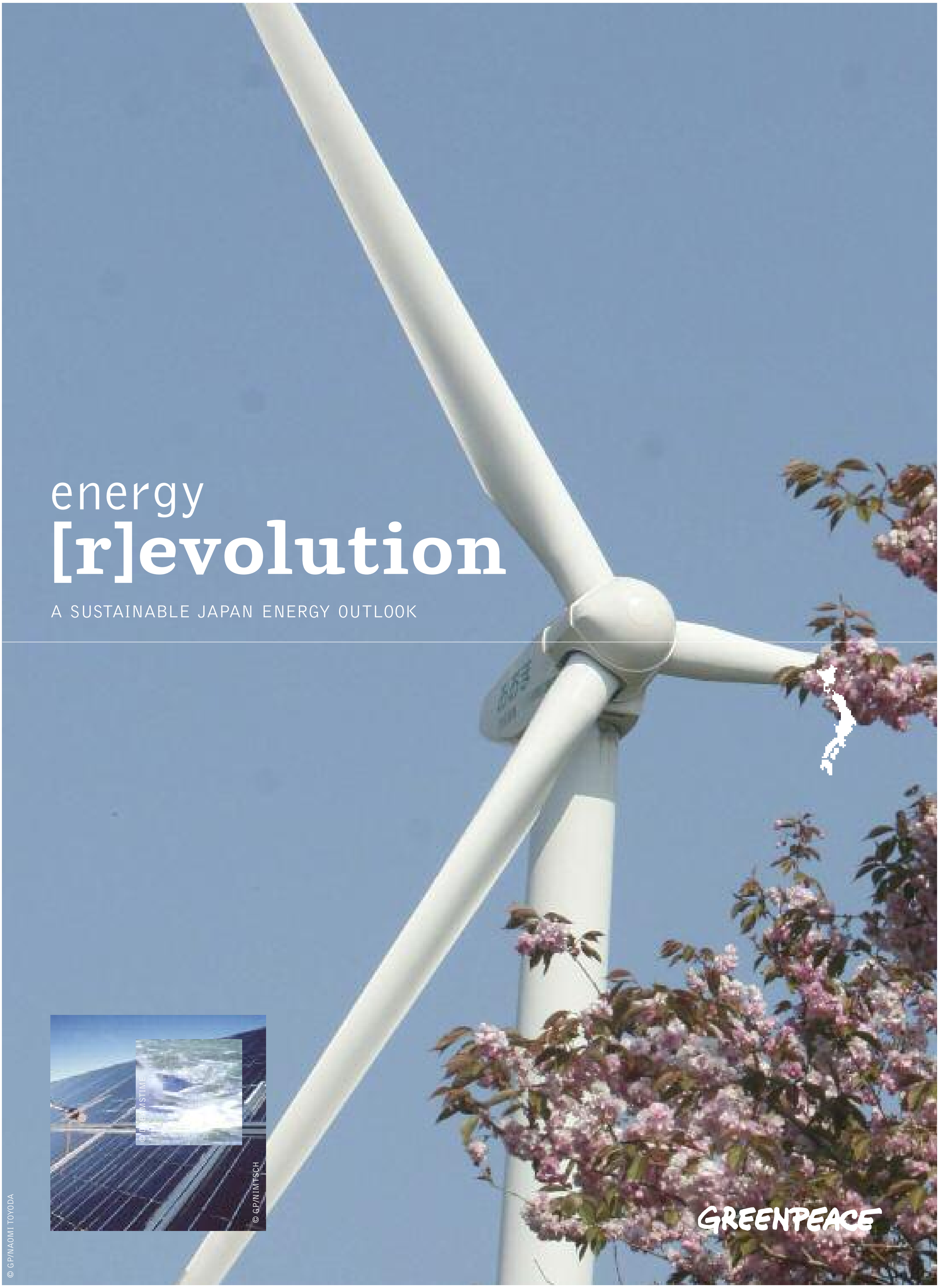
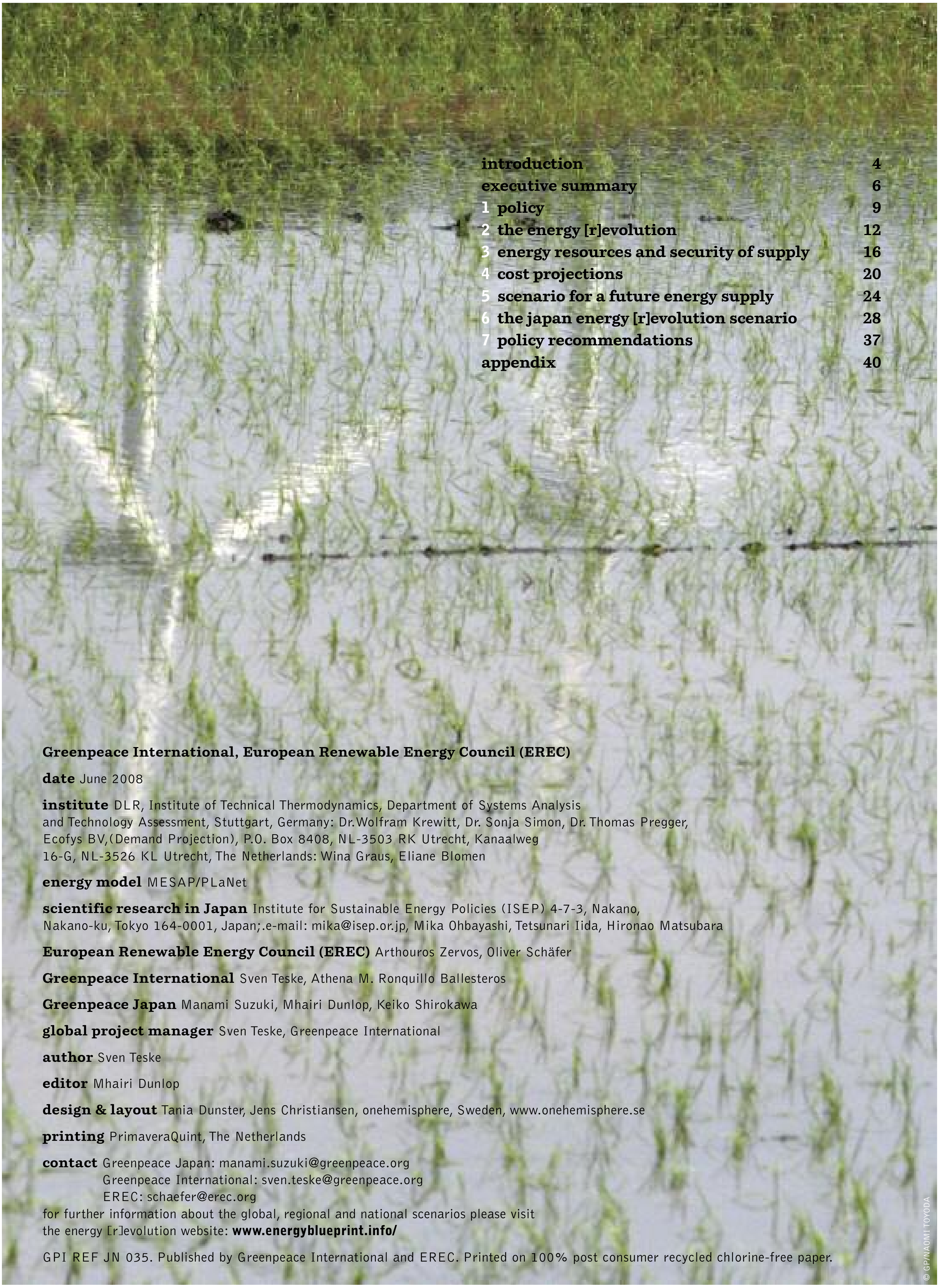


energy [r]evolution

A SUSTAINABLE JAPAN ENERGY OUTLOOK

GREENPEACE

report japan regional energy scenario



Greenpeace International, European Renewable Energy Council (EREC)

date June 2008

institute DLR, Institute of Technical Thermodynamics, Department of Systems Analysis and Technology Assessment, Stuttgart, Germany: Dr.Wolfram Krewitt, Dr. Sonja Simon, Dr. Thomas Pregger, Ecofys BV,(Demand Projection), P.O. Box 8408, NL-3503 RK Utrecht, Kanaalweg 16-G, NL-3526 KL Utrecht, The Netherlands: Wina Graus, Eliane Blomen

energy model MESAP/PLaNet

scientific research in Japan Institute for Sustainable Energy Policies (ISEP) 4-7-3, Nakano, Nakano-ku, Tokyo 164-0001, Japan;.e-mail: mika@isep.or.jp, Mika Ohbayashi, Tetsunari Iida, Hironao Matsubara

European Renewable Energy Council (EREC) Arthouros Zervos, Oliver Schäfer

Greenpeace International Sven Teske, Athena M. Ronquillo Ballesteros

Greenpeace Japan Manami Suzuki, Mhairi Dunlop, Keiko Shirokawa

global project manager Sven Teske, Greenpeace International

author Sven Teske

editor Mhairi Dunlop

design & layout Tania Dunster, Jens Christiansen, onehemisphere, Sweden, www.onehemisphere.se

printing PrimaveraQuint, The Netherlands

contact Greenpeace Japan: manami.suzuki@greenpeace.org
Greenpeace International: sven.teske@greenpeace.org
EREC: schaefer@erec.org

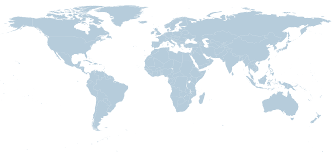
for further information about the global, regional and national scenarios please visit the energy [r]evolution website: **www.energyblueprint.info/**

GPI REF JN 035. Published by Greenpeace International and EREC. Printed on 100% post consumer recycled chlorine-free paper.

© GP/NAOMI TOYODA

cover image THE "CITIZENS' WINDMILL" IN AOMORI, NORTHERN JAPAN. PUBLIC GROUPS, SUCH AS CO-OPERATIVES, ARE BUILDING AND RUNNING LARGE-SCALE WIND TURBINES IN SEVERAL CITIES AND TOWNS ACROSS JAPAN. **image** WIND TURBINES REFLECTED IN WATER-FILLED PADDY FIELD, MID-MAY, NORTHERN JAPAN.

foreword



There is now growing awareness on the imperatives for a global energy future which marks a distinct departure from past trends and patterns of energy production and use. These imperatives emerge as much from the need to ensure energy security, as they do from the urgency of controlling local pollution from combustion of different fuels and, of course, the growing challenge of climate change, which requires reduction in emissions of greenhouse gases (GHSs), particularly carbon dioxide.

This publication provides stimulating analysis on future scenarios of energy use, which focus on a range of technologies that are expected to emerge in the coming years and decades. There is now universal recognition of the fact that new technologies and much greater use of some that already exist provide the most hopeful prospects for mitigation of emissions of GHGs. It is for this reason that the International Energy Agency, which in the past pursued an approach based on a single time path of energy demand and supply, has now developed alternative scenarios that incorporate future technological changes. In the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) as well, technology is included as a crosscutting theme in recognition of the fact that an assessment of technological options would be important both for mitigation as well as adaptation measures for tackling climate change.

The scientific evidence on the need for urgent action on the problem of climate change has now become stronger and convincing. Future solutions would lie in the use of existing renewable energy technologies, greater efforts at energy efficiency and the dissemination of decentralized energy technologies and options. This particular publication provides much analysis and well-researched material to stimulate thinking on options that could be adopted in these areas. It is expected that readers who are knowledgeable in the field as well as those who are seeking an understanding of the subjects covered in the ensuing pages would greatly benefit from reading this publication.

Dr. R. K. Pachauri

CHAIRMAN INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE

JANUARY 2007

introduction

"RENEWABLE ENERGY TECHNOLOGIES ARE ALREADY PROVEN AND ARE SHOWING SATISFACTORY RESULTS IN THE COUNTRIES THAT HAVE PROMOTED THEM"

image TEST WINDMILL N90 2500, BUILT BY THE GERMAN COMPANY NORDEX, IN THE HARBOUR OF ROSTOCK. THIS WINDMILL PRODUCES 2,5 MEGA WATT AND IS TESTED UNDER OFFSHORE CONDITIONS. AT LEAST 10 FACILITIES OF THIS TYPE WILL BE ERECTED 20 KM OFF THE ISLAND DARSS IN THE BALTIC SEA BY 2007. TWO TECHNICIANS WORKING INSIDE THE TURBINE.

In summer 2007, the highest temperature in Japan was observed since records began - 40.1°C, in Kumagaya City, Saitama prefecture. This record too will probably soon be broken. Due to the frequent occurrence of abnormal climatic events, such as large-scale typhoons and flooding, most Japanese have by now personally experienced the effects of climate change; this represents present global trends.

Earth has been described as the 'Miracle Planet'; life developed on Earth as a result of various coincidences, the presence of carbon dioxide (CO_2) and other greenhouse gases (GHGs) in the atmosphere. It is the only planet in our solar system where the existence of life has been confirmed. During Earth's 4.6 billion year history, temperatures have gone through major cycles of change. At present, we are in a warm (interglacial) period. However, the current warming trend that we are experiencing is different from the natural phenomena of the past. Temperatures have risen very rapidly over a period of just 100 years. The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), published in 2007, stated that this is very likely due to human activity, with massive consumption of energy (predominantly from fossil fuels) as the primary cause.

Since the latter half of the 19th century, when industrialization led to greater consumption of energy from fossil fuels, the concentration of GHG in the atmosphere has increased and this has continued with particular rapidity since the beginning of the 20th century. The IPCC predicts that if we continue business-as-usual, by the end of the present century the mean global temperature will rise by a maximum of 6.4°C.

If we allow this to happen, a large number of species that are unable to endure the sudden changes in climate will most likely face extinction. The IPCC model suggests that a temperature rise of over 2°C could cause the extinction of as many as 30% of all species, with any further rise leading to the risk of a major global extinction. It also warns that this would create a dangerous situation, prone to phenomena, such as the recurrence of severe tropical depressions (typhoons, hurricanes etc.), intense heavy rains, heatwaves and droughts, as well as food and water shortages, sea level rise and a greater incidence of infectious diseases.

So, how do we prevent warming from reaching these dangerous levels? The IPCC states that in order to keep the mean temperature increase below 2°C, global GHG emissions must peak by about 2015 and start to decrease thereafter. Time is running out.

climate policy of japan

In 1992, the United Nations Framework Convention on Climate Change (UNFCCC) was adopted, and an agreement on its practical implementation, the Kyoto Protocol, was formulated in 1997. Some time was then lost while the United States pulled out, and interests of various countries conflicted. The protocol finally came into force in 2005.

The first commitment phase of the Kyoto Protocol – from 2008 to 2012 – has now started (in Japan, with the start of the fiscal year on April 1, 2008). The protocol sets numerical targets for industrialized nations to cut GHG emissions during this period, taking 1990 as the base year. While the required reduction target for Japan is 6% below the 1990 level, Japan's emissions on the contrary have been increasing. In fiscal 2005, the year with the most up-to-date official figures available, Japan's emissions were 7.8% higher than the base year. This means Japan will actually have to achieve a reduction of about 14%, if it is to meet Kyoto Protocol commitments.

In order to fulfil its international pledge, Japan needs to move swiftly to implement effective "domestic" measures. The Japanese Government's policy proposal on climate change, 'Cool Earth 50', calls for halving the global GHG emissions by 2050, however the Government has remained silent on the absolute reduction goals of how much and by when for Japan (as of May, 2008.) Its Kyoto Target Achievement Plan, includes little legislative measurement but depends on voluntary action by industries, the development of innovative technology, and awareness-raising, such as the 'popular national movement' campaign entitled 'Cut 1 Kg of CO_2 per person per day'. Such weak initiatives can in no way guarantee significant reductions.

For innovative technologies, the Government lists high-cost, high-risk technologies such as fast breeder reactors and carbon capture and storage (CCS). It is highly doubtful that practical application of these technologies will become possible even after additional decades of investment. Evading dangerous climate change is indeed a struggle against time. Even if these technologies were to become commercially feasible in a half century, this could not serve to control the rise of temperature to below 2°C, let alone contribute to meeting the goals of the first commitment phase of the Kyoto Protocol.

In Japan, the rise of GHG emissions since the late 1990s is attributable to the increase of CO_2 emissions from electricity generation. One reason for this increase is the growing utilization of coal for its relatively cheaper price and lower taxation rate. Another reason is the heavy dependence on nuclear power in addressing emission reductions. The Japanese Government has based its estimate for reductions on the premise that there will be an increase in nuclear power generation capacity, but not only because of citizens' resistance to the expansion of nuclear power, but also due to the characteristics of Japan's electric energy demand and other factors, building more nuclear power plants in Japan is difficult. Also accidents, earthquakes and scandals have made plants stop operation one after another, escalating the dependence on fossil fuel for generating electricity, which has led to the steep increase of CO_2 emissions. The Government now aims at jacking up the operational capacity target for existing nuclear plants up to 88% in order to meet its goals. In reality, however, the average nuclear plant's utilization rate in Japan for the last several years has remained in the range of 60% - 70%, so a rate of 88% is fairly unrealistic. Depending on nuclear power, therefore, cannot ensure solid reductions in CO_2 emissions.

japan needs effective policy

Some countries are making steady reductions. One example is Germany, which by 2003 had succeeded in achieving a 19% reduction compared to the 1990 level. Several reasons can be given for this. Legislation promoting supportive measures for renewables has clearly affected this outcome favourably. The share of renewables in the electricity supply doubled between 1998 and 2007 from 6% to over 12 %. Originally the 12% share was set as a target for the year 2010, which was reached three years ahead of schedule. The German Government aims to further expand this to at least 20% by 2020, and a further expansion of this target is very likely.

By contrast, Japan's renewable portfolio standard (RPS) law, which obliges electric utilities to use renewable energy sources (excluding large hydro power) in total electricity supply, sets extremely low targets: 1.35% by 2010 and 1.63% by 2014. RPS is meant to promote renewables, but Japan's law is in fact obstructing its development.

In 1990, there was no great difference in wind power generation between Germany and Japan. Subsequently, supportive policies in Germany have expanded the wind turbine market there, resulting in a rapid increase in installation capacity, making Germany a top runner in this area. In solar power generation as well, Germany has become the world champion overtaking Japan, a former leader. Renewable energy sources ensure a stable electricity supply for Germany. In 2007, when the weather was favourable there, electricity generated by renewables exceeded that by nuclear power. The renewable energy industry in Germany also contributes to the economy and creates jobs.

Renewable energy technologies are already proven and are showing satisfactory results in the countries that have promoted them. Their wider application is not a matter of technology. It is a matter of policy.

japan's energy [r]evolution scenario

Greenpeace, in collaboration with the Tokyo-based Institute for Sustainable Energy Policies (ISEP), has produced this energy scenario, as a practical blueprint for a structural change of Japan's energy system. The scenario shows how to meet CO_2 reduction targets quickly and secure affordable energy supply while benefiting Japan's economy. The urgent need for change in the energy sector means that this scenario is based only on proven and sustainable technologies, in renewable energy sources and decentralized, efficient cogeneration. It excludes nuclear energy and so-called "CO_2-free," in other words carbon capture and storage technology. The future potential for renewable energy sources, which forms the basis of the Energy [R]evolution Scenario is based on Year 2050 Renewable Energy Vision in Japan (ISEP, Feb.2008.)

