains the position of the Republican Party, which controls the House of Representatives. Obama's climate and energy policies achieve little in terms of what is needed from the US on climate pollution reduction, and much of the policies in Obama's plan were already announced or implemented. However, several policies are very good steps toward scaling up renewable energy.

One goal that was already achieved upon announcement of the Obama climate plan was permitting enough renewables on public lands by 2020 to power more than 6 million homes. According to the Bureau of Land Management, 7.8 GW of capacity in wind, solar, and geothermal has been approved. Obama's plan expanded a program to encourage efficiency in commercial, industrial, and multi-family buildings, with the goal that buildings be 20 percent more energy efficient by 2020. The Obama administration also strengthened a goal for itself, aiming to increase the electricity it uses from renewables to 20% by 2020. The federal government is the largest energy consumer.

The Obama administration has also implemented, proposed, or announced plans for policies to deal with climate pollution from the transportation and electricity sector. Even if these policies do not achieve sufficient mitigation, they do encourage renewables. The pollution restrictions applying to passenger vehicles made from 2017 may already be helping to encourage electric vehicle production, marketing and development. Pollution limits on future power plants were supposed to be already finalized and promulgated, which has been delayed repeatedly. The limits on future plants would obviously have no impact with respect to current emissions, whereas no one knows what EPA may propose for limits on existing plants. Obama's climate plan aims to finalize standards for future plants by 2014, and for existing plants by 2015. Implementation of these standards would be phased in under the next President. Despite the feeble effort by Obama to deal with coal, the threat that the utility sector regulations may force some internalization of climate pollution costs does not stand on its own. President Obama also continues to call for the elimination of fossil fuel subsidies, reflected in his budget proposal, although a policy objective also dependent on assent from Congress.

The 2009 Federal Stimulus Package

The American Recovery and Reinvestment Act of 2009 (ARRA), designed to stimulate the national economy, provided several billion dollars for renewable energy and energy efficiency, and allocated about $3.5 billion for smart-grid investments. One significant aspect of the stimulus was the provision for a cash grant in place of the federal production tax credit (for wind, geothermal, and closed-loop biomass) and the investment tax credit (mostly solar and small wind projects). This was important because prior to ARRA developers had difficulty securing financing against potential tax equity. ARRA provided the certainty needed to get projects going again, meaning that construction moved forward on many projects that otherwise would have remained dormant. While the ARRA funds continued to be available for qualified projects that began construction before the end of 2011, the cash grant expired at the end of that year.

Renewable Electricity

Aside from targets in the Obama climate plan that address energy demand of the federal government and energy production on public lands, no standards or official targets exist at the national level.

The Investment Tax Credit (particularly important for solar) has been extended through 2016; in 2017 it reverts from the current 30% back to its original level of 10%. The Production Tax Credit, which has been important for driving investment in wind power in particular, was extended through 2012 under ARRA. As of early December, it was expected to expire at year's end for wind power, but to continue through 2013 for other technologies covered by the program.

Renewable Heating/Cooling

No policies specific to renewable heating/cooling exist at the national level, although investment tax credits are available for relevant technologies.

Renewable Transport

Aside from vehicle emissions rules encouraging low-emissions technology or electric vehicles, federal regulation related to renewable transport is directed at biofuels.

Several federal incentives for biofuels expired at the end of 2011. The national volumetric ethanol excise tax credit (VEETC) of $0.45 per gallon of pure ethanol, which was first introduced in the 1980s, was allowed to expire. In addition, the U.S. import tariff was eliminated at year's end. However, the U.S. Renewable Fuel Standard (RFS) remains in place. It is an ethanol blending mandate that requires 36 billion gallons of renewable fuel to be blended annually with transport fuel by 2022, with annual increases in the interim; over time the standard requires a rising share of advanced biofuels. The Environmental Protection Agency sets annual minimum volume requirements under the RFS – see Table 1 for the final volumes for 2012. The equivalent shares of fuel volume are 9.23% total renewable fuel, 1.21% advanced biofuel, 0.91% biodiesel, and 0.006% cellulosic biofuel. For 2013, the biomass-based diesel blend volume has been increased to 1.3 billion gallons.

The U.S. Department of Agriculture Rural Development oversees an Advanced Biofuel Payment Program that provides payments to eligible biofuel producers to expand production of advanced biofuels refined from non-corn sources. Under the same department, the Repowering Assistance Program encourages the replacement of fossil fuels with renewable biomass to provide process heat or power in the operation of eligible biorefineries.

table 1.1: final volumes for 2012

SCENARIO	ACTUAL VOLUME	ETHANOL EQUIVALENT VOLUME
Cellulosic biofuel	8.65 mill gal	10.45 mill gal
Biomass-based diesel	1.0 bill gal	1.5 bill gal
Advanced biofuel	2.0 bill gal	2.0 bill gal
Renewable fuel	15.2 bill gal	15.2 bill gal

source
HTTP://WWW.EPA.GOV/OTAQ/FUELS/RENEWABLEFUELS/DOCUMENTS/420F11044.PDF.

1.3.2 state policies

States continue to lead in implementing policies to advance renewable energy, with a variety of policies in use in all end-use sectors—power, heating and cooling, and transportation. However, the rate of new policy enactment has slowed and some incentives have been reduced in recent years due to a combination of factors including the economic slump and falling renewable energy costs.

General Incentives and Financing

Public Benefit Funds As of November 2012, 18 states plus Washington DC and Puerto Rico had public benefit funds to support renewable energy and energy efficiency. Funds totaled an estimated $7.8 billion by 2017. One example is Oregon, where the budget for renewables (and amount used) in 2012 was $14.2 million; other states include Vermont ($3 million used in FY 2012, though the payment for 2013 is expected to decline significantly) and Wisconsin (which increased its budget for 2012 from $7.6 million to $10 million). Note, however, that in some states the funds can be taken for purposes unrelated to renewable energy development.

In 2011 there were more state-funded clean energy projects (32,734) that in any previous year, representing an 18% increase over 2010 and a near doubling of projects relative to 2009.

PACE financing Property-Assessed Clean Energy (PACE) financing is a growing trend. PACE programs allow low-interest funding of renewable energy installations by property owners, usually to be repaid through additional property tax assessments. At last count, the laws of 28 states plus Washington DC allowed local governments to form PACE programs to facilitate and encourage renewable energy installations in their municipalities (Hawaii permits it based on existing law and 27 states have passed legislation). The latest additions include New Jersey (2012), Wyoming and Connecticut (both 2011). In 2012, Connecticut passed legislation enabling PACE financing for commercial properties.

Note, however, that in July 2010, the Federal Housing Financing Agency issued a statement regarding lien status associated with most PACE programs; as a result, most local programs have been suspended awaiting further clarification.

Investment Incentives At least 30 states and Washington D.C. have some sort of financial incentive to support renewable energy, and many of these also had incentives supported by utilities, non-profits or local governments.

As of October 2012, 16 states and 2 U.S. territories (Puerto Rico and the U.S. Virgin Islands) had grant programs in place to support renewable energy. Several of these states also had grant programs at the utility, local levels or in the private sector, and another six states had utility, local or private only (not state-level) grant programs. At the same time, 37 states and the U.S. Virgin Islands had loan programs for renewable energy.

image WIND FARM SINTFELDEN/PADERBORN IN GERMANY WITH 65 WINDMILLS MADE BY ENERCON, MICON AND VESTAS.

Other support programs in place by late 2012 include:

- Rebate programs – 16 states plus Washington D.C., Puerto Rico and U.S. Virgin Islands. One of the most recent rebates to become available (September 2012) was a biomass/clean-burning wood stove rebate program in Maryland. Connecticut's Residential Solar Investment Program (stemming from legislation enacted in 2011) provides a rebate for systems up to 10 kW and offers a performance-based incentive over 6 years for third-party-owned systems. In addition, about 17 states have utility, local or non-profit programs but no state-level rebate programs.
- Property tax incentives: 38 states and Puerto Rico
- Sales tax incentives: 27 states plus Puerto Rico
- Tax credits: 24 states (most offer both personal and corporate tax credits, while some offer only one or the other).

Most of these cover solar energy (particularly solar PV, but also solar thermal heat) while many include other RE technologies ranging from wind power to biomass heat and geothermal heat pumps. New York state has an aerobic digester gas to electricity rebate and performance incentive with a $57 million budget for 2011-2015.

Several states also have financial programs to support energy efficiency improvements, with some programs applying to both renewable energy and energy efficiency (particularly related to green buildings).

Renewable Electricity

Renewable Portfolio Standards After several years of state-level expansion of Renewable Portfolio Standards—with states enacting new policies or expanding targets and creating carve-outs for solar—no states added new RPS laws in 2011 or 2012. However, in 2011 at least three states revised existing mandates. California revised its existing mandate from 20% by 2010 to 20% by 2013, 25% by 2016, and 33% by 2020. New Jersey reduced the solar carve-out under its existing RPS, and Illinois added a requirement for distributed generation. In addition, Indiana established a voluntary goal of 4% electricity from renewables by 2013 and 10% by 2025.

During 2012, legislators attempted to repeal or weaken Renewable Portfolio Standards (RPS) in several states, although most such efforts failed to pass. By late October, three states had weakened their laws or rendered them irrelevant to renewables. In Ohio, a new law allowed anything that is a "new, retrofitted, refueled, or repowered generating facility" to qualify for the state RPS, while adding certain combined heat and power facilities and waste heat recovery systems to the renewable energy portion of the standard. The renewables portion of Ohio's mandate was reduced to 12.5% by 2025. In New Hampshire, the list of eligible resources was expanded and the solar electric carve-out was weakened. Virginia allowed research and development to meet 20% of the state's renewable energy target.

On the positive front, other states proposed new RPS laws during 2012 or considered converting non-binding goals to standards. Both Maryland and New Jersey made revisions to existing laws, with New Jersey addressing the oversupply of renewable energy credits and accelerating its solar carve-out. Maryland also accelerated its solar carve-out and advanced the 2% requirement for solar from 2022 to 2020.

As of November 2012, 29 U.S. states plus Washington DC and 2 territories had RPS laws, while 8 states and 2 territories had renewable portfolio (non-binding) goals. Most of these had final target dates in the 2020-2025 period; share targets range from a low of 10% in Indiana (by 2025), Michigan and Wisconsin (both by 2015) to a high of 40% in Hawaii (by 2030), with several states in the 15-25% range. At least two states have set capacity quotas rather than shares: Texas 5,880 MW by 2015 (with a non-wind goal of 500 MW), and Iowa 105 MW. Of the 29 states with binding quotas, 16 states plus Washington DC had RPS laws that included provisions for solar and/or distributed generation, with specific targets for solar and/or distributed generation, and/or multipliers for them. Delaware has one of the most aggressive solar carve-outs, mandating 3.5% solar PV by 2026.

Although more than half of U.S. states have RPS laws, their targets no longer challenge the industries' (particularly wind and solar power) capabilities, which have rapidly moved ahead of policy requirements. According to data from the Lawrence Berkeley National Laboratory, state mandates call for the equivalent of about 6 GW of incremental additions from the 2012-2020 period. This compares with the 5-10 GW of wind capacity added each year between 2009 and 2012. On the solar front the situation is similar. New Jersey's mandate enacted in July 2012, for example, calls for utilities to procure about 300 MW of new solar power assets through 2020, yet solar installations in the state reached 275 MW in the first half of 2012.

Feed-in Tariffs Some state and local (see below) governments have developed Feed-in Tariff (FIT) policies. In 2011, Rhode Island became the 5th U.S. state to implement a FIT, joining Vermont, Oregon, Hawaii and California. The Hawaiian FIT was revised during 2011 to include solar projects of 500 kW-5 MW scale, and wind projects of 100 kW-5 MW. Oregon also adjusted its FIT rates in 2011, reducing its solar payment option tariff for on-site generation.[3]

Net Metering As of November 2012, 43 states plus Washington DC and four U.S. territories (American Samoa, Guam, Puerto Rico, US Virgin Islands) had adopted net metering policies. Most policies apply only to certain utility types (for example, investor-owned utilities), and most states have established capacity limits; however, at least 3 states (New Jersey, Ohio and Arizona) have no capacity limit in place. In addition, three states with no state level policy have voluntary utility programs.

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As of August 2012, more than 180,000 net-metered renewable energy systems had been installed in the United States. One of the most significant developments during the year was a ruling by the California Public Utilities Commission regarding how the state's net metering cap should be calculated. The decision was projected to result in a near-doubling of net metering capacity available in the state, expanding the aggregate cap to more than 5 GW.[4]

It is important to note, however, that utility opposition to net metering is on the rise in some states, particularly those with significant distributed solar PV capacity, such as California. Under their current business models and rate structures, some utilities have argued that net metering is affecting their bottom line.

Green Power Purchasing Eight U.S. states (Colorado, Iowa, Maine, Montana, New Mexico, Oregon, Virginia and Washington) mandate electric utilities to offer voluntary green power options for their customers. These laws were enacted in the last decade (2000-2009 timeframe), with Maine's being the most recent (2009).

Renewable Heating and Cooling

A number of states now have incentives specifically targeting renewable heating, particularly solar water heating and geothermal heat pumps. In June 2008, Hawaii was the first state to enact renewable heating mandates, requiring that all new homes be outfitted with solar water heating systems. As of 1 January 2010, the law prohibits the issuing of building permits for single-family homes that do not have solar water heaters.

There also appears to be a growing interest in incorporating thermal energy sources into state RPS policy, which could help to promote investment in these technologies (although it could also negatively affect the economic viability of solar electric projects). In as many as 14 states, some type of thermal renewable energy now qualifies to meet at least a portion of RPS targets.[5] In 2012, New Hampshire became the first state to adopt a thermal renewable energy carve out, requiring that a portion of the RPS mandate be met with thermal energy. The law covers solar water/space heating, geothermal heat pumps and biomass systems that begin operation after 1 January 2013, and allocates the energy equivalent of 0.2% of the 2013 total electric load to renewable heat, increasing by that amount annual to a share of 2.6% by 2025. Also in 2012, Maryland created a thermal carve out in its RPS for solar water heating, geothermal heating and cooling, and biomass (systems primarily using animal waste) heating.

Renewable Transport

Several U.S. states have biofuel mandates in place. These include Missouri and Montana, which both require E10 (a blend of 10% ethanol and 90% gasoline), as well as Louisiana, Massachusetts, Minnesota, New Mexico, Oregon, Pennsylvania and Washington state. Many of the state blend requirements increase over time. Iowa's E10 mandate was no longer in force as of early 2012.

State Highlight

In December 2011, the state of Vermont implemented a Comprehensive Energy Plan, which sets out a framework for achieving the goal of 90% of the state's energy from renewable sources by 2050. The plan focuses on all end-use sectors, including better implantation of renewable energy technologies in the heating and transport sectors.

1.3.3 city and local policies

Thousands of city and local governments around the world have put in place policies, targets or plans to advance renewable energy and energy efficiency, and many of these are in the United States. For example, A growing number of U.S. cities have also enacted FITs, including Los Angeles and Sacramento in California, and Gainesville in Florida, which passed a FIT program in 2011 after the city's Assistant General Manager Ed Regan visited Germany to evaluate their FIT model up close. The Long Island Power Authority unveiled a new feed-in tariff program that offered 20-year contracts to projects of 50 kW - 20 MW in size, with an aggregate cap of 50 MW; the queue for applications opened in July 2012.

Other developments include the following: Ithaca in New York switched to renewable electricity in late 2011 and planned to produce 100% renewable electricity for all of the city's consumers starting in 2012. In late 2011 or early 2012, the city of Austin, Texas became the largest local U.S. government using 100% renewable energy. San Francisco has established a public utility to provide the city with 100% renewable electricity by 2020, and Cincinnati, Ohio, has developed a power aggregation deal to provide 100% renewable electricity to all customers. Cities have also adopted policies and programs to transform their buildings and transportation systems. For example, St. Paul in Minnesota started a program in 2011 that began providing solar district heat to 80% of its downtown. Chicago and New York City have built solar-powered charging systems to encourage use of electric vehicles that can run on renewable electricity. As of October 1, 2012, New York City mandates the use of 2% biodiesel in all oil heat to be used in the city (although this was temporarily suspended following "super storm" Sandy and not in effect as of early December).

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image WESERWIND GMBH IN BREMERHAVEN, PRODUCING FOUNDATION STRUCTURES FOR OFFSHORE WIND PARKS. STRUCTURES FOR OFFSHORE WINDPARK GLOBAL TECH ONE AND NORDSEE OST 1 IN THE NORTH SEA READY FOR SHIPPING.

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the energy [r]evolution concept

KEY PRINCIPLES

THE "3 STEP IMPLEMENTATION"

THE NEW ELECTRICITY GRID

CASE STUDY GERMANY

CASE STUDY BIHAR

GREENPEACE PROPOSAL TO SUPPORT A RENEWABLE ENERGY CLUSTER

ENERGY [R]EVOLUTION CLUSTER JOBS

"The planet is running a fever. There are no emergency rooms for planets. We must put in place the preventative care of unleashing a renewable energy revolution."

SENATORY ED MARKEY
FROM FIRST SPEECH AS SENATOR ON 19 SEPTEMBER 2013

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image AGRICULTURE AND THE PETROLEUM INDUSTRY COMPETE FOR LAND USE NEAR DENVER CITY, TEXAS, SOUTHWEST OF LUBBOCK NEAR THE NEW MEXICO BORDER. THE ECONOMY OF THIS REGION IS ALMOST COMPLETELY DEPENDENT ON ITS UNDERGROUND RESOURCES OF PETROLEUM AND WATER. THE WATER SUPPLY IS DRAWN FROM WELLS TAPPING THE VAST, BUT FAILING, OGALLALA AQUIFER.

image THE PELAMIS WAVE POWER MACHINE IN ORKNEY. IT ABSORBS THE ENERGY OF OCEAN WAVES AND CONVERTS IT INTO ELECTRICITY. THE MACHINE FLOATS SEMI-SUBMERGED ON THE SURFACE OF THE WATER AND IS MADE UP OF A NUMBER OF CYLINDRICAL SECTIONS JOINED TOGETHER BY HINGED JOINTS

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.[6] 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: localized 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 industrialized 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 decentralize 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.[7]

   Just as climate change is real, so is the renewable energy sector. Sustainable, decentralized energy systems produce fewer carbon emissions, are cheaper and are less dependent on imported fuel. They create more jobs and empower local communities. Decentralized 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.[8]

Now is the time to make substantial structural changes in the energy and power sector within the next decade. Many power plants in industrialized 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 decentralized, 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.

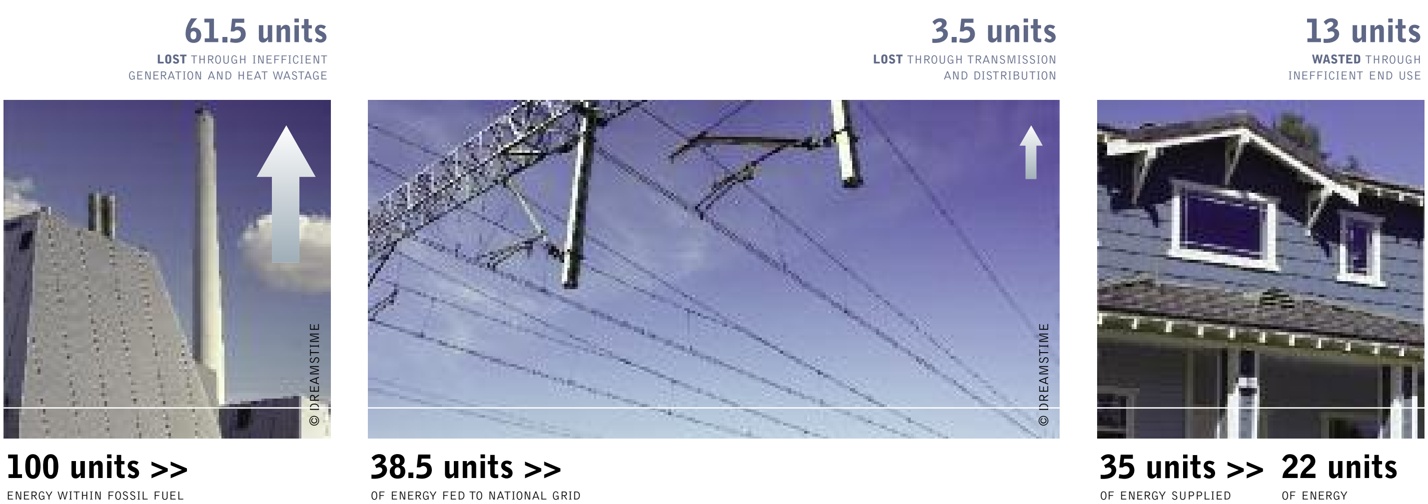
A transition phase is required to build up the necessary infrastructure because it is not possible to switch directly from a large scale fossil and nuclear fuel based energy system to a full renewable energy supply. Whilst remaining firmly committed to the promotion of renewable sources of energy, we appreciate that conventional natural gas, used in appropriately scaled cogeneration plants, is valuable as a transition fuel, and can also drive cost-effective decentralization 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. Industrialized 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 stabilization 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: centralized generation systems waste more than two thirds of their original energy input



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8 '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 Decentralized 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 Decentralized Energy (DE).This term refers to energy generated at or near the point of use.

Decentralized 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 centralized fossil fuel electricity plant.

Decentralized 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 commercialized for domestic users to provide sustainable, low emission heating. Some consider decentralized 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.

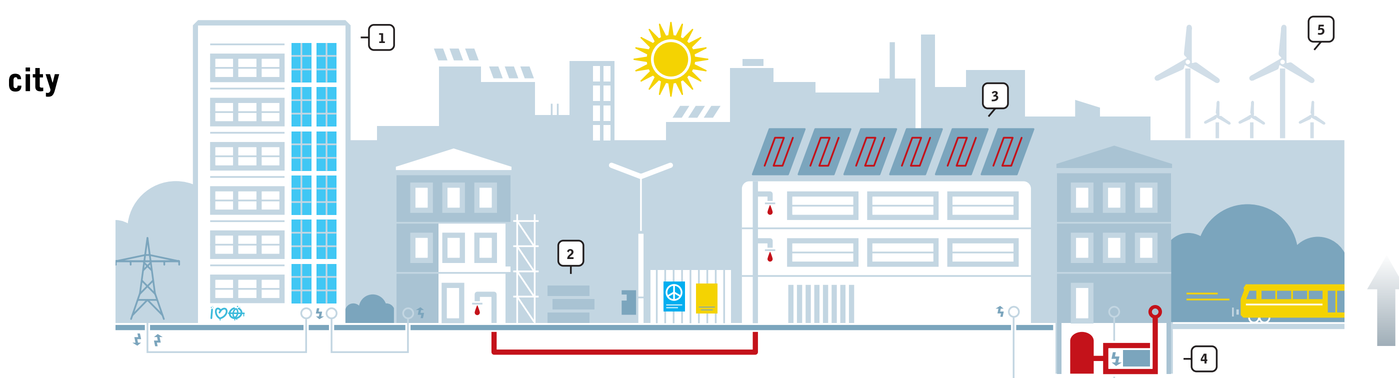
A huge proportion of global energy in 2050 will be produced by decentralized energy sources, although large scale renewable energy supply will still be needed for an energy revolution. Large offshore wind farms and concentrating solar power (CSP) plants in the sunbelt regions of the world will therefore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

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



1. **PHOTOVOLTAIC, SOLAR FACADES** 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 NEIGHBORING 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 mobilization of all technologies. Such a mobilization 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. Decentralized 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 revolutionized 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 decentralized power plants. Ownership will shift towards more private investors, the manufacturer of renewable energy technologies and EPC companies (engineering, procurement and construction) away from centralized 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 liberalization.
Market player							
Power plant engineering companies							
Utilities							
Mining companies							
Grid operator							
2020 AND BEYOND POWER MARKET	Renewable power plants are small in capacity, the amount of projects for project development, manufacturers and installation companies per installed 1 GW is bigger by an order of magnitude. In the case of PV it could be up to 500 projects, for onshore wind still 25 to 50 projects.			Many projects will be owned by private households or investment banks in the case of larger projects.		By 2050 almost all power generation technologies - except biomass - will operate without the need of fuel supply.	Grid operation will move towards state controlled grid companies or communities due to liberalization.
Market player							
Renewable power plant engineering companies							
Private & public investors							
Grid operator							

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: optimized 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, centralized 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 realized, 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'.[9] 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 decentralized 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 centralized 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 26).

reference

9 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 decentralized renewable energy sources and co-generation 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 thermal storage (e.g. for district heating) or, once the technology is available, for regeneration as electricity

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 decentralized 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.

