energy [r]evolution

A SUSTAINABLE WORLD ENERGY OUTLOOK

EREC
EUROPEAN RENEWABLE ENERGY COUNCIL

GREENPEACE

report global energy scenario

energy [r]evolution

Greenpeace International, European Renewable Energy Council (EREC)

date January 2007

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

Regional Partners: OECD North America WorldWatch Institute: Janet Sawin, Freyr Sverrisson; GP USA: John Coeguyt **Latin America** University of Sao Paulo: Ricardo J. Fujii, Prof. Dr. Stefan Krauter; GP Brazil: Marcelo Furtado **OECD Europe** EREC: Oliver Schäfer, Arthouros Zervos **Transition Economies** Vladimir Tchouprov **Africa & Middle East** Reference Project: "Trans-Mediterranean Interconnection for Concentrating Solar Power" 2006, Dr. Franz Trieb; GP Mediterranean: Nili Grossmann **South Asia** Rangan Banerjee, Bangalore, India; GP India: Srinivas Kumar **East Asia** ISEP-Institute Tokyo: Mika Ohbayashi; GP South East Asia: Jaspar Inventor, Tara Buakamsri **China** Prof. Zhang Xilian, Tsinghua University, Beijing; GP China: Ailun Yang **OECD Pacific** ISEP-Institute Tokyo, Japan: Mika Ohbayashi; Dialog Institute, Wellington, New Zealand: Murray Ellis; GP Australia Pacific: Catherine Fitzpatrick, Mark Wakeham; GP New Zealand: Vanessa Atkinson, Philip Freeman

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

Greenpeace International Gavin Edwards, Sven Teske, Steve Sawyer, Jan van de Putte

global project manager Sven Teske, Greenpeace International

authors Sven Teske, Arthouros Zervos, Oliver Schäfer

editor Crispin Aubrey

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

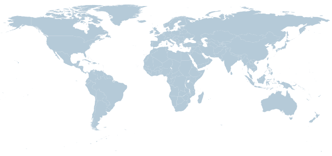
printing PrimaveraQuint, The Netherlands

contact sven.teske@int.greenpeace.org
schaefer@erec.org

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

cover image WIND ENERGY PARK NEAR DAHME. WIND TURBINE IN THE SNOW OPERATED BY VESTAS.
image A SMALL ICE BERG WHICH FLOATS IN THE BAY IN FRONT OF THE THE GREENLANDIC TOWN OF NARSAAQ, SOUTH WEST GREENLAND.

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

"TO ACHIEVE AN ECONOMICALLY ATTRACTIVE GROWTH OF RENEWABLE ENERGY SOURCES, A BALANCED AND TIMELY MOBILISATION OF ALL RENEWABLE ENERGY TECHNOLOGIES IS OF GREAT IMPORTANCE."

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.

The good news first. Renewable energy, combined with the smart use of energy, can deliver half of the world's energy needs by 2050. This new report, 'Energy [R]evolution: A sustainable World Energy Outlook', shows that it is economically feasible to cut global CO_2 emissions by almost 50% within the next 43 years. It also concludes that a massive uptake of renewable energy sources is technically possible. All that is missing is the right policy support.

The bad news is that time is running out. An overwhelming consensus of scientific opinion now agrees that climate change is happening, is caused in large part by human activities (such as burning fossil fuels), and if left un-checked, will have disastrous consequences. Furthermore, there is solid scientific evidence that we should act now. This is reflected in the conclusions of the Intergovernmental Panel on Climate Change (IPCC), a UN institution of more than 1,000 scientists providing advice to policy makers. Its next report, due for release in 2007, is unlikely to make any better reading.

In response to this threat, the Kyoto Protocol has committed its signatories to reduce their greenhouse gas emissions by 5.2% from their 1990 level by the target period of 2008-2012. This in turn has resulted in the adoption of a series of regional and national reduction targets. In the European Union, for instance, the commitment is to an overall reduction of 8%. In order to reach this target, the EU has also agreed to increase its proportion of renewable energy from 6% to 12% by 2010.

The Kyoto signatories are currently negotiating the second phase of the agreement, covering the period from 2013-2017. Within this timeframe industrialised countries need to reduce their CO_2 emissions by 18% from 1990 levels, and then by 30% between 2018 and 2022. Only with these cuts do we stand a reasonable chance of keeping the average increase in global temperatures to less than 2°C, beyond which the effects of climate change will become catastrophic.

Alongside global warming, other challenges have become just as pressing. Worldwide energy demand is growing at a staggering rate. Over-reliance on energy imports from a few, often politically unstable countries and volatile oil and gas prices have together pushed security of energy supply to the top of the political agenda, as well as threatening to inflict a massive drain on the global economy. But whilst there is a broad consensus that we need to change the way we produce and consume energy, there is still disagreement about how to do this.

global energy scenario

The European Renewable Energy Council (EREC) and Greenpeace International have produced this global energy scenario as a practical blueprint for how to urgently meet CO_2 reduction targets and secure affordable energy supply on the basis of steady worldwide economic development. Both these important aims are possible at the same time. The urgent need for change in the energy sector means that the scenario is based only on proven and sustainable technologies, such as renewable energy sources and efficient decentralised cogeneration. It therefore excludes "CO_2-free coal power plants" and nuclear energy.

Commissioned by Greenpeace and EREC from the Department of Systems Analysis and Technology Assessment (Institute of Technical Thermodynamics) at the German Aerospace Centre (DLR), the report develops a global sustainable energy pathway up to 2050. The future potential for renewable energy sources has been assessed with input from all sectors of the renewable energy industry around the world, and forms the basis of the Energy [R]evolution Scenario.

The energy supply scenarios adopted in this report, which both extend beyond and enhance projections by the International Energy Agency, have been calculated using the MESAP/PlaNet simulation model. This has then been further developed by the Ecofys consultancy to take into account the future potential for energy efficiency measures. The Ecofys study envisages an ambitious overall development path for the exploitation of energy efficiency potential, focused on current best practice as well as technologies available in the future. The result is that under the Energy [R]evolution Scenario, worldwide final energy demand can be reduced by 47% in 2050.

the potential for renewable energy

This report demonstrates that renewable energy is not a dream for the future – it is real, mature and can be deployed on a large scale. Decades of technological progress have seen renewable energy technologies such as wind turbines, solar photovoltaic panels, biomass power plants and solar thermal collectors move steadily into the mainstream. The global market for renewable energy is growing dramatically; in 2006 its turnover was US$ 38 billion, 26% more than the previous year.

The time window for making the shift from fossil fuels to renewable energy is still relatively short. Within the next decade many of the existing power plants in the OECD countries will come to the end of their technical lifetime and will need to be replaced. But a decision taken to construct a coal power plant today will result in the production of CO_2 emissions lasting until 2050. So whatever plans are made by power utilities over the next few years will define the energy supply of the next generation. We strongly believe that this should be the "solar generation".

While the industrialised world urgently needs to rethink its energy strategy, the developing world should learn from past mistakes and build its economies from the beginning on the strong foundation of a sustainable energy supply. A new infrastructure will need to be set up to enable this to happen.

Renewable energy could provide as much as 35% of the world's energy needs by 2030, given the political will to promote its large scale deployment in all sectors on a global level, coupled with far reaching energy efficiency measures. This report stresses that the future of renewable energy development will strongly depend on political choices by both individual governments and the international community.

By choosing renewable energy and energy efficiency, developing countries can virtually stabilise their CO_2 emissions, whilst at the same time increasing energy consumption through economic growth. OECD countries will have to reduce their emissions by up to 80%.

There is no need to "freeze in the dark" for this to happen. Strict technical standards will ensure that only the most efficient fridges, heating systems, computers and vehicles will be on sale. Consumers have a right to buy products that don't increase their energy bills and won't destroy the climate.

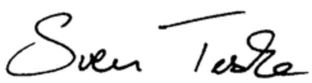
from vision to reality

This report shows that a "business as usual" scenario, based on the IEA's World Energy Outlook projection, is not an option for future generations. CO_2 emissions would almost double by 2050 and the global climate would heat up well over 2°C. This would have catastrophic consequences for the environment, the economy and human society. In addition, it is worth remembering that the former chief economist of the World Bank, Sir Nicholas Stern, in his report clearly pointed out that the ones who invest in energy saving technologies and renewable energies today will be the economic winners of tomorrow. Inaction will be much more expensive in the long run, than taking action now.

We therefore call on decision makers around the world to make this vision a reality. The political choices of the coming years will determine the world's environmental and economic situation for many decades to come. The world cannot afford to stick to the 'conventional' energy development path, relying on fossil fuels, nuclear and other outdated technologies. Renewable energy can and will have to play a leading role in the world's energy future.

For the sake of a sound environment, political stability and thriving economies, now is the time to commit to a truly secure and sustainable energy future – a future built on clean technologies, economic development and the creation of millions of new jobs.

Arthouros Zervos
EUROPEAN RENEWABLE
ENERGY COUNCIL (EREC)
JANUARY 2007



Sven Teske
CLIMATE & ENERGY UNIT
GREENPEACE INTERNATIONAL

executive summary

"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."

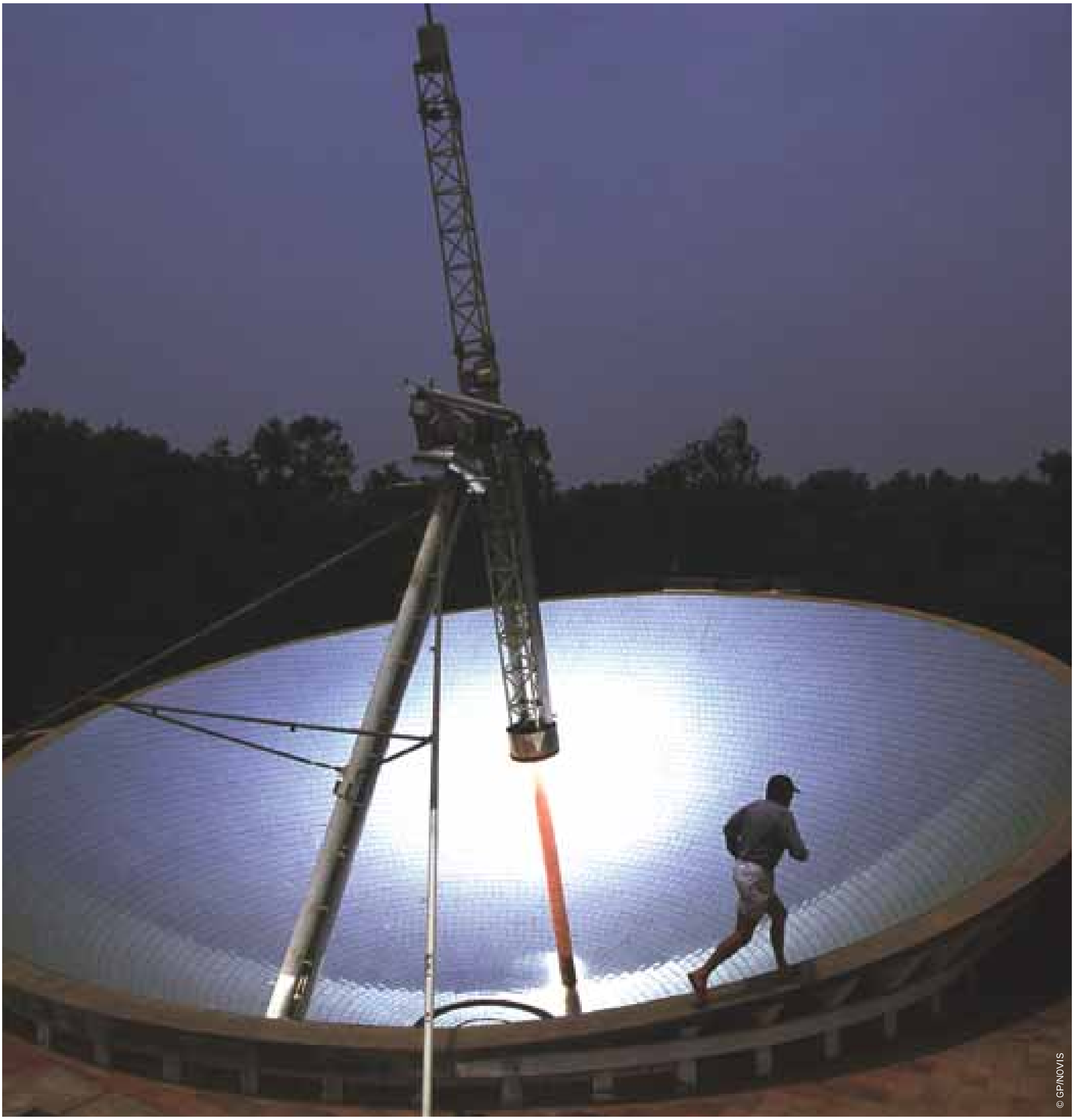


image MAN RUNNING ON THE RIM OF A SOLAR DISH WHICH IS ON TOP OF THE SOLAR KITCHEN AT AUROVILLE, TAMIL NADU, INDIA. THE SOLAR DISH CAPTURES ENOUGH SOLAR ENERGY TO GENERATE HEAT TO COOK FOR 2,000 PEOPLE PER DAY. THE TOWNSHIP OF AUROVILLE WAS CREATED IN 1968 BY PEOPLE FROM OVER 100 DIFFERENT COUNTRIES. AUROVILLE CONCENTRATES ON ACTIVITIES, SUCH AS ENVIRONMENTAL REGENERATION, ORGANIC FARMING, ALTERNATIVE ENERGY, VILLAGE DEVELOPMENT, THEATRE, MUSIC, AND ART.

climate threats and 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.[a] 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 scarcer and more expensive to produce.[b] 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.[c]

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.

The solution to our future energy needs lies in greater use of renewable energy sources for both heat and power. Nuclear power is not the solution as it poses multiple threats to people and the environment. 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 eliminated in this analysis.

references
a KOVATS, R.S., AND HAINES, A., "GLOBAL CLIMATE CHANGE AND HEALTH: RECENT FINDINGS AND FUTURE STEPS" CMAJ [CANADIAN MEDICAL ASSOCIATION JOURNAL] O FEB. 15, 2005; 172 (4).
b PLUGGING THE GAP, RES/GWEC 2006.
c DR NITSCH ET AL.

the energy [r]evolution

The climate change imperative demands nothing short of an energy revolution. 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.

Two scenarios up to the year 2050 are outlined in this report. The reference scenario is based on the business as usual scenario published by the International Energy Agency in World Energy Outlook 2004, extrapolated forward from 2030. Compared to the 2004 IEA projections, the new World Energy Outlook 2006 assumes a slightly higher average annual growth rate of world GDP of 3.4%, instead of 3.2%, for the 2004-2030 time horizon. At the same time, WEO 2006 expects final energy consumption in 2030 to be 4% higher than in WEO 2004. A sensitivity analysis on the impact of economic growth on energy demand under the Energy [R]evolution Scenario shows that an increase of average world GDP of 0.1% (over the time period 2003-2050) leads to an increase in final energy demand of about 0.2%.

The Energy [R]evolution Scenario has a target for the reduction of worldwide emissions by 50% below 1990 levels by 2050, with per capita carbon dioxide emissions reduced to less than 1.3 tonnes per year in order for the increase in global temperature to remain under +2°C. A second objective is to show that this is even possible with 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, cost-effective renewable energy sources are accessed for both heat and electricity generation, as well as the production of biofuels.

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 435,000 PJ/a (Peta Joules per year) to 422,000 PJ/a by 2050. Under the reference scenario there would be an increase to 810,000 PJ/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 7,100 GW 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.

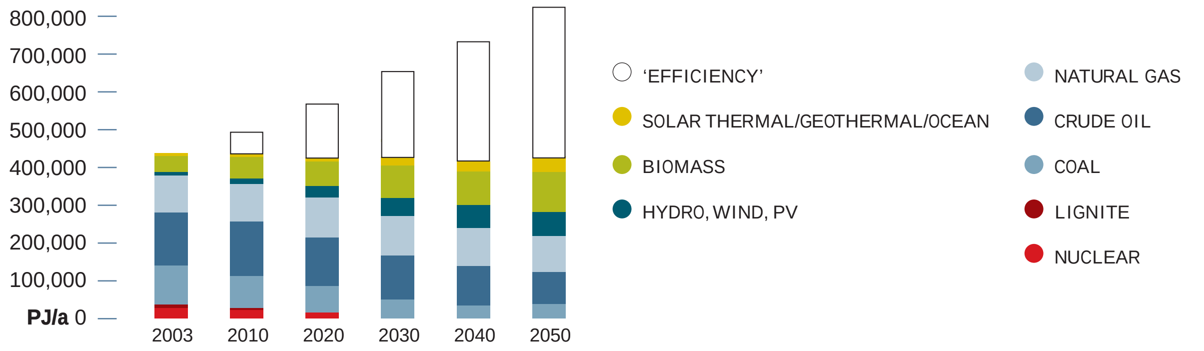
costs

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 bn 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

figure 1: development of primary energy consumption under the energy [r]evolution scenario
('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)



climate protection

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

1

the greenhouse effect and climate change

The greenhouse effect is the process by which the atmosphere traps some of the sun's energy, warming the earth and moderating our climate. A human-driven increase in 'greenhouse gases' is increasing this effect artificially, raising global temperatures and disrupting our climate. These greenhouse gases include carbon dioxide, produced by burning fossil fuels and through deforestation, methane, released fromagriculture, animals and landfill sites, and nitrous oxide, resulting from agricultural production plus a variety of industrial chemicals.

Every day we damage our climate by using fossil fuels (oil, coal and gas) for energy and transport. As a result, climate change is already impacting on our lives, and is expected to destroy the livelihoods of many people in the developing world, as well as ecosystems and species, in the coming decades. We therefore need to significantly reduce our greenhouse gas emissions. This makes both environmental and economic sense.

figure 2: the greenhouse effect

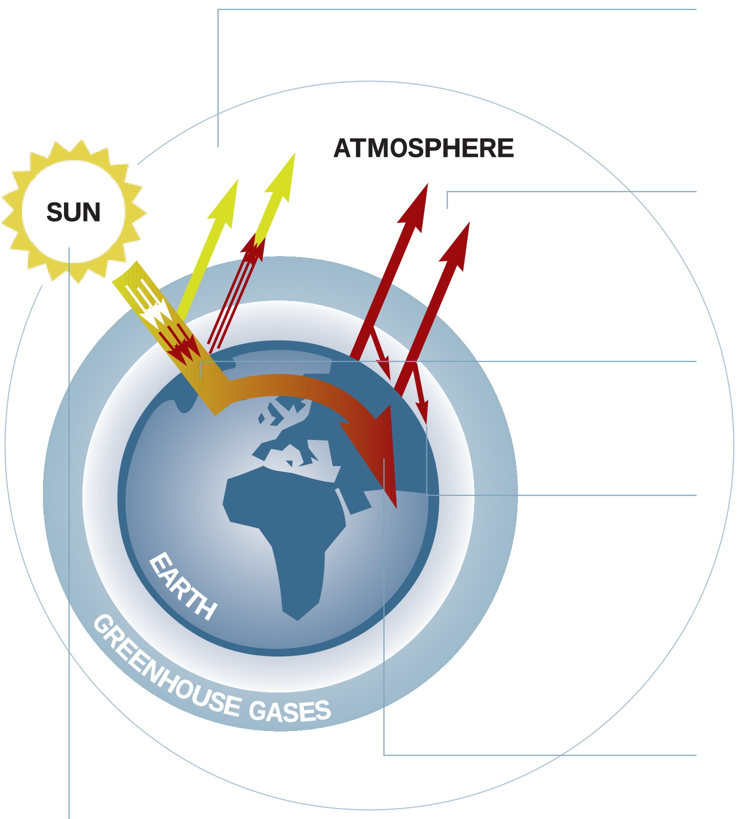


table 1: top 10 warmest years between 1850 and 2005

COMPARED TO MEAN GLOBAL TEMPERATURE 1880-2003

YEAR	GLOBAL TEMPERATURE ANOMALY	RANK
1998, 2005	+0.63°C	1
2003	+0.56°C	2 (tie)
2002	+0.56°C	2 (tie)
2004	+0.54°C	4
2001	+0.51°C	5
1997	+0.47°C	6
1995	+0.40°C	7 (tie)
1990	+0.40°C	7 (tie)
1999	+0.38°C	9
2000	+0.37°C	10

source NATIONAL CLIMATIC DATA CENTER

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.

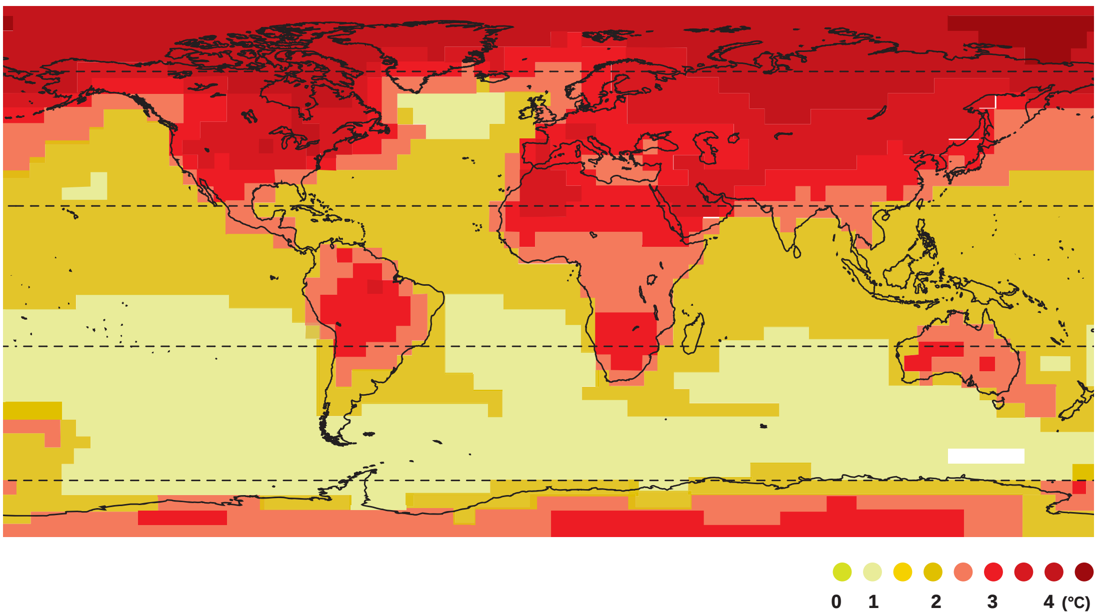
this is a summary of some likely effects if we allow current trends to continue:

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.

figure 3: mean surface temperature distribution for a global temperature increase of 2°C

+2°C AVERAGE



note EMPLOYED LINEAR PATTERN SCALING METHOD AS IMPLEMENTED IN THE SCENGEN MODEL (BY WIGLEY ET AL.). THE DISPLAYED PATTERN IS THE AVERAGE OF THE DEFAULT SET OF MODELS, NAMELY CSM (1998), ECHAM3 (1995), ECHAM4 (1998), GFDL (1990), HADAM2 (1995), HADAM3 (2000). THE PATTERN HAS BEEN DERIVED FOR A TEMPERATURE INCREASE OF 2°C ABOVE 1990 IN A TRANSIENT RUN WITH EMISSION SCENARIO IPCC SRES B2. NOTE THAT THE EQUILIBRIUM TEMPERATURE PATTERN FOR A 2°C INCREASE ABOVE PRE-INDUSTRIAL LEVELS WILL BE QUANTITATIVELY DIFFERENT, ALTHOUGH QUALITATIVELY SIMILAR.
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images 1. OYSTER FISHERMAN IOAN MIOC IN THE SMALL VILLAGE OF BURAS RETURNS BACK 21 DAYS AFTER THE HURRICANE KATRINA. HE FINDS HIS HOUSE, AS SO MANY OTHERS, DESTROYED AND PARTIALLY SUBMERGED IN MUD AND CONTAMINATED WATERS. **2.** A FAMILY LIVING NEXT TO THE SEA BUILD A SEA WALL FROM SAND BAGS IN AN ATTEMPT TO PROTECT THEIR PROPERTY FROM UNUSUAL HIGH TIDES CAUSED BY THE 'KING TIDES'. GREENPEACE AND SCIENTISTS ARE CONCERNED THAT LOW LYING ISLANDS FACE PERMANENT INUNDATION FROM RISING SEAS DUE TO CLIMATE CHANGE. **3.** 30TH OCTOBER 2006 - NONTHABURI, THAILAND - VILLAGERS PADDLE A BOAT AT A VILLAGE IN KOH KRED ISLAND WHICH WAS ENGULFED BY RECENT FLOODING. KOH KRED IS A TINY ISLAND IN THE CHAO PHRAYA RIVER, LOCATED IN NONTHABURI PROVINCE OUTSKIRT OF BANGKOK. EARLIER IN THE YEAR, SCIENTISTS WARNED THAT THAILAND WOULD EXPERIENCE MORE FREQUENT EXTREME WEATHER EVENTS DUE TO THE IMPACTS OF CLIMATE CHANGE. **5.** THOUSANDS OF FISH DIE AT THE DRY RIVER BED OF MANAQUIRI LAKE, 150 KILOMETERS FROM AMAZONAS STATE CAPITOL MANAUS, BRAZIL.

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 mean 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.

kyoto protocol

Recognising these threats the signatories to the 1992 UN Framework Convention on Climate Change - agreed the Kyoto Protocol in 1997. The Kyoto Protocol finally entered into force in early 2005 and its 165 member countries meet twice annually to negotiate further refinement and development of the agreement. Only two major industrialised nations, the United States and Australia, have not ratified Kyoto.

The Kyoto Protocol commits its signatories to reduce their greenhouse gas emissions by 5.2% from their 1990 level by the target period of 2008-2012. This has in turn resulted in the adoption of a series of regional and national reduction targets. In the European Union, for instance, the commitment is to an overall reduction of 8%. In order to reach this target, the EU has also agreed a target to increase its proportion of renewable energy from 6% to 12% by 2010.