The German Aerospace Center (DLR) has been commissioned to make the simulation for this scenario. The reference scenarios adopted in this report, which both extend beyond and enhance projections by the International Energy Agency in its World Energy Outlook 2007, have been calculated using the MESAP/PlaNet simulation model developed by DLR. The alternative scenario is based on the ISEP study, which envisages an ambitious overall development path for the exploitation of energy efficiency and renewables potential, focused on current best practices as well as technologies available in the future. Results show that by 2050, primary energy demand in Japan would decrease by 53%, renewable energy would meet over 60% of electricity demand, and CO_2 emissions would be reduced by 77 % compared to the 2005 level.

from vision to reality

Various types of action in all sectors of society is needed to avert further increase of global warming. Of those, a change of energy policy is at the top of the agenda. Political will is necessary for this change to take place. Public opinion is essential for this outcome, that is to say, the power of each and every one of us can make this a reality.

Jun Hoshikawa
EXECUTIVE DIRECTOR
GREENPEACE JAPAN

Tetsunari IIda
INSTITUTE FOR SUSTAINABLE
ENERGY POLICIES (ISEP)

Sven Teske
CLIMATE & ENERGY
UNIT, GREENPEACE
INTERNATIONAL

JUNE 2008

executive summary

"THE RESERVES OF RENEWABLE ENERGY THAT ARE TECHNICALLY ACCESSIBLE GLOBALLY ARE LARGE ENOUGH TO PROVIDE ABOUT SIX TIMES MORE ENERGY THAN THE WORLD CURRENTLY CONSUMES - FOREVER."

image MAN RUNNING ON THE RIM OF A SOLAR DISH WHICH IS ON TOP OF THE SOLAR KITCHEN AT AUROVILLE, TAMIL NADU, INDIA. THE SOLAR DISH CAPTURES ENOUGH SOLAR ENERGY TO GENERATE HEAT TO COOK FOR 2,000 PEOPLE PER DAY.

climate threats and climate solutions

Global climate change caused by the relentless build-up of greenhouse gases in the earth's atmosphere is already disrupting ecosystems and is already causing about 150,000 additional deaths per year. An average global warming of 2°C threatens millions of people with an increased risk of hunger, malaria, flooding and water shortages. If rising temperatures are to be kept within acceptable limits then we need to significantly reduce our greenhouse gas emissions. This makes both environmental and economic sense. The main greenhouse gas is carbon dioxide (CO_2) produced by using fossil fuels for energy and transport.

Spurred by recent large increases in the price of oil, the issue of security of supply is now at the top of the energy policy agenda. One reason for these price increases is the fact that supplies of all fossil fuels – oil, gas and coal – are becoming more scarce and more expensive to produce. The days of 'cheap oil and gas' are coming to an end. Uranium, the fuel for nuclear power, is also a finite resource. By contrast, the reserves of renewable energy that are technically accessible globally are large enough to provide about six times more power than the world currently consumes - forever.

Renewable energy technologies vary widely in their technical and economic maturity, but there are a range of sources which offer increasingly attractive options. These sources include wind, biomass, photovoltaic, solar thermal, geothermal, ocean and hydroelectric power. Their common feature is that they produce little or no greenhouse gases, and rely on virtually inexhaustible natural sources for their 'fuel'. Some of these technologies are already competitive. Their economics will further improve as they develop technically, as the price of fossil fuels continues to rise and as their saving of carbon dioxide emissions is given a monetary value.

At the same time there is enormous potential for reducing our consumption of energy, while providing the same level of energy 'services'. This study details a series of energy efficiency measures, which together can substantially reduce demand in industry, homes, business and services. Although nuclear power produces little carbon dioxide, there are multiple threats to people and the environment from its operations. These include the risks and environmental damage from uranium mining, processing and transport, the risk of nuclear weapons proliferation, the unsolved problem of nuclear waste and the potential hazard of a serious accident. The nuclear option is therefore discounted in this analysis. The solution to our future energy needs lies instead in greater use of renewable energy sources for both heat and power.

image ENERGY PLANT NEAR REYKJAVIK, ENERGY IS PRODUCED FROM THE GEOTHERMAL ACTIVITY. NORTH WEST OF ICELAND.

the energy [r]evolution

The climate change imperative demands nothing short of an Energy [R]evolution. At the core of this revolution will be a change in the way that energy is produced, distributed and consumed. The five key principles behind this shift will be to:

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

Decentralised energy systems, where power and heat are produced close to the point of final use, avoid the current waste of energy during conversion and distribution. They will be central to the Energy [R]evolution, as will the need to provide electricity to the two billion people around the world to whom access is presently denied.

the energy [r]evolution scenario for japan

Two scenarios up to the year 2050 are outlined in this report. The Reference Scenario is based on the regional reference scenario for OECD Pacific published by the International Energy Agency in the World Energy Outlook 2007, extrapolated forward from 2030. While the global Energy [R]evolution Scenario has a target for the reduction of worldwide emissions to be reduced by 50% below 1990 levels by 2050, with per capita carbon dioxide emissions reduced to about 1 tonne per year in order for the increase in global temperature to remain under +2°C. The Energy [R]evolution scenario for Japan aims to reduce national CO_2 emissions by 26% by 2020 and up to 77% by 2050.

To achieve these targets, the scenario is characterised by significant efforts to fully exploit the large potential for energy efficiency. At the same time, all cost-effective renewable energy sources are accessed for process heat and electricity generation, as well as the production of sustainable biofuels. Today, renewable energy sources account for 3.2% of Japan's primary energy demand. Biomass used almost entirely for heating and co-generation as well as geothermal and hydropower, both mainly used for electricity production, are the currently used renewable energy sources. The share of renewable energy in electricity generation is 9.6%. The contribution of renewables to primary energy demand for heat supply is around 2.6%. About 85.8% of Japan's primary energy supply still comes from fossil fuels.

The Energy [R]evolution Scenario describes a development pathway which turns the present situation into a sustainable energy supply:

- Exploitation of the existing large energy efficiency potential will reduce the growth of primary energy demand from the current 22,235 PJ/a (2005) to 10,459 PJ/a in 2050. This compares with a demand of 23,918 PJ/a in the Reference Scenario. This significant reduction in energy demand is a crucial prerequisite for achieving a significant share of renewable energy sources, compensating for reducing the consumption of fossil fuels.
- The increased use of combined heat and power generation (CHP) in the industrial sector will improve the supply system's energy conversion efficiency. Fossil fuels – mainly gas - will be used increasingly in CHP and will be steadily supported by biomass and geothermal energy. In other sectors the limited possibilities for district heating/cooling systems restrict the further expansion of CHP.
- The electricity sector will have the strongest growth in renewable energy utilisation. By 2050, more than 60% of electricity will be produced from renewable energy sources. A capacity of 205 GW will produce 523 TWh/a of electricity.
- In the heat supply sector, the contribution of renewables will continue to grow, reaching more than 47% by 2050. In particular, biomass, solar collectors and geothermal energy will replace conventional systems for direct heating and cooling, with traditional biomass being replaced by more efficient modern technologies.
- In the transport sector biofuels are currently the only available technology which could provide a major share of renewable energy. However, the rapid development of the biofuels market over the last few years has raised questions about its sustainability. From the sustainability point of view - a major driving factor for the development of the whole Energy [R]evolution scenario - biomass use must not threaten food security or increase CO_2 emissions, for example by encouraging deforestation for bio fuel plantations. The Energy [R]evolution scenario for Japan involves an increase in bio fuel use and a higher use of electricity for vehicles from 2020 onwards when efficiency potentials are fully exploited.
- By 2050 over 40% of primary energy demand will be covered by renewable energy sources.

To achieve an economically attractive growth of renewable energy sources, a balanced and timely mobilisation of all renewable technologies is of great importance. Such a mobilisation depends on technical potentials, actual costs, cost reduction potentials and technological maturity.

development of energy related CO_2 emissions

While energy related CO_2 emissions in Japan will decrease under the Reference Scenario by 8% by 2050 - far removed from a sustainable development path - under the Energy [R]evolution Scenario they drop significantly, decreasing from 1,135 million tonnes in 2005 to 275 million tonnes in 2050. Annual per capita emissions will drop from 8.9 to 2.7 t. Whilst the power sector today is the largest source of energy related CO_2 emissions in Japan, it will contribute about 39% of the total in 2050.

image 1 and 2. ORIGINAL PHOTOGRAPH TAKEN IN 1928 OF THE UPSALA GLACIER, PATAGONIA, ARGENTINA COMPARED WITH THE RECEDING GLACIER TODAY.

costs

Under the Reference Scenario, Japan is facing a significant increase in society's expenditure on electricity supply. The continuing growth in demand, the increase in fossil fuel prices and the costs of CO_2 emissions will result in electricity supply costs nearly doubling from $92 billion per year today to $138 billion per year in 2050. The Energy [R]evolution scenario, on the other hand, not only complies with global CO_2 reduction targets but also helps to stabilise energy costs and thus relieve the economic pressure on society. Increasing energy efficiency and shifting energy supply to renewable energy resources in the long term even lead to decreasing costs for electricity supply. It becomes obvious that following stringent environmental targets in the energy sector also pays off in terms of economics.

to make the energy [r]evolution real and to avoid dangerous climate change, Greenpeace demands for Japan's energy sector:

- The phasing out of all subsidies for fossil fuels and nuclear energy and the internalisation of external costs.
- The setting out of legally binding targets for renewable energy and new laws to implement those targets.
- The provision of defined and stable returns for investors.
- Guaranteed priority access to the grid for renewables.

figure 1: japan: development of primary energy consumption under the energy [r]evolution scenario

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

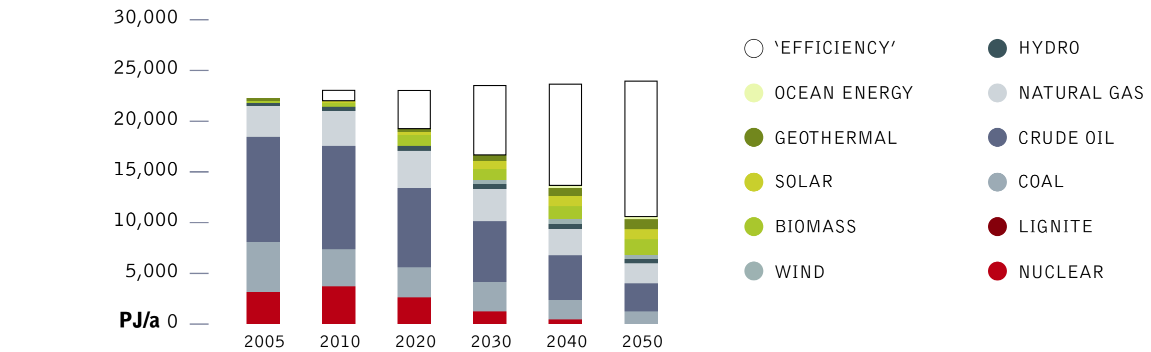
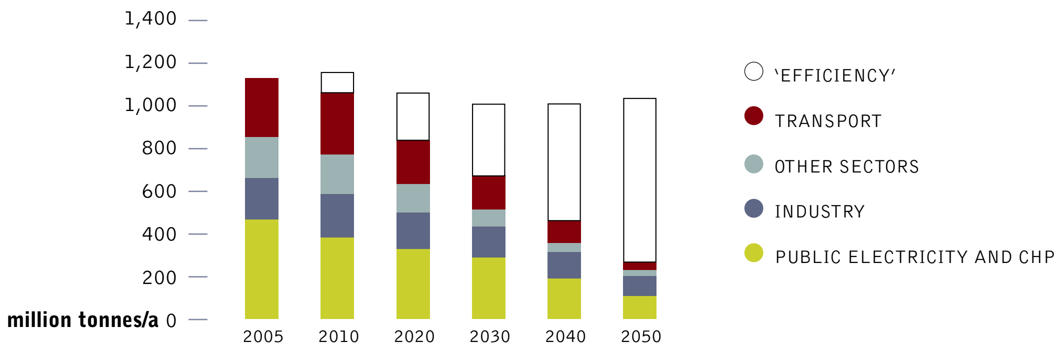


figure 2: japan: development of co_2 emissions by sector under the energy [r]evolution scenario

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



policy recommendation

table 1: japan: key parameters for policy makers

		TARGET FOR 2020	TARGET FOR 2030	TARGET FOR 2050
climate sector				
- CO_2 reduction (cf.1990)	Set legally binding targets	25%	40%	80%
power sector				
- Renewable energies	Set legally binding targets	20%	30%	65%
primary energy				
- Renewable energies	Set legally binding targets	10%	20%	40%

policy

"IF WE DO NOT TAKE URGENT AND IMMEDIATE ACTION TO STOP GLOBAL WARMING, THE DAMAGE COULD BECOME IRREVERSIBLE."

1

© GP/RAP RIOS

image MAJESTIC VIEW OF THE WIND FARM IN ILOCOS NORTE, AROUND 500 KILOMETERS NORTH OF MANILA.
THE 25 MEGAWATT WIND FARM, OWNED AND OPERATED BY DANISH FIRM NORTHWIND, IS THE FIRST OF ITS KIND IN SOUTHEAST ASIA.

climate policy

According to the Intergovernmental Panel on Climate Change, the United Nations forum for established scientific opinion, the world's temperature is expected to increase over the next hundred years by up to 5.8° Celsius. This is much faster than anything experienced so far in human history. The goal of climate policy should be to keep the global mean temperature rise to less than 2°C above pre-industrial levels. At 2°C and above, damage to ecosystems and disruption to the climate system increases dramatically. We have very little time within which we can change our energy system to meet these targets. This means that global emissions will have to peak and start to decline by the end of the next decade at the latest.

Climate change is already harming people and ecosystems. Its reality can be seen in disintegrating polar ice, thawing permafrost, dying coral reefs, rising sea levels and fatal heat waves. It is not only scientists that are witnessing these changes. From the Inuit in the far north to islanders near the Equator, people are already struggling with the impacts of climate change. An average global warming of 2°C threatens millions of people with an increased risk of hunger, malaria, flooding and water shortages. Never before has humanity been forced to grapple with such an immense environmental crisis. If we do not take urgent and immediate action to stop global warming, the damage could become irreversible. This can only happen through a rapid reduction in the emission of greenhouse gases into the atmosphere.

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

likely effects of small to moderate warming

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

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

longer term catastrophic effects

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

the kyoto protocol

Recognizing these threats the signatories to the 1992 United Nations Framework Convention on Climate Change (UNFCCC) - agreed the Kyoto Protocol in 1997. The Kyoto Protocol finally entered into force in early 2005 and its 180 member countries met regularly each year to negotiate further refinement and development of the agreement. The United States of America is the only industrialized nation not to have ratified the Protocol. The Kyoto Protocol commits thirty-seven developed countries and the European Community to reduce their overall greenhouse gas emissions by 5.2% from 1990 levels within the target period of 2008-2012.

This aggregate target in turn resulted in the adoption of a series of legally binding regional and national reduction targets. In the European Union, for instance, the commitment is to an overall reduction of 8%. In order to achieve this the EU has also agreed a target to increase its proportion of renewable energy from 6% to 12% by 2010 and 20% by 2020.

The 'Kyoto' countries are currently negotiating the second phase of the agreement, due to begin in 2013. Greenpeace is calling on industrialized countries to raise their level of ambition in this 'second commitment period'. They must agree to reduce greenhouse gas emissions by at least 30% on 1990 levels by 2020 and must virtually decarbonise (more than 80% reductions on 1990 levels) by 2050. Only with these cuts do we stand a reasonable chance of staying below a global mean temperature increase of 2°C.

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

However, because it took so long for Kyoto to enter into force after the U.S. pulled out in early 2001, negotiators are running out of time. Countries agreed a negotiating 'mandate' – known as the Bali Action Plan - in December 2007, but they must end these negotiations with a final agreement on the second commitment period of the Kyoto Protocol by the end of 2009 at the absolute latest.

This is necessary to give time for it to be ratified and for Governments to implement the policies and measures necessary for the next stage of deeper emissions reductions. There must be no gap between the first and second commitment periods in order to retain confidence in the carbon market and encourage investment in low carbon technologies.

international energy policy

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

At a time when Governments around the world are in the process of liberalising their electricity markets, the increasing competitiveness of renewable energy should lead to higher demand. Without political support, however, renewable energy remains at a disadvantage, marginalised by distortions in the world's electricity markets created by decades of massive financial, political and structural support to conventional technologies. Developing renewables will therefore require strong political and economic efforts, especially through laws which guarantee stable tariffs over a period of up to 20 years.

The following is an overview of some current international political frameworks, which should help to overcome barriers in order to unlock renewable energy's great potential to become a major contributor to global energy supply. In the process, it would also contribute to sustainable economic growth, high quality jobs, technology development, global competitiveness and industrial and research leadership.

renewable energy targets

In recent years, as part of their greenhouse gas reduction policies, as well as for increasing security of energy supply, an increasing number of countries have established targets for renewable energy. These are either expressed in terms of installed capacity or as a percentage of energy consumption. Although these targets are not often legally binding, they have served as an important catalyst for increasing the share of renewable energy throughout the world. A time horizon of just a few years is not long enough in the electricity sector where the investment horizon can be up to 40 years. Renewable energy targets therefore need to have short, medium and long-term steps and must be legally binding in order to be effective. They should also be supported by mechanisms such as the 'feed-in tariff' In order for the proportion of renewable energy to increase significantly, targets must be set in accordance with the local

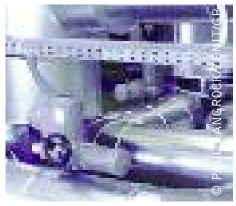


image GEOTHERMAL POWER STATION PRODUCING ELECTRICITY.

potential for each technology (wind, solar, biomass etc) and according to the local infrastructure, both existing and planned. In recent years the wind and solar power industries have shown that it is possible to maintain a growth rate of 30% to 35% in the renewables sector. In conjunction with the European Photovoltaic Industry Association[1], the European Solar Thermal Power Industry Association[2], the Global Wind Energy Council[3], European Renewable Energy Council and Greenpeace have documented the development of those industries from 1990 onwards and outlined a prognosis for growth up to 2020 and 2040.