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 centralized networks or island systems. The main aim of power system operation is to balance electricity consumption and generation.

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.

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:

- Fulfill 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 thermal or electrical 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.[10] 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.[11] 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.[12] 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

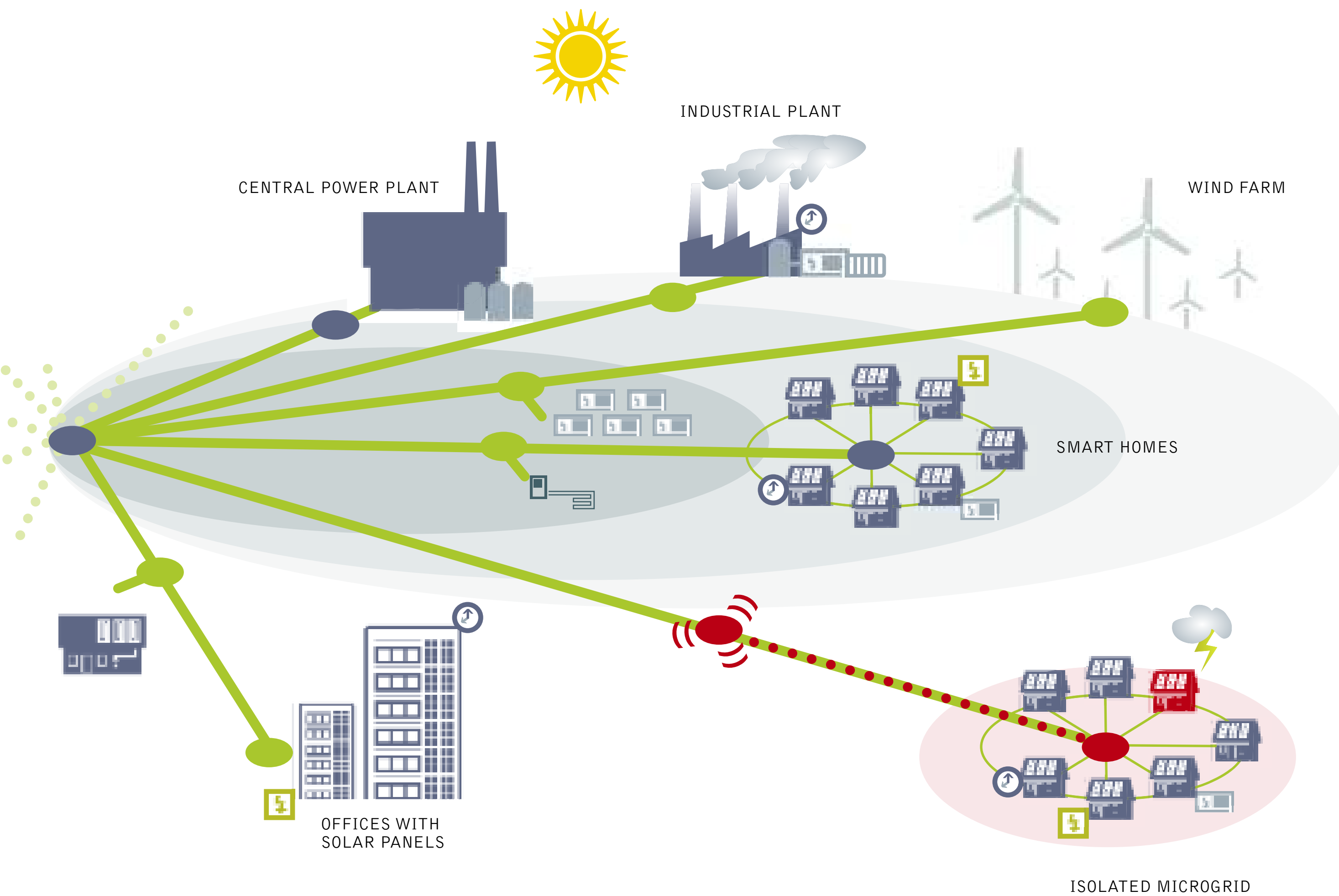
10 SEE ALSO ECOGRID PHASE 1 SUMMARY REPORT, AVAILABLE AT: http://www.energinet.dk/NR/rdonlyres/8B1A4A06-CBA3-41DA-9402-B56C2C288FB0/0/EcoGriddk_phase1_summaryreport.pdf

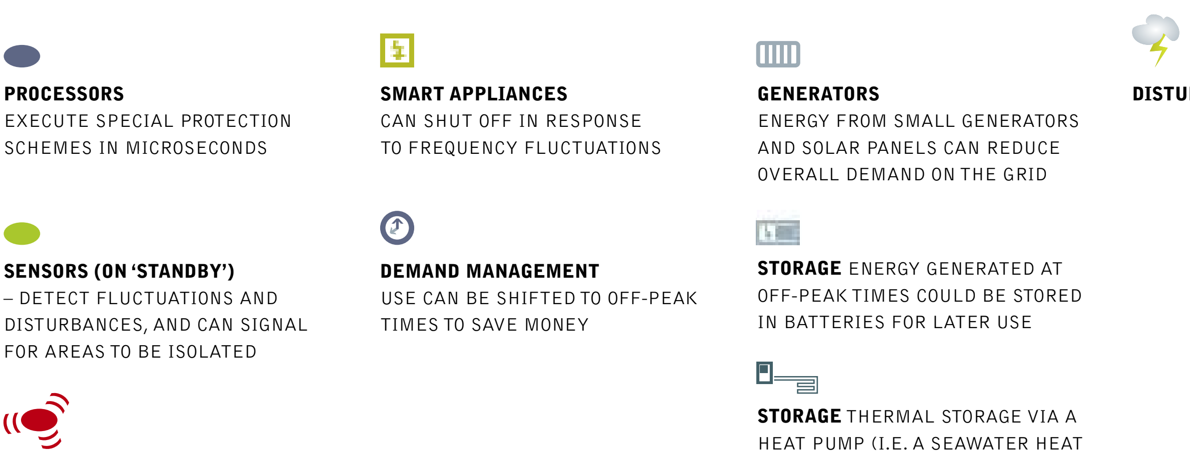
11 SEE ALSO http://www.kombikraftwerk.de/index.php?id=27

12 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

STORAGE THERMAL STORAGE VIA A HEAT PUMP (I.E. A SEAWATER HEAT PUMP), FOR DISTRICT HEATING USE

DISTURBANCE IN THE GRID

image AERIAL VIEW OF THE WORLD'S LARGEST OFFSHORE WIND PARK 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 centers, 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 centers. 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 kilometers 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.[13]

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?[14]

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 favor 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.

references

13 GREENPEACE REPORT, 'NORTH SEA ELECTRICITY GRID [R]EVOLUTION', SEPTEMBER 2008.
14 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

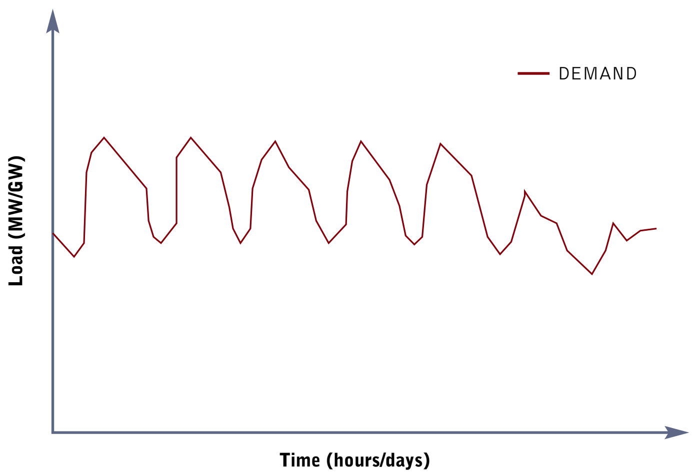
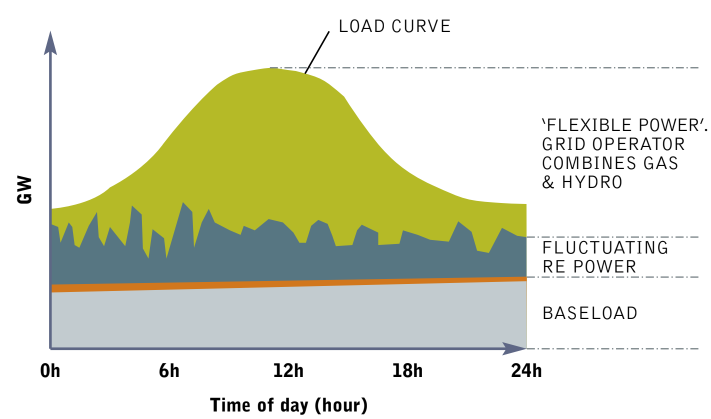


figure 2.5: the evolving approach to grids: 4 options

Option 1: 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.



Option 2: 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.

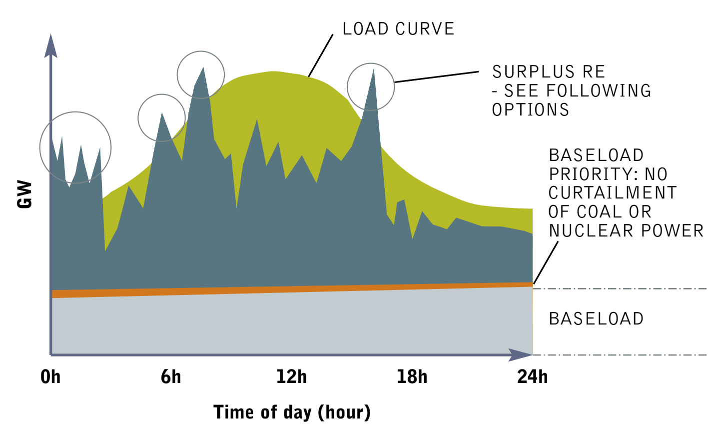


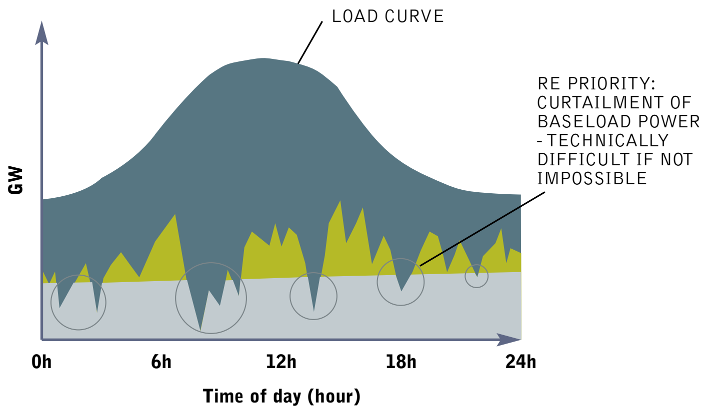
image GREENPEACE OPENS A SOLAR ENERGY WORKSHOP IN BOMA. A MOBILE PHONE GETS CHARGED BY A SOLAR ENERGY POWERED CHARGER.

figure 2.5: the evolving approach to grids: 4 options *continued*

Option 3: 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.

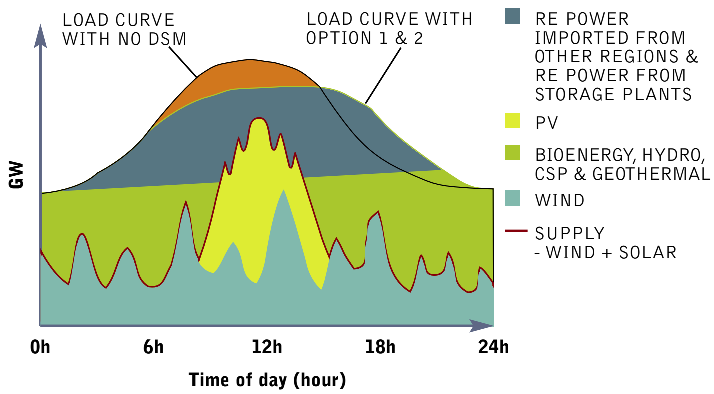
Technically difficult, not a solution.



Option 4: The solution: an optimized system with over 90% renewable energy supply

- A fully optimized 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.

3

scenario for a future energy supply

3

"towards a sustainable energy supply system."

© NASA

image THE MISSISSIPPI RIVER SPILLED OVER ITS BANKS IN ARKANSAS AND TENNESSEE ON MAY 12, 2011. THE IMAGE SHOWS MUDDY WATER SITTING ON FLOODPLAINS AROUND TOMATO, ARKANSAS, AS WELL AS EXTENSIVE FLOODING TO THE NORTH.

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 global Reference scenario of the Energy [R]evolution 2012 was based on the Current Policies scenarios published by the International Energy Agency (IEA) in World Energy Outlook 2011 (WEO 2011).[15] 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 liberalization 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.

The Reference scenario for this updated US study is based on the Reference case of the Annual Energy Outlook 2013 (AEO2013), prepared by the U.S. Energy Information Administration (EIA). As the EIA's projections only extend to 2040, 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 projections are based generally on federal, state, and local laws and regulations in effect as of the end of September 2012, the Reference case projection is defined as a business-as-usual trend estimate, given known technology and technological and demographic trends.

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 USA, 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[16] 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% of USA energy supply just after 2035.

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

3.1 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.[17] The global 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) analyzed the employment effects of the Energy [R]evolution and Reference scenarios.

3.1.1 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.

3.2 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. For this study the population projections from United Nations Development Programme (UNDP) up to 2050 are applied.[18]

3.3 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.[19] 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

table 3.1: population development projection

(IN MILLIONS)

	2011	2015	2020	2025	2030	2040	**2050**
USA	317	328	341	354	366	388	**407**

table 3.2: 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%
USA	2.6%	2.3%	1.1%	1.9%
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%
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)

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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.

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 USA countries is assumed to grow by around 1.9% per year over the projection period.

3.4 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 3.3).

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 3.3: 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).

3.5 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 $US\$_{2010}/tCO_2$)[20], 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 3.4: assumptions on CO_2 emissions cost development for Annex-B and Non-Annex-B countries of the UNFCCC.

(US$2010)

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

3.6 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.[21]

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[22], while a 2007 US Department of Energy report found installing carbon capture systems to most modern plants resulted in a near doubling of costs.[23] These costs are estimated to increase the price of electricity in a range from 21-91%.[24]

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.[25] 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.[26]

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.[27] 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.[28]

For the above reasons, CCS power plants are not included in our economic analysis. Greenpeace also advocates against CCS because of other social, political, and environmental costs.[29]

Table 3.5 summarises our assumptions on the technical and economic parameters of future fossil-fueled 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 3.5: 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)	2,119	2,087	2,052	2,003	1,950	1,901
	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)	2,383	2,332	2,280	2,232	2,182	2,134
	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)	772	753	736	702	666	632
	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.

3.7 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[30], from the analysis of recent technology foresight and road mapping studies, including the European Commission funded NEEDS project (New Energy Externalities Developments for Sustainability)[31] 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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3.7.1 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 decentralized / centralized 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 3.6. 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).

3.7.2 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 10,000 C°, 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 realized 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 3.7 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 3.6: 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$/kWp)	2,648	1,954	1,450	1,125	914	930
O & M costs US$/(kW/a)	53	37	21	15	15	15

O & M = Operation and maintenance.

table 3.7: 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$/kWp)	9,038	6,621	5,739	5,273	4,949	4,806
O & M costs US$/(kW/a)	350	265	229	211	197	192

O & M = Operation and maintenance.

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

3.7.3 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 3.9.

3.7.4 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 realize 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 3.8: 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$/kWp)	4,634	3,190	2,407	2,085	1,937	1,964
O & M costs US$/(kW/a)	196	142	122	109	106	107
Wind turbine onshore						
Investment costs (US$/kWp)	2,119	1,760	1,525	1,513	1,521	1,590
O & M costs US$/(kW/a)	68	56	54	56	58	61

O & M = Operation and maintenance.

table 3.9: biomass cost assumptions

SCENARIO	2009	2015	2020	2030	2040	2050
E[R]						
Biomass power plant						
Investment costs (US$/kWp)	3,443	3,174	2,996	2,894	2,777	2,717
O & M costs US$/(kW/a)	212	185	175	168	163	159
Biomass CHP						
Investment costs (US$/kWp)	3,972	3,530	3,088	2,696	2,485	2,361
O & M costs US$/(kW/a)	417	355	310	270	250	237

O & M = Operation and maintenance.

box 3.1: biomass in the 2012 energy [r]evolution (4th edition)

The 2012 Energy [R]evolution (4th ed.) is an energy scenario which shows a possible pathway for the global energy system to move from fossil fuels dominated supply towards energy efficiency and sustainable renewable energy use. The aim is to only use sustainable bioenergy and reduce the use of unsustainable bioenergy in developing countries which is currently in the range of 30 to 40 EJ/a. The fourth edition of the Energy [R]evolution again decreases the amount of bioenergy used significantly due to sustainability reasons, and the lack of global environmental and social standards. The amount of bioenergy used in this report is based on bioenergy potential surveys which are drawn from existing studies, but not necessarily reflecting all the ecological assumptions that Greenpeace would use. It is intended as a coarsescale, "order-of-magnitude" example of what the energy mix would look like in the future (2050) with largely phased-out fossil fuels. The rationale underpinning the use of biomass in the 2012 Energy [R]evolution is explained here but note the amount of bioenergy included in the Energy [R]evolution does not mean that Greenpeace per se agrees to the amount without strict criteria.

The Energy [R]evolution takes a precautionary approach to the future use of bioenergy. This reflects growing concerns about the greenhouse gas balance of many biofuel sources, and also the risks posed by expanded biofuels crop production to biodiversity (forests, wetlands and grasslands) and food security. It should be stressed, however, that this conservative approach is based on an assessment of today's technologies and their associated risks. The development of advanced forms of bio energies which do not involve significant land take, are demonstrably sustainable in terms of their impacts on the wider environment, and have clear greenhouse gas benefits, should be an objective of public policy, and would provide additional flexibility in the renewable energy mix.

All energy production has some impact on the environment. What is important is to minimise the impact on the environment, through reduction in energy usage, increased efficiency and careful choice of renewable energy sources. Different sources of energy have different impacts and these impacts can vary enormously with scale. Hence, a range of energy sources are needed, each with its own limits of what is sustainable.

Biomass is part of the mix of a wide variety of non-finite fuels that, together, provide a practical and possible means to eliminate our dependency on fossil fuels. Thereby we can minimise greenhouse gas emissions, especially from fossil carbon, from energy production. Concerns have also been raised about how countries account for the emissions associated with biofuels production and combustion. The lifecycle emissions of different biofuels can vary enormously. To ensure that biofuels are produced and used in ways which maximise its greenhouse gas saving potential, these accounting problems will need to be resolved in future. The Energy [R]evolution prioritises non-combustion resources (wind, solar etc.). Greenpeace does not consider biomass as carbon, or greenhouse gas neutral because of the time biomass takes to regrow and because of emissions arising from direct and indirect land use changes. The Energy [R]evolution scenario is an energy scenario, therefore only energy-related CO2 emissions are calculated and no other GHG emissions can be covered, e.g. from agricultural practices. However, the Energy [R]evolution summarises the entire amount of bioenergy used in the energy model and indicates possible additional emissions connected to the use of biofuels. As there are many scientific publications about the GHG emission effects of bioenergy which vary between carbon neutral to higher CO_2 emissions than fossil fuels a range is given in the Energy [R]evolution.

Bioenergy in the Energy [R]evolution scenario is largely limited to that which can be gained from wood processing and agricultural (crop harvest and processing) residues as well as from discarded wood products. The amounts are based on existing studies, some of which apply sustainability criteria but do not necessarily reflect all Greenpeace's sustainability criteria. Largescale biomass from forests would not be sustainable.[32] The Energy [R]evolution recognises that there are competing uses for biomass, e.g. maintaining soil fertility, use of straw as animal feed and bedding, use of woodchip in furniture and does not use the full potential. Importantly, the use of biomass in the 2012 Energy [R]evolution has been developed within the context of Greenpeace's broader bioenergy position to minimise and avoid the growth of bioenergy and in order to prevent use of unsustainable bioenergy. The Energy [R]evolution uses the latest available bioenergy technologies for power and heat generation, as well as transport systems. These technologies can use different types of fuel and biogas is preferred due to higher conversion efficiencies. Therefore the primary source for biomass is not fixed and can be changed over time. Of course, any individual bioenergy project developed in reality needs to be thoroughly researched to ensure our sustainability criteria are met.

Greenpeace supports the most efficient use of biomass in stationary applications. For example, the use of agricultural and wood processing residues in, preferably regional and efficient cogeneration power plants, such as CHP (combined heat and power plants).

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image WIND TURBINES ON THE STORY COUNTY 1 ENERGY CENTER, JUST NORTH OF COLO, IOWA. EACH TURBINE HAS A 1.5-MEGAWATT CAPACITY AND CONTRIBUTES TO GENERATING ELECTRICITY FOR UP TO 75,000 HOMES.

3.7.5 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 co-generation 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 US$ 15 cents/kWh to about US$ 9 cents/kWh;
- for EGS, despite the presently high figures (about US$ 20-30 cents/kWh), electricity production costs - depending on the credits for heat supply - are expected to come down to around US$ 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.