At present, the Kyoto countries are negotiating the second phase of the agreement, covering the period from 2013-2017. Greenpeace is calling for industrialised country emissions to be reduced by 18% from 1990 levels for this second commitment period, and by 30% by the third period covering 2018-2022. Only with these cuts do we stand a reasonable chance of meeting the 2°C target.

The Kyoto Protocol's architecture relies fundamentally on legally binding emissions reduction obligations. To achieve these targets, 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 US pulled out in early 2001, negotiators are running out of time. This is a crucial year because countries must agree a firm negotiating mandate at the next meeting in Indonesia in December 2007, in order that the second commitment period of the Kyoto Protocol can be agreed in 2008 or 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.

nuclear threats

"THE RISK OF NUCLEAR ACCIDENTS, THE PRODUCTION OF HIGHLY RADIOACTIVE WASTE AND THE THREAT OF PROLIFERATING NUCLEAR WEAPONS ARE ONLY A FEW REASONS WHY NUCLEAR POWER NEEDS TO BE PHASED OUT."

2

image IRAQ 17 JUNE 2003. GREENPEACE ACTIVISTS MAKE MEASURMENTS OUTSIDE THE AL-MAJIDAT SCHOOL FOR GIRLS (900 PUPILS) NEXT TO AL-TOUWAITHA NUCLEAR FACILITY. HAVING FOUND LEVELS OF RADIOACTIVITY 3.000 TIMES HIGHER THAN BACKGROUND LEVEL THEY CORDONNED THE AREA OFF.

figure 4: end nuclear threats - from mining to waste storage

U#92

1. uranium mining

Uranium, used in nuclear power plants, is extracted from huge mines in Canada, Australia, Russia and Nigeria. Mine workers can breathe in radioactive gas from which they are in danger of contracting lung cancer. Uranium mining produces huge quantities of mining debris, including radioactive particles which can contaminate surface water and food.

2. uranium enrichment

Natural uranium and concentrated 'yellow cake' contain just 0.7% of fissionable uranium 235. To use the material in a nuclear reactor, the share must go up to 3 or 5 %. This process can be carried out in 16 facilities around the world. 80% of the total volume ends up as 'tails', a waste product. Enrichment generates massive amounts of 'depleted uranium' that ends up as long-lived radioactive waste or is used in weapons or as tank shielding.

3. fuel rod – production

Enriched material is converted into uranium dioxide and compressed to pellets in fuel rod production facilities. These pellets fill 4m long tubes called fuel rods. There are 29 fuel rod production facilities globally. The worst accident in this type of facility happened in September 1999 in Tokaimura, Japan, when two workers died. Several hundred workers and villagers have suffered radioactive contamination.

4. power plant operation

Uranium nuclei are split in a nuclear reactor, releasing energy which heats up water. The compressed steam is converted in a turbine generator into electricity. This process creates a radioactive 'cocktail' which involves more than 100 products. One of these is the highly toxic and long-lasting plutonium. Radioactive material can enter the environment through accidents at nuclear power plants. The worst accident to date happened at Chernobyl in the then Soviet Union in 1986. A nuclear reactor generates enough plutonium every year for the production of as many as 39 nuclear weapons.

5. reprocessing

Reprocessing involves the chemical extraction of contaminated uranium and plutonium from used reactor fuel rods. There are now over 230,000 kilograms of plutonium stockpiled around the world from reprocessing – five kilograms is sufficient for one nuclear bomb. Reprocessing is not the same as recycling: the volume of waste increases many tens of times and millions of litres of radioactive waste are discharged into the sea and air each day. The process also demands the transport of radioactive material and nuclear waste by ship, rail, air and road around the world. An accident or terrorist attack could release vast quantities of nuclear material into the environment. There is no way to guarantee the safety of nuclear transport.

6. waste storage

There is not a single final storage facility for nuclear waste available anywhere in the world. Safe secure storage of high level waste over thousands of years remains unproven, leaving a deadly legacy for future generations. Despite this the nuclear industry continues to generate more and more waste each day.

nuclear threats

There are multiple threats to people and the environment from nuclear operations. The main risks are:

- Nuclear Proliferation
- Nuclear Waste
- Safety Risks

Together these explain why it has been discounted as a future technology in the energy [r]evolution scenario.

nuclear proliferation

Manufacturing a nuclear bomb requires fissile material - either uranium-235 or plutonium-239. Most nuclear reactors use uranium as a fuel and produce plutonium during their operation. It is impossible to adequately protect a large reprocessing plant to prevent the diversion of plutonium to nuclear weapons. A small-scale plutonium separation plant can be built in four to six months, so any country with an ordinary reactor can produce nuclear weapons relatively quickly.

The result is that nuclear power and nuclear weapons have grown up like Siamese twins. Since international controls on nuclear proliferation began, Israel, India, Pakistan and North Korea have all obtained nuclear weapons, demonstrating the link between civil and military nuclear power. Both the International Atomic Energy Agency (IAEA) and the Nuclear Non-proliferation Treaty (NPT) embody an inherent contradiction - seeking to promote the development of 'peaceful' nuclear power whilst at the same time trying to stop the spread of nuclear weapons.

Israel, India, and Pakistan used their civil nuclear operations to develop weapons capability, operating outside international safeguards. North Korea developed a nuclear weapon even as a signatory of the NPT. A major challenge to nuclear proliferation controls has been the spread of uranium enrichment technology to Iran, Libya and North Korea. The Director General of the International Atomic Energy Agency, Mohamed ElBaradei, has said that "should a state with a fully developed fuel-cycle capability decide, for whatever reason, to break away from its non-proliferation commitments, most experts believe it could produce a nuclear weapon within a matter of months[1]."

The United Nations Intergovernmental Panel on Climate Change has also warned that the security threat of trying to tackle climate change with a global fast reactor programme (using plutonium fuel) "would be colossal"[2]. Even without fast reactors, all of the reactor designs currently being promoted around the world could be fuelled by MOX (mixed oxide fuel), from which plutonium can be easily separated.

Restricting the production of fissile material to a few 'trusted' countries will not work. It will engender resentment and create a colossal security threat. A new UN agency is needed to tackle the twin threats of climate change and nuclear proliferation by phasing out nuclear power and promoting sustainable energy, in the process promoting world peace rather than threatening it.

nuclear waste

The nuclear industry claims it can 'dispose' of its nuclear waste by burying it deep underground, but this will not isolate the radioactive material from the environment forever. A deep dump only slows down the release of radioactivity into the environment. The industry tries to predict how fast a dump will leak so that it can claim that radiation doses to the public living nearby in the future will be "acceptably low". But scientific understanding is not sufficiently advanced to make such predictions with any certainty.

As part of its campaign to build new nuclear stations around the world, the industry claims that problems associated with burying nuclear waste are to do with public acceptability rather than technical issues. The industry often points to nuclear dumping proposals in Finland, Sweden or the United States to underline its point.

The most hazardous waste is the highly radioactive waste (or spent) fuel removed from nuclear reactors, which stays radioactive for hundreds of thousands of years. In some countries the situation is exacerbated by 'reprocessing' this spent fuel – which involves dissolving it in nitric acid to separate out weapons-usable plutonium. This process leaves behind a highly radioactive liquid waste. There are about 270,000 tonnes of spent nuclear waste fuel in storage, much of it at reactor sites. Spent fuel is accumulating at around 12,000 tonnes per year, with around a quarter of that going for reprocessing[3]. No country in the world has a solution for high level waste.

The least damaging option for waste already created at the current time is to store it above ground, in dry storage at the site of origin, although this option also presents major challenges and threats. The only real solution is to stop producing the waste.

safety risks

Windscale (1957), Three Mile Island (1979), Chernobyl (1986) and Tokaimura (1999) are only a few of the hundreds of nuclear accidents which have occurred to date.

A recent simple power failure at a Swedish nuclear plant highlighted our vulnerability to nuclear catastrophe. As a result, Sweden shut down four of its 10 nuclear plants after faults were discovered. Emergency power systems at the Forsmark plant failed for 20 minutes during a power cut. If power was not restored there could have been a major incident within hours. A former director of the plant later said that "it was pure luck there wasn't a meltdown". The closure of the plants removed at a stroke roughly 20% of Sweden's electricity supply.

A nuclear chain reaction must be kept under control, and harmful radiation must, as far as possible, be contained within the reactor, with radioactive products isolated from humans and carefully managed. Nuclear reactions generate high temperatures, and fluids used for cooling are often kept under pressure. Together with the intense radioactivity, these high temperatures and pressures make operating a reactor a difficult and complex task.

The risks from operating reactors are increasing and the likelihood of an accident is now higher than ever. Most of the world's reactors are more than 20 years old and therefore more prone to age related failures. Many utilities are attempting to extend their life from the 40 years or so they were originally designed for to around 60 years, posing new risks.

De-regulation has meanwhile pushed nuclear utilities to decrease safety-related investments and limit staff whilst increasing reactor pressure and operational temperature and the burn-up of the fuel. This accelerates ageing and decreases safety margins. Nuclear regulators are not always able to fully cope with this new regime.

New so-called passively safe reactors have many safety systems replaced by 'natural' processes, such as gravity fed emergency cooling water and air cooling. This can make them more vulnerable to terrorist attack.

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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."

3

The climate change imperative demands nothing short of an energy [r]evolution. 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 [r]evolution therefore, there 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.

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.

> "THE STONE AGE DID NOT END FOR LACK OF STONE, AND THE OIL AGE WILL END LONG BEFORE THE WORLD RUNS OUT OF OIL."
>
> ***Sheikh Zaki Yamani, former Saudi Arabian oil minister***

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

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[4].

reference
4 IEA; WORLD ENERGY OUTLOOK 2004

use the current "time window"

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.

infrastructure changes

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 appreciate 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, trigeneration, 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.

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.

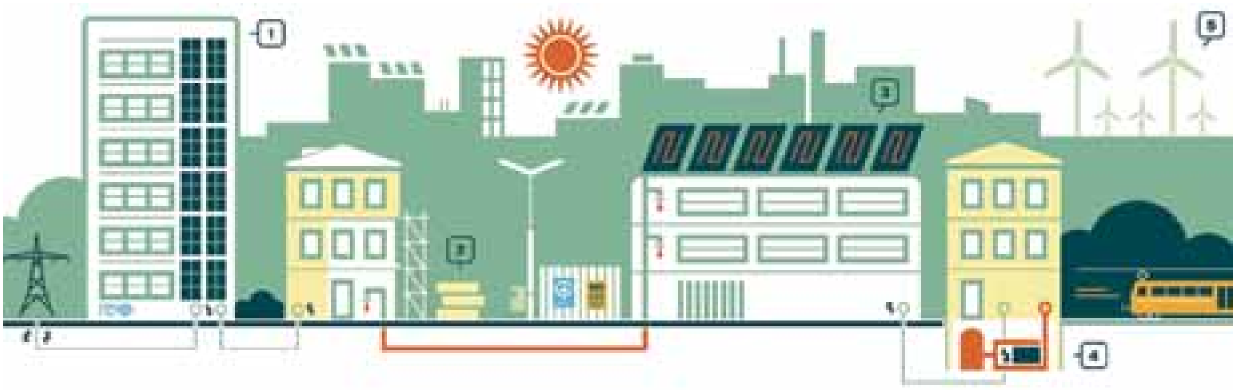
scenario principles in a nutshell

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

figure 5: 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 FASCADE 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.

suburbs

1. PHOTOVOLTAIC
2. MINI-COGENERATION POWER PLANT = COMBINED HEAT AND POWER [CHP]
3. SOLAR COLLECTORS (HEATING)
4. LOW-ENERGY BUILDINGS
5. GEOTHERMAL HEAT- AND POWER PLANT[CHP]

optimised integration of renewable energy

Modification of the energy system will be necessary to accommodate the significantly higher shares of renewable energy expected under the energy [r]evolution scenario. This is not unlike what happened in the 1970s and 1980s, when most of the centralised power plants now operating were constructed in OECD countries. New high voltage power lines were built, night storage heaters marketed and large electric-powered hot water boilers installed in order to sell the electricity produced by nuclear and coal-fired plants at night.

Several OECD countries have demonstrated that it is possible to smoothly integrate a large proportion of decentralised energy including variable sources such as wind. A good example is Denmark, which has the highest percentage of combined heat and power generation and wind power in Europe. With strong political support, 50% of electricity and 80% of district heat is now supplied by cogeneration plants. The contribution of wind power has reached more than 18% of Danish electricity demand. Under some conditions, electricity generation from cogeneration and wind turbines even exceeds demand. The load compensation required for grid stability in Denmark is managed both through regulating the capacity of the few large power stations and through import and export to neighbouring countries. A three tier tariff system enables balancing of power generation from the decentralised power plants with electricity consumption on a daily basis.

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

appropriate power station mix The power supply in OECD countries is mostly generated by coal and - in some cases - nuclear power stations, which are difficult to regulate. Modern gas power stations, by contrast, are not only highly efficient but easier and faster to regulate and thus better able to compensate for fluctuating loads. Coal and nuclear power stations have lower fuel and operation costs but comparably high investment costs. They must therefore run round-the-clock as "base load" in order to earn back their investment. Gas power stations have lower investment costs and are profitable even at low output, making them better suited to balancing out the variations in supply from renewable energy sources.

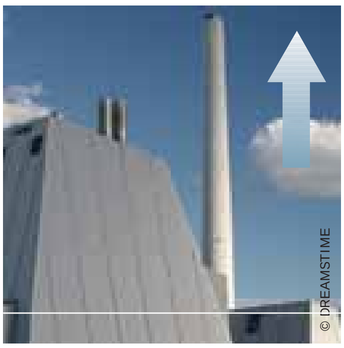
load management The level and timing of demand for electricity can be managed by providing consumers with financial incentives to reduce or shut off their supply at periods of peak consumption. Control technology can be used to manage the arrangement. This system is already used for some large industrial customers. A Norwegian power supplier even involves private household customers by sending them a text message with a signal to shut down. Each household can decide in advance whether or not they want to participate. In Germany, experiments are being conducted with time flexible tariffs so that washing machines operate at night and refrigerators turn off temporarily during periods of high demand.

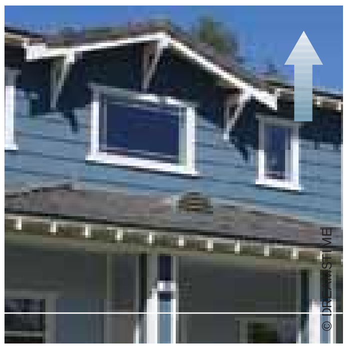
figure 6: centralised energy infrastructures waste more than two thirds of their energy

61.5 units
LOST THROUGH INEFFICIENT GENERATION AND HEAT WASTAGE

3.5 units
LOST THROUGH TRANSMISSION AND DISTRIBUTION

13 units
WASTED THROUGH INEFFICIENT END USE





100 units >>
ENERGY WITHIN FOSSIL FUEL

38.5 units >>
OF ENERGY FED TO NATIONAL GRID

35 units >>
OF ENERGY SUPPLIED

22 units
OF ENERGY ACTUALLY UTILISED

This type of load management has been simplified by advances in communications technology. In Italy, for example, 30 million innovative electricity counters have been installed to allow remote meter reading and control of consumer and service information. Many household electrical products or systems, such as refrigerators, dishwashers, washing machines, storage heaters, water pumps and air conditioning, can be managed either by temporary shut-off or by rescheduling their time of operation, thus freeing up electricity load for other uses.

generation management Renewable electricity generation systems can also be involved in load optimisation. Wind farms, for example, can be temporarily switched off when too much power is available on the network.

energy storage Another method of balancing out electricity supply and demand is through intermediate storage. This storage can be decentralised, for example in batteries, or centralised. So far, pumped storage hydropower stations have been the main method of storing large amounts of electric power. In a pumped storage system, energy from power generation is stored in a lake and then allowed to flow back when required, driving turbines and generating electricity. 280 such pumped storage plants exist worldwide. They already provide an important contribution to security of supply, but their operation could be better adjusted to the requirements of a future renewable energy system.

In the long term, other storage solutions are beginning to emerge. One promising solution besides the use of hydrogen is the use of compressed air. In these systems, electricity is used to compress air into deep salt domes 600 metres underground and at pressures of up to 70 bar. At peak times, when electricity demand is high, the air is allowed to flow back out of the cavern and drive a turbine. Although this system, known as CAES (Compressed Air Energy Storage) currently still requires fossil fuel auxiliary power, a so-called "adiabatic" plant is being developed which does not. To achieve this, the heat from the compressed air is intermediately stored in a giant heat store. Such a power station can achieve a storage efficiency of 70%.

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

the "virtual power station"

The rapid development of information technologies is helping to pave the way for a decentralised energy supply based on cogeneration plants, renewable energy systems and conventional power stations. Manufacturers of small cogeneration plants already offer internet interfaces which enable remote control of the system. It is now possible for individual householders to control their electricity and heat usage so that expensive electricity drawn from the grid can be minimised - and the electricity demand profile is smoothed. This is part of the trend towards the "smart house" where its mini cogeneration plant becomes an energy management centre. We can go one step further than this with a "virtual power station". Virtual does not mean that the power station does not produce real electricity. It refers to the fact that there is no large, spatially located power house with turbines and generators. The hub of the virtual power station is a control unit which processes data from many decentralised power stations, compares them with predictions of power demand, generation and weather conditions, retrieves the prevailing power market prices and then intelligently optimises the overall power station activity.Some public utilities already use such systems, integrating cogeneration plants, wind farms, photovoltaic systems and other power plants. The virtual power station can also link consumers into the management process.

future power grids

The **power grid network** must also change in order to realise decentralised structures with a high share of renewable energy. Whereas today's grids are designed to transport power from a few centralised power stations out to the consumers, a future system must be more versatile. Large power stations will feed electricity into the high voltage grid but small decentralised systems such as solar, cogeneration and wind plants will deliver their power into the low or medium voltage grid. In order to transport electricity from renewable generation such as offshore wind farms in remote areas, a limited number of new high voltage transmission lines will also need to be constructed. These power lines will also be available for cross-border power trade. Within the energy [r]evolution scenario, the share of variable renewable energy sources is expected to reach about 30% of total electricity demand by 2020 and about 40% by 2050.

rural electrification[5]

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

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

The Millennium Development Goal of halving global poverty by 2015 will not be reached without energy to increase production, income and education, create jobs and reduce the daily grind involved in having to just survive. Halving hunger will not come about without energy for more productive growing, harvesting, processing and marketing of food. Improving health and reducing death rates will not happen without energy for the refrigeration needed for clinics, hospitals and vaccination campaigns. The world's greatest child killer, acute respiratory infection, will not be tackled without dealing with smoke from cooking fires in the home. Children will not study at night without light in their homes. Clean water will not be pumped or treated without energy.

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

the role of sustainable, clean renewable energy

To achieve the dramatic emissions cuts needed to avoid climate change – in the order of 80% in OECD countries by 2050 – will require a massive uptake of renewable energy. The targets for renewable energy must be greatly expanded in industrialised countries both to substitute for fossil fuel and nuclear generation and to create the necessary economies of scale necessary for global expansion. Within the energy [r]evolution scenario we assume that modern renewable energy sources, such as solar collectors, solar cookers and modern forms of bio energy, will replace inefficient, traditional biomass use.

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

reference
5 SUSTAINABLE ENERGY FOR POVERTY REDUCTION: AN ACTION PLAN, IT-POWER, GREENPEACE INTERNATIONAL SEPTEMBER 2002

scenarios for a future energy supply

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

4

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)[6]. 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 11 Gigatonnes per year by 2050 in order for the increase in global temperature to remain under +2°C. A second objective is to show that this is even possible with 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, cost-effective renewable energy sources are accessed for both heat and electricity generation as well as the production of biofuels. The general framework parameters for population and GDP growth remain unchanged from the reference scenario.

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.

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 a similar study by DLR covering the EU-25 countries[7]. 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 sectoral 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.

main scenario assumptions

Development of a global energy scenario requires the use of a multi-region model in order to reflect the significant structural differences between energy supply systems. The International Energy Association's breakdown of world regions, as used in the ongoing series of World Energy Outlook reports, has been chosen because the IEA also provides the most comprehensive global energy statistics. The list of countries covered by each of the ten world regions in the IEA's breakdown is shown in Figure 7.

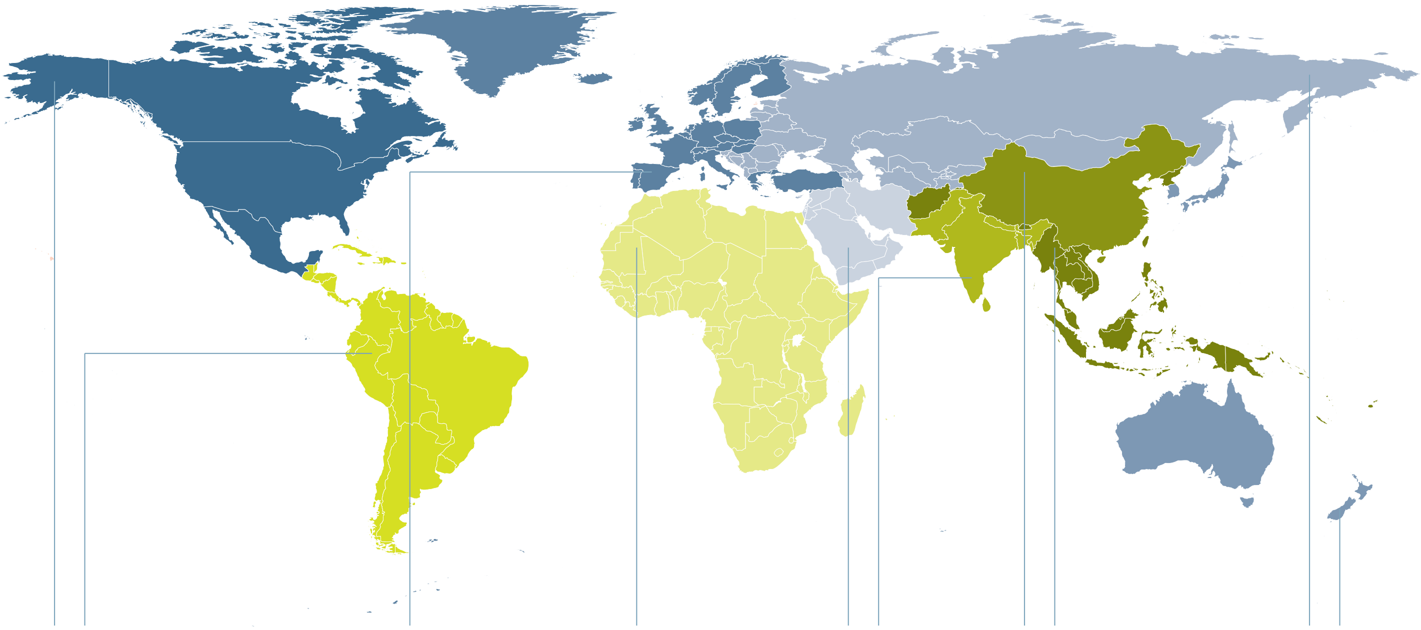
references

6 INTERNATIONAL ENERGY AGENCY, WORLD ENERGY OUTLOOK 2004, PARIS 2004 - A NEW WORLD ENERGY OUTLOOK HAS BEEN PUBLISHED IN NOVEMBER 2007 - BASIC PARAMETERS SUCH AS GDP DEVELOPMENT AND POPULATION REMAIN IN THE SAME RANGE (SEE BOX "SENSITIVITY ANALYSIS IEA WEO 2004 -> 2006)

7 "ENERGY REVOLUTION: A SUSTAINABLE PATHWAY TO A CLEAN ENERGY FUTURE FOR EUROPE", GREENPEACE INTERNATIONAL, SEPTEMBER 2005

figure 7: definition of world regions

WEO 2004



oecd north america

Canada, Mexico, United States

latin america

Antigua and Barbuda, Argentina, Bahamas, Barbados, Belize, Bermuda, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Domenica, Dominican Republic, Ecuador, El Salvador, French Guiana, Grenada, Guadeloupe, Guatemala, Guyana, Haiti, Honduras, Jamaica, Martinique, Netherlands Antilles, Nicaragua, Panama, Paraguay, Peru, Puerto Rico, St. Kitts-Nevis-Anguila, Saint Lucia, St. Vincent-Grenadines and Suriname, Trinidad and Tobago, Uruguay, Venezuela

oecd europe

Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Poland, Portugal, Slovak Republic, Spain, Sweden, Switzerland, Turkey, United Kingdom

africa

Algeria, Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Cape Verde, Central African Republic, Chad, Congo, Democratic Republic of Congo, Cote d'Ivoire, Djibouti, Egypt, Equatorial Guinea, Eritrea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Libya, Madagascar, Malati, Mali, Mauritania, Mauritius, Marocco, Mozambique, Namibia, Niger, Nigeria, Rwanda, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, Somalia, South Africa, Sudan, Swaziland, United Republic of Tanzania, Togo, Tunisia, Uganda, Zambia, Zimbabwe

middle east

Bahrain, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, Syria, United Arab Emirates, Yemen

south asia

Bangladesh, India, Nepal, Pakistan, Sri Lanka

china

China

east asia

Afghanistan, Bhutan, Brunei, Cambodia, Chinese Taipei, Fiji, French Polynesia, Indonesia, Kiribati, Democratic People's Republic of Korea, Laos, Malaysia, Maldives, Myanmar, New Caledonia, Papua New Guinea, Philippines, Samoa, Singapore, Solomon Islands, Thailand, Vietnam, Vanuatu

transition economies

Albania, Armenia, Azerbaijan, Belarus, Bosnia-Herzegovina, Bulgaria, Croatia, Estonia, Federal Republic of Yugoslavia, Macedonia, Georgia, Kazakhstan, Kyrgyzstan, Latria, Lithuania, Moldova, Romania, Russia, Slovenia, Tajikistan, Turkmenistan, Ukraine, Uzbekistan, Cyprus, Gibraltar*), Malta*)

oecd pacific

Japan, South-Korea, Australia, New Zealand

* ALLOCATION OF GIBRALTAR AND MALTA TO TRANSITION ECONOMIES FOR STATISTICAL REASONS

population growth

Population growth rates for the regions of the world are taken from WEO 2004 up to the end of its projection period in 2030. From 2030 to 2050, data is taken from the 2004 revision of the United Nations' World Population Prospects.