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 as follows:

- Phase out all subsidies for fossil and nuclear energy and internalise external costs
- Establish legally binding targets for renewable energy
- Provide defined and stable returns for investors
- Guarantee priority access to the grid for renewable power generators
- Strict efficiency standards for all energy consuming appliances, buildings and vehicles

Conventional energy sources receive an estimated $250-300 billion[4] in subsidies per year worldwide, resulting in heavily distorted markets. The Worldwatch Institute estimates that total world coal subsidies are $63 billion, whilst in Germany alone the total is $21 billion, including direct support of more than $85,000 per miner. Subsidies artificially reduce the price of power, keep renewable energy out of the market place and prop up non-competitive technologies and fuels. Eliminating direct and indirect subsidies to fossil fuels and nuclear power would help move us towards a level playing field across the energy sector. Renewable energy would not need special provisions if markets were not distorted by the fact that it is still virtually free for electricity producers (as well as the energy sector as a whole) to pollute. Subsidies to fully mature and polluting technologies are highly unproductive. Removing subsidies from conventional electricity would not only save taxpayers' money, it would also dramatically reduce the need for renewable energy support.

international initiatives for renewable energy

At the G8 summit in July 2005 in Scotland, the Heads of State and Heads of Government set out the common purpose in tackling climate change, promoting clean energy and achieving sustainable development in a joint statement. In the statement, the areas of further action are defined, and a global dialogue on climate change, clean energy and sustainable development is announced, the results of which shall be reported to the G8 during the Japanese presidency in 2008. The IEA and the World Bank are given specific tasks, and the consistency with the UNFCCC is assured. Paragraph 16 of the Gleneagles Plan of Action highlights the initiative started in Bonn 2004:[5]

"We will promote the continued development and commercialisation of renewable energy by: (a) promoting the International Action Programme of the Renewables 2004 conference in Bonn, starting with a Conference at the end of 2005, hosted by the Chinese Government, and supporting the goals of the Renewable Energy Policy Network (REN 21)..."

In view of the indecisive outcomes of the World Summit on Sustainable Development (WSSD) in Johannesburg 2002 with respect to Renewable Energy, the German Government invited all the stakeholders to come to Bonn in 2004 for an International Renewable Energy Conference called "Renewables 2004". This conference was well prepared in a series of regional conferences and by an international steering committee and increased the global political momentum in favour of Renewable Energy. In order to keep the momentum and expand it to developing countries two further conferences have taken place. The Beijing International Renewable Energy Conference, 'BIREC', in November 2005 and the Washington International Renewable Energy Conference 'WIREC' in March 2008. The next conference in this series will be held in India in 2010.

reference
1 SOLARGENERATION, SEPTEMBER 2007
2 CONCENTRATED SOLAR POWER –NOW! NOVEMBER 2008
3 GLOBAL WIND ENERGY OUTLOOK, OCTOBER 2008
4 UNDP REPORT
5 HTTP://WWW.REN21.ORG/POLICYPROCESS/DEFAULT.ASP

the energy [r]evolution

"THE EXPERT CONSENSUS IS THAT THIS FUNDAMENTAL CHANGE MUST HAPPEN WITHIN THE NEXT TEN YEARS IN ORDER TO AVERT THE WORST IMPACTS."

2

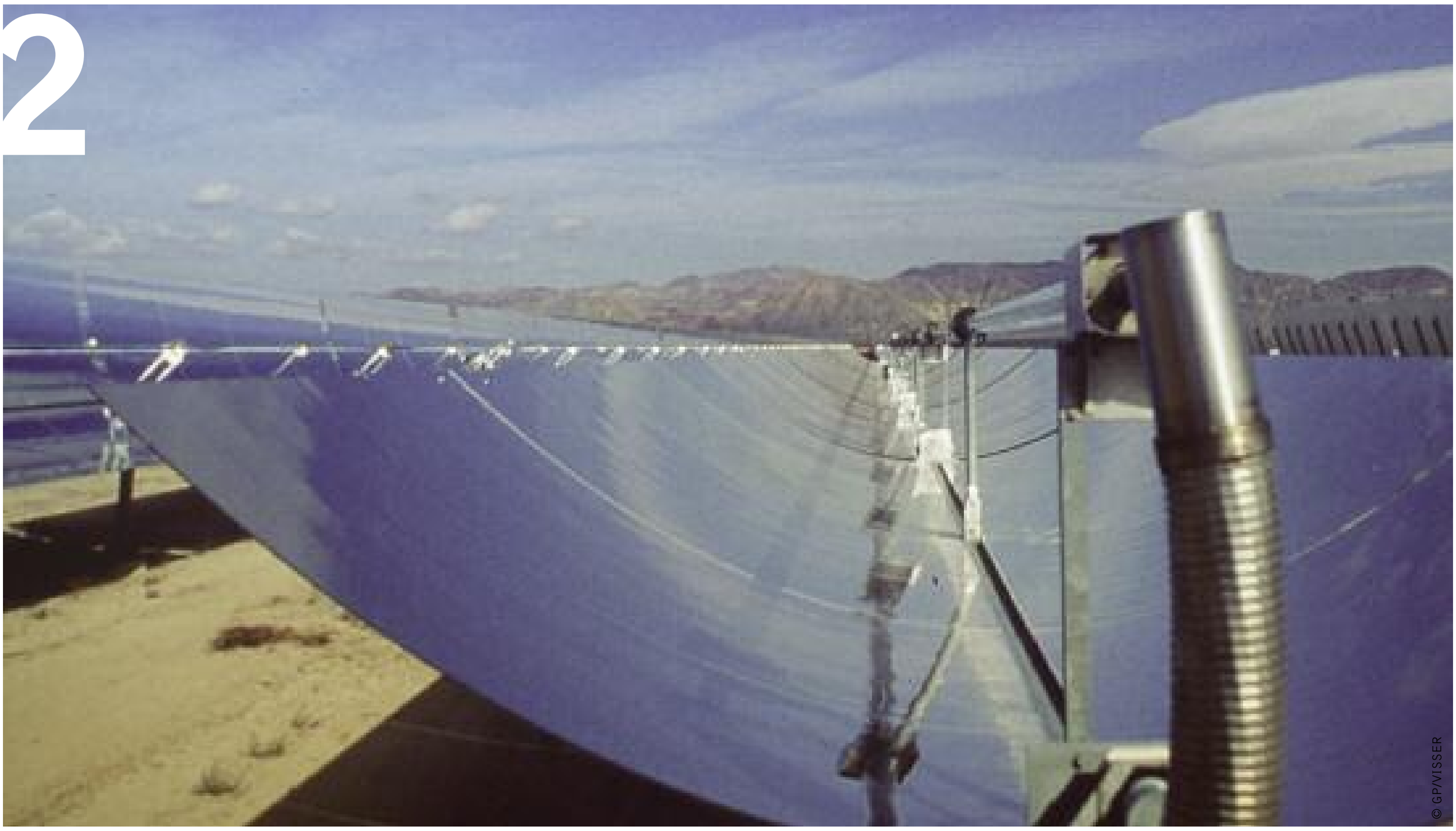


image CONCENTRATING SOLAR POWER (CSP) AT A SOLAR FARM IN DAGGETT, CALIFORNIA, USA.

The climate change imperative demands nothing short of an Energy Revolution. The expert consensus is that this fundamental change must begin very soon and well underway within the next ten years in order to avert the worst impacts. We do not need nuclear power. What we do need is a complete transformation in the way we produce, consume and distribute energy. Nothing short of such a revolution will enable us to limit global warming to less than 2°Celsius, above which the impacts become devastating. Current electricity generation relies mainly on burning fossil fuels, with their associated CO_2 emissions, in very large power stations which waste much of their primary input energy.

More energy is lost as the power is moved around the electricity grid network and converted from high transmission voltage down to a supply suitable for domestic or commercial consumers. The system is innately vulnerable to disruption: localised technical, weather-related or even deliberately caused faults can quickly cascade, resulting in widespread blackouts. Whichever technology is used to generate electricity within this old fashioned configuration, it will inevitably be subject to some, or all, of these problems. At the core of the Energy Revolution therefore needs to be a change in the way that energy is both produced and distributed.

five key principles

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

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

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

image PLATFORM/OIL RIG DUNLIN IN THE NORTH SEA SHOWING OIL POLLUTION.


© GP/LANGER

2 respect natural limits We must learn to respect natural limits. There is only so much carbon that the atmosphere can absorb. Each year we emit about 23 billion tonnes of CO_2; we are literally filling up the sky. Geological resources of coal could provide several 100 years of fuel, but we cannot burn them and keep within safe limits. Oil and coal development must be ended.

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

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

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

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

5 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.
- We need to make the transition to renewable energy – away from fossil fuels – quickly in order to enable clean and sustainable growth.

from principles to practice

Today, renewable energy sources account for 13% of the world's primary energy demand. Biomass, which is mainly used for heating, is the main renewable energy source. The share of renewable energy in electricity generation is 18%. The contribution of renewables to primary energy demand for heat supply is around 26%. About 80% of primary energy supply today still comes from fossil fuels, and the remaining 7% from nuclear power[6]. The time is right to make substantial structural changes in the energy and power sector within the next decade. Many power plants in industrialised countries, such as the USA, Japan and the European Union, are nearing retirement; more than half of all operating power plants are over 20 years old. At the same time developing countries, such as China, India and Brazil, are looking to satisfy the growing energy demand created by expanding economies. Within the next ten years, the power sector will decide how this new demand will be met, either by fossil and nuclear fuels or by the efficient use of renewable energy. The Energy [R]evolution Scenario is based on a new political framework in favour of renewable energy and cogeneration combined with energy efficiency.

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

As it is not possible to switch directly from the current large scale fossil and nuclear fuel based energy system to a full renewable energy supply, a transition phase is required to build up the necessary infrastructure. Whilst remaining firmly committed to the promotion of renewable sources of energy, we appreciates that gas, used in appropriately scaled cogeneration plant, is valuable as a transition fuel, able to drive cost-effective decentralisation of the energy infrastructure. With warmer summers, tri-generation, which incorporates heat-fired absorption chillers to deliver cooling capacity in addition to heat and power, will become a particularly valuable means to achieve emission 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 is aimed at the ambitious exploitation of the potential for energy efficiency. It focuses on current best practice and available technologies for the future, assuming continuous innovation. The energy savings are fairly equally distributed over the three sectors – industry, transport and domestic/business. Intelligent use, not abstinence, is the basic philosophy for future energy conservation.

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

A dramatic reduction in primary energy demand compared to the International Energy Agency's "reference scenario" (see Chapter 4) – but with the same GDP and population development - is a crucial prerequisite for achieving a significant share of renewable energy sources in the overall energy supply system, compensating for the phasing out of nuclear energy and reducing the consumption of fossil fuels.

reference
6 IEA; WORLD ENERGY OUTLOOK 2004

step 2: structural changes

decentralised energy and large scale renewables

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

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

DE technologies also include dedicated systems such as ground source and air source heat pumps, solar thermal and biomass heating. These can all be commercialised at a domestic level to provide sustainable low emission heating. Although DE technologies can be considered 'disruptive' because they do not fit the existing electricity market and system, with appropriate changes they have the potential for exponential growth, promising 'creative destruction' of the existing energy sector.

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

cogeneration

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

renewable electricity

The electricity sector will be the pioneer of renewable energy utilisation. All renewable electricity technologies have been experiencing steady growth over the past 20 to 30 years of up to 35% per year and are expected to consolidate at a high level between 2030 and 2050. By 2050, the majority of electricity will be produced from renewable energy sources.

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 thermal collectors and geothermal. By 2050, renewable energy technologies will satisfy the major part of heating and cooling demand.

transport

Before biofuels can play a substantial role in the transport sector, the existing large efficiency potentials should be exploited. In this study, biomass is primarily committed to stationary applications and the use of biofuels for transport is limited by the availability of sustainably grown biomass.

Overall, to achieve an economically attractive growth in renewable energy sources, a balanced and timely mobilisation of all technologies is of great importance. Such a mobilisation depends on the resource availability, cost reduction potential and technological maturity.

scenario principles in a nutshell

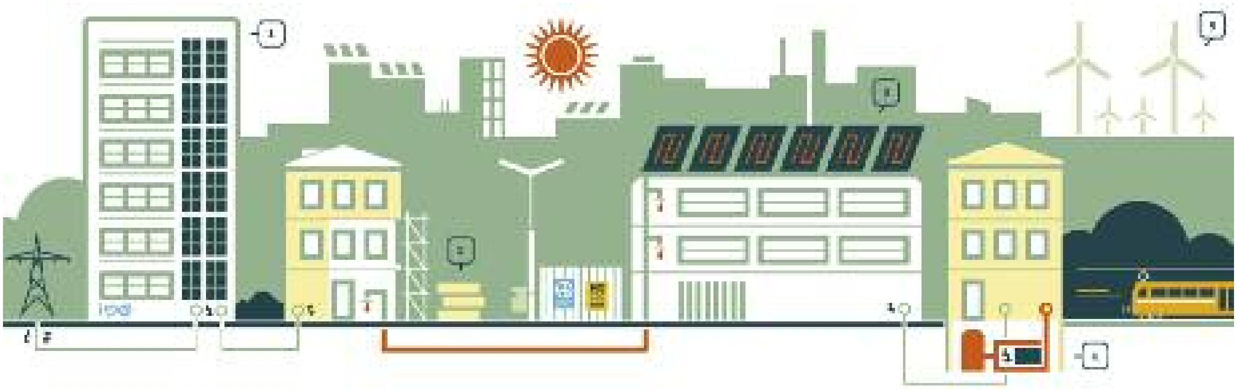
- Smart consumption, generation and distribution
- Energy production moves closer to the consumer
- Maximum use of locally available, environmentally friendly fuels

image SOLON AG PHOTOVOLTAICS FACILITY IN ARNSTEIN, GERMANY OPERATING 1500 HORIZONTAL AND VERTICAL SOLAR 'MOVERS'.

figure 3: a decentralised energy future

THE CITY CENTRES OF TOMORROW'S NETWORKED WORLD WILL PRODUCE POWER AND HEAT AS WELL AS CONSUME IT. THE ROOFS AND FACADES OF PUBLIC BUILDINGS ARE IDEAL FOR HARVESTING SOLAR ENERGY. 'LOW ENERGY' WILL BECOME THE STANDARD FOR ALL BUILDINGS. GOVERNMENTS COMMITTED TO TIGHT CLIMATE-PROTECTION TARGETS WILL HAVE TO IMPOSE STRICT CONDITIONS AND OFFER INCENTIVES FOR RENOVATING THESE BUILDINGS. THIS WILL HELP TO CREATE JOBS.

city



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

villages & island

1. BIOMASS PLANT
2. BIOMASS
3. SOLAR PHOTOVOLTAIC (ELECTRICITY)
4. WIND ENERGY
5. HYDRO POWER

energy resources and security of supply

"AT PRESENT AROUND 80% OF GLOBAL ENERGY DEMAND IS MET BY FOSSIL FUELS. THE UNRELENTING INCREASE IN ENERGY DEMAND IS MATCHED BY THE FINITE NATURE OF THESE SOURCES."

image GEOTHERMAL ACTIVITY.

the reserves chaos

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

Historically, private oil companies consistently underestimated their reserves to comply with conservative stock exchange rules and through natural commercial caution. Whenever a discovery was made, only a portion of the geologist's estimate of recoverable resources was reported; subsequent revisions would then increase the reserves from that same oil field over time. National oil companies, almost fully represented by OPEC (Organisation of Petroleum Exporting Countries), are not subject to any sort of accountability so their reporting practices are even less clear.

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 nationalised, between 1985 and 1990, OPEC countries increased their joint reserves by 82%. Not only were these dubious revisions never corrected, but many of these countries have reported untouched reserves for years, even if no sizeable discoveries were made and production continued at the same pace. Additionally, the Former Soviet Union's oil and gas reserves have been overestimated by about 30% because the original assessments were later misinterpreted.

Whilst private companies are now becoming more realistic about the extent of their resources, the OPEC countries hold by far the majority of the reported reserves, and 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.

image OIL FIELDS NEAR BIBI-HEYDAT IN AZERBAIJAN. OIL-WELL DERRICKS.

gas

Natural gas has been the fastest growing fossil energy source in the last two decades, boosted by its increasing share in the electricity generation mix. Gas is generally regarded as a largely abundant resource and public concerns about depletion are limited to oil, even though few in-depth studies address the subject. Gas resources are more concentrated than oil so they were discovered faster because a few massive fields make up for most of the reserves: the largest gas field in the world holds 15% of the "Ultimate Recoverable Resources" (URR), compared to 6% for oil. Unfortunately, information about gas resources suffers from the same bad practices as oil data because gas mostly comes from the same geological formations, and the same stakeholders are involved.

Most reserves are initially understated and then gradually revised upwards, giving an optimistic impression of growth. By contrast, Russia's reserves, the largest in the world, are considered to have been overestimated by about 30%. Owing to geological similarities, gas follows the same depletion dynamic as oil, and thus the same discovery and production cycles. In fact, existing data for gas is of worse quality than for oil and some ambiguities arise as to the amount of gas already produced 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 primary energy until it was overtaken by oil in the 1960s. Today, coal supplies almost one quarter of the world's energy. Despite being the most abundant of fossil fuels, coal's development is currently threatened by environmental concerns, hence its future will unfold in the context of both energy security and global warming.

Coal is abundant and more equally distributed throughout the world than oil and gas. Global recoverable reserves are the largest of all fossil fuels, and most countries have at least some. Moreover, existing and prospective big energy consumers like the US, China and India are self-sufficient in coal and will be for the foreseeable future. Coal has been exploited on a large scale for two centuries so both the product and the available resources are well known; no substantial new deposits are expected to be discovered. Extrapolating the demand forecast, the world will consume 20% of its current reserves by 2030 and 40% by 2050[7]. Hence, if current trends are maintained, coal would still last several 100 years.

reference

7 "PLUGGING THE GAP -A SURVEY OF WORLD FUEL RESOURCES AND THEIR IMPACT ON THE DEVELOPMENT OF WIND ENERGY"; GWEC, RES SEPTEMBER 2006

table 2: overview of fossil fuel reserves and resources

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

ENERGY CARRIER		BROWN, 2002 EJ	IEA, 2002c EJ		IPCC, 2001a EJ		NAKICENOVIC ET AL., 2000 EJ		UNDP ET AL., 2000 EJ		BGR, 1998 EJ
Gas	reserves	6,600	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

nuclear

Uranium, the fuel used in nuclear power plants, is a finite resource whose economically available resource is 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 sources will soon be used up. Mining capacities will have to be nearly doubled in the next few years to meet current needs.

