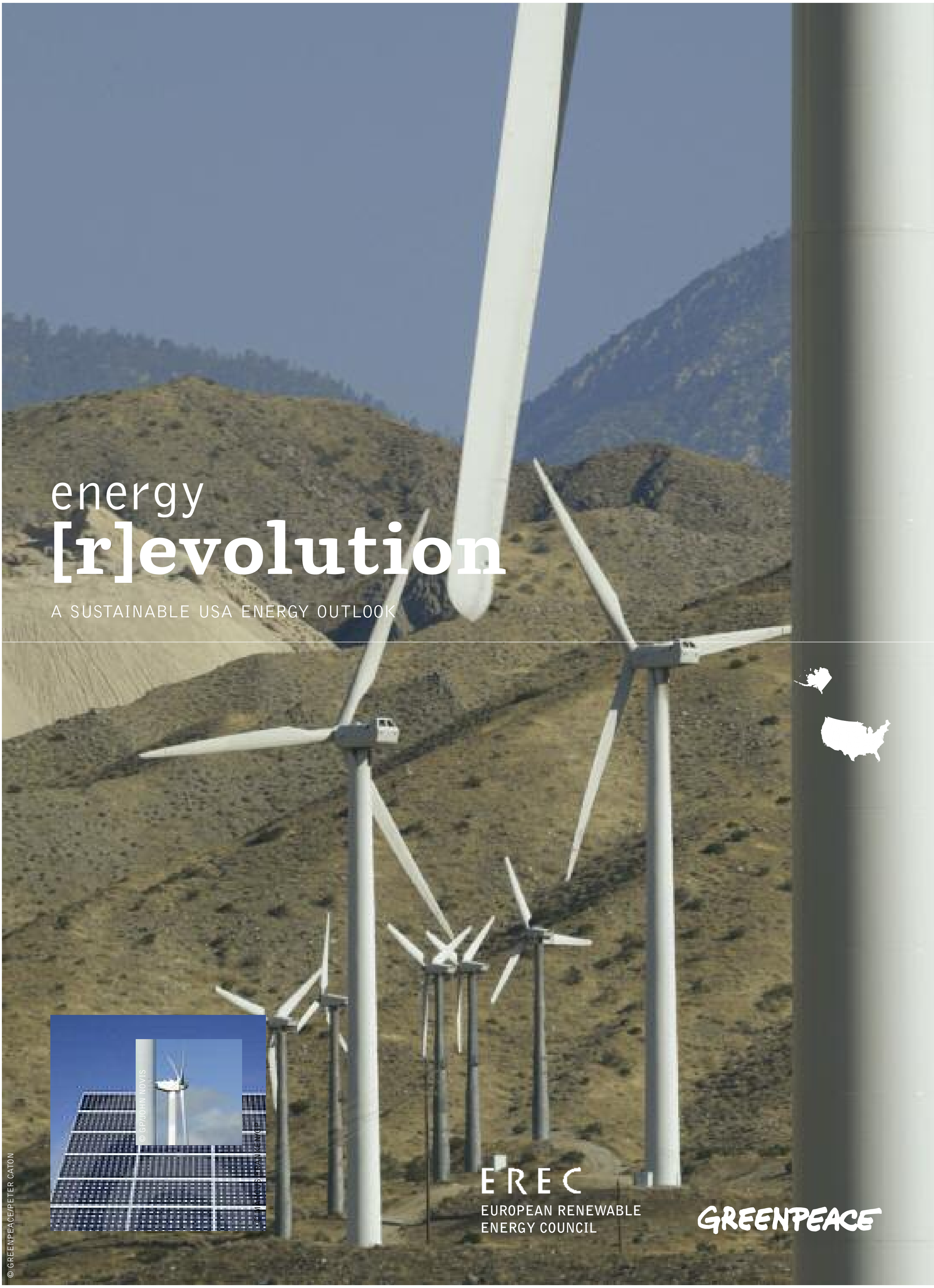

energy

[r]evolution

A SUSTAINABLE USA ENERGY OUTLOOK

EREC
EUROPEAN RENEWABLE
ENERGY COUNCIL

GREENPEACE

report national energy scenario

foreword

Of all the sectors of a modern economic system, the one that appears to be getting the maximum attention currently is the energy sector. While the recent fluctuations in oil prices certainly require some temporary measures to tide over the problem of increasing costs of oil consumption particularly for oil importing countries, there are several reasons why the focus must now shift towards longer term solutions. First and foremost, of course, are the growing uncertainties related to oil imports both in respect of quantities and prices, but there are several other factors that require a totally new approach to planning energy supply and consumption in the future. Perhaps, the most crucial of these considerations is the threat of global climate change which has been caused overwhelmingly in recent decades by human actions that have resulted in the buildup of greenhouse gases (GHGs) in the Earth's atmosphere.

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

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

contents

image CHECKING THE SOLAR PANELS ON TOP OF THE GREENPEACE POSITIVE ENERGY TRUCK IN BRAZIL.
cover image LUZ INTERNATIONAL SOLAR POWER PLANT, CALIFORNIA, USA.

Impacts of climate change are diverse and serious, and unless the emissions of GHGs are effectively mitigated these would threaten to become far more serious over time. There is now, therefore, a renewed interest in renewable sources of energy, because by creating and using low carbon substitutes to fossil fuels, we may be able to reduce emissions of GHGs significantly while at the same time ensuring economic growth and development and the enhancement of human welfare across the world. As it happens, there are major disparities in the levels of consumption of energy across the world, with some countries using large quantities per capita and others being deprived of any sources of modern energy forms. Solutions in the future would, therefore, also have to come to grips with the reality of lack of access to modern forms of energy for hundreds of millions of people. For instance, there are 1.6 billion people in the world who have no access to electricity. Households, in which these people reside, therefore, lack a single electric bulb for lighting purposes, and whatever substitutes they use provide inadequate lighting and environmental pollution, since these include inefficient lighting devices using various types of oil or the burning of candles.

Future policies can be guided by the consideration of different scenarios that can be linked to specific developments. This publication advocates the need for something in the nature of an energy revolution. This is a view that is now shared by several people across the world, and it is also expected that energy plans would be based on a clear assessment of specific scenarios related to clearly identified policy initiatives and technological developments. This edition of Energy [R]evolution Scenarios provides a detailed analysis of the energy efficiency potential and choices in the transport sector. The material presented in this publication provides a useful basis for considering specific policies and developments that would be of value not only to the world but for different countries as they attempt to meet the global challenge confronting them. The work carried out in the following pages is comprehensive and rigorous, and even those who may not agree with the analysis presented would, perhaps, benefit from a deep study of the underlying assumptions that are linked with specific energy scenarios for the future.

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OCTOBER 2008

Greenpeace International, European Renewable Energy Council (EREC)

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executive summary

"NOW IS THE TIME TO CONFRONT THIS CHALLENGE ONCE AND FOR ALL. DELAY IS NO LONGER AN OPTION. DENIAL IS NO LONGER AN ACCEPTABLE RESPONSE. THE STAKES ARE TOO HIGH. THE CONSEQUENCES, TOO SERIOUS." – PRESIDENT BARACK OBAMA

image WORKERS EXAMINE PARABOLIC TROUGH COLLECTORS IN THE PS10 CONCENTRATING SOLAR TOWER PLANT IN SEVILLA, SPAIN. EACH PARABOLIC TROUGH HAS A LENGTH OF 150 METERS AND CONCENTRATES SOLAR RADIATION INTO A HEAT-ABSORBING PIPE INSIDE WHICH A HEAT-BEARING FLUID FLOWS. THE HEATED FLUID IS THEN USED TO HEAT STEAM IN A STANDARD TURBINE GENERATOR.

introduction

Energy [R]evolution is a groundbreaking report which shows how the U.S. and the world can cut global warming pollution to the levels needed to prevent the worst effects of global warming while also meeting the energy needs of a growing world and phasing out nuclear power.

Commissioned from the German Aerospace Center by Greenpeace and the European Renewable Energy Council, the study shows how the U.S. can, with off-the-shelf technology, cut CO_2 emissions from current levels by 23 percent by 2020 and 85 percent by 2050.

The U.S. edition of the Energy [R]evolution Scenario is part of a series of reports which examine carefully energy needs and clean energy potential worldwide. Taken together, the reports are a blueprint for a safer climate and stronger, more sustainable economy.

For an even more detailed explication of the scenario as well as its application worldwide, we encourage readers to review the global Energy [R]evolution Scenario, available at http://www.energyblueprint.info.

global warming: the challenge of our time

Global warming is a clear and present danger to America's public health, economy, and environment. One record-breaking hurricane season follows another. Declining mountain snowpack is aggravating water shortages in the West. Species including the polar bear and the walrus are in jeopardy as a result of fast-disappearing Arctic sea ice. California's destructive wildfire season has become longer and more destructive than ever before. This is what global warming looks like.

If left unchecked, global warming will cause truly catastrophic damage. According to the Nobel Prize-winning U.N. Intergovernmental Panel on Climate Change (IPCC)[1], up to 30 percent of plant and animal species could face extinction by mid-century. Hundreds of millions of people worldwide including millions here in the U.S. will face severe water shortages. And the melting of the Greenland and West Antarctic ice sheets would trigger sea level rise of 13-20 feet or more.

The economic cost of global warming to the U.S. economy from just four impacts—hurricane damage, water shortage, energy costs, and real estate losses—are projected to reach $271 billion by 2025.[2]

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"renewable energy, combined with the smart use of energy, can deliver half of the world's energy needs by 2050."

image ICEBERG MELTING ON GREENLAND'S COAST.

Former World Bank chief economist Sir Nicholas Stern estimated that global warming could reduce worldwide GDP by 20 percent.[3] The costs in terms of human lives and ecological destruction are incalculable.

Numerous studies[4,5] have concluded that to prevent catastrophic global warming worldwide average temperatures cannot rise by more than 2 degrees C (3.6°F) above pre-industrial levels. To minimize the risk of catastrophic warming, we must limit warming to 1.5 degrees C or less. Further research shows that to have an approximately 50 percent chance of keeping warming below 2 degrees Celsius, atmospheric greenhouse gas concentrations must stabilize below 450 parts per million (ppm). For the chances of keeping warming below these levels to be considered "likely," total greenhouse gases must stabilize at 350-400 ppm or lower.[6]

With prudent assumptions about projected emissions in the developing world, IPCC[7] projected that to keep greenhouse gas concentrations below 450 ppm developed countries as a whole would need to reduce emissions by 25-40 percent below 1990 levels by 2020 and by 80-95 percent by 2050. Again, to ensure the lowest possible degree of risk of triggering catastrophic global warming, cuts in developed world emissions should reach the upper end of the IPCC range by 2020, and developed nations should aim to achieve net zero emissions by 2050.

Given this body of science, urgent action can't wait.

energy [r]evolution: the blueprint for a safe climate

In Energy [R]evolution, Greenpeace and the European Renewable Energy Council (Europe's largest renewable energy trade association) posed a simple but daring series of questions.

First, is it possible, using currently available technologies, to cut carbon dioxide (CO_2) emissions worldwide to the levels needed to prevent the worst effects of global warming? Second, can we do it while also achieving strong economic growth? Third, since the dangers of nuclear waste and proliferation pose similar existential threats to humanity as global warming itself, can we also phase out all nuclear power by 2050? And, finally, can we do it here in the U.S.?

The answer, from some of the world's top energy experts at the German Aerospace Center (Germany's counterpart to National Aeronautics and Space Administration), is a resounding yes on all counts.

Every step of the way, we made conservative assumptions to ensure that the Energy [R]evolution Scenario would not just add up on paper but also work in the real world. We used numbers from the International Energy Agency (IEA) to project economic and population growth.[8] The Energy [R]evolution Scenario assumes that only currently available, off-the-shelf technology will be utilized between now and 2050, and unproven technologies like "carbon-free coal" were omitted. We assumed that no current energy infrastructure—from power plants to home appliances—will be retired prematurely. Even with these conservative assumptions, the Energy [R]evolution Scenario demonstrates how the U.S. can transition to a clean energy economy and stop global warming.

By following the Energy [R]evolution blueprint, the U.S. can cut carbon dioxide emissions from domestic fossil fuel use by 83 percent by 2050, while still greater additional net emissions cuts can be achieved through changes in land use and agricultural practices.

Further, the report provides guidance for how the U.S. can achieve additional cuts by providing critical financing for the adoption of clean technologies in the developing world (see chapter 5). Finally, the U.S. can achieve still further reductions by funding efforts to stop tropical deforestation, which is responsible for 20 percent of worldwide global warming emissions.[9] If properly implemented, these strategies together will allow the U.S. to achieve total cuts of at least 25 percent by 2020 and 80-95 percent 1990 levels by 2050.

If we follow the path presented in the Energy [R]evolution Scenario, we can solve global warming, but we must start now.

total carbon emissions reductions under energy [r]evolution scenario

The Energy [R]evolution Scenario cuts CO_2 emissions from every sector of the U.S. economy. Specifically:

- Electricity and steam generation emissions would drop 98 percent from 2,538 million tons per year ($MMtCO_2$/yr) to 42 $MMtCO_2$/yr by 2050. Electricity generation from both coal and oil would be phased out entirely by 2050.
- Transportation sector emissions would fall 79 percent from 1,928 to 400 $MMtCO_2$/yr by 2050.
- Emissions from industry would fall 77 percent from 482 to 112 $MMtCO_2$/yr by 2050.
- On a per capita basis, U.S. emissions would drop from 18.6 to 2.1 tons/yr by 2050. For comparison, today, the developed nations of Europe together emit 7.6 tons/yr per capita, China emits 3.4 tons/yr per capita, and India just 1 ton/yr per capita.
- Total emissions would decline 85 percent from current levels (83 percent from 1990 levels) by 2050.
- Because achieving the emissions cuts demanded by the science becomes more costly and difficult the longer we wait, it is critical to set strong targets for near-term emissions reductions as well as long-term reductions by 2050. Under the Energy [R]evolution Scenario, emissions would fall to 4,426 $MMtCO_2$/yr by 2020, a 12 percent reduction from 1990 levels and a 23 percent reduction from current levels.

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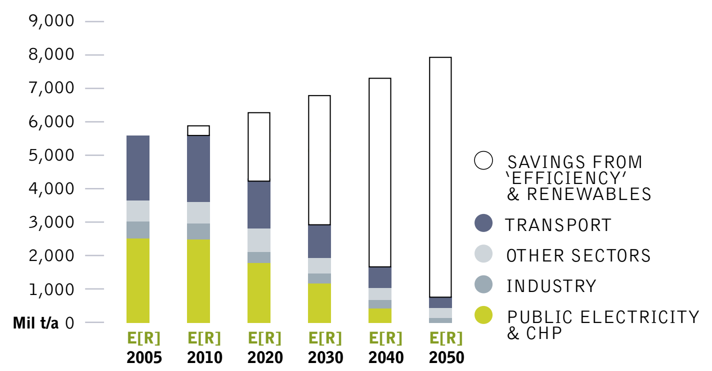
figure 0.1: USA: decline of CO_2 emissions by sector under the energy [r]evolution scenario

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



step one: use energy smarter

The fastest, cheapest, and most effective way to cut global warming emissions is to simply reduce energy use. By deploying currently available energy efficiency technologies, the U.S. can dramatically cut global warming emissions while at the same time saving consumers and businesses money. Additionally, these savings act like a massive economy-wide tax cut, stimulating further economic growth and job creation.

For example, consider the tremendous potential for emission reductions through energy efficiency in home heating and cooling, which accounts for almost half of home energy use.[10] Drafty windows, poor insulation, and other air leaks waste vast amounts of energy. In fact, the Department of Energy's home weatherization program cuts energy use for heating and cooling by an average of 30 percent per home.[11] By expanding this program nationwide, the U.S. could cut household energy use by 30 percent nationally and save $1.50 for every dollar invested. Similarly dramatic improvements are currently available from super-efficient air conditioners, water heaters, and appliances.

The transportation sector is another area of tremendous potential efficiency gains. In the Energy [R]evolution Scenario, the U.S. car fleet grows by 20 percent from the year 2000 to 2050. However, with highly efficient technology, including plug-in hybrid vehicles that get 100 miles per gallon or more, battery-electric powertrains, as well as expanded access to public transportation, the energy demand of the transportation sector is reduced 40 percent by 2050.

Under the Energy [R]evolution Scenario, the U.S. would stop wasting energy and reap enormous efficiency gains. In contrast, the IEA Reference Scenario predicts that total primary energy demand in the U.S. will increase more than 40 percent by 2050. In the Energy [R]evolution Scenario, energy demand decreases by nearly 24 percent compared to current consumption due to smart energy use and increased efficiency.

Energy savings by sector:

- Heat supply: under the Energy [R]evolution Scenario, demand for heat supply will grow up to 2030, but after that can even be reduced to below the 2015 level. Compared to the Reference Scenario, consumption equivalent to 6,963 PJ/yr is avoided through efficiency gains by 2050.
- Electricity: under the Energy [R]evolution Scenario, electricity demand is expected to decrease in the industry sector, but to grow in the transport as well as in the residential and service sectors. Total electricity demand will rise to 5,408 TWh/yr in the year 2050. Compared to the Reference Scenario, efficiency measures avoid the generation of about 2,244 TWh/yr.
- Transportation: In the transport sector, it is assumed under the Energy [R]evolution Scenario that energy demand will decrease by 50 percent to 13,505 PJ/yr by 2050, saving 66 percent compared to the Reference Scenario.

figure 0.2: USA: total energy demand (2005-2050). Reference scenario vs. energy [r]evolution scenario

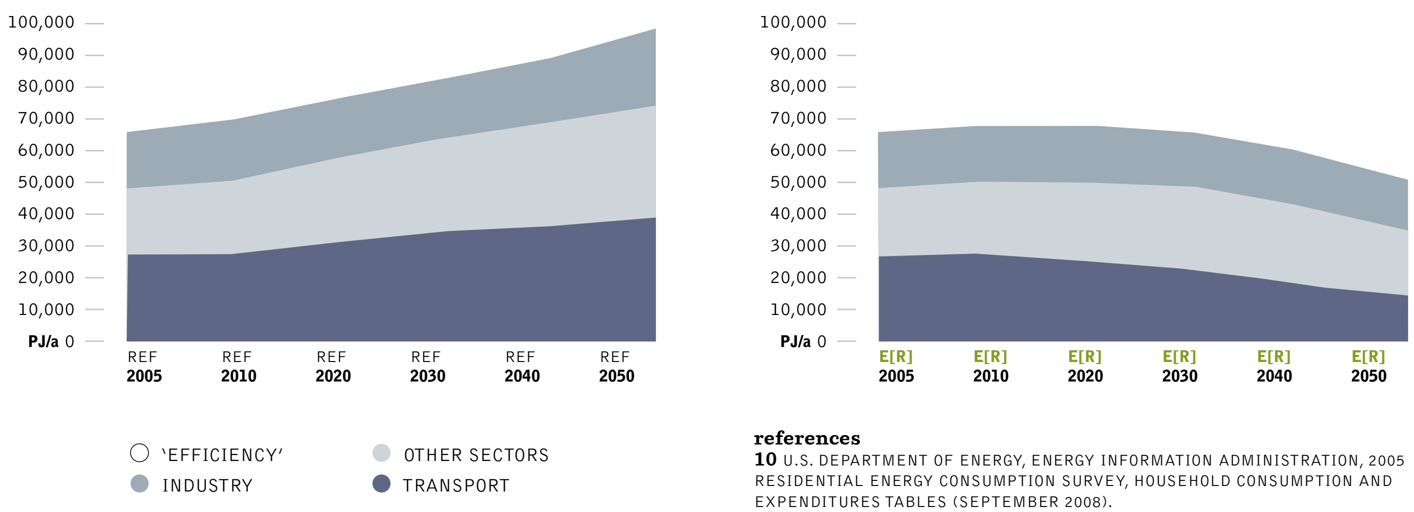


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image THE PS10 CONCENTRATING SOLAR TOWER PLANT IN SEVILLA, SPAIN, USES 624 LARGE MOVABLE MIRRORS CALLED HELIOSTATS. THE MIRRORS CONCENTRATE THE SUN'S RAYS TO THE TOP OF A 115 METER (377 FOOT) HIGH TOWER WHERE A SOLAR RECEIVER AND A STEAM TURBINE ARE LOCATED. THE TURBINE DRIVES A GENERATOR, PRODUCING ELECTRICITY.

step two: repower america with clean energy

The U.S. today is heavily dependent on polluting fossil fuels for electricity. Nearly 71 percent of U.S. electricity comes from fossil fuels, including 53 percent from coal. Of the remainder, 21 percent is generated from nuclear power, 15 percent from natural gas, 7 percent from hydro and less than 2 percent from other renewable sources. As a result, the U.S. emits 2,557 $MMtCO_2$ from the production of electricity and steam every year.

Under the IEA Reference Scenario, U.S. dependence on fossil fuels increases still further, and emissions from electricity and steam generation grow 52 percent to 3,769 $MMtCO_2$, an emissions increase that would, if replicated by other countries, make catastrophic global warming impacts virtually certain.

However, this is a wholly avoidable fate. The U.S. can repower with renewable, clean energy. For example, the five states of North Dakota, South Dakota, Kansas, Montana and Texas have enough wind energy potential to meet the electricity needs of the entire country, and Nevada could do the same with solar thermal plants covering only 9 percent of the state's land area.[12] Off-shore wind could produce nearly as much energy as all U.S. electricity generators combined.[13] Solar panels installed on all U.S. rooftops could provide more than 70 percent of current total generation capacity.[14]

Obviously these are hypothetical scenarios—land use issues, technological and structural limitations and other challenges make it impossible to capture and use 100 percent of the theoretical potential from any renewable energy source. However, even after accounting for these restrictions, the amount of energy that can be accessed using current technologies from wind, solar, geothermal, hydro, biomass, and ocean energy could supply 5.9 times current global demand.

Under the Energy [R]evolution Scenario, the aggressive ramp-up of clean energy sources combined with efficiency gains discussed in step one drastically reduce greenhouse gas emissions. Highlights of the Energy [R]evolution Scenario include:

- Wind power capacity would grow from 8 gigawatts (GW) in 2005 to 398 GW in 2050, an increase from less than 1 percent to 26 percent of total U.S. capacity by 2050.
- Solar photovoltaic (PV) capacity would rise from 0.01 GW in 2005 to 511 GW in 2050, 33 percent of total capacity in that year.
- Solar thermal plants, which have the potential to store energy and be used as base-load power, would increase from 0.3 to 148 GW, 9.6 percent of total U.S. energy capacity. Solar power overall would provide 43 percent of total capacity.
- Combined capacity from geothermal, biomass, and ocean energy would rise from 7 GW in 2005 to 281 GW in 2050, 18 percent of total U.S. energy capacity.
- Energy generation from natural gas would play an important role in the transition to a clean energy economy. Supply from natural gas would rise from 340 GW in 2005 to a peak of 505 GW in 2030 before declining to 80 GW in 2050 as renewable energy technologies fully mature.
- Energy generation from coal, oil, and nuclear power would be completely phased out in the generation of electricity by 2050.

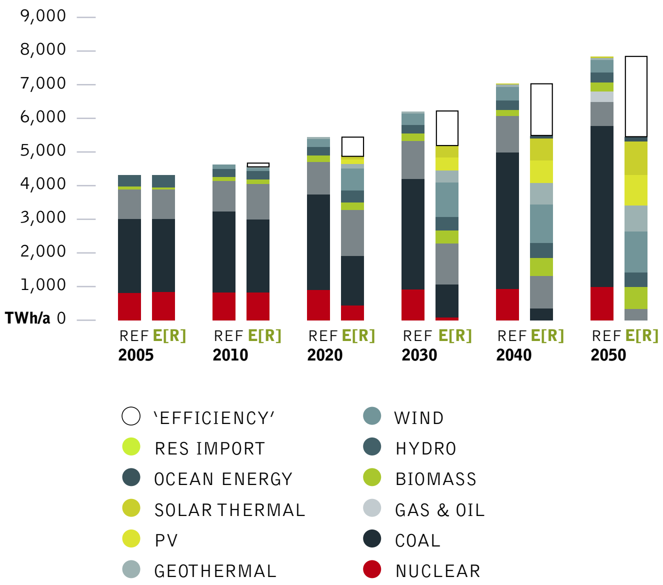
table 0.1: USA: total energy capacity (2005 – 2050)

GW	2005	2010	2020	2030	2040	2050
Total generation	**982**	**1,059**	**1,356**	**1,508**	**1,606**	**1,531**
Fossil	780	823	780	646	419	80
Coal	213	217	174	151	54	0
Lignite	156	152	75	14	0	0
Gas	340	393	505	468	361	80
Oil	46	44	17	8	2	0
Diesel	24	18	10	5	3	0
Nuclear	99	94	48	6	1	0
Renewables	**102**	**142**	**528**	**856**	**1,187**	**1,451**
Hydro	76	80	101	106	111	112
Wind	8	31	258	355	382	398
PV	0	2	69	200	358	511
Biomass	15	22	46	79	116	134
Geothermal	2	5	21	52	93	114
Solar thermal	0	1	31	55	106	148
Ocean energy	0	1	2	8	20	33
Fluctuating RES (PV, Wind, Ocean)	8.4	33.3	329.7	562.9	760.9	942.4
Share of fluctuating RES	0.9%	3.1%	24.3%	37.3%	47.4%	61.5%
RES share	**10.4%**	**13.4%**	**38.9%**	**56.8%**	**73.9%**	**94.8%**

It is important to note that all power plants under the Energy [R]evolution scenario are phased out over the course of their typical depreciation period, about 40 years. Most coal plants in the U.S. are already near or past their 40th birthday. In contrast, many natural gas plants in the U.S. were built over the last decade.

figure 0.3: USA: electricity generation capacity. Reference scenario vs. energy [r]evolution scenario

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



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fossil fuels: penny-wise, pound-foolish

The Energy [R]evolution Scenario shows us what the old axiom "penny-wise and pound-foolish" really means. Under the Reference Scenario, the rising costs of fossil fuels and lost savings from energy efficiency will far outstrip the up-front investment costs needed to achieve the clean energy future envisioned here.