The world's population is expected to grow by 0.78 % over the period 2003 to 2050, rising from 6.3 to almost 8.9 billion. Population growth will slow over the projection period, from 1.2% between 2003 and 2010 to 0.42% from 2040 to 2050. The developing regions will continue to grow most rapidly, whilst the transition economies are expected to undergo a continuous decline. Populations in the OECD Europe and OECD Pacific countries are expected to peak around 2020/2030, followed by a significant decline. OECD North America's population will continue to grow, maintaining its global share.

The population share for those countries classified now as 'developing regions' will increase from 76% to 82% by 2050. The OECD's share of the world population will decrease, as will China's, from 20.8% today to 16%. Africa will remain the region with the highest population growth, leading to a share of 21% of world population in 2050. Satisfying the energy needs of a growing population in the developing regions of the world in an environmentally friendly manner is a key challenge for achieving a global sustainable energy supply.

economic growth

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.

To make a fairer comparison between economic growth in different countries, and more thoroughly reflect comparative standards of living, an adaptation to GDP has been made by using purchasing power parity (PPP) exchange rates. All data on economic development in the WEO 2004 is based on PPP adjusted GDP. This study follows that approach, and all GDP data in this report is expressed in year 2000 US dollars using PPP rather than market exchange rates.

As the WEO 2004 reference scenario only covers the period up to 2030, we have had to look for other assumptions on economic growth after that. The 2000 IPCC Emission Scenarios provide guidance on potential development pathways to the year 2050, offering four basic storylines and related scenario families. The WEO annual average world GDP growth rate between 2002 and 2010 (3.7%) is significantly higher than in any of the IPCC scenarios, but it shows a rapid decline to 2.7% in the period 2020-2030. From 2030 onwards we have therefore chosen the IPCC B2 scenario family, which describes a world in which the emphasis is on local solutions to economic, social and environmental sustainability combined with an intermediate level of economic development.

figure 8: development of world population by regions

2003 AND 2050

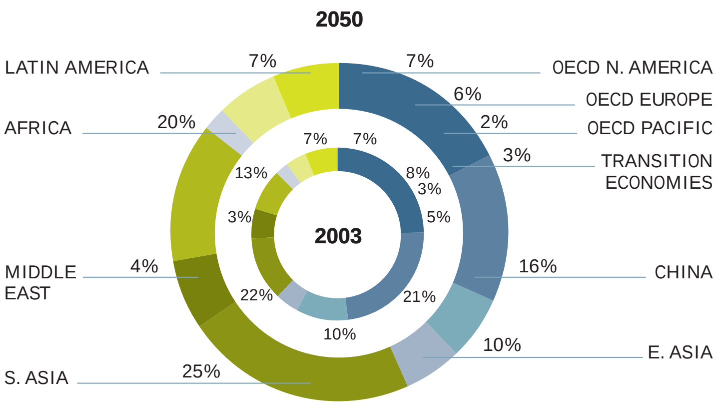


table 2: development of world population by regions

THOUSANDS

REGION	2003	2010	2020	2030	2040	**2050**
World	6309590	6848630	7561980	8138960	8593660	**8887550**
OECD Europe	527300	538470	543880	543880	527560	**508970**
OECD N. America	425800	456520	499310	535380	563110	**586060**
OECD Pacific	199000	201800	201800	197800	190990	**182570**
Transition Economies	345000	340200	333460	320360	303170	**284030**
China	1311300	1376920	1447330	1461870	1448710	**1407150**
E. Asia	622600	686240	765570	829070	871470	**889060**
S. Asia	1410000	1575710	1792960	1980540	2123630	**2210120**
Latin America	439570	481170	536790	581310	612610	**630020**
Africa	847660	980400	1183430	1387010	1615780	**1835730**
Middle East	181360	211200	257450	301740	336630	**353840**

source UNITED NATIONS (UN)

The result of this analysis is that GDP growth in all regions of the world is expected to slow gradually over the coming decades. World GDP is assumed to grow by an average of 3.2% per year over the period 2002-2030, compared to 3.3% from 1971 to 2002, and by 2.7% per year over the entire period. China and other Asian countries are expected to grow fastest, followed by Africa and the Transition Economies. The Chinese economy will slow as it becomes more mature, but will nonetheless become the largest in the world by the early 2020s. GDP in OECD Europe and OECD Pacific is assumed to grow by slightly less than 2% per year over the projection period, while economic growth in OECD North America is expected to be slightly higher. The OECD share of global PPP adjusted GDP will decrease from 58% in 2002 to 38% in 2050.

Compared to the 2004 IEA projections, the new World Energy Outlook 2006 assumes a slightly higher average annual growth rate of world GDP of 3.4%, instead of 3.2%, for the 2004-2030 time horizon. At the same time, WEO 2006 expects final energy consumption in 2030 to be 4% higher than in WEO 2004. A sensitivity analysis on the impact of economic growth on energy demand under the energy [r]evolution scenario shows that an increase of average world GDP of 0.1% (over the whole time period 2003-2050) leads to an increase in final energy demand of about 0.2%.

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 $\$_{2000}$.

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.

figure 9: development of world GDP by regions, 2002 and 2050 future development of costs

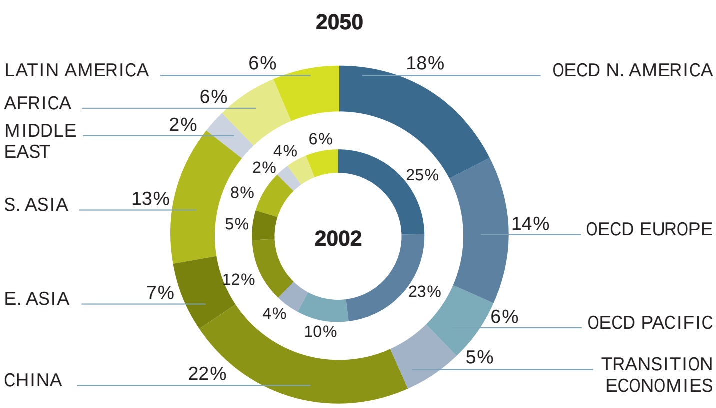


table 2: GDP development projections

(AVERAGE ANNUAL GROWTH RATES)

REGION	2002 - 2010	2010 - 2020	2020 - 2030	2030 - 2040	2040 - 2050	**2002 - 2050**
World	3.7%	3.2%	2.7%	2.3%	2.0%	**2.7%**
OECD Europe	2.4%	2.2%	1.7%	1.3%	1.1%	**1.7%**
OECD North America	3.2%	2.4%	1.9%	1.6%	1.5%	**2.1%**
OECD Pacific	2.5%	1.9%	1.7%	1.5%	1.4%	**1.8%**
Transition Economies	4.6%	3.7%	2.9%	2.6%	2.5%	**3.2%**
China	6.4%	4.9%	4.0%	3.2%	2.6%	**4.1%**
East Asia	4.5%	3.9%	3.1%	2.5%	2.2%	**3.2%**
South Asia	5.5%	4.8%	4.0%	3.2%	2.5%	**3.9%**
Latin America	3.4%	3.2%	2.9%	2.6%	2.4%	**2.9%**
Africa	4.1%	3.8%	3.4%	3.4%	3.4%	**3.6%**
Middle East	3.5%	3.0%	2.6%	2.3%	2.0%	**2.6%**

source (2002-2030: IEA 2004; 2030-2050: OWN ASSUMPTIONS)

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[8] 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, however. The IEA assumes a 'CO_2 reduction incentive' of $25/t$CO_2$ in 2050. The European CASCADE-MINTS project, on the other hand, assumes CO_2 costs of $50/t$CO_2$ in 2020 and $100/t$CO_2$ beyond 2030. For this scenario we have assumed CO_2 costs of $50/t$CO_2$ in 2050, which is twice as high as the IEA's projection, but still conservative compared with other studies. We assume that CO_2 emission costs will be accounted for in Non-Annex B countries only after 2020.

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 3: assumptions on fossil fuel price development

FOSSIL FUELS	2003	2010	2020	2030	2040	2050
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**

table 4: assumptions on biomass price development

$2000/GJ

BIOMASS	2003	2010	2020	2030	2040	2050
Biomass in $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**

table 5: assumptions on CO_2 price development

($/T$CO_2$)

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

table 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.

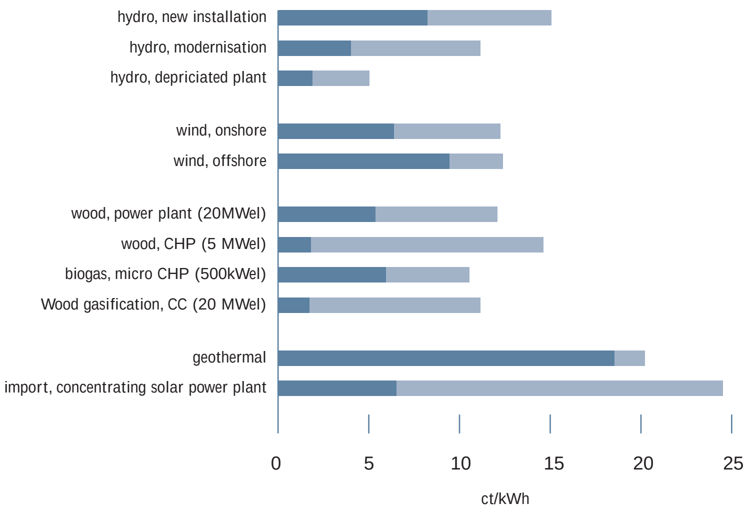
By using the individual advantages of the different technologies, and linking them with each other, a wide spectrum of available options can be developed to market maturity and integrated step by step into the existing supply structures. This will eventually provide a complementary portfolio of environmentally 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[9]. 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.

figure 10: range of current electricity generation costs from renewable energy sources in europe

(EXCLUDING PV, WITH COSTS OF 25 TO 50 $ CENT/kWh). HIGH (LIGHT SHADING) AND LOW (DARK SHADING) ENDS OF RANGE REFLECT VARYING LOCAL CONDITIONS - WIND SPEED, SOLAR RADIATION ETC.



1. photovoltaics (PV)

Although the worldwide PV market has been growing at over 40% per annum in recent years, the contribution it makes to electricity generation is still very small. Development work is focused on improving existing modules and system components and developing new types of cells in the thin-film sector and new materials for crystalline cells. It is expected that the efficiency of commercial crystalline cells will improve by between 15 and 20% in the next few years, and that thin-film cells using less raw material will become commercially available.

The learning factor for PV modules has been fairly constant over a period of 30 years at around 0.8, indicating a continuously high rate of technical learning and cost reduction. Assuming a globally installed capacity of 2,000 GW in 2050, and a decrease in the learning rate after 2030, we can expect that electricity generation costs of around 5-9 cents/kWh will be possible by 2030[10]. Compared with other technologies for utilising renewables, photovoltaic power must therefore be classified as a long-term option. Its importance derives from its great flexibility and its enormous technical potential for rural electrification for the 2 billion people currently having no access to electricity.

2. concentrating solar power plants

Solar thermal 'concentrating' power stations can only use direct sunlight and are therefore dependent on high irradiation locations. North Africa, for example, has a technical potential which far exceeds local demand. The various solar thermal technologies (parabolic trough, power towers and parabolic dish concentrators) offer good prospects for further development and cost reductions. One important objective is the creation of large thermal energy reservoirs in order to extend the operating time of these systems beyond the sunlight period.

Owing to the small number of Concentrating Solar Power (CSP) plants built to date, it is difficult to arrive at reliable learning factors for this sector. Here it is assumed that the learning factor of 0.88 derived from the data for parabolic trough reflectors built in California will change to 0.95 in the course of market introduction up to 2030. The UN's World Energy Assessment expects solar thermal electricity generation will enjoy a dynamic market growth similar to the wind industry, but with a time lag of 20 years. Depending on the level of irradiation and mode of operation, electricity generation costs of 5-8 cents/kWh are expected. This presupposes rapid market introduction in the next few years.

3. solar thermal collectors for heating and cooling

Small solar thermal collector systems for water and auxiliary heating are well developed today and used for a wide variety of applications. By contrast, large seasonal heat reservoirs that store heat from the summer until it is needed in the winter are only available as pilot plants. Only by means of local heating systems with seasonal storage would it be possible to supply large parts of the low temperature heat market with solar energy. Crucial factors for market launch will be low storage costs and an adequate usable heat yield.

Data for the European collector market show a learning factor of nearly 0.90 for solar collectors, which indicate a relatively well developed system from a technological point of view. By contrast, the construction of seasonal heat reservoirs is expected to show a long term cost reduction of over 70%. Depending on the configuration of the system, it will be possible in the long term to achieve solar thermal costs of between 4 and 7 $cents/kWh_{thermal}$.

4. wind power

Within a short period of time, the dynamic development of wind power has resulted in the establishment of a flourishing global market. The world's largest wind turbines, several of which have been installed in Germany, have a capacity of 6 MW. The cost of new systems has, however, stagnated in some countries in recent years due to the continuing high level of demand and the manufacturers' considerable advance investment in the development and introduction of a succession of new systems. The result is that the learning factor observed for wind turbines built between 1990 and 2000 in Germany was only 0.94. Nevertheless, since technical developments have led to increases in specific yield, electricity generation costs should reduce further. Owing to the relative lack of experience in the offshore sector, a larger cost reduction potential is expected here, with the learning rate correspondingly higher.

Whilst the IEA's World Energy Outlook 2004 expects worldwide wind capacity to grow to only 330 GW by 2030, the United Nations' World Energy Assessment assumes a global saturation level of around 1,900 GW by the same time. The Global Wind Energy Outlook (2006)[11] projects a global capacity of up to 3,000 GW by 2050. An experience curve for wind turbines is derived by combining the currently observed learning factors with a high market growth assumption, oriented towards the Global Wind Energy Outlook, indicating that costs for wind turbines will reduce by 40% up to 2050.

references
9 DLR 2006, DR. WOLFRAM KREWITT ET. AL.
10 EPIA/GREENPEACE INTERNATIONAL: SOLARGENERATION 2006
11 EUROPEAN WIND ENERGY ASSOCIATION AND GREENPEACE

5. biomass

The crucial factor for the economics of biomass utilisation is the cost of the feedstock, which today ranges from a negative cost for waste wood (credit for waste disposal costs avoided) through inexpensive residual materials to the more expensive energy crops. The resulting spectrum of energy generation costs is correspondingly broad. One of the most economic options is the use of waste wood in steam turbine combined heat and power (CHP) plants. Gasification of solid bio fuels, on the other hand, which opens up a wide range of applications, is still relatively expensive. In the long term it is expected that favourable electricity production costs will be achieved by using wood gas both in micro CHP units (engines and fuel cells) and in gas-and-steam power plants. Great potential for the utilisation of solid biomass also exists for heat generation in both small and large heating centres linked to local heating networks. Converting crops into ethanol and 'bio diesel' made from rapeseed methyl ester (RME) has become increasingly important in recent years, for example in Brazil and the USA. Processes for obtaining synthetic fuels from biogenic synthesis gases will also play a growing role.

A great potential for exploiting modern technologies exists in Latin America, Europe and the Transition Economies either in stationary appliances or the transport sector. For these regions it is assumed that in the long term 60% of the potential for biomass will come from energy crops, the rest from forest residues, industrial wood waste and straw.

In other regions, like the Middle East, South Asia or China, the additional use of biomass is restricted, either due to a generally low availability or already high traditional use. For the latter, using more efficient technologies will improve the sustainability of current biomass use.

6. geothermal

Geothermal energy has long been used worldwide for supplying heat, whilst electricity generation is limited to a few sites with specific geological conditions. Further intensive research and development work is needed to speed up progress. In particular, the creation of large underground heat-exchange surfaces (HDR technology) and the improvement of heat-and-power machines with Organic Rankine Cycle (ORC) must be optimised in future projects.

As a large part of the costs for a geothermal power plant come from deep drilling, data from the oil sector can be used, with learning factors observed there of less than 0.8. Assuming a global average market growth for geothermal power capacity of 9% per year until 2020, reducing to 4% beyond 2030, the result would be a cost reduction potential of 50% by 2050. Thus, despite the present high figures (about 20 cents/kWh), electricity production costs – depending on payments for heat supply – are expected to come down to around 6-10 cents/kWh in the long term. Because of its non-fluctuating supply, geothermal energy is considered to be a key element in a future supply structure based on renewable sources.

7. hydro power

Hydro power is a mature technology that has long been used for economic generation of electricity. Additional potential can be exploited primarily by modernising and expanding existing systems. The remaining limited cost reduction potential will probably be offset by increasing site development problems and growing environmental requirements. It can be assumed that for small scale systems, where power generation costs are generally higher, the need to comply with ecological requirements will involve proportionately higher costs than for large systems.

summary of renewable energy cost development

Figure 12 summarises the cost trends for renewable energy technologies as derived from the respective learning curves. It should be emphasised that the expected cost reduction is basically not a function of time, but of cumulative capacity, so dynamic market development is required. Most of the technologies will be able to reduce their specific investment costs to between 30% and 60% of current levels by 2020, and to between 20% and 50% once they have achieved full development (after 2040).

Reduced investment costs for renewable energy technologies lead directly to reduced heat and electricity generation costs, as shown in Figure 12. Generation costs today are around 8 to 20 cents/kWh for the most important technologies, with the exception of photovoltaics. 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.

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

figure 11: future development of investment costs

NORMALISED TO CURRENT COST LEVELS) FOR RENEWABLE ENERGY TECHNOLOGIES, DERIVED FROM LEARNING CURVES

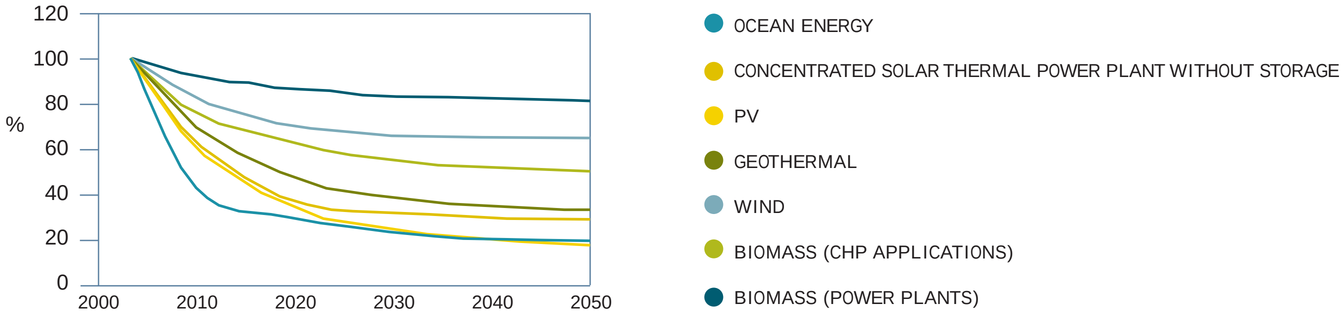
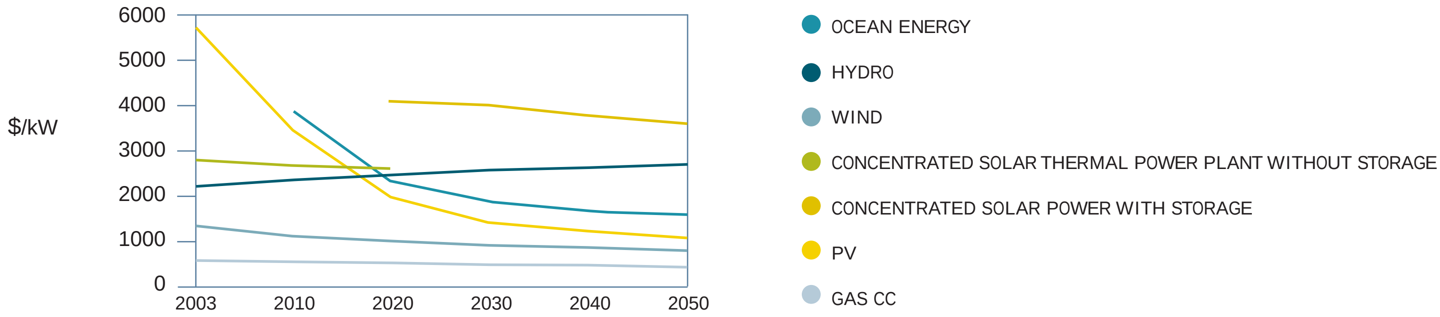
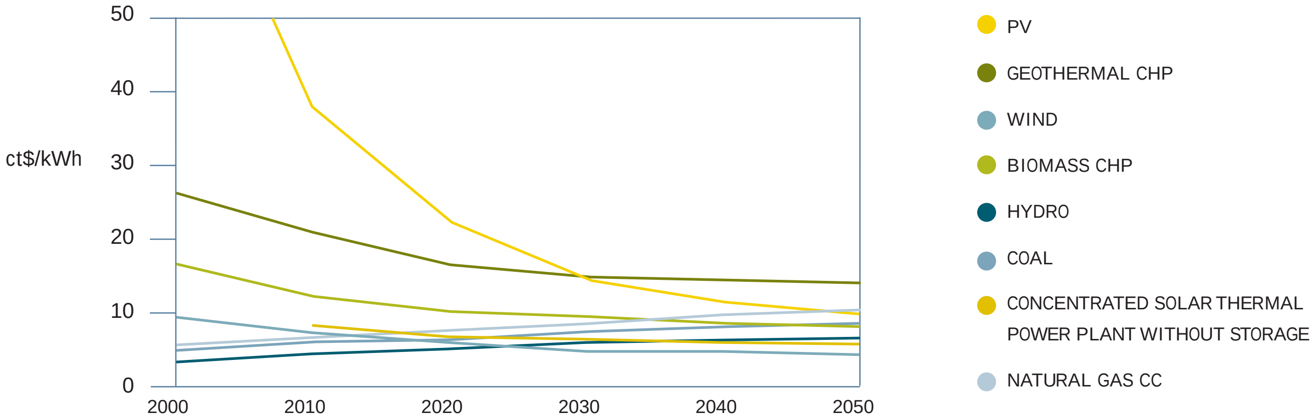


figure 12: future development of investment costs for selected renewable electricity generation technologies



reference FIGURES FOR OECD EUROPE, CONCENTRATED SOLAR THERMAL POWER PLANT WITHOUT STORAGE FOR MIDDLE EAST. (*GENERATION COSTS DEPEND PARTLY ON SITE SPECIFIC FUEL COSTS AND HEAT CREDITS.)

figure 13: expected development of electricity generation costs from fossil and renewable options



reference FIGURES FOR OECD EUROPE, CONCENTRATED SOLAR THERMAL POWER PLANT WITHOUT STORAGE FOR MIDDLE EAST. (GENERATION COSTS DEPEND PARTLY ON SITE SPECIFIC FUEL COSTS AND HEAT CREDITS.)

map 2: CO_2 emissions reference scenario and the energy [r]evolution scenario

WORLDWIDE SCENARIO

EMISSIONS

CO_2

LEGEND

>20 | 10-20 | 5-10 | 0-5 % EMISSIONS GLOBALLY

REF REFERENCE SCENARIO

ALT ALTERNATIVE SCENARIO

0 1000 KM

CO_2 **EMISSIONS TOTAL** MILLION TONNES [mio t] | % INCREASE/DECREASE FROM 2003 | % INCREASE/DECREASE FROM 1990

EMISSIONS PER PERSON TONNES [t]

H HIGHEST | M MIDDLE | L LOWEST

OECD NORTH AMERICA

		REF mio t	REF %	ALT mio t	ALT %
CO_2	2003	6,646H		6,646H	
	2050	9,297H	+40	1,787	-73L/-68
		t		t	
Per person	2003	16H		16H	
	2050	16H		3	

LATIN AMERICA

		REF mio t	REF %	ALT mio t	ALT %
CO_2	2003	802		802	
	2050	3,200	+300	442L	-45M/-34
		t		t	
Per person	2003	2		2	
	2050	5		1	

OECD EUROPE

		REF mio t	REF %	ALT mio t	ALT %
CO_2	2003	3,886		3,886	
	2050	5,210	34%	1,160M	-70/-71
		REF t		ALT t	
	2003	7		7	
	2050	10		2M	

MIDDLE EAST

		REF mio t	REF %	ALT mio t	ALT %
CO_2	2003	1,004		1,004	
	2050	2,116L	+111	493	-51/-22
		REF t		ALT t	
	2003	6M		6M	
	2050	6M		1	

CHINA

		REF mio t	REF %	ALT mio t	ALT %
CO_2	2003	3,313		3,313	
	2050	8,547	+158	3,284H	-1/+30
		REF t		ALT t	
	2003	3		3	
	2050	6M		2M	

TRANSITION ECONOMIES

		REF mio t	REF %	ALT mio t	ALT %
CO_2	2003	2,685M		2,685M	
	2050	3,655	+36	745	-72/-81
		REF t		ALT t	
	2003	8		8	
	2050	13		3	

AFRICA

		REF mio t	REF %	ALT mio t	ALT %
CO_2	2003	727L		727L	
	2050	3,440	+373H	1,075	+48H/+21
		REF t		ALT t	
	2003	1L		1L	
	2050	2L		1	

SOUTH ASIA

		REF mio t	REF %	ALT mio t	ALT %
CO_2	2003	1,126		1,126	
	2050	4,039M	+259	1,077	-4/+47
		REF t		ALT t	
	2003	1L		1L	
	2050	2L		0.5L	