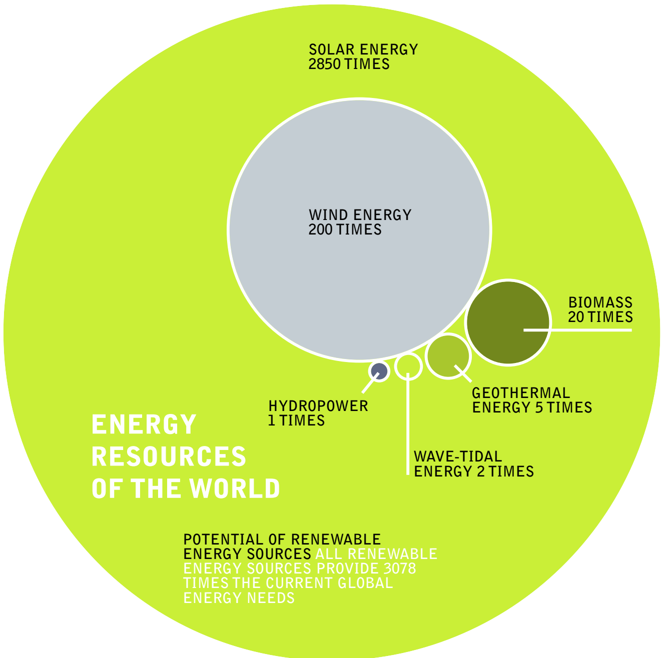
A joint report by the OECD Nuclear Energy Agency and the International Atomic Energy Agency, (Uranium 2003: Resources, Production and Demand) estimates that all existing nuclear power plants will have used up their nuclear fuel, employing current technology in less than 70 years. In the light of various scenarios for the worldwide development of nuclear power, it is likely that uranium supplies will be exhausted sometime between 2026 and 2070. Assuming a downward trend in the use of nuclear power, realistic estimates indicate that supplies will be enough for only a few countries by 2050. This forecast includes uranium deposits as well as the use of mixed oxide fuel (MOX), a mixture of uranium and plutonium.

renewable energy potential

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

On average, the energy in the sunshine that reaches the earth is about one kilowatt per square metre worldwide. According to the Research Association for Solar Power, power is gushing from renewable energy sources at a rate of 3,078 times more energy than is needed in the world today. 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 energy than the world currently requires.

figure 4: energy resources of the world



source WBGU

table 3: technically accessible today

THE AMOUNT OF ENERGY THAT CAN BE ACCESSED WITH CURRENT TECHNOLOGIES SUPPLIES A TOTAL OF 5.9 TIMES THE GLOBAL DEMAND FOR ENERGY.

Sun	3.8 times
Geothermal heat	1 time
Wind	0.5 times
Biomass	0.4 times
Hydrodynamic power	0.15 times
Ocean power	0.05 times

source DR. JOACHIM NITSCH


© GP/MIZUKOSHI

definition of types of energy resource potential[8]

theoretical potentials

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

conversion potential

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

technical potential

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

economic potential

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

sustainable potential

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

renewable energy potential by region and technology

Based on a recently published report "Renewable Energies Potentials" from REN 21, a global policy network, we can provide a more detailed overview of renewable energy potentials by regions and technology. The below shown estimates focus on large economies, which consume 80 percent of the world's primary energy and produce a similar share of the world's greenhouse gas emissions. Most of these economies are represented in the Gleneagles Dialogue.

Solar photovoltaic (PV) technology can be harnessed almost everywhere, and its potential is estimated at over 1500 EJ/year, closely followed by concentrating solar thermal power (CSP). These two potentials cannot simply be added up, because they would require much of the same land resources.

The onshore wind potentials are vast, with almost 400 EJ/year beyond the order of magnitude of future electricity consumption. The estimate for offshore wind potentials (22 EJ/year) is cautious as only wind intensive areas on ocean shelf areas and outside shipping lines and protected areas are included.

The various ocean or marine energy potentials also add up to a similar magnitude, most of it from ocean waves. More cautious estimates arrive at around 50 EJ/year. The estimates of hydro and geothermal power resources are rather well established and identify the technical potentials at around 50 EJ/year for each.

With respect to heating and cooling (apart from biomass), there is the option of using direct geothermal energy. The potential is extremely large and could cover 20 times the current world energy demand for heat. The potential for solar heating, including passive solar building design, is virtually endless. However, heat is costly to transport and therefore one should only consider geothermal heat and solar water heating potentials which are sufficiently close to consumption areas. (see also below: The challenge of matching supply and demand). Passive solar technology which in fact contributes very massively to provide heating services, is not considered as a (renewable energy) supply source in this analysis but as an efficiency factor that is implicitly accounted for in the demand.

reference
8 WBGU

table 4: technical renewable energy by region
EXCLUDING BIO ENERGY

sector	SOLAR CSP	SOLAR PV	HYDRO POWER	WIND ONSHORE	WIND OFFSHORE	OCEAN POWER	GEO THERMAL ELECTRIC	GEO THERMAL DIRECT USES	SOLAR WATER HEATING	TOTAL
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-OECD Europe + Transition Economies	58	120	5	67	4	27	6	667	6	926
Africa and Middle East	679	863	9	33	1	19	5	1,217	12	2,838
East and 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

cost projections

"THE MAIN DRIVERS ARE THE PRICES OF FUELS, THE INVESTMENT COSTS OF FUTURE POWER PLANT TECHNOLOGIES AND THE POTENTIAL COSTS OF CO_2 EMISSIONS."

4

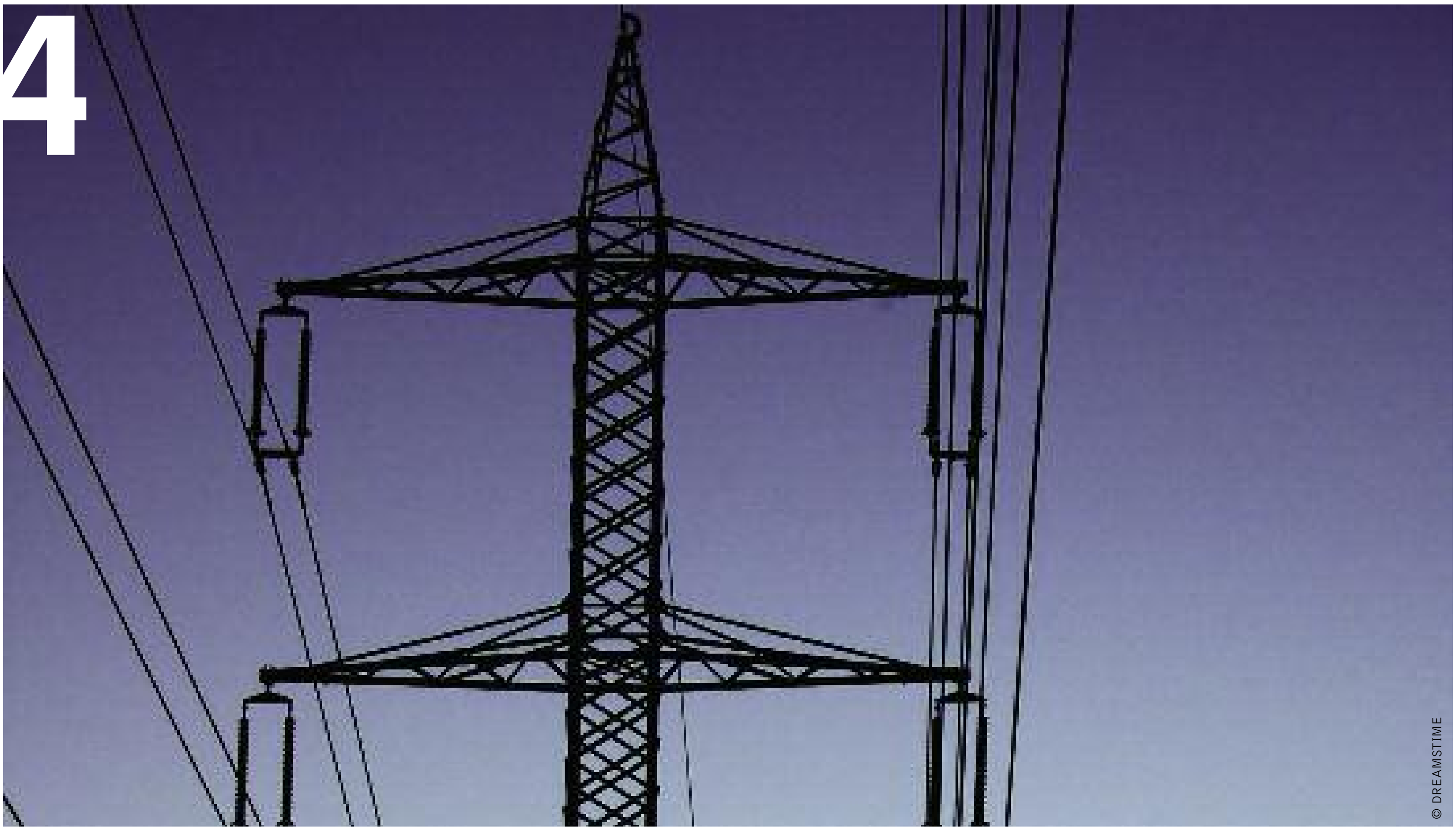


image ELECTRICITY LINES.

future development of costs

The cost of electricity supply is a key parameter for the evaluation of future energy scenarios. The main drivers are the prices of fuels, the investment costs of future power plant technologies and the potential costs of CO_2 emissions.

Future energy prices have been based on projections by the IEA, the US Department of Energy and the European Commission. Future investment costs for power plants have been estimated using a learning curve approach. Technology specific learning factors (progress ratios) have been derived from a literature review. The development of cumulative capacity for each technology is taken from the results of the Energy [R]evolution Scenario. All prices are given in $2000.

The oil price in May 2008 was already higher than the quoted oil price projections for 2050. Cost benefits for the energy [r]evolution scenario will therefore be even higher.

fossil fuel price projections

The recent dramatic increase in global oil prices has resulted in much higher forward price projections. Under the 2004 'high oil and gas price' scenario by the European Commission, for example, an oil price of just $34/bbl was assumed in 2030. Ongoing modelling funded by the Commission (CASCADE-MINTS 2006), on the other hand, assumes an oil price of $94/bbl in 2050, a gas price of $15/GJ and an international coal price of $95/t. Current projections of oil prices in 2030 range from the IEA's $52/bbl (55 $2005/bbl) up to over $100.

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. Current projections of gas prices in 2030 range from the US Department of Energy's $4.5/GJ up to its highest figure of $6.9/GJ.

Taking into account the recent development of energy prices, these projections might be considered too conservative. Considering the growing global demand for oil and gas we have assumed a price development path for fossil fuels in which the price of oil reaches $85/bbl by 2030 and $100/bbl in 2050. Gas prices are assumed to increase to $9-$10/GJ by 2050.

biomass price projections

Compared to fossil fuels, biomass prices are highly variable, ranging from no or low costs for residues or traditional biomass in Africa or Asia to comparatively high costs for biofuels from cultivated energy crops. Despite this variability a biomass price was aggregated for Europe[9] up to 2030 and supplemented with our own assumptions up to 2050. The increasing biomass prices reflect the continuing link between biofuel and fossil fuel prices and a rising share of energy crops. For other regions prices were assumed to be lower, considering the large amount of traditional biomass use in developing countries and the high potential of yet unused residues in North America and the Transition Economies.

cost of CO_2 emissions

Assuming that a CO_2 emissions trading system will be established in all world regions in the long term, the cost of CO_2 allowances needs to be included in the calculation of electricity generation costs. Projections of emission costs are even more uncertain than energy prices.

table 5: assumptions on fossil fuel, biomass and CO_2 price development

	2003	2010	2020	2030	2040	**2050**
FOSSIL FUELS						
Crude oil in $2000/bbl	28.0	62.0	75.0	85.0	93.0	**100.0**
Natural gas in $2000/GJ						
- America	3.1	4.4	5.6	6.7	8.0	**9.2**
- Europe	3.5	4.9	6.2	7.5	8.8	**10.1**
- Asia	5.3	7.4	7.8	8.0	9.2	**10.5**
Hard coal $2000/t	42.3	59.4	66.2	72.9	79.7	**86.4**
BIOMASS $2000/GJ						
- Europe	4.8	5.8	6.4	7.0	7.3	**7.6**
- other Regions	1.4	1.8	2.3	2.7	3.0	**3.2**
COUNTRIES($/T$CO_2$)						
Kyoto Annex B countries		10	20	30	40	**50**
Non-Annex B countries			20	30	40	**50**

reference
9 NITSCH ET AL. (2004) AND THE GEMIS-DATABASE (ÖKO-INSTITUT, 2005)

summary of conventional energy cost development

Table 6 gives a summary of expected investment costs for different fossil fuel technologies with varying levels of efficiency.

table 6: development of efficiency and investment costs for selected power plant technologies

		2010	2030	2050
Coal-fired condensing power plant	Efficiency (%)	41	45	**48**
	Investment costs ($/kW)	980	930	**880**
	Electricity generation costs including CO_2 emission costs ($ cents/kWh)	6.0	7.5	**8.7**
	CO_2 emissions [a)] (g/kWh)	837	728	**697**
Oil fired condensing power plant	Efficiency (%)	39	41	**41**
	Investment costs ($/kW)	670	620	**570**
	Electricity generation costs including CO_2 emission costs ($ cents/kWh)	22.5	31.0	**46.1**
	CO_2 emissions [a)] (g/kWh)	1,024	929	**888**
Natural gas combined cycle	Efficiency (%)	55	60	**62**
	Investment costs ($/kW)	530	490	**440**
	Electricity generation costs including CO_2 emission costs ($ cents/kWh)	6.7	8.6	**10.6**
	CO_2 emissions [a)] (g/kWh)	348	336	**325**

reference
8 (EUROPE ONLY) NITSCH ET AL. (2004) AND THE GEMIS-DATABASE (ÖKO-INSTITUT, 2005)

source DLR, 2006 **a)** REFERS TO DIRECT EMISSIONS ONLY, LIFE-CYCLE EMISSIONS ARE NOT CONSIDERED HERE.

renewable energy price projections

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

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

Most of the renewable technologies employed today are at an early stage of market development. Accordingly, their costs are generally higher than for competing conventional systems. Costs can also depend on local conditions such as the wind regime, the availability of cheap biomass supplies or the need for nature conservation requirements when building a new hydro power plant. There is a large potential for cost reduction, however, through technical and manufacturing improvements and large-scale production, especially over the long timescale of this study.

To identify long-term cost developments, learning curves have been applied which reflect the correlation between cumulative capacity and the development of 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. Technology specific progress ratios are derived from a literature review[10]. This shows, for example, that the learning factor for PV solar modules has been fairly constant at 0.8 over 30 years whilst that for wind energy varies from 0.75 in the UK to 0.94 in the more advanced German market.

reference
10 DLR 2006, DR. WOLFRAM KREWITT ET. AL.

image CLOSE-UP OF A SOLAR PANEL.

summary of renewable energy cost development

Reduced investment costs for renewable energy technologies lead directly to reduced heat and electricity generation costs, as shown in Table 7. Generation costs today are around 8 to 20 cents/kWh for the most important technologies, with the exception of PV. In the long term, costs are expected to converge at around 4 to 10 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.

table 7: investment cost projections for renewable energy technologies

			2010	2010	2010
Photovoltaic	investment costs	€/kWp	2,853	1,126	994
	generation costs (min/max)	ct/kWh	0.21-0.45	0.07-0.14	0.05-0.01
Concentrating solar thermal	investment costs	€/kWp	1,426	738	676
	generation costs (min/max)	ct/kWh	0.08-0.12	0.06-0.09	0.05-0.09
Wind	investment costs	€/kWp	1,141	948	886
	generation costs (min/max)	ct/kWh	0.07-0.08	0.05-0.06	0.05-0.06
Biomass (no CHP applications)	investment costs	€/kWp	2,893	2,132	1,914
	generation costs (min/max)	ct/kWh	0.06-0.11	0.06-0.12	0.07-0.12
Geothermal	investment costs	€/kWp	6,349	4,606	4,087
	generation costs (min/max)	ct/kWh	0.11-0.19	0.08-0.12	0.07-0.10
Hydro	investment costs	€/kWp	2,331	2,571	2,734
	generation costs (min/max)	ct/kWh	0.04-0.09	0.05-0.10	0.06-0.11
Ocean energy	investment costs	€/kWp	3,204	1,830	1,524
	generation costs (min/max)	ct/kWh	0.11-0.36	0.06-0.17	0.04-0.10

references for the cost assumptions section INTERNATIONAL ENERGY AGENCY: "ENERGY TECHNOLOGY PERSPECTIVES – SCENARIOS AND STRATEGIES TO 2050" (IEA 2006); "WORLD ENERGY OUTLOOK 2005" (IEA 2005); "WORLD ENERGY OUTLOOK 2004" (IEA 2004). ENERGY INFORMATION ADMINISTRATION, US DEPARTMENT OF ENERGY: "ANNUAL ENERGY OUTLOOK 2006 WITH PROJECTIONS TO 2030" (EIA 2006). EUROPEAN COMMISSION: "EUROPEAN ENERGY AND TRANSPORT – SCENARIOS ON KEY DRIVERS" (EUROPEAN COMMISSION, 2004). CASCADE (2006): HTTP://WWW.E3MLAB.NTUA.GR/CASCADE.HTML. NITSCH, J.; KREWITT, W.; NAST, M.; VIEBAHN, P.; GÄRTNER, S.; PEHNT, M.; REINHARDT, G.; SCHMIDT, R.; UIHLEIN, A.; BARTHEL, C.; FISCHEDICK, M.; MERTEN, F.; SCHEURLEN, K. (2004): ÖKOLOGISCH OPTIMIERTER AUSBAU DER NUTZUNG ERNEUERBARER ENERGIEN IN DEUTSCHLAND. IN: BUNDESMINISTERIUM FÜR UMWELT, NATURSCHUTZ UND REAKTORSICHERHEIT [ED.]: UMWELTPOLITIK, KÖLLEN DRUCK. ÖKO-INSTITUT (2005): GLOBAL EMISSION MODEL FOR INTEGRATED SYSTEMS (GEMIS), VERSION 4.3; INSTITUTE FOR APPLIED ECOLOGY E.V.; HTTP://WWW.GEMIS.DE. WBGU (2003): ÜBER KIOTO HINAUS DENKEN – KLIMASCHUTZSTRATEGIEN FÜR DAS 21. JAHRHUNDERT. SONDERGUTACHTEN DES WISSENSCHAFTLICHEN BEIRATS DER BUNDESREGIERUNG FÜR GLOBALE UMWELTVERÄNDERUNG, BERLIN, 2003. HTTP://WWW.WBGU.DE/WBGU_SN2003.HTML

global scenario for a future energy supply

"ANY ANALYSIS THAT SEEKS TO TACKLE ENERGY AND ENVIRONMENTAL ISSUES NEEDS TO LOOK AHEAD AT LEAST HALF A CENTURY."

5

© GP/NIMTSCH

image SOLAR AND WIND-FACILITY NEAR ROSTOCK, GERMANY.

the global energy [r]evolution scenario

Moving from principles to action on energy supply and climate change mitigation requires a long-term perspective. Energy infrastructure takes time to build up; new energy technologies take time to develop. Policy shifts often also need many years to have an effect. Any analysis that seeks to tackle energy and environmental issues therefore needs to look ahead at least half a century. Scenarios are important in describing possible development paths, to give decision-makers an overview of future perspectives and to indicate how far they can shape the future energy system. Two different scenarios are used here to characterise 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, which is 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 2004 (WEO 2004). This only takes existing policies into account. The assumptions include, for example, continuing progress in electricity and gas market reforms, the liberalisation of cross border energy trade and recent policies designed to combat environmental pollution. The Reference Scenario does not include additional policies to reduce greenhouse gas emissions.