3.7.6 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[33], 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, optimization 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.[34]

table 3.10: geothermal cost assumptions

SCENARIO	2009	2015	2020	2030	2040	2050
E[R]						
Geothermal power plant						
Investment costs (US$/kWp)	2,503	2,089	1,580	1,082	899	773
O & M costs US$/(kW/a)	637	538	418	318	297	281

O & M = Operation and maintenance.

table 3.11: ocean energy cost assumptions

SCENARIO	2009	2015	2020	2030	2040	2050
E[R]						
Ocean energy power plant						
Investment costs (US$/kWp)	5,909	4,620	3,300	2,295	1,905	1,696
O & M costs US$/(kW/a)	290	185	132	91	77	68

O & M = Operation and maintenance.

references

33 G.J. DALTON, T. LEWIS (2011): PERFORMANCE AND ECONOMIC FEASIBILITY ANALYSIS OF 5 WAVE ENERGY DEVICES OFF THE WEST COAST OF IRELAND; EWTEC 2011.

34 www.needs-project.org

3.7.7 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 3.12: hydro power cost assumptions

SCENARIO	2009	2015	2020	2030	2040	2050
E[R]						
Investment costs (US$/kWp)	3,296	3,400	3,505	3,662	3,795	3,910
O & M costs US$/(kW/a)	130	136	140	147	152	156

O & M = Operation and maintenance.

3.7.8 summary of renewable energy cost development

Figure 3.1 summarizes 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 3.2. 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 3.1: future development of investment costs for renewable energy technologies (NORMALIZED TO 2010 COST LEVELS)

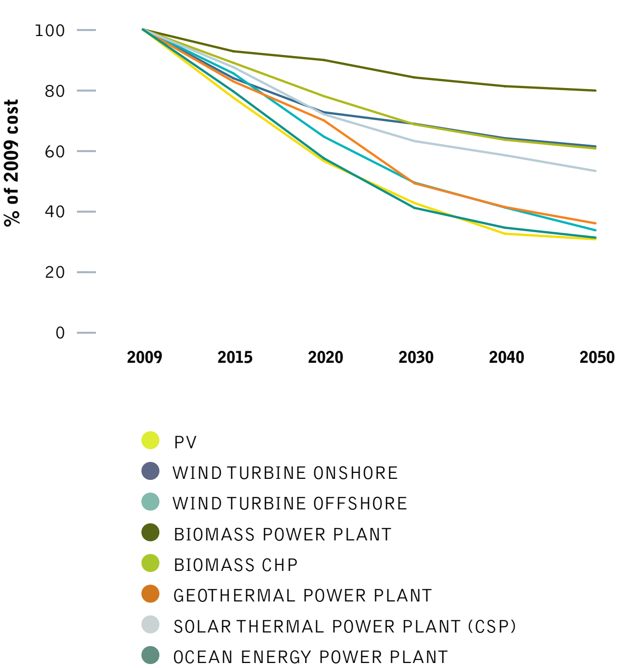


figure 3.2: expected development of electricity generation costs from fossil fuel and renewable options

EXAMPLE FOR OECD EUROPE

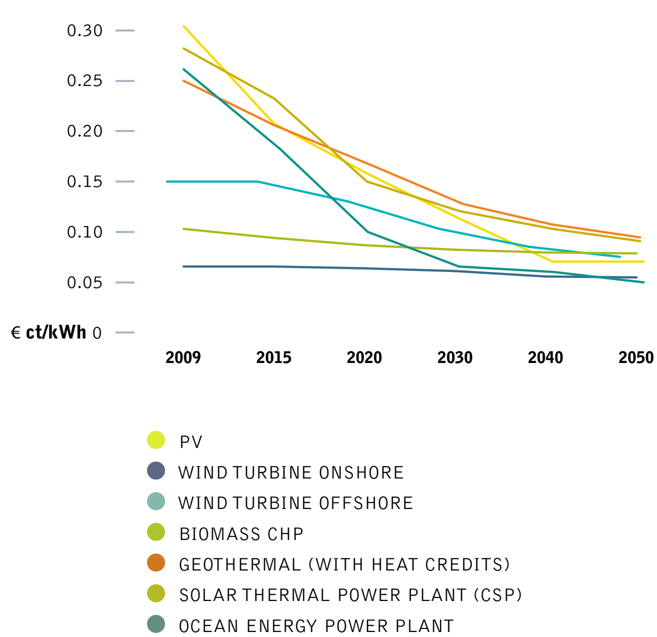


image ANDASOL 1 SOLAR POWER STATION IS EUROPE'S FIRST COMMERCIAL PARABOLIC TROUGH SOLAR POWER PLANT. IT WILL SUPPLY UP TO 200,000 PEOPLE WITH CLIMATE-FRIENDLY ELECTRICITY AND SAVE ABOUT 149,000 TONNES OF CARBON DIOXIDE PER YEAR COMPARED WITH A MODERN COAL POWER PLANT.

© GP/MARKEL REDONDO

3.8 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.

3.8.1 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 260 $/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 390-940 $/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.

3.8.2 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
780 $/kWth (shallow) to 4,700 $/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.

3.8.3 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 780-2,500 $/kW for ground water systems and from 1,900-4,700 $/kW for ground source or aerothermal systems.

3.8.4 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 150 $/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 630-1,900 $/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 620-1,100 $/kW. Heating plants can deliver process heat or provide whole neighborhoods 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 centers 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 optimized, whereas integration in large systems is neither technological nor economical mature. Table 3.13 shows average development pathways for a variety of heat technology options.

table 3.13: overview over expected investment costs pathways for heating technologies IN $/KW

	2015	2020	2030	2040	2050
Geothermal district 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

3.9 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.

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

3.9.1 oil – production decline assumptions

Figure 3.3 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.

3.9.2 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 3.3: global oil production 1950 to 2011 and projection till 2050

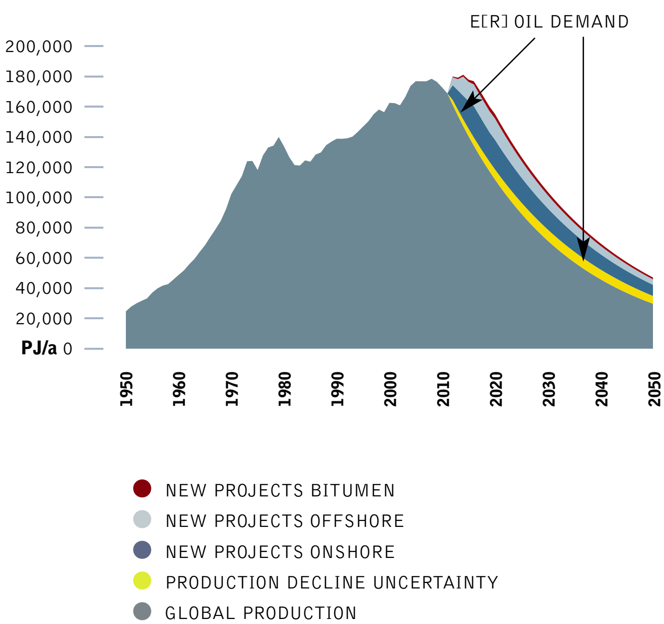
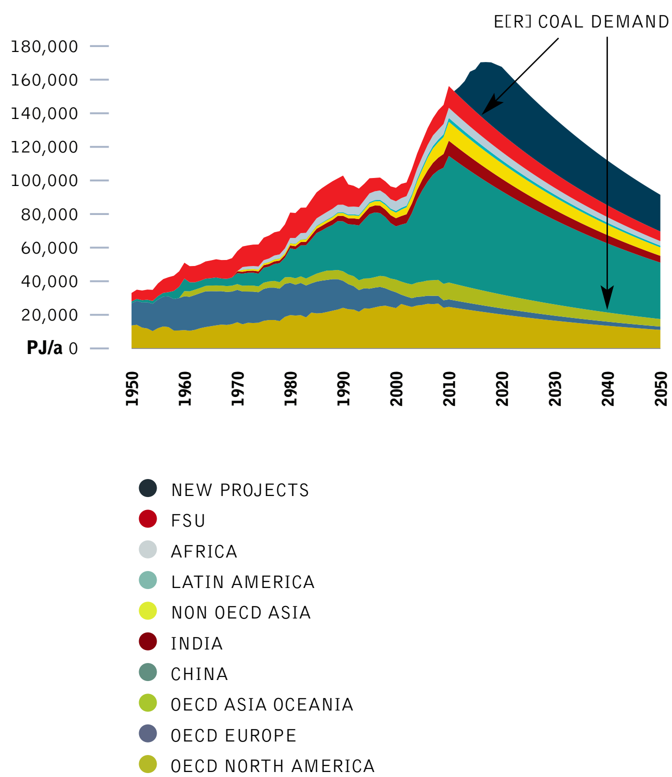


figure 3.4: coal scenario: base decline of 2% per year and new projects



3.10 review: greenpeace scenario projections of the past

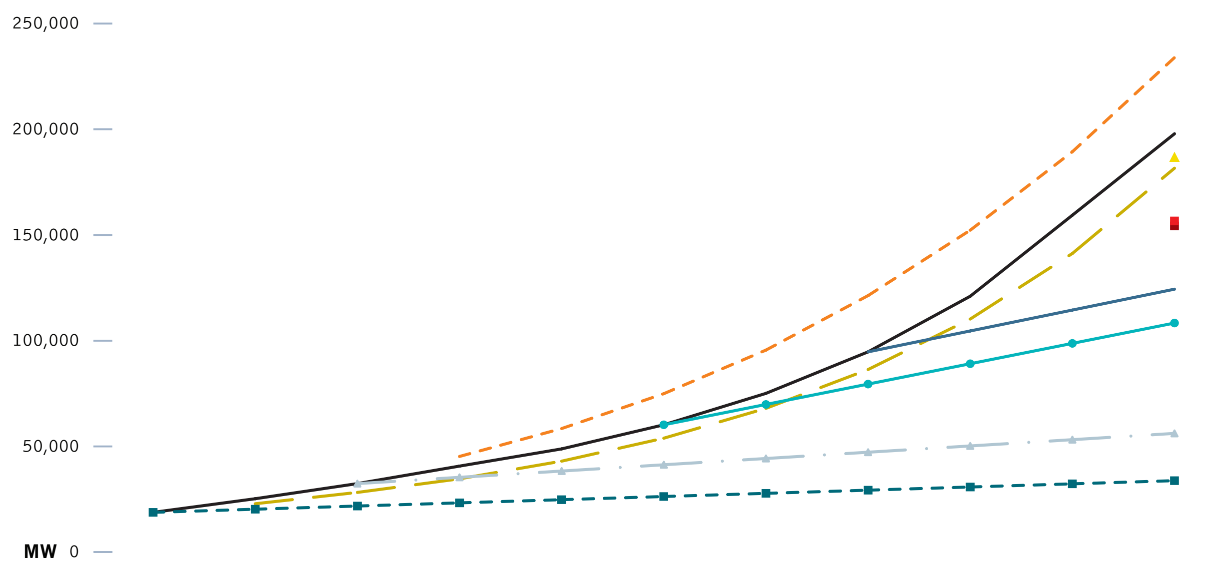
Greenpeace has published numerous projections in cooperation with renewable industry associations and scientific institutions in the past decade. This section provides an overview of the projections between 2000 and 2011 and compares them with real market developments and projections of the IEA World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

3.10.1 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 organization of all regional wind industry associations. Figure 3.5 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

figure 3.5: 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

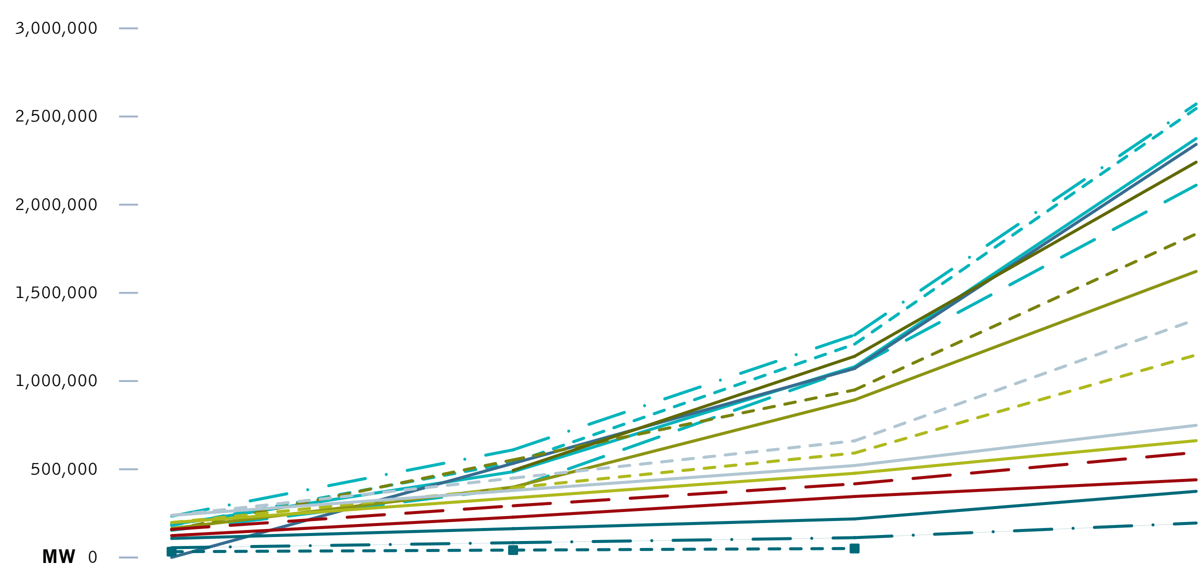
image A PRAWN SEED FARM ON MAINLAND INDIA'S SUNDARBANS COAST LIES FLOODED AFTER CYCLONE AILA. INUNDATING AND DESTROYING NEARBY ROADS AND HOUSES WITH SALT WATER.

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 criticized at the time, being called "over ambitious" or even "impossible".

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 3.6: 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

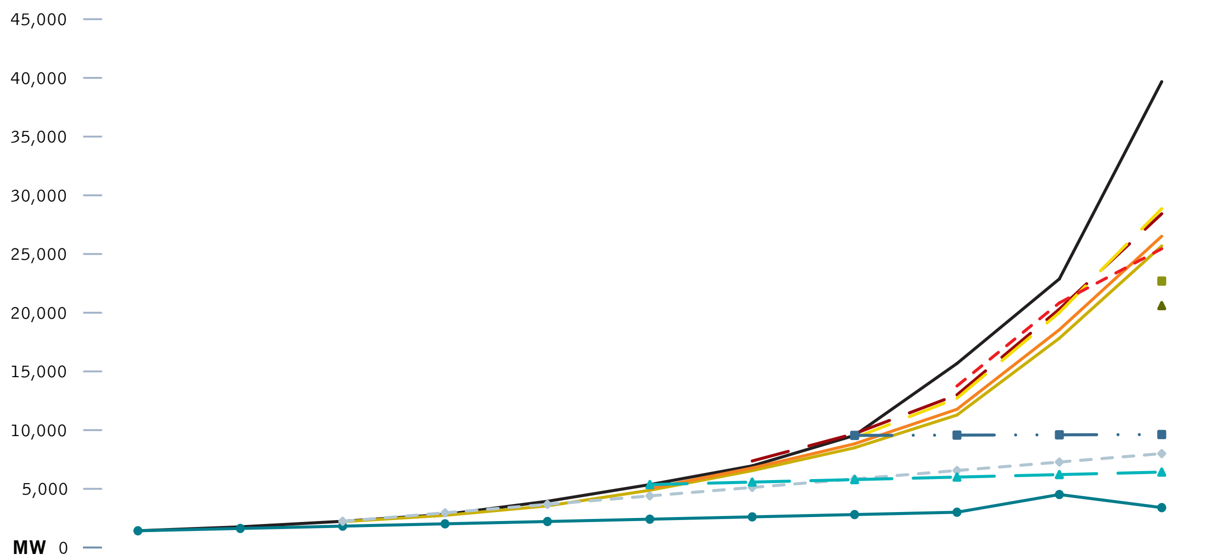
3.10.2 the development of the global solar photovoltaic industry

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 organizations.

Figure 3.7 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 analyzed in the research, instead the category "Solar/Tidal/Other" are presented in Figure 3.7 and 3.8.

In contrast to the wind projections, all the SolarGeneration projections have been too conservative. The total installed capacity in

figure 3.7: photovoltaics: short term prognosis vs real market development - global cumulative capacity



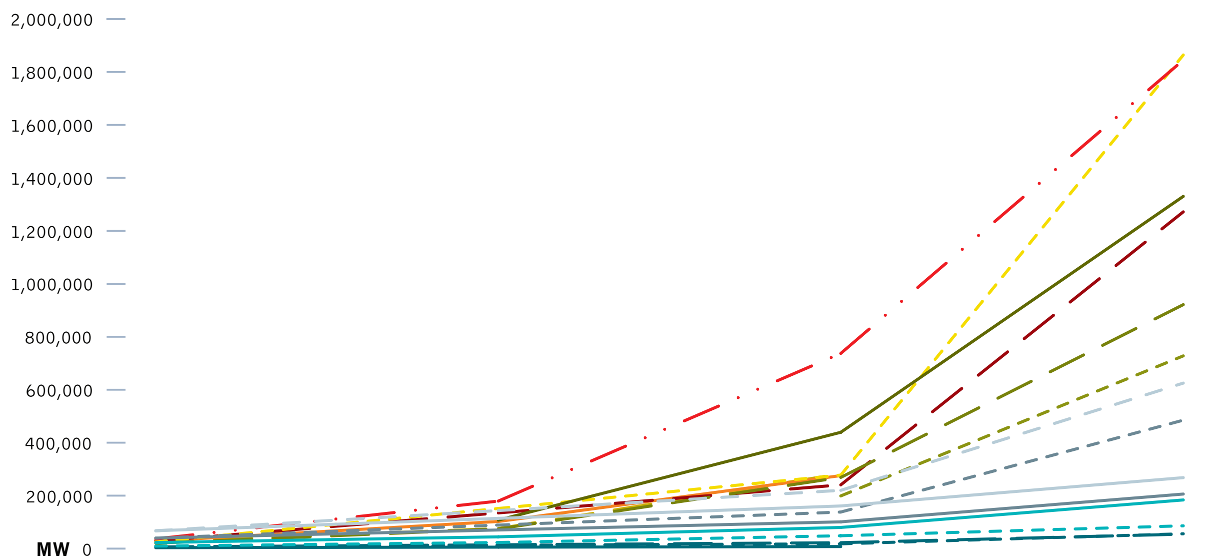
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
REAL	1,428	1,762	2,236	2,818	3,939	5,361	6,956	9,550	15,675	22,878	39,678
SG I 2001			2,205	2,742	3,546	4,879	6,549	8,498	11,285	17,825	25,688
SG II 2004						5,026	6,772	8,833	11,775	18,552	26,512
SG III 2006							7,372	9,698	13,005	20,305	28,428
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.

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 3.8: 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

3.11 how does the global 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 summarizes 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 analyzed use different modelling architectures, demand projections and technology portfolios for the supply side. The full results are provided in Table 3.14, 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 Organization of Economic Co-Operation and Development (OECD) as inputs to project GSP. The other two scenarios calculate GDP from within their model.

table 3.14: 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	
Technology pathway	UNIT	2007	2030	2050(1)	2030	2050	2030	2050	2030	2050
Renewables			al	all	generic solar	generic solar	generic 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.

key results of the USA energy [r]evolution scenario

ENERGY DEMAND BY SECTOR

ELECTRICITY GENERATION

FUTURE COSTS OF ELECTRICITY GENERATION

FUTURE INVESTMENTS IN THE POWER SECTOR

ENERGY SUPPLY FOR HEATING AND COOLING

FUTURE INVESTMENT IN THE HEATING AND COOLING SECTOR

TRANSPORT

DEVELOPMENT OF CO_2 EMISSIONS

PRIMARY ENERGY CONSUMPTION

4

"There certainly is a place for these renewable technologies, and solar power especially seems to me to have great promise. Fortunately, we have plenty of rooftops on which to put solar panels"

SENATOR LAMAR ALEXANDER
FROM SPEECH AT OAK RIDGE LABORATORIES 29 MAY 2013

image A VIEW OF THE SOUTHWESTERN UNITED STATES AND NORTHERN MEXICO. SNOW COVERS THE PEAKS OF THE ROCKY MOUNTAINS IN THE NORTH. RUNNING FROM THE TOP CENTER TOWARDS THE LOWER LEFT SIDE OF THE IMAGE, THE PINK VEIN OF ROCKS FOLLOWING THE COURSE OF THE COLORADO RIVER IS AN EXPANSE OF CANYON LANDS.

4.1 energy demand by sector

Combining the projections on population development, GDP growth and energy intensity results in future development pathways for the final energy demand of the USA. These are shown in Figure 4.1 for the Reference and the Energy [R]evolution scenario. Under the Reference scenario, total primary energy demand increases by 11% from the current 95,201 Trillion BTU/a to around 105,800 Trillion BTU/a in 2050. In the Energy [R]evolution scenario, primary energy demand decreases by 40% compared to current consumption and it is expected to reach 57,500 Trillion BTU/a by 2050.

Under the Energy [R]evolution scenario, electricity demand is expected to decrease in both the industry sector as well as in the residential and service sector, but to grow in the transport sector (see Figure 4.2). Total electricity demand in the scenario rises from 3,796 TWh/a to 4,153 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 1,930 TWh/a. This reduction can be achieved in particular by introducing highly efficient electronic devices using the best available technology in all demand sectors.