EAST ASIA

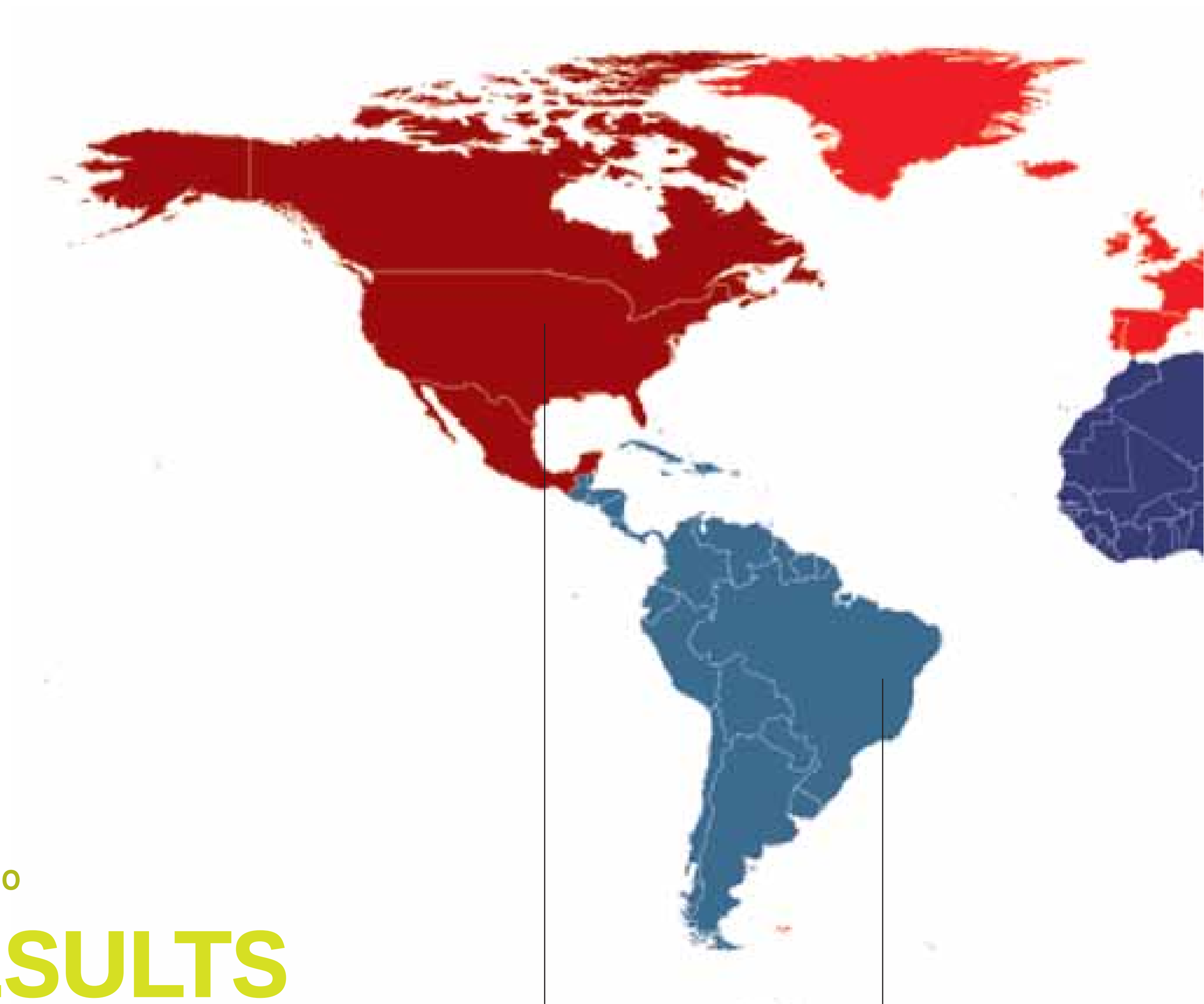
		REF mio t	REF %	ALT mio t	ALT %
CO_2	2003	1,063		1,063	
	2050	3,726	+250	831	-22/+22
		REF t		ALT t	
	2003	2		2	
	2050	4		1	

OECD PACIFIC

		REF mio t	REF %	ALT mio t	ALT %
CO_2	2003	1,871		1,871	
	2050	2,259	+21	700	-63/-29
		REF t		ALT t	
	2003	9		9	
	2050	12		4H	

map 1: results reference scenario and the energy [r]evolution scenario

WORLDWIDE SCENARIO



SCENARIO RESULTS

LEGEND

> -50 | > -40 | > -30
> -20 | > -10 | > 0
> +10 | > +20 | > +30
> +40 | > +50

% CHANGE OF ENERGY CONSUMPTION IN ALTERNATIVE SCENARIO 2050 COMPARED TO CURRENT CONSUMPTION 2003

REF REFERENCE SCENARIO

ALT ALTERNATIVE SCENARIO

0 1000 KM

SHARE OF RENEWABLES %

SHARE OF FOSSIL FUELS %

SHARE OF NUCLEAR ENERGY %

H HIGHEST | **M** MIDDLE | **L** LOWEST

PE PRIMARY ENERGY PRODUCTION/DEMAND IN PETA JOULE [PJ]

EL ELECTRICITY PRODUCTION/GENERATION IN TERAWATT HOURS [TWh]

OECD NORTH AMERICA

		REF		ALT	
		PE PJ	**EL** TWh	**PE** PJ	**EL** TWh
	2003	113,980H	4,857H	113,980H	4,857H
	2050	161,936H	8,960H	69,874	4,605
		%		%	
Renewables	**2003**	6	15	6	15
	2050	8	16M	52M	8
		%		%	
Fossil fuels	**2003**	86	67M	86	67M
	2050	86	75	48	20
		%		%	
Nuclear	**2003**	8	18M	NUCLEAR POWER PHASED OUT BY 2030	
	2050	6	9		

LATIN AMERICA

		REF		ALT	
		PE PJ	**EL** TWh	**PE** PJ	**EL** TWh
	2003	19,393	830	19,393	830
	2050	62,854	3,982	30,220	2,308
		%		%	
Renewables	**2003**	28	71H	28	71H
	2050	15	33H	70H	90H
		%		%	
Fossil fuels	**2003**	71	27L	71	27L
	2050	84M	66	30L	10L
		%		%	
Nuclear	**2003**	1	3	NUCLEAR POWER PHASED OUT BY 2030	
	2050	1	1		

OECD EUROPE

	REF PE PJ	REF EL TWh	ALT PE PJ	ALT EL TWh
2003	76,319	3,323	76,319	3,323
2050	93,356	4,988	50,999	3,141
	%		%	
2003	7	18M	7	18%M
2050	12	28	48	80%
	%		%	
2003	79	53	79	53
2050	84M	64	52M	20
	%		%	
2003	14H	30H	NUCLEAR POWER PHASED OUT BY 2030	
2050	4M	8		

MIDDLE EAST

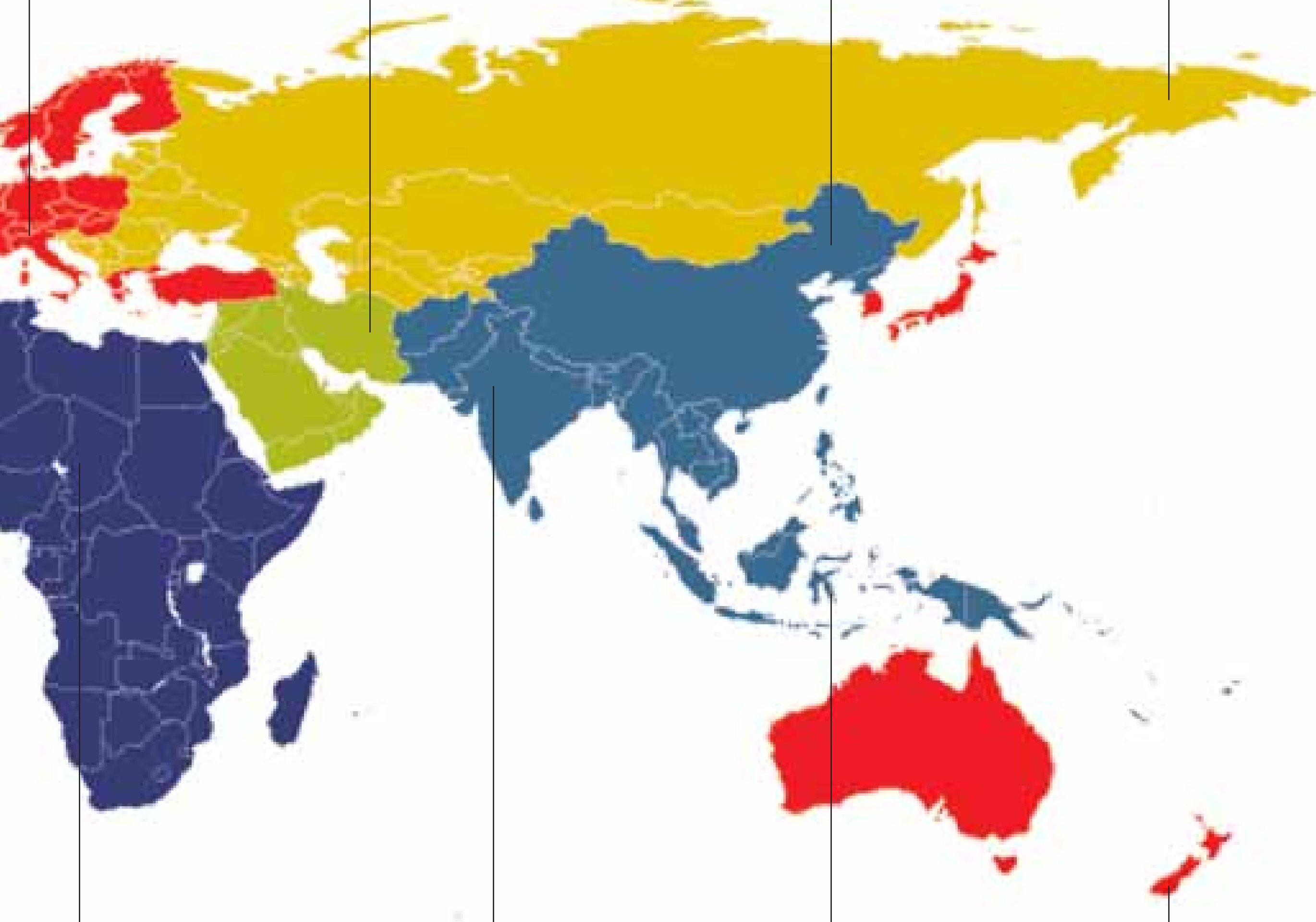
	REF PE PJ	REF EL TWh	ALT PE PJ	ALT EL TWh
2003	17,569L	554	17,569L	554
2050	39,205L	1,941L	20,171L	1,671
	%		%	
2003	1L	3L	1L	3L
2050	1L	4L	53	84
	%		%	
2003	99H	97H	99H	97H
2050	98H	96H	47	16
	%		%	
2003	0L	0L	NUCLEAR POWER PHASED OUT BY 2030	
2050	0L	0L		

CHINA

	REF PE PJ	REF EL TWh	ALT PE PJ	ALT EL TWh
2003	55,379	1,943	55,379	1,943
2050	127,688	9,045	76.066H	7,556H
	%		%	
2003	19M	15	19M	15
2050	12M	16M	34L	53L
	%		%	
2003	80M	82	80M	82
2050	85	80	66H	47H
	%		%	
2003	1	2	NUCLEAR POWER PHASED OUT BY 2030	
2050	3	4		

TRANSITION ECONOMIES

	REF PE PJ	REF EL TWh	ALT PE PJ	ALT EL TWh
2003	45,472M	1,574	45,472M	1,574
2050	67,537	3,287	37,469M	2,413
	%		%	
2003	4	18M	4	18M
2050	7M	14	58	79
	%		%	
2003	90	64	90	64
2050	90	79M	42	21
	%		%	
2003	7	18M	NUCLEAR POWER PHASED OUT BY 2030	
2050	3	6M		



AFRICA

	REF PE PJ	REF EL TWh	ALT PE PJ	ALT EL TWh
2003	22,292	502L	22,292	502L
2050	74,255M	3,852	43,869	2,698
	%		%	
2003	47H	17	47H	17
2050	29H	5	58	56
	%		%	
2003	53L	80	53L	80
2050	71L	94	42	44
	%		%	
2003	1	3	NUCLEAR POWER PHASED OUT BY 2030	
2050	0L	0L		

SOUTH ASIA

	REF PE PJ	REF EL TWh	ALT PE PJ	ALT EL TWh
2003	26,921	744	26,921	744
2050	71,709	4,551M	37,220	2,790M
	%		%	
2003	41	15	41	15
2050	20	9	50M	59
	%		%	
2003	58	82	58	82
2050	77	87	50	41%
	%		%	
2003	1	3	NUCLEAR POWER PHASED OUT BY 2030	
2050	3	4		

EAST ASIA

	REF PE PJ	REF EL TWh	ALT PE PJ	ALT EL TWh
2003	22,348	686	22,348	686
2050	59,955	3,232	32,400	2,133L
	%		%	
2003	23	14	23	14
2050	10	13	51M	81
	%		%	
2003	75	80	75	80
2050	88	85	49	19
	%		%	
2003	2	6	NUCLEAR POWER PHASED OUT BY 2030	
2050	1	2		

OECD PACIFIC

	REF PE PJ	REF EL TWh	ALT PE PJ	ALT EL TWh
2003	35,076	1,649M	35,076	1,649M
2050	46,716	2,661	23,616	1,619
	%		%	
2003	3	10	3	10
2050	7	17	37	70M
	%		%	
2003	85	67M	85	67
2050	79	60L	63	30M
	%		%	
2003	11	22	NUCLEAR POWER PHASED OUT BY 2030	
2050	14H	23H		

the global energy [r]evolution scenario

"AN INCREASE IN ECONOMIC ACTIVITY AND A GROWING POPULATION DOES NOT NECESSARILY HAVE TO RESULT IN AN EQUIVALENT INCREASE IN ENERGY DEMAND. "

5

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

Following the IEA's reference scenario, which uses United Nations population development projections, the world's population will increase from 6.3 billion people now to 8.9 billion in 2050. This continuing growth will put additional pressure on energy resources and the environment.

projection of energy intensity

An increase in economic activity and a growing population does not necessarily have to result in an equivalent increase in energy demand. There is still a large potential for exploiting energy efficiency measures. Under the reference scenario, we assume that energy intensity will be reduced by 1.3% per year, leading to a reduction in final energy demand per unit of GDP of about 45% between 2003 and 2050. Under the energy [r]evolution scenario, it is assumed that active policy and technical support for energy efficiency measures will lead to an even higher reduction in energy intensity of almost 70%.

development of global energy demand

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 almost doubles from the current 310,000 PJ/a to 550,000 PJ/a in 2050. In the energy [r]evolution scenario, a much smaller 14% increase on current consumption is expected by 2050, reaching 350,000 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.

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 26,000 TWh/a in the year 2050. Compared to the reference scenario, efficiency measures avoid the generation of about 13,000 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. Introduction of passive solar design in both residential and commercial buildings will help to curb the growing demand for active air-conditioning.

figure 15: global population development projection

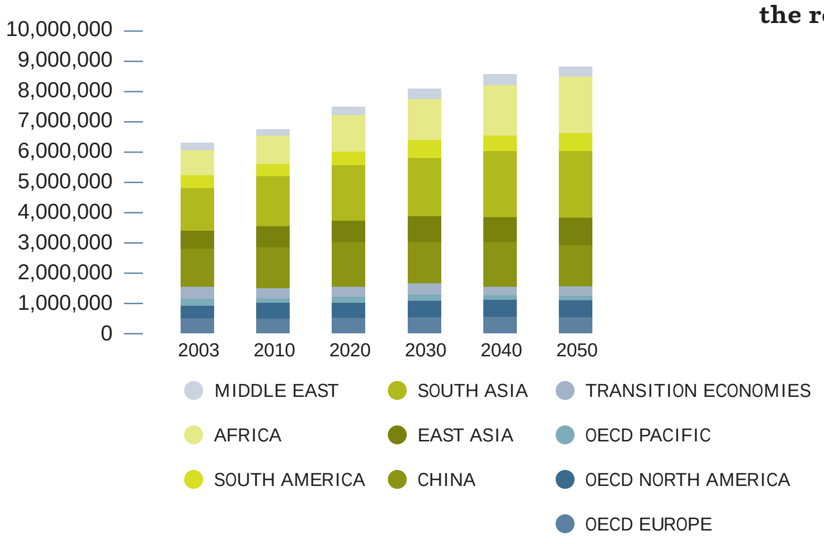
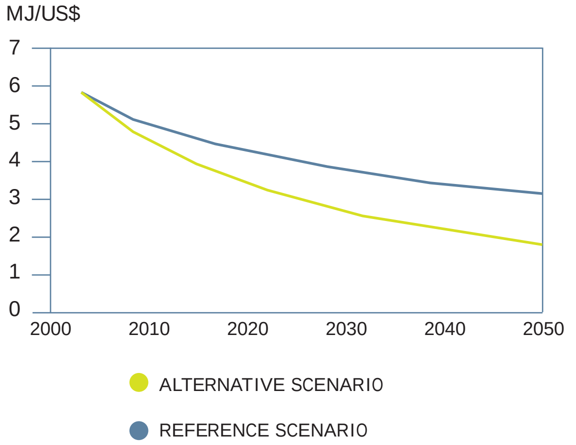


figure 16: projection of energy intensity under the reference and energy [r]evolution scenarios



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 Figure 19). Compared to the reference scenario, consumption equivalent to 94,000 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.

In the transport sector, which is not analysed in detail in the present study, it is assumed under the energy [r]evolution scenario that energy demand will increase by a quarter to 100,600 PJ/a by 2050, saving 80% compared to the reference scenario. This reduction can be achieved by the introduction of highly efficient vehicles, by shifting the transport of goods from road to rail and by changes in mobility-related behaviour patterns.

figure 17: projection of global final energy demand by sector in the reference and energy [r]evolution scenarios

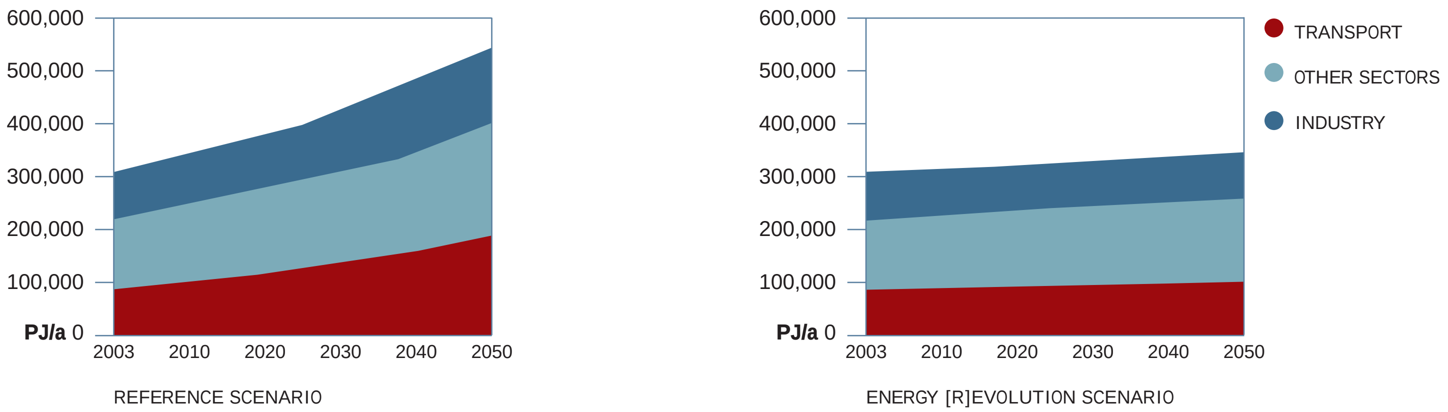


figure 18: development of global electricity demand by sectors in the energy [r]evolution scenario

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

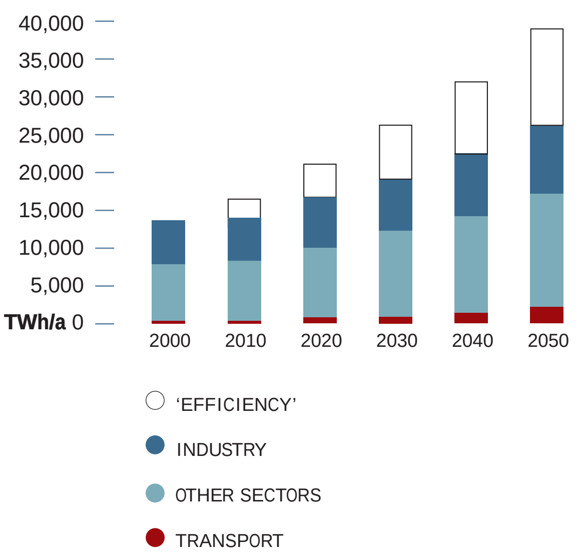
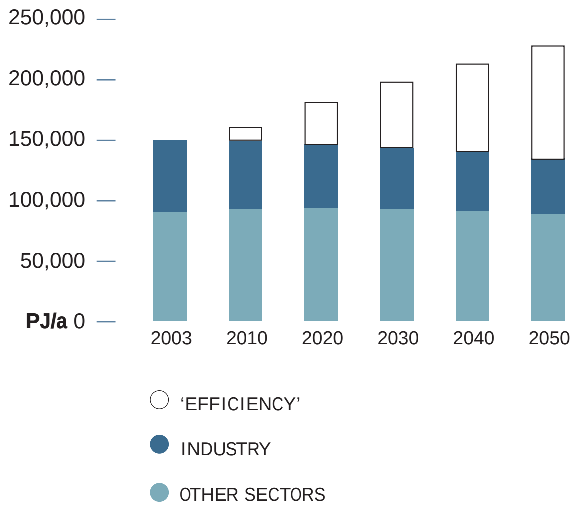


figure 19: development of global heat supply demand in the energy [r]evolution scenario

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



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 phasing out of nuclear energy and reduce the number of fossil fuel-fired power plants required for grid stabilisation. By 2050, 70% of the electricity produced worldwide will come from renewable energy sources. 'New' renewables – mainly wind, solar thermal energy and PV – will contribute 42% of electricity generation. The following strategy paves the way for a future renewable energy supply:

- The phasing out of nuclear energy and rising electricity demand will be met initially by bringing into operation new highly efficient gas-fired combined-cycle power plants, plus an increasing capacity of wind turbines and biomass. In the long term, wind will be the most important single source of electricity generation.
- Solar energy, hydro and biomass will make substantial contributions to electricity generation. In particular, as non-fluctuating renewable energy sources, hydro and solar thermal, combined with efficient heat storage, are important elements in the overall generation mix.
- The installed capacity of renewable energy technologies will grow from the current 800 GW to 7,100 GW in 2050. Increasing renewable capacity by a factor of nine within the next 43 years requires political support and well-designed policy instruments, however. There will be a considerable demand for investment in new production capacity over the next 20 years. As investment cycles in the power sector are long, decisions on restructuring the world's energy 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, cost reduction and technological maturity. Figure 22 shows the comparative evolution of the different renewable technologies over time. Up to 2020, hydro-power and wind will remain the main contributors to the growing market share. After 2020, the continuing growth of wind will be complemented by electricity from biomass, photovoltaics and solar thermal (CSP) energy.

figure 20: development of global electricity generation under the reference scenario

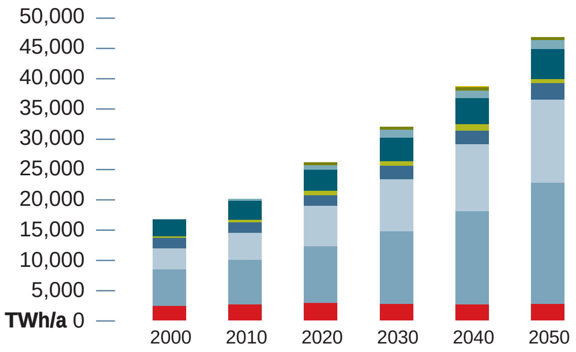


figure 21: development of global electricity generation under the energy [r]evolution scenario

'EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO

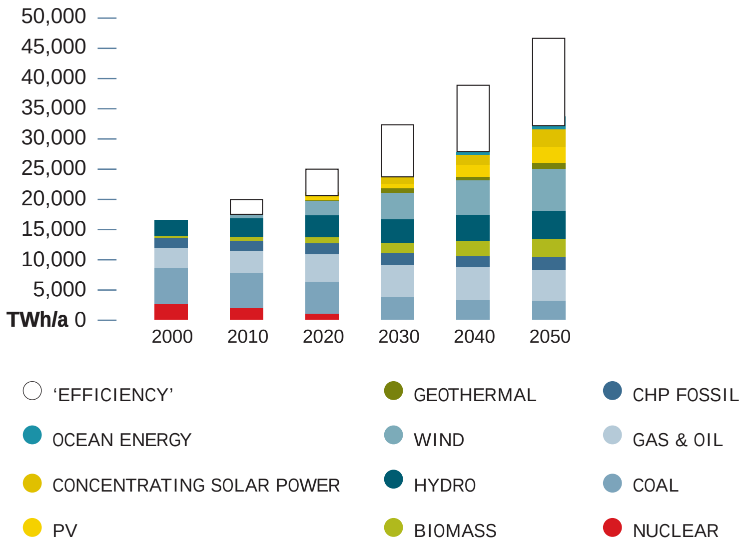


figure 22: growth of global renewable electricity supply under the energy [r]evolution scenario, by source

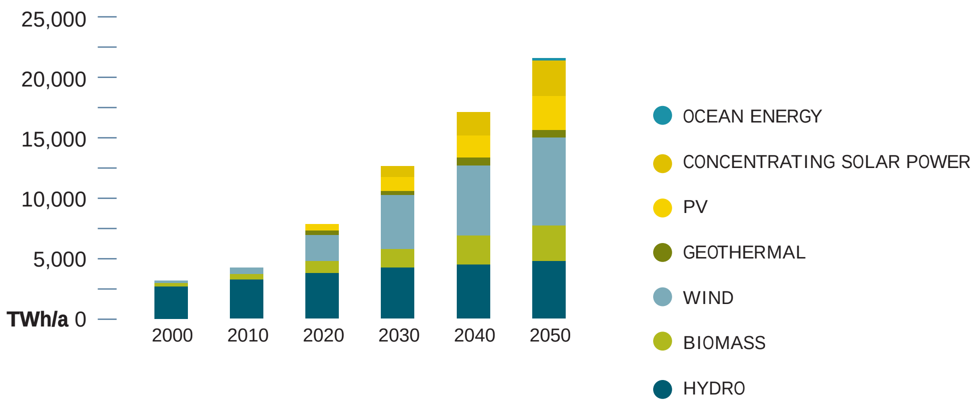


table 7: projection of global renewable electricity generation capacity under the energy [r]evolution scenario

IN MW

	2003	2010	2020	2030	2050
Hydro	728,000	854,800	994,190	1,091,490	1,257,300
Biomass	48,030	110,000	211,310	305,780	504,610
Wind	30,280	156,150	949,800	1,834,290	2,731,330
Geothermal	10,170	20,820	40,780	70,380	140,010
PV	560	22,690	198,900	727,820	2,033,370
Concentrating Solar Power	250	2,410	29,190	137,760	404,820
Ocean energy	240	2,250	13,530	28,090	63,420
Total	**817,000**	**1,169,120**	**2,437,700**	**4,195,610**	**7,134,860**

heat supply

Development of renewables in the heat supply sector raises different issues. Today, renewables provide 26% of primary energy demand for heat supply, the main contribution coming from the use of biomass. The lack of district heating networks is a severe structural barrier to the large scale utilisation of geothermal and solar thermal energy. 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.