As the IEA's scenario only covers a time horizon up to 2030, it has been extended 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 to 12 Gigatonnes per year by 2050 in order for the increase in global temperature to remain under +2°C. A second objective is the global phasing out of nuclear energy. To achieve these targets, the scenario is characterised by significant efforts to fully exploit the large potential for energy efficiency. At the same time, all cost-effective renewable energy sources are accessed for both heat and electricity generation as well as the production of bio fuels. The general framework parameters for population and GDP growth remain unchanged from the Reference Scenario.

These scenarios by no means 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 to indicate the efforts and actions required to achieve its ambitious objectives and to illustrate the options we have at hand to change our energy supply system into one that is sustainable.

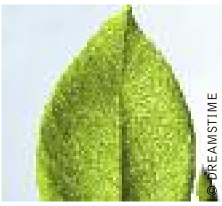


image THE TECHNOLOGY FOR SOLAR PANELS WAS ORIGINAL INSPIRED BY NATURE.

scenario background

The scenarios in this report were jointly commissioned by Greenpeace and the European Renewable Energy Council from DLR, the German Aerospace Centre. The supply scenarios were calculated using the MESAP/PlaNet simulation model used for the previous version of Energy [R]evolution scenarios published in January 2007. Energy demand projections were developed by Ecofys based on the analysis of future potential for energy efficiency measures.

energy efficiency study

The aim of the Ecofys study was to develop low energy demand scenarios for the period 2003 to 2050 on a sector level 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 sectors which were taken into account were industry, transport and other consumers, including households and services. Two low energy demand scenarios were developed, a reference version and a more ambitious energy efficiency version. This more advanced scenario focuses on current best practice and available technologies in the future, assuming continuous innovation in the field of energy efficiency. Worldwide final energy demand is reduced by 47% in 2050 in comparison to the Reference Scenario, resulting in a final energy demand of 350 EJ in 2050. The energy savings are fairly equally distributed over the three sectors of industry, transport and other uses. The most important energy saving options are efficient passenger and freight transport and improved heat insulation and building design, together accounting for 46 % of the worldwide energy savings.

global population growth

One driving factor of energy scenario building is future population development. Population growth affects the size and composition of energy demand, directly and through its impact on economic growth and development. The IEA World Energy Outlook 2007 refers to the most recent United Nation projections for population development (UNPD 2007) up to 2030. For the Energy [R]evolution study 2008 the same population projections are applied, also for the expanded time frame until 2050.

The world's population is expected to grow by 0.77 % on average over the period 2005 to 2050, from 6.5 billion in 2005 to more than 9.1 billion in 2050. Population growth will slow over the projection period, from 1.2% in 2005-2010 to 0.41% in 2040-2050. However the updated projections show an increase in population of almost 300 million compared to the previous version. This will further incite 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 by the OECD Pacific countries with a short time lag. OECD Europe and OECD North America are expected to maintain their population, with a peak around 2020/2030 and a slight decline in population afterwards. The share of the population living in the today's Non-OECD countries will increase from 82% today 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 population growth, leading to a share of 21% of the world's 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

Economic growth is a key driver for energy demand. Since 1971, each 1% increase in global Gross Domestic Product (GDP) has been accompanied by a 0.6% increase in primary energy consumption. The decoupling of energy demand and GDP growth is therefore a prerequisite for reducing demand in the future. Most global energy-economic-environment models constructed in the past have relied on market exchange rates to put 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 costs in different currencies of a fixed basket of traded and non-traded goods and services and yield a widely-based measure of standard living. This is important in analysing the main drivers of energy demand or comparing energy intensities among countries.

Although PPP accounts today are still conceptually unsettled and empirically imprecise relative to the construction of national income and product accounts and national price indexes, they are considered to provide a better basis for global scenario development (Nordhaus, 2005). Thus all data on economic development in the IEA-WEO 2007 refer to purchasing power adjusted GDP. We follow this approach, and all GDP data in this report are expressed in year-2006 US dollars using purchasing power parities (PPP) rather than market exchange rates. Following the IEA-WEO 2007, we use PPPs constant over time. As the IEA-WEO 2007 only covers the time period until 2030, the projections for the period 2030-2050 are based on own estimates.

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

the global energy [r]evolution scenario

Today, renewable energy sources account for 13% of the world's primary energy demand. Biomass, which is mainly used for heating, is the largest renewable source. The share of renewable energy in electricity generation is 18%, whilst the contribution of renewables to heat supply is around 26%. About 80% of primary energy supply still comes from fossil fuels, and the remaining 7% from nuclear power.

The Energy [R]evolution Scenario describes a development pathway, which transforms the present situation into a sustainable energy supply.

- Exploitation of the large energy efficiency potential will reduce primary energy demand from the current 435,000PJ/a (Peta Joules per year) to 422,000PJ/a by 2050. Under the reference scenario there would be an increase to 810,000PJ/a. This dramatic reduction is a crucial prerequisite for achieving a significant share of renewable energy sources, compensating for the phasing out of nuclear energy and reducing the consumption of fossil fuels.
- The increased use of combined heat and power generation (CHP) also improves the supply system's energy conversion efficiency, increasingly using natural gas and biomass. In the long term, decreasing demand for heat and the large potential for producing heat directly from renewable energy sources limits the further expansion of CHP.
- The electricity sector will be the pioneer of renewable energy utilisation. By 2050, around 70% of electricity will be produced from renewable energy sources, including large hydro. An installed capacity of 7,100GW will produce 21,400 Terawatt hours per year (TWh/a) of electricity in 2050.
- In the heat supply sector, the contribution of renewables will increase to 65% by 2050. Fossil fuels will be increasingly replaced by more efficient modern technologies, in particular biomass, solar collectors and geothermal.
- Before biofuels can play a substantial role in the transport sector, the existing large efficiency potentials have to be exploited. In this study, biomass is primarily committed to stationary applications; the use of biofuels for transport is limited by the availability of sustainably grown biomass.
- By 2050, half of primary energy demand will be covered by renewable energy sources.

To achieve an economically attractive growth of renewable energy sources, a balanced and timely mobilisation of all renewable technologies is of great importance. This depends on technical potentials, actual costs, cost reduction potentials and technological maturity.

development of CO_2 emissions

Whilst worldwide CO_2 emissions will almost double under the reference scenario by 2050 - far removed from a sustainable development path – under the Energy [R]evolution Scenario emissions will decrease from 23,000 million tonnes in 2003 to 11,500 million tonnes in 2050. Annual per capita emissions will drop from 4.0 t to 1.3 t. In the long run, efficiency gains and the increased use of biofuels will even reduce CO_2 emissions in the transport sector. With a share of 36% of total CO_2 emissions in 2050, the power sector will be overtaken by the transport sector as the largest source of emissions.

costs

Due to the growing demand for power, we are facing a significant increase in society's expenditure on electricity supply. Under the reference scenario, the undiminished growth in demand, the increase in fossil fuel prices and the costs of CO_2 emissions all result in electricity supply costs rising from today's $1,130 billion per year to more than $4,300 billion per year in 2050.

The Energy [R]evolution Scenario not only complies with global CO_2 reduction targets but also helps to stabilise energy costs and thus relieve the economic pressure on society. Increasing energy efficiency and shifting energy supply to renewable energy resources leads to long term costs for electricity supply that are one third lower than in the reference scenario. It becomes obvious that following stringent environmental targets in the energy sector also pays off in economic terms.

to make the energy [r]evolution real and to avoid dangerous climate change, the following assumptions need to be implemented:

- The phasing out of all subsidies for fossil fuels and nuclear energy and the internalisation of external costs
- The setting out of legally binding targets for renewable energy
- The provision of defined and stable returns for investors
- Guaranteed priority access to the grid for renewable generators
- Strict efficiency standards for all energy consuming appliances, buildings and vehicles

image SOLAR PANELS ON REFRIGERATION PLANT (FOR KEEPING FISH FRESH). LIKIEP ATOLL, MARSHALL ISLANDS.

figure 5: development of global primary energy consumption under the energy [r]evolution scenario

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

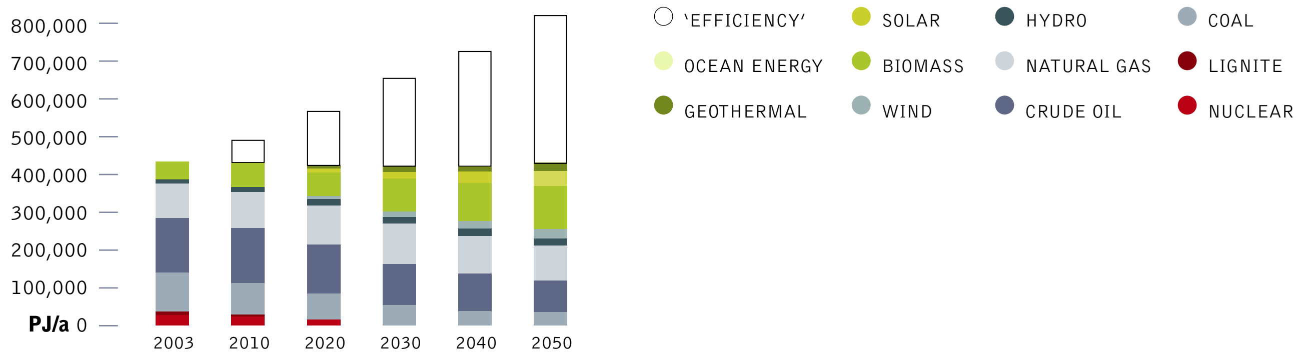
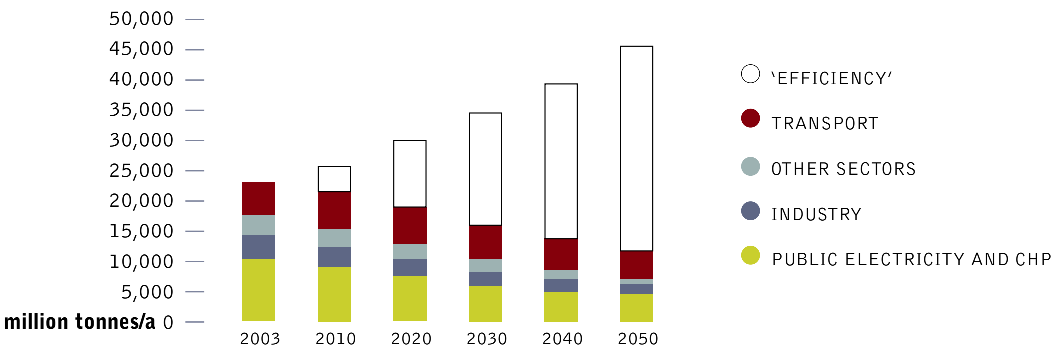


figure 6: development of global CO_2 emissions by sector under the energy [r]evolution scenario

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



the japan energy [r]evolution scenario

"UNDER THE ENERGY [R]EVOLUTION SCENARIO, IT IS ASSUMED THAT ACTIVE POLICY AND TECHNICAL SUPPORT FOR EFFICIENCY MEASURES WILL LEAD TO A FURTHER SIGNIFICANT REDUCTION IN ENERGY INTENSITY OF MORE THAN 75%."

6

image RICE PLANTING IN LATE SPRING, NORTHERN JAPAN. TWO WOMEN WORKING IN PADDY FIELD NEXT TO WIND TURBINES.

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

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

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, differs between the two, taking into account the measures to increase energy efficiency under the Energy [R]evolution Scenario.

projection of population development

According to projections by the Japanese Government, the population of Japan will decrease from its current level of 128 million people to a population of over 103 million in 2050. This continuing decline will ease pressure on energy resources and the environment a little bit.

projection of energy intensity

An increase in economic activity does not necessarily result in an equivalent increase in energy demand. There is still a large potential for exploiting energy efficiency measures. Even under the Reference Scenario, we assume that energy intensity will be reduced by about 1.0% per year, leading to a reduction in final energy demand per unit of GDP of about 40% between 2003 and 2050. Under the Energy [R]evolution Scenario, it is assumed that active policy and technical support for efficiency measures will lead to a further significant reduction in energy intensity of almost 75%.

image WIND TURBINE IN NORTHERN JAPAN.

figure 7: japan: population development projection

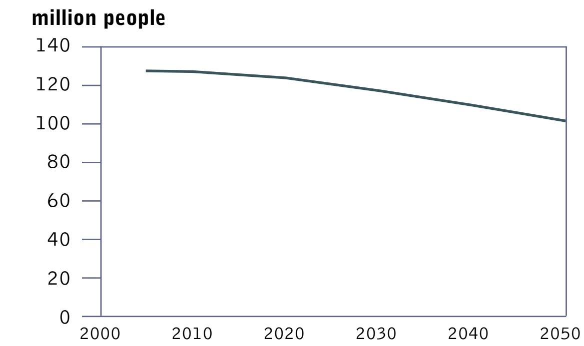


figure 8: japan: projection of energy intensity under the reference and energy [r]evolution scenarios

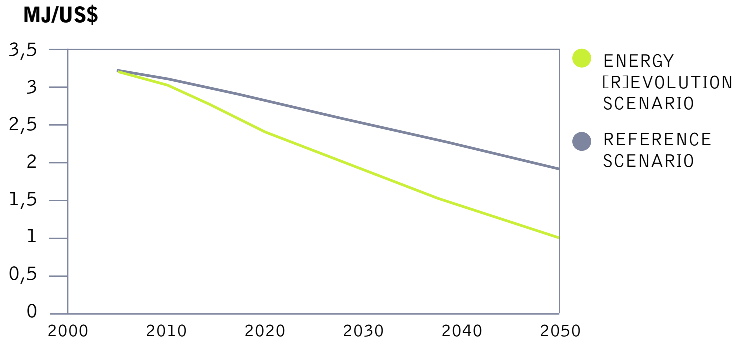
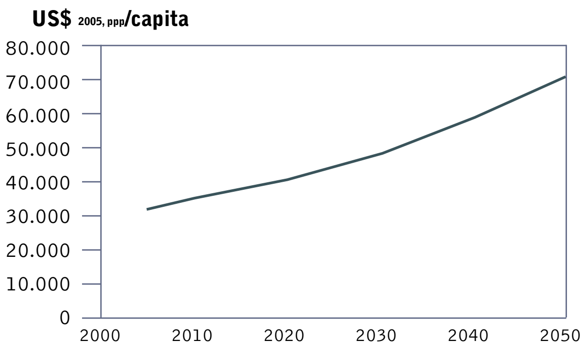


figure 9: japan: gdp per capita development



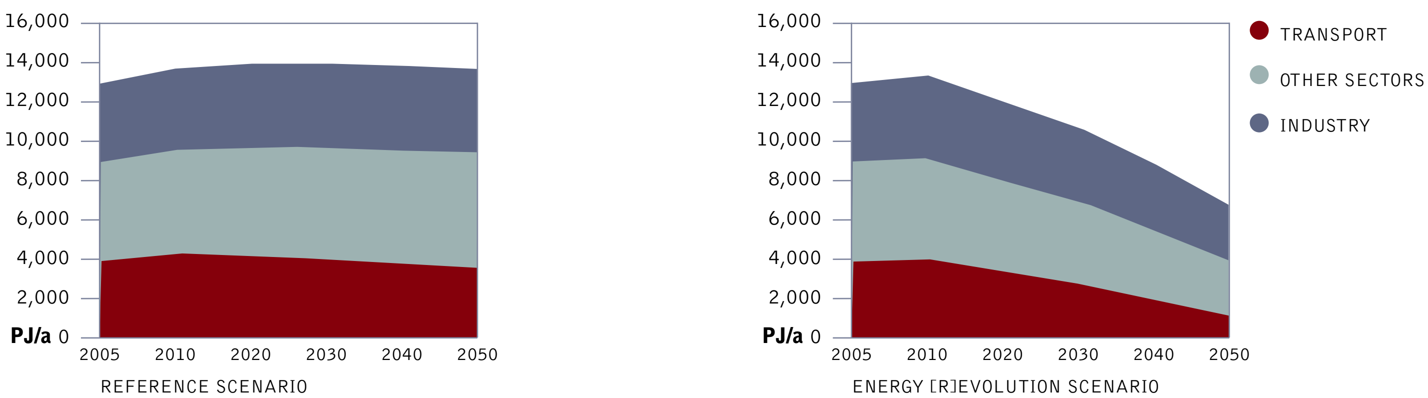
development of energy demand by sector

Combining the projections on population development, GDP growth and energy intensity results in future development pathways for the world's energy demand. These are shown in Figure 17 for both the Reference and the Energy [R]evolution Scenarios. Under the Reference Scenario, total energy demand increases from the current 22,235 PJ/a to 23,918 PJ/a in 2050. In the Energy [R]evolution Scenario, a 53% decrease on current consumption is expected by 2050, reaching 10,459 PJ/a.

An accelerated increase in energy efficiency, which is a crucial prerequisite for achieving a sufficiently large share of renewable sources in energy supply, will be beneficial not only for the environment but from an economic point of view. Taking into account the full life cycle, in most cases the implementation of energy efficiency measures saves money compared to increasing energy supply. A dedicated energy efficiency strategy therefore helps to compensate in part for the additional costs required during the market introduction phase of renewable energy sources.

figure 10: japan: projection of final energy demand by sector in the reference and energy [r]evolution scenarios

(EXCLUDING NON-ENERGY USE, OWN USE AND LOSSES)

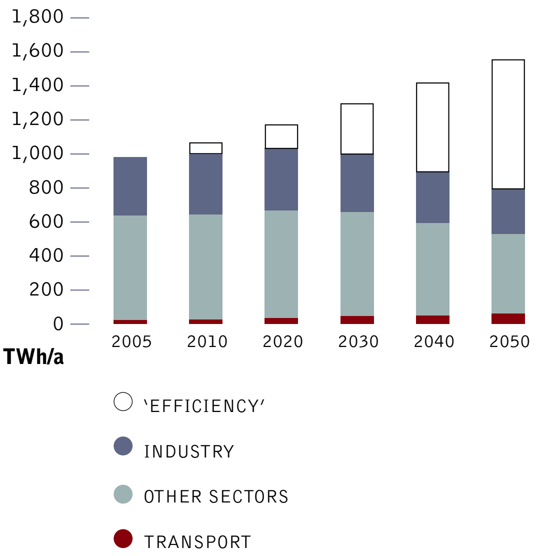


electricity demand by sector

Under the Energy [R]evolution Scenario, electricity demand is expected to increase disproportionately, with households and services the main source of growing consumption (see Figure 18). With the exploitation of efficiency measures, however, an even higher increase can be avoided, leading to electricity demand of around 782 TWh/a in the year 2050. Compared to the Reference Scenario, efficiency measures avoid the generation of about 779 TWh/a. This reduction in energy demand can be achieved in particular by introducing highly efficient electronic devices using the best available technology in all demand sectors. Employment of solar architecture in both residential and commercial buildings will help to curb the growing demand for active air-conditioning.

figure 11: japan: development of electricity demand by sectors in the energy [r]evolution scenario

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



electricity generation

The development of the electricity supply sector is characterised by a dynamically growing renewable energy market and an increasing share of renewable electricity. This will compensate for the significant reduction of coal and nuclear power plants. By 2050, 60% of the electricity produced in Japan will come from renewable energy sources. 'New' renewables – wind, biomass, geothermal and solar energy – will contribute 65% of this capacity. The following strategy paves the way for a future renewable energy supply:

- The reduction of coal and nuclear power plants and decreasing electricity demand will be compensated by bringing into operation new highly efficient gas-fired combined-cycle power plants, plus an increasing capacity of geothermal- and biomass power plants, as well as wind turbines. In the long term, geothermal, solar photovoltaic, biomass and wind will be the most important sources of electricity generation.
- PV, biomass and hydro energy will make substantial contributions to electricity production. In particular, as non-fluctuating renewable energy sources, geothermal and biomass will be important elements in the overall generation mix.
- Because of nature conservation concerns, the use of hydropower will only slightly increase from currently 30,000 MW to 44,000 MW – partly achieved by repowering and modernising existing hydropower stations.
- The installed capacity of renewable energy technologies will increase from the current 36 GW to 205 GW in 2050. Increasing renewable capacity by a factor of 5.7 within the next 42 years requires policy support and well-designed policy instruments. Because electricity demand will decrease relatively slowly, there will be a large demand for investment in new capacity over the next 20 years. As investment cycles in the power sector are long, decisions for restructuring the Japanese supply system need to be taken now.