The total investment required to achieve the Energy [R]evolution Scenario from 2005-2030 is just under $2.8 trillion, about $1.1 trillion more than what would be needed to meet America's energy needs under the Reference Scenario.

However, because the fuel costs of renewable energy and energy efficiency are zero, the Energy [R]evolution Scenario will bring enormous savings overall. The total fuel cost for fossil fuels in the Reference Scenario between 2005-2030 amounts to $10.85 trillion, compared to $8.7 trillion in the Energy [R]evolution Scenario, a savings of $2.089 trillion.

Bottom line, the long-term savings in fuel costs are nearly double the additional up-front investment required to achieve the Energy [R]evolution.

If one includes the staggering economic costs of unchecked global warming, the economic advantages of the Energy [R]evolution Scenario are beyond question.

a win-win scenario: stop global warming and create millions of new jobs

The Energy [R]evolution will not only help ensure a safer climate—it will also spark an explosion of good new jobs that can never be moved over seas. The scenario will create all kinds of new jobs all over the country, from agricultural workers at biomass plants in the Midwest to "Rust Belt" workers building wind turbines to accountants and other white collar employees all across the country.

By contrast, coal is one of the least job-intensive industries in America. According to the University of Massachusetts's Political Economy Research Institute, investments in wind and solar power create 2.8 times as many jobs as the same investment in coal; mass transit and conservation would create 3.8 times as many jobs as coal.[15]

Using frequently cited job creation models, Greenpeace projects that the Energy [R]evolution Scenario will create a net of over 14.5 million new jobs by 2050 in the energy efficiency and renewable energy sectors alone. (Because of insufficient data, job gains from biomass and hydroelectric power, as well as the transportation sector, were not calculated.)

table 0.2: Net job gains from energy [r]evolution scenario versus reference scenario

	2030	2050
Energy Efficiency[16]	4,154,150	9,312,600
Solar PV[17]	3,462,075	7,018,839
Solar Thermal[18]	107,246	4,024,022
Wind[19]	3,739,974	4,097,521
Geothermal[20]	226,386	620,528
Natural Gas[21]	871,959	-181,996
Nuclear[22]	-120,455	-138,802
Coal[23]	-4,594,783	-10,209,101
Total	**7,846,552**	**14,543,611**

moving from ideas to action

to implement the energy [r]evolution scenario, the following policy changes are recommended:

1. Enact "cap and auction" legislation to reduce U.S. global warming pollution emissions to science-based levels needed to minimize the risk of catastrophic global warming.
2. End all subsidies for fossil fuels and nuclear energy.
3. Set mandatory efficiency standards for all energy consuming appliances, buildings and vehicles.
4. Establish binding targets for renewable energy generation.
5. Reform the electricity markets by guaranteeing priority access to the electricity grid for renewable power generators.
6. Provide defined and stable returns for investors, for example through renewable energy payments (also known as feed-in tariff) programs.
7. Implement consumer transparency measures to provide more information about the environmental impacts of consumer products and energy sources.
8. Increase funding for research and development of renewable energy and energy efficiency.

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22 NUCLEAR ENERGY INSTITUTE, ECONOMIC BENEFITS OF NUCLEAR POWER PLANTS, AVAILABLE AT HTTP://WWW.NEI.ORG/KEYISSUES/NEWNUCLEARPLANTS/ECONOMICBENEFITSOFNEWNUCLEARPLANTS/
23 SEE FOOTNOTE 18.

the energy [r]evolution

1

> **"we should not wait, we cannot wait, we must not wait, we have everything we need - save perhaps political will. and in our democracy, political will is a renewable resource."**
>
> FORMER VICE PRESIDENT AL GORE

The climate crisis demands nothing short of an energy revolution. This chapter summarizes the basic principles and goals underlying the Energy [R]evolution Scenario.

key principles of the energy [r]evolution

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

The Energy [R]evolution Scenario represents a major change in the way that energy is both produced and distributed. The scenario sets out to fulfill the following goals:

1. **achieve science-based emissions reductions to minimize climate risk.** There is only so much carbon that the atmosphere can absorb. Each year we emit over 25 billion tons of CO_2; we are literally filling up the sky. Coal supplies could provide several hundred years of fuel, but coal and oil development must be ended to stay with safe CO_2 emission limits. The Energy [R]evolution Scenario aims to reduce energy-related CO_2 emissions to a maximum of 10 Gt (gigatons) by 2050 and phase out fossil fuels worldwide by 2085.

2. **ensure equity and fairness.** We must ensure a fair distribution of benefits and costs within societies and between nations. At one extreme, a third of the world's population has no access to electricity, while 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 Energy [R]evolution Scenario aims to achieve energy equity as soon as technically possible. By 2050, average global per capita carbon dioxide should be between 1 and 2 tons.

3. **implement clean, renewable solutions and 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.

   Sustainable decentralized energy systems powered by renewable energy produce less carbon emissions, are cheaper and involve less dependence on imported fuel. Renewable energy systems create jobs and empower local communities. Decentralized systems are more secure and more efficient. This is what the Energy [R]evolution Scenario aims to create.

4. **decouple growth from fossil fuel use.** Starting in the developed countries, economic growth must fully decouple from fossil fuels. 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 – away from fossil fuels – quickly in order to enable clean and sustainable growth.

5. **phase out dirty, unsustainable energy.** The U.S. needs to phase out coal and nuclear power. This country cannot continue to build coal plants at a time when global warming emissions pose a real and present danger to both ecosystems and people. And we cannot continue to ignore nuclear risks. There is no role for nuclear power in the Energy [R]evolution.

transitioning to clean energy

In 2005, renewable energy sources accounted for 13 percent of the world's primary energy demand. Biomass, which is mostly used for heating, is the main renewable energy source. The share of renewable energy in electricity generation was 18 percent. The contribution of renewable energy to primary energy demand for heat supply was around 24 percent. About 80 percent of primary energy supply today still comes from fossil fuels, and 6 percent from nuclear power.[24]

references
24 INTERNATIONAL ENERGY AGENCY, ENERGY BALANCE OF NON-OECD COUNTRIES (2008) AVAILABLE AT: HTTP://WDS.IEA.ORG/WDS/PDF/DOC_WEDBAL_EN_2008.PDF INTERNATIONAL ENERGY AGENCY, ENERGY BALANCE OF OECD COUNTRIES (2008) AVAILABLE AT: HTTP://WDS.IEA.ORG/WDS/PDF/DOC_OECDBAL_2008.PDF.

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

Within the next ten years, the U.S. will decide whether to meet demand with fossil and nuclear fuels or with the efficient use of renewable energy. The Energy [R]evolution Scenario is based on a new political framework in favor of renewable energy and cogeneration combined with energy efficiency.

To make this happen, 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.

It is not possible to switch immediately from the current large-scale fossil and nuclear fuel based energy supply to a renewable energy supply. A transition phase is required to build up the necessary infrastructure. While remaining firmly committed to the promotion of renewable sources of energy, Greenpeace appreciates that gas, used in appropriately scaled cogeneration plants, is a necessary transition fuel, and will drive cost-effective decentralization of U.S. energy infrastructure. With warmer summers, tri-generation, which incorporates heat-fired absorption chillers to deliver cooling capacity in addition to heat and power, will also become a particularly valuable means to achieve emissions reductions.

a development pathway

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

step 1: energy efficiency

The Energy [R]evolution aims to aggressively exploit the potential for energy efficiency in the U.S. It focuses on current best practices and new technologies which will become available in the future, assuming continuous innovation. Energy savings are equally distributed over the three sectors – industry, transport and domestic/business. Intelligent use, not abstinence, is the basic philosophy for future energy conservation.

The most important energy-saving options are: improved heat insulation and building design; super-efficient appliances and electronic devices; replacement of old style electrical heating systems with renewable heat production (such as solar collectors); and a reduction in energy consumption by vehicles used for goods and passenger traffic. Industrialized countries, which currently use energy in the most inefficient way, can reduce energy consumption drastically without the loss of either housing comfort or entertainment electronics. The Energy [R]evolution Scenario uses energy saved in developed countries as a compensation for 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 Energy [R]evolution Scenario aims to create "energy equity" by shifting wasted energy in industrialized countries towards a fair, worldwide energy supply distribution.

The Energy [R]evolution Scenario makes a dramatic reduction in primary energy demand compared to the IEA's "Reference Scenario" – but with the same GDP and population development. This is a crucial prerequisite for renewable energy growth in the overall energy supply system and will help compensate for the phase-out of nuclear energy and fossil fuels.

step 2: deliver clean energy to power a growing world

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 is energy generated at or near the point of use.

DE is connected to a local distribution network system, supplying homes and offices, rather than the high voltage transmission system. The proximity of electricity generating plant to consumers allows any waste heat from combustion processes to be piped to buildings nearby, a system known as cogeneration or combined heat and power. DE uses nearly all the input energy, unlike traditional centralized fossil fuel plants, which use only a fraction of input energy.

DE can also include stand-alone systems, separate from public networks, like heat pumps, solar thermal panels or biomass heating systems. These can all be commercialized to provide sustainable low emission heating. Although DE technologies can be considered 'disruptive' because they do not fit the existing electricity market and system, with appropriate changes they have the potential for exponential growth.

By 2050, a large proportion of global energy will be produced by decentralized energy sources. Large-scale renewable energy supply will still be needed in order to achieve a fast transition to a renewables-dominated energy system. Large offshore wind farms and concentrated solar power (CSP) plants in sunbelt regions are prime examples of the technologies that will be needed.

cogeneration The increased use of combined heat and power generation (CHP) will improve energy supply efficiency, whether using natural gas or biomass. In the longer term, decreasing demand for heat and the ability to produce heat directly from renewable energy sources will limit the further expansion of CHP.

renewable electricity The electricity sector will pioneer renewable energy utilization in the U.S. All renewable electricity technologies are experiencing steady growth, and over the past 20-30 years have grown up to 35 percent annually. By 2050, the majority of electricity will be produced from renewable energy sources. Expected growth of electricity use in the transportation sector will further promote the use of renewable power generation technologies.

image OFF SHORE WINDFARM, MIDDELGRUNDEN, COPENHAGEN, DENMARK.

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

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

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

optimized integration of renewable energy Modification of the energy system will be necessary to accommodate the significantly higher shares of renewable energy expected under the Energy [R]evolution Scenario. This is not unlike the 1970s and 1980s, when the U.S. experienced unprecedented growth in the energy sector. In addition to building centralized power plants, the U.S. constructed high-voltage power lines, night storage heaters, and installed large electric-powered hot water boilers to sell the electricity produced by nuclear and coal-fired plants at night.

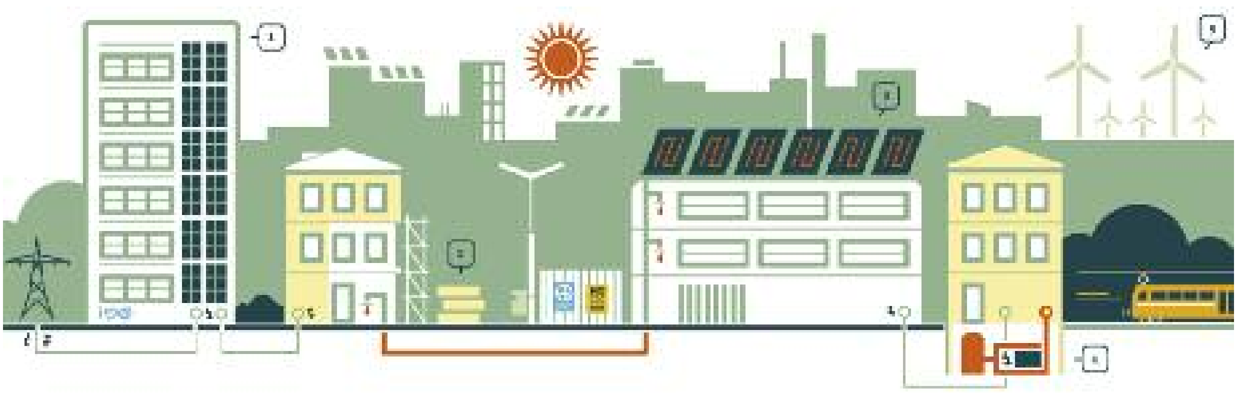
Several developed countries have demonstrated that it is possible to smoothly integrate a large proportion of decentralized energy, including variable sources such as wind. For example, Denmark has the highest percentage of combined heat and power generation and wind power in Europe. With strong political support for renewable energy, 50 percent of electricity and 80 percent of district heat in Denmark is now supplied by cogeneration plants. Wind power contributes more than 18 percent of Danish electricity demand. At certain times, electricity generation from cogeneration and wind turbines even exceeds demand. In Denmark, grid stability is managed both through regulating the capacity of large power stations and through energy imports and exports to neighboring countries. A three-tier tariff system enables power generation balancing from decentralized power plants that provide daily electricity consumption.

It is important to optimize the energy system as a whole through intelligent management by both producers and consumers, by an appropriate mix of power stations and through new systems for storing electricity.

figure 1.1: 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 COGENERATION TECHNOLOGIES PRODUCING BOTH HEAT (AND SOMETIMES COOLING) PLUS ELECTRICITY, DISTRIBUTED VIA LOCAL NETWORKS. THIS SUPPLEMENTS THE ENERGY PRODUCED FROM BUILDING INTEGRATED GENERATION. ENERGY SOLUTIONS COME FROM LOCAL OPPORTUNITIES AT BOTH A SMALL AND COMMUNITY SCALE. THE TOWN SHOWN HERE MAKES USE OF – AMONG OTHERS – WIND, BIOMASS AND HYDRO RESOURCES. NATURAL GAS, WHERE NEEDED, CAN BE DEPLOYED IN A HIGHLY EFFICIENT MANNER.

city



1. **PHOTOVOLTAIC, SOLAR FAÇADES** WILL BE A DECORATIVE ELEMENT ON OFFICE AND APARTMENT BUILDINGS. PHOTOVOLTAIC SYSTEMS WILL BECOME MORE PRICE-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 CAN** PRODUCE ENOUGH HOT WATER FOR SEVERAL BUILDINGS.
4. **EFFICIENT THERMAL POWER (CHP) STATIONS** WILL COME IN A VARIETY OF SIZES - FITTING THE CELLAR OF A HOUSE OR SUPPLYING WHOLE BUILDING COMPLEXES OR APARTMENT BLOCKS WITH POWER AND WARMTH WITHOUT TRANSMISSION LOSSES.
5. **CLEAN ELECTRICITY** FOR CITIES WILL ALSO COME FROM OFFSHORE WIND PARKS AND SOLAR POWER STATIONS.

figure 1.2: centralized energy infrastructures waste more than two thirds of their energy

61.5 units LOST THROUGH INEFFICIENT GENERATION AND HEAT WASTAGE

3.5 units LOST THROUGH TRANSMISSION AND DISTRIBUTION

13 units WASTED THROUGH INEFFICIENT END USE

100 units >> ENERGY WITHIN FOSSIL FUEL

38.5 units >> OF ENERGY FED TO NATIONAL GRID

35 units >> OF ENERGY SUPPLIED

22 units OF ENERGY ACTUALLY UTILISED

appropriate power station mix The right combination of power sources is essential to implement the Energy [R]evolution Scenario in the U.S. Modern gas power stations, unlike coal or nuclear power stations, are not only highly efficient but easier to regulate for fluctuating energy supply into the grid. Coal and nuclear power stations have lower fuel and operating costs, but comparably high investment costs. Coal and nuclear power stations must run around the clock as 'base load' in order to earn back their investment and take hours to bring up to full speed. Gas-fired power stations have lower investment costs and are profitable even at low output, making them suitable to balance out the variations in energy supply from renewable sources.

By contrast, renewable electricity generation systems can also be involved in supply optimization. Wind farms, for example, can be temporarily switched off when too much power is available on the network or scaled down incrementally by adjusting the angle of the turbines.

load management Electricity demand can be managed by providing consumers with financial incentives to reduce or shut off their supply at periods of peak consumption. Control technology can be used to manage the arrangement and is already used to assist large industrial customers. For example, a Norwegian power supplier sends private household customers a text message with a signal to shut down during peak times. Each household can decide in advance whether or not they want to participate. In Germany, experiments are being conducted with time-flexible tariffs so that washing machines operate at night and refrigerators turn off temporarily during periods of high demand.

This type of load management has been simplified by advances in communications technology. For example, Italy installed 30 million innovative electricity counters 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 supply for other uses.

energy storage Another method of balancing out electricity supply and demand is through intermediate storage. Intermediate storage can be decentralized, for example by the use of batteries, or centralized. To date, pumped storage hydro power stations are most often used to store large amounts of electric power. In a pumped storage system, energy from power generation is stored in a lake and then allowed to flow back when required, driving turbines and generating electricity. Intermediate storage already provides an important contribution to energy security, and 280 pumped storage plants exist worldwide.

In the long term, other storage solutions are needed. One promising solution is the use of compressed air. In this storage system, electricity is used to compress air into deep salt domes .37 miles underground and at pressures of up to 1015,26 pounds per square inch. When electricity demand peaks, the compressed air is allowed to flow back out of the cavern and drive a turbine. Although this system, known as CAES (Compressed Air Energy Storage), currently still requires fossil fuel auxiliary power, a so-called "adiabatic" plant is being developed which does not require fossil fuel. To achieve this, the heat from the compressed air is intermediately stored in a giant heat store. Such a power station can achieve a storage efficiency of 70 percent. Most exciting, paired with these energy storage technologies, solar thermal plants have the potential to become truly clean, renewable base-load power.

forecasting The forecasting of renewable electricity generation is also continually improving. Regulating supply is particularly expensive when it has to be found at short notice. However, prediction techniques for wind power generation have become considerably more accurate in recent years and are still being improved. The demand for balancing supply will therefore decrease in the future.

image PHOTOVOLTAICS FACILITY AT 'WISSENSCHAFTS UND TECHNOLOGIEZENTRUM ADLERSHOF' NEAR BERLIN, GERMANY. SHEEP BETWEEN THE 'MOVERS' KEEPING THE GRASS SHORT.

"it is important to optimize the energy system as a whole through intelligent management by both producers and consumers..."

the "virtual power station"[25] The rapid development of information technologies is helping to pave the way for a decentralized energy supply based on cogeneration plants, renewable energy systems and conventional power stations. Manufacturers of small cogeneration plants already offer Internet interfaces which enable remote control of the system. It is now possible for individual householders to control their electricity and heat usage so that expensive electricity drawn from the grid can be minimized—and electricity demand stabilized. This is part of the trend towards the 'smart house' where a mini cogeneration plant becomes a day-to-day energy management center.

We can go one step further than this with a 'virtual power station.' 'Virtual' does not mean that real energy isn't generated. Instead, the hub of the power station is a control unit which processes data from many decentralized power stations, compares them with demand predictions, generation and weather conditions, retrieves available power market prices, and then intelligently optimizes the overall power station activity. Some public utilities already use such systems to integrate cogeneration plants, wind farms, photovoltaic systems and other power plants. The virtual power station can also connect consumers directly to the power management process.

how the energy [r]evolution scenario was created

To achieve the dramatic emissions cuts needed to avoid climate change will require a massive uptake of renewable energy. In the U.S., renewable energy targets must be greatly expanded both to substitute for fossil fuel and nuclear generation and to create the necessary economy of scale for global expansion. Within the Energy [R]evolution Scenario we assume that modern renewable energy sources, such as solar collectors, solar cookers and modern forms of bio energy, will replace inefficient, traditional biomass use.

Moving from principles to action for a secure, clean energy supply and climate change mitigation requires a long-term perspective. Energy infrastructure takes time to build, and new energy technologies take time to develop. Policy shifts often need many years to have an effect. Therefore, any analysis that seeks to tackle energy and environmental issues needs to look ahead at least half a century.

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

The **reference scenario** is based on the Reference Scenario published by the International Energy Agency in World Energy Outlook 2007 (WEO 2007). (IEA recently released WEO 2008, however too late for use in in this study.)[26] The Reference Scenario only takes existing international energy and environmental policies into account. The assumptions include, for example, continuing progress in electricity and gas market reforms, the liberalization of cross-border energy trade and new policies designed to combat environmental pollution. The Reference Scenario does not include additional policies to reduce greenhouse gas emissions. As the IEA Reference Scenario only forecasts energy growth to 2030, Greenpeace extended the Reference Scenario to 2050 by extrapolating its key macroeconomic indicators. This provides a baseline for comparison with the Energy [R]evolution Scenario.

The **energy [r]evolution** scenario has a key target for the reduction of worldwide carbon dioxide emissions down to a level of around 10 gigatons per year by 2050 to meet science-based levels necessary to reduce the risk of catastrophic global warming. A second objective is a global phase-out of nuclear energy. To achieve these goals, the Energy [R]evolution Scenario proposes an ambitious plan to fully exploit the large potential for energy efficiency. At the same time, all cost-effective renewable energy sources are used for heat, electricity generation, and the production of bio fuels. The general framework parameters for population and GDP growth remain unchanged from the Reference Scenario.

These scenarios do not claim to predict the future; they simply describe two potential development paths out of the broad range of possible 'futures'. The Energy [R]evolution Scenario is designed as a roadmap for the efforts and actions required to achieve its ambitious objectives and as an illustration of the options we have at hand to create a sustainable energy supply system.

scenario background The scenarios in this report were jointly commissioned by Greenpeace and the European Renewable Energy Council from the Institute of Technical Thermodynamics, part of the German Aerospace Center (DLR). The supply scenarios were calculated using the MESAP/PlaNet simulation model used for the previous Energy [R]evolution study.[27] Energy demand projections were developed by Ecofys Netherlands, based on an analysis of the future potential for energy efficiency measures. The biomass potential, using Greenpeace sustainability criteria, has been developed especially for this scenario by the German Biomass

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26 INTERNATIONAL ENERGY AGENCY, WORLD ENERGY OUTLOOK 2007 (2007) AVAILABLE AT: HTTP://WWW.WORLDENERGYOUTLOOK.ORG/2007.ASP.
27 GREENPEACE INTERNATIONAL, ENERGY [R]EVOLUTION: A SUSTAINABLE WORLD ENERGY OUTLOOK (2007).

"moving from principles to action.."

Research Centre. The future development pathway for car technologies is based on a special report produced in 2008 by the Institute of Vehicle Concepts, DLR for Greenpeace International.

The aim of the Ecofys study was to develop a low energy demand scenario for the period 2005 to 2050 for the IEA regions as defined in the World Energy Outlook report series. Calculations were made for each decade from 2010 onwards. Energy demand was split up into electricity and fuels. The Ecofys study took the following sectors into account: industry, transport, and consumers, including households and services.

Under the low energy demand scenario, worldwide final energy demand is reduced by 38 percent in 2050 in comparison to the Reference Scenario, resulting in a final energy demand of 350 EJ (ExaJoules). The energy savings are equally distributed over the three sectors of industry, transport and other uses. The most important energy saving methods are efficient passenger and freight transport and improved heat insulation and building design.

The Institute of Vehicle Concepts (IVC) in Stuttgart, Germany developed a global scenario for cars covering ten world regions. The goal was to produce a demanding but feasible scenario to lower global car CO_2 emissions within the context of the Energy [R]evolution Scenario. The IVC approach takes into account a vast range of technical measures to reduce vehicle energy consumption, but also considers the dramatic increase in vehicle ownership and annual mileage taking place in developing countries. In addition, the IVC examined vehicle technology, alternative fuels, changes in sales of different vehicle sizes (segment split) and changes in usage and driving distances (modal split).