- Energy efficiency measures can decrease the current demand for heat supply by 35%.
- For direct heating, solar collectors, biomass/biogas as well as geothermal energy are increasingly substituting for fossil fuel-fired systems.
- A shift from coal and oil to natural gas in the remaining conventional applications will lead to a further reduction of CO_2 emissions.

figure 23: development of global heat supply under the reference scenario

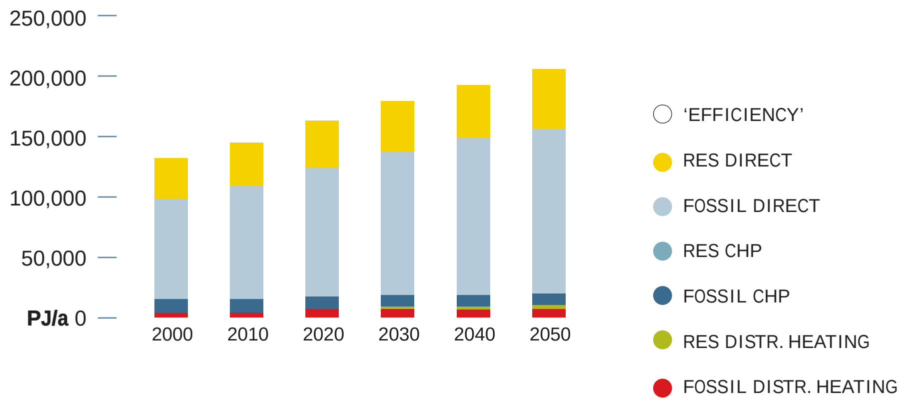
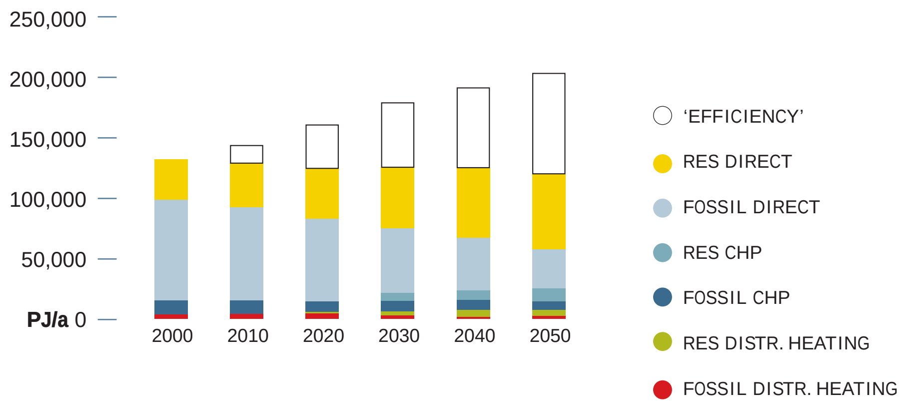


figure 24: development of global heat supply under the energy [r]evolution scenario

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



primary energy consumption

Taking into account the assumptions discussed above, the resulting primary energy consumption under the energy [r]evolution scenario is shown in Figure 26. Compared to the reference scenario, overall energy demand will be reduced by almost 50% in 2050. Around half of the remaining demand will be 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 suppliers.

development of CO_2 emissions

Whilst worldwide emissions of CO_2 will almost double under the reference scenario, under the energy [r]evolution scenario they will decrease from 23,000 million tons 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 in 2050, the power sector will drop below transport as the largest source of emissions.

figure 25: development of global primary energy consumption under the reference scenario

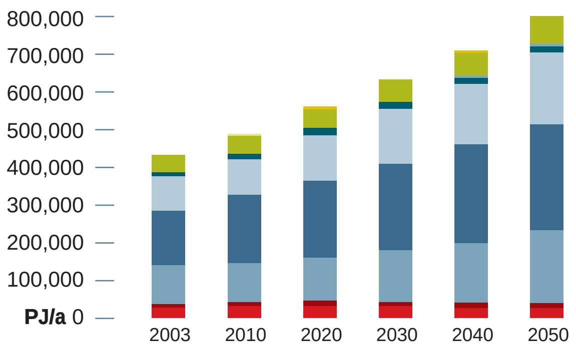


figure 26: development of global primary energy consumption under the energy [r]evolution scenario

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

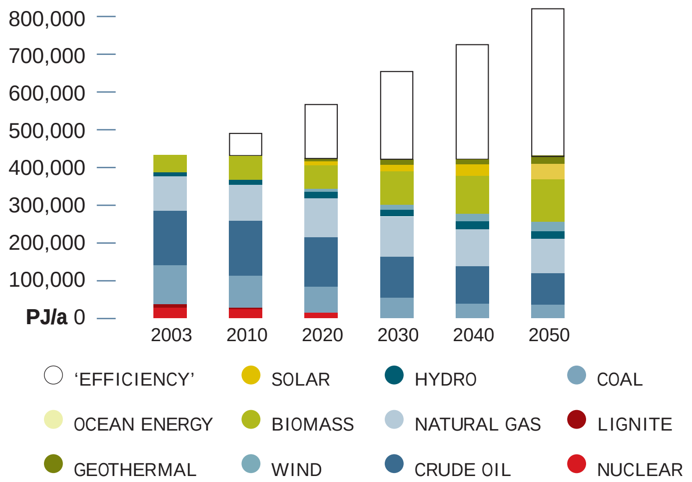
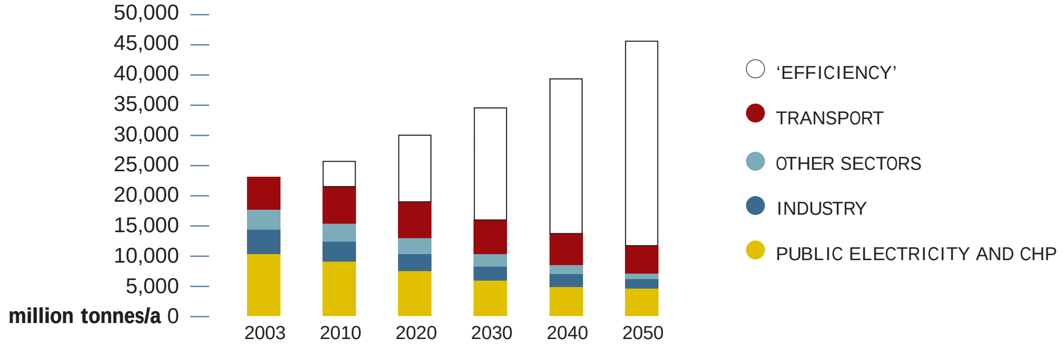


figure 27: development of global co_2 emissions by sector under the energy [r]evolution scenario

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



future costs of electricity generation

Figure 28 shows that the introduction of renewable technologies under the energy [r]evolution scenario slightly increases the costs of electricity generation compared to the reference scenario. This difference will be less than 0.1 cents/kWh up to 2020. Note that any increase in fossil fuel prices beyond the projection given in Table 3 will reduce the gap between the two scenarios. Because of the lower CO_2 intensity of electricity generation, by 2020 electricity generation costs will become economically favourable under the energy [r]evolution scenario, and by 2050 generation costs will be more than 1.5 cents/kWh below those in the reference scenario.

Due to growing demand, we face a significant increase in society's expenditure on electricity supply. Under the reference scenario, the unchecked growth in demand, the increase in fossil fuel prices and the cost of CO_2 emissions result in total electricity supply costs rising from today's $1,130 billion per year to more than $4,300 bn in 2050. Figure 29 shows that the energy [r]evolution scenario not only complies with global CO_2 reduction targets but also helps to stabilise energy costs and relieve the economic pressure on society. Increasing energy efficiency and shifting energy supply to renewables leads to long term costs for electricity supply that are one third lower than in the reference scenario. It becomes clear that pursuing stringent environmental targets in the energy sector also pays off in terms of economics.

figure 28: development of global electricity generation costs under the two scenarios

(CO_2 EMISSION COSTS IMPOSED FROM 2010 IN INDUSTRIALISED REGIONS, FROM 2020 IN ALL REGIONS, WITH INCREASE FROM 15 $/$T_{CO2}$ IN 2010 TO 50 $/$T_{CO2}$ IN 2050)

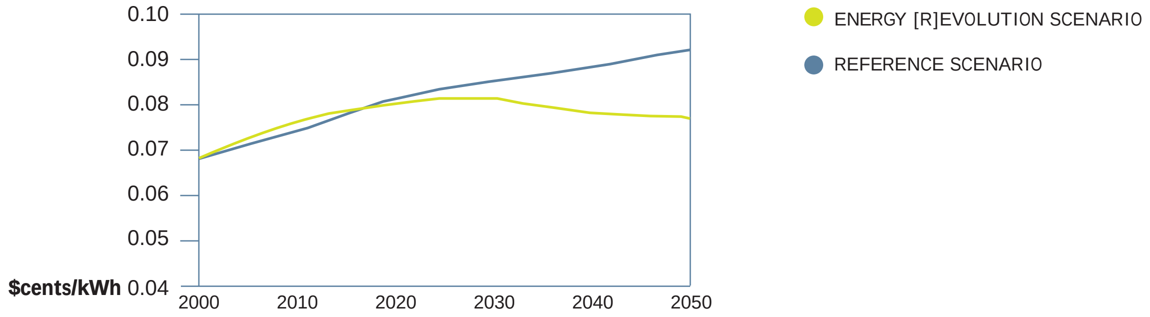


figure 29: development of total global electricity supply costs

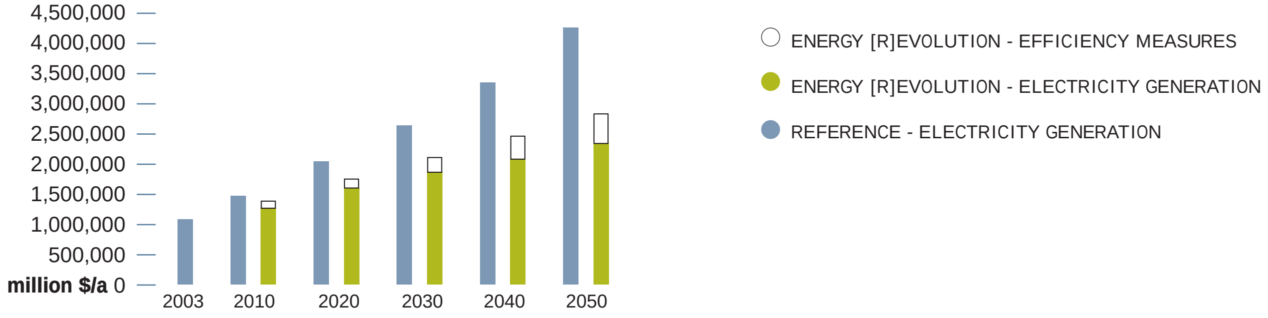
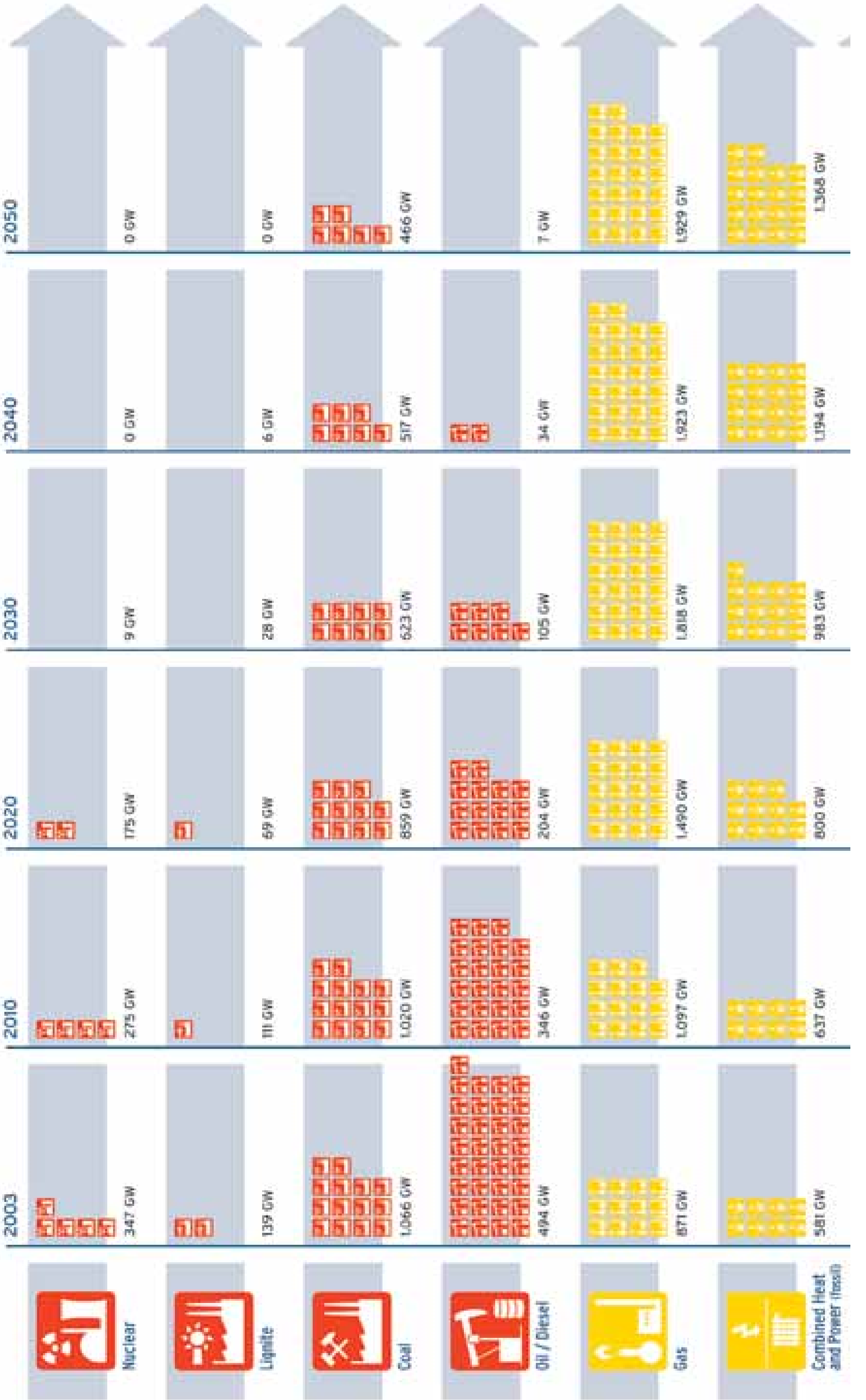
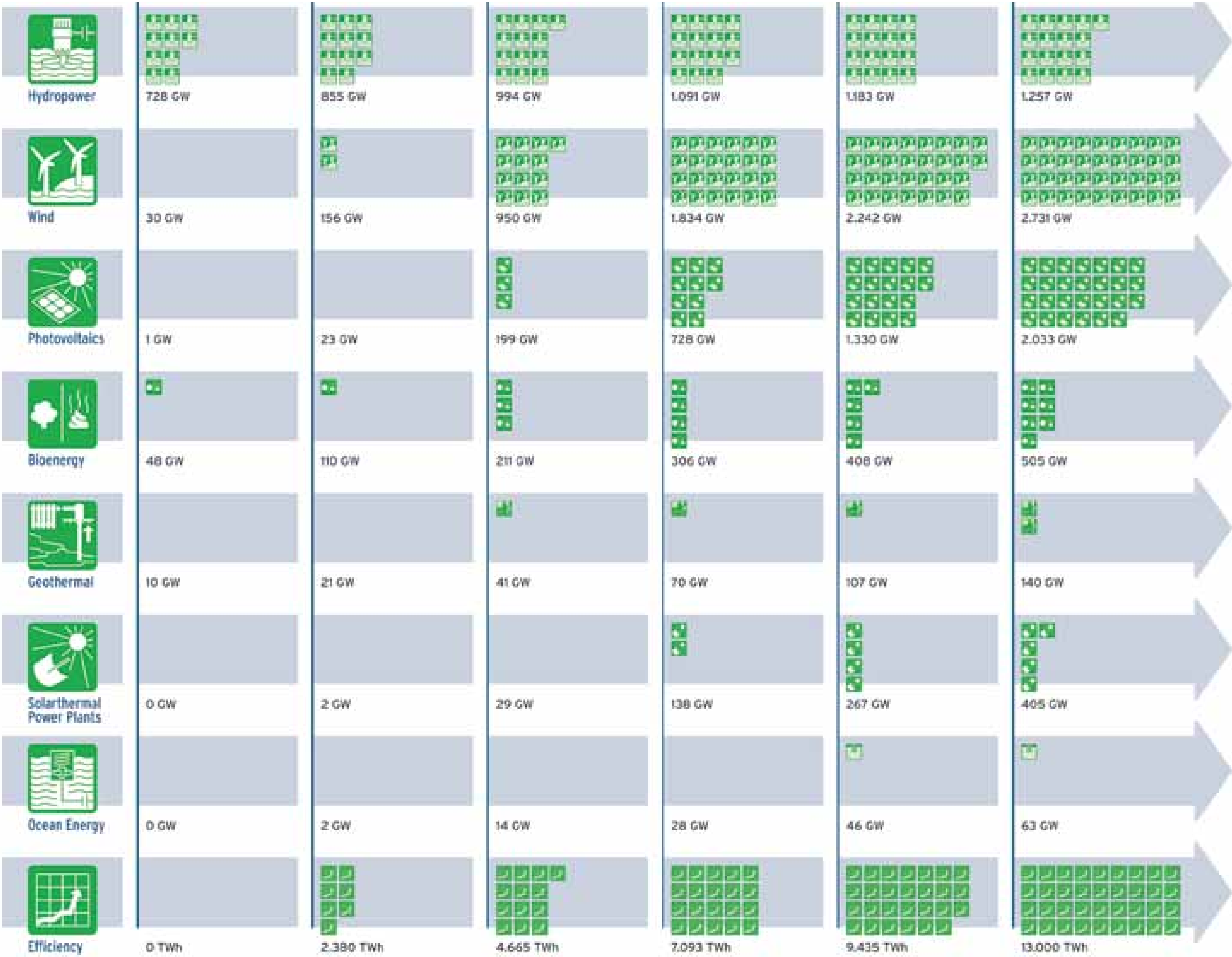


chart 1: energy [r]evolution
A SUSTAINABLE WORLD ENERGY OUTLOOK




Hydropower
728 GW
855 GW
994 GW
1.091 GW
1.183 GW
1.257 GW
Wind
30 GW
156 GW
950 GW
1.834 GW
2.242 GW
2.731 GW
Photovoltaics
1 GW
23 GW
199 GW
728 GW
1.330 GW
2.033 GW
Bioenergy
48 GW
110 GW
211 GW
306 GW
408 GW
505 GW
Geothermal
10 GW
21 GW
41 GW
70 GW
107 GW
140 GW
Solarthermal
Power Plants
0 GW
2 GW
29 GW
138 GW
267 GW
405 GW
Ocean Energy
0 GW
2 GW
14 GW
28 GW
46 GW
63 GW
Efficiency
0 TWh
2.380 TWh
4.665 TWh
7.093 TWh
9.435 TWh
13.000 TWh

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."

6

The issue of security of supply is now at the top of the energy policy agenda. Concern is focused both on price security and the security of physical 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. The regional distribution of oil and gas resources also does not match the distribution of demand. Some countries have to rely almost entirely on fossil fuel imports. The maps on the following pages provide an overview of the availability of different fuels and their regional distribution. Information in this chapter is based partly on the report Plugging the Gap (Renewable Energy Systems/Global Wind Energy Council, 2006).

oil

Oil is the blood of the modern global economy, as the effects of the supply disruptions of the 1970s made clear. It is the number one source of energy, providing 36% of the world's needs and the fuel employed almost exclusively for essential uses such as transportation. However, a passionate debate has developed over the ability of supply to meet increasing consumption, a debate obscured by poor information and stirred by recent soaring prices.

the reserves chaos

Public data about oil and gas reserves is strikingly inconsistent, and potentially unreliable for legal, commercial, historical and sometimes political reasons. The most widely available and quoted figures, those from 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.

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[12]. Hence, if current trends are maintained, coal would still last several 100 years.

table 8: overview of fossil fuel reserves and resourcesario

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

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

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.

tables 9 - 11: assumptions on fossil fuel use in the energy [r]evolution scenario

Oil	2003	2010	2020	2030	2040	2050
Reference [PJ]	147,425	176,791	206,365	231,237	256,069	284,010
Reference [million barrels]	24,089	28,887	33,720	37,784	41,841	46,407
Alternative [PJ]	147,425	144,085	128,606	110,865	98,832	87,135
Alternative [million barrels]	24,089	23,543	21,014	18,115	16,149	14,238

Gas	2003	2010	2020	2030	2040	2050
Reference [PJ]	93,230	101,344	123,691	145,903	166,033	189,471
Reference [billion cubic metres = 10E9m^3]	2,453	2,667	3,256	3,840	4,369	4,986
Alternative [PJ]	93,230	98,994	103,975	107,023	100,822	93,055
Alternative [billion cubic metres = 10E9m^3]	2,453	2,605	2,736	2,816	2,653	2,449

Coal	2003	2010	2020	2030	2040	2050
Reference [PJ]	107,902	112,992	126,272	146,387	170,053	202,794
Reference [million tonnes]	5,367	5,499	6,006	6,884	7,916	9,356
Alternative [PJ]	107,903	90,125	70,858	51,530	39,717	31,822
Alternative [million tonnes]	5,367	4,380	3,325	2,343	1,748	1,382

map 3: oil reference scenario and the energy [r]evolution scenario

WORLDWIDE SCENARIO

OECD NORTH AMERICA

		REF		ALT	
		TMB	%	TMB	%
Reserves	2005	59.5	5.0%	59.5	5.0%
		MB	PJ	MB	PJ
Consumption per region	2003	6,849H	41,917	6,849H	41,917
	2050	10,863H	66,481	2,940H	17,991
		B		B	
Consumption per person	2003	16H		16H	
	2050	18H		5	

LATIN AMERICA

		REF		ALT	
		TMB	%	TMB	%
Reserves	2005	103.5	8.6%	103.5	8.6%
		MB	PJ	MB	PJ
Consumption per region	2003	1,464	8,961	1,464	8,961
	2050	4,319	26,430	750	4,589
		B		B	
Consumption per person	2003	3		3	
	2050	7		1	

NON RENEWABLE RESOURCE

OIL

LEGEND

>60 | 50-60 | 40-50 | 30-40 | 20-30 | 10-20 | 5-10 | 0-5 — % RESOURCES GLOBALLY

REF — REFERENCE SCENARIO

ALT — ALTERNATIVE SCENARIO

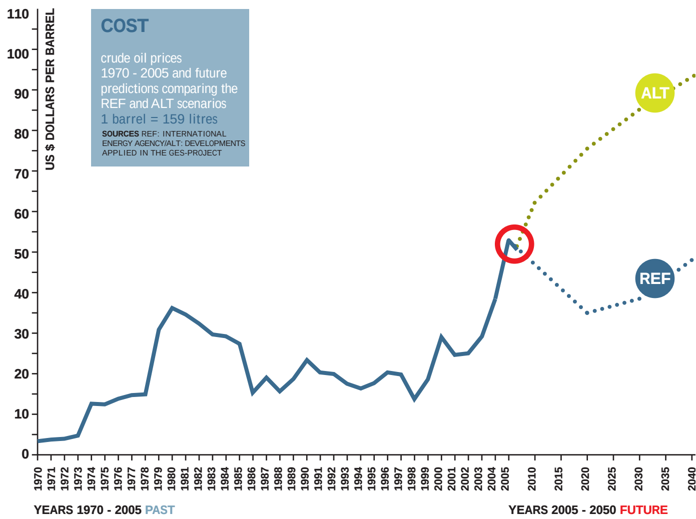
0 — 1000 KM

RESERVES TOTAL THOUSAND MILLION BARRELS [TMB] | SHARE IN % OF GLOBAL TOTAL [END OF 2005]

CONSUMPTION PER REGION MILLION BARRELS [MB] | PETA JOULE [PJ]

CONSUMPTION PER PERSON BARRELS [B]