To achieve an economically attractive growth in renewable energy sources, a balanced and timely mobilisation of all technologies is of great importance. This mobilisation depends on technical potentials, actual costs, cost reduction potentials and technological maturity. Figure 22 shows the complementary evolution of the different renewable technologies over time. Up to 2010, hydro-power and biomass will remain the main contributors. From 2020 onwards, the continually growing use of geothermal, solar photovoltaic and wind power will be complemented by electricity from ocean energy.

image WIND TURBINE IN AOMORI, NORTHERN JAPAN, WHERE 'FAVOURABLE' WIND IS CONSTANT. TREES BELOW ARE PROTECTING CROPS FROM 'UNFAVOURABLE' WIND.

figure 12: japan: development of electricity generation under the reference scenario

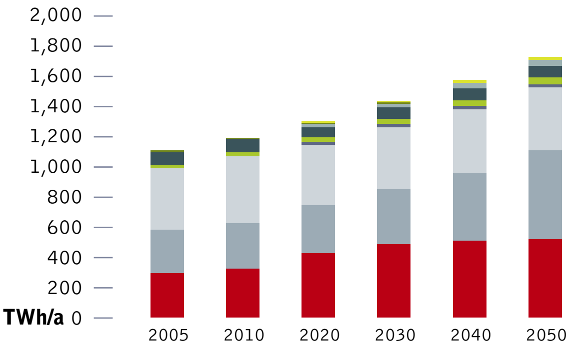


figure 13: japan: development of electricity generation under the energy [r]evolution scenario

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

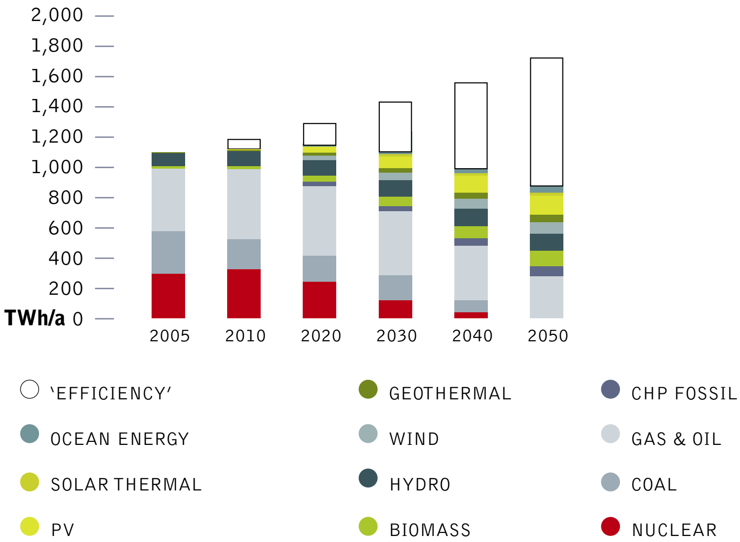


figure 14: japan: growth of renewable electricity supply under the energy [r]evolution scenario, by source

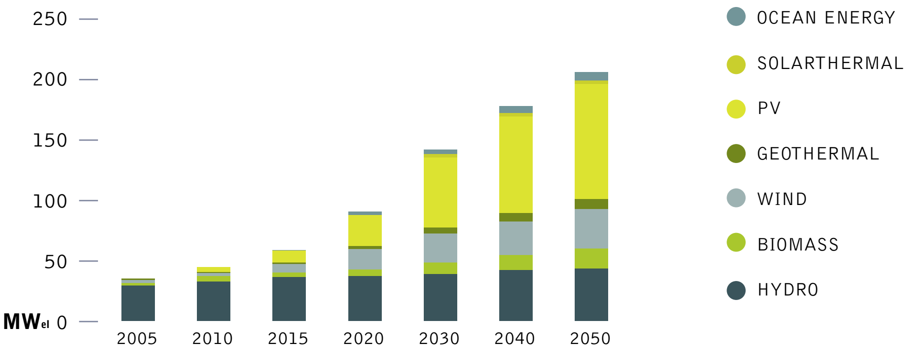


table 8: japan: projection of renewable electricity generation capacity under the energy [r]evolution scenario

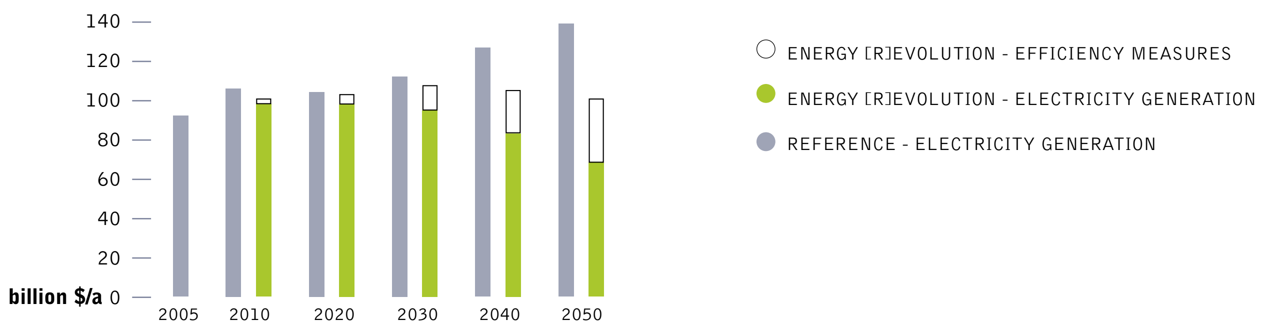
IN MW

	2005	2010	2015	2020	2030	2040	2050
Hydro	25,000	-	-	-	-	-	-
Wind	1,000	2,500	7,900	17,000	24,500	27,700	31,500
PV	1,350	2,850	9,300	26,400	59,285	81,400	95,000
Biomass	2,600	3,500	4,000	5,900	9,200	12,800	17,450
Geothermal	560	1,000	1,200	1,970	3,850	5,500	7,500
Concentrated solar power	-	-	-	-	500	1,500	2,000
Ocean energy	-	-	600	1,500	3,800	6,200	7,500
Total	**30,510**	**9,850**	**23,000**	**52,770**	**101,135**	**135,100**	**160,950**

future costs of electricity generation

Due to growing demand, Japan faces a significant increase in society's expenditure on electricity supply. Under the Reference Scenario, undiminished growth in demand, the increase in fossil fuel prices and the costs of CO_2 emissions result in electricity supply costs of around $138 billion in 2050. Figure 28 shows that the Energy [R]evolution scenario not only complies with global CO_2 reduction targets but also helps to relieve the economic pressure on society. Increasing energy efficiency and shifting energy supply to renewable energy resources reduces the long-term costs for electricity supply by nearly 38% compared to the Reference Scenario. It becomes obvious that following stringent environmental targets in the energy sector also pays off in terms of economics.

figure 15: japan: development of total electricity supply costs



heat demand

Efficiency gains in the heat supply sector are even larger. Under the Energy [R]evolution Scenario, final demand for heat supply can even be reduced (see 19). Compared to the Reference Scenario, consumption equivalent to 1381 PJ/a is avoided through efficiency gains by 2050. As a result of energy-related renovation of the existing stock of residential buildings, as well as the introduction of low energy standards and 'passive houses' for new buildings, enjoyment of the same comfort and energy services will be accompanied by a much lower future energy demand.

figure 16: japan: development of heat supply demand in the energy [r]evolution scenario

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

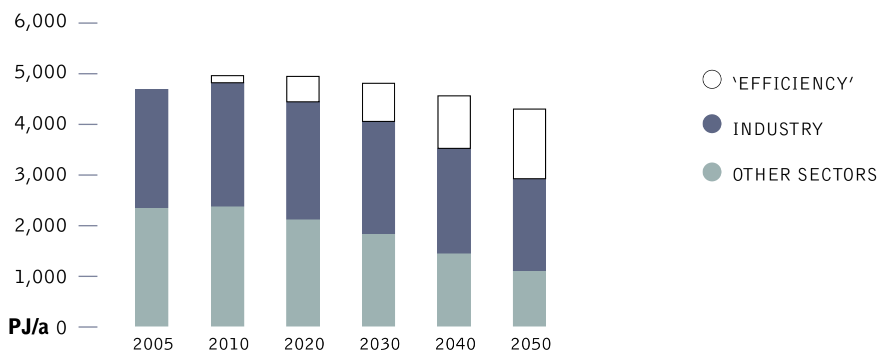


image WIND TURBINE IN NORTHERN JAPAN.

heat and cooling supply

Development of renewables in the heating and cooling supply sector raises different issues. Today in Japan, renewables provide over 2.6% of primary energy demand for heat supply, the main contribution being the use of biomass for heating. Large-scale utilisation of geothermal and solar thermal energy for heat supply is not only restricted to the housing sector, but increasingly used within the industrial sector. Past experience shows that it is easier to implement effective support instruments in the grid-connected electricity sector than in the heat market, with its multitude of different actors. Dedicated support instruments are required to ensure a dynamic development of renewables in the heat market.

- Energy efficiency measures can reduce the current demand for heat supply by about 38%, in spite of improving living standards.
- In the housing sector, solar collectors, biomass/biogas as well as geothermal energy will increasingly replace conventional fossil-fuelled heating 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 17: japan: development of heat supply under the reference scenario

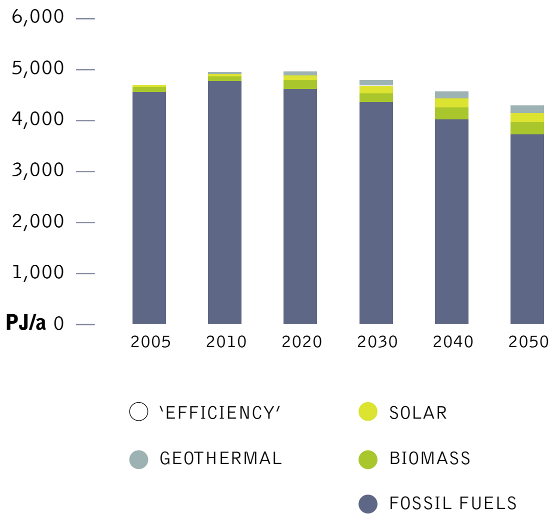
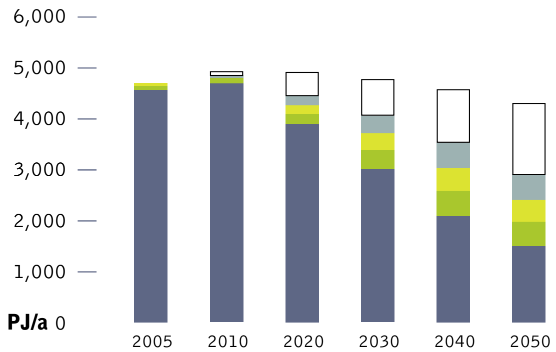


figure 18: japan: development of heat supply under the energy [r]evolution scenario

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



primary energy consumption

Taking into account the assumptions discussed above, the resulting primary energy consumption in Japan under the Energy [R]evolution Scenario is shown in Figure 25. Compared to the Reference Scenario, primary energy demand will be reduced by almost 51% in 2050. Over 30% of the remaining demand is covered by renewable energy sources. Note that because of the 'efficiency method' used for the calculation of primary energy consumption, which postulates that the amount of electricity generation from hydro, wind, solar and geothermal energy equals the primary energy consumption, the share of renewables seems to be lower than their actual importance as energy carriers.

figure 19: japan: development of primary energy consumption under the reference scenario

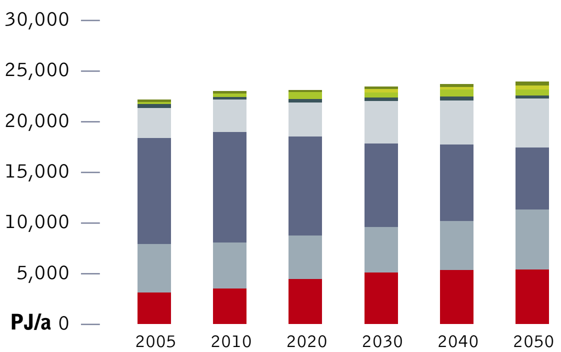


figure 20: japan: development of primary energy consumption under the energy [r]evolution scenario

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

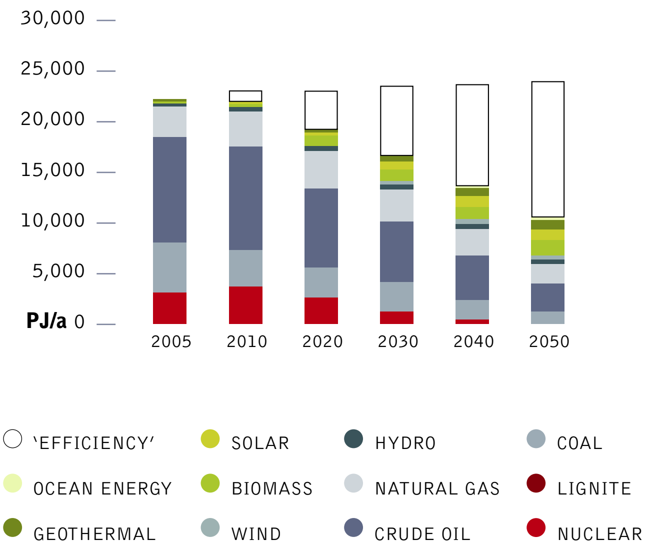


image A WIND TURBINE AND CHERRY BLOSSOMS, LATE SPRING IN AOMORI.

fuel costs

development of CO_2 emissions Japan's past record of CO emissions is shown in Figure 1 and greenhouse gas emissions (both sets of data provided by the Inventory Office of Japan) are shown in Table 5. CO_2 emission related energy in 2005 is 113% of 1990.

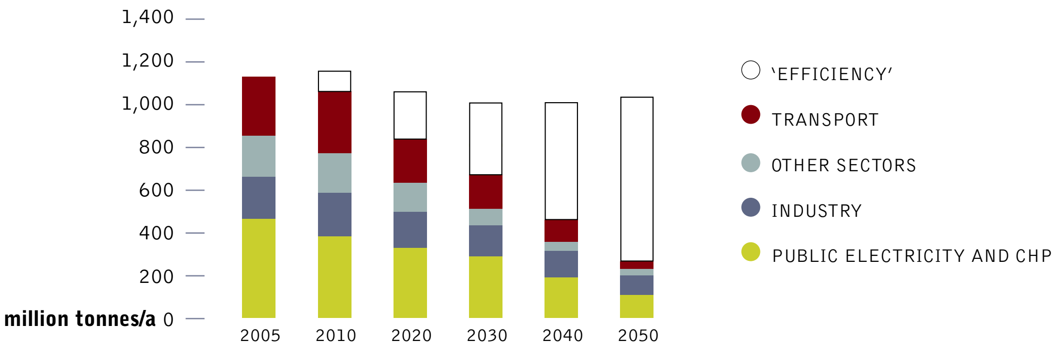
While energy related CO_2 emissions in Japan will decrease under the Reference Scenario by 8% by 2050 - far removed from a sustainable development path - under the Energy [R]evolution Scenario they drop to significantly, decreasing from 1,135 million tonnes in 2005 to 275 m/t in 2050. Annual per capita emissions will drop from 8.9 tonnes to 2.7 tonnes. Whilst the power sector today is the largest sources of energy related CO_2 emissions in Japan, it will contribute about 39% of the total in 2050.

table 9: japan: CO_2 emission data from the inventory office of japan

SECTOR	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Power Generation	318	320	327	309	350	338	338	334	324	341	348	340	371	385	382	397
Industry	390	386	377	375	383	387	396	397	373	379	389	378	385	390	390	381
Transport	211	222	227	232	244	251	257	259	258	260	259	262	257	254	254	250
Commercial	84	81	82	87	85	93	91	89	94	101	101	108	112	109	109	107
Residential	57	57	61	65	62	66	66	65	65	67	69	66	68	64	64	68
Sub Total	**1,059**	**1,067**	**1,074**	**1,068**	**1,123**	**1,135**	**1,147**	**1,143**	**1,113**	**1,148**	**1,167**	**1,153**	**1,193**	**1,198**	**1,199**	**1,203**
Ratio(year/1990)	100.0%	100.7%	101.4%	100.8%	106.0%	107.2%	108.3%	100.8%	105.1%	108.4%	110.2%	108.9%	112.6%	113.1%	113.2%	113.6%

figure 21: japan: development of co_2 emissions by sector under the energy [r]evolution scenario

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



overview - scenario assumptions

The Energy [R]evolution scenario for Japan is based on a long term renewable energy and energy potential assessment[11] for Japan from the Institute for Sustainable Energy Policies (ISEP) in Tokyo. The ISEP research is built upon the following assumptions:

energy demand

- The demand for each sector is based on a study - "Low Carbon Society 2050"[12]- from the National Institute of Environmental Studies (NIES) from which the energy balance between residential and commercial sectors is taken and slightly modified. Compared to the NIES study, there is a larger increase in efficiency due to the use of the heat pump (HP) for heating, hot water supply, and cooking in the commercial and residential sectors. In addition, there are assumed improvements in insulation, affecting heating demand in the residential sector. Apart from these two areas, the assumptions for energy efficiency are the same as those in the NIES study.

energy supply – power generation:

- The energy supply from renewables is based upon proposals from renewable industry associations and a study on the potential of renewables by ISEP. The involved industry associations are: Japanese Wind Power Association, the Japan Photovoltaic Energy Association and the Geothermal Research Society Japan and the Japan Developer's Council.
- Biomass for power generation and heat supply is produced as a domestic resource. By contrast, biomass for transport fuel is assumed to be obtained through international trade with a sustainability standard. Biomass potential and calorific coefficient are taken from the Biomass GIS Database by NEDO (New Energy and Industrial Technology Development Organization)
- "Electricity generation" refers to the power supply from utilities and "decentralised power sources" refers to the supply from private power generation from industries and others.

heat supply

- "Heat supply refers to heat produced from fossil fuels and renewables consumed by the industrial, commercial and residential sectors
- "Fuel supply" refers to fossil fuels and renewables consumed by the transport sector (both passenger and freight).
- The primary energy equivalent values of electricity generation by fossil fuels and biomass are values of fuel input; others are calibrated by generation efficiency of 40%
- The consumption of energy in the production of oil and cork is also considered as primary energy
- The assumptions for electricity generation efficiency in 2050 are as follows: for the electricity utilities (electricity generation column) – coal 48%, LNG 55% and oil/biomass 40%
- Compared to the NIES Scenario B, there is a larger increase in efficiency due to the use of the heat pump (HP) for heating, hot water supply and cooking in the commercial and residential sectors. In addition, there is a greater improvement in insulation assumed for heating in the residential sector. Apart from these two areas, the other assumptions for energy efficiency are the same as those in the NIES scenario.
- The estimation for 2020 is calculated by linear interpolation between 2000 and 2050.
- In regard to geothermal, using heat exchange from hot springs is included in the commercial sector.
- Decentralized photovoltaic is estimated at one and a half times more capacity than the NIES Scenario B

reference

11 YEAR 2050 RENEWABLE ENERGY VISION IN JAPAN", INSTITUTE FOR SUSTAINABLE ENERGY POLICIES, FEB.2008, HTTP://WWW.ISEP.OR.JP/EVENT/080221SYMPO2050.HTML

12 "JAPAN SCENARIOS TOWARDS LOW-CARBON SOCIETY(LCS) – FEASIBILITY STUDY FOR 70% CO2 EMISSION REDUCTION BY 2050 BELOW 1990 LEVEL", IES, KYOTO UNIV., RITSUMEIKAN UNIV. AND MIZUHO INFORMATION AND RESEARCH INSTITUTE, FEB. 2007. HTTP://2050.NIES.GO.JP/INDEX.HTML

policy recommendation

"...CONTRIBUTE TO SUSTAINABLE ECONOMIC GROWTH, HIGH QUALITY JOBS, TECHNOLOGY DEVELOPMENT, GLOBAL COMPETITIVENESS AND INDUSTRIAL AND RESEARCH LEADERSHIP."