The scenario assumes that a large share of renewable electricity will be available in the future. A combination of ambitious efforts towards higher efficiency in vehicle technologies, a major switch to grid-connected electric vehicles, and incentives for vehicle users to save carbon dioxide lead to the conclusion that it is possible to reduce CO_2 emissions from 'well-to-wheel' in 2050 by roughly 25 percent[28] compared to 1990 and 40 percent compared to 2005.

Under the scenario, by 2050, 60 percent of the energy used in transport will still come from fossil fuels, mainly gasoline and diesel. Renewable electricity will provide 25 percent of transport energy needs, bio fuels 13 percent, and hydrogen will provide 2 percent by 2050. However, total global energy consumption in 2050 will be similar to 2005 consumption levels, in spite of enormous increases in fuel use in some regions of the world.

The peak in global CO_2 emissions from transport occurs between 2010 and 2015. From 2010 onwards, new legislation in the US and Europe will help break the upwards trend in emissions. From 2020 onwards, the effect of introducing grid-connected electric cars can be clearly seen.

scenario principles in a nutshell

- Smart energy consumption, generation and distribution
- Decentralized energy production
- Maximum use of locally available, environmentally friendly fuels

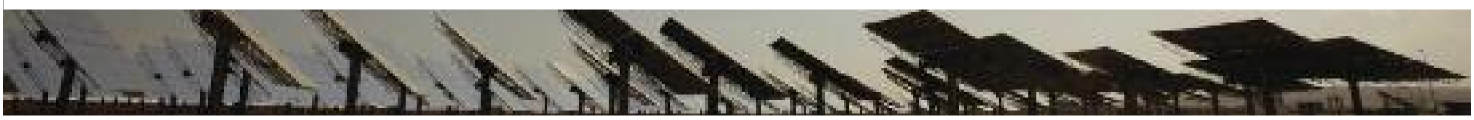


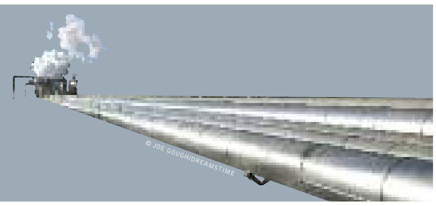
image THE PS10 CONCENTRATING SOLAR TOWER PLANT USES 624 LARGE MOVABLE MIRRORS CALLED HELIOSTATS. THE MIRRORS CONCENTRATE THE SUN'S RAYS TO THE TOP OF A 115 METER (377 FOOT) HIGH TOWER WHERE A SOLAR RECEIVER AND A STEAM TURBINE ARE LOCATED. THE TURBINE DRIVES A GENERATOR, PRODUCING ELECTRICITY, SEVILLA, SPAIN.

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

the world's energy resources

2

> **"we must make a greater, more committed push towards energy independence and with it a more secure energy system."**
>
> U.S. SECRETARY OF ENERGY STEPHEN CHU



The issue of energy security is now at the top of the U.S. policy agenda. Concern is focused both on price stability and the security of physical supply. At present, around 80 percent of global energy demand is met by fossil fuels. There is an unrelenting increase in energy demand, yet finite energy sources. This chapter, based partly on the report 'Plugging the Gap,[29] examines the potential sources of energy to meet the world's growing energy needs.

oil

Oil is the lifeblood of the modern global economy, as the effects of the supply disruptions of the 1970s made clear. Oil provides 36 percent of the world's energy needs and is the fuel employed almost exclusively for essential uses such as transportation. However, a passionate debate has developed over the ability of supply to meet increasing consumption, a debate obscured by poor information and stirred by unstable oil prices.

the reserves chaos

Public data about oil and gas reserves is strikingly inconsistent and potentially unreliable for legal, commercial, historical and sometimes political reasons. The most widely available and quoted figures, those from industry journals like Oil & Gas Journal and World Oil, have limited value as they report the reserve figures provided by companies and governments without analysis or verification. Moreover, as there is no agreed definition of reserves or standard reporting practice, these figures usually stand for different physical and conceptual magnitudes. Confusing terminology ('proved', 'probable', 'possible', 'recoverable', 'reasonable certainty') only adds to the problem.

Historically, private oil companies have consistently underestimated their reserves to comply with conservative stock exchange rules and to provide a conservative resource estimate in the marketplace. When an oil discovery is made, often just a portion of the geologist's estimate of recoverable resources is reported and subsequent reporting may increase the reserves from that same oil field over time. On the other hand, national oil companies, mostly represented by the Organization of Petroleum Exporting Countries (OPEC), are not subject to any reporting standards. In the late 1980s, OPEC countries blatantly overstated their reserves while competing for production quotas, which were allocated as a proportion of the reserves. Although some revision was needed after the companies were nationalized, between 1985 and 1990, OPEC countries increased their joint reserves by 82 percent. Not only were these dubious revisions never corrected, but many of these countries have reported untouched reserves for years, even if no sizeable discoveries were made and production continued at the same pace. Additionally, the Former Soviet Union's oil and gas reserves have been overestimated by about 30 percent because the original assessments were later misinterpreted.

While private companies are now becoming more realistic about the extent of their resources, the OPEC countries hold by far the majority of the reported reserves, and information on their resources is as unsatisfactory as ever. In brief, these information sources should be treated with considerable caution. To fairly estimate the world's oil resources a regional assessment of the mean backdated (i.e. 'technical') discoveries would need to be performed.

natural gas

Natural gas has been the fastest-growing fossil energy source in the U.S. and comprises an increasing share among electricity generation fuels. Gas is generally regarded as an abundant resource, and public concerns about depletion are limited to oil, even though few in-depth studies address the subject. Gas resources are very concentrated, and a few massive fields make up most of the reserves. The largest gas field in the world holds 15 percent of the 'Ultimate Recoverable Resources' (URR), compared to 6 percent for oil. Unfortunately, information about gas resources suffers from the same bad practices as oil data, because gas mostly comes from the same geological formations, and the same stakeholders are involved.

Most reserves are initially understated and then gradually revised upwards, giving an optimistic impression of growth. By contrast, Russia's reserves, the largest in the world, are considered to have been overestimated by about 30 percent. Owing to geological similarities, gas follows the same depletion dynamic as oil, and thus the same discovery and production cycles. In fact, existing data for gas is of worse quality than for oil, with ambiguities arising over the amount produced partly because flared and vented gas is not always accounted for. As opposed to published reserves, the technical ones have been almost constant since 1980 because discoveries have roughly matched production.

coal

Coal was the world's largest source of energy until it was overtaken by oil in the 1960s. Today, coal supplies almost one-quarter of the world's energy. Despite being the most abundant of fossil fuels, the continued use of coal is currently threatened by environmental

references

29 GLOBAL WIND ENERGY COUNCIL (GWEC) AND RENEWABLE ENERGY SYSTEMS LIMITED (RES), PLUGGING THE GAP - A SURVEY OF WORLD FUEL RESOURCES AND THEIR IMPACT OF THE DEVELOPMENT OF WIND ENERGY (2006) AVAILABLE AT: HTTP://WWW.GWEC.NET/UPLOADS/MEDIA/RESGWEC-_PLUGGING_THE_GAP_REPORT_01.09.06.PDF concerns. Coal reserves are abundant and more equally distributed throughout the world than oil and gas. Global recoverable reserves are the largest of all fossil fuels, and most countries have at least some. Moreover, existing and prospective big energy consumers like the U.S., China and India are self-sufficient in coal and will be for the foreseeable future. Coal has been exploited on a large scale for two centuries, so both the product and the available resources are well known, and no substantial new deposits are expected to be discovered. In the future, the world will likely consume 20 percent of its current reserves by 2030 and 40 percent by 2050. Therefore, even if current trends are maintained, coal supplies would still last several hundred years.

nuclear

Uranium, the fuel used in nuclear power plants, is a finite resource whose economically available reserves are limited. Its distribution is almost as concentrated as oil and does not match regional consumption. Five countries - Canada, Australia, Kazakhstan, Russia and Niger - control three quarters of the world's supply. As a significant user of uranium, however, Russia's reserves will be exhausted within ten years.

Secondary sources, such as old deposits, currently make up nearly half of worldwide uranium reserves. However, those will soon be used up. Mining capacities will have to be nearly doubled in the next few years to meet current needs.

A joint report by the OECD Nuclear Energy Agency and the International Atomic Energy Agency estimates that all existing nuclear power plants will have used up their nuclear fuel, employing current technology, within less than 70 years.[30] Given the range of scenarios for the worldwide development of nuclear power, it is likely that uranium supplies will be exhausted sometime between 2026 and 2070. This forecast includes the use of mixed oxide fuel (MOX), a mixture of uranium and plutonium.

renewable energy

Nature offers a variety of freely available options for producing energy. Their exploitation is mainly a question of how to convert sunlight, wind, biomass or water into electricity, heat or power as efficiently, sustainably and cost-effectively as possible.

On average, the energy in the sunshine that reaches the Earth is about one kilowatt per square meter worldwide. According to the Research Association for Solar Power, power is gushing from renewable energy sources at a rate of 2,850 times more energy than is needed in the world. In one day, the sunlight which reaches the Earth produces enough energy to satisfy the world's current power requirements for eight years. Even though only a percentage of that potential is technically accessible, this is still enough to provide just under six times more power than the world currently requires.

definition of types of energy resource potential[31]

theoretical potential The theoretical potential identifies the physical upper limit of the energy available from a certain source. For solar energy, for example, this would be the total solar radiation falling on a particular surface.

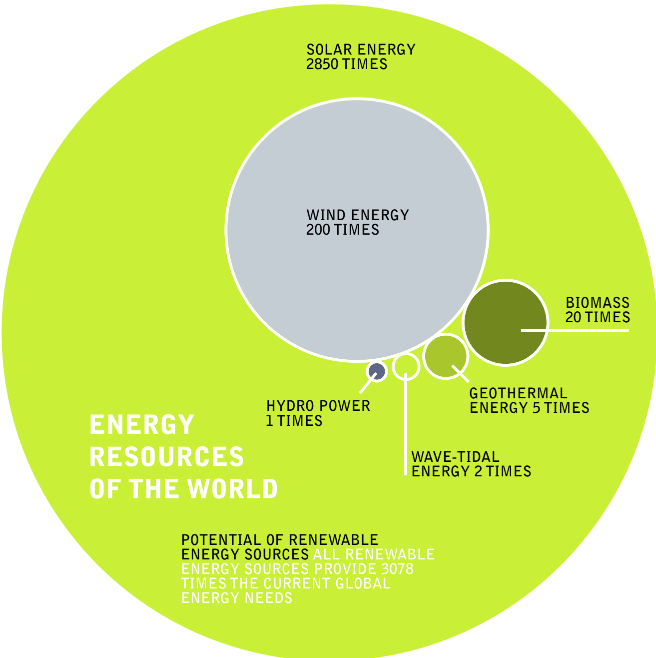
conversion potential The conversion potential is derived from the annual efficiency of the respective conversion technology. It is therefore not a strictly defined value, since the efficiency of a particular technology depends on technological progress.

technical potential The technical potential takes into account additional restrictions regarding the area that is realistically available for energy generation. Technological, structural and ecological restrictions, as well as legislative requirements, are accounted for.

economic potential The proportion of the technical potential that can be utilized economically. For biomass, for example, those quantities are included that can be exploited economically in competition with other products and land uses.

sustainable potential This limits the potential of an energy source based on evaluation of ecological and socio-economic factors.

figure 2.1: **energy resources of the world**



source WBGU

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31 GERMAN ADVISORY COUNCIL ON GLOBAL CHANGE (WGBU) AVAILABLE AT: WWW.WBGU.DE.

image GREENPEACE INSTALLED 40 PHOTOVOLTAIC SOLAR PANELS THAT MUST SUPPLY 30% TO 60% OF THE DAILY DEMAND OF ELECTRICITY IN THE GREENPEACE OFFICE IN SAO PAULO. THE PANELS ARE CONNECTED TO THE NATIONAL ENERGY GRID, WHICH IS NOT ALLOWED BY LAW IN BRAZIL. ONLY ABOUT 20 SYSTEMS OF THIS TYPE EXIST IN BRAZIL AS THEY REQUIRE A SPECIAL LICENSE TO FUNCTION.

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

renewable energy potential by region and technology

Based on the report 'Renewable Energy Potentials' from REN 21, a global policy network,[32] the Energy [R]evolution Scenario can provide a more detailed overview of renewable energy prospects by world region and technology.

Solar photovoltaic (PV) technology can be harnessed almost everywhere, and its technical potential is estimated at over 1,500 EJ/year, closely followed by concentrating solar thermal power (CSP). These two cannot simply be added together, however, because they would require much of the same land resources. Onshore wind potential is equally vast, with almost 400 EJ/year available beyond the future electricity consumption. The estimate for offshore wind potential (22 EJ/year) is cautious, as only wind intensive areas on ocean shelf areas, with a relatively shallow water depth, outside shipping lines and protected areas, are included. Various ocean or marine energy potentials also reach a similar magnitude, mostly from ocean waves. Cautious estimates reach a figure of around 50 EJ/year. The estimates for hydro and geothermal (energy generated from the Earth's natural heat) resources are well established, each having a technical potential of around 50 EJ/year. To put these figures in context, current global energy demand of around 500 EJ.

In terms of heating and cooling, using direct geothermal energy also has great potential to meet and exceed current world energy demand for heat. The potential for solar heating, including passive solar building design, is virtually limitless. However, heat is costly to transport, and one should only consider geothermal heat and solar water heating potentials which are sufficiently close to the point of consumption. Passive solar technology, which contributes enormously to the provision of heating services, is not considered as a supply source in the Energy [R]evolution Scenario, but as an efficiency factor to be taken into account in energy demand forecasts.

references
32 REN 21, RENEWABLE ENERGY POTENTIALS: OPPORTUNITIES FOR THE RAPID DEPLOYMENT OF RENEWABLE ENERGY IN LARGE ENERGY ECONOMIES (2007) AVAILABLE AT: HTTP://WWW.REN21.NET/PDF/RENEWABLE_ENERGY_DEPLOYMENT_POTENTIALS_IN_LARGE_ECONOMIES.PDF

table 2.1: energy resources that are technically accessible today

RESERVES, RESOURCES AND ADDITIONAL OCCURRENCES OF FOSSIL ENERGY CARRIERS ACCORDING TO DIFFERENT AUTHORS. **C** CONVENTIONAL (PETROLEUM WITH A CERTAIN DENSITY, FREE NATURAL GAS, PETROLEUM GAS, **NC** NON-CONVENTIONAL) HEAVY FUEL OIL, VERY HEAVY OILS, TAR SANDS AND OIL SHALE, GAS IN COAL SEAMS, AQUIFER GAS, NATURAL GAS IN TIGHT FORMATIONS, GAS HYDRATES). THE PRESENCE OF ADDITIONAL OCCURRENCES IS ASSUMED BASED ON GEOLOGICAL CONDITIONS, BUT THEIR POTENTIAL FOR ECONOMIC RECOVERY IS CURRENTLY VERY UNCERTAIN. IN COMPARISON: IN 1998, THE GLOBAL PRIMARY ENERGY DEMAND WAS 402EJ (UNDP ET AL., 2000).

ENERGY CARRIER		BROWN, 2002 EJ	IEA, 2002c EJ	IPCC, 2001a	EJ	NAKICENOVIC ET AL., 2000	EJ	UNDP ET AL., 2000	EJ	BGR, 1998	EJ
Gas	reserves	5,600	6,200	c	5,400	c	5,900	c	5,500	c	5,300
				nc	8,000	nc	8,000	nc	9,400	nc	100
	resources	9,400	11,100	c	11,700	c	11,700	c	11,100	c	7,800
				nc	10,800	nc	10,800	nc	23,800	nc[a)]	111,900
	additional occurrences				796,000		799,700		930,000		
Oil	reserves	5,800	5,700	c	5,900	c	6,300	c	6,000	c	6,700
				nc	6,600	nc	8,100	nc	5,100	nc	5,900
	resources	10,200	13,400	c	7,500	c	6,100	c	6,100	c	3,300
				nc	15,500	nc	13,900	nc	15,200	nc	25,200
	additional occurrences				61,000		79,500		45,000		
Coal	reserves	23,600	22,500		42,000		25,400		20,700		16,300
	resources	26,000	165,000		100,000		117,000		179,000		179,000
	additional occurrences				121,000		125,600				
Total	resource (reserves + resources)	**180,600**	**223,900**		**212,200**		**213,200**		**281,900**		**361,500**
Total	occurrence				**1,204,200**		**1,218,000**		**1,256,000**		

source SEE TABLE **a)** INCLUDING GAS HYDRATES

table 2.2: technical renewable energy potential by region

EXCL. BIO ENERGY

	SOLAR CSP	SOLAR PV	HYDRO POWER	WIND ON-SHORE	WIND OFF-SHORE	OCEAN POWER	GEO-THERMAL ELECTRIC	GEO-THERMAL DIRECT USES	SOLAR WATER HEATING	TOTAL
	ELECTRICITY [EJ/YEAR]							HEATING [EJ/YEAR]		
OECD North America	21	72	4	156	2	68	5	626	23	976
Latin America	59	131	13	40	5	32	11	836	12	1,139
OECD Europe	1	13	2	16	5	20	2	203	23	284
Non OCED Europe & Transition Economies	25	120	5	67	4	27	6	667	6	926
Africa & Middle East	679	863	9	33	1	19	5	1,217	12	2,838
East & South Asia	22	254	14	10	3	103	12	1,080	45	1,543
Oceania	187	239	1	57	3	51	4	328	2	872
World	**992**	**1,693**	**47**	**379**	**22**	**321**	**45**	**4,955**	**123**	**8,578**

source REN21

the global potential for sustainable biomass

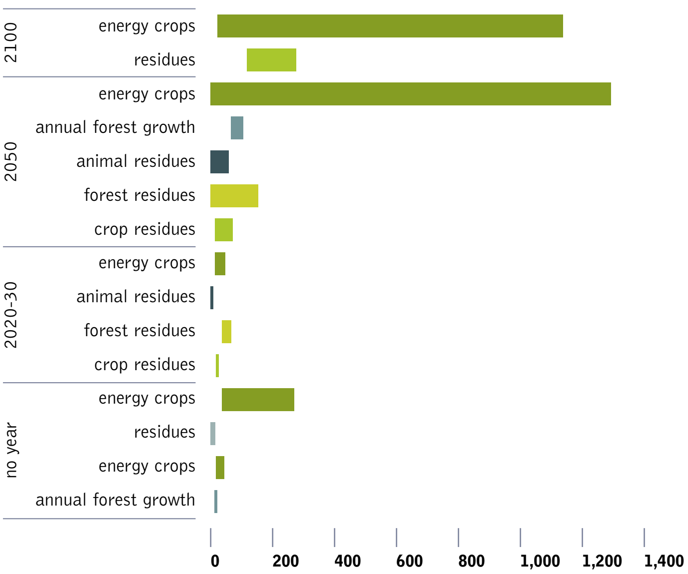
As part of background research for the Energy [R]evolution Scenario, Greenpeace commissioned the German Biomass Research Centre, the former Institute for Energy and Environment, to investigate the worldwide potential for energy crops in different scenarios up to 2050. In addition, information has been compiled from scientific studies of the worldwide potential and from data derived from state of the art remote sensing techniques such as satellite images.

Various studies have looked historically at the potential for bio energy and come up with widely differing results. Comparison between them is difficult because they use different definitions of the various biomass resource fractions. This problem is particularly significant in relation to forest derived biomass. Most research has focused almost exclusively on energy crops, as their development is considered to be more significant for satisfying the demand for bio energy. The result is that the potential for using forest residues (wood left over after harvesting) is often underestimated.

Data from eighteen studies were examined, with a concentration on those studies which report the potential for biomass residues. Among these there were ten comprehensive assessments with more or less detailed documentation of the methodology. The majority focus on the long-term potential for 2050 and 2100. Little information is available for 2020 and 2030. Most of the studies were published within the last ten years. Figure 2.2 shows the variations in potential by biomass type from the different studies.

Looking at the contribution of individual resources to the total biomass potential, the majority of studies agree that the most promising resource is energy crops from dedicated plantations. Only six give a regional breakdown, however, and only a few quantify all types of residues separately. Quantifying the potential of minor fractions, such as animal residues and organic wastes, is difficult, as the data are relatively poor.

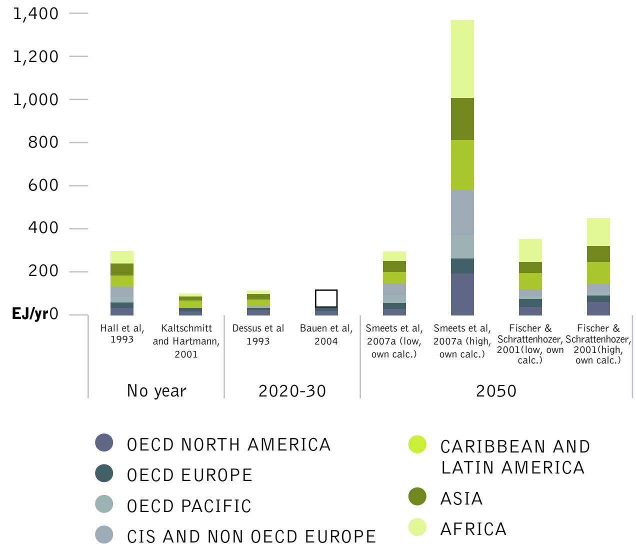
figure 2.2: a comparison of energy potential from biomass sources



source GERMAN BIOMASS RESEARCH CENTRE (DBFZ)

figure 2.3: bio energy potential analysis from different authors

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



source GERMAN BIOMASS RESEARCH CENTRE (DBFZ)

image THE BIOENERGY VILLAGE OF JUEHNDE WHICH WAS THE FIRST COMMUNITY IN GERMANY TO PRODUCE ALL ITS ENERGY NEEDED FOR HEATING AND ELECTRICITY, WITH CO_2 NEUTRAL BIOMASS.

image A NEWLY DEFORESTED AREA WHICH HAS BEEN CLEARED FOR AGRICULTURAL EXPANSION IN THE AMAZON, BRAZIL.

potential of energy crops

Apart from the utilization of biomass from waste, the cultivation of energy crops in agricultural production systems is of greatest significance. The technical potential for growing energy crops was calculated on the assumption that demand for food takes priority. As a first step the demand for arable and grassland for food production has been calculated for each of 133 countries in different scenarios. These scenarios are:

- Business as usual (BAU) scenario: Present agricultural activity continues for the foreseeable future.
- Basic scenario: No forest clearing; reduced use of fallow areas for agriculture.
- Sub-scenario 1: Basic scenario plus expanded ecological protection areas and reduced crop yields.
- Sub-scenario 1: Basic scenario plus expanded ecological protection areas and reduced crop yields.
- Sub-scenario 3: Combination of sub-scenarios 1 and 2.

The results of this exercise show that the availability of biomass resources is not only driven by the effect on global food supply but also by the effect on natural resources, and the need for conservation. The assessment of future biomass energy potential is only the starting point of a discussion about the integration of bioenergy into a renewable energy system.

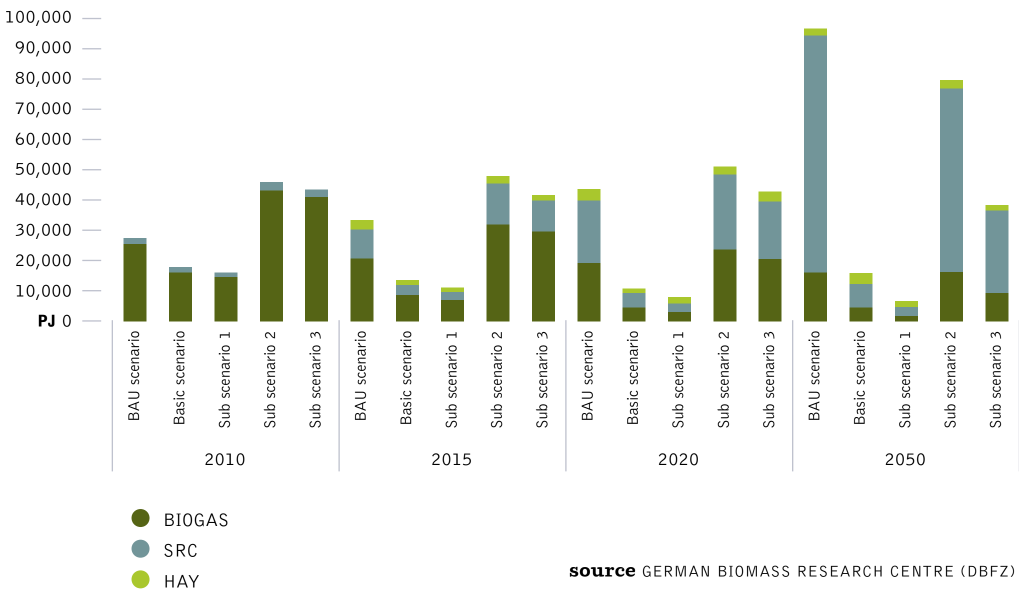
In a next step the surpluses of agricultural areas were classified either as arable land or grassland. On grassland, hay and grass silage are produced, while on arable land fodder silage and Short Rotation Coppice (such as fast-growing willow or poplar) are cultivated. Silage of green fodder and grass are assumed to be used for biogas production, wood from SRC and hay from grasslands for the production of heat, electricity and synthetic fuels. Country-specific yield variations were also taken into consideration.