Efficiency gains in the heat supply sector are even larger. Under the Energy [R]evolution scenario, demand for heat supply is expected to decrease almost constantly (see Figure 4.4). Compared to the Reference scenario, consumption equivalent to around 5,400 Trillion BTU/a is avoided through efficiency gains by 2050. As a result of energy-related renovation of the existing stock of residential buildings, as well as the introduction of low energy standards and 'passive houses' for new buildings, enjoyment of the same comfort and energy services will be accompanied by a much lower future energy demand.

figure 4.1: total final energy demand by sector under the reference scenario and the energy [r]evolution scenario

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

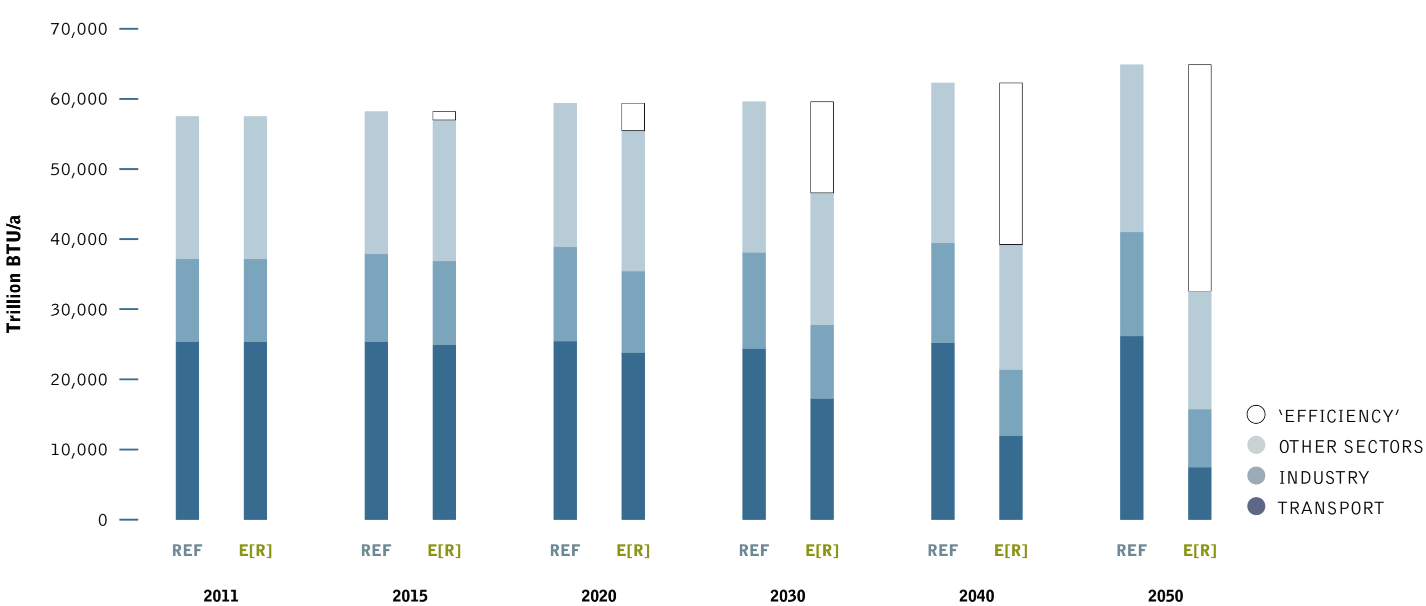


image COAL TRAINS THREE AND AT TIMES FOUR WIDE, WIND THEIR WAY THROUGH CAMPBELL COUNTY COAL COUNTRY IN THE POWDER RIVER BASIN, WYOMING.

image SOLAR PANELS AT DENVER INTERNATIONAL AIRPORT, PART OF A MORE THAN 8 MW GROUND MOUNTED SOLAR POWER SYSTEM, MORE THAN ANY OTHER COMMERCIAL AIRPORT IN THE UNITED STATES.

figure 4.2: development of electricity demand by sector in the energy [r]evolution scenario

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

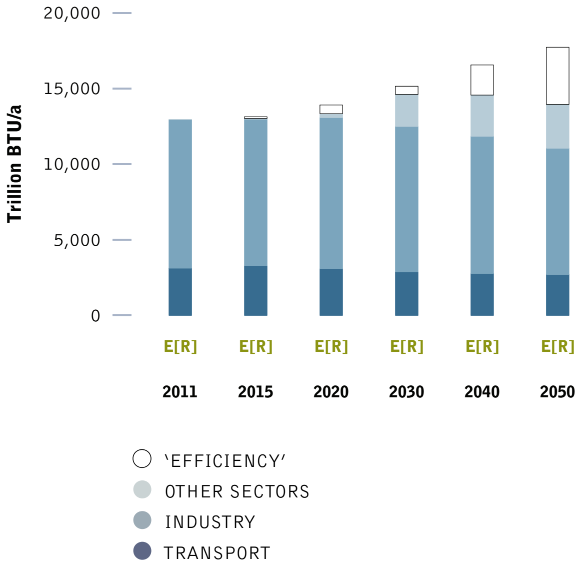


figure 4.4: development of energy demand for heating and cooling by sector in the energy [r]evolution scenario

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

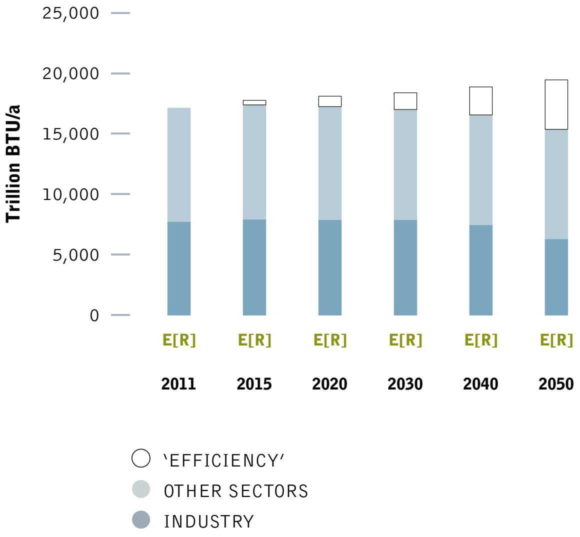


figure 4.3: development of the transport demand by sector in the energy [r]evolution scenario

4.2 electricity generation

The development of the electricity supply sector is characterized by a dynamically growing renewable energy market and an increasing share of renewable electricity. This will compensate for the phasing out of nuclear energy and reduce the number of fossil fuel-fired power plants required for grid stabilization. By 2050, 97% of the electricity produced in the USA will come from renewable energy sources. 'New' renewables – mainly wind, solar thermal energy and PV – will contribute 88% of electricity generation. Already by 2020 the share of renewable electricity production will be 37% and 71% by 2030. The installed capacity of renewables will reach 1,370 GW in 2030 and 1,857 GW by 2050.

Table 4.1 shows the comparative evolution of the different renewable technologies in the US over time. Up to 2020 hydro and wind will remain the main contributors of the growing market share. After 2020, the continuing growth of wind will be complemented by electricity from photovoltaics, concentrating solar thermal power (CSP) and biomass. The Energy [R]evolution scenario will lead to a high share of fluctuating power generation sources (photovoltaic, wind and ocean) of 44% by 2030, therefore the expansion of smart grids, demand side management (DSM) and storage capacities will be used for a better grid integration and power generation management. CSP plants with thermal energy storage play an important role in the scenario making solar power generation dispatchable, like conventional power plants.

table 4.1: renewable electricity generation capacity under the reference scenario and the energy [r]evolution scenario

IN GW

		2011	2020	2030	2040	2050
Hydro	REF	79	79	80	81	83
	E[R]	79	85	85	85	85
Biomass	REF	13	24	30	37	43
	E[R]	13	16	21	28	32
Wind	REF	46	60	62	88	119
	E[R]	46	281	568	646	674
Geothermal	REF	3	5	7	10	12
	E[R]	3	23	63	97	124
PV	REF	4	21	26	50	61
	E[R]	4	123	339	441	522
CSP	REF	0.5	2	2	2	2
	E[R]	0.5	76	245	283	326
Ocean energy	REF	0	0	0	0	0
	E[R]	0	10	45	78	94
Total	**REF**	145	190	208	267	319
	E[R]	145	614	1,366	1,658	1,857

figure 4.5: electricity generation structure under the reference scenario and the energy [r]evolution scenario (INCLUDING ELECTRICITY FOR ELECTROMOBILITY, HEAT PUMPS AND HYDROGEN GENERATION)

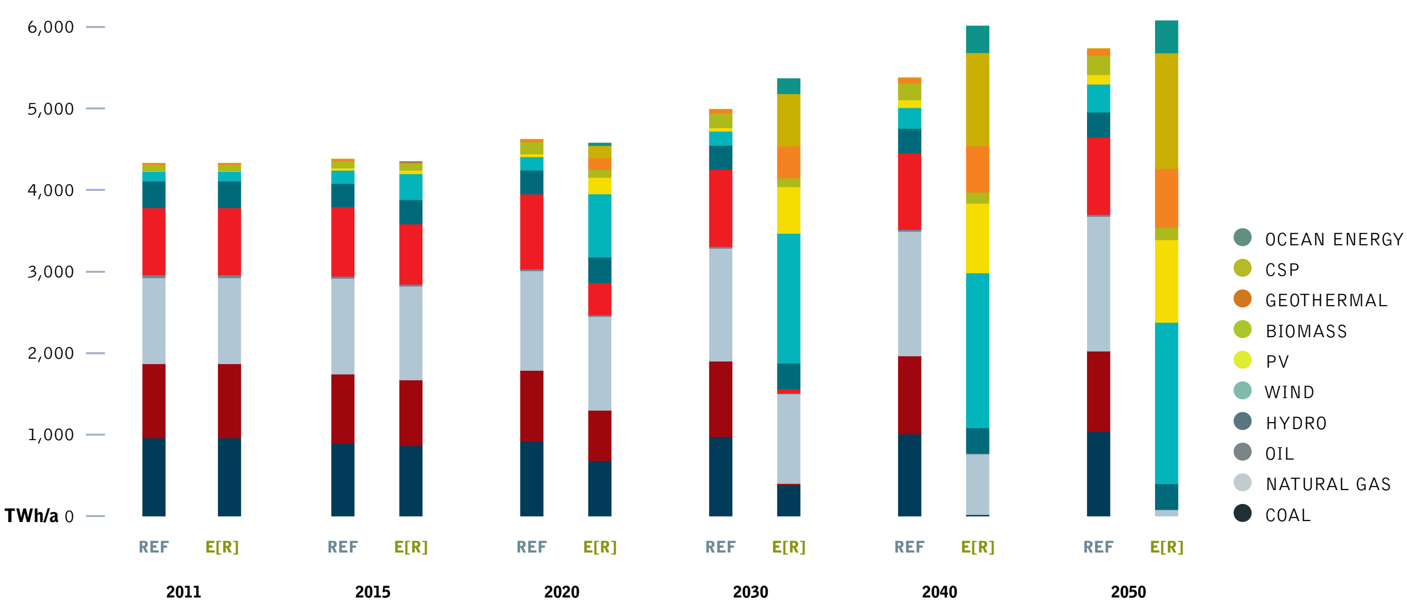


image HYDRAULIC FRACTURING SITES IN WELD COUNTY IN NORTH CENTRAL COLORADO.

image TURBINES SPIN IN A WIND FARM IN THE COACHELLA VALLEY NEAR PALM SPRINGS, CALIFORNIA. THE PROJECT HAS MORE THAN 4,000 INDIVIDUAL TURBINES AND POWERS PALM SPRINGS AND THE REST OF THE DESERT VALLEY.

4.3 future costs of electricity generation

Figure 4.6 shows that the introduction of renewable technologies under the Energy [R]evolution scenario slightly increases the future costs of electricity generation compared to the Reference scenario. This difference will be only around 0.3 US$ cent/kWh up to 2025, however, if increasing fossil fuel prices are assumed. Because of high costs for conventional fuels and the lower CO_2 intensity of electricity generation, electricity generation costs will become economically favorable under the Energy [R]evolution scenario and by 2050 costs will be 10.5 US$ cents/kWh below those in the Reference version.

Under the Reference scenario,on the other hand, unchecked growth in demand, an increase in fossil fuel prices and the cost of CO_2 emissions result in total electricity supply costs rising from today's US$ 469 billion per year to more than US$ 1,088 billion in 2050. Figure 4.6 shows that the Energy [R]evolution scenario not only complies with USA's CO_2 reduction targets but also helps to stabilize 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 47% lower than in the Reference scenario.

4.4 future investments in the power sector

It would require US$ 6,754 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$ 4,084 billion or US$ 103 billion annual more than in the Reference scenario (US$ 2,670 billion). Under the Reference version, the levels of investment in conventional power plants add up to almost 66% while approx. 34% would be invested in renewable energy and cogeneration (CHP) until 2050.

Under the Energy [R]evolution scenario, however, USA would shift almost 95% of the entire investment towards renewables and cogeneration. Until 2030, the fossil fuel share of power sector investment would be focused mainly on CHP plants. The average annual investment in the power sector under the Energy [R]evolution scenario between today and 2050 would be approximately US$ 169 billion.

Because renewable energy has no fuel costs, however, the fossil fuel cost savings (excluding nuclear) in the Energy [R]evolution scenario reach a total of US$ 6,124 billion up to 2050, or US$ 153 billion per year. The total fuel cost savings therefore would cover 150% of 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 4.6: total electricity supply costs and specific electricity generation costs under two scenarios

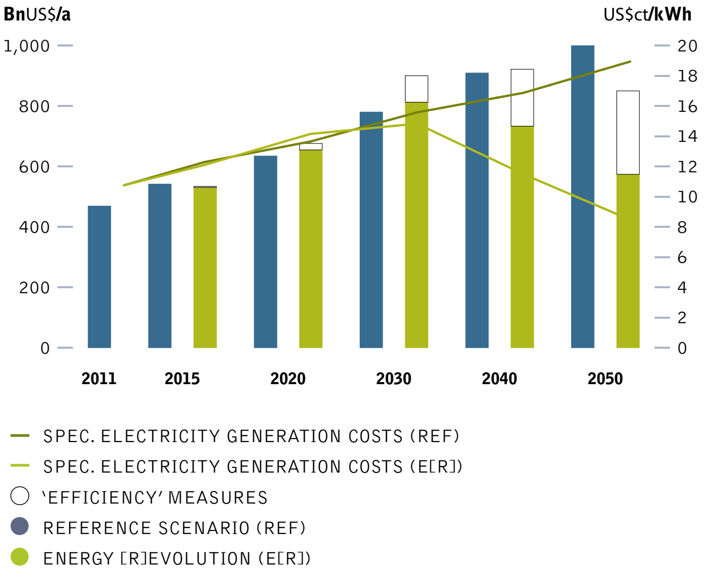
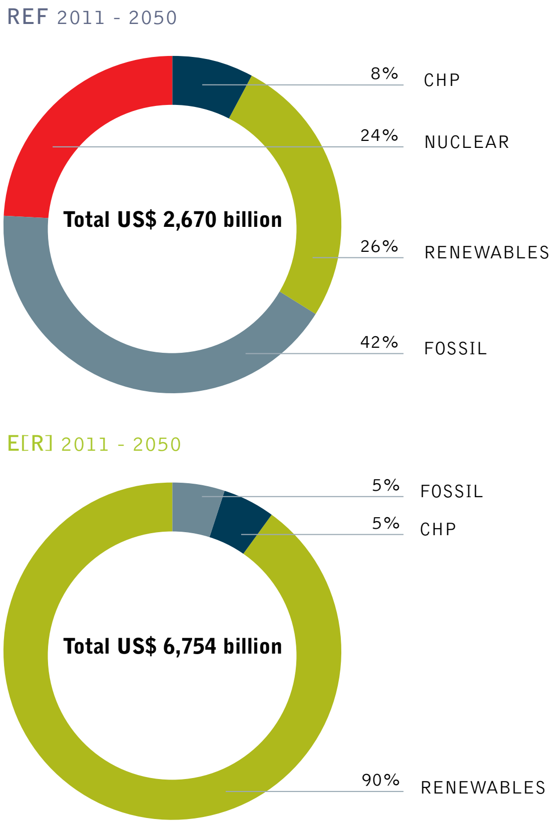


figure 4.7: investment shares - reference scenario versus energy [r]evolution scenario



4.5 energy supply for heating and cooling

Today, renewables meet 10% of USA's primary energy demand for heat supply, the main contribution coming from the use of biomass. The lack of district heating networks is a severe structural barrier to the large scale utilization of geothermal and solar thermal energy. Dedicated support instruments are required to ensure a dynamic development. In the Energy [R]evolution scenario, renewables provide 45% of USA's total heat demand in 2030 and 94% 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 4.2 shows the development of the different renewable technologies for heating in the US over time. Up to 2020 biomass will remain the main contributor of the growing market share. After 2020, the continuing growth of solar collectors and a growing share of geothermal heat pumps will reduce the dependence on fossil fuels.

table 4.2: projection of renewable heating and cooling energy supply under the reference and the energy [r]evolution scenario IN TRILLION BTU/A

		2011	2020	2030	2040	2050
Biomass	REF	1,627	1,798	2,007	2,253	2,506
	E[R]	1,627	1,779	1,862	2,012	2,053
Solar collectors	REF	56	68	80	93	105
	E[R]	56	766	2,484	3,713	3,996
Geothermal	REF	14	16	21	28	39
	E[R]	14	818	2,607	4,444	5,841
Hydrogen	REF	0	0	0	0	0
	E[R]	0	229	692	1,144	1,426
Total	**REF**	**1,697**	**1,882**	**2,108**	**2,373**	**2,651**
	E[R]	**1,697**	**3,592**	**7,646**	**11,313**	**13,316**

figure 4.8: supply structure for heating and cooling under the reference scenario and the energy [r]evolution scenario

(WITHOUT ELECTRICITY FOR HEAT) ('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)

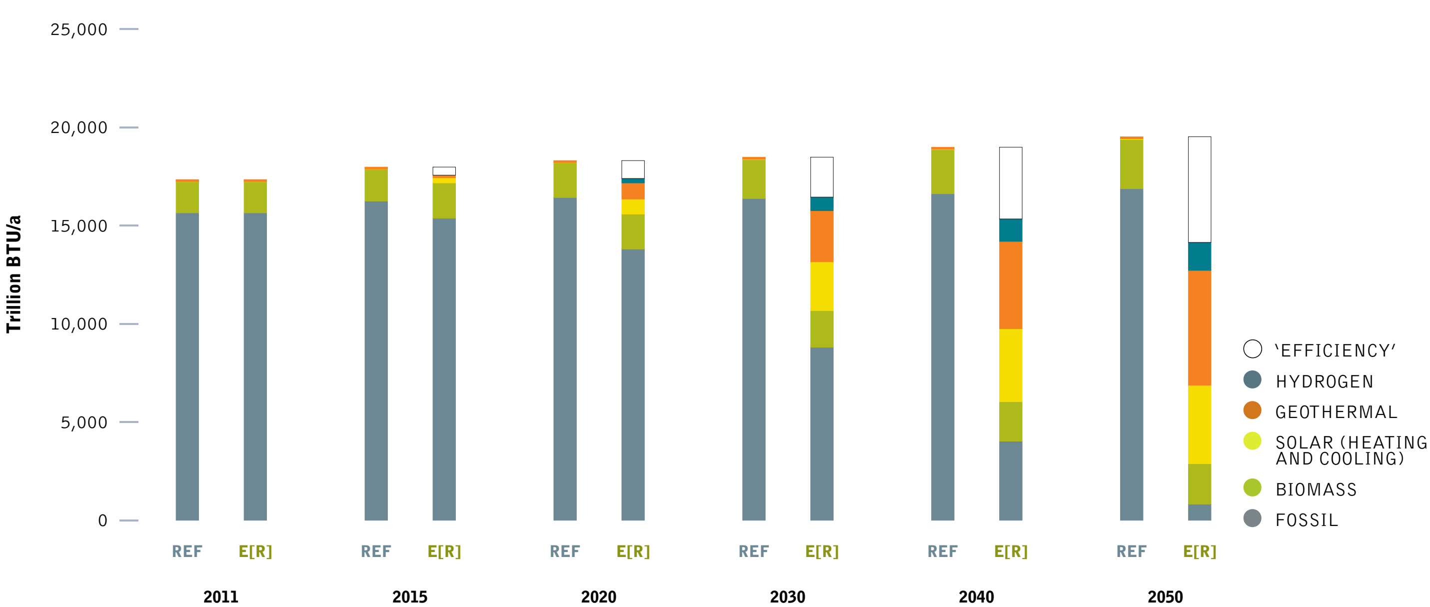


image SALVAGE TEAMS CONDUCT AN ASSESSMENT OF SHELL'S KULLUK DRILL BARGE ON JANUARY 9, 2013 IN KODIAK ISLAND'S KILIUDA BAY IN ALASKA. THE KULLUK, RAN AGROUND NEW YEAR'S EVE IN A POWERFUL STORM OFF THE COAST OF SITKALIDAK ISLAND.

image XCEL ENERGY'S GREATER SANDHILL SOLAR PROJECT IN MOSCA, COLORADO. THE SUNPOWER CONSTRUCTED FACILITY ON 200 ACRES GENERATES 19 MWAC POWER WITH 50,000 PV MODULES ON A GROUND-MOUNT TRACKER SYSTEM USING SUNPOWER T20 TRACKER SUNPOWER HIGH-EFFICIENCY PV MODULES.

4.6 future investment in the heating and cooling sector

In the heat sector the Energy [R]evolution scenario would require a major revision of current investment strategies in heating technologies. Especially solar and heat pump technologies need enormous increase in installations, if these potentials are to be tapped for the heat sector. Installed capacity needs to increase by the factor of 70 for solar thermal and by the factor of about 400 for heat pumps. Capacity of biomass technologies will decrease but remain a pillar of heat supply. In addition, a strong role of geothermal heat for district heating and low temperature process heat in industry was assumed.

Renewable heating technologies are extremely variable, from low tech biomass stoves and unglazed solar collectors to very sophisticated enhanced geothermal systems and solar thermal district heating plants with seasonal storage. Thus it can only roughly be calculated, that the Energy [R]evolution scenario in total requires around US$ 4,300 billion to be invested in renewable heating technologies until 2050 (including investments for replacement after the economic lifetime of the plants) - approximately US$ 108 billion per year.