H HIGHEST | **M** MIDDLE | **L** LOWEST



OECD EUROPE

	REF		ALT	
	TMB	%	TMB	%
2005	12.2	1.3%	12.2	1.3%
	MB	PJ	MB	PJ
2003	4,877	29,848	4,877	29,848
2050	4,960M	30,358	2,238	13,695
	B		B	
2003	9		9	
2050	10		4	

MIDDLE EAST

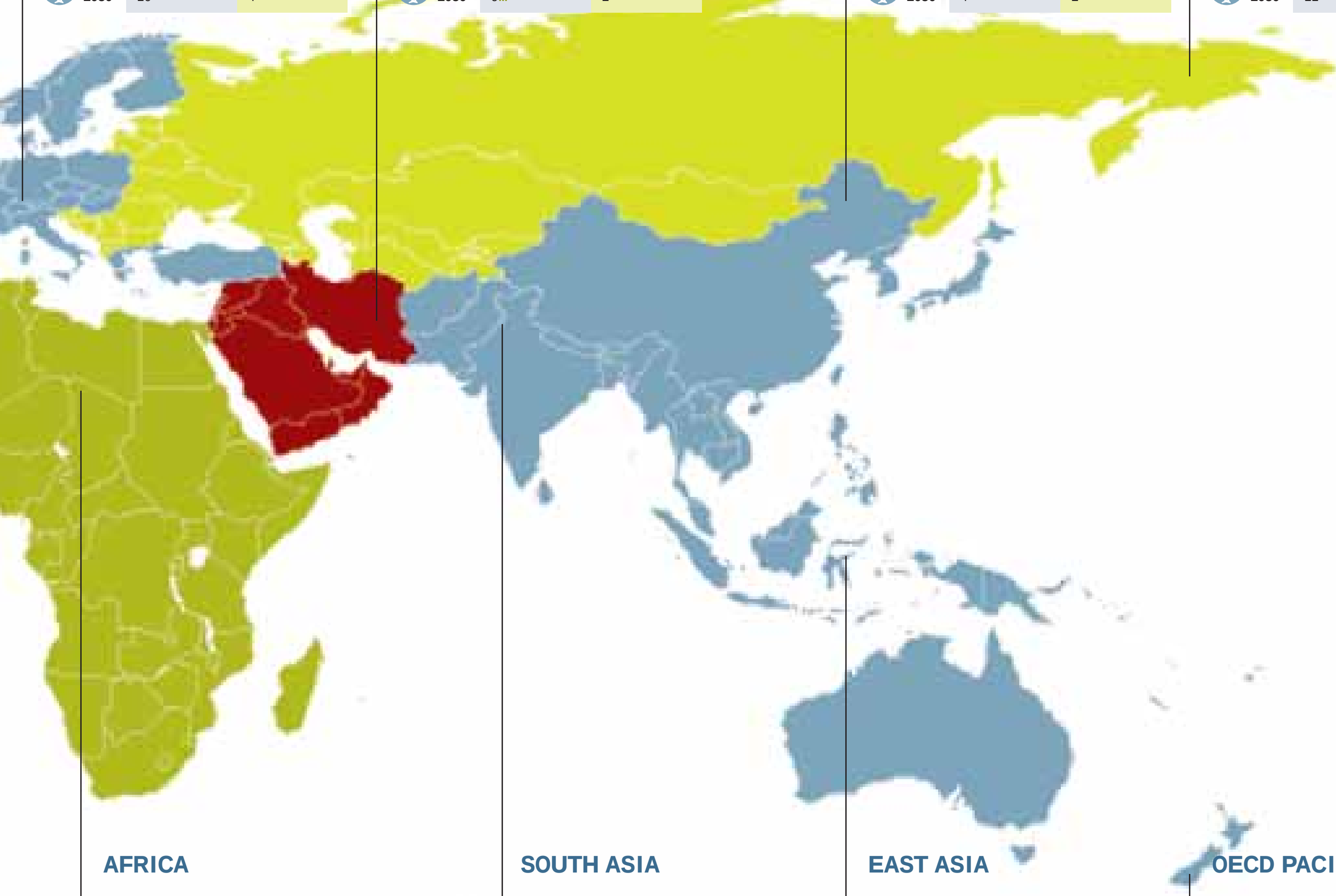
	REF		ALT	
	TMB	%	TMB	%
2005	742.7	61.9%H	742.7	61.9%H
	MB	PJ	MB	PJ
2003	1,598	9,782	1,598	9,782
2050	3,198	19,570	645L	3,949
	B		B	
2003	9		9	
2050	9M		2	

CHINA

	REF		ALT	
	TMB	%	TMB	%
2005	16.0	1.3%	16.0	1.3%
	MB	PJ	MB	PJ
2003	1,742	10,664	1,742	10,664
2050	6,163	37,718	2,366	14,480
	B		B	
2003	1		1	
2050	4		2	

TRANSITION ECONOMIES

	REF		ALT	
	TMB	%	TMB	%
2005	124.4	10.3%M	124.4	10.3%M
	MB	PJ	MB	PJ
2003	1,563	9,568	1,563	9,568
2050	3,215	19,678	835	5,110
	B		B	
2003	5M		5M	
2050	11		3M	



AFRICA

	REF		ALT	
	TMB	%	TMB	%
2005	114.3	9.5%	114.3	9.5%
	MB	PJ	MB	PJ
2003	833L	5,099	833L	5,099
2050	3,304	20,220	868	5,312
	B		B	
2003	1		1	
2050	2		0	

SOUTH ASIA

	REF		ALT	
	TMB	%	TMB	%
2005	5.9	0.5%	5.9	0.5%
	MB	PJ	MB	PJ
2003	914	5,597	914	5,597
2050	3,063L	18,747	896	5,481
	B		B	
2003	1L		1L	
2050	1L		0L	

EAST ASIA

	REF		ALT	
	TMB	%	TMB	%
2005	13.2	1.0%	13.2	1.0%
	MB	PJ	MB	PJ
2003	1,411	8,634	1,411	8,634
2050	4,027	24,648	1,404M	8,593
	B		B	
2003	2		2	
2050	5		2	

OECD PACIFIC

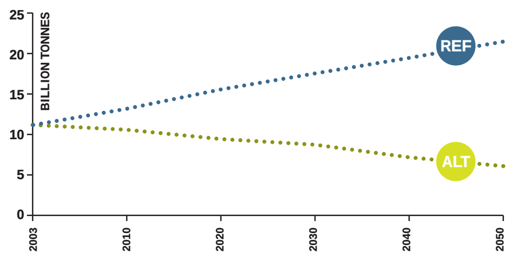
	REF		ALT	
	TMB	%	TMB	%
2005	4.0	0.3% L	4.0	0.3% L
	MB	PJ	MB	PJ
2003	2,836M	17,355	2,836M	17,355
2050	3,294	20,160	1,296	7,934
	B		B	
2003	14		14	
2050	18		7H	

CO_2 EMISSIONS

comparison between the REF and ALT scenarios 2003 - 2050

billion tonnes

SOURCE GPI/EREC

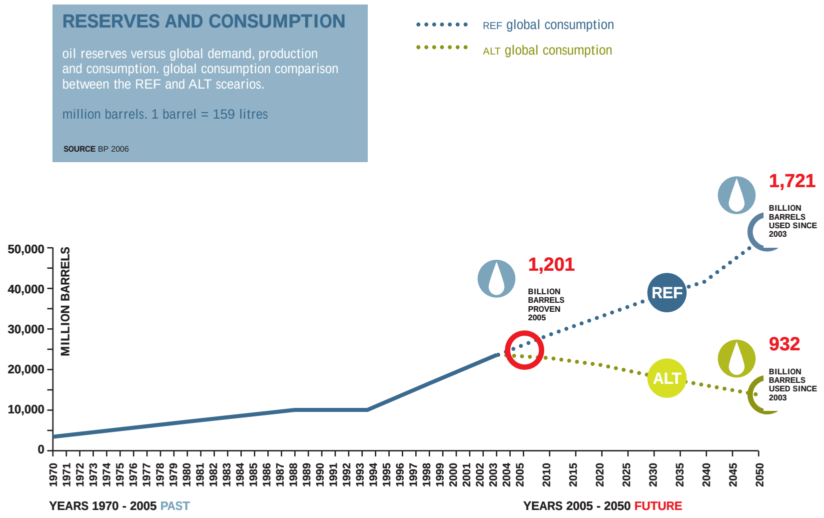


RESERVES AND CONSUMPTION

oil reserves versus global demand, production and consumption. global consumption comparison between the REF and ALT scearios.

million barrels. 1 barrel = 159 litres

SOURCE BP 2006

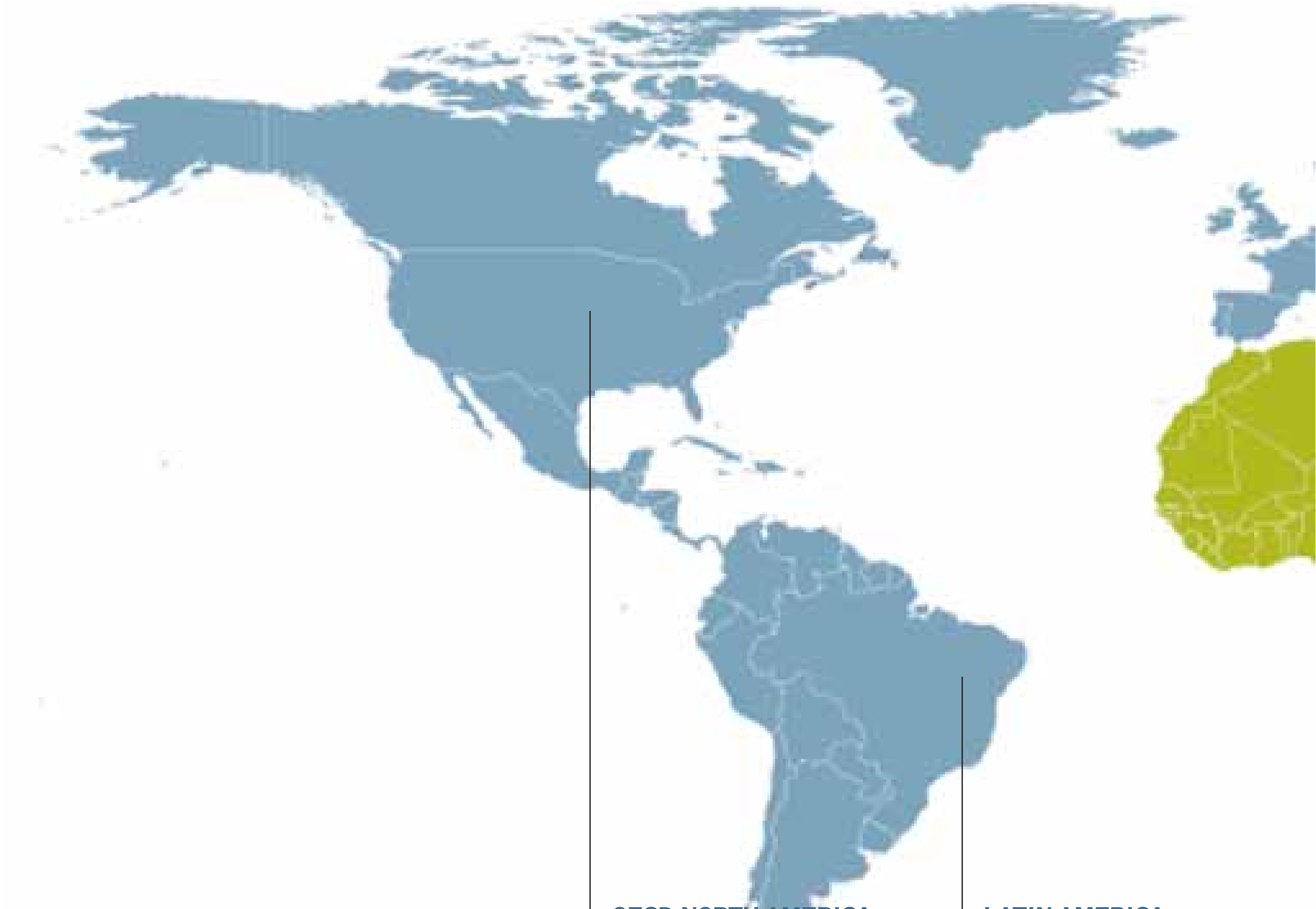


GREENPEACE

DESIGN WWW.ONEHEMISPHERE.SE CONCEPT SVEN TESKE/GREENPEACE INTERNATIONAL.

map 4: gas reference scenario and the energy [r]evolution scenario

WORLDWIDE SCENARIO



OECD NORTH AMERICA

		REF		ALT	
		tn m³	%	tn m³	%
Reserves	2005	7.5	**4.1%**	7.5	**4.1%**
		bn m³	PJ	bn m³	PJ
Consumption per region	2003	752H	28.568	752H	28.568
	2050	1,035H	39.312	352H	13.368
		m³		m³	
Consumption per person	2003	1770H		1770H	
	2050	1770		600H	

LATIN AMERICA

		REF		ALT	
		tn m³	%	tn m³	%
Reserves	2005	7.0	**3.9%**	7.0	**3.9%**
		bn m³	PJ	bn m³	PJ
Consumption per region	2003	103	3.916	103	3.916
	2050	570	21.666	104	3.940
		m³		m³	
Consumption per person	2003	230		230	
	2050	900		170	

NON RENEWABLE RESOURCE

GAS

LEGEND

>50 | 40-50 | 30-40 | 20-30 | 10-20 | 5-10 | 0-5 % RESOURCES GLOBALLY

REF REFERENCE SCENARIO

ALT ALTERNATIVE SCENARIO

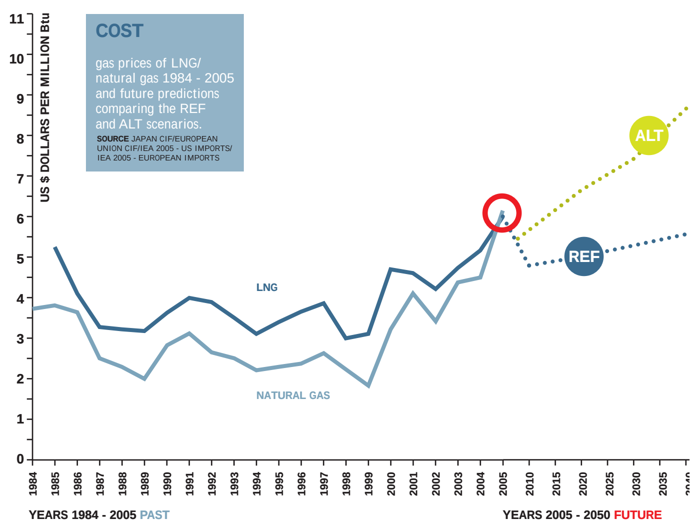
0 1000 KM

RESERVES TOTAL TRILLION CUBIC METRES [tn m³] | SHARE IN % OF GLOBAL TOTAL [END OF 2005]

CONSUMPTION PER REGION BILLION CUBIC METRES [bn m³] | PETA JOULE [PJ]

CONSUMPTION PER PERSON CUBIC METRES [m³]

H HIGHEST | M MIDDLE | L LOWEST



OECD EUROPE

		REF		ALT	
		tn m³	%	tn m³	%
	2005	4.9	2.7%	4.9	2.7%
		bn m³	PJ	bn m³	PJ
	2003	457	17.354	457	17.354
	2050	583	22.139	285	10.935
		m³		m³	
	2003	870		870	
	2050	1140		560M	

MIDDLE EAST

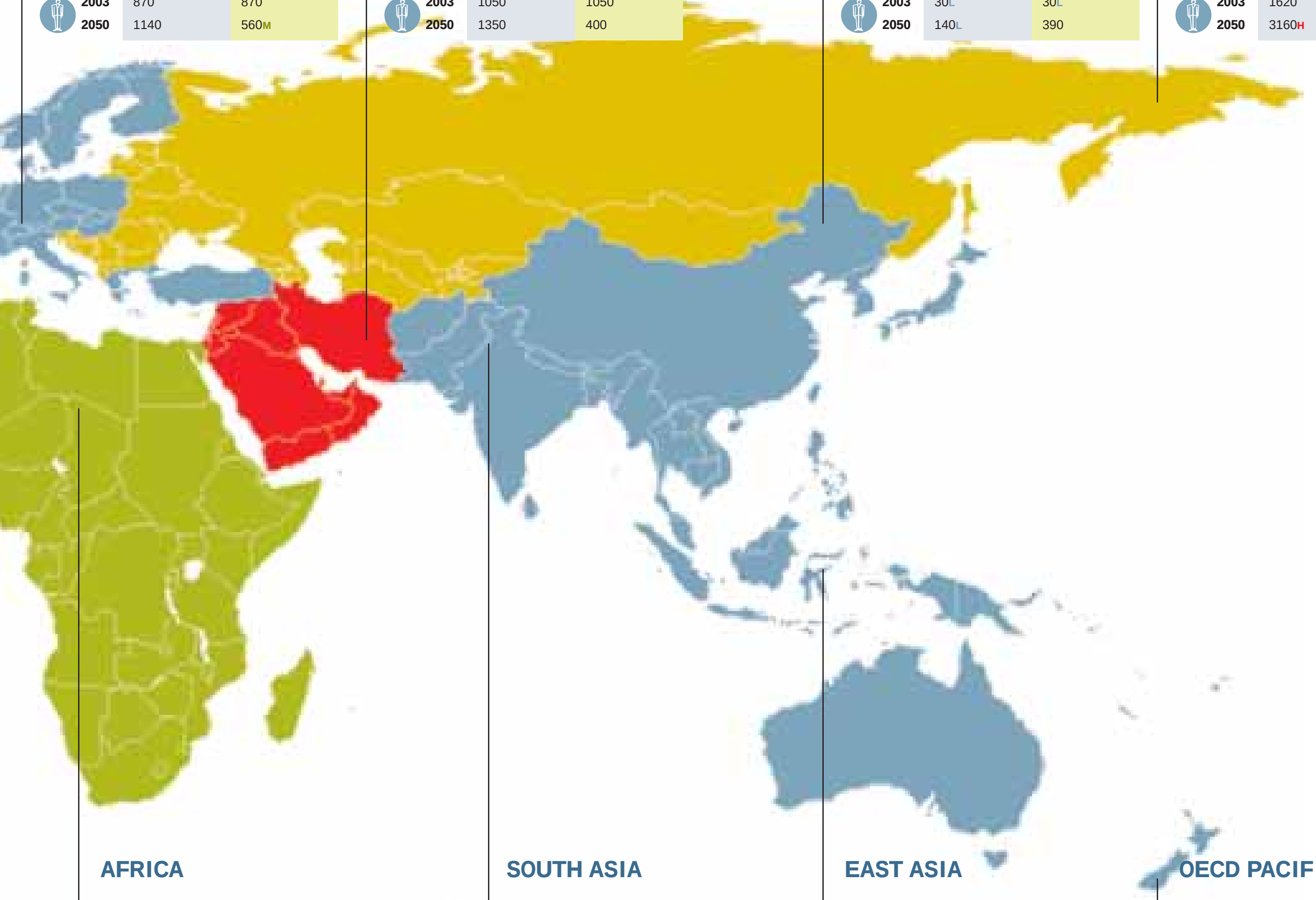
		REF		ALT	
		tn m³	%	tn m³	%
	2005	72.1	40.1%H	72.1	40.1%H
		bn m³	PJ	bn m³	PJ
	2003	191M	7.262	191M	7.262
	2050	478M	18.154	142	5.401
		m³		m³	
	2003	1050		1050	
	2050	1350		400	

CHINA

		REF		ALT	
		tn m³	%	tn m³	%
	2005	2.4	1.3%	2.4	1.3%
		bn m³	PJ	bn m³	PJ
	2003	35L	1.327	35L	1.327
	2050	200L	7.604	551	20,932
		m³		m³	
	2003	30L		30L	
	2050	140L		390	

TRANSITION ECONOMIES

		REF		ALT	
		tn m³	%	tn m³	%
	2005	59.1	32.9%	59.1	32.9%
		bn m³	PJ	bn m³	PJ
	2003	559	21.260	559	21.260
	2050	897	34.074	266	10.122
		m³		m³	
	2003	1620		1620	
	2050	3160H		940	



AFRICA

		REF		ALT	
		tn m³	%	tn m³	%
	2005	14.4	8.0%M	14.4	8.0%M
		bn m³	PJ	bn m³	PJ
	2003	65	2.472	65	2.472
	2050	420	15.952	210	7.978
		m³		m³	
	2003	80		80	
	2050	230		110	

SOUTH ASIA

		REF		ALT	
		tn m³	%	tn m³	%
	2005	1.1	0.6%L	1.1	0.6%L
		bn m³	PJ	bn m³	PJ
	2003	59	2.255	59	2.255
	2050	324	12.314	256	9.737
		m³		m³	
	2003	40		40	
	2050	150		120L	

EAST ASIA

		REF		ALT	
		tn m³	%	tn m³	%
	2005	8.5	4.7%	8.5	4.7%
		bn m³	PJ	bn m³	PJ
	2003	112	4.241	112	4.241
	2050	274	10.395	163M	6.195
		m³		m³	
	2003	180		180	
	2050	310		180	

OECD PACIFIC

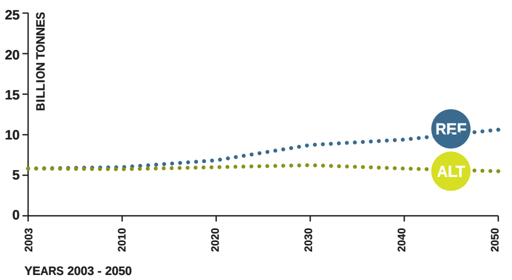
		REF		ALT	
		tn m³	%	tn m³	%
	2005	2.5	1.4%	2.5	1.4%
		bn m³	PJ	bn m³	PJ
	2003	120	4.575	120	4.575
	2050	207	7.862	117L	4.446
		m³		m³	
	2003	610M		610M	
	2050	1130M		640	

CO_2 EMISSIONS

comparison between the REF and ALT scenarios 2003 - 2050

billion tonnes

SOURCE GPI/EREC

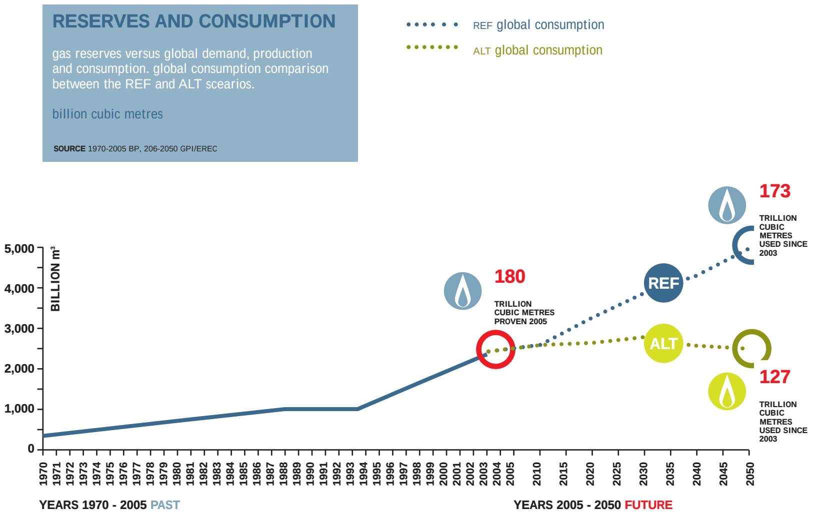


RESERVES AND CONSUMPTION

gas reserves versus global demand, production and consumption. global consumption comparison between the REF and ALT scearios.

billion cubic metres

SOURCE 1970-2005 BP, 206-2050 GPI/EREC

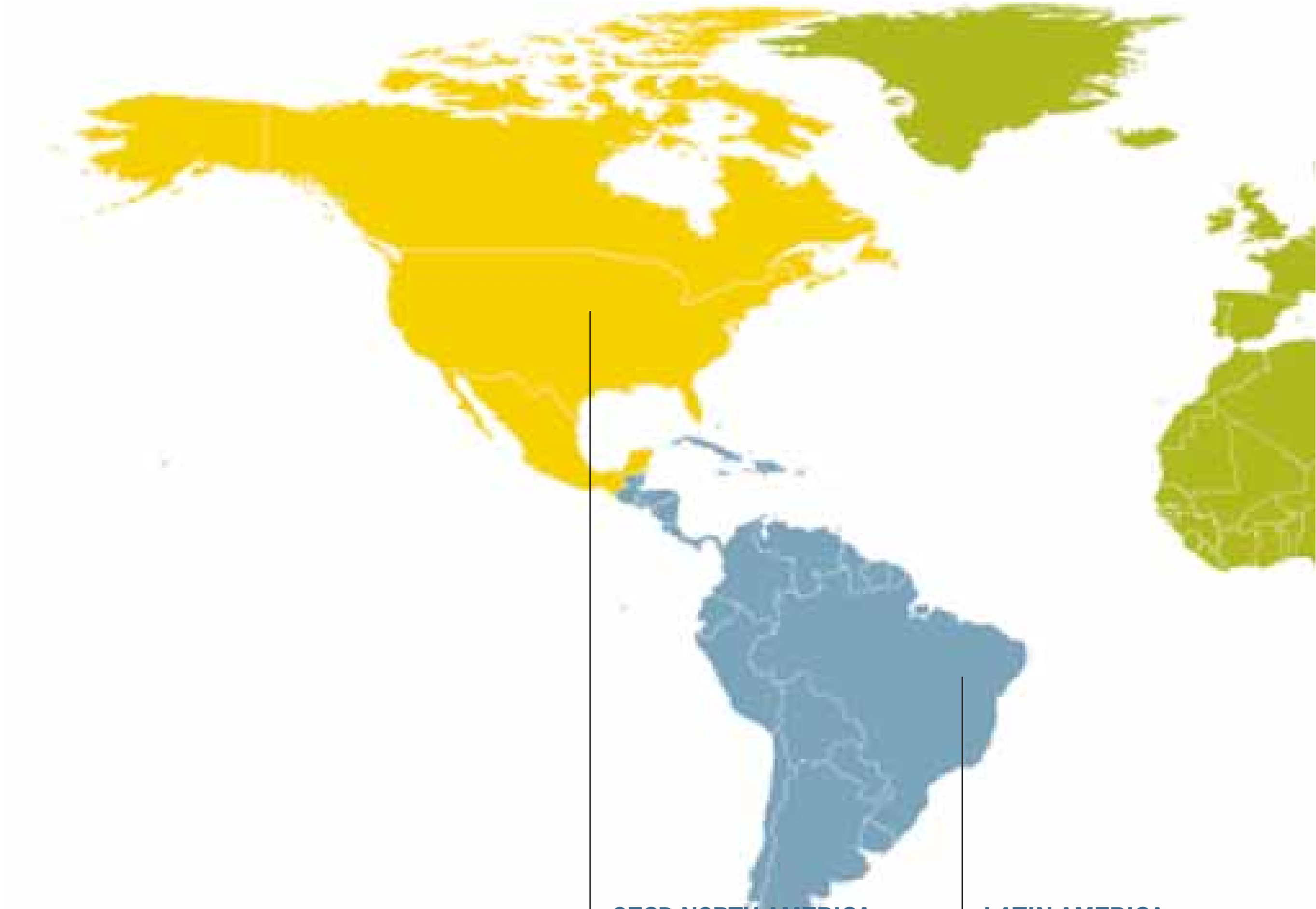


GREENPEACE

DESIGN WWW.ONEHEMISPHERE.SE **CONCEPT** SVEN TESKE/GREENPEACE INTERNATIONAL.