Global biomass potential from energy crops in 2050 falls within a range from 6 EJ in Sub-scenario 1 up to 97 EJ in the BAU scenario.

The best example of a country which would see a very different future under these scenarios in 2050 is Brazil. Under the BAU scenario large agricultural areas would be released by deforestation, whereas in the Basic and Sub 1 scenarios this would be forbidden, and no agricultural areas would be available for energy crops. By contrast a high potential would be available under Sub-scenario 2 as a consequence of reduced meat consumption. Because of their high populations and relatively small agricultural areas, no surplus land is available for energy crop production in Central America, Asia and Africa. The EU, North America and Australia, however, have relatively stable potentials.

The total global biomass potential (energy crops and residues) therefore ranges in 2020 from 66 EJ (Sub-scenario 1) up to 110 EJ (Sub-scenario 2) and in 2050 from 94 EJ (Sub-scenario 1) to 184 EJ (BAU scenario). These numbers are conservative and include a level of uncertainty, especially for 2050. The reasons for this uncertainty are the potential effects of climate change on agriculture and forests, possible changes in the worldwide political and economic situation, a higher yield as a result of changed agricultural techniques and/or faster development in plant breeding.

figure 2.4: world wide energy crop potentials in different scenarios



source GERMAN BIOMASS RESEARCH CENTRE (DBFZ)

projections of future energy demand and cost

3

"time and time again, when the nation has set a new environmental standard, the naysayers have warned that it will cost too much. but american ingenuity and innovation have found a solution at a far lower cost than predicted."

U.S. "CLIMATE CZARINA" CAROL BROWNER

This chapter summarizes the projections for population growth, economic growth, and the costs of various energy sources between now and 2050. These underlying assumptions are critical to the soundness of the overall scenario.

population development projections

An important underlying factor in the Energy [R]evolution Scenario is future population development. Population growth affects the size and composition of energy demand, directly and through its impact on economic growth and development. World Energy Outlook 2007 (WEO) uses the United Nations Development Programme (UNDP) projections for population development. For this study, the most recent population projections from UNDP up to 2050 are applied.[33]

Table 3.1 summarizes this study's assumptions. The world's population is expected to grow by 0.77 % on average over the period 2005 to 2050, from 6.5 billion people in 2005 to more than 9.1 billion in 2050. Population growth will slow over the projection period, from 1.2% during 2005-2010 to 0.4% during 2040- 2050. However, the updated projections show an increase in population of almost 300 million compared to the previous edition. This will further increase the demand for energy. The population of the developing regions will continue to grow most rapidly. The Transition Economies will face a continuous decline, followed after a short while by the OECD Pacific countries. OECD Europe and OECD North America are expected to maintain their population, with a peak in around 2020/2030 and a slight decline afterwards. The share of the population living in today's Non-OECD countries will increase from the current 82% to 86% in 2050. China's contribution to world population will drop from 20% today to 15% in 2050. Africa will remain the region with the highest growth rate, leading to a share of 21% of world population in 2050. Satisfying the energy needs of a growing population in the developing regions of the world in an environmentally friendly manner is a key challenge for achieving a global sustainable energy supply.

economic growth projections

Economic growth is a key driver for energy demand. Since 1971, each 1 percent increase in global Gross Domestic Product (GDP) has been accompanied by a 0.6 percent increase in primary energy consumption. The decoupling of energy demand and GDP growth is therefore a prerequisite for reducing demand in the future. Most global energy and economic models constructed in the past have relied on market exchange rates to place countries in a common currency for estimation and calibration. This approach has been the subject of considerable discussion in recent years, and the alternative of purchasing power parity (PPP) exchange rates has been proposed. Purchasing power parities compare the costs in different currencies of a fixed basket of traded and non-traded goods and services and yield a widely-based measure of the standard of living. This is important in analyzing 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, product trade and national price indexes, they are considered to provide a better basis for global scenario development.[34] Thus all data on economic development in WEO 2007 refers to purchasing power adjusted GDP. However, as WEO 2007 only covers the time period up to 2030, the projections for 2030-2050 are based on our own estimates.

GDP growth in all regions is expected to slow gradually over the coming decades. World GDP is assumed to grow on average by 3.6 percent per year over the period 2005-2030, compared to 3.3 percent from 1971 to 2002, and on average by 3.3 percent per year over the entire modeling period. China and India are expected to grow faster than other regions, followed by developing countries in Asia, Africa and the other Transition Economies. The Chinese economy will slow as it becomes more mature, but will nonetheless become the largest in the world in PPP terms early in the 2020s. GDP in OECD Europe and OECD Pacific is assumed to grow by around 2% per year over the projection period, while economic growth in OECD North America is expected to be slightly higher. The OECD share of global PPP-adjusted GDP will decrease from 55% in 2005 to 29% in 2050.

fossil fuel and biomass price projections

The recent dramatic fluctuations in global oil prices has resulted in rising forward price projections for fossil fuels. Under the 2004 'high oil and gas price' scenario from the European Commission, for example, oil was projected to cost just $34 per barrel in 2030. More recent projections of oil prices in 2030 range from the IEA's $60 per barrel (in 2005 dollars) in WEO 2007 up to $115 per barrel in the 'high price' scenario of the US Energy Information Administration's Annual Energy Outlook 2008.

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image ICE AND WATER IN THE NORTH POLE. GREENPEACE EXPLORERS, LONNIE DUPRE AND ERIC LARSEN MAKE HISTORY AS THEY BECOME THE FIRST-EVER TO COMPLETE A TREK TO THE NORTH POLE IN SUMMER. THE DUO UNDERTAKE THE EXPEDITION TO BRING ATTENTION TO THE PLIGHT OF THE POLAR BEAR WHICH SCIENTISTS CLAIM COULD BE EXTINCT AS EARLY AS 2050 DUE TO THE EFFECTS OF GLOBAL WARMING.

table 3.1: the growth of fuel prices

	2005	2006	2007	2010	2015	2020	2030	2040	2050
Crude oil import prices in $2005 per barrel	52.5	60.1	71.2						
IEA WEO 2007 ETP 2008				57.2	55.5		60.1		63
US EIA 2008 'Reference'				71.7		57.9	68.3		
US EIA 2008 'High Price'				76.6		99.1	115.0		
Energy [R]evolution 2008				100	105	110	120	130	140
Gas import prices in $2005 per GJ	2000	2005	2006						
IEA WEO 2007/ ETP 2008									
US imports	4.59		7.38	7.52	7.52		8.06		8.18
European imports	3.34		7.47	6.75	6.78		7.49		7.67
Japan imports	5.61		7.17	7.48	7.49		8.01		8.18
Energy [R]evolution 2008									
US imports		5.7		11.5	12.7	14.7	18.4	21.9	24.6
European imports		5.8		10.0	11.4	13.3	17.2	20.6	23.0
Asia imports		5.6		11.5	12.6	14.7	18.3	21.9	24.6
Hard coal import prices in $2005 per tonne	2000	2005	2006						
IEA WEO 2007/ ETP 2008	37.8		60.9	54.3	55.1		59.3		59.3
Energy [R]evolution 2008				142.7	167.2	194.4	251.4	311.2	359.1
Biomass (solid) prices in $2005 per GJ	2005								
Energy [R]evolution 2008									
OECD Europe	7.5			7.9	8.5	9.4	10.3	10.6	10.8
OECD Pacific, NA	3			3.3	3.5	3.8	4.3	4.7	5.2
Other regions	2.5			2.8	3.2	3.5	4.0	4.6	4.9

Since the last Energy [R]evolution report was published, however, the price of oil has moved over $100/bbl for the first time (at the end of 2007), and in July 2008 reached a record high of more than $140/bbl. Although oil prices have fallen since then, the above projections might still be considered too conservative considering long-term global trends in reserves and demand. Considering the growing global demand for oil and gas the Energy [R]evolution projects a price development path for fossil fuels in which the price of oil reaches $120/bbl by 2030 and $140/bbl in 2050.

As the supply of natural gas is limited by the availability of pipeline infrastructure, there is no world market price for natural gas. In most regions of the world the gas price is directly tied to the price of oil. Gas prices are assumed to increase to $20-25/GJ by 2050.

cost of CO_2 emissions

Assuming that a global CO_2 emissions trading system is established, the cost of long-term CO_2 allowances will need to be included in the calculation of electricity generation costs. Projections of emissions costs are even more uncertain than energy prices, and available studies span a broad range of future CO_2 cost estimates. As in the previous Energy [R]evolution study we assume CO_2 costs of $10/t$CO_2$ in 2010, rising to $50/t$CO_2$ in 2050. Additional CO_2 costs are applied to developing countries that are signatories to the Kyoto Protocol after 2020 (see table 3.2).

power plant investment costs

fossil fuel technologies and carbon capture and storage (CCS)

Although fossil fuel power technologies in use today for coal, gas, lignite and oil are at an advanced stage of market development, further cost reduction potentials are possible. The potential for cost reductions is limited, however, and will be achieved mainly through an increase in efficiency, or a reduction in investment costs.[35]

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

CCS is a means of trapping CO_2 from fossil fuels, either before or after they are burned, and 'storing' (as a means of disposal) it in the sea or beneath the surface of the Earth. There are currently three different methods of capturing CO_2: 'pre-combustion,' 'postcombustion,' and 'oxyfuel combustion.' However, development is at a very early stage, and commercial-scale CCS will not be implemented—in the best case—before 2020 and will probably not become commercially viable as an effective mitigation option until 2030 or later. Indeed there is no guarantee at this stage that CCS will ever be made to work on a commercial scale.

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Cost estimates for CCS vary considerably, depending on factors such as power station configuration, technology, fuel costs, project size and location. One thing is certain, however: CCS is expensive. CCS requires significant funds to construct the power stations and the necessary infrastructure to transport and store carbon. The IPCC cost estimates range from $15 to $75 per ton of captured CO_2[36] while a recent U.S. Department of Energy report found installing carbon capture systems to most modern plants resulted in a near doubling of costs.[37] These costs are estimated to increase the price of electricity in a range from 21-91 percent.

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.[38] Costs will vary depending on a number of factors, including pipeline length, diameter, manufacture from corrosion-resistant steel, and the volume of CO_2 to be transported. Pipelines built through or near population centers or on difficult terrain, such as marshy or rocky ground, are more expensive.[39]

The IPCC estimates a cost range for pipelines of $1-8/ton of CO_2 transported. A U.S. Congressional Research Service report calculated capital costs for an 11-mile pipeline in the Midwest at approximately $6 million. The same report estimates that a dedicated interstate pipeline network in North Carolina would cost upwards of $5 billion due to the limited geological sequestration potential in that part of the country.[40] Storage and subsequent monitoring and verification costs are estimated by the IPCC to range from $0.5-8/t$CO_2$ injected and $0.1-0.3/t$CO_2$ injected, respectively. The overall cost of CCS could therefore serve as a major barrier to its deployment.[41]

For the above reasons, CCS power plants are not included in the Energy [R]evolution Scenario's financial analysis. Table 3.3 summarizes our assumptions on the technical and economic parameters of future fossil-fuelled power plant technologies. In spite of growing raw material prices, we assume that further technical innovation will result in a moderate reduction of future investment costs as well as improved power plant efficiencies. These improvements are, however, outweighed by the expected increase in fossil fuel prices, resulting in a significant rise in electricity generation costs.

table 3.2: rising costs of co_2 emissions

($/t$CO_2$)

COUNTRIES	2010	2020	2030	2040	**2050**
Kyoto Annex B countries	10	20	30	40	**50**
Non-Annex B countries		20	30	40	**50**

table 3.3: growth of efficiency and investment costs for selected power plant technologies

		2005	2010	2020	2030	2040	**2050**
Coal-fired condensing power plant	Efficiency (%)	45	46	48	50	52	**53**
	Investment costs ($/kW)	1,320	1,230	1,190	1,160	1,130	**1,100**
	Electricity generation costs including CO_2 emission costs ($cents/kWh)	6.6	9.0	10.8	12.5	14.2	**15.7**
	CO_2 emissions [a)] (g/kWh)	744	728	697	670	644	**632**
Lignite-fired condensing power plant	Efficiency (%)	41	43	44	44.5	45	**45**
	Investment costs ($/kW)	1,570	1,440	1,380	1,350	1,320	**1,290**
	Electricity generation costs including CO_2 emission costs ($cents/kWh)	5.9	6.5	7.5	8.4	9.3	**10.3**
	CO_2 emissions [a)] (g/kWh)	975	929	908	898	888	**888**
Natural gas combined cycle	Efficiency (%)	57	59	61	62	63	**64**
	Investment costs ($/kW)	690	675	645	610	580	**550**
	Electricity generation costs including CO_2 emission costs ($cents/kWh)	7.5	10.5	12.7	15.3	17.4	**18.9**
	CO_2 emissions [a)] (g/kWh)	354	342	330	325	320	**315**

source DLR, 2008 **a)** CO_2 EMISSIONS REFER TO POWER STATION OUTPUTS ONLY; LIFE-CYCLE EMISSIONS ARE NOT CONSIDERED.

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40 PARFOMAK, P ET AL., PIPELINES FOR CARBON DIOXIDE (CO_2) CONTROL: NETWORK NEEDS AND COST UNCERTAINTIES, CONGRESSIONAL RESEARCH SERVICE, PG. 5-12 (2008) AVAILABLE AT: HTTP://NCSEONLINE.ORG/NLE/CRSREPORTS/08FEB/RL34316.PDF
41 RUBIN, ET. AL., 2005B, PG. 4444

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

cost projections for renewable energy technologies

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

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

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

To identify long-term cost developments, learning curves have been applied which reflect the correlation between cumulative production volumes of a particular technology and a reduction in its costs. For many technologies, the learning factor (or progress ratio) falls in the range between 0.75 for less mature systems to 0.95 and higher for well-established technologies. A learning factor of 0.9 means that costs are expected to fall by 10% every time the cumulative output from the technology doubles. Empirical data shows, for example, that the learning factor for PV solar modules has been fairly constant at 0.8 over 30 years while 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,[42] for example by Lena Neij and others, from the analysis of recent technology foresight and road mapping studies, including the European Commission funded NEEDS (New Energy Externalities Developments for Sustainability)[43] project or the IEA Energy Technology Perspectives 2008, and a discussion with experts from the renewable energy industry.

photovoltaics (pv)

The worldwide photovoltaics (PV) market has been growing at over 35 percent per year and the contribution it can make to electricity generation is starting to become significant. Development work is focused on improving existing modules and system components by increasing their energy efficiency and reducing material usage. Technologies like PV thin film (using alternative semiconductor materials) or dye sensitive solar cells are developing quickly and present a huge potential for cost reduction. The mature technology crystalline silicon, with a proven lifetime of 30 years, is continually increasing its cell and module efficiency (by 0.5 percent 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 percent depending on silicon quality and fabrication process.

The learning factor for PV modules has been fairly constant over the last 30 years; with a cost reduction of 20 percent each time the installed capacity doubles, indicating a high rate of technical learning. Assuming a global installed PV capacity of 1,600 GW between 2030 and 2040 and electricity output of 2,600 TWh, we can expect generation costs of around 5-10 cents/kWh (depending on the region). 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 2050. The importance of photovoltaics comes from the decentralized/centralized character of the technology, its flexibility for use in an urban environment, and huge potential for cost reduction.

concentrating solar power (csp)

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

Thermal storage systems are a key component for reducing CSP electricity generation costs. The Spanish Andasol 1 plant, for example, is equipped with molten salt storage with a capacity of 7.5 hours. A higher level of full load operation can be 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. Significantly, this storage technology can allow CSP plants to function as baseload energy, producing power 24 hours a day even when the sun is not shining.

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

references

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

wind power

Within a short period of time, the development of wind power has resulted in the establishment of a flourishing global market. The world's largest wind turbines, several of which have been installed in Germany, have a capacity of 6 MW. While favorable policy incentives have made Europe the main driver for the global wind market, in 2007 more than half of the annual market was outside Europe. This trend is likely to continue. The boom in demand for wind power technology has nonetheless led to supply constraints. As a consequence, the cost of new systems has stagnated or even increased. Because of the continuous expansion of production capacities, the industry expects to resolve the bottlenecks in the supply chain over the next few years. Taking into account market development projections, learning curve analysis, and industry expectations, we project that investment costs for wind turbines will reduce by 30 percent for onshore and 50 percent for offshore installations by 2050.

biomass

The crucial factor for the economics of biomass utilization is the cost of the feedstock, which today ranges from a negative cost for waste wood (based on credit for waste disposal costs avoided) to expensive energy crops. The resulting spectrum of energy generation costs is correspondingly broad.

One of the most economical options is the use of waste wood in steam turbine combined heat and power (CHP) plants. Gasification of solid biomass, on the other hand, which opens up a wide range of applications, is still relatively expensive. In the long term it is expected that favorable electricity production costs will be achieved by using wood gas both in micro CHP units (engines and fuel cells) and in gas-and-steam power plants. Great potential for the utilization of solid biomass also exists for heat generation in both small and large heating centers linked to local heating networks. Converting crops into ethanol and 'bio diesel' made from rapeseed methyl ester (RME) has become increasingly important in the U.S., as well as Brazil and Europe. Processes for obtaining synthetic fuels from biogenic synthesis gases will also play a larger role.

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

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

geothermal

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

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

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

Because of its non-fluctuating supply and continuous feed to the electricity grid, geothermal energy is considered to be a key element in a future energy supply structure based on renewable sources. Until now we have just used a marginal part of the geothermal heating and cooling potential. Shallow geothermal drilling makes possible the delivery of heating and cooling at anytime, anywhere, and can be used for thermal energy storage.

ocean energy

Ocean energy, particularly offshore wave energy, is a significant resource, and has the potential to satisfy an important percentage of electricity supply worldwide. Globally, the potential of ocean energy has been estimated at around 90,000 TWh/year. The most significant advantages are the vast availability and high predictability of the resource and a technology with very low visual impact and no CO_2 emissions. Many different concepts and devices have been developed, including taking energy from the tides, waves, currents and both thermal and saline gradient resources. Many of these concepts are in an advanced phase of research and development, and large scale prototypes have been deployed in real ocean conditions.

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

The cost of energy from initial tidal and wave energy farms has been estimated to be in the range of 15-55 cents/kWh, and for initial tidal stream farms in the range of 11-22 cents/kWh. Generation costs of 10-25 cents/kWh are expected by 2020. Key areas for development will include concept design, 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 percent for offshore wave and 5-10 percent for tidal stream. In the medium term, ocean energy has the potential to become one of the most competitive and cost effective forms of generation. In the next few years a dynamic market penetration is expected, following a similar curve to wind energy.

Because of the early development stage any future cost estimates for ocean energy systems are uncertain, and no learning curve data is available. Present cost estimates are based on analysis from the European NEEDS project.[44]

hydro power

Hydro power is a mature technology, yet there is still great potential to exploit new schemes (especially small-scale run-of-river projects with little or no reservoir impoundment) and to improve and re-power existing sites. The significance of hydro power is also likely to be encouraged by the increasing need for flood control and maintenance of water supply during dry periods. The future is in sustainable hydro power that integrates power plants with river ecosystems while reconciling ecology with economically attractive power generation.

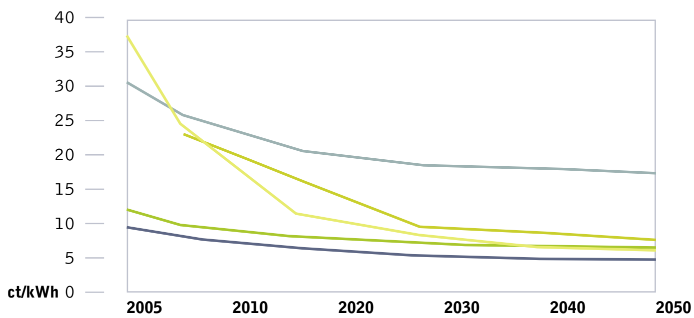
summary of renewable energy cost development

Figure 3.1 summarizes the cost trends for renewable energy technologies as derived from the respective learning curves. It should be emphasized that the expected cost reduction is basically not a function of time, but of cumulative capacity, so dynamic market development is required. Most technologies will be able to reduce their specific investment costs between 30 percent and 70 percent of current levels by 2020, and between 20 percent and 60 percent once they have achieved full development after 2040.

Reduced investment costs for renewable energy technologies lead directly to a reduction of heat and electricity generation costs, as shown in Figure 3.2. Generation costs today are around 10-25 cents/kWh for the most important technologies, with the exception of photovoltaics. In the long term, costs are expected to converge at around 5-12 cents/kWh). These estimates depend on site-specific conditions such as the local wind regime or solar irradiation, the availability of biomass at reasonable prices or the credit granted for heat supply in the case of combined heat and power generation.

figure 3.1: expected development of electricity generation costs from fossil fuel and renewable options

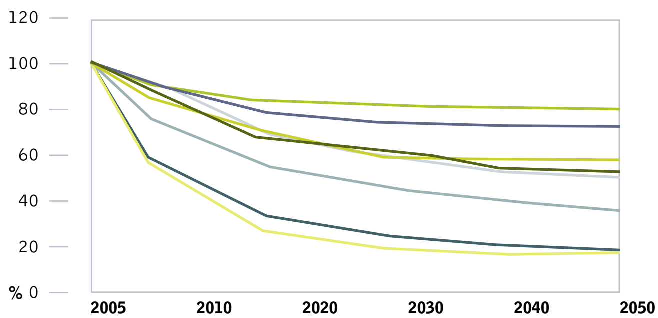
EXAMPLE FOR OECD NORTH AMERICA



- PV
- WIND
- BIOMASS CHP
- GEOTHERMAL CHP
- CONCENTRATING SOLAR THERMAL

figure 3.2: future development of investment costs

(NORMALISED TO CURRENT COST LEVELS) FOR RENEWABLE ENERGY TECHNOLOGIES



- PV
- WIND ONSHORE
- WIND OFFSHORE
- BIOMASS POWER PLANT
- BIOMASS CHP
- GEOTHERMAL CHP
- CONCENTRATING SOLAR THERMAL
- OCEAN ENERGY

references
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key results of the u.s. energy [r]evolution scenario

4

"each day brings further evidence that the ways we use energy strengthen our adversaries and threaten our planet."

PRESIDENT BARACK OBAMA

The development of future U.S. energy demand will be determined by three key factors:

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

Both the Reference and Energy [R]evolution Scenarios are based on the same projections of population and economic development. The future development of energy intensity, however, is different, and only the Energy [R]evolution Scenario takes into account measures to increase energy efficiency.

projection of energy intensity

An increase in economic activity and a growing population does not necessarily have to result in an equivalent increase in energy demand. There is still a large potential for exploiting energy efficiency measures. Under the Reference Scenario, energy intensity will be reduced by 1.25 percent on average per year, leading to a reduction in final energy demand per unit of GDP of about 56 percent between 2005 and 2050. Under the Energy [R]evolution Scenario, it is assumed that active policy and technical support for energy efficiency measures will lead to an even higher reduction in energy intensity of almost 73 percent.

figure 4.1: USA: projection of average energy intensity under the reference and energy [r]evolution scenarios

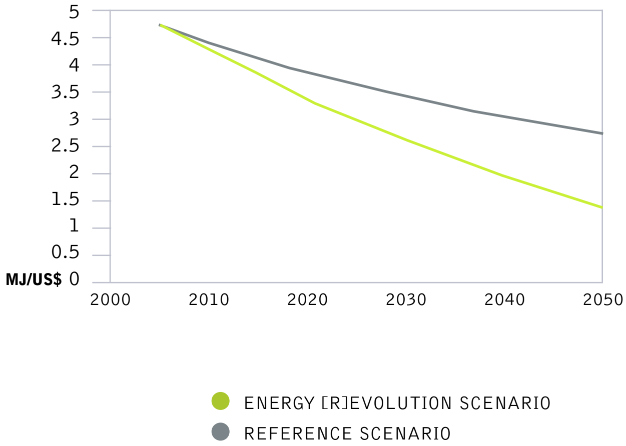


image SUN SETTING OFF THE GULF OF MEXICO.

image AERIAL VIEW OF THE CHEVRON EMPIRE, SITUATED IN PLAQUEMINES PARISH NEAR THE MOUTH OF THE MISSISSIPPI RIVER, AN AREA DEVASTATED BY HURRICANE KATRINA.AROUND 991,000 GALLONS OF OIL WERE RELEASED, AROUND 4,000 GALLONS WERE RECOVERED, AND A FURTHER 3,600 GALLONS WERE CONTAINED DURING THE HURRICANE. NINETEEN DAYS AFTER HURRICANE KATRINA HIT THE DEVASTATION IS EVIDENT, WITH TOWNS STILL FLOODED WITH CONTAMINATED WATER.

energy demand by sector

The Energy [R]evolution Scenario combines population projections, GDP growth, and energy intensity to propose a new pathway for U.S. energy demand. These are shown in Figure 4.2 for both the Reference and Energy [R]evolution Scenarios. Under the Reference Scenario, total primary energy demand increases by more than 40 percent from the current 96,826 PJ/a to 138,186 PJ/a in 2050. In the Energy [R]evolution Scenario, primary energy demand decreases by 24 percent compared to current consumption and is expected to reach 63,294 PJ/a by 2050

Under the Energy [R]evolution Scenario, electricity demand is expected to decrease in the industry sector, but to grow in the transport as well as in the residential and service sectors (see 4.3). Total electricity demand will rise to 5,408 TWh/a in the year 2050. Compared to the Reference Scenario, efficiency measures avoid the generation of about 2,244 TWh/a. This reduction in energy demand can be achieved in particular by introducing highly efficient electronic devices using the best available technology in all demand sectors. For example, employment of solar architecture in both residential and commercial buildings will help to curb the growing demand for active air-conditioning.