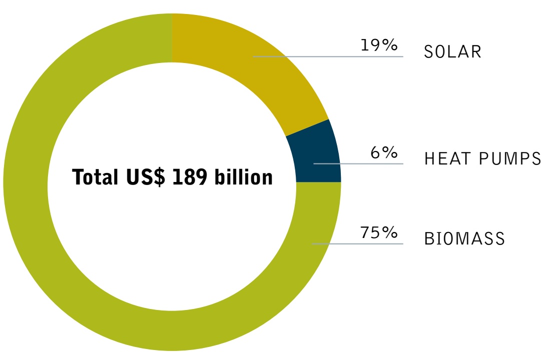
table 4.3: renewable heating and cooling capacities under the reference scenario and the energy [r]evolution scenario

IN GW

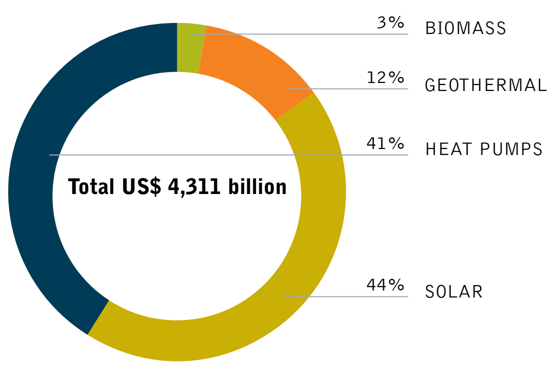
		2011	2020	2030	2040	2050
Biomass	REF	215	223	248	270	296
	E[R]	215	228	210	199	190
Geothermal	REF	0	0	0	0	0
	E[R]	0	18	75	184	223
Solar thermal	REF	17	19	23	27	31
	E[R]	17	243	809	1,245	1,341
Heat pumps	REF	2	2	3	4	5
	E[R]	2	128	352	528	652
Total	**REF**	**234**	**244**	**273**	**300**	**332**
	E[R]	**234**	**617**	**1,446**	**2,156**	**2,406**

figure 4.9: investments for renewable heat and cooling technologies under the reference scenario and the energy [r]evolution scenario

REF 2011 - 2050



E[R] 2011 - 2050



4.7 transport

A key target in the USA is to introduce incentives for people to drive smaller cars, something almost completely absent today. In addition, it is vital to shift transport use to efficient modes like rail, light rail and buses, especially in the expanding large metropolitan areas as well as reduced air travel per capita. Together with rising prices for fossil fuels, these changes reduce the huge car sales projected under the Reference scenario. Energy demand from the transport sector is reduced by around 18,700 Trillion BTU/a in 2050 (saving 71%) compared to the Reference scenario. Energy demand in the transport sector will therefore decrease between 2011 and 2050 by 71% to 7,480 Trillion BTU/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 12% of the transport sector's total energy demand in the Energy [R]evolution, while in 2050 the share will be 39%.

table 4.4: transport energy demand by mode under the reference scenario and the energy [r]evolution scenario

(WITHOUT ENERGY FOR PIPELINE TRANSPORT) IN TRILLION BTU/a

		2011	2020	2030	2040	2050
Rail	REF	499	547	602	633	663
	E[R]	499	560	582	610	614
Road	REF	21,464	21,394	20,132	20,797	21,593
	E[R]	21,464	20,205	14,172	9,363	5,271
Domestic aviation	REF	2,254	2,288	2,388	2,482	2,578
	E[R]	2,254	1,967	1,592	1,285	1,095
Domestic navigation	REF	455	508	508	520	533
	E[R]	455	470	413	378	343
Total	**REF**	**24,672**	**24,738**	**23,630**	**24,432**	**25,367**
	E[R]	**24,672**	**23,202**	**16,758**	**11,636**	**7,323**

figure 4.10: final energy consumption for transport under the reference scenario and the energy [r]evolution scenario

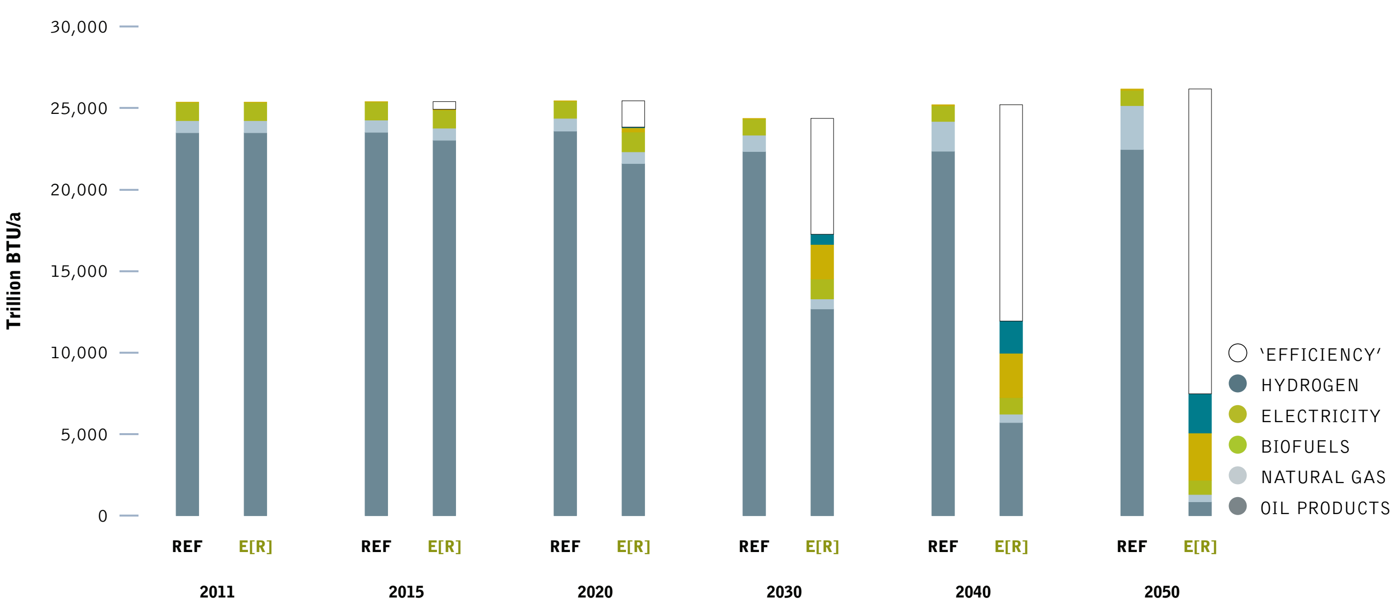


image WIND TURBINES AT THE MINCO 1 ENERGY CENTER IN MINCO, OKLAHOMA. EACH TURBINE HAS A 1.6-MEGAWATT CAPACITY, GENERATING 99.2 MEGAWATTS OF RENEWABLE ENERGY.

image A FEW DAYS BEFORE THE FUKUSHIMA NUCLEAR DISASTER ANNIVERSARY, GREENPEACE ACTIVISTS PLANT CHERRY TREES IN FRONT OF DUKE ENERGY'S SHEARON HARRIS NUCLEAR POWER PLANT NEAR NEW HILL, NORTH CAROLINA, WHERE THE COMPANY IS PLANNING TO BUILD A NEW REACTOR.

4.8 development of CO_2 emissions

Whilst USA's emissions of CO_2 will increase by 4% between 2011 and 2050 under the Reference scenario, under the Energy [R]evolution scenario they will decrease from 5,420 million tonnes in 2011 to 188 million tonnes in 2050. Annual per capita emissions will drop from 17.1 tonnes to 0.5 tonnes. In spite of the phasing out of nuclear energy and increasing demand, CO_2 emissions will decrease in the electricity sector. In the long run efficiency gains and the increased use of renewable energy in vehicles will reduce emissions in the transport sector. With a share of 45 % of CO_2, the transport sector will be the largest remaining source of emissions in 2050. By 2025, USA's CO_2 emissions are 27% below 1990 levels, by 2030 the reduction is 48%, while by 2050 the total energy related CO_2 reduction reaches 96%.

4.9 primary energy consumption

Taking into account the assumptions discussed above, the resulting primary energy consumption under the Energy [R]evolution scenario is shown in Figure 4.12. Compared to the Reference scenario, overall primary energy demand will be reduced by 46% in 2050. Around 87% of the remaining demand will be covered by renewable energy sources.

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 42% in 2030 and 87% in 2050. Nuclear energy is phased out just after 2035.

figure 4.11: development of CO_2 emissions by sector under the energy [r]evolution scenario ('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)

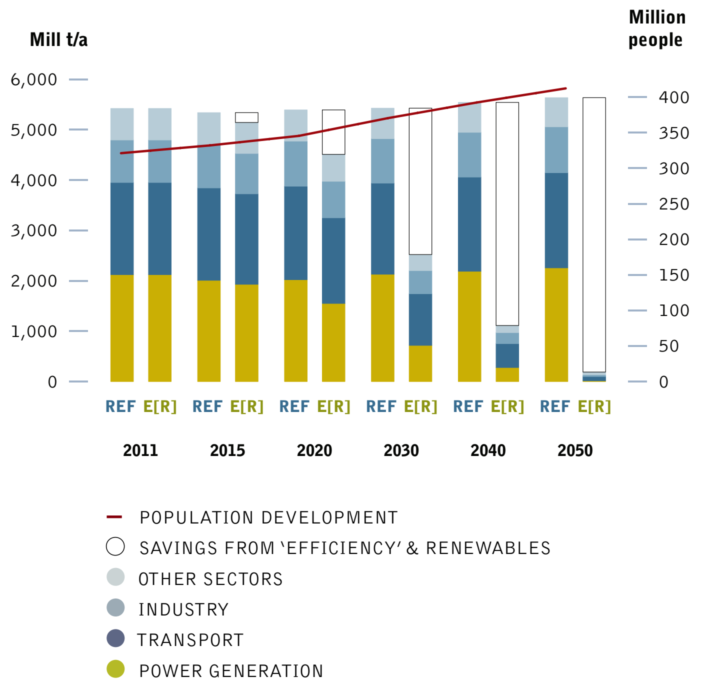


figure 4.12: primary energy consumption under the reference scenario and the energy [r]evolution scenario

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

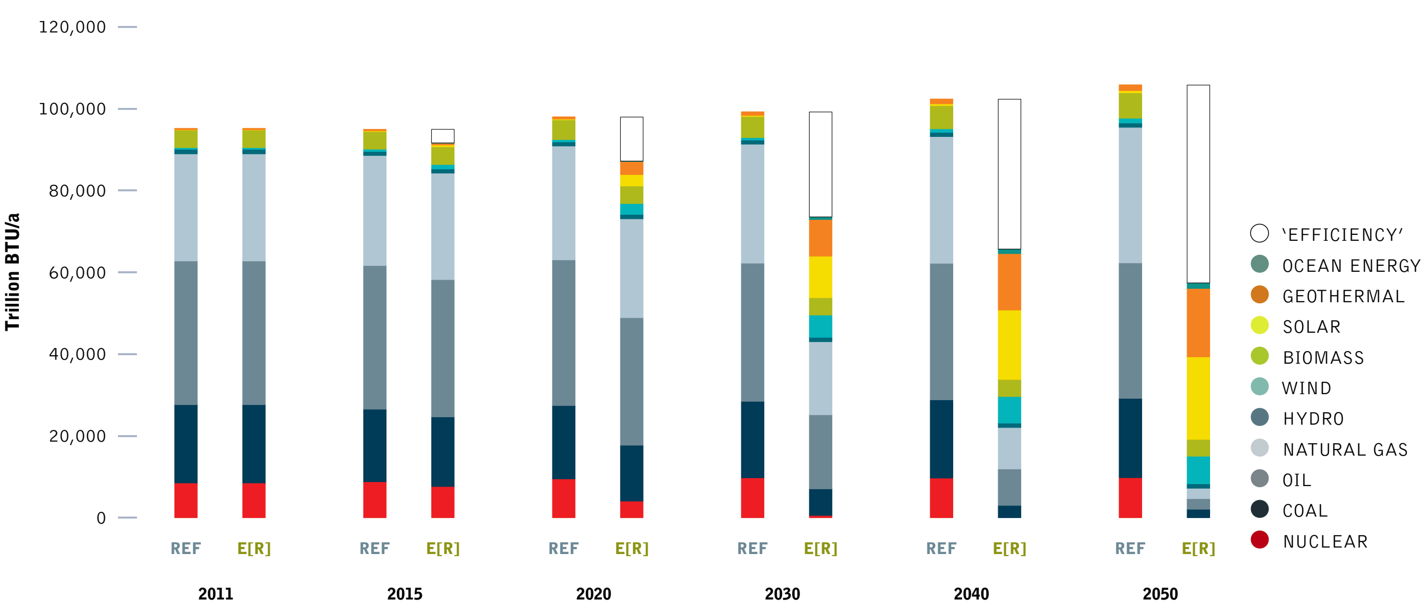


table 5.5: investment costs for electricity generation and fuel cost savings under the energy [r]evolution scenario compared to the reference scenario

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$	-287.9	-413.4	-432.5	-432.5	-1,403.7	-35.1
Renewables	billion US$	1,077.9	1,783.5	905.7	905.7	5,487.8	137.2
Total	billion US$	**790.0**	**1,370.1**	**473.2**	**473.2**	**4,084.2**	**102.1**

ACCUMULATED FUEL COST SAVINGS							
SAVINGS CUMULATIVE E[R] VERSUS REF							
Fuel oil	billion US$/a	1.0	10.6	26.9	35.9	74.3	1.9
Gas	billion US$/a	48.1	294.2	1,070.9	2,646.7	4,059.9	101.5
Hard coal	billion US$/a	41.8	272.4	526.2	661.7	1,502.2	37.6
Lignite	billion US$/a	15.2	103.1	172.1	197.0	487.3	12.2
Total	billion US$/a	**106.1**	**680.3**	**1,796.1**	**3,541.2**	**6,123.7**	**153.1**

employment projections

5

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

image RECORD-BREAKING RAIN TRIGGERED SEVERE AND WIDESPREAD FLOODING ACROSS TENNESSEE STARTING ON MAY 1, 2010. FLOODS ACROSS TENNESSEE, MISSISSIPPI, AND KENTUCKY CAUSED AT LEAST 27 DEATHS AND DAMAGED PARTS OF HISTORIC NASHVILLE, REPORTED CNN ON MAY 4.

5.1 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, 2011a). The Institute for Sustainable Futures (ISF) analyzed 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 USA's Energy [R]evolution and Reference scenario.

Employment is projected for the US 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 (O&M), 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 & Harris, 2012a.

5.2 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; and
- 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; and
- The percentage of world trade which originates in the region for coal and gas fuels, and for renewable traded components.

The electrical capacity increase and energy use figures from each scenario are multiplied by the employment factors for each of the technologies, as well as the proportion of fuel or manufacturing occurring locally. The calculation is summarized in Table 5.1.

table 5.1: methodology overview

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

JOBS = MANUFACTURING + CONSTRUCTION + OPERATION & MAINTENANCE (O&M) + FUEL + HEAT

EMPLOYMENT FACTOR AT 2020 OR 2030 = **2010 EMPLOYMENT FACTOR ×** TECHNOLOGY DECLINE FACTOR$^{\text{(NUMBER OF YEARS AFTER 2010)}}$

image NAMASTE SOLAR INSTALLER JOSH FORD ON A ROOFTOP IN AURORA, COLORADO, DURING A PHOTOVOLTAIC SYSTEM INSTALLATION.

5.3 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.

5.4 employment factors

The employment factors used in the 2013 USA analysis are shown in Table 5.2, with the main source given in the notes. Most factors are from the 2012 global analysis (Rutovitz & Harris, 2012a), but USA only factors are used for coal fuel, nuclear construction and O&M, hydro, and solar thermal power. The data for coal mining employment and geothermal heat has been updated.

table 5.2: employment factors used in the 2013 analysis for the USA 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	25.5	Note 2
Nuclear	10	14.4	1.3	0.6	0.0009 jobs/GWh (not PJ)	Note 3
Biomass	2	14.0	2.9	1.5	32.2	Note 4
Hydro	2	6.0	1.5	0.1		Note 5
Wind onshore	2	2.5	6.1	0.2		Note 6
Wind offshore	4	7.1	10.7	0.2		Note 7
PV	1	9.0	11.0	0.2		Note 8
Geothermal	2	6.8	3.9	0.4		Note 9
Solar thermal	2	5.3	4.0	0.4		Note 10
Ocean	2	9.0	1.0	0.3		Note 11
Geothermal - heat	6.92 jobs/ MW (construction and manufacturing)					Note 12
Solar - heat	7.4 jobs/ MW (construction and manufacturing)					Note 13
Combined Heat and Power (CHP)	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:** Construction, manufacturing and O&M factors are from the JEDI model (National Renewable Energy Laboratory, 2011a). Fuel employment is calculated from the 2010 mining employment of 86,195 from the US EIA (U.S. Energy Information Administration, 2011) and the coal production from the BP world statistical review (BP, 2013).
2. **Gas, oil and diesel:** Installation and manufacturing factors are from the Jobs and Economic Development Impact (JEDI) model (National Renewable Energy Laboratory, 2011b). The O&M factor is an average of the figure from the 2010 report, the JEDI model, a US study (National Commission on Energy Policy, 2009) and ISF research (National Commission on Energy Policy, 2009; National Renewable Energy Laboratory, 2011b; Rutovitz & Harris, 2012a; Rutovitz & Usher, 2010). The fuel factor per PJ is from 2008 information on US gas production (America's Natural Gas Alliance, 2008).
3. **Nuclear:** The construction and O& M factor is from a US study (National Commission on Energy Policy, 2009). The manufacturing factor is from the 2012 global report (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 studies from Greece, the UK, Spain, USA, and Europe wide (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 studies (Domac, Richards, & Risovic, 2005; EPRI, 2001; Hillring, 2002; Thornley, 2006; Upham & Speakman, 2007; Valente, Spinelli, & Hillring, 2011).
5. **Hydro – large:** Employment factors are from a US study (Navigant Consulting, 2009).
6. **Wind – onshore:** The installation factor used is from the European Wind Energy Association (EWEA). The manufacturing factor is derived using the employment per MW in turbine manufacture at Vestas from 2007 to 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 employment factors are all from the JEDI model (National Renewable Energy Laboratory, 2011)
9. **Geothermal:** The construction and installation, and O&M factor is derived from a study conducted by Sinclair Knight Merz (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:** Construction and O&M jobs were derived from a weighted average of eight reported power plants (1512 MW) in the US (Rutovitz & Harris, 2012a). The manufacturing factor came 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 jobs creation potential for that technology, and the O&M factor used here is based on that report (Soerensen, 2008).
12. **Geothermal and heat pumps:** One overall factor has been used for jobs per MW installed. This is derived from analysis of a US industry survey in 2012, which reported 9,088 total jobs in 2012, including 2,611 manufacturing jobs (Battocletti & Glassley, 2012). Shipments of heat pumps during that year came to 1,314 MW.
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 comes is derived from the IEA heating and cooling program report (Weiss & Mauthner, 2011).

5.5 coal, gas and renewable technology trade

It is assumed that all net manufacturing for energy technologies, including wind and PV, occurs within the US.

The USA is a significant producer of coal and gas, and is the fourth largest hard coal exporter (International Energy Agency, 2011b). Coal exports in the Reference scenario are taken from the 2011 World Energy Outlook New Policies scenario (International Energy Agency, 2011a). Coal exports in the Energy [R]evolution scenario are calculated from the percentage of trade which the US has in the IEA scenario at 2020 and 2030, multiplied by the projected world imports of coal in MTCE from the global Energy [R]evolution scenario (Teske et al., 2012).

The proportion of domestic gas production in the Reference scenario is taken from the US Energy Information Agency projection (U.S. Energy Information Administration, 2012); both consumption and production has increased more rapidly than projected in the 2011 World Energy Outlook (International Energy Agency, 2011a). In the [R]evolution scenario, gas production is assumed to increase, but only to keep pace with consumption. It is assumed that the projected rise in production in the US EIA projection would not eventuate if global and US consumption increases more slowly.

The proportion of domestic coal and gas production, and the MTCE coal exports in each scenario, are shown in Table 5.3 and Table 5.4. It is assumed that the US becomes self-sufficient in gas production, but does not become an exporter.

5.6 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 5.5. These declines rates are calculated directly from the cost data used in the Energy [R]evolution modelling for the USA.

table 5.5: 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	-0.6%	-0.6%	-0.9%
Wind onshore	1.6%	2.2%	0.2%
Solar PV	12.0%	4.6%	2.2%
Geothermal power	3.5%	5.4%	7.3%
Solar thermal power	5.6%	5.1%	2.8%
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 5.3: proportion of coal and gas consumption produced within the USA

		REFERENCE SCENARIO			ENERGY [R]EVOLUTION SCENARIO		
	2010	2015	2020	2030	2015	2020	2030
Coal	100%	100%	100%	100%	100%	100%	100%
Gas	89%	89%	93%	96%	99%	100%	100%

table 5.4: coal exports from the USA in both scenarios (MTCE)

		REFERENCE SCENARIO			ENERGY [R]EVOLUTION SCENARIO		
	2010	2015	2020	2030	2015	2020	2030
Coal	35.9	55.2	74.6	79.4	24.0	4.2	1.4

image A STUDENT, LEFT, AND TEACHER, WORK TOGETHER ON AN ADVANCED TROUBLE SHOOTING COURSE AMONG SOLAR PANELS AT THE SOLAR ENERGY INTERNATIONAL, A NON-PROFIT SOLAR ENERGY TECHNOLOGY TRAINING PROGRAM IN PAONIA WHERE MORE THAN 30,000 TECHNICIANS HAVE TRAINED SINCE 1991.

5.7 future employment in the energy sector

Energy sector jobs in USA are higher in the Energy [R]evolution scenario at every stage in the projection. In 2015, extremely strong growth in renewable energy in the Energy [R]evolution scenario mean overall energy employment increases by 665,300 (61%), while jobs in the Reference scenario remain static. Jobs in the Energy [R]evolution drop between 2020 and 2030, but remain 414,000 above 2010 levels. Jobs in the Reference scenario are just 27,000 above 2010 levels by 2030.

- In 2015, jobs in the Energy [R]evolution scenario increase by 61% to 1.8 million, while jobs in the Reference scenario remain static.
- In 2020, there are nearly 2.0 million energy sector jobs in the Energy [R]evolution scenario and just over 1.1 million in the Reference scenario.
- In 2030, there are approximately 1.5 million jobs in the Energy [R]evolution scenario and 1.1 million jobs in the Reference scenario.

Figure 5.1 shows the change in job numbers under both scenarios for each technology between 2010 and 2030. Jobs in the Reference scenario remain relatively constant over the entire period.