7

renewable energy policy

1. Establish Long-term, high numerical targets and political commitment

- Set legally binding target (12% by 2020 and 40% by 2050) for the final energy use, as well as specific sectorial renewable targets for electricity, heating and transport
- Pay particular attention to the electric power generation sector, in which political action with numerical targets will yield certain results.
- Although a commitment to those targets should, properly speaking, be made by the central Government, it is natural that local governments be expected to take the initiative when central Governments are unable or unwilling to engender an adequate response to renewable energy.

2. Gradually abolish fossil fuel subsidies to internalize external costs

- Under a national consensus, establish a framework to share costs and/or burdens in a fair manner by reforming taxation in a way that promotes further introduction of renewable energy,
- Specifically, adopt an environmental tax (carbon tax) or energy consumption charge scheme.

3. Reduce the harmful obstacles of old customs, traditions and existing regulations in "energy markets"

- In attempt to introduce decentralized renewable energy, it is necessary to review a wide body of laws, which can create barriers through inconsistency and inflexibility; the nature parks law, the agriculture land law, building standard regulations, the waste and cleaning law, and others must be appraised with the necessary flexibility in mind.
- Review a scheme of existing/vested rights, especially water rights, geo- (hot-spring) thermal access, fishery rights and others, which have a potential for instigated rivalries, through restoring and integrating them so as to establish fair and transparent procedures.

4. Create a stable market with transparency

- In order to reduce the risks to financial interests of the renewable energy business over long periods of time, it is vital to take the following, necessary measures;
- Set long-term, stable monetary support for renewable energy businesses
- Harmonize the verification of CO_2 emission reduction and the creation of a CO_2 market
- Create a market which is demonstrably stable in the long term from an investor's point of view
- Create a renewable energy market from which users may choose directly among various options
- Create initial demand through active introduction of renewable energy by central and local government and other public offices.
- Place community development, new building construction, hot-spring utilization under obligation to utilize renewable energy
- Establish a "public-private fund for the development phase" in order to share the risks that renewable energy businesses face

5. Public and community participation scheme generating the benefits of renewable energy for the local community

- In order to enable local residents to take an early role in the renewable energy development process, it is required to establish transparent land-use planning and environment assessment systems.
- In light of the fact that the introduction of renewable energy brings rewards to a local community, there is a need to establish a local financial scheme in which locals can own part of the renewable business by themselves.
- For increased participation by local governments, businesses and individuals in renewable energy, it is necessary to create an organization like a local environmental office that is expected to form a partnership between community and renewable energy activities.

6. Review and reinforce existing policies, the following measures have been implemented, but require further review and support.

- National support for research and development
- Award ceremony for the best practice and system
- Expansion and implementation of education, enlightenment and publicity activities

policies for the renewable energy electricity

policies for a power system and electrical power markets Regarding the renewable energy electricity sector, reviewing the rule of access to the power supply is a crucial element. To that end, the following measures are recommended;

1. principle: Priority access to the power supply by the renewable energy business.

- At this moment, access to the power supply has been permitted solely at an electric power company's own discretion. This should be changed in order to give any renewable energy businesses, in principle, the "priority right" to use the network

2. cost: Social sharing of power supply costs for access of renewable energy, which needs strengthening system interconnection,

- Share the cost of access from renewable energy businesses to power supply network among all members of network users (renewable energy businesses need to pay for all costs as far as access point)

3. cost: Social sharing of imbalance (ancillary) costs of renewable energy

- Among the businesses, share costs of imbalanced (ancillary) situations which will be caused by any unstable features of renewable energy

4. technology: Take action to strengthen and utilize supply interconnection among the power utilities

- By taking advantage of "power supply interconnection lines", which connects the power utilities to one another, operate the whole system flexibly enough to cover itself against any imbalance caused by access of renewable energy

5. technology: Increase the capacity for system interconnection coordination in order to make the demand side bear their own costs by themselves

- By introducing an adjustment system through both engineering measures and market mechanisms against a load generated by the demand side, the coordinative capacity of the whole system's interconnection will be increased.

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

policies for PV power generation

1. introduce: an obligation for new building construction to install solar PV

- Impose an obligation at the time of new building construction and/or rebuilding work to install renewable energy, including solar PV power at a certain rate

policies for micro-hydro power generation

1. review: the definition of new energy in the New Energy Law, Renewable Portfolio Standard (RPS) Law

- The definition of micro-hydro, which is limited by New Energy Law and RPS Law, should be consistent with the standard of the "International Dam Committee"

2. impose: an obligation in principle at the time of construction of a new waterway and of repair to utilize them with a steep surplus drop for power generation

- At the any point of efficient utilization of renewable energy generated by new waterway construction and retrieval of water, use in principle a power generator with steep surplus water drop

policies for biomass power generation

1. stabilize: the forestry business management and integrate forestry policy with environmental and energy policies

- Based on establishing forestry as a sound business management, forestry policy should be integrated with environment and energy policies

2. establish: an efficient biomass supply chain

- For biomass supplied from forest and agriculture to waste, there is a need to establish a scheme in order to realize efficient use of biomass energy

2. revise: the Waste and Clean Law to utilize biomass waste more flexibly

- Review the definition and operation of biomass waste with practical function in mind in order to make it more efficient and effective.

policies for geothermal power generation

1. enactment: of Geothermal Law

- Enact a "Geothermal Law", which imposes an obligation in principle of utilization of geothermal energy at the point of underground development like hot-spa construction

2. implement: flexibly national policies so as to support commercialization of geothermal energy

- Review the boundary of new energy (which RPS Law puts in consideration; the present boundary which is limited only for binary use under RPS Laws)
- Introduce commercialization research at the time of the research for geothermal development and promotion
- Second use of recycled waste hot water: utilization of hot spring warmth and direct heat

policies for renewable energy heat

1. establish: heat and thermal policies of giving priority to renewable energy taking energy into account.

2. unify: methods of building and energy saving

- Utilize renewable energy, including solar heat and energy saving apparatus at a certain rate for renovation and new construction.
- Introduce the obligation for new housing construction to install solar heat

3. establish: CO_2 value incentives of green power certification

policies for renewable energy fuel

1. create: and reach an agreement upon the international "Sustainable Bio-fuel Standard"

appendix: reference scenario

table 10: electricity generation

TWh/a

	2005	2010	2015	2020	2030	2040	2050
Power plants	**1,093**	**1,182**	**1,182**	**1,277**	**1,415**	**1,543**	**1,691**
Coal	267	288	319	312	349	435	579
Lignite	0	0	0	0	0	0	0
Gas	271	305	308	312	360	393	407
Oil	141	137	110	95	59	33	9
Diesel	5	3	2	1	0	0	0
Nuclear	305	335	376	425	493	515	520
Biomass	20	25	27	31	35	39	41
Hydro	78	78	79	79	81	83	86
Wind	1.8	4	9	13	26	28	30
PV	1.9	3	3	5	8	12	14
Geothermal	3	3	4	4	4	5	5
Solar thermal power plants	0	0	0	0	0	0	0
Ocean energy	0	0	0	0	0	0	0
Combined heat & power production	**0**	**3**	**6**	**11**	**15**	**19**	**23**
Coal	0	0	0	0	0	0	0
Lignite	0	0	0	0	0	0	0
Gas	0	0	6	11	15	18	22
Oil	0	0	0	0	0	0	0
Biomass	0	0	0	0	0	1	1
Geothermal	0	0	0	0	0	0	0
CHP by producer							
Main acitivity producers	0	0	0	0	0	0	0
Autoproducers	0	3	6	11	15	19	23
Total generation	**1,093**	**1,185**	**1,242**	**1,288**	**1,430**	**1,562**	**1,714**
Fossil	684	736	745	731	782	879	1,017
Coal	267	288	319	312	349	435	579
Lignite	0	0	0	0	0	0	0
Gas	271	308	314	323	375	411	429
Oil	141	137	110	95	59	33	9
Diesel	5	3	2	1	0	0	0
Nuclear	305	335	376	425	493	515	520
Renewables	**105**	**113**	**121**	**132**	**155**	**167**	**177**
Hydro	78	78	79	79	81	83	86
Wind	1.8	4.0	9.0	13	26	28	30
PV	1.9	2.5	3.2	5.0	8.0	12.0	14.0
Biomass	19.5	25.0	27.1	31	35	40	42
Geothermal	3.2	3.4	3.6	4	4	5	5
Solar thermal	0.0	0.0	0.0	0	0	0	0
Ocean energy	0.0	0.0	0.0	0	0	0	0
Import	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Import RES	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Export	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Distribution losses	50.4	53.0	53.3	54.0	59.0	64.0	71.0
Own consumption electricity	57.5	63.0	64.0	66.0	71.0	79.0	87.0
Final energy consumption (electricity)	**985**	**1,069**	**1,125**	**1,168**	**1,300**	**1,419**	**1,556**
Fluctuating RES (PV, Wind, Ocean)	4	7	12	18	34	40	44
Share of fluctuating RES	0.3%	0.5%	1.0%	1.4%	2.4%	2.6%	2.6%
RES share	**9.6%**	**9.6%**	**9.8%**	**10.2%**	**10.8%**	**10.7%**	**10.3%**

table 11: installed capacity

GW

	2005	2010	2015	2020	2030	2040	2050
Power plants	**391**	**363**	**332**	**313**	**309**	**319**	**330**
Coal	44	48	53	53	58	73	97
Lignite	0	0	0	0	0	0	0
Gas	72	80	79	78	88	94	96
Oil	78	76	63	56	45	28	8
Diesel	120	77	47	25	0	0	0
Nuclear	40	44	49	56	65	68	68
Biomass	2.6	3.3	3.6	4.1	4.7	5.2	5.5
Hydro	30	30	30	30	31	32	33
Wind	1.0	2.0	4.2	5.7	10.6	10.6	11.4
PV	1.4	1.8	2.3	3.6	5.7	8.6	10.0
Geothermal	0.6	0.6	0.6	0.6	0.7	0.8	0.9
Solar thermal power plants	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ocean energy	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Combined heat & power production	**0**	**1**	**1**	**2**	**3**	**4**	**5**
Coal	0	0	0	0	0	0	0
Lignite	0	0	0	0	0	0	0
Gas	0	1	1	2	3	4	5
Oil	0	0	0	0	0	0	0
Biomass	0	0	0	0	0	0	0
Geothermal	0	0	0	0	0	0	0
CHP by producer							
Main activity producers	0	0	0	0	0	0	0
Autoproducers	0	1	1	2	3	4	5
Total generation≈	**391**	**363**	**333**	**315**	**313**	**323**	**334**
Fossil	315	281	243	215	195	198	205
Coal	44	48	53	53	58	73	97
Lignite	0	0	0	0	0	0	0
Gas	72	80	80	80	91	98	100
Oil	78	76	63	56	45	28	8
Diesel	120	77	47	25	0	0	0
Nuclear	40	44	49	56	65	68	68
Renewables	**36**	**38**	**41**	**44**	**53**	**57**	**61**
Hydro	30	30	30	30	31	32	33
Wind	1.0	2.0	4	6	11	11	11
PV	1.4	1.8	2	4	6	9	10
Biomass	2.6	3.3	3.6	4.2	4.8	5.4	5.7
Geothermal	1	1	1	1	1	1	1
Solar thermal	0	0	0	0	0	0	0
Ocean energy	0	0	0	0	0	0	0
Fluctuating RES (PV, Wind, Ocean)	2.3	3.8	6.5	9.2	16.3	19.2	21.4
Share of fluctuating RES	0.6%	1.1%	2.0%	2.9%	5.2%	5.9%	6.4%
RES share	**9.1%**	**10.4%**	**12.3%**	**14.1%**	**16.9%**	**17.7%**	**18.3%**

table 12: primary energy demand

PJ/A

	2005	2010	2015	2020	2030	2040	2050
Total	**22,235**	**23,091**	**23,401**	**23,157**	**23,470**	**23,717**	**23,918**
Fossil	**18,196**	**18,669**	**18,354**	**17,428**	**16,781**	**16,621**	**16,636**
Hard coal	4,701	4,654	4,644	4,254	4,238	4,760	5,678
Lignite	0	0	0	0	0	0	0
Natural gas	3,030	3,346	3,444	3,513	4,074	4,413	4,504
Crude oil	10,466	10,669	10,266	9,662	8,469	7,447	6,454
Nuclear	**3,325**	**3,655**	**4,103**	**4,637**	**5,379**	**5,619**	**5,674**
Renewables	**714**	**766**	**945**	**1,091**	**1,310**	**1,477**	**1,608**
Hydro	282	282	283	284	292	299	310
Wind	6	14	32	47	94	101	108
Solar	31	49	83	130	196	247	284
Biomass	270	355	475	528	588	667	723
Geothermal	125	67	73	102	141	164	183
Ocean Energy	0	0	0	0	0	0	0
RES share	**3.2%**	**3.3%**	**4.0%**	**4.7%**	**5.6%**	**6.2%**	**6.7%**

image BROWN COAL SURFACE MINING IN HAMBACH. GIANT COAL EXCAVATOR AND SPOIL PILE.

© BERND ARNOLD/VISUM/GP

reference scenario

table 13: heat supply

PJ/A

	2005	2010	2015	2020	2030	2040	2050
District heating plants	**26**	**27**	**28**	**28**	**27**	**25**	**24**
Fossil fuels	19	20	21	20	19	18	17
Biomass	7	7	8	8	7	7	6
Solar collectors	0	0	0	0	0	0	0
Geothermal	0	0	0	0	0	0	0
Heat from CHP	**0**	**21**	**37**	**59**	**64**	**68**	**71**
Fossil fuels	0	21	36	58	63	65	67
Biomass	0	0	0	1	1	2	4
Geothermal	0	0	0	0	0	0	0
Direct heating[1]	**4,680**	**4,891**	**4,984**	**4,874**	**4,709**	**4,472**	**4,202**
Fossil fuels	4,563	4,732	4,766	4,570	4,294	3,977	3,631
Biomass	84	96	116	132	153	179	210
Solar collectors	24	40	71	112	167	204	234
Geothermal	9	25	30	59	95	113	127
Total heat supply[1]	**4,710**	**4,944**	**5,053**	**4,964**	**4,803**	**4,569**	**4,300**
Fossil fuels	4,582	4,773	4,823	4,649	4,376	4,061	3,716
Biomass	91	103	124	141	161	188	220
Solar collectors	24	40	71	112	167	204	234
Geothermal	9	25	30	59	95	113	127
Electricity	4	4	4	4	4	4	4
RES share (including RES electricity)	**2.6%**	**3.4%**	**4.5%**	**6.3%**	**8.8%**	**11.0%**	**13.5%**

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

table 14: CO_2 emissions

MILL t/a

	2005	2010	2015	2020	2030	2040	2050
Condensation power plants	**467**	**468**	**451**	**410**	**414**	**463**	**542**
Coal	262.9	264.6	273.0	248.8	259.6	313.3	404.2
Lignite	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gas	121.4	124.8	115.2	106.6	121.0	131.0	132.3
Oil	79.6	77.2	62.0	53.5	33.3	18.6	5.1
Diesel	2.7	1.8	1.1	0.6	0.0	0.0	0.0
Combined heat & power production	**0**	**3**	**4**	**7**	**8**	**8**	**9**
Coal	0	0	0	0	0	0	0
Lignite	0	0	0	0	0	0	0
Gas	0	3	4	7	8	8	9
Oil	0	0	0	0	0	0	0
CO_2 emissions electricity & steam generation	**467**	**471**	**456**	**417**	**421**	**471**	**550**
Coal	263	265	273	249	260	313	404
Lignite	0	0	0	0	0	0	0
Gas	121	127	120	114	129	139	141
Oil & diesel	82	79	63	54	33	19	5
CO_2 emissions by sector	**1,135**	**1,164**	**1,142**	**1,070**	**1,020**	**1,019**	**1,044**
% of 2000 emissions	100%	103%	101%	94%	90%	90%	92%
Industry	201	206	201	188	172	154	138
Other sectors	191	197	198	188	168	151	133
Transport	276	292	291	283	265	249	230
Electricity & steam generation	467	468	451	410	414	463	542
District heating	1	1	1	1	1	1	1
Population (Mill.)	127.9	127.8	126.6	124.5	118.3	110.7	102.5
CO_2 emissions per capita (t/capita)	**8.9**	**9.1**	**9.0**	**8.6**	**8.6**	**9.2**	**10.2**

The numbers provided in the table are the data from the model. The estimation for the 2003 CO_2 emissions is 2.7% below the Government's figure for the same year (31.17 Mill t/a). For consistency, we have corrected the figures accordingly and used these to estimate the CO_2 emission reductions.