Efficiency gains in the heat supply sector are even larger. Under the Energy [R]evolution Scenario, demand for heat supply will grow up to 2030, but after that can be reduced to below the 2015 level (see 4.4). Compared to the Reference Scenario, consumption equivalent to 6,963 PJ/a is avoided through efficiency gains by 2050. As a result of energy-related renovation of the existing residential buildings, as well as the introduction of low energy standards for new buildings, enjoyment of the same comfort and energy services will be accompanied by much lower future energy demand.

In the transport sector, the Energy [R]evolution Scenario forecasts that energy demand will decrease by 50 percent to 13,505 PJ/a by 2050, saving 66 percent compared to the Reference Scenario. This reduction can be achieved by the introduction of highly efficient vehicles, by shifting the transport of goods from road to rail, and by making mobility-related lifestyle changes.

figure 4.2: USA: projection of total final energy demand by sector for the two scenarios

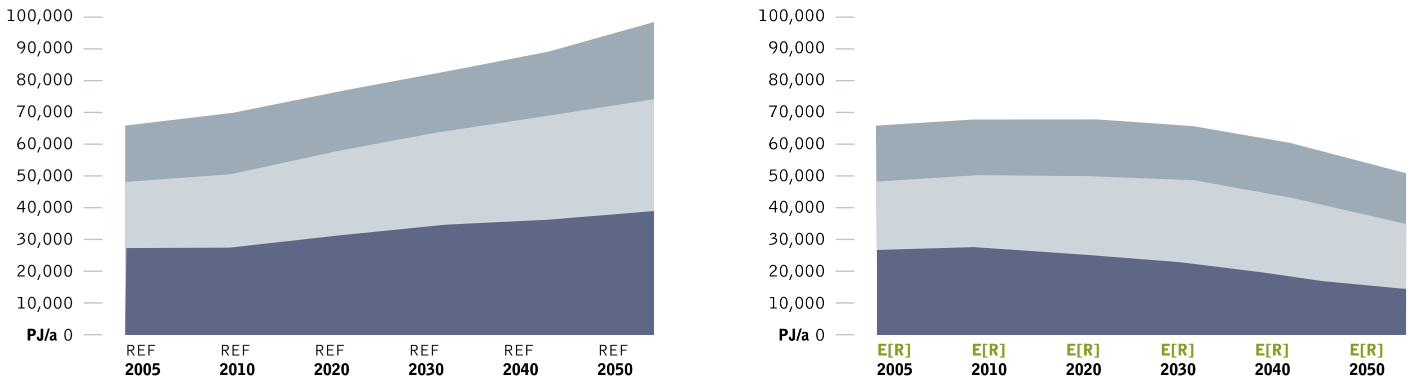


figure 4.3: USA: development of electricity demand by sector

('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO; OTHER SECTORS = SERVICES, HOUSEHOLDS)

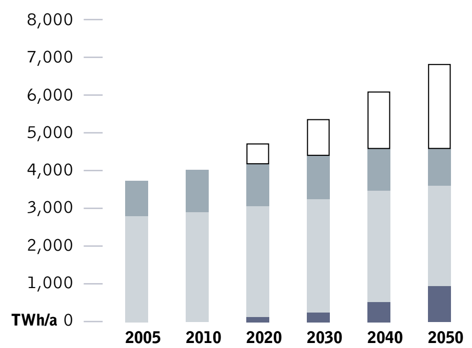
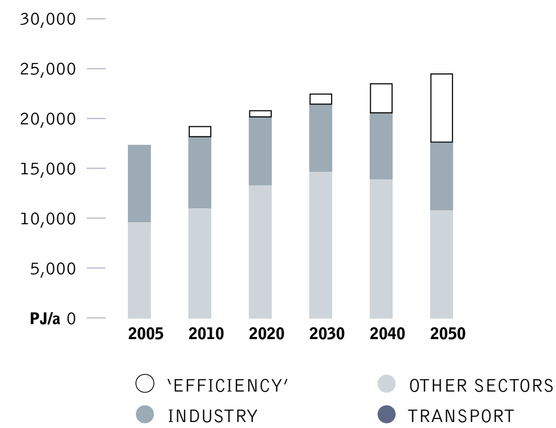


figure 4.4: USA: development of heat demand by sector

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



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 growth will compensate for the phasing out of nuclear energy and will reduce the number of fossil fuel-fired power plants required for grid stabilization. By 2050, 95 percent of the electricity produced in the U.S. will come from renewable energy sources. 'New' renewables—mainly wind, solar thermal energy and PV—will contribute over 85 percent of electricity generation.

Figure 4.6 shows the comparative evolution of the different renewable technologies in the U.S. over time. Up to 2020, hydropower and wind will remain the main contributors to the growing market share. After 2020, the continuing growth of wind will be complemented by electricity from biomass, photovoltaics and solar thermal (CSP) energy.

table 4.1: USA: projection of renewable electricity generation capacity under the energy [r]evolution scenario

IN GW

	2005	2010	2020	2030	2040	2050
Hydro	76	80	101	106	111	112
Biomass	15	22	46	79	116	134
Wind	8	31	258	355	382	398
Geothermal	2	5	21	52	93	114
PV	0	2	69	200	358	511
Solar thermal	0	1	31	55	106	148
Ocean energy	0	1	2	8	20	33
Total	**102**	**142**	**528**	**856**	**1,187**	**1,451**

figure 4.5: USA: electricity generation growth under the two scenarios

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

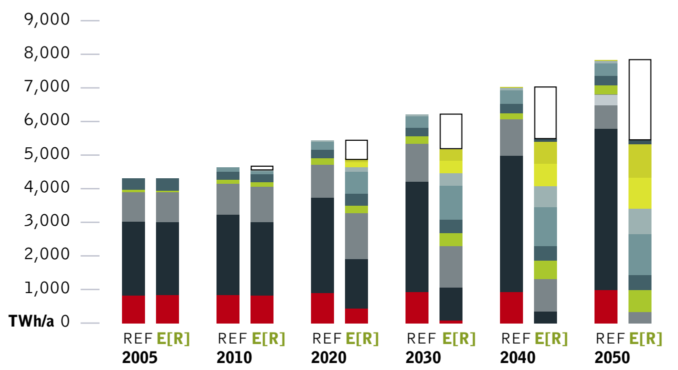


figure 4.6: USA: growth of renewable electricity generation capacity under the energy [r]evolution scenario

BY INDIVIDUAL SOURCE

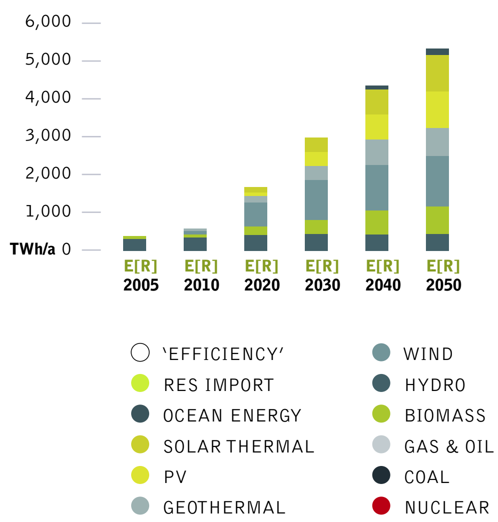


image WIND TURBINE GENERATORS IN CALIFORNIA, USA.

image AN IMAGE OF A WINDMILL IS MADE INTO A CROP FORMATION BY GREENPEACE AND THE IOWA FARMERS UNION. THE TWO GROUPS PARTNERED WITH OTHERS TO CALL ON CONGRESS TO LOOK TO IOWA FOR REAL SOLUTIONS TO GLOBAL WARMING LIKE WIND POWER. IOWANS ARE WORKING TO SOLVE GLOBAL WARMING WITH SOLUTIONS LIKE WIND POWER, BUT THEY NEED THEIR EFFORTS MATCHED BY THEIR CONGRESSIONAL DELEGATION.

future costs of electricity generation

Figure 4.7 shows that the up-front investment costs associated with the introduction of renewable technologies under the Energy [R]evolution Scenario will slightly but temporarily increase the price of electricity compared to the Reference Scenario. This difference will be less than 0.8 cents/kWh before 2020. Because of the better energy efficiency, the development of renewable energy technologies, and lower CO_2 intensity, by 2020 electricity generation costs will become economically favorable under the Energy [R]evolution Scenario, and by 2050 generation costs will be more than 3 cents/kWh below those in the Reference Scenario.

Under the Reference Scenario, on the other hand, unchecked growth in demand, the increase in fossil fuel prices and the cost of CO_2 emissions result in total electricity supply costs rising from today's $352 billion per year to more than $904 billion in 2050. Figure 4.8 shows that the Energy [R]evolution Scenario helps stabilize energy costs and relieve societal economic pressure.

Long term, costs for electricity supply in the Energy [R]evolution Scenario are one-third lower than in the Reference Scenario.

heat and cooling supply

Today, renewables provide 9.9 percent of U.S energy demand for heat supply, the main contribution coming from the use of biomass. The lack of district heating networks is a severe structural barrier to the large-scale utilization of geothermal and solar thermal energy. Dedicated government support is required to ensure a dynamic development. In the Energy [R]evolution Scenario, renewables provide 69 percent of USA's total heating demand by 2050.

- Energy efficiency measures help to reduce the currently growing demand for heating and cooling, in spite of improving living standards.
- For direct heating, solar collectors, biomass/biogas as well as geothermal energy replace fossil fuel systems.
- A shift from coal and oil to natural gas in the remaining conventional applications will lead to a further reduction of CO_2 emissions.

figure 4.7: USA: specific electricity generation costs under the two scenarios

(CO₂ EMISSION COSTS IMPOSED FROM 2020, WITH AN INCREASE FROM 20 $/$T_{CO_2}$ IN 2020 TO 50 $/$T_{CO_2}$ IN 2050)

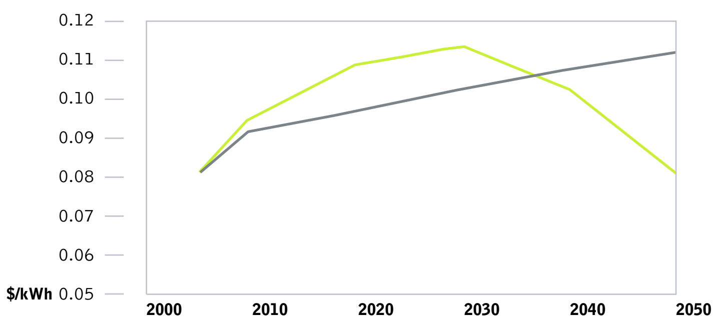


figure 4.8: USA: total electricity supply costs

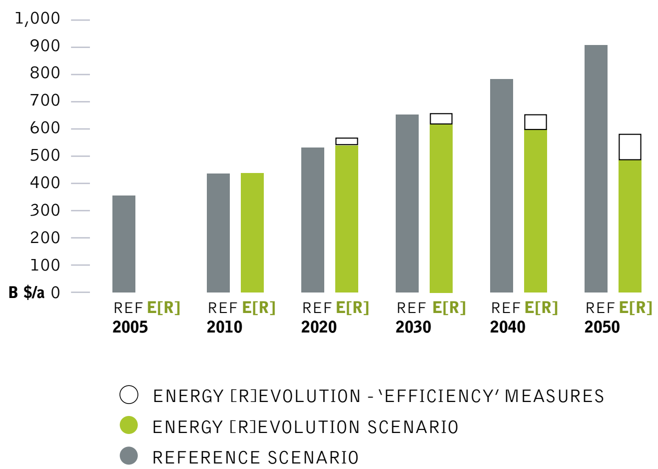
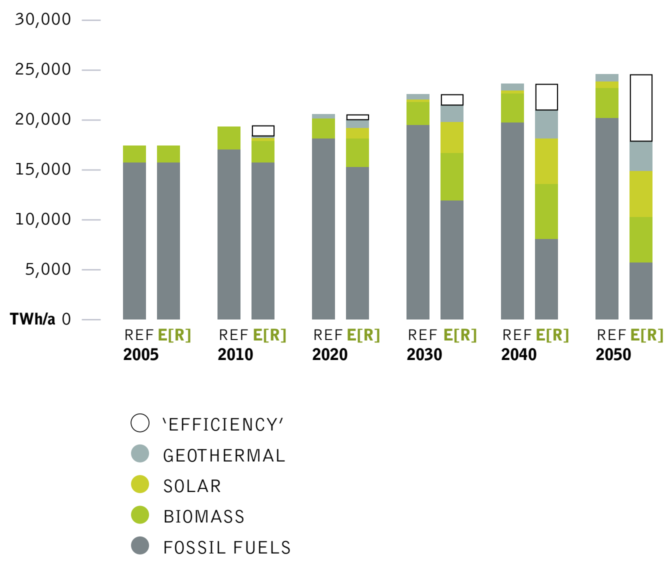


figure 4.9: USA: heat supply structure under the two scenarios

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

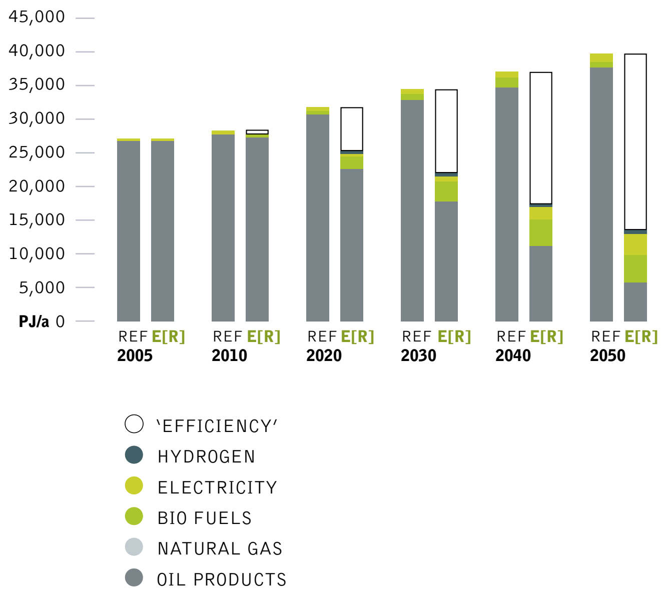


transport

A key initiative in the U.S. is to improve the fuel efficiency of the cars we drive. In addition, a shift to efficient modes of transport like rail, light rail and public transportation is important, especially in metropolitan areas. In the Energy [R]evolution Scenario, the car fleet still grows by 20 percent from the year 2000 to 2050, and per capita miles traveled increase as well with the growth of the economy. However, transport sector energy demand is reduced by 40 percent. Highly efficient propulsion technology, including hybrid, plug-in hybrid and battery-electric powertrains, will bring large efficiency gains. By 2050, 25 percent of U.S. transport energy demand will be provided by electricity.

figure 4.10: USA: transport under the two scenarios

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

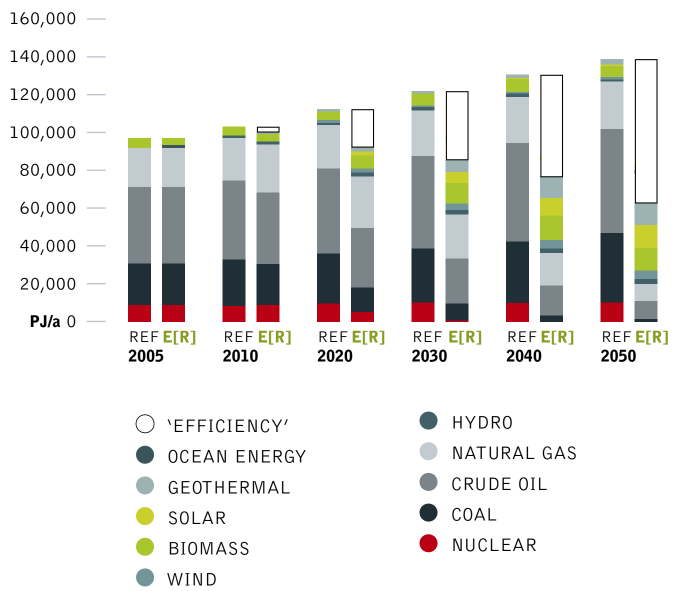


primary energy consumption

Taking into account the assumptions discussed above, the resulting primary energy consumption under the Energy [R]evolution Scenario is shown in Figure 4.11. Compared to the Reference Scenario, overall primary energy demand will be reduced by 55 percent in 2050. Around 75 percent of the remaining demand in North America will be covered by renewable energy sources.

figure 4.11: USA: primary energy consumption under the two scenarios

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



development of CO_2 emissions

Although U.S. CO_2 emissions will increase by 42 percent under the Reference Scenario, under the Energy [R]evolution Scenario they will decrease from 5,575 MMT in 2005 to 827 MMT in 2050. Annual per capita emissions will drop from 18.6 tons to 2.1 tons. In spite of the phasing out of nuclear energy and increasing demand, CO_2 emissions will decrease in the electricity sector. In the long run, efficiency gains and the increased use of renewable electricity will also reduce CO_2 emissions in the transport sector. With a share of 48 percent of total CO_2, the transport sector will be the largest source of emissions in 2050. These figures could be further reduced by simple behavioral changes.

figure 4.12: USA: CO_2 emissions by sector under the energy [r]evolution scenario

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

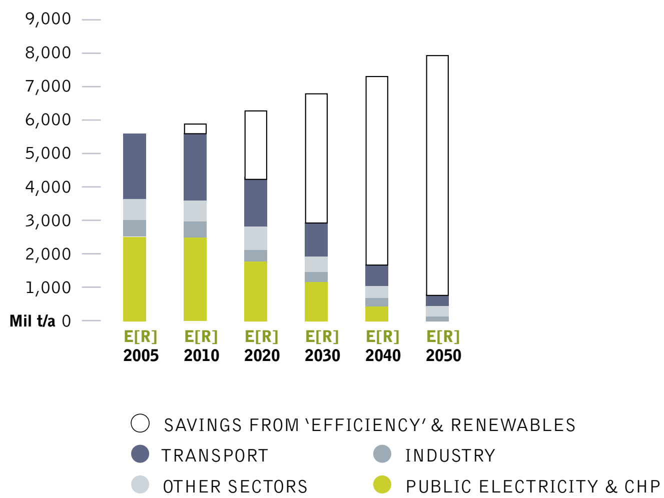


image CONCENTRATING SOLAR POWER (CSP) AT A SOLAR FARM IN DAGGETT, CALIFORNIA, USA.

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

investment in new power plants

The overall level of investment required for new power plants before 2030 will cost as much as $1.7 to 2.7 trillion. Aging power plants will be the main driver for investment in new energy generation capacity in the U.S.

Utilities will make their technology choices within the next five to ten years based on national energy policies, in particular market liberalization, renewable energy and CO_2 reduction targets. A possible future emissions trading scheme will have an important influence on whether the majority of investment goes into fossil fuel power plants or renewable energy and co-generation. The investment volume required to realize the Energy [R]evolution Scenario is $2.8 trillion, approximately $1.1 trillion higher than in the Reference Scenario, which will require $1.7 trillion.

While over 60 percent of investment under the Reference Scenario will go into fossil fuels and nuclear power plants, at about $1 trillion up to 2030, the Energy [R]evolution Scenario shifts about 70 percent of investment towards renewable energy. The fossil fuel share of power sector investment is focused mainly on combined heat and power, and efficient gas-fired power plants.

The average annual investment required in the power sector under the Energy [R]evolution Scenario between 2005 and 2030 is approximately $111 billion. Most investment in new renewable power generation will go towards wind power, followed by solar photovoltaics.

figure 4.14: USA: change in cumulative power plant investment under the energy [r]evolution scenario

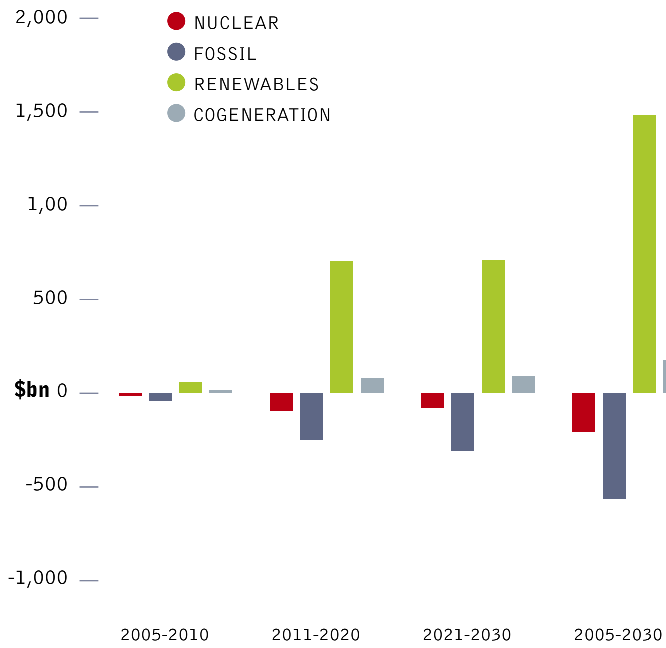
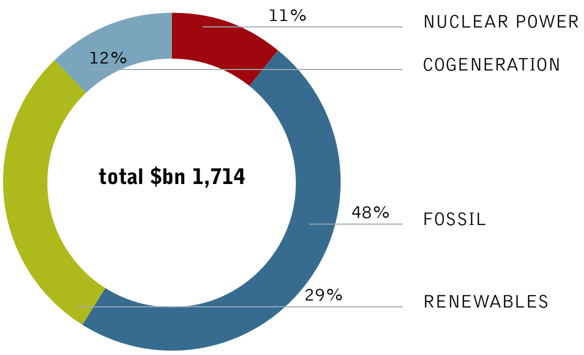
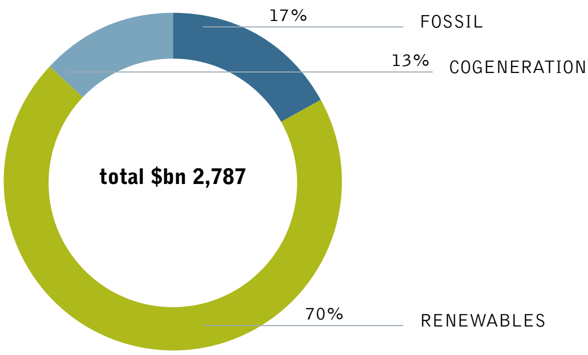


figure 4.13: USA: change in cumulative power plant investment in the energy [r]evolution scenario

reference scenario 2005 - 2030



energy [r]evolution scenario 2005 - 2030



renewable power generation investment

Under the Reference Scenario, investment in renewable electricity generation will be $491 billion. This compares to $1,956 billion in the Energy [R]evolution Scenario. How investment is divided between the different renewable power generation technologies depends on their level of technical development and regionally available resources.

Technologies such as wind power, which in many regions is already cost competitive with existing power plants, will take a larger investment volume and a bigger market share. The market volume attributed to different technologies also depends on local resources and policy frameworks within the U.S. states. Figure 4.15 provides an overview of the investment required for each technology.

For solar photovoltaic, the primary market will remain in southern states and sunny states like California for years to come, but should soon expand to other U.S. states. Because solar photovoltaic energy is a highly modular and decentralized technology that can be used almost anywhere, its market will eventually spread across the entire U.S. Solar photovoltaic is expected to reach grid parity (generation costs on the same level as consumer electricity prices) by 2012 to 2015.

Concentrated solar power systems, on the other hand, can only be operated in U.S. states with more than 2000 hours of direct sunlight. The main investment in this technology will therefore take place in California, Arizona and New Mexico.