In the Energy [R]evolution scenario, energy sector jobs double by 2015, with 0.7 million additional jobs. Jobs drop between 2015 and 2030, but despite this are 38% above 2010 levels. Renewable energy accounts for 61% of energy jobs by 2030, with solar heat having the greatest share (18%), followed by geothermal and heat pump heat and wind.

figure 5.1: employment in the energy sector under the reference and energy [r]evolution scenarios

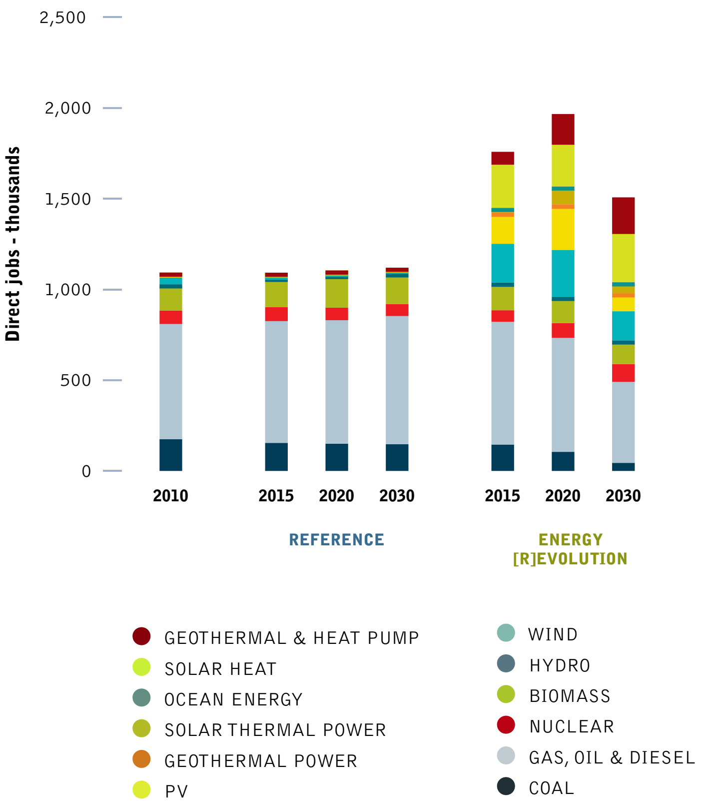


table 5.6: total employment in the energy sector THOUSAND JOBS

		REFERENCE			ENERGY [R]EVOLUTION		
	2010	2015	2020	2030	2015	2020	2030
Coal	175	155	150	148	145	105	44
Gas, oil & diesel	634	671	680	706	676	628	446
Nuclear	75	77	70	67	63	81	98
Renewable	209	190	205	200	873	1,152	919
Total Jobs (thousands)	**1,093**	**1,093**	**1,105**	**1,120**	**1,759**	**1,967**	**1,507**
Construction and installation	61	42	29	26	394	548	490
Manufacturing	48	13	12	20	330	429	250
Operations and maintenance	231	235	241	242	235	253	251
Fuel supply (domestic)	749	796	816	824	797	736	516
Coal and gas export	4	6	8	8	3	0	0
Total Jobs (thousands)	**1,093**	**1,093**	**1,105**	**1,120**	**1,759**	**1,967**	**1,507**

note
numbers may not add up due to rounding

figure 5.2: employment in the energy sector by technology in 2010 and 2030

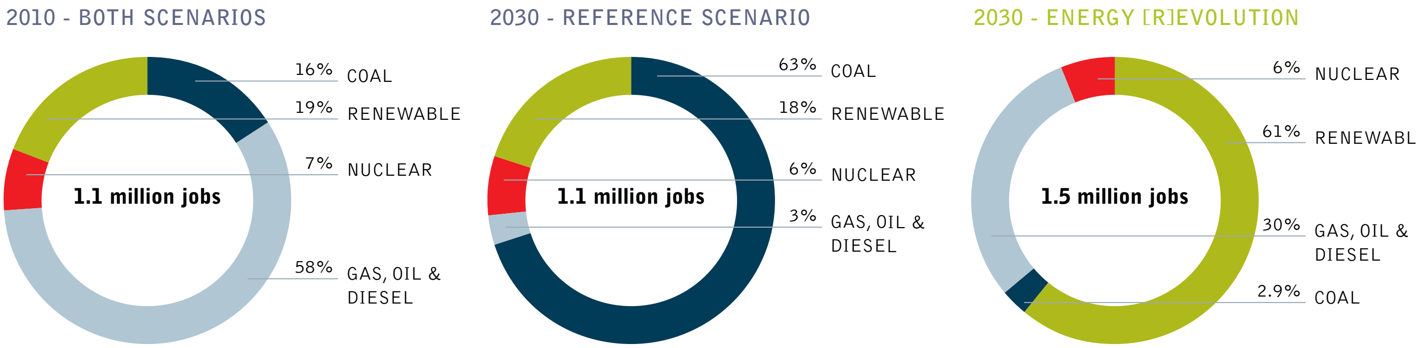


table 5.7: employment in the energy sector by technology, two scenarios THOUSAND JOBS

		REFERENCE			ENERGY [R]EVOLUTION		
By sector	2010	2015	2020	2030	2015	2020	2030
Construction and installation	60	42	27	24	176	280	175
Manufacturing	47	13	11	19	240	299	97
Operations and maintenance	231	235	241	242	235	253	251
Fuel supply (domestic)	749	796	816	824	797	736	516
Coal and gas export	4	6	8	8	3	0	0
Solar and geothermal heat	1	1	3	3	309	399	468
Total jobs (thousands)	**1,093**	**1,093**	**1,105**	**1,120**	**1,759**	**1,967**	**1,507**
By technology							
Coal	175	155	150	148	145	105	44
Gas, oil & diesel	634	671	680	706	676	628	446
Nuclear	75	77	70	67	63	81	98
Renewable	**209**	**190**	**205**	**200**	**873**	**1,152**	**919**
Biomass	*134*	*151*	*167*	*156*	*137*	*132*	*118*
Hydro	*11*	*11*	*13*	*13*	*15*	*13*	*13*
Wind	*37*	*12*	*12*	*20*	*214*	*259*	*160*
PV	*23*	*12*	*8*	*6*	*154*	*226*	*78*
Geothermal power	*2.0*	*2.7*	*1.8*	*1.8*	*17.5*	*25.8*	*21.5*
Solar thermal power	*1.5*	*0.5*	*0.4*	*0.2*	*24.1*	*83.9*	*46.1*
Ocean	*-*	*-*	*-*	*-*	*2.3*	*14.5*	*14.5*
Solar - heat	*1*	*0*	*2*	*2*	*237*	*229*	*266*
Geothermal & heat pump	*0.2*	*0.2*	*0.1*	*0.4*	*71*	*170*	*202*
Total jobs (thousands)	**1,093**	**1,093**	**1,105**	**1,120**	**1,759**	**1,967**	**1,507**

note
numbers may not add up due to rounding

image WORKER WORKING ON TOP OF WIND TURBINE AT THE FOREST CREEK WIND FARM IN TEXAS WHICH PRODUCES 2.3 MW.

5.8 employment in the renewable heating sector

Employment in the renewable heat sector includes jobs in installation, manufacturing and fuel supply. However, this analysis does not capture jobs associated with export of solar thermal heating systems, so may be an underestimate of jobs in this sector.

5.8.1 employment in solar heating

In the Energy [R]evolution scenario, solar heating would provide 16% of total heat supply by 2030, and would employ approximately 266,000 people. Growth is much more modest in the Reference scenario, with solar heating providing only 0.3% of heat supply in 2030. In the Energy [R]evolution scenario, capacity increases by 47 times over the period, and only 1 fold in the Reference scenario.

5.8.2 employment in geothermal and heat pump heating

In the Energy [R]evolution scenario, geothermal and heat pump heating would provide 17% of total heat supply by 2030, and employ approximately 202,000 people. Growth is very slow in the Reference scenario, with geothermal and heat pump heating providing only 0.1% of heat supply, and only employing about 400 people.

5.8.3 employment in biomass heat (fuel supply only)

The Energy [R]evolution and the Reference scenarios are similar, with biomass heating providing between 6% and 12% of the total heat supply, and employing from 49,000 to 58,000 people. In 2030 onwards, employment and capacities are slightly higher in the Reference scenario compared to the [R]evolution scenario.

table 5.8: solar heating: capacity, heat supplied and direct jobs

		REFERENCE			ENERGY [R]EVOLUTION		
Energy	UNIT	2015	2020	2030	2015	2020	2030
Installed capacity	GW	17.4	19.1	23.0	81	243	809
Heat supplied	Trillion BTU	61	68	80	263	796	2,722
Share of total supply	%	0.3%	0.2%	0.3%	1.5%	4.6%	16%
Annual increase in capacity	MW	53	333	387	32,075	32,331	44,948
Employment							
Direct jobs in installation and manufacture	jobs	400	2,400	2,300	237,000	229,000	266,000

table 5.9: 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	2.1	2.1	2.8	22.6	146.2	426.9
Heat supplied	Trillion BTU	14	16	21	139	818	2,607
Share of total supply	%	0.1%	0.1%	0.1%	0.9%	5.2%	17%
Annual increase in capacity	MW	25	18	67	10,300	24,719	32,252
Employment							
Direct jobs in installation and manufacture	jobs	200	100	400	71,000	170,000	202,000

table 5.10: biomass heat: direct jobs in fuel supply

		REFERENCE			ENERGY [R]EVOLUTION		
Energy	UNIT	2015	2020	2030	2015	2020	2030
Heat supplied	Trillion BTU	1,660	1,798	2,007	1,796	1,779	1,862
Share of total supply	%	10%	6%	7%	11%	11%	12%
Employment							
Direct jobs in fuel supply	jobs	53,000	56,000	53,000	58,000	55,000	49,000

note
this does not include biomass CHP

5.8.4 employment in biomass

Electricity generation from biomass stays relatively constant in the Energy [R]evolution scenario, with biomass generation increasing from 1.7% in 2010, to 2.0% in 2030. Job numbers in biomass for electricity and heat combined reach 118,000 in 2030, 12% higher than in 2010.

In the Reference scenario, biomass generation almost doubles, and provides 3.5% of electricity in 2030. Jobs increase by 13% to 151,000 in 2015, and reach 156,000 by 2030, 17% above 2010 levels. Jobs in biomass fuels for heating are included here.

5.8.5 employment in solar photovoltaics

In the Energy [R]evolution scenario, solar photovoltaics grow from less than 0.9% of electricity supply in 2010 to provide nearly 11% of electricity by 2030. Employment increases to 2020 and then reduces somewhat, but is still 38% above 2010 levels by 2030, at 77,800. In the Reference scenario, growth is very modest. Solar photovoltaics provides 0.9% of generation in 2030, and employs 6,400 people, 72% below the number of solar PV jobs in 2010.

5.8.6 employment in wind energy

In the Energy [R]evolution scenario, wind energy grows very strongly and would provide 30% of total electricity generation by 2030, and employ approximately 160,000 people. Growth is much more modest in the Reference scenario, with wind energy providing only 3% of generation, and employing approximately 20,000 people.

table 5.11: biomass: capacity, generation and direct jobs

		REFERENCE			ENERGY [R]EVOLUTION		
Energy	UNIT	2015	2020	2030	2015	2020	2030
Installed electrical capacity	GW	14	24	30	13	16	21
Total generation	TWh	88	150	177	81	96	109
Share of total supply	%	2.0%	3.2%	3.5%	1.9%	2.1%	2.0%
Annual increase in capacity	MW	1,524	836	450	393	199	595
Employment							
Direct jobs in construction, manufacture, operation and maintenance, and fuel supply (includes biomass for heat)	jobs	150,700	166,900	155,900	137,000	132,200	117,500

table 5.12: solar photovoltaics: capacity, generation and direct jobs

		REFERENCE			ENERGY [R]EVOLUTION		
Energy	UNIT	2015	2020	2030	2015	2020	2030
Installed capacity	GW	18	21	26	26	123	339
Total generation	TWh	29	34	43	42	202	571
Share of total supply	%	0.7%	0.7%	0.9%	1.0%	4.4%	10.6%
Annual increase in capacity	MW	0.6	0.4	1.4	9.5	14.7	16.4
Employment							
Direct jobs in construction, manufacture, operation and maintenance	jobs	12,100	8,100	6,400	154,400	225,700	77,800

table 5.13: wind energy: capacity, generation and direct jobs

		REFERENCE			ENERGY [R]EVOLUTION		
Energy	UNIT	2015	2020	2030	2015	2020	2030
Installed capacity	GW	59	60	62	115	281	568
Total generation	TWh	163	165	174	318	777	1,593
Share of total supply	%	4%	4%	3%	7%	17%	30%
Annual increase in capacity	MW	0.4	0.2	1.6	26.7	27.9	12.7
Employment							
Direct jobs in construction, manufacture, operation and maintenance	jobs	12,100	12,100	19,600	214,100	258,600	160,300

image WORKER ASSEMBLES A SOLAR ARRAY ON THE ROOF OF THE EAGLE LEARNING CENTER AT EASTERN UNIVERSITY IN ST DAVIDS, PHILADELPHIA.

5.8.7 employment in solar thermal power

In the Energy [R]evolution scenario, solar thermal power grows strongly to provide 12% of total electricity generation by 2030, and employs approximately 46,100 people. Growth is very modest in the Reference Scenario, with solar thermal power providing less than 1% of generation, and employing approximately 200 people in 2030.

5.8.8 employment in geothermal power

In the Energy [R]evolution scenario, geothermal power grows strongly to provide 7% of total electricity generation by 2030, and employs approximately 22,000 people. Growth is very modest in the Reference Scenario, with geothermal power providing less than 1% of generation, and employing approximately 1,800 people.

5.8.9 employment in wave and tidal power

In the Energy [R]evolution scenario, wave and tidal power would provide 3% of total electricity generation by 2030, and would employ approximately 15,000 people. Growth is much more modest in the Reference Scenario, with wave and tidal power providing less than 1% of generation, and employing approximately 0 people.

table 5.14: solar thermal power: capacity, generation and direct jobs

		REFERENCE			ENERGY [R]EVOLUTION		
Energy	UNIT	2015	2020	2030	2015	2020	2030
Installed capacity	GW	1.5	1.5	1.5	2.0	76	245
Total generation	TWh	3	3	3	4	153	643
Share of total supply	%	-	0.1%	0.1%	0.1%	3.3%	11.9%
Annual increase in capacity	MW	--	0.00	-0.00	2.14	9.66	2.65
Employment							
Direct jobs in construction, manufacture, operation and maintenance	jobs	500	400	200	24,100	83,900	46,100

table 5.15: geothermal power: capacity, generation and direct jobs

		REFERENCE			ENERGY [R]EVOLUTION		
Energy	UNIT	2015	2020	2030	2015	2020	2030
Installed capacity	GW	3.5	4.7	7.4	3.8	23	63
Total generation	TWh	21	29	49	22	142	389
Share of total supply	%	0%	1%	1%	1%	3%	7%
Employment							
Direct jobs in construction, manufacture, operation and maintenance	jobs	2,730	1,800	1,800	17,500	25,800	21,500

table 5.16: wave and tidal power: capacity, generation and direct jobs

		REFERENCE			ENERGY [R]EVOLUTION		
Energy	UNIT	2015	2020	2030	2015	2020	2030
Installed capacity	GW	-	-	-	0.1	10	45
Total generation	TWh	-	-	-	0.5	33	188
Share of total supply	%	0.0%	0.0%	0.0%	0.0%	0.7%	3.5%
Employment							
Direct jobs in construction, manufacture, operation and maintenance	jobs	0	0	0	2,300	14,500	14,500

5.8.10 employment in coal

Coal sector employment in the Energy [R]evolution scenario falls by 75% from 2010, to reach 44,400 in 2030. In the same period, generation drops to 7% of total supply. Coal sector jobs in the [R]eference scenario also drop, although much less significantly, to reach 147,500 by 2030.

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

5.8.11 employment in gas, oil & diesel

Gas generation in the Energy [R]evolution scenario is projected to be -4% lower in 2030 than in 2010. Jobs are reduced by 188,000 in the same period. In the Reference scenario, gas generation remains relatively constant, and jobs fall by only - 71,600 between 2010 and 2030, -11% below 2010 levels.

5.8.12 employment in nuclear energy

In the Reference scenario, nuclear power is projected to provide 19% of the USA's electricity by 2030. The sector would employ approximately 66,500 people. In the Energy [R]evolution scenario, nuclear power is reduced by 94% over the period. Projected employment in the Energy [R]evolution scenario is 98,100, more than double the Reference scenario employment in nuclear energy. This is because of the large number of people employed on decommissioning as a result of the rapid program to remove nuclear facilities.

table 5.17: 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	154,500	150,200	147,500	145,400	105,200	44,400
gas, oil & diesel	jobs	670,900	680,200	705,900	676,400	628,100	446,300
nuclear energy	jobs	77,300	69,700	66,500	63,400	81,200	98,100
COAL							
Energy							
Installed capacity	GW	317	292	291	304	212	61
Total generation	TWh	1,741	1,787	1,900	1,669	1,298	399
Share of total supply	%	40%	39%	38%	38%	28%	7%
Annual increase in capacity	GW	-5.3	-0.1	0.1	-21.1	-20.8	-14.2
GAS, OIL & DIESEL							
Energy							
Installed capacity	GW	468	469	525	466	451	420
Total generation	TWh	1,200	1,242	1,406	1,174	1,169	1,108
Share of total supply	%	27%	27%	28%	27%	26%	21%
Annual increase in capacity	GW	-0.1	3.8	7.6	-3.5	-2.7	-12.6
NUCLEAR ENERGY							
Energy							
Installed capacity	GW	110	116	119	95	50	6.7
Total generation	TWh	852	919.8	944	739	393	53
Share of total supply	%	19%	19.9%	19%	17%	9%	1%
Annual increase in capacity	GW	1.3	0.7	-1	-11.5	-5.3	-0.7

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
JEDI	Jobs and Economic Development Impact
MW	Megawatt
O&M	Operations and Maintenance
OECD	Organization for Economic Co-operation and Development
PV	Photovoltaic

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

> "the bright future for renewable energy is already underway."

technology DISAPPEARING ISLANDS IN CHESAPEAKE BAY, MARYLAND AND VIRGINIA. SEA LEVELS ARE RISING AS THE OCEAN WARMS AND EXPANDS—AND AS GLACIERS AND ICE SHEETS MELT—BUT THE RISE ISN'T UNIFORM AROUND THE PLANET. RECENT RESEARCH FOUND THAT THE U.S. MID-ATLANTIC COAST IS ONE OF THE AREAS OF ACCELERATED SEA-LEVEL RISE. THE RATE OF INCREASE IN THE DENSELY POPULATED MID-ATLANTIC IS THREE TO FOUR TIMES GREATER THAN AVERAGE GLOBAL SEA-LEVEL RISE.

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

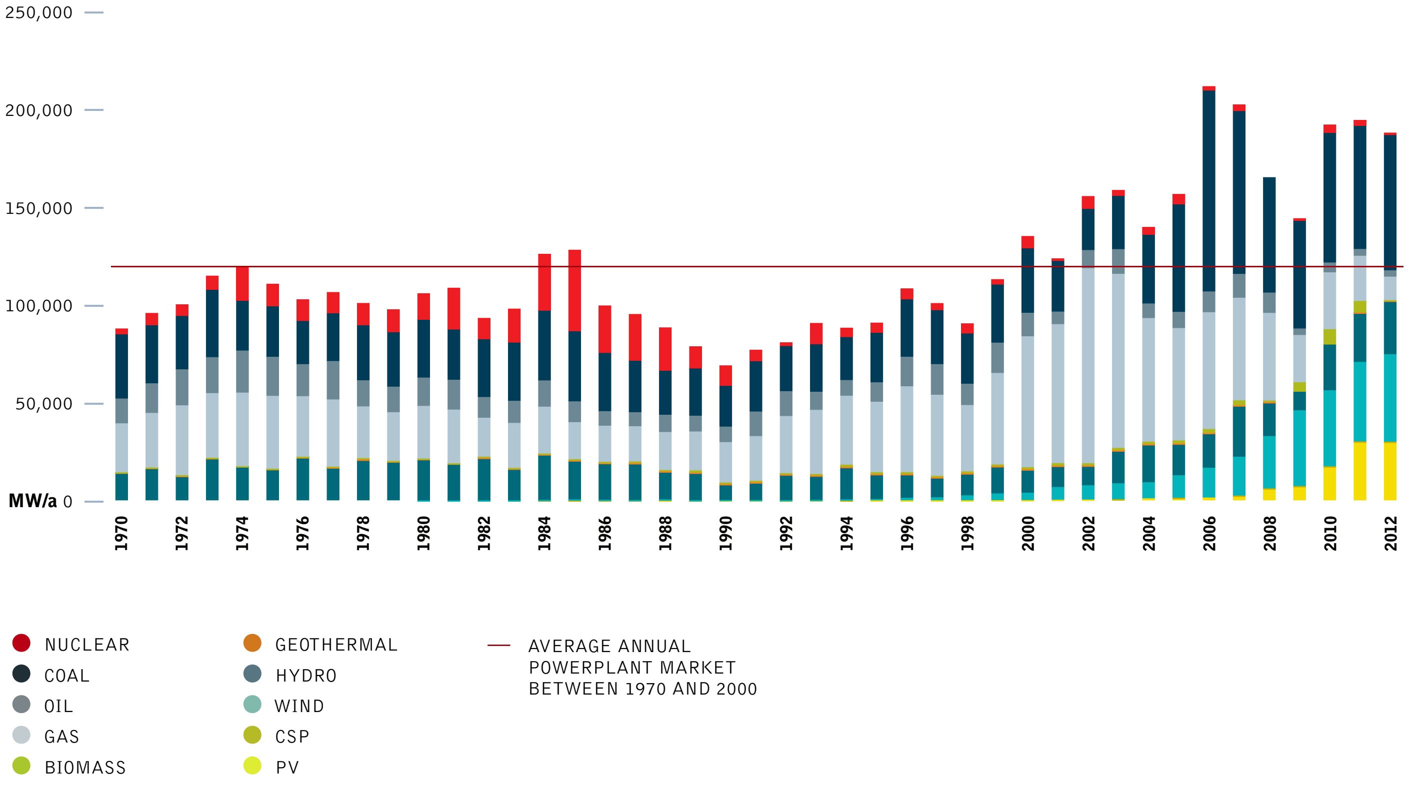
A new analysis of the global power plant market shows that since the late 1990s, renewable energy especially wind and solar photovoltaic installations grew faster than any other power plant technology across the world – over 630,000 MW total new installed capacities between 2000 and 2012. However, it 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 close 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[35] 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 liberalize 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 1970-2012



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

reference
35 ORGANIZATION 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 USA 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 liberalized power markets is fueled 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.

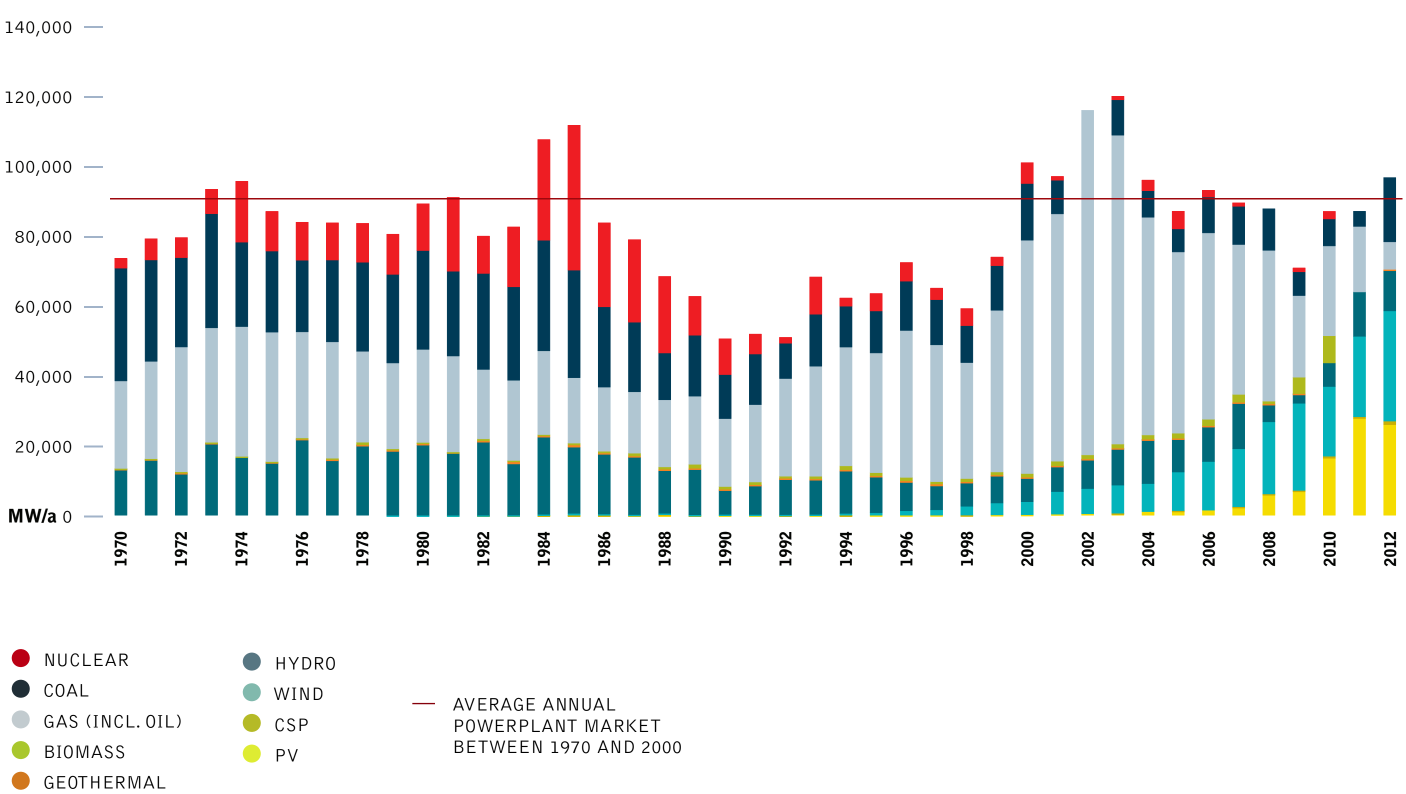
7.2 power plant markets in the US, Europe and China

The graphs show how much electricity market liberalization influences the choice of power plant technology. While the US and European power sectors moved towards deregulated markets, which favor mainly gas power plants, China added a large amount of coal until 2009, with the first signs for a change in favor of renewable energy in 2009 and 2010.