map 5: coal reference scenario and the energy [r]evolution scenario

WORLDWIDE SCENARIO



OECD NORTH AMERICA

		REF		ALT	
		mn t	%	mn t	%
Reserves	2005	254,432	28.0% H	254,432	28.0% H
		mn t	PJ	mn t	PJ
Consumption per region	2003	1,326	27,417	1,326	27,417
	2050	1,618	33,475	84	1,926
		t		t	
Consumption per person	2003	3.1 H		3.1 H	
	2050	2.8 H		0.1 M	

LATIN AMERICA

		REF		ALT	
		mn t	%	mn t	%
Reserves	2005	19,893	2.2%	19,893	2.2%
		mn t	PJ	mn t	PJ
Consumption per region	2003	38	869	38	869
	2050	217	4,997	17	394
		t		t	
Consumption per person	2003	0.1 L		0.1 L	
	2050	0.3		0.0 L	

NON RENEWABLE RESOURCE

COAL

LEGEND

>60 | 50-60 | 40-50 | 30-40 | 20-30 | 10-20 | 5-10 | 0-5 — % RESOURCES GLOBALLY

REF — REFERENCE SCENARIO

ALT — ALTERNATIVE SCENARIO

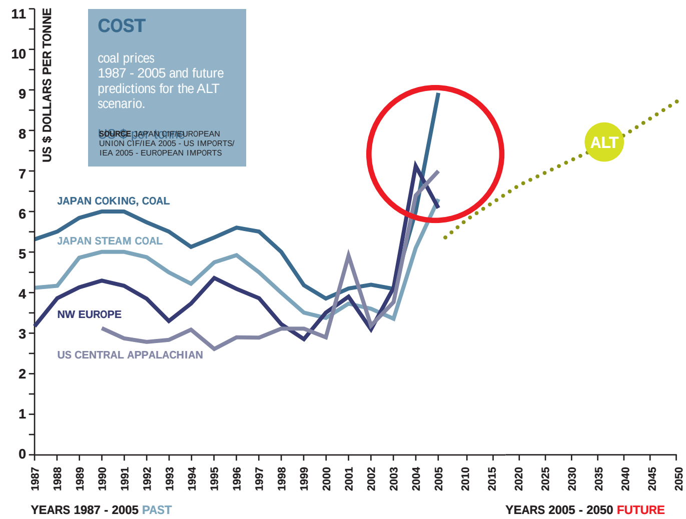
0 — 1000 KM

RESERVES TOTAL MILLION TONNES [mn t] | SHARE IN % OF GLOBAL TOTAL [END OF 2005]

CONSUMPTION PER REGION MILLION TONNES [mn t] | PETA JOULE [PJ]

CONSUMPTION PER PERSON TONNES [t]

H HIGHEST | M MIDDLE | L LOWEST



OECD EUROPE

	REF mn t	REF %	ALT mn t	ALT %
2005	61,972	6.8%	61,972	6.8%

	REF mn t	REF PJ	ALT mn t	ALT PJ
2003	839	13,166	839	13,166
2050	1,197	25,539	71	1,635

	REF t	ALT t
2003	1.6	1.6
2050	2.4	0.1

MIDDLE EAST

	REF mn t	REF %	ALT mn t	ALT %
2005	419	0.0%L	419	0.0%L

	REF mn t	REF PJ	ALT mn t	ALT PJ
2003	17L	397	17L	397
2050	38L	861	9L	208

	REF t	ALT t
2003	0.1	0.1
2050	0.1L	0.0

CHINA

	REF mn t	REF %	ALT mn t	ALT %
2005	114,500	12.6%	114,500	12.6%

	REF mn t	REF PJ	ALT mn t	ALT PJ
2003	1,400H	32,241	1,400H	32,241
2050	2,754H	63,434	648H	14,916

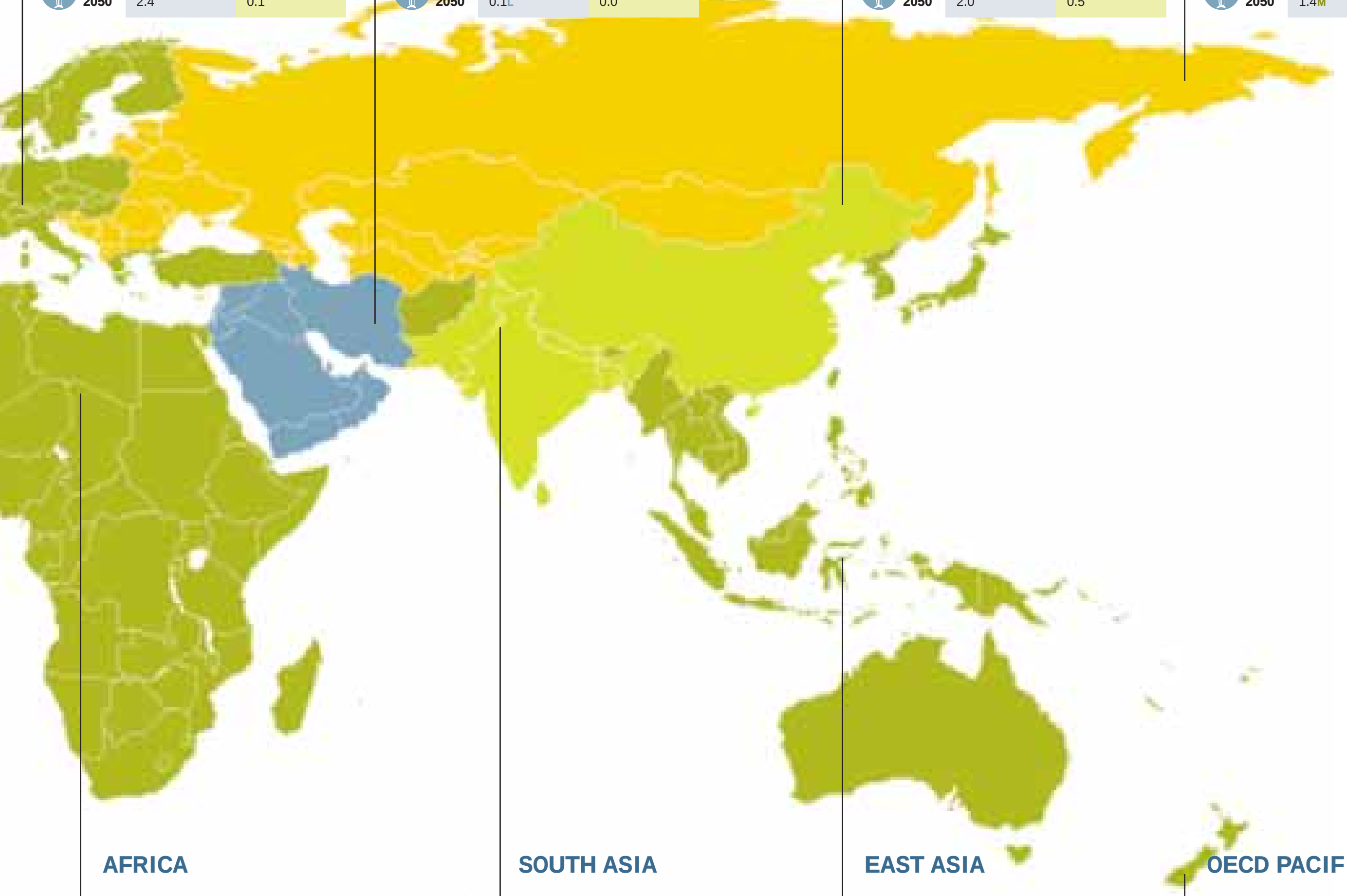
	REF t	ALT t
2003	1.1M	1.1M
2050	2.0	0.5

TRANSITION ECONOMIES

	REF mn t	REF %	ALT mn t	ALT %
2005	225,123	24.8%	225,123	24.8%

	REF mn t	REF PJ	ALT mn t	ALT PJ
2003	634M	9,957	634M	9,957
2050	391	6,923	27	628

	REF t	ALT t
2003	1.8	1.8
2050	1.4M	0.1



AFRICA

	REF mn t	REF %	ALT mn t	ALT %
2005	50,336	5.5%	50,336	5.5%

	REF mn t	REF PJ	ALT mn t	ALT PJ
2003	181	4,163	181	4,163
2050	727	16,732	225	5,171

	REF t	ALT t
2003	0.2	0.2
2050	0.4	0.1

SOUTH ASIA

	REF mn t	REF %	ALT mn t	ALT %
2005	95,495	10.5%M	95,495	10.5%M

	REF mn t	REF PJ	ALT mn t	ALT PJ
2003	362	7,727	362	7,727
2050	1,103	24,057	152M	3,500

	REF t	ALT t
2003	0.3	0.3
2050	0.5	0.1

EAST ASIA

	REF mn t	REF %	ALT mn t	ALT %
2005	1,287	4.7%	1,287	4.7%

	REF mn t	REF PJ	ALT mn t	ALT PJ
2003	190	3,990	190	3,990
2050	902M	17,944	44	1,006

	REF t	ALT t
2003	0.3	0.3
2050	1.0	0.0

OECD PACIFIC

	REF mn t	REF %	ALT mn t	ALT %
2005	79,510	8.7%	79,510	8.7%

	REF mn t	REF PJ	ALT mn t	ALT PJ
2003	382	7,975	382	7,975
2050	409	8,832	106	2,438

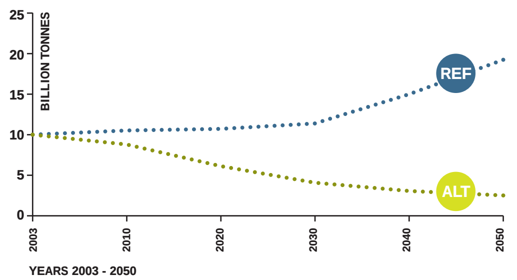
	REF t	ALT t
2003	1.9	1.9
2050	2.2	0.6H

CO_2 EMISSIONS

comparison between the REF and ALT scenarios 2003 - 2050

billion tonnes

SOURCE GPI/EREC

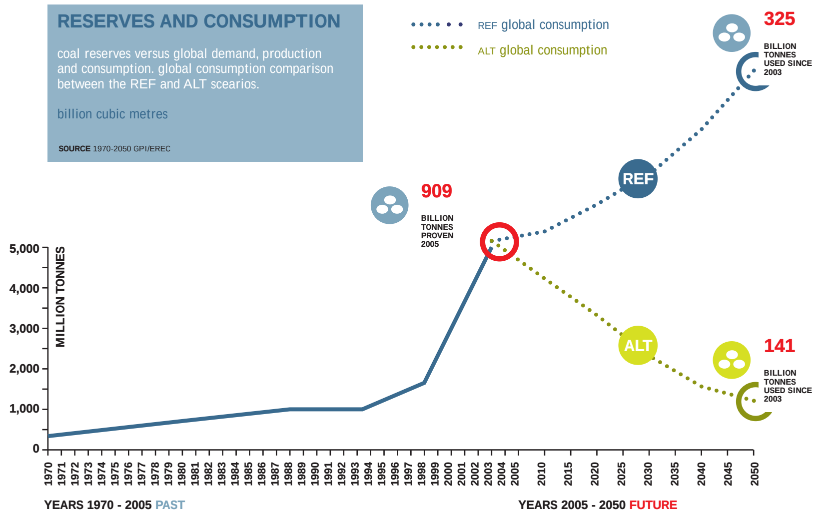


RESERVES AND CONSUMPTION

coal reserves versus global demand, production and consumption. global consumption comparison between the REF and ALT scearios.

billion cubic metres

SOURCE 1970-2050 GPI/EREC



GREENPEACE

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map 6: nuclear reference scenario and the energy [r]evolution scenario

WORLDWIDE SCENARIO

OECD NORTH AMERICA

	Year	REF		ALT	
		t	%	t	%
Reserves	2005	680,109	21%	680,109	21%
		TWh		TWh	
Generation	2003	873		PHASED OUT BY 2030	
	2050	840H			
		PJ		PJ	
Consumption	2003	9,526		9,526	
	2050	9,164H		0	
		kWh		kWh	
Per person	2003	2,051H		2,051H	
	2050	1,433		0	

LATIN AMERICA

	Year	REF		ALT	
		t	%	t	%
Reserves	2005	95,045	3%	95,045	3%
		TWh		TWh	
Generation	2003	21		PHASED OUT BY 2030	
	2050	29			
		PJ		PJ	
Consumption	2003	228		228	
	2050	316		0	
		kWh		kWh	
Per person	2003	48		48	
	2050	46		0	

NON RENEWABLE RESOURCE

NUCLEAR

LEGEND

>30 | 20-30 | 10-20 | 5-10 | 0-5 % RESOURCES GLOBALLY

REF REFERENCE SCENARIO

ALT ALTERNATIVE SCENARIO

0 1000 KM

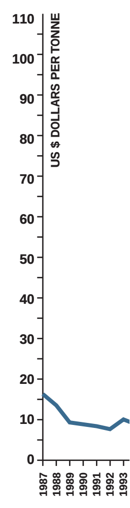
RESERVES TOTAL TONNES | SHARE IN % OF GLOBAL TOTAL [END OF 2005]

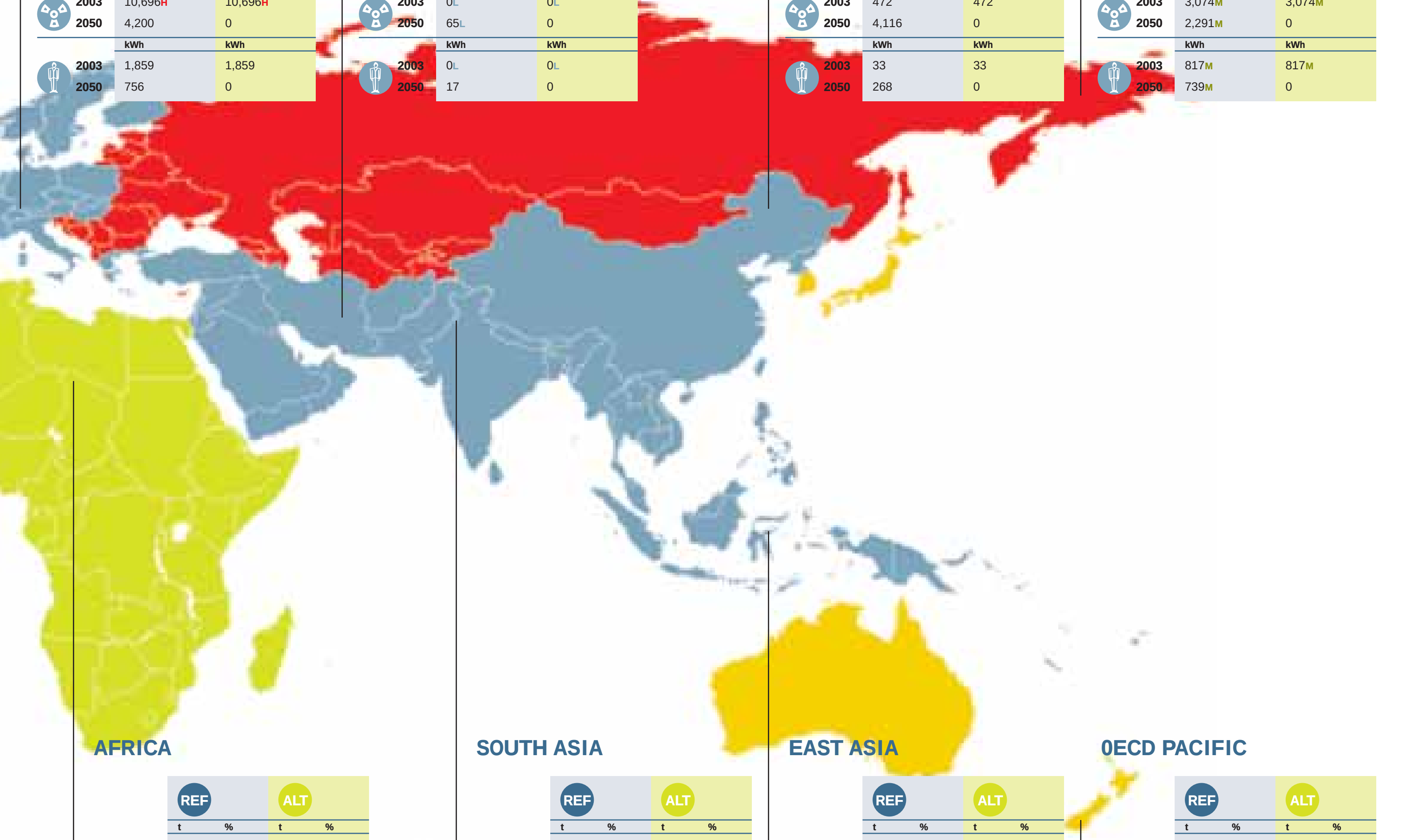
GENERATION PER REGION TERAWATT HOURS [TWh]

CONSUMPTION PER REGION PETA JOULE [PJ]

CONSUMPTION PER PERSON KILOWATT HOURS [kWh]

H HIGHEST | M MIDDLE | L LOWEST





OECD EUROPE

	REF		ALT	
	t	%	t	%
2005	56,445	2%	56,445	2%
	TWh		TWh	
2003	981H		PHASED OUT BY 2030	
2050	385			
	PJ		PJ	
2003	10,696H		10,696H	
2050	4,200		0	
	kWh		kWh	
2003	1,859		1,859	
2050	756		0	

MIDDLE EAST

	REF		ALT	
	t	%	t	%
2005	0	0%L	0	0%L
	TWh		TWh	
2003	0L		PHASED OUT BY 2030	
2050	6L			
	PJ		PJ	
2003	0L		0L	
2050	65L		0	
	kWh		kWh	
2003	0L		0L	
2050	17		0	

CHINA

	REF		ALT	
	t	%	t	%
2005	35,060	1%	35,060	1%
	TWh		TWh	
2003	43		PHASED OUT BY 2030	
2050	377			
	PJ		PJ	
2003	472		472	
2050	4,116		0	
	kWh		kWh	
2003	33		33	
2050	268		0	

TRANSITION ECONOMIES

	REF		ALT	
	t	%	t	%
2005	997,487	31%H	997,487	31%H
	TWh		TWh	
2003	282M		PHASED OUT BY 2030	
2050	210M			
	PJ		PJ	
2003	3,074M		3,074M	
2050	2,291M		0	
	kWh		kWh	
2003	817M		817M	
2050	739M		0	

AFRICA

	REF		ALT	
	t	%	t	%
2005	470,312	15%M	470,312	15%M
	TWh		TWh	
2003	13		PHASED OUT BY 2030	
2050	13			
	PJ		PJ	
2003	139		139	
2050	142		0	
	kWh		kWh	
2003	15		15	
2050	7L		0	

SOUTH ASIA

	REF		ALT	
	t	%	t	%
2005	40,980	1%	40,980	1%
	TWh		TWh	
2003	20		PHASED OUT BY 2030	
2050	190			
	PJ		PJ	
2003	213		213	
2050	2,073		0	
	kWh		kWh	
2003	14		14	
2050	86		0	

EAST ASIA

	REF		ALT	
	t	%	t	%
2005	5,630	0%	5,630	0%
	TWh		TWh	
2003	39		PHASED OUT BY 2030	
2050	70			
	PJ		PJ	
2003	424		424	
2050	764		0	
	kWh		kWh	
2003	62		62	
2050	79		0	

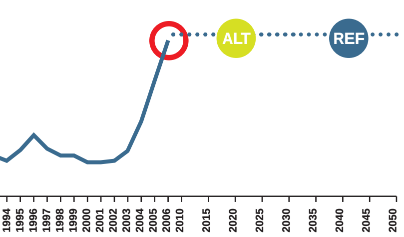
0ECD PACIFIC

	REF		ALT	
	t	%	t	%
2005	741,600	23%	741,600	23%
	TWh		TWh	
2003	370		PHASED OUT BY 2030	
2050	610			
	PJ		PJ	
2003	4,033		4,033	
2050	6,655		0	
	kWh		kWh	
2003	1,858		1,858	
2050	3,341H		0	

COST

yellow cake prices 1987 - 2006 and future predictions comparing the REF and ALT scenarios
tonnes

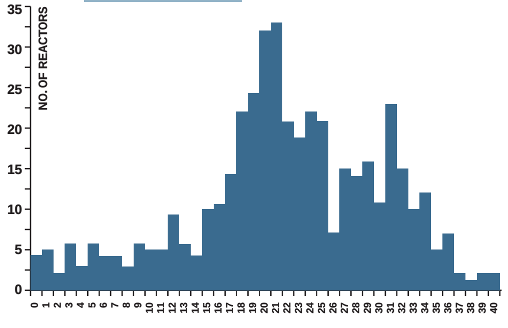
SOURCES REF: INTERNATIONAL ENERGY AGENCY/ALT: DEVELOPMENTS APPLIED IN THE GES-PROJECT



REACTORS

age and number of reactors worldwide

SOURCES XXX

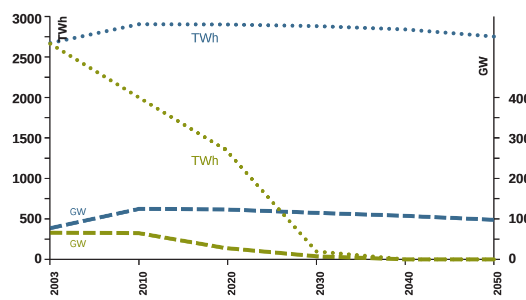


PRODUCTION

coal generation versus installed capacity. comparison between the REF and ALT scenrios. TWh and GW

SOURCES XXX

REF global generation
REF global capacity
ALT global capacity
ALT global generation



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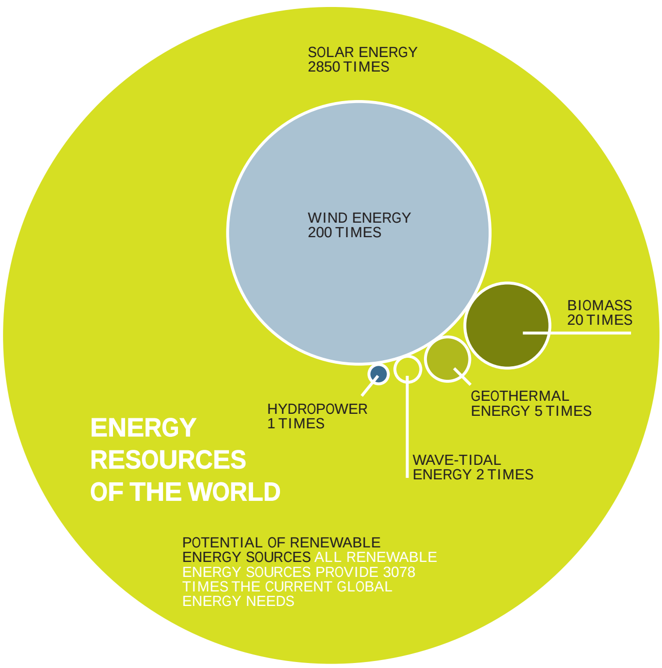
renewable energy

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 2,850 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 power than the world currently requires.

figure 30: energy resources of the world



source WBGU

table 12: technically accessible today

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

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

definition of types of energy resource potential[13]

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

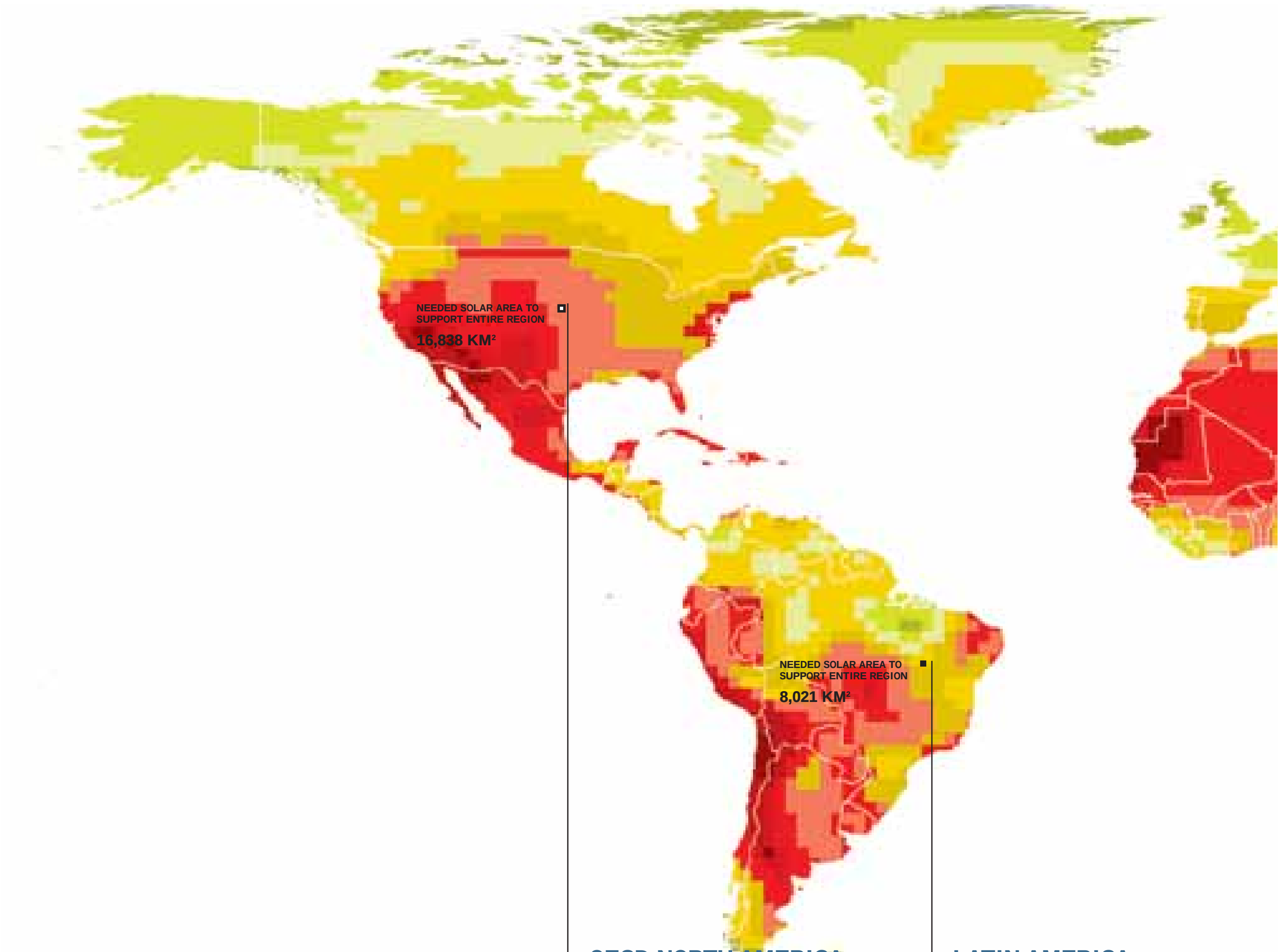
This limits the potential of an energy source based on evaluation of ecological and socio-economic factors.