table 15: final energy demand

PJ/a

	2005	2010	2015	2020	2030	2040	2050
Total (incl. non energy use)	**14,751**	**15,564**	**15,919**	**15,831**	**15,826**	**15,739**	**15,600**
Total (energy use)	**13,023**	**13,826**	**14,172**	**14,075**	**14,051**	**13,944**	**13,786**
Transport	**3,894**	**4,167**	**4,242**	**4,160**	**3,970**	**3,776**	**3,552**
Oil products	3,826	4,048	4,039	3,927	3,665	3,420	3,115
Natural gas	0	18	37	55	85	112	115
Biofuels	0	17	69	73	82	101	11
Electricity	69	80	88	94	121	121	187
RES electricity	6.6	7.7	8.6	9.7	13.1	13.0	19.4
Hydrogen	0	4	8	11	17	22	23
RES share transport	0.2%	0.6%	1.9%	2.0%	2.4%	3.1%	3.1%
Industry	**4,056**	**4,277**	**4,341**	**4,291**	**4,358**	**4,344**	**4,322**
Electricity	1,253	1,358	1,423	1,473	1,634	1,784	1,938
RES electricity	*120*	130	139	151	177	191	200
District heat	0	21	37	59	64	68	71
RES district heat	0	0	0	1	1	2	4
Coal	536	576	486	360	223	168	118
Oil products	1,381	1,418	1,366	1,240	1,077	865	689
Gas	682	773	878	974	1,124	1,179	1,190
Solar	0	2	12	24	47	66	83
Biomass and waste	105	115	124	133	143	159	171
Geothermal	0	12	15	29	47	55	62
RES share industry	**5.6%**	**6.1%**	**6.7%**	**7.9%**	**9.5%**	**10.9%**	**12.0%**
Other sectors	**5,073**	**5,382**	**5,589**	**5,623**	**5,722**	**5,824**	**5,913**
Electricity	2,226	2,403	2,527	2,621	2,901	3,171	3,447
RES electricity	*213*	230	247	269	314	340	356
District heat	26	27	28	28	27	25	24
RES district heat	*7*	7	8	8	7	7	6
Coal	27	20	9	6	11	11	1
Oil products	1,820	1,837	1,776	1,605	1,246	970	707
Gas	940	1,038	1,152	1,214	1,326	1,398	1,443
Solar	24	37	59	88	120	137	151
Biomass and waste	2	6	22	31	44	55	76
Geothermal	9	12	15	30	48	57	65
RES other sectors	**5.0%**	**5.4%**	**6.3%**	**7.6%**	**9.3%**	**10.2%**	**11.1%**
Total RES	**487**	**577**	**720**	**847**	**1,043**	**1,186**	**1,285**
RES share	**3.3%**	**3.7%**	**4.5%**	**5.4%**	**6.6%**	**7.5%**	**8.2%**
Non energy use	**1,782**	**1,738**	**1,747**	**1,756**	**1,775**	**1,794**	**1,814**
Oil	1,697	1,706	1,715	1,725	1,743	1,762	1,781
Gas	15	15	15	15	15	15	16
Coal	16	16	17	17	17	17	17

alternative scenario

table 16: electricity generation

TWh/a

	2005	2010	2015	2020	2030	2040	2050
Power plants	**1,093**	**1,109**	**1,129**	**1,1107**	**1,024**	**871**	**717**
Coal	267	187	186	167	151	79	7
Lignite	0	0	0	0	0	0	0
Gas	271	317	345	376	371	321	263
Oil	141	137	110	95	59	33	9
Diesel	5	2	1	0	0	0	0
Nuclear	305	335	325	245	121	45	0
Biomass	20	25	27	31	33	32	30
Hydro	78	89	95	99	104	111	115
Wind	1.8	5	17	39	60	73	83
PV	1.9	4	13	37	83	114	133
Geothermal	3	6	7	11	20	23	27
Solar thermal power plants	0	0	0	1	4	11	15
Ocean energy	0	1	3	7	18	29	35
Combined heat & power production	**0**	**6**	**14**	**31**	**68**	**107**	**148**
Coal	0	0	0	0	0	0	0
Lignite	0	0	0	0	0	0	0
Gas	0	4	11	22	42	55	63
Oil	0	0	1	1	1	0	0
Biomass	0	1	2	8	24	44	71
Geothermal	0	0	0	0	2	7	14
CHP by producer							
Main acitivity producers	0	2	5	11	23	44	75
Autoproducers	0	4	9	20	45	63	73
Total generation	**1,093**	**1,114**	**1,143**	**1,138**	**1,092**	**978**	**865**
Fossil	684	648	653	660	624	488	342
Coal	267	187	186	167	151	79	7
Lignite	0	0	0	0	0	0	0
Gas	271	321	356	398	413	376	326
Oil	141	137	111	96	60	33	9
Diesel	5	2	1	0	0	0	0
Nuclear	305	335	325	245	121	45	0
Renewables	**105**	**131**	**164**	**233**	**347**	**445**	**523**
Hydro	78	89	95	99	104	111	115
Wind	1.8	5	17	39	60	73	83
PV	1.9	4	13	37	83	114	133
Biomass	19.5	26	29	39	57	76	101
Geothermal	3.2	6	7	11	22	30	41
Solar thermal	0.0	0	0	1	4	11	15
Ocean energy	0.0	1	3	7	18	29	35
Import	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Import RES	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Export	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Distribution losses	50.4	53.0	53.0	51.0	49.0	44.0	39.0
Own consumption electricity	57.5	60.0	60.0	59.0	56.0	50.0	44.0
Final energy consumption (electricity)	**985**	**1,001**	**1,030**	**1,028**	**987**	**884**	**782**
Fluctuating RES (PV, Wind, Ocean)	4	10	33	83	161	216	251
Share of fluctuating RES	0.3%	0.9%	2.9%	7.3%	14.7%	22.1%	29.0%
RES share	**9.6%**	**11.8%**	**14.4%**	**20.5%**	**31.8%**	**45.5%**	**60.5%**
'Efficiency' savings (compared to Ref.)	**0**	**70**	**100**	**149**	**338**	**584**	**850**

table 17: installed capacity

GW

	2005	2010	2015	2020	2030	2040	2050
Power plants	**391**	**331**	**297**	**298**	**311**	**291**	**260**
Coal	44	31	31	27	23	13	1
Lignite	0	0.0	0.0	0.0	0.0	0.0	0.0
Gas	72	82.7	88.1	94.0	90.9	77.0	61.9
Oil	78	76.1	62.9	55.9	45.4	27.5	8.2
Diesel	120	52.5	12.5	0.0	0.0	0.0	0.0
Nuclear	40	44.1	42.8	32.2	15.9	5.9	0.0
Biomass	2.6	3.3	3.6	4.1	4.4	4.3	4.0
Hydro	30	34	37	38	40	43	44
Wind	1.0	2.5	8.0	17.0	24.5	27.8	31.6
PV	1.4	2.9	9.3	26.4	59.3	81.4	95.0
Geothermal	0.6	1.0	1.2	1.9	3.5	4.0	4.7
Solar thermal power plants	0.0	0.0	0.0	0.1	0.6	1.5	2.1
Ocean energy	0.0	0.3	0.6	1.5	3.8	6.2	7.4
Combined heat & power production	**0**	**1**	**4**	**8**	**17**	**27**	**38**
Coal	0	0	0	0	0	0	0
Lignite	0	0	0	0	0	0	0
Gas	0	1	3	6	12	17	22
Oil	0	0	0	0	0	0	0
Biomass	0	0	0	2	5	9	13
Geothermal	0	0	0	0	0	1	3
CHP by producer							
Main activity producers	0	1	2	4	8	14	24
Autoproducers	0	1	2	4	10	13	14
Total generation≈	**391**	**332**	**300**	**307**	**329**	**318**	**298**
Fossil	315	244	198	183	171	134	93
Coal	44	31	31	27	23	13	1
Lignite	0	0	0	0	0	0	0
Gas	72	84	91	100	103	94	84
Oil	78	76	63	56	46	28	8
Diesel	120	53	13	0	0	0	0
Nuclear	40	44	43	32	16	6	0
Renewables	**36**	**45**	**60**	**91**	**141**	**178**	**205**
Hydro	30	34	37	38	40	43	44
Wind	1.0	3	8	17	24	28	32
PV	1.4	3	9	26	59	81	95
Biomass	2.6	3.6	4.1	6	9	13	17
Geothermal	1	1	1	2	4	5	8
Solar thermal	0	0	0	0	1	2	2
Ocean energy	0	0	1	1	4	6	7
Fluctuating RES (PV, Wind, Ocean)	2.3	5.7	17.9	44.9	87.6	115.4	134.0
Share of fluctuating RES	0.6%	1.7%	6.0%	14.6%	26.7%	36.3%	44.9%
RES share	**9.1%**	**13.4%**	**19.9%**	**29.7%**	**43.0%**	**55.9%**	**68.8%**

table 18: primary energy demand

PJ/A

	2005	2010	2015	2020	2030	2040	2050
Total	**22,235**	**21,985**	**21,194**	**19,229**	**16,590**	**13,499**	**10,486**
Fossil	**18,196**	**17,477**	**16,390**	**14,448**	**12,152**	**9,023**	**6,043**
Hard coal	4,701	3,663	3,390	2,965	2,630	1,963	1,335
Lignite	0	0	0	0	0	0	0
Natural gas	3,030	3,495	3,632	3,658	3,448	2,775	2,055
Crude oil	10,466	10,319	9,368	7,826	6,074	4,285	2,653
Nuclear	**3,325**	**3,655**	**3,546**	**2,673**	**1,320**	**491**	**0**
Renewables	**714**	**853**	**1,258**	**2,107**	**3,118**	**3,985**	**4,443**
Hydro	282	320	342	356	374	400	414
Wind	6	18	61	140	216	263	299
Solar	31	39	111	306	677	903	947
Biomass	270	376	606	1,001	1,289	1,551	1,656
Geothermal	125	95	128	278	497	764	1,001
Ocean Energy	0	4	11	25	65	104	126
RES share	**3.2%**	**3.9%**	**5.9%**	**11.0%**	**18.8%**	**29.5%**	**42.4%**
'Efficiency' savings (compared to Ref.)	**0**	**1,106**	**2,207**	**3,928**	**6,881**	**10,217**	**13,431**

image A WIND TURBINE AND CHERRY BLOSSOMS, LATE SPRING IN AOMORI.

alternative scenario

table 19: heat supply

PJ/A

	2005	2010	2015	2020	2030	2040	2050
District heating plants	**26**	**91**	**136**	**206**	**314**	**319**	**172**
Fossil fuels	19	65	93	129	127	55	0
Biomass	7	24	39	66	138	163	93
Solar collectors	0	1	3	10	47	99	77
Geothermal	0	0	1	1	2	2	2
Heat from CHP	**0**	**26**	**66**	**128**	**252**	**382**	**520**
Fossil fuels	0	22	56	97	165	189	200
Biomass	0	4	9	28	71	127	194
Geothermal	0	0	1	3	17	67	127
Direct heating[1)]	**4,680**	**4,735**	**4,524**	**4,122**	**3,495**	**2,804**	**2,224**
Fossil fuels	4,563	4,602	4,308	3,671	2,705	1,825	1,277
Biomass	84	88	103	117	176	227	210
Solar collectors	24	24	61	161	316	354	337
Geothermal	9	21	53	174	298	397	399
Total heat supply[1)]	**4,706**	**4,852**	**4,726**	**4,456**	**4,062**	**3,505**	**2,916**
Fossil fuels	4,582	4,689	4,457	3,897	2,997	2,069	1,477
Biomass	91	116	151	211	385	517	497
Solar collectors	24	25	63	171	363	453	414
Geothermal	9	22	54	178	316	466	528
Fuel cell (hydrogen)	0	0	0	0	0	0	0
RES share (including RES electricity)	**2.6%**	**3.4%**	**5.7%**	**12.6%**	**26.2%**	**41.0%**	**49.4%**
'Efficiency' savings (compared to Ref.)		**92**	**327**	**508**	**742**	**1,064**	**1,384**

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

table 20: CO_2 emissions

MILL t/a

	2005	2010	2015	2020	2030	2040	2050
Condensation power plants	**467**	**380**	**351**	**315**	**271**	**182**	**95**
Coal	262.9	172.0	159.2	133.1	112.7	56.6	4.7
Lignite	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gas	121.4	129.8	129.0	128.5	124.7	107.0	85.5
Oil	79.6	77.2	62.0	53.5	33.3	18.6	5.1
Diesel	2.7	1.2	0.3	0.0	0.0	0.0	0.0
Combined heat & power production	**0**	**3**	**7**	**13**	**22**	**25**	**25**
Coal	0	0	0	0	0	0	0
Lignite	0	0	0	0	0	0	0
Gas	0	3	7	13	21	25	25
Oil	0	0	0	0	0	0	0
CO_2 emissions electricity & steam generation	**467**	**383**	**358**	**328**	**292**	**207**	**121**
Coal	263	172	159	133	113	57	5
Lignite	0	0	0	0	0	0	0
Gas	121	133	136	141	146	132	111
Oil & diesel	82	79	63	54	34	19	5
CO_2 emissions by sector	**1,135**	**1,061**	**982**	**839**	**681**	**463**	**262**
% of 2000 emissions	100%	93%	86%	74%	60%	41%	23%
Industry	201	204	194	173	151	121	95
Other sectors	191	187	170	138	85	45	24
Transport	276	285	260	202	160	102	36
Electricity & steam generation	467	381	353	319	277	192	108
District heating	1	4	5	8	7	3	0
Population (Mill.)	127.9	128	127	124	118	111	103
CO_2 emissions per capita (t/capita)	**8.9**	**8.3**	**7.8**	**6.7**	**5.8**	**4.2**	**2.6**
Efficiency' savings (compared to Ref.)	**0.0**	**103.6**	**160.6**	**230.4**	**339.3**	**556.6**	**781.3**

The numbers provided in the table are the data from the model. The estimation for the 2003 CO_2 emissions is 2.7% below the Government's figure for the same year (31.17 Mill t/a). For consistency, we have corrected the figures accordingly and used these to estimate the CO_2 emission reductions.

table 21: final energy demand

PJ/a

	2005	2010	2015	2020	2030	2040	2050
Total (incl. non energy use)	**14,751**	**15,048**	**14,699**	**13,679**	**12,330**	**10,398**	**8,287**
Total (energy use)	**13,023**	**13,365**	**13,061**	**12,084**	**10,818**	**8,966**	**6,929**
Transport	**3,894**	**4,061**	**3,867**	**3,320**	**2,843**	**2,086**	**1,161**
Oil products	3,826	3,944	3,612	2,862	2,310	1,512	505
Natural gas	0	18	34	43	61	62	44
Biofuels	0	17	126	304	318	355	407
Electricity	69	83	94	111	154	158	205
RES electricity	6.6	10	14	23	49	72	124
Hydrogen	0	0	0	0	0	0	0
RES share Transport	0.2%	0.7%	3.8%	10.2%	13.6%	21.6%	35.1%
Industry	**4,056**	**4,167**	**4,164**	**3,974**	**3,738**	**3,341**	**2,922**
Electricity	1,253	1,270	1,317	1,289	1,214	1,081	945
RES electricity	*120*	150	189	264	386	492	572
District heat	0	24	54	107	210	251	271
RES district heat	0	5	8	27	81	139	180
Coal	536	597	471	321	208	143	75
Oil products	1,381	1,385	1,312	1,162	957	680	537
Gas	682	771	861	884	865	809	691
Solar	0	12	27	57	106	123	133
Biomass and waste	105	102	112	122	129	159	156
Geothermal	0	6	11	31	50	95	115
RES share Industry	**5.6%**	**6.6%**	**8.3%**	**12.6%**	**20.1%**	**30.1%**	**39.5%**
Other sectors	**5,073**	**5,137**	**5,031**	**4,790**	**4,237**	**3,539**	**2,846**
Electricity	2,226	2,251	2,296	2,303	2,187	1,943	1,664
RES electricity	*213*	265	330	472	696	884	1,007
District heat	26	93	149	227	356	450	421
RES district heat	*7*	25	45	81	193	318	313
Coal	27	3	0	0	0	0	0
Oil products	1,820	1,700	1,519	1,164	674	350	187
Gas	940	1,055	988	861	565	275	120
Solar	24	12	34	104	210	231	205
Biomass and waste	2	9	17	23	85	114	92
Geothermal	9	13	29	108	159	176	158
RES share Other Sectors	**5.0%**	**6.3%**	**9.0%**	**16.4%**	**31.7%**	**48.7%**	**62.3%**
Total RES	**488**	**628**	**947**	**1,627**	**2,483**	**3,180**	**3,336**
RES share	**3.3%**	**4.2%**	**6.4%**	**11.9%**	**20.1%**	**30.6%**	**40.2%**
Non energy use	**1,782**	**1,683**	**1,638**	**1,595**	**1,512**	**1,433**	**1,358**
Oil	1,697	1,652	1,608	1,565	1,482	1,404	1,330
Gas	15	15	14	14	14	14	13
Coal	16	16	16	16	15	15	15

energy [r]evolution

GREENPEACE

Greenpeace is a global organisation that uses non-violent direct action to tackle the most crucial threats to our planet's biodiversity and environment. Greenpeace is a non-profit organisation, present in 40 countries across Europe, the Americas, Asia and the Pacific. It speaks for 2.8 million supporters worldwide, and inspires many millions more to take action every day. To maintain its independence, Greenpeace does not accept donations from governments or corporations but relies on contributions from individual supporters and foundation grants.

Greenpeace has been campaigning against environmental degradation since 1971 when a small boat of volunteers and journalists sailed into Amchitka, an area west of Alaska, where the US Government was conducting underground nuclear tests. This tradition of 'bearing witness' in a non-violent manner continues today, and ships are an important part of all its campaign work.

greenpeace japan
NF building 2F 8-13-11 Nishi-Shinjuku, Shinjuku, Tokyo, Japan
t +81 3 5338 9800 f +81 3 5338 9817
manami.suzuki@greenpeace.org
www.greenpeace.or.jp

EREC

european renewable energy council - [EREC]
EREC is an umbrella organisation of the leading European renewable energy industry, trade and research associations active in the sectors of photovoltaic, wind energy, small hydropower, biomass, geothermal energy and solar thermal:

AEBIOM (European Biomass Association)
EGEC (European Geothermal Energy Council)
EPIA (European Photovoltaic Industry Association)
ESHA (European Small Hydropower Association)
ESTIF (European Solar Thermal Industry Federation)
EUBIA (European Biomass Industry Association)
EWEA (European Wind Energy Association)
EUREC Agency (European Association of Renewable Energy Research Centers)

EREC represents the European renewable energy industry which has an annual €20 billion turnover. It provides jobs to around 300,000 people!

EREC european renewable energy council
Renewable Energy House, 63-65 rue d'Arlon,
B-1040 Brussels, Belgium
t +32 2 546 1933 f+32 2 546 1934
erec@erec.org
www.erec.org

image ICE FLOES ON THE SNOW COVERED LAKE BAIKAL, RUSSIA, IN THE SUN.