US: Liberalization 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 liberalized 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 programs. 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.

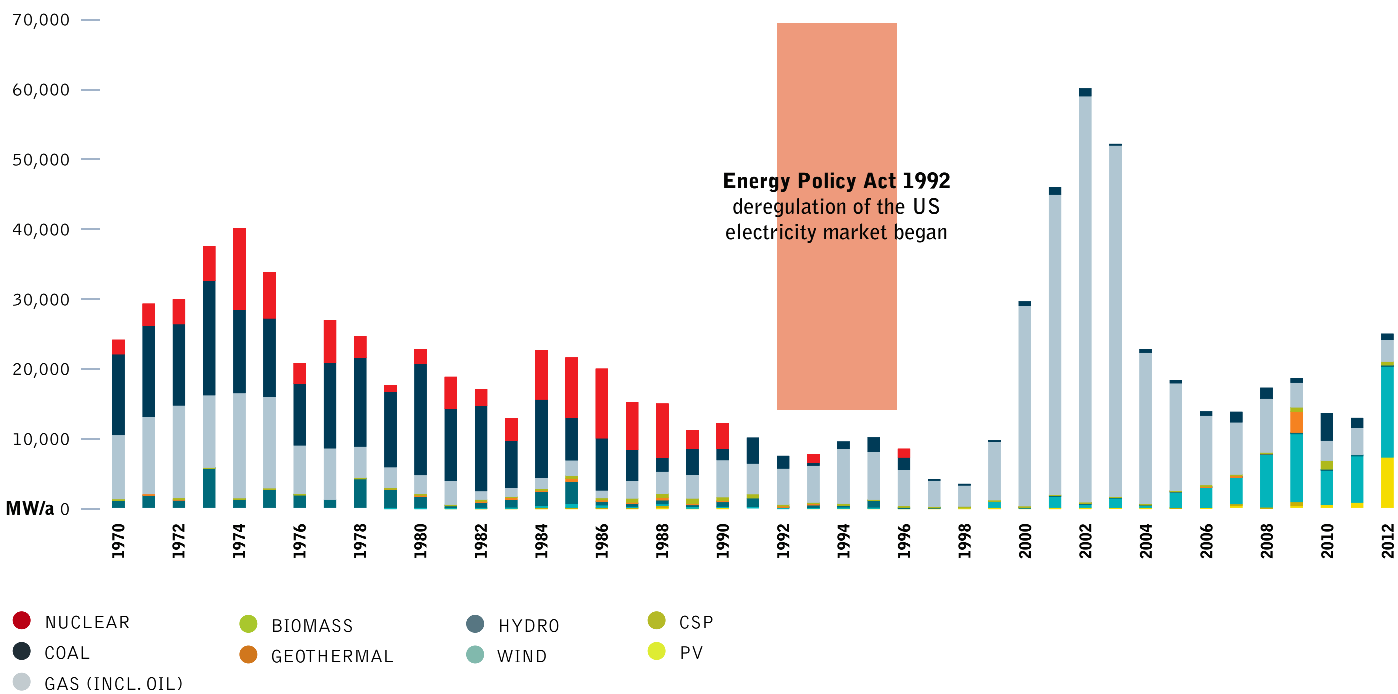
figure 6.2: global power plant market 1970-2012, excluding china



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

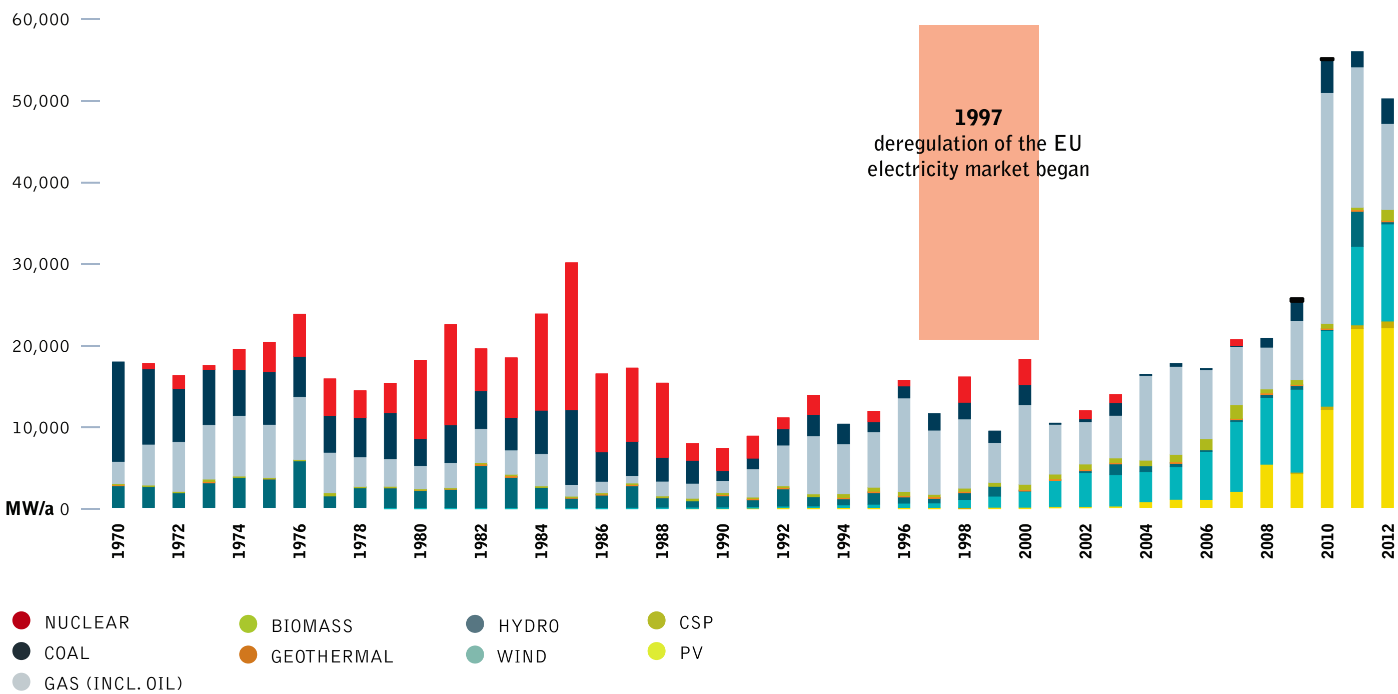
image NESJAVELLIR GEOTHERMAL PLANT GENERATES ELECTRICITY AND HOT WATER BY UTILIZING GEOTHERMAL WATER AND STEAM. IT IS THE SECOND LARGEST GEOTHERMAL POWER STATION IN ICELAND. THE STATION PRODUCES APPROXIMATELY 120MW OF ELECTRICAL POWER, AND DELIVERS AROUND 1,800 LITRES (480 US GAL) OF HOT WATER PER SECOND, 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 6.3: usa: annual power plant market 1970-2012



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

figure 6.4: europe (eu27): annual power plant market 1970-2012



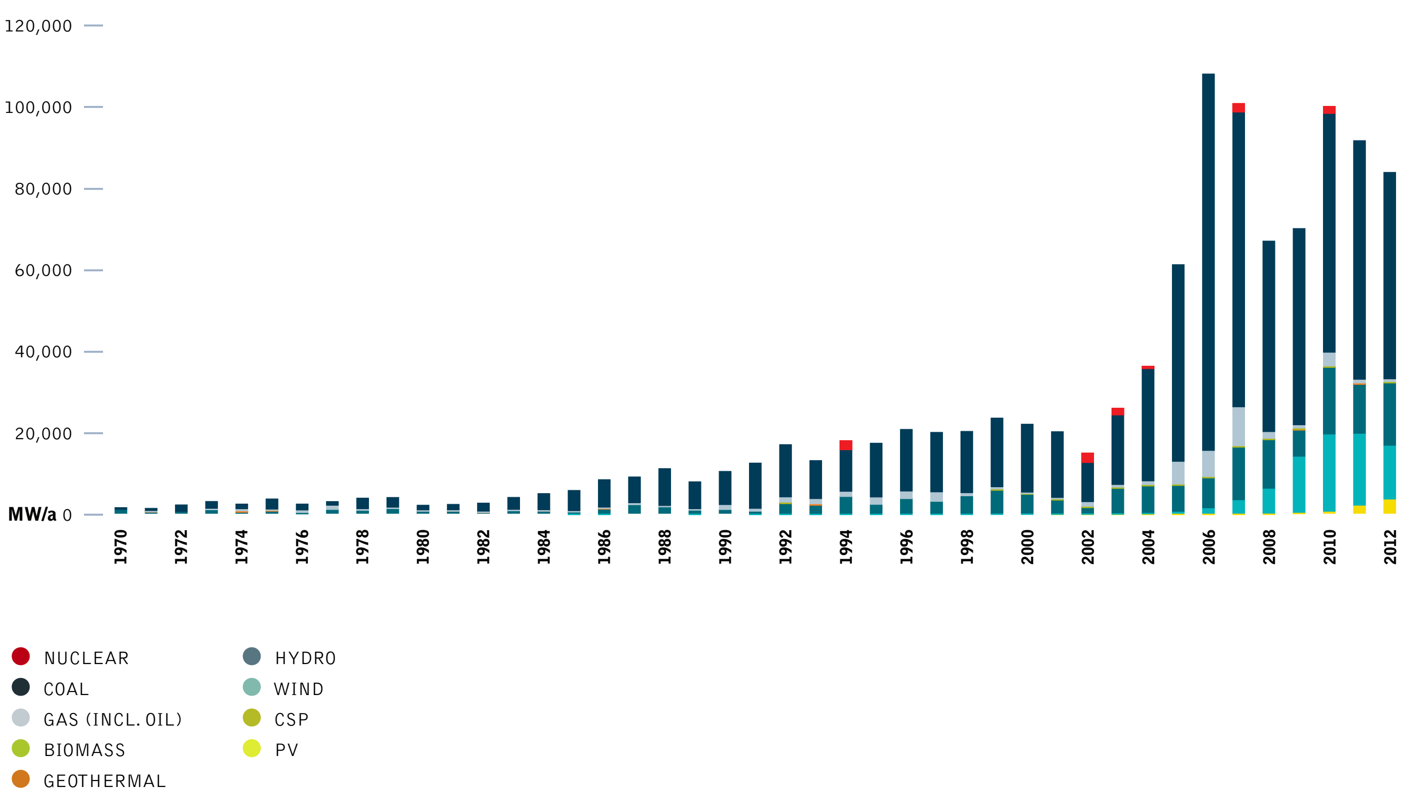
source Platts, REN21, EWEA, GWEC, EPIA, National Statistics, IEA, Breyer, Teske.

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 Program. 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[36] 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 6.5: china: annual power plant market 1970-2012



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

reference

36 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.

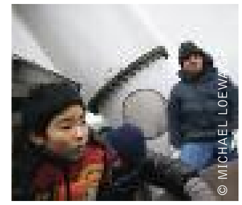


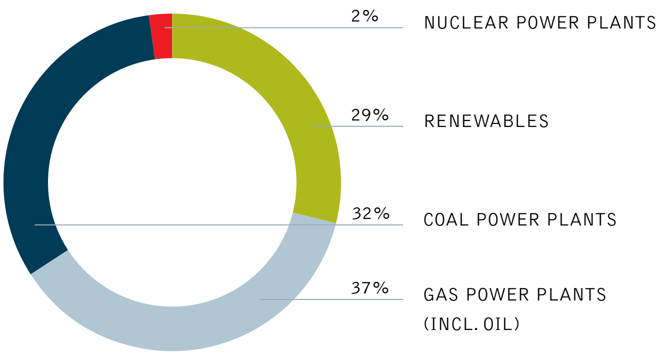
image WITNESSES FROM FUKUSHIMA, JAPAN, KANAKO NISHIKATA, HER TWO CHILDREN KAITO AND FUU AND TATSUKO OGAWARA VISIT A WIND FARM IN KLENNOW IN WENDLAND.

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.

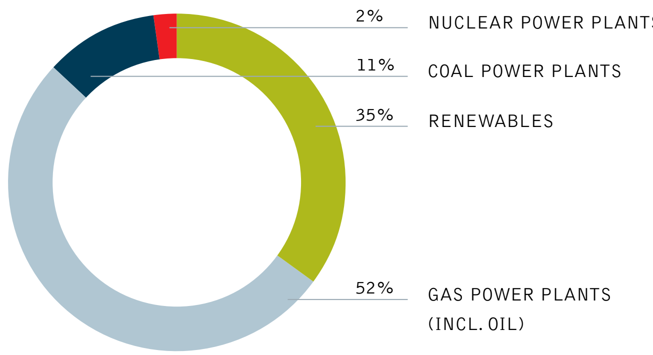
The energy revolution has started on a global level already. This picture is even clearer when we look into the global market shares but exclude China, the country with where the majority of coal expansion takes place. About 35% of all *new* power plants since 2000 have been renewables and 52% have been 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 6.6: power plant market shares

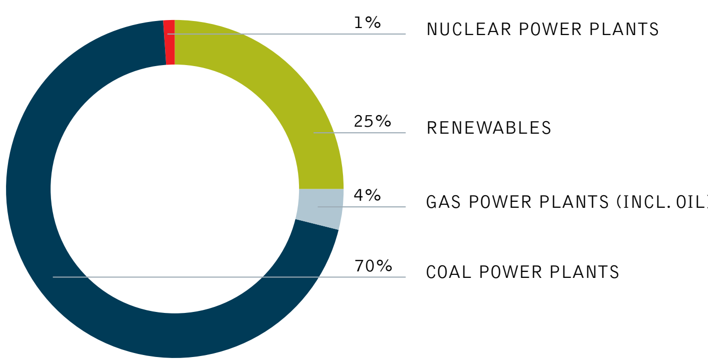
global power plant market shares 2000-2012



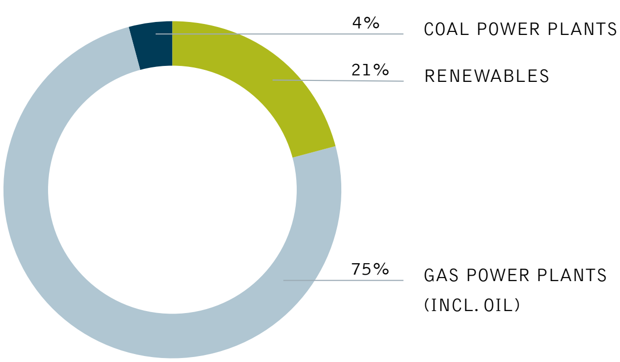
global power plant market shares 2000-2012 - excluding china



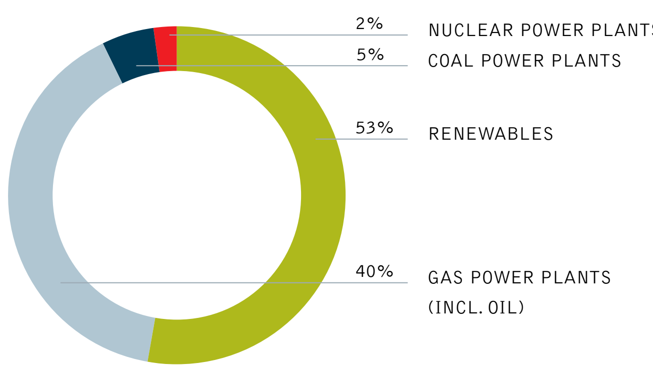
china: power plant market shares 2000-2012



usa: power plant market shares 2000-2012



eu 27: power plant market shares 2000-2012



source PLATTS, IEA, BREYER, TESKE.

6.4 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.

6.4.1 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.

6.4.2 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% CO_2 reduction target and plans for climate mitigation, energy efficiency, and renewable energy.

6.4.3 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).

6.4.4 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 6.1: 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.

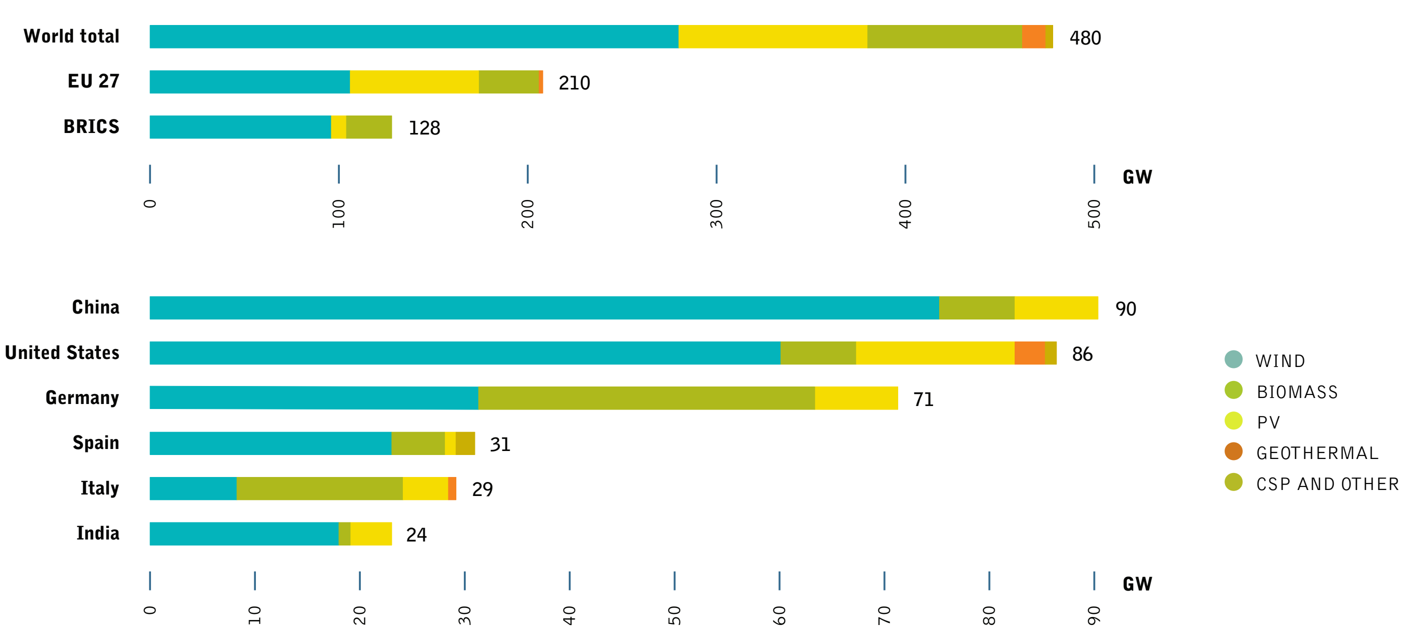
b HYDROPOWER DATA DO NOT INCLUDE PUMPED STORAGE-CAPACITY. FOR MORE INFORMATION, SEE NOTE ON REPORTING AND ACCOUNT ON PAGE XX.

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 6.7: 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

USA: SCENARIO RESULTS DATA

7

> **"Those in Congress who would deny science to protect the polluting interests increasingly look ridiculous, even to their own side... People are waking up. And inevitably, the truth will be fully known."**
>
> **SENATOR SHELDON WHITEHOUSE**
> FROM SPEECH ON SENATE FLOOR 13 NOVEMBER 2013

image THE TOWN OF PAGE ON THE COLORADO RIVER IN NORTHERN ARIZONA. PAGE HOME OF TWO OF THE LARGEST ELECTRICAL GENERATION UNITS IN THE WESTERN UNITED STATES. GLEN CANYON DAM HAS A 1,288,000 KILOWATTS CAPACITY WHEN FULLY ONLINE. THE OTHER POWER PLANT TO THE SOUTHEAST IS THE NAVAJO GENERATING STATION, A COAL-FIRED STEAM PLANT WITH AN OUTPUT CAPABILITY OF 2,250,000 KILOWATTS.

7.1 glossary of commonly used terms and abbreviations

AEO Annual Energy Outlook
CHP Combined Heat and Power
CO_2 Carbon dioxide, the main greenhouse gas
EIA Energy Information Administration
GDP Gross Domestic Product (means of assessing a country's wealth)
IEA International Energy Agency
PPP Purchasing Power Parity (adjustment to GDP assessment to reflect comparable standard of living)
WEO World Energy Outlook

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

7.2 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.

table 7.1: 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 7.2: 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

USA: scenario results data

7

image THE GRAY URBAN FOOTPRINT OF SAN FRANCISCO, OAKLAND, SAN JOSE, AND THEIR SURROUNDING SUBURBS CONTRAST STRONGLY WITH THE GREEN HILLSIDES.