The main development of the wind industry will take place especially in coastal areas, but also areas further inland such as Texas, Nebraska, and the Dakotas. Offshore wind technology will take a larger share from around 2015 onwards. The main offshore wind development will take place around the Atlantic coast. Bio energy power plants will be distributed across the U.S., as there is potential almost everywhere for biomass and/or biogas (cogeneration) power plants.

fossil fuel power generation investment

Under the Reference Scenario, the primary market expansion of new fossil fuel power plants will be gas-fired power plants, followed by coal power plants. In the Energy [R]evolution Scenario, the overall investment in fossil fuel power plants up to 2030 will be $468 billion, a figure significantly lower than the Reference Scenario's $823 billion.

figure 4.15: USA: renewable energy investments 2005-2030

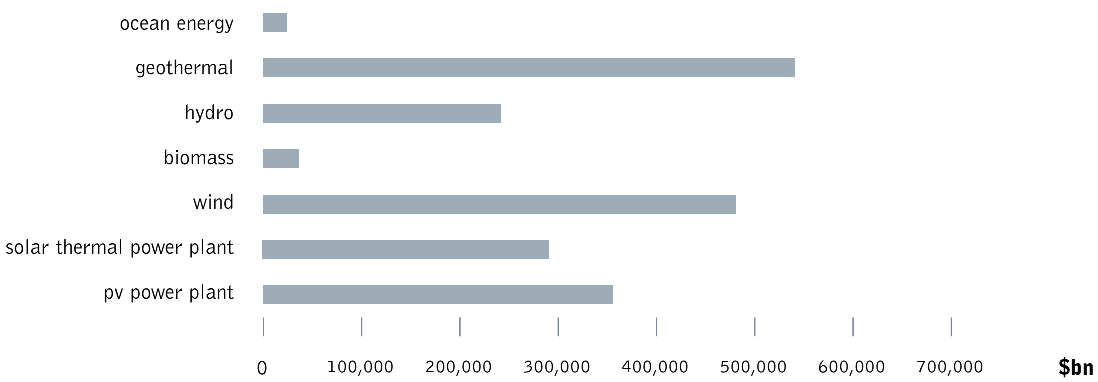


image SOLON AG PHOTOVOLTAICS FACILITY IN ARNSTEIN OPERATING 1,500 HORIZONTAL AND VERTICAL SOLAR "MOVERS". LARGEST TRACKING SOLAR FACILITY IN THE WORLD. EACH "MOVER" CAN BE BOUGHT AS A PRIVATE INVESTMENT FROM THE S.A.G. SOLARSTROM AG, BAYERN, GERMANY.

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

fuel cost savings with renewables

The total cost for fossil fuels in the Reference Scenario between 2005 and 2030 amounts to $10.85 trillion, compared to $8.7 trillion in the Energy [R]evolution Scenario with fuel costs decreasing as renewable energy takes up a larger share of the energy mix. This means that fuel costs in the Energy [R]evolution Scenario are 20 percent lower by 2030 than the Reference Scenario and 50 percent lower by 2050.

Although the investment costs of gas-fired power stations and cogeneration plants remains relatively high in both Scenarios, total investment in coal-fired power plants in the Energy [R]evolution Scenario is 75 percent less than the Reference Scenario. In fact, the additional costs for coal fuel from today until the year 2030 would be as high as $2.3 trillion under the Reference Scenario. This savings alone would cover the entire investment in renewable and cogeneration capacity required to implement the Energy [R]evolution Scenario.

On the other hand, because renewable energy has no fuel costs, the total fuel cost savings in the Energy [R]evolution Scenario is nearly $2.1 trillion, or $84 billion per year. These renewable energy sources will produce electricity without any further fuel costs beyond 2030, while the costs for coal and gas will continue to burden the U.S. economy.

Bottom line, the additional fuel costs required by the Reference Scenario are almost double the additional investment required by the Energy [R]evolution Scenario.

table 4.2: USA: fuel and investment costs in the reference and the energy [r]evolution scenario

INVESTMENT COST	UNIT	2005-2010	2011-2020	2021-2030	2005-2030	2005-2030 AVERAGE PER YEAR BILLION$/A
REFERENCE SCENARIO						
Total Nuclear	$bn 2005	46	85	81	212	8
Total Fossil	$bn 2005	185	315	323	823	33
Total Renewables	$bn 2005	106	231	154	491	20
Total Cogeneration	$bn 2005	52	76	61	189	8
Total	$bn 2005	388	708	618	1,714	69
E[R] SCENARIO						
Total Fossil	$bn 2005	197	161	110	468	19
Total Renewables	$bn 2005	158	930	868	1,956	78
Total Cogeneration	$bn 2005	68	151	143	363	15
Total	$bn 2005	424	1,242	1,121	2,787	111
DIFFERENCE E[R] VERSUS REF						
Total Fossil & Nuclear	$bn 2005	-34	-240	-293	-567	-23
Total Cogeneration	$bn 2005	53	699	714	1,466	59
Total Renewables	$bn 2005	16	75	82	174	7
Total	$bn 2005	35	534	503	1,072	43
FUEL COSTS						
REFERENCE SCENARIO						
Total Fuel Oil	$bn 2005	86	195	180	461	18
Total Gas	$bn 2005	314	821	1, 067	2,202	88
Total Coal	$bn 2005	1,125	2,974	3,676	7,774	311
Total Lignite	$bn 2005	80	156	177	413	17
Total Fossil Fuels	$bn 2005	1,605	4,145	5,099	10,850	434
E[R] SCENARIO						
Total Fuel Oil	$bn 2005	84	123	57	264	11
Total Gas	$bn 2005	341	1,092	1.388	2,821	113
Total Coal	$bn 2005	1,086	2,364	2,016	5,467	219
Total Lignite	$bn 2005	75	98	36	209	8
Total Fossil Fuels	$bn 2005	1,586	3,677	3,497	8,761	350
SAVINGS REF VERSUS E[R]						
Fuel Oil	$bn 2005	2	72	123	198	8
Gas	$bn 2005	-27	-272	-321	-619	-25
Coal	$bn 2005	39	609	1,659	2,308	92
Lignite	$bn 2005	4	58	141	204	8
Total Fossil Fuel Savings	$bn 2005	19	468	1,602	2,089	84

implementing the energy [r]evolution in developing countries

5

> "to those nations like ours that enjoy relative plenty, we say we can no longer afford indifference to the suffering outside our borders; nor can we consume the world's resources without regard to effect"
>
> **PRESIDENT BARACK OBAMA**

greenpeace proposal: feed-in tariff support mechanism

This chapter outlines a Greenpeace proposal for a feed-in tariff system (also known in the U.S. as a "clean energy payment system") in developing countries. The additional costs of the program would be financed by a combination of new sectoral emissions trading mechanisms and direct finance from technology funds to be developed in the Copenhagen climate deal.

The Energy [R]evolution Scenario demonstrates that renewable electricity generation can have considerable environmental and economic benefits. However, developing countries generally lack the resources required to transition to a clean energy economy while meeting the most basic energy needs of their populations. To bridge this investment and cost gap between conventional fossil fuel-based power generation and renewables, a support mechanism is needed.

Greenpeace International conceived a support mechanism for developing countries—the Feed-in Tariff Support Mechanism (FTSM)[45]—to provide financial support from developed nations.

A feed-in tariff incentivizes the production of renewable energy by setting a guaranteed, premium price for renewable energy. The premium pricing provides investors with a guaranteed return while defraying the up-front investment costs associated with building new clean energy infrastructure. The value of the feed-in tariff can be adjusted for different sources of energy so that less mature industries that require additional subsidies can receive additional support, while more advanced technologies do not.

Several European nations have enacted feed-in tariffs with great success. In Europe, the feed-in tariff is usually financed through a very small additional fee on ratepayer's energy bills. However, the extra costs associated with the program remain an obstacle for developing nations, and an alternative funding source would be needed.

The FSTM would be created as what's known as a "sectoral no-lose mechanism." Such a program allows developing countries to pledge to set sector-specific emission targets and issue tradable emission credits. However, if the country fails to meet its emission target, there is no penalty—hence the term "no-lose."

Signatories to the Kyoto Protocol are currently negotiating the second phase of their agreement, covering the period from 2013-2017. The FTSM could be built around new sectoral no-lose targets for developing countries during these negotiations. Proceeds from the sale of emission units under a sectoral no-lose target mechanism in developing countries could be used to fund the additional costs of the FTSM in that country. For some countries a directly funded FTSM may be more appropriate than funding through sectoral no-lose targets.

energy [r]evolution means reducing poverty[46]

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

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

The Millennium Development Goal of halving global poverty by 2015 will not be reached without adequate energy to increase production, income, education, and create jobs. Halving hunger will not come about without energy for more productive growing, harvesting, processing and marketing of food.

Improving health and reducing death rates will not happen without energy for the refrigeration needed at clinics, hospitals and vaccination campaigns. The world's greatest child killer, acute respiratory infection, will not be tackled without dealing with smoke from cooking fires in the home. Children will not study at night without light in their homes. Clean water will not be pumped or treated without energy.

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

references
45 GREENPEACE INTERNATIONAL, IMPLEMENTING THE ENERGY [R]EVOLUTION (OCTOBER 2008) AVAILABLE AT: HTTP://WWW.GREENPEACE.ORG/INTERNATIONAL/PRESS/REPORTS/ENERGYREVOLUTIONREPORT
46 IT POWER/GREENPEACE INTERNATIONAL, SUSTAINABLE ENERGY FOR POVERTY REDUCTION: AN ACTION PLAN (2002) AVAILABLE AT: HTTP://WWW.GREENPEACE.ORG/RAW/CONTENT/INTERNATIONAL/PRESS/REPORTS/SUSTAINABLE-ENERGY-FOR-POVERTY.PDF.

image GROUP OF YOUNG PEOPLE TOUCHING SOLAR PANELS IN BRAZIL.

feed-in tariffs: proven effective clean energy policy

Since the early development of renewable energy, there has been an ongoing debate about the best and most effective type of support scheme. The European Commission published a survey in December 2005 which provides a good overview of the experience so far. According to this report, feed-in tariffs are by far the most efficient and successful mechanism. Globally more than 40 countries have adopted some version of the feed-in tariff mechanism.

Although the specific form of these tariffs differs from country to country, there are certain clear criteria which are essential. For example, a bankable support scheme for renewable energy projects that can provide long-term stability and certainty for both investors and equipment suppliers is essential.[47] Bankable support schemes result in lower cost projects, for example, because they lower the risk for both investors and equipment suppliers. The cost of wind-powered electricity in Germany is up to 40 percent less than in the United Kingdom[48], for example, because Germany's support scheme is more stable and reliable.

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

1. Clear, bankable pricing system.
2. Priority access to the grid with clear identification of who's responsible for what in terms of interconnection and transition, and how it is incentivized.
3. Clear, simple administrative and planning permission procedures.
4. Public acceptance and support.

For developing countries, feed-in tariffs have the potential to meet all of these imperatives and therefore are an excellent mechanism for investing in clean energy. The main argument against feed-in tariffs is the short-term cost. This is a particular challenge for developing countries, where many cannot afford costly electricity services. However, with international support, this obstacle can be overcome.

bridging the gap with international financing

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

FTSM aims to facilitate the implementation of feed-in tariff laws in developing countries by providing additional financial resources to a scale appropriate to the circumstances of each developing country. For countries with higher levels of renewable energy capacity, the creation of a new sectoral no-lose mechanism can generate saleable emission reduction units, the proceeds from which can be used to offset any additional costs associated with the feed-in tariff system. In other countries, direct funding may be a more appropriate approach to assisting developing countries with the additional costs to consumers of the feed-in tariff system.

Funding could come through the connection of the FTSM to the international emission trading system via a new no-lose sectoral trading mechanism to be developed in the Copenhagen Agreement. The Energy [R]evolution Scenario shows that the average additional costs (under the proposed energy mix) between 2008 and 2015 are between 1 and 4 cents per kilowatt-hour, so the cost per ton of CO_2 avoided would be between $13 and $50, indicating that emission reduction units generated under a no-lose mechanism designed to support FTSM would be competitive in the post-2012 carbon market.

All renewable energy projects must have a clear set of environmental criteria which are part of the national licensing procedure in the country where the project will generate electricity. Those criteria will have to meet a minimum environmental standard defined by an independent monitoring group. If there are already acceptable criteria developed, for example for CDM projects, they should be adopted rather than reinventing the wheel. The board members will come from NGOs, energy and finance experts as well as members of the governments involved. The fund will not be able to use the money for speculative investments. It can only provide soft loans for FTSM projects.

Key parameters for feed-in tariffs under FTSM:

- Tariffs must be variable for different renewable energy technologies, depending on their costs and technology maturity, paid for 20 years.
- Payments must be based on actual generation in order to achieve properly maintained renewable energy projects with high performance ratios.
- Any additional costs for renewable generation will be paid by calculating the wholesale electricity price plus a fixed premium.

To implement FTSM, a developing country must:

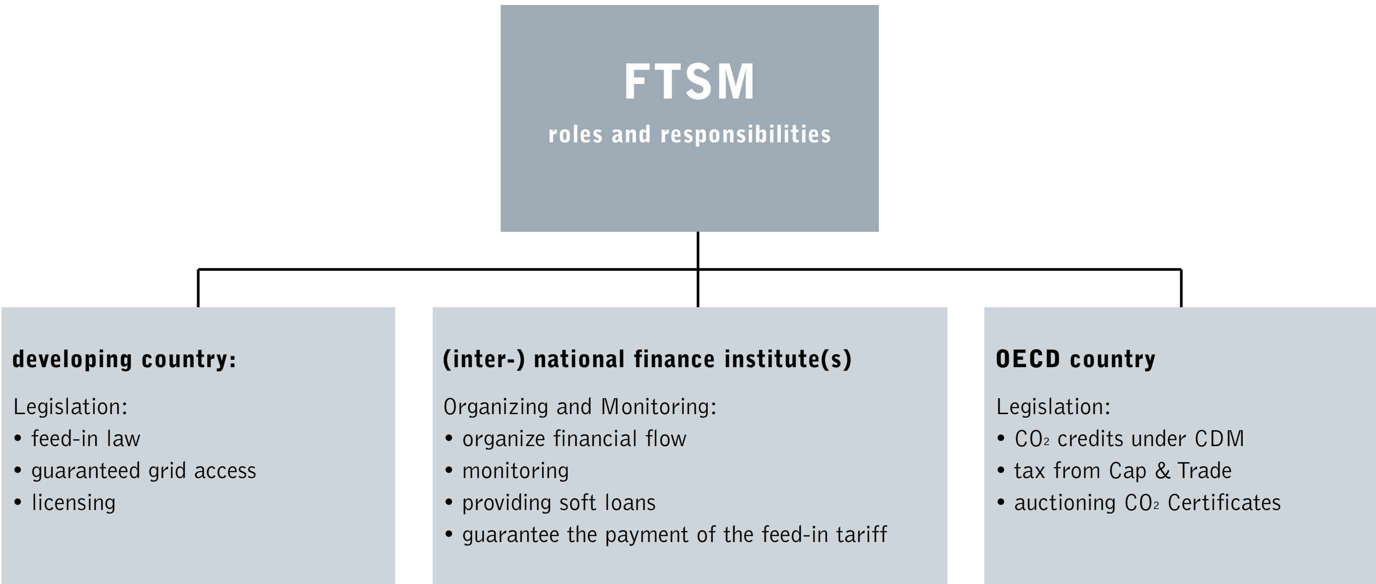
- Establish regulations to guarantee access to the electricity grid for renewable electricity projects.
- Establish feed-in tariff laws and regulations based on successful examples.
- Establish regulations to ensure transparency when establishing the feed-in tariff, including full records of generated electricity.
- Set clear regulations for the renewable energy sector, including licensing procedures.

references
47 COMMISSION OF THE EUROPEAN COMMUNITIES, THE SUPPORT OF ELECTRICITY FROM RENEWABLE ENERGY SOURCES, COM (2005) 627 (DECEMBER 2005).
48 ID., AT 27, FIGURE 4.

Key parameters for the FTSM fund:

- The FTSM fund will guarantee payment of the total feed-in tariffs over a period of 20 years if the renewable energy project is operated properly.
- The FTSM fund will receive annual income from emissions trading or from direct funding.
- The FTSM fund will pay feed-in tariffs annually on the basis of generated electricity.
- Every FTSM-funded project must have a professional maintenance company to ensure high performance.
- Grid operators must monitor and report energy generation data to the FTSM fund for comparison with data submitted by renewable energy projects.

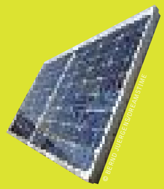
figure 5.1: **ftsm scheme**



elements of successful clean energy policies

6

> **"our environment and our economy depend on congressional action to confront the threat of climate change and secure our energy independence."**
>
> U.S CONGRESSMAN HENRY WAXMAN



While every country and U.S. state must craft effective climate and energy policies specific to their own resources and needs, this chapter provides a general overview of the key imperatives that public policies must achieve and obstacles the government intervention is needed to overcome.

towards an efficient global energy market

Policies and measures to promote energy efficiency exist in many countries. Energy and information labels, mandatory minimum energy performance standards, and voluntary efficiency agreements are the most popular efficiency measures. While effective government policies usually contain two elements, those that push the markets (such as standards) and pull the market (incentives), efficiency standards have proven to be an effective, low-cost way to coordinate a transition to more energy efficiency. For example, Japan has an energy efficiency program that sets mandatory targets subject to ongoing revision and provides incentives to manufacturers and importers of energy-consuming equipment to continuously improve the energy efficiency of products within selected market segments.

To maximize the potential for efficiency gains, energy efficiency policies must:

support innovation in energy efficiency, low-carbon transport systems, and renewable energy production Innovation will play an important role in making the Energy [R]evolution more attractive and is needed to realize ambitious, ever-improving efficiency and emissions standards. Programs supporting renewable energy and energy efficiency development and diffusion are a traditional focus of energy and environmental policies because energy innovations face barriers all along the energy-supply chain (from research and development, to demonstration projects, to widespread deployment).

set stringent and ever-improving efficiency and emissions standards for appliances, buildings and vehicles In the residential sector in industrialized countries, standby power consumption ranges from 20 to 60 watts per household, equivalent to 4 to 10 percent of total residential energy consumption. Yet the technology is available to reduce standby power to 1 watt and a global standard, as proposed by the IEA, could mandate this reduction. Japan, South Korea and the state of California have already adopted energy standby standards.

develop and implement market transformation policies that overcome current barriers and other market failures to reduce energy demand In addition to setting and implementing efficiency standards, market transformation policies promote the manufacture and purchase of energy-efficient products and services. The goal of this strategy is to create lasting structural and behavioral changes in the marketplace, resulting in increased adoption of energy-efficient technologies. A key element is to overcome market barriers that inhibit the manufacture and purchase of energy-efficient products.

no fuel, no emissions, no problems: renewable energy

At a time when governments around the world are in the process of 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 by distortions in the world's electricity markets created by decades of massive financial, political and structural support to conventional technologies. Developing renewables will therefore require strong political and economic efforts.

At present, renewable energy generators have to compete with old nuclear and fossil fuel power plants that produce electricity at marginal costs because consumers and taxpayers subsidize their operation. Political action is needed to overcome these distortions and create a level playing field.

In fact, renewable energy technologies would already be competitive if they received the same research and development funding and subsidies as fossil fuels and nuclear power, research and development and if external costs were reflected in energy prices. Removing public subsidies to fossil fuels and nuclear and applying the 'polluter pays' principle to energy markets would go a long way towards leveling the playing field and would drastically reduce the need for government support of renewable energy. Until these disparities are corrected, renewable energy technologies will need additional support measures from policymakers in order to compete with conventional fuels.

Support mechanisms for different energy sectors and technologies can vary according to regional characteristics, priorities and initial policy goals. But some general principles apply to any kind of support mechanism. These criteria are:

effectiveness in reaching the targets Experience shows that it is possible with the right support mechanisms to reach agreed upon, national renewable energy targets. Any national system should focus on the effective deployment of new renewable energy projects to increase the percentage of installed capacity and meet renewable energy targets.

long-term stability Policymakers need to make sure that investors can rely on the long-term stability of any support scheme. It is absolutely crucial to avoid stop-and-go markets with frequent regulatory changes. Market stability will be created when governments implement long-term plans and funding for renewable energy projects.

simple and fast administrative procedures Complex licensing procedures constitute one of the most difficult obstacles that renewable energy projects have to face. Policymakers should remove administrative barriers at all levels. A user-friendly 'one-stop-shop' system should be introduced that includes a clear timetable for project approval.

encouraging local and regional benefits and public acceptance The development of renewable technologies can have a significant impact on local and regional areas, resulting from both installation and manufacturing. The public must be involved in order to facilitate the acceptance of renewable technologies. Local projects should encourage regional development, employment and income generation.

demands for the energy sector

Greenpeace and the renewables industry have a clear agenda for changes which need to be made in energy policy to encourage a shift to renewable sources. The main demands are:

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

removing energy market distortions

The following steps provide a description of what needs to be done to eliminate or compensate for current distortions in the energy market.

eliminate subsidies for dirty energy Conventional energy sources receive an estimated $250-300billion[49] in subsidies per year worldwide, resulting in heavily distorted markets. Subsidies artificially reduce the price of power, keep renewable energy out of the market place and prop up noncompetitive technologies and fuels. Eliminating direct and indirect subsidies to fossil fuels and nuclear power would help move towards a level playing field across the energy sector. The 2001 report of the G8 Renewable Energy Task Force argued that "readdressing them [subsidies] and making even a minor re-direction of these considerable financial flows toward renewables, provides an opportunity to bring consistency to new public goals and to include social and environmental costs in prices."

Providing subsidies to fully mature and polluting technologies is highly unproductive for the energy sector. Removing subsidies from conventional electricity would save taxpayer money and dramatically reduce the need for renewable energy support.

internalization of the social and environmental costs of polluting energy The real cost of energy production by conventional energy includes expenses absorbed by society, such as health impacts and local and regional environmental degradation - from mercury pollution to acid rain – as well as the global negative impacts from climate change. Hidden costs include the waiving of nuclear accident insurance that is too expensive for nuclear power plant operators. The Price Anderson Act, for instance, limits the liability of U.S. nuclear power plants up to $98 million per accident, and only $15 million per year per plant. The rest is drawn from an industry fund of up to $10 billion, and after that, the taxpayer becomes responsible.

Environmental damage should, as a priority, be rectified at source. Translated into energy generation that would mean that, ideally, production of energy should not pollute, and it is the energy producers' responsibility to prevent it. If energy producers do pollute they should pay an amount equal to the damage the production causes to society as a whole. However, the environmental impacts of electricity generation can be difficult to quantify. How do we put a price on Pacific Island homes lost as a result of melting icecaps or on deteriorating health and human lives?

An ambitious project, funded by the European Commission—ExternE—has tried to quantify the true costs, including the environmental costs, of electricity generation. It estimates that the cost of producing electricity from coal or oil would double and that from gas would increase by 30 percent if external costs, in the form of damage to the environment and health, were taken into account. If those environmental costs were levied on electricity generation according to their impact, many renewable energy sources would not need any support. If, at the same time, direct and indirect subsidies to fossil fuels and nuclear power were removed, the need to support renewable electricity generation would seriously diminish or cease to exist.

As with the other subsidies, external costs must be factored into energy pricing if the market is to be truly competitive. This requires that governments apply a "polluter pays" system that charges the emitters accordingly or applies suitable compensation to non-emitters. Adoption of polluter pays taxation to electricity sources, or equivalent compensation to renewable energy sources, and exclusion of renewables from environment-related energy taxation, is essential to achieve fairer competition in the world's electricity markets.

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image THE PS10 SOLAR TOWER PLANT AT SAN LUCAR LA MAYOR OUTSIDE SEVILLE, SPAIN, APRIL 29, 2008.

© REDONDO/GP

removal of electricity sector barriers Complex licensing procedures and bureaucratic hurdles constitute one of the most difficult obstacles faced by renewable energy projects in many countries. Regulatory agencies should set a clear timetable for approving renewable energy projects at all levels. In addition, U.S. regulators should propose more detailed procedural guidelines to strengthen existing legislation and at the same time streamline the licensing procedure for renewable energy projects.

A major barrier is the short to medium-term surplus of electricity generating capacity in many countries. Due to over-capacity it is still cheaper to burn more coal or gas in an existing power plant than to build, finance and depreciate a new renewable power plant. Even in those situations where a new technology would be fully competitive with new coal or gas fired power plants, the investment will not be made. Until we reach a situation where electricity prices start reflecting the cost of investing in new capacity rather than the marginal cost of existing capacity, policy support for renewable energy will be required to level the playing field.

Other barriers include the lack of long-term planning at national, regional and local level; lack of integrated resource planning; lack of integrated grid planning and management; lack of predictability and stability in the markets; no legal framework for international bodies of water; grid ownership by vertically integrated companies; and a lack of long-term research and development funding.