USA: reference scenario

table 7.3: USA: electricity generation

TWh/a	2011	2015	2020	2030	2040	2050
Total generation	**4,330**	**4,381**	**4,623**	**4,992**	**5,379**	**5,736**
Fossil	2,959	2,941	3,029	3,306	3,515	3,699
Coal	957	892	915	973	1,005	1,035
Lignite	911	849	871	927	959	988
Gas	1,054	1,175	1,221	1,384	1,528	1,652
Oil	29	18	15	16	17	18
Diesel	7	7	6	6	6	6
Nuclear	822	852	920	944	939	949
Hydrogen	0	0	0	0	0	0
Renewables	**550**	**588**	**674**	**742**	**925**	**1,089**
Hydro	328	285	293	297	301	306
Wind	120	163	165	174	254	343
PV	6	29	34	43	96	118
Biomass (& renewable waste)	77	88	150	177	205	237
Geothermal	19	21	29	49	65	82
Solar thermal	1	3	3	3	3	3
Ocean energy	0	0	0	0	0	0
Distribution losses	260	262	269	282	302	322
Own consumption electricity	312	299	302	285	243	246
Electricity for hydrogen production	0	0	0	0	0	0
Final energy consumption (electricity)	**3,796**	**3,848**	**4,076**	**4,439**	**4,851**	**5,194**
Fluctuating RES (PV, Wind, Ocean)	126	192	199	217	350	460
Share of fluctuating RES	2.9%	4.4%	4.3%	4.3%	6.5%	8.0%
RES share (domestic generation)	**12.7%**	**13.4%**	**14.6%**	**14.9%**	**17.2%**	**19.0%**

table 7.4: USA: energy supply for heating and cooling

TRILLION BTU/a	2011	2015	2020	2030	2040	2050
Heat from CHP and district heating[1]	**478**	**477**	**476**	**426**	**384**	**334**
Fossil fuels	450	432	421	382	346	304
Biomass[3]	28	45	55	44	38	30
Geothermal	0	0	0	0	0	0
Solar collectors	0	0	0	0	0	0
Hydrogen	0	0	0	0	0	0
Direct heating and cooling[2]	**16,862**	**17,499**	**17,830**	**18,054**	**18,604**	**19,186**
Fossil fuels	15,193	15,808	16,004	15,990	16,268	16,565
Biomass[3]	1,599	1,616	1,743	1,963	2,215	2,476
Solar collectors	56	61	68	80	93	105
Geothermal[1]	14	14	16	21	28	39
Total heat supply[2]	**17,340**	**17,977**	**18,306**	**18,480**	**18,988**	**19,520**
Fossil fuels	15,643	16,241	16,424	16,372	16,614	16,869
Biomass[3]	1,627	1,660	1,798	2,007	2,253	2,506
Solar collectors	56	61	68	80	93	105
Geothermal	14	14	16	21	28	39
Hydrogen	0	0	0	0	0	0
RES share (including RES electricity)	**9.8%**	**9.7%**	**10.3%**	**11.4%**	**12.5%**	**13.6%**

1) including heat pumps 2) including cooling 3) The biomass data is based on the EIA assumption that biomass is carbon neutral which is not the Greenpeace position.

table 7.5: USA: CO_2 emissions

MILL t/a	2011	2015	2020	2030	2040	2050
Condensation power plants	**2,018**	**1,914**	**1,926**	**2,022**	**2,067**	**2,122**
Hard Coal (incl. non-renewable waste)	825	752	742	739	706	688
Lignite	821	760	769	813	836	863
Gas	355	394	408	463	517	564
Oil	12	4	2	2	3	3
Diesel	5	5	4	4	4	4
Combined heat & power production	**154**	**147**	**149**	**163**	**177**	**190**
Hard Coal (incl. non-renewable waste)	47	48	51	60	71	81
Lignite	4	4	3	2	2	1
Gas	95	86	87	92	95	98
Oil	8	9	9	9	9	9
CO_2 emissions power and CHP plants	**2,172**	**2,062**	**2,075**	**2,185**	**2,244**	**2,312**
Hard Coal (incl. non-renewable waste)	872	800	793	799	777	769
Lignite	825	764	772	816	838	864
Gas	449	480	495	555	613	662
Oil & diesel	26	19	15	15	16	17
CO_2 emissions by sector	**5,420**	**5,337**	**5,391**	**5,425**	**5,540**	**5,634**
% of 1990 emissions	111%	109%	111%	111%	114%	116%
Industry[1]	504	540	572	573	584	598
Other sectors[1]	625	633	619	605	594	578
Transport	1,829	1,833	1,855	1,809	1,870	1,888
Power generation[2]	2,122	2,009	2,021	2,129	2,188	2,256
District heating & other conversion[3]	340	321	323	308	304	313
Population (Mill.)	317	328	341	366	388	407
CO_2 emissions per capita (t/capita)	**17.1**	**16.3**	**15.8**	**14.8**	**14.3**	**13.8**

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

table 7.6: USA: installed capacity

GW	2011	2015	2020	2030	2040	2050
Total generation	**1,051**	**1,079**	**1,074**	**1,151**	**1,290**	**1,397**
Fossil	799	794	769	824	904	958
Coal	172	163	149	149	150	154
Lignite	164	155	142	142	143	147
Gas	419	446	451	506	583	627
Oil	36	22	18	19	20	22
Diesel	9	9	8	7	7	7
Nuclear	106	110	116	119	119	121
Hydrogen	0	0	0	0	0	0
Renewables	**145**	**175**	**190**	**208**	**267**	**319**
Hydro	79	79	79	80	81	83
Wind	46	59	60	62	88	119
PV	4	18	21	26	50	61
Biomass	13	14	24	30	37	43
Geothermal	3	4	5	7	10	12
Solar thermal	1	2	2	2	2	2
Ocean energy	0	0	0	0	0	0
Fluctuating RES (PV, Wind, Ocean)	50	77	81	88	138	180
Share of fluctuating RES	4.8%	7.1%	7.5%	7.7%	10.7%	12.9%
RES share (domestic generation)	**13.8%**	**16.2%**	**17.7%**	**18.0%**	**20.7%**	**22.8%**

table 7.7: USA: primary energy demand

TRILLION BTU/a	2011	2015	2020	2030	2040	2050
Total	**94,848**	**94,696**	**97,787**	**99,115**	**102,221**	**105,628**
Fossil	**80,110**	**79,509**	**81,162**	**81,451**	**83,346**	**85,463**
Hard coal	10,339	9,644	9,770	10,165	10,288	10,262
Lignite	8,455	7,833	7,931	8,425	8,692	8,935
Natural gas	26,192	26,924	27,840	29,086	30,979	33,143
Crude oil	35,124	35,108	35,621	33,776	33,387	33,123
Nuclear	**8,493**	**8,795**	**9,491**	**9,745**	**9,686**	**9,791**
Renewables	**6,246**	**6,392**	**7,134**	**7,919**	**9,189**	**10,374**
Hydro	1,118	972	999	1,012	1,029	1,045
Wind	409	556	562	592	867	1,170
Solar	83	186	211	254	447	533
Biomass	4,270	4,289	4,827	5,175	5,656	6,204
Geothermal/ambient heat	366	390	536	886	1,190	1,423
Ocean energy	0	0	0	0	0	0
RES share	**6.6%**	**6.7%**	**7.3%**	**8.0%**	**9.0%**	**9.8%**

table 7.8: USA: final energy demand

TRILLION BTU/a	2011	2015	2020	2030	2040	2050
Total (incl. non-energy use)	**62,778**	**63,606**	**65,457**	**65,650**	**68,178**	**70,636**
Total (energy use)	**57,497**	**58,197**	**59,379**	**59,593**	**62,274**	**64,875**
Transport	**25,371**	**25,402**	**25,450**	**24,371**	**25,208**	**26,178**
Oil products	23,490	23,516	23,588	22,338	22,354	22,463
Natural gas	740	750	787	1,001	1,830	2,688
Biofuels	1,118	1,111	1,045	987	958	939
Electricity	22	25	30	45	66	88
RES electricity	3	3	4	7	11	17
Hydrogen	0	0	0	0	0	0
RES share Transport	**4.4%**	**4.4%**	**4.1%**	**4.1%**	**3.8%**	**3.6%**
Industry	**11,794**	**12,532**	**13,461**	**13,747**	**14,270**	**14,839**
Electricity	3,121	3,408	3,739	3,749	3,680	3,628
RES electricity	397	457	545	557	633	689
District heat	208	213	227	233	247	253
RES district heat	12	20	26	24	24	22
Hard coal + lignite	933	878	875	870	919	976
Oil products	1,663	1,811	1,922	1,893	1,955	2,026
Gas	4,571	4,895	5,226	5,288	5,470	5,658
Solar	0	0	0	0	1	1
Biomass and waste	1,294	1,323	1,467	1,709	1,993	2,283
Geothermal	4	4	5	5	6	14
Hydrogen	0	0	0	0	0	0
RES share Industry	**14.5%**	**14.4%**	**15.2%**	**16.7%**	**18.6%**	**20.3%**
Other Sectors	**20,332**	**20,263**	**20,469**	**21,475**	**22,795**	**23,858**
Electricity	9,809	9,698	10,138	11,352	12,807	14,008
RES electricity	1,246	1,301	1,478	1,687	2,204	2,659
District heat	54	52	45	28	18	14
RES district heat	2	4	4	2	1	1
Hard coal + lignite	52	53	53	52	52	43
Oil products	1,822	1,785	1,695	1,562	1,479	1,397
Gas	8,037	8,129	7,991	7,924	7,879	7,834
Solar	56	61	67	80	92	104
Biomass	499	480	474	466	454	442
Geothermal	5	5	6	10	14	15
RES share Other Sectors	**8.9%**	**9.1%**	**9.9%**	**10.5%**	**12.1%**	**13.5%**
Total RES	**4,636**	**4,770**	**5,122**	**5,533**	**6,391**	**7,185**
RES share	**8.1%**	**8.2%**	**8.6%**	**9.3%**	**10.3%**	**11.1%**
Non energy use	**5,281**	**5,409**	**6,078**	**6,057**	**5,904**	**5,761**
Oil	4,820	4,911	5,529	5,547	5,457	5,377
Gas	461	498	549	510	447	385
Coal	0	0	0	0	0	0

USA: energy [r]evolution scenario

table 7.9: USA: electricity generation

TWh/a	2011	2015	2020	2030	2040	2050
Total generation	**4,330**	**4,348**	**4,583**	**5,394**	**6,070**	**6,159**
Fossil	2,959	2,843	2,467	1,507	767	81
Coal	957	861	678	379	18	0
Lignite	911	808	620	20	0	0
Gas	1,054	1,150	1,150	1,100	745	79
Oil	29	17	15	6	4	1
Diesel	7	7	4	2	1	0
Nuclear	822	739	393	53	0	0
Hydrogen	0	0	6	26	57	81
Renewables	**550**	**766**	**1,718**	**3,808**	**5,246**	**5,997**
Hydro	328	298	315	315	315	315
Wind	120	318	777	1,593	1,900	1,980
PV	6	42	202	571	855	1,012
Biomass (& renewable waste)	77	81	96	109	135	154
Geothermal	19	22	142	389	569	719
Solar thermal	1	4	153	643	1,143	1,419
Ocean energy	0	0	33	188	329	397
Distribution losses	260	262	264	262	257	257
Own consumption electricity	312	299	297	265	198	186
Electricity for hydrogen production	0	0	133	578	1,318	1,584
Final energy consumption (electricity)	**3,796**	**3,815**	**3,913**	**4,303**	**4,315**	**4,153**
Fluctuating RES (PV, Wind, Ocean)	126	360	1,012	2,352	3,084	3,389
Share of fluctuating RES	2.9%	8.3%	22.1%	43.6%	50.8%	55.0%
RES share (domestic generation)	**12.7%**	**17.6%**	**37.5%**	**70.6%**	**86.4%**	**97.4%**
'Efficiency' savings (compared to Ref.)	**0**	**40**	**236**	**767**	**1,363**	**1,931**

table 7.10: USA: energy supply for heating and cooling

TRILLION BTU/a	2011	2015	2020	2030	2040	2050
Heat from CHP and district heating[1]	**478**	**692**	**1,685**	**3,217**	**4,008**	**3,837**
Fossil fuels	450	607	1,332	1,958	1,420	197
Biomass[3]	28	74	253	560	1,001	1,277
Geothermal	0	10	79	552	1,263	1,900
Solar collectors	0	3	30	238	594	648
Hydrogen	0	0	20	148	325	462
Direct heating and cooling[2]	**16,862**	**16,872**	**15,710**	**13,231**	**11,328**	**10,305**
Fossil fuels	15,193	14,762	12,470	6,845	2,604	629
Biomass[3]	1,599	1,721	1,526	1,303	1,011	776
Solar collectors	56	260	766	2,484	3,713	3,996
Geothermal[1]	14	129	738	2,055	3,181	3,941
Hydrogen	0	0	209	544	819	964
Total heat supply[2]	**17,340**	**17,564**	**17,394**	**16,448**	**15,336**	**14,142**
Fossil fuels	15,643	15,369	13,802	8,803	4,024	825
Biomass[3]	1,627	1,796	1,779	1,862	2,012	2,053
Solar collectors	56	260	766	2,484	3,713	3,996
Geothermal	14	139	818	2,607	4,444	5,841
Hydrogen	0	0	229	692	1,144	1,426
RES share (including RES electricity)	**9.8%**	**12.5%**	**19.8%**	**45.2%**	**72.8%**	**93.9%**
'Efficiency' savings (compared to Ref.)	**0**	**413**	**912**	**2,032**	**3,651**	**5,378**

1) including heat pumps 2) including cooling 3) The biomass data is based on the EIA assumption that biomass is carbon neutral which is not the Greenpeace position.

table 7.11: USA: CO_2 emissions

MILL t/a	2011	2015	2020	2030	2040	2050
Condensation power plants	**2,018**	**1,840**	**1,462**	**643**	**236**	**6**
Hard Coal (incl. non-renewable waste)	825	736	556	291	14	0
Lignite	821	723	548	18	0	0
Gas	355	372	353	333	221	6
Oil	12	3	2	0	0	0
Diesel	5	5	3	1	1	0
Combined heat & power production	**154**	**146**	**153**	**132**	**80**	**26**
Hard Coal (incl. non-renewable waste)	47	36	31	20	0	0
Lignite	4	3	1	0	0	0
Gas	95	97	112	108	77	25
Oil	8	10	9	4	3	1
CO_2 emissions power and CHP plants	**2,172**	**1,985**	**1,615**	**775**	**316**	**33**
Hard Coal (incl. non-renewable waste)	872	772	587	311	14	0
Lignite	825	726	549	18	0	0
Gas	449	469	465	441	299	32
Oil & diesel	26	18	14	5	3	1
CO_2 emissions by sector	**5,420**	**5,141**	**4,508**	**2,520**	**1,112**	**188**
% of 1990 emissions	111%	105%	92%	52%	23%	4%
Industry[1]	504	482	414	216	83	10
Other sectors[1]	625	615	534	318	140	55
Transport	1,829	1,796	1,700	1,025	475	85
Power generation[2]	2,122	1,930	1,550	717	278	15
District heating & other conversion[3]	340	319	311	244	136	24
Population (Mill.)	317	328	341	366	388	407
CO_2 emissions per capita (t/capita)	**17.1**	**15.7**	**13.2**	**6.9**	**2.9**	**0.5**
'Efficiency' savings (compared to Ref.)	**0**	**195**	**883**	**2,905**	**4,428**	**5,446**

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

table 7.12: USA: installed capacity

GW	2011	2015	2020	2030	2040	2050
Total generation	**1,051**	**1,108**	**1,328**	**1,860**	**1,980**	**1,915**
Fossil	799	770	663	481	311	42
Coal	172	157	111	58	3	0
Lignite	164	147	101	3	0	0
Gas	419	437	428	411	303	40
Oil	36	21	18	7	4	2
Diesel	9	9	5	2	1	0
Nuclear	106	95	50	7	0	0
Hydrogen (fuel cells, gas power plants, gas CHP)	0	0	1	6	11	16
Renewables	**145**	**242**	**614**	**1,366**	**1,658**	**1,857**
Hydro	79	83	85	85	85	85
Wind	46	115	281	568	646	674
PV	4	26	123	339	441	522
Biomass	13	13	16	21	28	32
Geothermal	3	4	23	63	97	124
Solar thermal	1	2	76	245	283	326
Ocean energy	0	0	10	45	78	94
Fluctuating RES (PV, Wind, Ocean)	50	141	415	952	1,165	1,290
Share of fluctuating RES	4.8%	13%	31%	51%	59%	67%
RES share (domestic generation)	**13.8%**	**22%**	**46%**	**73%**	**84%**	**97%**

table 7.13: USA: primary energy demand

TRILLION BTU/a	2011	2015	2020	2030	2040	2050
Total	**94,848**	**91,394**	**87,146**	**73,526**	**65,673**	**57,402**
Fossil	**80,110**	**76,385**	**68,973**	**42,469**	**22,043**	**7,200**
Hard coal	10,339	9,441	8,066	6,306	2,999	2,064
Lignite	8,455	7,343	5,565	180	0	0
Natural gas	26,192	26,041	24,179	17,859	10,141	2,543
Crude oil	35,124	33,560	31,163	18,125	8,903	2,592
Nuclear	**8,493**	**7,625**	**4,055**	**547**	**0**	**0**
Renewables	**6,246**	**7,385**	**14,117**	**30,509**	**43,629**	**50,202**
Hydro	1,118	1,017	1,075	1,075	1,075	1,075
Wind	409	1,085	2,652	5,437	6,484	6,757
Solar	83	441	2,790	10,156	16,975	20,203
Biomass	4,270	4,337	4,300	4,242	4,178	4,092
Geothermal/ambient heat	366	503	3,188	8,959	13,795	16,721
Ocean energy	0	2	113	641	1,123	1,355
RES share	**6.6%**	**8.1%**	**16.3%**	**41.5%**	**66.5%**	**87.5%**
'Efficiency' savings (compared to Ref.)	**0**	**3,321**	**10,757**	**25,658**	**36,638**	**48,365**

table 7.14: USA: final energy demand

TRILLION BTU/a	2011	2015	2020	2030	2040	2050
Total (incl. non-energy use)	**62,778**	**62,132**	**60,940**	**51,443**	**43,536**	**36,628**
Total (energy use)	**57,497**	**56,994**	**55,469**	**46,597**	**39,226**	**32,595**
Transport	**25,371**	**24,928**	**23,838**	**17,263**	**11,939**	**7,480**
Oil products	23,490	23,028	21,602	12,681	5,715	854
Natural gas	740	741	717	614	514	448
Biofuels	1,118	1,112	1,213	1,223	1,013	873
Electricity	22	46	264	2,121	2,724	2,898
RES electricity	3	8	99	1,497	2,354	2,821
Hydrogen	0	0	42	624	1,973	2,408
RES share Transport	**4.4%**	**4.5%**	**5.6%**	**18.3%**	**42.5%**	**80.7%**
Industry	**11,794**	**11,949**	**11,597**	**10,504**	**9,455**	**8,276**
Electricity	3,121	3,273	3,080	2,870	2,766	2,706
RES electricity	397	576	1,154	2,026	2,390	2,635
District heat	208	359	891	1,915	2,268	2,072
RES district heat	12	44	191	839	1,598	2,029
Hard coal + lignite	933	738	550	225	0	0
Oil products	1,663	1,388	1,075	294	127	2
Gas	4,571	4,647	4,159	2,576	1,044	128
Solar	0	156	304	683	867	867
Biomass and waste	1,294	1,358	1,157	938	720	465
Geothermal	4	28	163	442	828	1,063
Hydrogen	0	0	218	561	836	973
RES share Industry	**14.5%**	**18.1%**	**26.3%**	**50.7%**	**75.4%**	**96.7%**
Other Sectors	**20,332**	**20,118**	**20,034**	**18,830**	**17,832**	**16,839**
Electricity	9,809	9,698	9,991	9,615	9,072	8,342
RES electricity	1,246	1,708	3,744	6,788	7,840	8,123
District heat	54	77	486	1,209	1,932	2,023
RES district heat	2	7	92	447	1,287	1,985
Hard coal + lignite	52	141	12	0	0	0
Oil products	1,822	1,676	1,510	891	372	32
Gas	8,037	7,789	6,567	3,576	1,395	622
Solar	56	104	462	1,801	2,846	3,129
Biomass and waste	499	568	556	523	416	409
Geothermal	5	65	451	1,214	1,799	2,281
RES share Other Sectors	**8.9%**	**12.2%**	**26.5%**	**57.2%**	**79.6%**	**94.6%**
Total RES	**4,636**	**5,736**	**9,684**	**19,259**	**26,384**	**29,972**
RES share	**8.1%**	**10.1%**	**17.5%**	**41.3%**	**67.3%**	**92.0%**
Non energy use	**5,281**	**5,138**	**5,470**	**4,846**	**4,310**	**4,033**
Oil	4,820	4,499	4,407	2,983	2,180	1,636
Gas	461	485	516	457	407	380
Coal	0	154	547	1,405	1,724	2,016

USA: investment & employment

table 7.15: USA: 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)	**541,219**	**583,044**	**521,450**	**272,856**	**1,918,569**	**47,964**
Renewables	**203,219**	**155,189**	**227,678**	**165,503**	**751,589**	**18,790**
Biomass	57,155	32,545	50,389	34,645	174,734	4,368
Hydro	47,100	53,139	55,600	60,135	215,974	5,399
Wind	44,357	55,723	69,757	52,353	222,189	5,555
PV	40,824	8,038	43,430	14,560	106,852	2,671
Geothermal	5,473	4,940	2,774	3,807	16,994	425
Solar thermal power plants	8,310	804	5,728	2	14,844	371
Ocean energy	0	0	0	0	0	0
Energy [R]evolution						
Conventional (fossil & nuclear)	**253,344**	**169,656**	**88,962**	**2,929**	**514,891**	**12,872**
Renewables	**1,281,124**	**1,938,698**	**1,133,345**	**1,886,268**	**6,239,435**	**155,986**
Biomass	34,045	31,324	34,696	31,996	132,061	3,302
Hydro	67,616	49,412	50,602	56,620	224,251	5,606
Wind	425,098	503,552	509,198	498,885	1,936,733	48,418
PV	214,662	274,276	225,321	274,295	988,555	24,714
Geothermal	40,238	60,134	42,028	71,356	213,756	5,344
Solar thermal power plants	461,010	924,005	201,362	873,586	2,459,963	61,499
Ocean energy	38,456	95,994	70,136	79,529	284,116	7,103

table 7.16: USA: 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	**55,047**	**69,183**	**24,514**	**39,943**	**188,686**	**4,717**
Biomass	40,680	54,535	16,663	30,460	142,337	3,558
Geothermal	0	0	0	1	1	0
Solar	12,064	11,995	5,416	6,350	35,825	896
Heat pumps	2,303	2,653	2,434	3,133	10,524	263
Energy [R]evolution scenario						
Renewables	**609,975**	**1,027,975**	**1,401,201**	**1,271,706**	**4,310,858**	**107,771**
Biomass	63,536	6,154	21,879	15,076	106,644	2,666
Geothermal	47,185	37,205	269,091	177,274	530,755	13,269
Solar	248,429	565,364	583,594	504,702	1,902,089	47,552
Heat pumps	250,826	419,253	526,637	574,654	1,771,370	44,284

table 7.17: USA: total employment

THOUSAND JOBS		REFERENCE			ENERGY [R]EVOLUTION		
	2010	2015	2020	2030	2015	2020	2030
By sector							
Construction and installation	60	42	27	24	176	280	175
Manufacturing	47	13	11	19	240	299	97
Operations and maintenance	231	235	241	242	235	253	251
Fuel supply (domestic)	749	796	816	824	797	736	516
Coal and gas export	4	6	8	8	3	0	0
Solar and geothermal heat	1	1	3	3	309	399	468
Total jobs	**1,093**	**1,093**	**1,105**	**1,120**	**1,759**	**1,967**	**1,507**
By technology							
Coal	175	155	150	148	145	105	44
Gas, oil & diesel	634	671	680	706	676	628	446
Nuclear	75	77	70	67	63	81	98
Total renewables	**209**	**190**	**205**	**200**	**873**	**1,152**	**919**
Biomass	*134*	*151*	*167*	*156*	*137*	*132*	*118*
Hydro	*11*	*11*	*13*	*13*	*15*	*13*	*13*
Wind	*37*	*12*	*12*	*20*	*214*	*259*	*160*
PV	*23*	*12*	*8*	*6*	*154*	*226*	*78*
Geothermal power	*2.0*	*2.7*	*1.8*	*1.8*	*17.5*	*25.8*	*21.5*
Solar thermal power	*1.5*	*0.5*	*0.4*	*0.2*	*24.1*	*83.9*	*46.1*
Ocean	*-*	*-*	*-*	*-*	*2.3*	*14.5*	*14.5*
Solar - heat	*1*	*0*	*2*	*2*	*237*	*229*	*266*
Geothermal & heat pump	*0.2*	*0.2*	*0.1*	*0.4*	*71*	*170*	*202*
Total jobs	**1,093**	**1,093**	**1,105**	**1,120**	**1,759**	**1,967**	**1,507**

note
numbers may not add up due to rounding

energy
[r]evolution

GREENPEACE

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GWEC
GLOBAL WIND ENERGY COUNCIL

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 organization that represents the entire wind energy sector. The members of GWEC represent over 1,500 companies, organizations 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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