There is also a complete absence of grids for large-scale renewable energy sources, such as offshore wind power or concentrating solar power (CSP) plants; weak or non-existent grids onshore; little recognition of the economic benefits of embedded/distributed generation; and discriminatory requirements from utilities for grid access that do not reflect the nature of the renewable technology.

The reforms needed to address market barriers to renewables include:

- Streamlined and uniform planning, licensing, and permitting procedures and a system to integrate cost-efficiency into energy network planning.
- Access to the grid at fair, transparent prices and the removal of discriminatory access and transmission tariffs.
- Fair and transparent pricing for power throughout an energy network, with recognition and remuneration for the benefits of embedded generation.
- Unbundling of utilities into separate generation and distribution companies.
- Grid management authority must carry the costs of grid infrastructure development and reinforcement, rather than individual renewable energy projects.
- Disclosure of fuel mix and environmental impact to end users to enable consumers to make informed choices regarding power sources.

priority grid access Rules on grid access, transmission and cost sharing are often inadequate. Legislation must be clear, especially concerning cost distribution and transmission fees. Renewable energy generators should be guaranteed priority grid access. Where necessary, grid extension or reinforcement costs should be borne by the grid operators, and shared between all consumers.

support mechanisms for renewables

The following section provides an overview of the existing support mechanisms and operation experiences. Support mechanisms remain a second best solution for correcting market failures in the electricity sector. However, introducing them is a practical political solution to acknowledge that, in the short term, there are no other practical ways to apply the "polluter pays" principle.

Overall, there are two types of incentives to promote deployment of renewable energy. These are Fixed Price Systems, which dictate the electricity price (or premium) paid to the producer and lets the market determine the quantity, and Renewable Electricity Standards, which dictate the quantity of renewable electricity and leaves it to the market to determine the price. Both systems create a protected market against a background of subsidized, depreciated conventional generators whose external environmental costs are not accounted for. These policies aim is to provide incentives for technology improvements and cost reductions, leading to cheaper renewables that can compete with conventional sources in the future.

The main difference between quota-based and price-based systems is that the former aims to introduce competition between electricity producers. However, competition between technology manufacturers, which is the most crucial factor in bringing down electricity production costs, is present regardless of whether government dictates prices or quantities. Prices paid to wind power producers are currently higher in many European quota-based systems (UK, Belgium, and Italy) than in fixed price or premium systems (Germany, Spain, Denmark).

fixed price systems Fixed price systems include investment subsidies, fixed feed-in tariffs, fixed premium systems and tax credits.

- Investment subsidies are capital payments usually made on the basis of the rated power (in kW) of the generator. It is generally acknowledged, however, that systems which base the amount of support on generator size rather than electricity output can lead to less efficient technology development. There is therefore a global trend away from these payments, although they can be effective when combined with other incentives.

- Fixed feed-in tariffs (FITs), widely adopted in Europe, have proved extremely successful in expanding wind energy in Germany, Spain and Denmark. Operators are paid a fixed price for every kWh of electricity they feed into the grid. In Germany the price paid varies according to the relative maturity of the particular technology and reduces each year to reflect falling costs. The additional cost of the system is borne by taxpayers or electricity consumers.

  The main benefit of a FIT is that it is administratively simple and encourages better planning. Although the FIT is not associated with a formal Power Purchase Agreement, distribution companies are usually obliged to purchase all the production from renewable installations. Germany has guaranteed payments for 20 years. The main problem associated with a fixed price system is that it does not lend itself easily to adjustment – whether up or down - to reflect changes in the production costs of renewable technologies.

- Fixed premium systems, sometimes called an "environmental bonus" mechanism, operate by adding a fixed premium to the basic wholesale electricity price. From an investor perspective, the total price received per kWh is less predictable than under a feed-in tariff because it depends on a constantly changing electricity price. From a market perspective, however, it is argued that a fixed premium is easier to integrate into the overall electricity market because those involved will be reacting to market price signals. Spain is the most prominent country to have adopted a fixed premium system.

  Tax credits, as operated in the US and Canada, offer a credit against tax payments for every kWh produced. In the United States, the market has been driven by a federal Production Tax Credit (PTC) of approximately 1.8 cents per kWh. It is adjusted annually for inflation.

renewable quota systems Two types of renewable quota systems have been employed: tendering systems and green certificate systems.

- Tendering systems involve competitive bidding for contracts to construct and operate a particular project, or a fixed quantity of renewable capacity in a country or state. Although other factors are usually taken into account, the lowest priced bid invariably wins. This system has been used to promote wind power in Ireland, France, the UK, Denmark and China.

  The downside is that investors can bid an uneconomically low price in order to win the contract and then not build the project. Under the UK's NFFO (Non-Fossil Fuel Obligation) tender system, for example, many contracts remained unused. The system was eventually abandoned. If properly designed, however, with long contracts, a clear link to planning consent and a possible minimum price, tendering for large scale projects could be effective, as it has been for offshore oil and gas extraction in Europe's North Sea.

- Tradable green certificate (TGC) systems operate by offering "green certificates" for every kWh generated by a renewable producer. The value of these certificates, which can be traded on a market, is then added to the value of the basic electricity. A green certificate system usually operates in combination with a rising quota of renewable electricity generation. Power companies are bound by law to purchase an increasing proportion of renewables input. Countries that have adopted this system include the UK, Sweden, Italy and many individual states in the U.S., where the system is known as a Renewable Electricity Standard.

  Compared with a fixed tender price, the TGC model is more risky for the investor, because the price fluctuates on a daily basis, unless effective markets for long-term certificate (and electricity) contracts are developed. Such markets do not currently exist. The system is also more complex than other payment mechanisms.

  Which one out of this range of incentive systems works best? Based on past experience it is clear that policies based on fixed tariffs and premiums can be designed to work effectively. However, introducing them is not a guarantee for success. Almost all countries with experience in renewable energy support policies have, at some point in time, used feed-in tariffs, but not all have contributed to an increase in renewable electricity production. It is detailed policy design, in combination with other measures, which determine success.

renewables for heating and cooling

Largely forgotten, but equally important is the heating and cooling sector. In many regions of the world, such as Europe, nearly half of the total energy demand is for heating/cooling, a demand which can be addressed easily at competitive prices.

Policies should make sure that specific targets and appropriate measures for renewable heating and cooling are part of any national renewables strategy. These should foresee a coherent set of measures dedicated to the promotion of renewables for heating and cooling, including financial incentives, awareness raising campaigns, training of installers, architects and heating engineers, and demonstration projects. For new buildings, and those undergoing major renovation, there should be an obligation to use a minimum share of renewable energy for heat consumption.

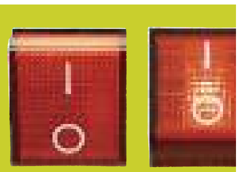
Policy measures should stimulate the deployment of cost-effective renewable heating and cooling, available already with today's technologies. At the same time, increased research and development efforts should be undertaken, particularly in the fields of heat storage and renewable cooling.

current u.s. climate and energy policy

7

"we have at most ten years - not ten years to decide upon action, but ten years to alter fundamentally the trajectory of global greenhouse gas emissions."

DR. JAMES HANSEN, NASA, 2006



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Although the economic and environmental benefits of the Energy [R]evolution are clear, we will not be able to achieve this clean energy future or cut emissions as quickly as necessary to solve global warming without strong government support worldwide. Unfortunately, the historical track record in the U.S. is one of overwhelming support for fossil fuels and nuclear power at the expense of renewables and energy efficiency.

This chapter provides very brief summary of energy and climate policy at the state and local level in the U.S.

u.s. federal energy and climate policies

At the national level, U.S. energy policy has long favored fossil fuels and expanding energy production rather than improving energy efficiency and renewables. For example, between 1948 and 1998, the federal government spent $111.5 billion on energy research and development programs. Of this amount, 60 percent, or $66 billion, was dedicated to nuclear energy research, and 23 percent, or $26 billion, was directed to fossil fuel energy research.[50]

Oil companies and other mining interests have for decades been allowed to pay royalties at a far below market rate when they mine or drill on public lands. Under the Bush administration, additional previously protected public lands were opened to still more drilling, while environmental standards were weakened, and a moratorium banning new off-shore drilling was allowed to expire. Efforts to increase royalties for drilling and mining on public lands were blocked in 2008, but the issue may be revisited in the future. Further, the Obama administration is expected to reverse at least some Bush-era policies allowing drilling and mining on public lands and off U.S. coastlines.

Historically, the overwhelming share (currently about 80 percent) of tax dollars spent on transportation has gone towards the construction of roads and highways, not public transit. In 2009, Congress is slated to reauthorize the nation's transportation policy and has an opportunity to redirect more resources towards public transit, though it remains to be seen whether the political will for such a shift exists.

The nuclear industry has arguably been more heavily subsidized than any other source of energy. The Price-Anderson Act alone, which caps the nuclear industry's liability in the event of a nuclear accident, represents a subsidy of almost immeasurable value. If forced to buy private insurance on the free market in the absence of this liability shield, the nuclear industry couldn't exist.

In recent years, the number of proposed nuclear plants has increased considerably, including with 23 new applications for construction and operating licenses between 2004 and late 2008. However, only four of these included actual plant designs, and all proposed plants are dependent on federal loan guarantees. Federal funds appropriated to date could support only two of the proposed 23 nuclear power plants.

In an effort to extend the life of the coal industry into a carbon-regulated future, the coal industry has successfully lobbied for generous public funding for thus far fruitless efforts to burn coal without emitting high levels of carbon dioxide (known as carbon capture and sequestration, or CCS). In 2008, the Department of Energy's budget request raised funding for CCS-related programs by 26.4 percent to $623.6 billion while at the same time cutting renewable energy and efficiency research by 27.1 percent to $146.2 million.[51] There are few indications that these subsidies will end or be reduced.

Recent developments suggest, however, that the tide may be turning as concerns about global warming have become more urgent. In 2007, the U.S. Supreme Court ruled in Massachusetts v. EPA that the federal EPA has the authority to regulate global warming pollution under the Clean Air Act and directed the EPA to review its previous decision not to regulate emissions from cars. Under the new Administrator Lisa Jackson, EPA is expected to determine that global warming pollution represents a danger to the public health and welfare, triggering the regulation of global warming emissions under existing law.

In November 2008, the Environmental Appeals Board of the EPA declined to approve a permit for a new coal plant in Utah. EPA was again urged to consider if carbon dioxide is a pollutant under the Clean Air Act. President Obama's administration may now establish a requirement that new coal plants meet a standard for "best available control technology" for CO_2 emissions.

Meanwhile, support for renewable energy has been sporadic. As part of the financial bailout package in October 2008, Congress passed long-awaited extensions of the federal Production (PTC) and Investment Tax Credits (ITC). The PTC was established by the Energy Policy Act of 1992 and first become available in 1994; it has expired several times and been extended retroactively for only a year or two at a time. Again, in 2008, it was extended for one additional year (through 2009 for wind projects and for two years for geothermal facilities). The ITC, which applies to residential and business installations of solar, small wind and geothermal systems, was extended for eight years. A $2,000 cap on residential ITC was removed, and the prohibition on utilities from obtaining the ITC was eliminated. A two-year ITC for marine energy technologies was created. In addition, the legislation authorized $800 million for clean energy bonds for renewable energy generating facilities.

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51 US DEPARTMENT OF ENERGY FY2009 CONGRESSIONAL BUDGET REQUEST, FEBRUARY 2008.

In 2007, the Federal Energy Regulatory Commission (FERC) revised a rule requiring "transparency" for grid access. It creates a new category of transmission service that recognizes the variable nature of use of the grid by some renewable resources, and provides renewables with better access to the system. The rule also requires that imbalance charges, which reflect differences between the scheduled and actual delivery of energy, account for the special circumstances presented by renewable generators and their limited ability to precisely forecast or control generation levels.

Efforts to mandate targets for renewable energy at the federal level have been unsuccessful to date, with biofuels the only exception. In December 2007, the Renewable Fuels Standard of 2005 was amended to require that 36 billion gallons of biofuels be included in the U.S. liquid fuel mix by 2022. A certain share of this must come from cellulosic ethanol.

Federal gas mileage (Corporate Average Fuel Economy) standards for light trucks and cars were tightened by Congress in 2007 for the first time since the 1970s. As a result, automakers must increase their fleetwide gas mileage for the U.S. market from the 2007 combined (cars and light trucks) average of 22.2 miles per gallon (mpg) to 35 mpg by 2020. Additionally, the Obama administration has the authority and has indicated a willingness to set still higher standards. However, U.S. standards remain well below those in China, the European Union, Japan, and several other countries.

Finally, momentum is increasing in Congress for adoption of a federal cap on global warming emissions. Legislation to enact a federal cap-and-trade program failed in the U.S. Senate in 2008; however, signs of growing support in Congress are clear. In the U.S. House of Representatives, 152 members signed principles authored by new House Energy & Commerce Committee Chair Henry Waxman calling for strong legislation that would require emissions cuts of 15-20 percent from current levels by 2020 and 80 percent from 1990 levels by 2050.

state policies

As the federal government has largely dragged its feet over the last eight years, states in the U.S. have been leading the way to advance renewables and energy efficiency. The overwhelming majority of states have at least some policies in place to promote renewable energy or energy efficiency.

In combination with federal tax credits, state renewable electricity standards (RES) are among the most important factors driving the growth of renewable energy in the United States. RES laws require a specific share of electricity to come from renewable sources or that a specific amount of renewable energy capacity is installed by a given date. By late 2008, there were mandatory RES laws in 28 U.S. states plus Washington, DC, and 5 additional states had adopted voluntary goals. When fully implemented, state RES laws will affect more than 46 percent of national retail electricity sales and together will require more than 10 percent of electricity in the U.S. come from clean, renewable sources by 2020.

A number of states are also considering Renewable Energy Payments (REPs, also known as feed-in tariffs) to assist in meeting state-mandated renewable energy targets. By late 2008, REP legislation was introduced in six states and under consideration in at least six more. In 2006, California created a renewable energy payment program for projects of no more than 1.5 megawatts (MW), with a 250 MW cap. The payment was based on time-of-use generating costs and was originally developed for wastewater and water treatment facilities. California has since expanded its REP program to include all customer types and increased the cap to 480 MW. (See below for more on California's ground-breaking energy policies)

In addition, 16 states and Washington, DC have Public Benefit Funds (worth an estimated $6.8 billion by 2017) to advance renewables and energy efficiency (as well as low-income assistance). Funding is derived from a very small per kWh charge on electricity.

Many U.S. states have also enacted laws that require net-metering to allow customers who produce their own renewable electricity to feed their excess electricity into the grid. As of November 2008, net-metering was available in 44 states and Washington, DC.

A number of states have adopted renewable fuels standards (RFS) for biofuels. Although most are for ethanol, some require biodiesel blending. For example, Minnesota has enacted a 20 percent by 2015 biodiesel mandate; the legislation requires that 5 percent of the feedstock come from non-traditional state agricultural resources.

Several states have also begun taking steps to regulate global warming pollution directly. Fourteen states and the District of Columbia have adopted tailpipe emissions standards for automobiles. The rule, known sometimes as the California clean cars standard, requires federal approval under the Clean Air Act, because the standard exceeds the standard set by federal law (in fact, carbon emissions are totally unregulated federally). After years of obstruction by the Bush administration, President Obama recently directed his EPA Administrator to review the decision to reject the waiver, and approval is considered only a matter of time.

Finally, six states have enacted economy-wide caps on global warming pollution. California was the first, but Hawaii, Connecticut, and Massachusetts, New Jersey, and Washington have followed suit. Several other states have adopted non-binding emissions reductions targets on either a state basis or as part of regional partnerships.

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

© VISSER/GP

highlight: california The state of California has one of the more aggressive RES laws, requiring that renewable energy account for 20 percent of retail sales by 2010 and reach 33 percent by 2020. The California Solar Initiative, or "Million Solar Roofs Initiative," offers $3.2 billion in incentives over ten years for solar energy projects (including solar space heat, solar thermal electric, solar thermal process heat, and photovoltaics) to provide 3,000 megawatts (MW) of solar capacity in the state by the end of 2017. In 2004, the state set standards requiring carmakers to reduce global warming emissions by approximately 30 percent by 2016. In 2006, the state enacted the Global Warming Solutions Act, which cuts global warming emissions statewide to 1990 levels by 2020 and by 80 percent by 2050. In late 2007, the California legislature also enacted the Solar Water Heating and Efficiency Act of 2007, a 10-year, statewide incentive program to encourage the installation of approximately 200,000 solar water heating systems to offset natural gas usage in homes and businesses throughout the state.

highlight: hawaii In October 2008, Hawaii Governor Linda Lingle announced a comprehensive agreement that aims to transition the state from its heavy reliance on fossil fuels for transportation and electricity generation to local renewable energy sources. The agreement includes a requirement that renewable energy provide 40 percent of electricity by 2030; the immediate deployment of advanced meters and implementation of time-of-use rates; a prohibition on the construction of any new coal-fired power plants; and a commitment from the state's electric companies to gradually retire fossil fuel-fired power plants or convert them to biofuels. In addition, as of January 2010, Hawaii will be the first U.S. state to require the installation of solar thermal water heaters on all new single family homes.

city policies

Several U.S. cities have adopted renewable energy targets and enacted policies to achieve global warming pollution reduction goals, create new jobs, and improve the quality of life. For example, in late 2007, Berkeley, California adopted a plan to finance the cost of solar panels for property owners who agree to repay the investment with a 20-year tax assessment on their property. Over two decades, the property tax would be the same or less than the property owner's electricity savings. In June of 2008, the city of San Francisco adopted the largest municipal solar incentive program in the United States – a 10-year program to provide $2.5 million of subsidies annually for solar installations.

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image THREE MILE ISLAND NUCLEAR POWER PLANT, PENNSYLVANIA, USA.

glossary & appendix

8

"i say the debate is over. we know the science, we see the threat and we know the time for action is now."

CALIFORNIA GOVERNOR ARNOLD SCHWARZENEGGER

glossary of commonly used terms and abbreviations

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

J Joule, a measure of energy:
kJ = 1,000 Joules,
MJ = 1 million Joules,
GJ = 1 billion Joules,
PJ = 10^{15} Joules,
EJ = 10^{18} Joules

W Watt, measure of electrical capacity:
kW = 1,000 watts,
MW = 1 million watts,
GW = 1 billion watts

kWh Kilowatt-hour, measure of electrical output:
TWh = 10^{12} watt-hours
t/Gt Tonnes, measure of weight:
Gt = 1 billion tonnes

conversion factors - fossil fuels

FUEL				
Coal	23.03	GJ/t	1 cubic	0.0283 m^3
Lignite	8.45	GJ/t	1 barrel	159 liter
Oil	6.12	GJ/barrel	1 US gallon	3.785 liter
Gas	38000.00	kJ/m^3	1 UK gallon	4.546 liter

conversion factors - different energy units

FROM / TO: MULTIPLY BY	TJ	Gcal	Mtoe	Mbtu	GWh
TJ	1	238.8	2.388×10^{-5}	947.8	0.2778
Gcal	4.1868×10^{-3}	1	$10^{(-7)}$	3.968	1.163×10^{-3}
Mtoe	4.1868×10^{4}	10^{7}	1	3968×10^{7}	11630
Mbtu	1.0551×10^{-3}	0.252	2.52×10^{-8}	1	2.931×10^{-4}
GWh	3.6	860	8.6×10^{-5}	3412	1

image LOCALS AND GREENPEACE SETTING UP WIND TURBINES IN THAILAND.

definition of sectors

The definition of different sectors is analog to 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 and 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: This category covers use of other petroleum products such as paraffin waxes, lubricants, bitumen etc.

image NAN WIND FARM IN NAN'AO. GUANGDONG PROVINCE HAS ONE OF THE BEST WIND RESOURCES IN CHINA AND IS ALREADY HOME TO SEVERAL INDUSTRIAL SCALE WIND FARMS. MASSIVE INVESTMENT IN WIND POWER WILL HELP CHINA OVERCOME ITS RELIANCE ON CLIMATE DESTROYING FOSSIL FUEL POWER AND SOLVE ITS ENERGY SUPPLY PROBLEM.

appendix: USA reference scenario

table 8.1: USA: electricity generation

TWh/a	2005	2010	2020	2030	2040	2050
Power plants	**3,937**	**4,273**	**5,047**	**5,739**	**6,486**	**7,246**
Coal	1,151	1,268	1,525	1,944	2,495	3,123
Lignite	943	1,034	1,205	1,295	1,380	1,470
Gas	574	612	672	695	711	724
Oil	108	112	107	87	67	43
Diesel	10	8	5	3	2	1
Nuclear	811	830	892	933	957	972
Biomass	32	42	93	125	145	152
Hydro	272	285	294	297	300	300
Wind	18	57	195	282	335	355
PV	0	3	14	19	23	26
Geothermal	17	21	37	45	52	55
Solar thermal power plants	1	1	8	13	17	21
Ocean energy	0	0	1	1	2	4
Combined heat & power production	**332**	**337**	**366**	**437**	**496**	**561**
Coal	55	57	65	85	112	144
Lignite	2	2	2	0	0	0
Gas	216	212	215	249	270	292
Oil	21	20	17	15	9	2
Biomass	39	45	64	84	99	115
Geothermal	0	1	2	4	5	9
CHP by producer						
Main acitivity producers	187	189	194	237	260	283
Autoproducers	145	148	172	200	236	278
Total generation	**4,269**	**4,610**	**5,412**	**6,176**	**6,982**	**7,807**
Fossil	3,080	3,325	3,812	4,373	5,046	5,798
Coal	1,206	1,325	1,589	2,029	2,607	3,266
Lignite	945	1,036	1,207	1,295	1,380	1,470
Gas	790	824	887	944	981	1,016
Oil	129	132	124	102	76	45
Diesel	10	8	5	3	2	1
Nuclear	811	830	892	933	957	972
Renewables	**379**	**455**	**708**	**870**	**979**	**1,036**
Hydro	272	285	294	297	300	300
Wind	18	57	195	282	335	355
PV	0.016	3	14	19	23	26
Biomass	71	87	157	209	244	267
Geothermal	17	22	39	49	57	64
Solar thermal	1	1	8	13	17	21
Ocean energy	0	0	1	1	2	4
Import	44.5	44.5	44.5	44.5	44.5	44.5
Import RES	6.7	6.7	6.7	6.7	6.7	6.7
Export	19.8	19.8	19.8	19.8	19.8	19.8
Distribution losses	265	282	326	368	412	454
Own consumption electricity	308	330	383	433	485	542
Electricity for hydrogen production	0	0	5	9	14	23
Final energy consumption (electricity)	**3,721**	**4,023**	**4,722**	**5,391**	**6,094**	**6,812**
Fluctuating RES (PV, Wind, Ocean)	18	**60**	**210**	**302**	**360**	**385**
Share of fluctuating RES	0.4%	**1.3%**	**3.9%**	**4.9%**	**5.2%**	**4.9%**
RES share	**8.9%**	**9.9%**	**13.1%**	**14.1%**	**14.0%**	**13.3%**

table 8.2: USA: heat supply

PJ/A	2005	2010	2020	2030	2040	2050
District heating plants	**0**	**12**	**44**	**63**	**71**	**74**
Fossil fuels	0	12	43	60	64	59
Biomass	0	0	1	3	6	13
Solar collectors	0	0	0	1	1	1
Geothermal	0	0	0	0	0	0
Heat from CHP	**538**	**583**	**713**	**942**	**1,213**	**1,656**
Fossil fuels	389	407	471	636	861	1,249
Biomass	149	167	222	272	304	330
Geothermal	0	9	20	34	48	77
Direct heating[1]	**16,947**	**18,788**	**19,817**	**21,531**	**22,301**	**22,919**
Fossil fuels	15,367	16,888	17,573	18,624	18,771	18,817
Biomass	1,493	1,781	1,898	2,242	2,597	2,881
Solar collectors	51	56	101	198	337	458
Geothermal	35	63	245	468	596	764
Total heat supply[1]	**17,484**	**19,384**	**20,574**	**22,537**	**23,585**	**24,649**
Fossil fuels	15,756	17,308	18,088	19,319	19,696	20,125
Biomass	1,642	1,948	2,120	2,517	2,907	3,224
Solar collectors	51	56	101	199	338	459
Geothermal	35	72	265	502	644	841
RES share (including RES electricity)	**9.9%**	**10.7%**	**12.1%**	**14.3%**	**16.5%**	**18.4%**

1) heat from electricity (direct and from electric heat pumps) not included; covered in the model under 'electric appliances'

table 8.3: USA: CO_2 emissions

MILL t/a	2005	2010	2020	2030	2040	2050
Condensation power plants	**2,415**	**2,611**	**2,818**	**3,104**	**3,431**	**3,769**
Coal	1,022.6	1,129.0	1,302.5	1,521.0	1,843.0	2,178.1
Lignite	1,052.7	1,126.2	1,146.5	1,238.0	1,271.5	1,305.4
Gas	253.4	272.1	292.6	285.9	271.2	256.1
Oil	78.2	77.5	72.2	57.3	44.1	28.3
Diesel	7.9	6.1	3.7	2.2	1.3	0.8
Combined heat & power production	**142**	**100**	**84**	**102**	**132**	**188**
Coal	48	19	13	22	40	74
Lignite	2	1	1	0	0	0
Gas	83	71	61	72	87	113
Oil	9	9	8	7	5	1
CO_2 emissions electricity & steam generation	**2,557**	**2,711**	**2,901**	**3,206**	**3,563**	**3,957**
Coal	1,071	1,148	1,316	1,544	1,883	2,253
Lignite	1,055	1,127	1,147	1,238	1,271	1,305
Gas	337	343	354	358	358	369
Oil & diesel	95	92	84	67	50	30
CO_2 emissions by sector	**5,575**	**5,884**	**6,315**	**6,846**	**7,336**	**7,925**
% of 1990 emissions	100%	106%	113%	123%	132%	142%
Industry	482	499	432	441	447	469
Other sectors	627	699	800	862	871	866
Transport	1928	1994	2204	2368	2506	2720
Electricity & steam generation	2,538	2,691	2,874	3,168	3,506	3,863
District heating	1	1	5	6	7	6
Population (Mill.)	300	315	343	366	386	402
CO_2 emissions per capita (t/capita)	**18.6**	**18.7**	**18.4**	**18.7**	**19.0**	**19.7**

table 8.4: USA: installed capacity

GW	2005	2010	2020	2030	2040	2050
Power plants	**873**	**929**	**1,084**	**1,215**	**1,338**	**1,462**
Coal	190	206	246	319	409	512
Lignite	155.2	167.8	194.4	212.3	226.2	241.0
Gas	274.8	279.8	299.1	320.3	327.6	333.6
Oil	38.6	40	36.9	29.0	21.6	13.4
Diesel	24.4	18.9	11.4	6.9	4.1	2.5
Nuclear	99.5	101.3	108.1	113.0	115.9	117.7
Biomass	4.7	6.1	13.5	18.7	21.6	22.7
Hydro	76	78	79	79	80	80
Wind	8.4	26.0	79.6	97.2	108.1	112.7
PV	0	1.7	7.8	10.6	12.8	14.4
Geothermal	2.3	2.9	5.3	6.5	7.5	8.0
Solar thermal power plants	0.3	0.6	2.6	2.2	2.7	3.2
Ocean energy	0	0	0.1	0.3	0.6	1.1
Combined heat & power production	**108**	**106**	**105**	**118**	**132**	**148**
Coal	24	26	25	30	39	50
Lignite	1	1	1	0	0	0
Gas	65	61	59	66	70	75
Oil	7	6	5	4	2	0
Biomass	11	11	15	17	19	22
Geothermal	0	0	0	1	1	2
CHP by producer						
Main activity producers	72	72	67	75	83	90
Autoproducers	37	35	38	43	49	58
Total generation	**982**	**1035**	**1,189**	**1,333**	**1,470**	**1,611**
Fossil	780	807	877	987	1100	1227
Coal	213	232	271	349	448	561
Lignite	156	169	195	212	226	241
Gas	340	341	358	387	398	408
Oil	46	46	42	33	24	14
Diesel	24	19	11	7	4	3
Nuclear	99	101	108	113	116	118
Renewables	**102**	**127**	**204**	**233**	**254**	**266**
Hydro	76	78	79	79	80	80
Wind	8	26	80	97	108	113
PV	0	2	8	11	13	14
Biomass	15	18	29	36	41	45
Geothermal	2	3	6	7	9	10
Solar thermal	0	1	3	2	3	3
Ocean energy	0	0	0	0	1	1
Fluctuating RES (PV, Wind, Ocean)	8.4	27.7	87.5	108.1	121.4	128.3
Share of fluctuating RES	0.9%	2.7%	7.4%	8.1%	8.3%	8.0%
RES share	**10.4%**	**12.3%**	**17.1%**	**17.5%**	**17.3%**	**16.5%**

table 8.5: USA: primary energy demand

PJ/A	2005	2010	2020	2030	2040	2050
Total	**96,826**	**102,629**	**111,984**	**121,552**	**130,085**	**138,186**
Fossil	**83,509**	**88,464**	**94,996**	**102,309**	**108,765**	**116,643**
Hard coal	13,184	13,975	15,450	17,783	21,252	25,091
Lignite	9,501	10,156	10,336	11,153	11,455	11,760
Natural gas	20,940	22,621	23,653	24,633	24,920	25,535
Crude oil	39,884	41,712	45,558	48,740	51,138	54,257
Nuclear	**8,846**	**9,056**	**9,733**	**10,180**	**10,442**	**10,606**
Renewables	**4,472**	**5,109**	**7,256**	**9,063**	**10,878**	**10,938**
Hydro	981	1,026	1,058	1,069	1,080	1,080
Wind	64	205	702	1,015	1,206	1,278
Solar	54	72	180	314	482	628
Biomass	3,011	3,456	4,625	5,682	6,902	6,476
Geothermal	362	350	688	979	1,201	1,461
Ocean Energy	0	1	2	4	7	14
RES share	**4.6%**	**5.0%**	**6.5%**	**7.5%**	**8.4%**	**7.9%**

table 8.6: USA: final energy demand

PJ/A	2005	2010	2020	2030	2040	2050
Total (incl. non-energy use)	**66,824**	**71,499**	**78,949**	**86,425**	**92,930**	**99,393**
Total (energy use)	**60,159**	**64,142**	**70,987**	**77,805**	**83,661**	**89,479**
Transport	**27,147**	**28,196**	**31,605**	**34,338**	**37,009**	**39,635**
Oil products	26,750	27,669	30,580	32,846	34,752	37,716
Natural gas	22	25	32	40	49	62
Biofuels	347	400	693	900	1,352	685
Electricity	28	103	287	531	817	1,110
RES electricity	2	10	38	75	115	147
Hydrogen	0	0	13	22	38	62
RES share Transport	**1.3%**	**1.5%**	**2.3%**	**2.8%**	**4.0%**	**2.1%**
Industry	**11,997**	**13,176**	**12,632**	**13,333**	**13,960**	**14,557**
Electricity	3,326	3,996	4,415	4,827	5,248	5,658
RES electricity	295	395	577	680	736	751
District heat	384	474	515	608	749	1,004
RES disrict heat	133	153	183	208	232	271
Coal	1,054	1,018	654	542	373	266
Oil products	1,460	1,426	1,286	1,322	1,338	1,339
Gas	4,602	4,974	4,473	4,586	4,619	4,576
Solar	0	0	22	52	91	118
Biomass and waste	1,168	1,286	1,210	1,296	1,415	1,421
Geothermal	4	3	59	100	126	174
RES share Industry	**13.3%**	**13.9%**	**16.2%**	**17.5%**	**18.6%**	**18.8%**
Other Sectors	**21,015**	**22,769**	**26,750**	**30,135**	**32,692**	**35,287**
Electricity	10,042	10,383	12,299	14,050	15,874	17,757
RES electricity	891	1,026	1,609	1,980	2,225	2,357
District heat	124	91	212	368	505	696
RES disrict heat	14	18	53	95	120	145
Coal	98	81	83	64	44	27
Oil products	2,600	2,884	3,351	3,728	3,739	3,448
Gas	7,557	8,497	9,657	10,277	10,425	10,758
Solar	51	56	79	146	246	340
Biomass and waste	510	727	945	1,255	1,536	1,851
Geothermal	31	49	123	247	324	411
RES share Other Sectors	**7.1%**	**8.2%**	**10.5%**	**12.4%**	**13.6%**	**14.5%**
Total RES	**3,448**	**4,123**	**5,593**	**7,036**	**8,522**	**8,681**
RES share	**5.2%**	**5.8%**	**7.1%**	**8.1%**	**9.2%**	**8.7%**
Non energy use	**6,665**	**7,357**	**7,962**	**8,620**	**9,269**	**9,914**
Oil	6,046	6,674	7,222	7,819	8,408	8,993
Gas	619	683	740	801	861	921
Coal	0	0	0	0	0	0

appendix: USA energy [r]evolution scenario

table 8.7: USA: electricity generation

TWh/a	2005	2010	2020	2030	2040	2050
Power plants	**3,937**	**4,163**	**4,244**	**4,426**	**4,627**	**4,532**
Coal	1,151	1,194	1,028	917	326	0
Lignite	943	930	463	86	0	0
Gas	574	703	895	820	675	102
Oil	108	105	37	23	5	0
Diesel	10	7	4	2	1	0
Nuclear	811	768	393	53	7	0
Biomass	32	55	63	64	65	65
Hydro	272	293	375	398	417	420
Wind	18	68	632	1,030	1,185	1,255
PV	0	3	125	360	645	920
Geothermal	17	32	125	316	565	690
Solar thermal power plants	1	3	96	330	665	965
Ocean energy	0	2	8	27	71	115
Combined heat & power production	**332**	**389**	**619**	**740**	**823**	**876**
Coal	55	52	20	4	1	0
Lignite	2	1	0	0	0	0
Gas	216	255	412	364	222	158
Oil	21	22	15	0	0	0
Biomass	39	57	159	339	547	648
Geothermal	0	3	14	32	54	70
CHP by producer						
Main acitivity producers	187	193	228	254	275	297
Autoproducers	145	196	391	486	548	579
Total generation	**4,269**	**4,552**	**4,863**	**5,166**	**5,450**	**5,408**
Fossil	3,080	3,268	2,874	2,216	1,229	260
Coal	1,206	1,246	1,048	921	327	0
Lignite	945	931	463	86	0	0
Gas	790	958	1,307	1,184	897	260
Oil	129	127	52	23	5	0
Diesel	10	7	4	2	1	0
Nuclear	811	768	393	53	7	0
Renewables	**379**	**516**	**1,596**	**2,896**	**4,214**	**5,148**
Hydro	272	293	375	398	417	420
Wind	18	68	632	1,030	1,185	1,255
PV	0.016	3	125	360	645	920
Biomass	71	112	222	403	612	713
Geothermal	17	35	139	348	619	760
Solar thermal	1	3	96	330	665	965
Ocean energy	0	2	8	27	71	115
Import	44.5	44.5	44.5	44.5	44.5	44.5
Import RES	6.7	11.1	18.7	25.4	30.3	35.2
Export	19.8	19.8	19.8	19.8	19.8	19.8
Distribution losses	265	278.0	293.0	308.0	322.0	314.0
Own consumption electricity	308	326.0	344.0	362.0	379.0	375.0
Electricity for hydrogen production	0	0	71.6	130	190.9	175.1
Final energy consumption (electricity)	**3,721**	**3,973**	**4,180**	**4,390**	**4,583**	**4,568**
Fluctuating RES (PV, Wind, Ocean)	18	73	765	1417	1901	2290
Share of fluctuating RES	0.4%	1.6%	15.7%	27.4%	34.9%	42.3%
RES share	**8.9%**	**11.3%**	**32.8%**	**56.1%**	**77.3%**	**95.2%**
'Efficiency' savings (compared to Ref.)	**0**	**50**	**543**	**1,001**	**1,512**	**2,244**

table 8.8: USA: heat supply

PJ/A	2005	2010	2020	2030	2040	2050
District heating plants	**0**	**178**	**1,088**	**2,487**	**3,388**	**2,812**
Fossil fuels	0	0	0	0	0	0
Biomass	0	89	490	995	1,186	844
Solar collectors	0	45	326	871	1,355	1,266
Geothermal	0	45	272	622	847	703
Heat from CHP	**538**	**704**	**1,432**	**2,173**	**2,837**	**3,037**
Fossil fuels	389	466	738	743	608	485
Biomass	149	211	571	1,141	1,748	1,920
Geothermal	0	27	122	289	482	632
Direct heating[1)]	**16,947**	**17,436**	**17,818**	**16,878**	**14,723**	**11,836**
Fossil fuels	15,367	15,417	14,425	11,026	7,378	4,964
Biomass	1,493	1,680	2,358	2,659	2,563	1,990
Solar collectors	51	235	635	2,341	3,370	3,390
Geothermal	35	104	400	852	1,412	1,492
Total heat supply[1)]	**17,484**	**18,318**	**20,337**	**21,539**	**20,948**	**17,686**
Fossil fuels	15,756	15,884	15,163	11,769	7,985	5,448
Biomass	1,642	1,980	3,419	4,795	5,497	4,754
Solar collectors	51	280	962	3,212	4,725	4,656
Geothermal	35	176	794	1,763	2,741	2,828
RES share (including RES electricity)	**9.9%**	**13.3%**	**25.4%**	**45.4%**	**61.9%**	**69.2%**
'Efficiency' savings (compared to Ref.)	**0**	**1,065**	**237**	**998**	**2,636**	**6,963**

1) heat from electricity (direct and from electric heat pumps) not included; covered in the model under 'electric appliances'

table 8.9: USA: CO_2 emissions

MILL t/a	2005	2010	2020	2030	2040	2050
Condensation power plants	**2,415**	**2,467**	**1,737**	**1,153**	**502**	**36**
Coal	1,022.6	1,063.3	878.6	717.1	240.7	0
Lignite	1,052.7	1,012.9	440.5	82.2	0	0
Gas	253.4	312.5	389.7	337.4	257.5	36.0
Oil	78.2	72.7	25.0	15.1	3.3	0
Diesel	7.9	5.7	3.2	1.6	0.8	0
Combined heat & power production	**142**	**108**	**119**	**102**	**79**	**62**
Coal	48	17	4	2	0	0
Lignite	2	1	0	0	0	0
Gas	83	80	107	101	78	62
Oil	9	10	7	0	0	0
CO_2 emissions electricity & steam generation	**2,557**	**2,575**	**1,856**	**1,256**	**581**	**98**
Coal	1,071	1,080	883	719	241	0
Lignite	1,055	1,014	441	82	0	0
Gas	337	393	497	438	336	98
Oil & diesel	95	88	35	17	4	0
CO_2 emissions by sector	**5,575**	**5,600**	**4,426**	**3,239**	**1,867**	**827**
% of 1990 emissions	112%	112%	88%	65%	37%	17%
Industry	482	405	317	230	149	112
Other sectors	627	694	677	531	385	274
Transport	1928	1953	1626	1283	815	400
Electricity & steam generation	2,538	2,549	1,806	1,195	519	42
District heating	0	0	0	0	0	0
Population (Mill.)	300	315	343	366	386	402
CO_2 emissions per capita (t/capita)	**18.6**	**17.8**	**12.9**	**8.8**	**4.8**	**2.1**

table 8.10: USA: installed capacity

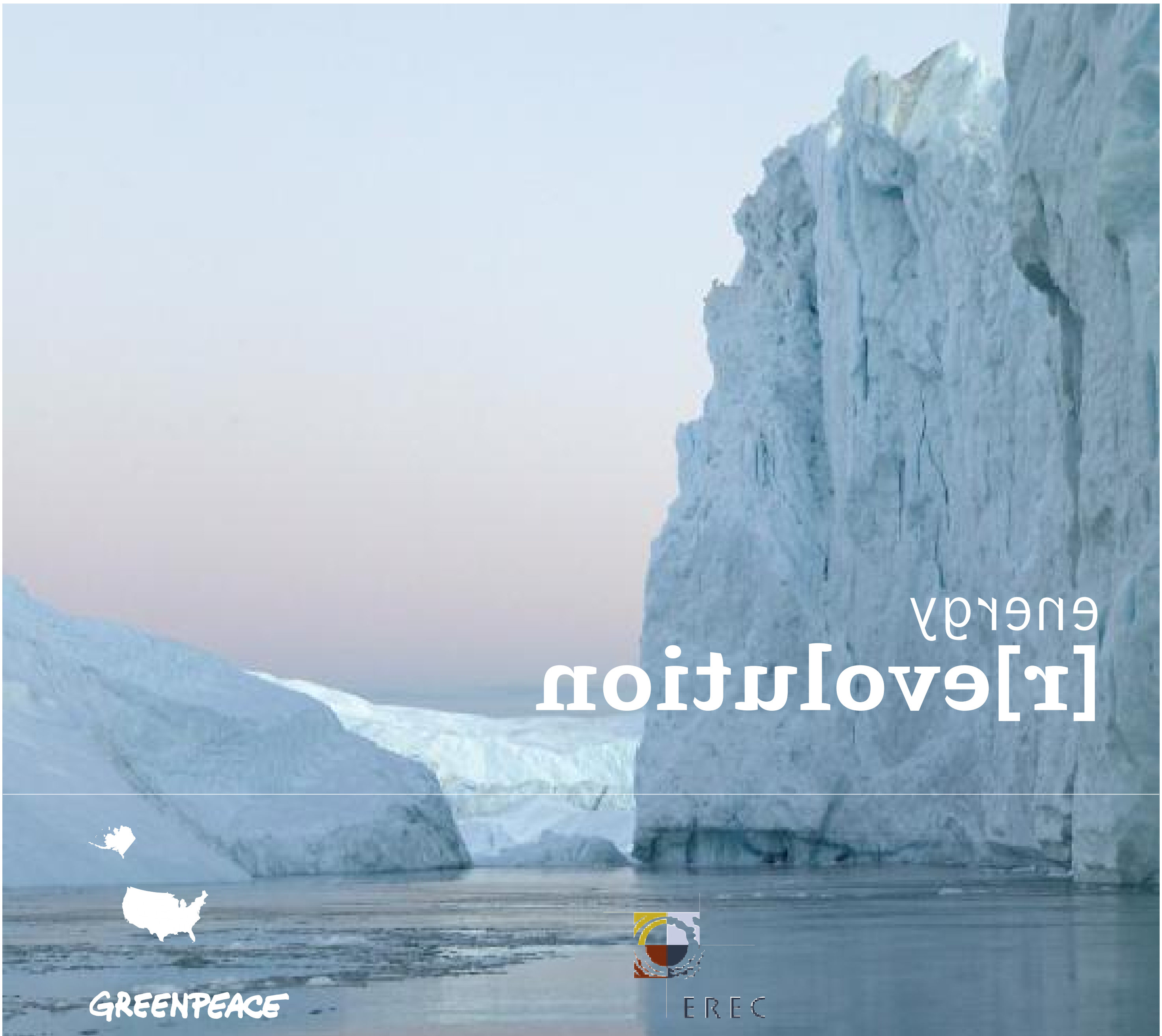
GW	2005	2010	2020	2030	2040	2050
Power plants	**873**	**942**	**1,198**	**1,341**	**1,439**	**1,360**
Coal	190	194	166	150	53	0
Lignite	155.2	151	75	14	0	0
Gas	274.8	321	398	378	311	47
Oil	38.6	38	13	8	2	0
Diesel	24.4	18	10	5	3	0
Nuclear	99.5	94	48	6	1	0
Biomass	4.7	8	9	10	10	10
Hydro	76	80	101	106	111	112
Wind	8.4	31	258	355	382	398
PV	0	1.7	69	200	358	511
Geothermal	2.3	4.5	18	46	82	100
Solar thermal power plants	0.3	1.4	31	55	106	148
Ocean energy	0	0.6	2	8	20	33
Combined heat & power production	**108**	**117**	**158**	**167**	**167**	**172**
Coal	24	23	8	1	0	0
Lignite	1	1	0	0	0	0
Gas	65	72	107	90	50	33
Oil	7	7	4	0	0	0
Biomass	11	14	37	70	107	124
Geothermal	0	1	3	6	11	14
CHP by producer						
Main activity producers	72	71	72	64	58	57
Autoproducers	37	46	86	103	110	114
Total generation	**982**	**1,059**	**1,356**	**1,508**	**1,606**	**1,531**
Fossil	780	823	780	646	419	80
Coal	213	217	174	151	54	0
Lignite	156	152	75	14	0	0
Gas	340	393	505	468	361	80
Oil	46	44	17	8	2	0
Diesel	24	18	10	5	3	0
Nuclear	99	94	48	6	1	0
Renewables	**102**	**142**	**528**	**856**	**1,187**	**1,451**
Hydro	76	80	101	106	111	112
Wind	8	31	258	355	382	398
PV	0	2	69	200	358	511
Biomass	15	22	46	79	116	134
Geothermal	2	5	21	52	93	114
Solar thermal	0	1	31	55	106	148
Ocean energy	0	1	2	8	20	33
Fluctuating RES (PV, Wind, Ocean)	8.4	33.3	329.7	562.9	760.9	942.4
Share of fluctuating RES	0.9%	3.1%	24.3%	37.3%	47.4%	61.5%
RES share	**10.4%**	**13.4%**	**38.9%**	**56.8%**	**73.9%**	**94.8%**

table 8.11: USA: primary energy demand

PJ/A	2005	2010	2020	2030	2040	2050
Total	**96,826**	**100,001**	**92,707**	**85,306**	**76,165**	**63,294**
Fossil	**83,509**	**85,596**	**72,707**	**56,738**	**37,297**	**20,796**
Hard coal	13,184	13,520	10,693	8,676	3,496	889
Lignite	9,501	9,133	3,969	741	0	0
Natural gas	20,940	25,592	28,072	24,058	18,156	10,526
Crude oil	39,884	37,351	29,974	23,264	15,645	9,381
Nuclear	**8,846**	**8,380**	**4,288**	**578**	**76**	**0**
Renewables	**4,472**	**6,025**	**15,712**	**27,989**	**38,792**	**42,498**
Hydro	981	1,055	1,350	1,433	1,501	1,512
Wind	64	245	2,275	3,708	4,266	4,518
Solar	54	301	1,757	5,696	9,441	11,442
Biomass	3,011	3,772	7,781	11,142	13,319	12,818
Geothermal	362	645	2,520	5,914	10,010	11,794
Ocean Energy	0	7	29	97	256	414
RES share	**4.6%**	**6.0%**	**17.0%**	**32.8%**	**50.9%**	**67.1%**
'Efficiency' savings (compared to Ref.)	**0**	**2,656**	**19,332**	**36,315**	**53,993**	**74,975**

table 8.12: USA: final energy demand

PJ/A	2005	2010	2020	2030	2040	2050
Total (incl. non-energy use)	**66,824**	**69,560**	**68,374**	**66,026**	**60,013**	**50,919**
Total (energy use)	**60,159**	**62,208**	**61,772**	**59,769**	**53,881**	**44,953**
Transport	**27,147**	**27,665**	**25,091**	**22,088**	**17,519**	**13,505**
Oil products	26,750	27,094	22,552	17,797	11,290	5,530
Natural gas	22	24	24	24	21	19
Biofuels	347	452	1,935	3,030	3,765	4,141
Electricity	28	96	404	908	1,943	3,342
RES electricity	2	11	133	509	1,503	3,182
Hydrogen	0	0	176	329	499	473
RES share Transport	**1.3%**	**1.7%**	**8.5%**	**16.9%**	**32.3%**	**57.6%**
Industry	**11,997**	**11,682**	**11,412**	**11,183**	**10,933**	**10,465**
Electricity	3,326	3,834	4,020	3,984	3,933	3,440
RES electricity	295	434	1,320	2,234	3,041	3,275
District heat	384	559	1,223	1,794	2,297	2,479
RES disrict heat	133	262	794	1,423	2,092	2,365
Coal	1,054	625	273	34	0	0
Oil products	1,460	1,131	674	364	150	138
Gas	4,602	4,252	3,613	2,901	2,068	1,588
Solar	0	135	305	633	812	976
Biomass and waste	1,168	1,103	1,128	1,189	1,176	1,179
Geothermal	4	44	175	284	497	664
RES share Industry	**13.3%**	**16.9%**	**32.6%**	**51.5%**	**69.7%**	**80.8%**
Other Sectors	**21,015**	**22,861**	**25,270**	**26,498**	**25,429**	**20,984**
Electricity	10,042	10,373	10,622	10,914	10,621	9,664
RES electricity	891	1,175	3,487	6,119	8,212	9,200
District heat	124	271	1,241	2,811	3,871	3,313
RES disrict heat	14	129	942	2,443	3,470	2,943
Coal	98	308	0	7	5	1
Oil products	2,600	2,705	1,752	858	582	544
Gas	7,557	8,247	9,582	7,935	5,407	3,425
Solar	51	100	330	1,708	2,558	2,414
Biomass and waste	510	808	1,590	1,871	1,756	1,065
Geothermal	31	49	153	394	629	557
RES share Other Sectors	**7.1%**	**9.9%**	**25.7%**	**47.3%**	**65.4%**	**77.1%**
Total RES	**3,448**	**4,702**	**12,349**	**22,021**	**29,896**	**32,411**
RES share	**5.2%**	**6.8%**	**18.1%**	**33.4%**	**49.8%**	**63.7%**
Non energy use	**6,665**	**7,352**	**6,602**	**6,257**	**6,132**	**5,966**
Oil	6,046	3,484	3,129	2,965	2,906	2,827
Gas	619	3,412	3,064	2,904	2,846	2,769
Coal	0	456	409	388	380	370



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