The accompanying resource maps show the regional distribution of the estimated energy that can be recovered and utilised. The calculations were carried out based on a global grid with a resolution of 0.5° longitude and latitude. The resulting potential is specified as average power density per surface area or per tilted module/converter area, so that the unit of measurement is always ‘output per area’.

reference
13 WBGU

map 7: solar reference scenario and the energy [r]evolution scenario

WORLDWIDE SCENARIO



OECD NORTH AMERICA

		REF		ALT	
		%	PJ	%	PJ
Production per region	2003	0.05M	57H		
	2050	0.26M	423	6.7	4,677
			kWh		kWh
Production per person	2003		37		
	2050		201		2,217M

LATIN AMERICA

		REF		ALT	
		%	PJ	%	PJ
Production per region	2003	0.01	2		
	2050	0.03	16L	7.4	2,228
			kWh		kWh
Production per person	2003		1		
	2050		7		982

RENEWABLE RESOURCE

SOLAR

LEGEND

RADIATION IN kW/h PER SQUARE METER (SOURCE DLR): 2600-2800 | 2400-2600 | 2200-2400 | 2000-2200 | 1800-2000 | 1600-1800 | 1400-1600 | 1200-1400 | 1000-1200 | 800-1000 | 600-800 | 400-600 | 200-400 | 0-200

REF REFERENCE SCENARIO

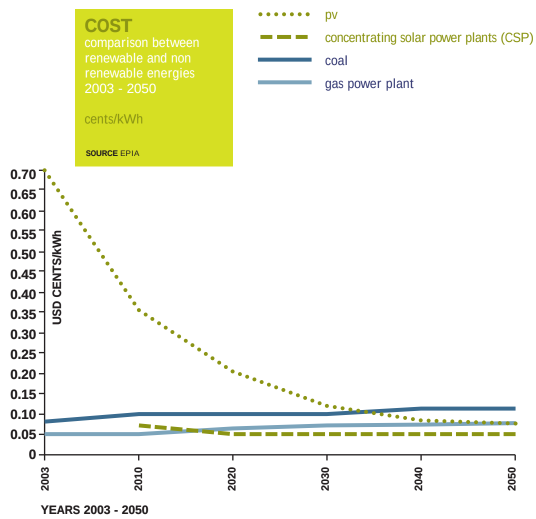
ALT ALTERNATIVE SCENARIO

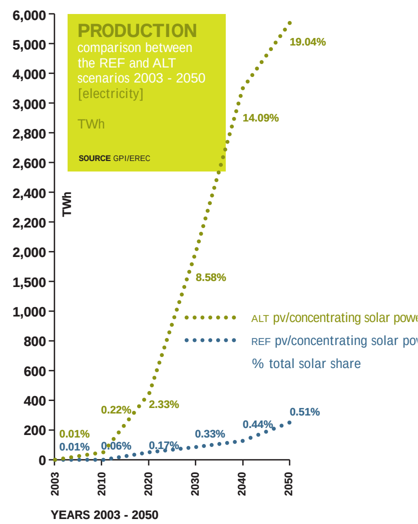
0 1000 KM

PRODUCTION PER REGION % OF GLOBAL SHARE | PETA JOULE [PJ]

PRODUCTION PER PERSON KILOWATT HOUR [kWh]

H HIGHEST | M MIDDLE | L LOWEST





OECD EUROPE

	REF		ALT	
	%	PJ	%	PJ
2003	0.05M	39		
2050	0.25	233M	6	3,062
		kWh		kWh
2003		20M		
2050		127M		1,671

MIDDLE EAST

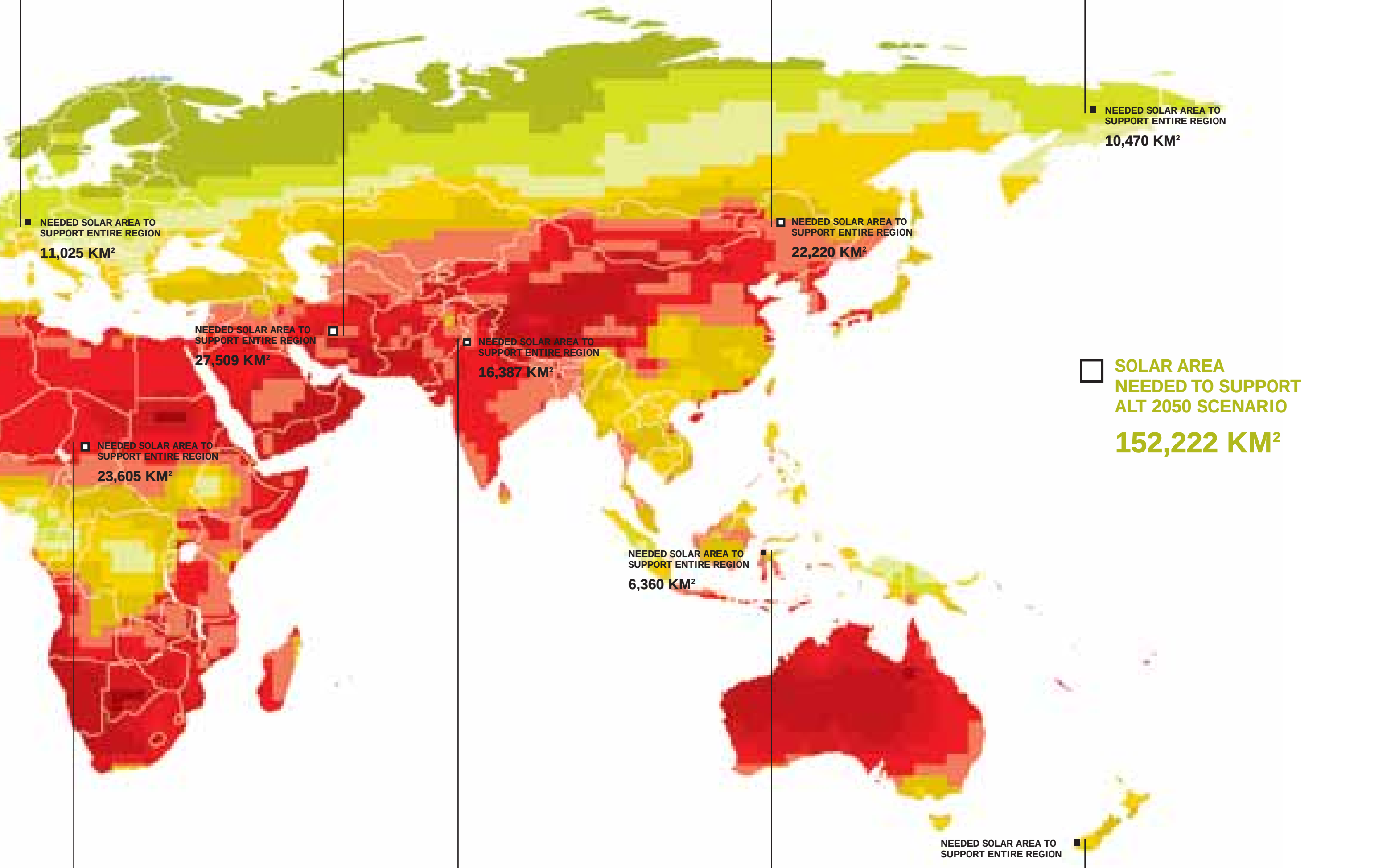
	REF		ALT	
	%	PJ	%	PJ
2003	0.18H	32		
2050	0.32	125	38H	7,641H
		kWh		kWh
2003		49H		
2050		98		5,999H

CHINA

	REF		ALT	
	%	PJ	%	PJ
2003	0.00L	0L		
2050	0.46	584H	8.1	6,172
		kWh		kWh
2003		0L		
2050		115		1,218

TRANSITION ECONOMIES

	REF		ALT	
	%	PJ	%	PJ
2003	0.00	1		
2050	0.00	3	7.8	2,908
		kWh		kWh
2003		1		
2050		3L		2,844



AFRICA

	REF		ALT	
	%	PJ	%	PJ
2003	0.00L	0L		
2050	0.17	127	14.9	6,557
		kWh		kWh
2003		0L		
2050		19		992

SOUTH ASIA

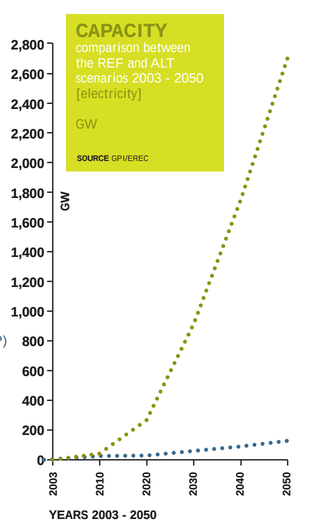
	REF		ALT	
	%	PJ	%	PJ
2003	0.00L	0L		
2050	0.17	121	12.2M	4,552M
		kWh		kWh
2003		0L		
2050		15		572

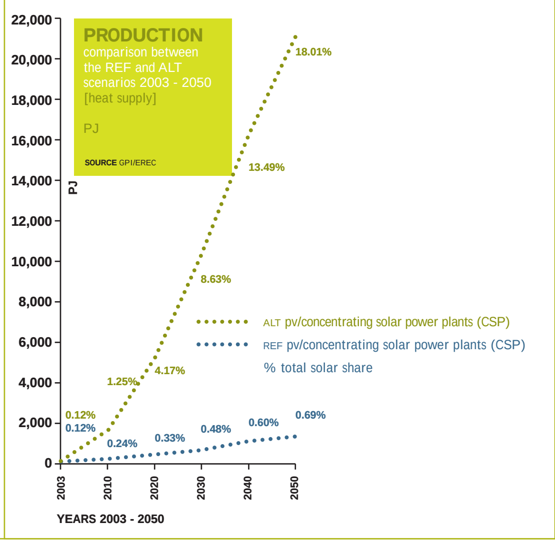
EAST ASIA

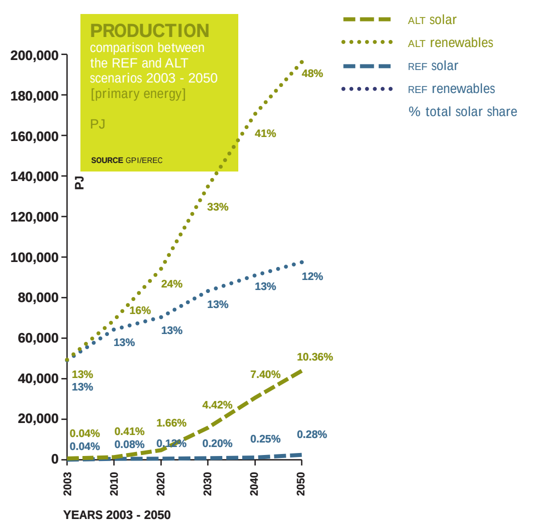
	REF		ALT	
	%	PJ	%	PJ
2003	0.00L	0L		
2050	0.39	235	5.5L	1,767L
		kWh		kWh
2003		0L		
2050		73		552L

OECD PACIFIC

	REF		ALT	
	%	PJ	%	PJ
2003	0.09	31M		
2050	0.85H	397	11.5	2,719
		kWh		kWh
2003		44		
2050		604H		4,137



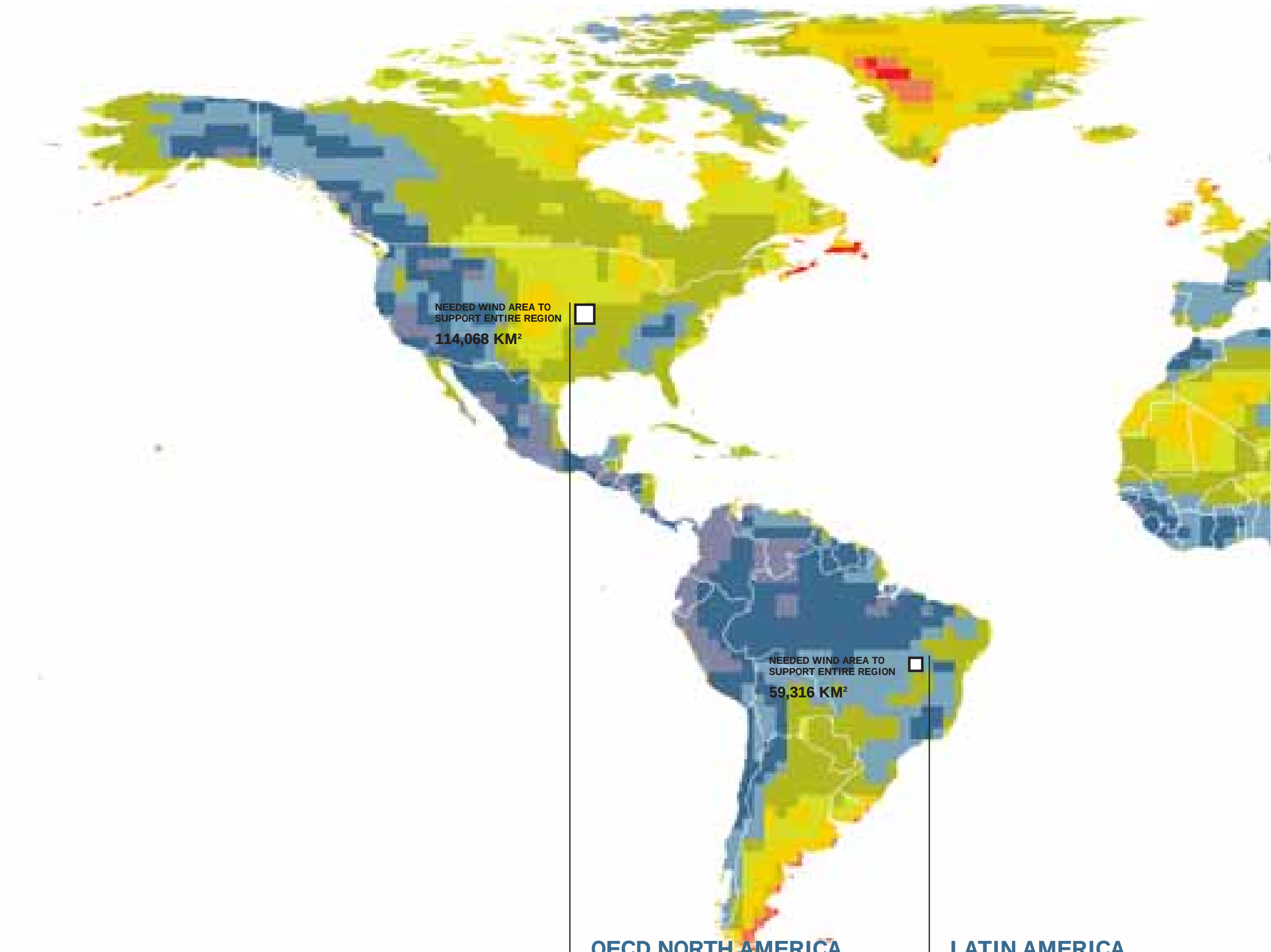




GREENPEACE
DESIGN WWW.ONEHEMISPHERE.SE CONCEPT SVEN TESKE/GREENPEACE INTERNATIONAL.

map 8: wind reference scenario and the energy [r]evolution scenario

WORLDWIDE SCENARIO



RENEWABLE RESOURCE

WIND

OECD NORTH AMERICA

	REF %	REF PJ	ALT %	ALT PJ
2003	0.04M	44		
2050	0.73	1,188	7.7	5,400H
		kWh		kWh
2003		28		
2050		563		2,559

LATIN AMERICA

	REF %	REF PJ	ALT %	ALT PJ
2003	0.01	1		
2050	0.32	198	9.3H	2,808M
		kWh		kWh
2003		1		
2050		87		1,238M

LEGEND

>11 | 10-11 | 9-10 | 8-9 | 7-8 | 6-7 | 5-6 | 4-5 | 3-4 | 1-2 | 0-1

AVERAGE WIND SPEED IN METRES PER SECOND
SOURCE DLR

REF REFERENCE SCENARIO

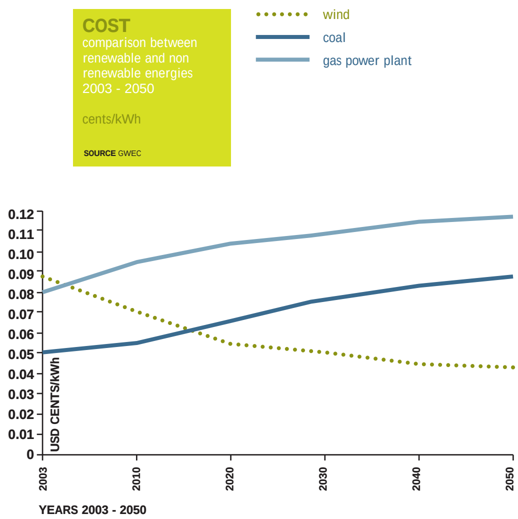
ALT ALTERNATIVE SCENARIO

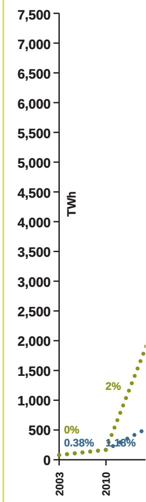
0 1000 KM

PRODUCTION PER REGION % OF GLOBAL SHARE | PETA JOULE [PJ]

PRODUCTION PER PERSON KILOWATT HOUR [kWh]

H HIGHEST | M MIDDLE | L LOWEST





OECD EUROPE

	REF %	REF PJ	ALT %	ALT PJ
2003	0.21H	160H		
2050	2.10H	1,962H	7.2	3,654
		REF kWh		ALT kWh
2003		84H		
2050		1,071H		1,994

MIDDLE EAST

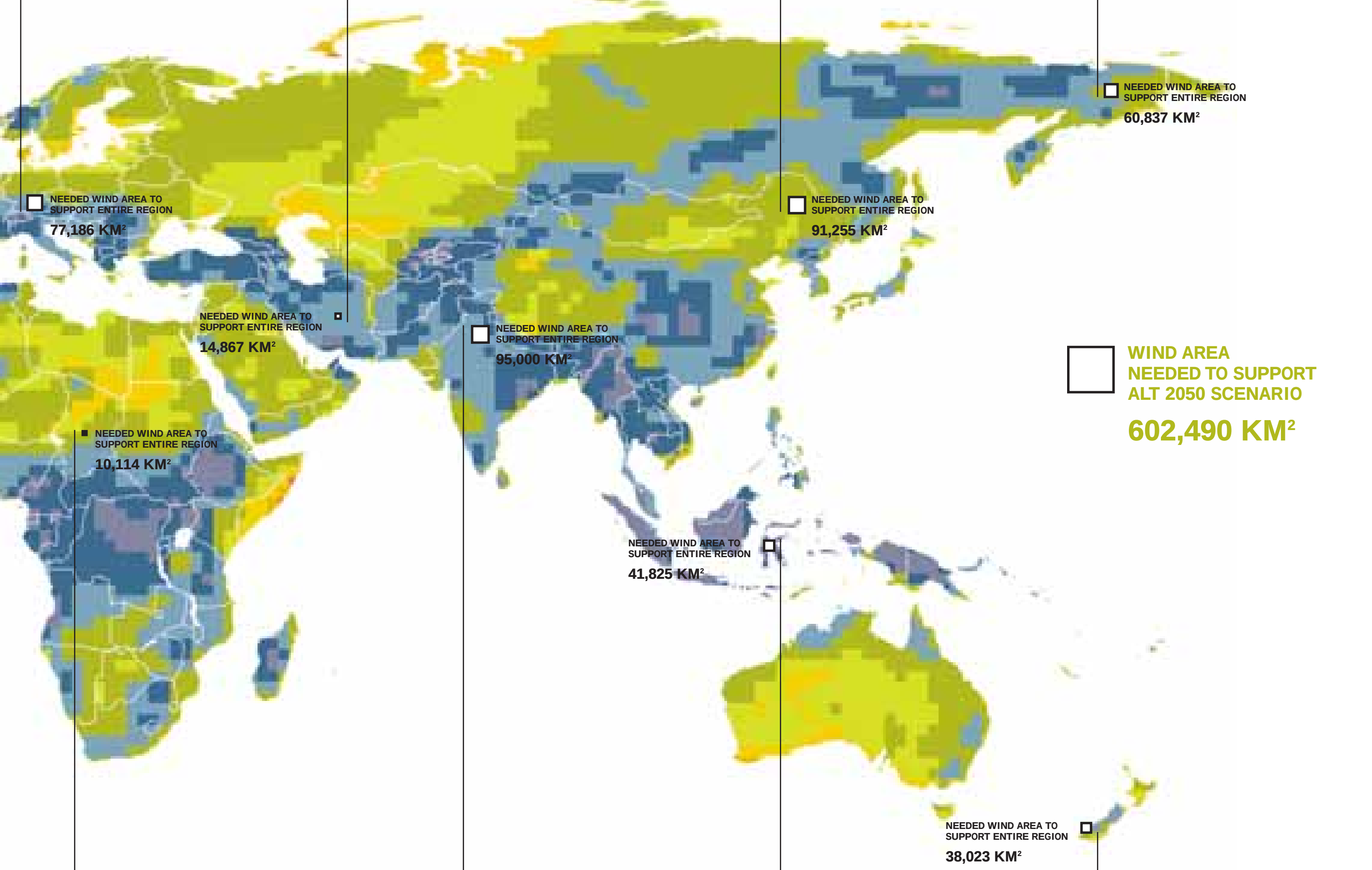
	REF %	REF PJ	ALT %	ALT PJ
2003	0.00L	0L		
2050	0.18	72L	3.5	704
		REF kWh		ALT kWh
2003		0L		
2050		57		553

CHINA

	REF %	REF PJ	ALT %	ALT PJ
2003	0.01	4		
2050	0.53M	681	5.7	4,320
		REF kWh		ALT kWh
2003		1		
2050		135		853

TRANSITION ECONOMIES

	REF %	REF PJ	ALT %	ALT PJ
2003	0.00L	0L		
2050	0.21	139	7.7	2,880
		REF kWh		ALT kWh
2003		0		
2050		136M		2,817H



WIND AREA NEEDED TO SUPPORT ALT 2050 SCENARIO

602,490 KM²

AFRICA

	REF %	REF PJ	ALT %	ALT PJ
2003	0.01	2		
2050	0.14L	104	1.1L	479L
		REF kWh		ALT kWh
2003		1		
2050		16L		72L

SOUTH ASIA

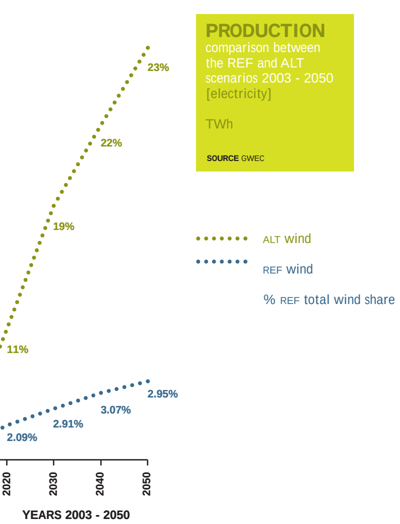
	REF %	REF PJ	ALT %	ALT PJ
2003	0.05M	13M		
2050	0.26M	137	4.6	1,710
		REF kWh		ALT kWh
2003		3		
2050		17		215

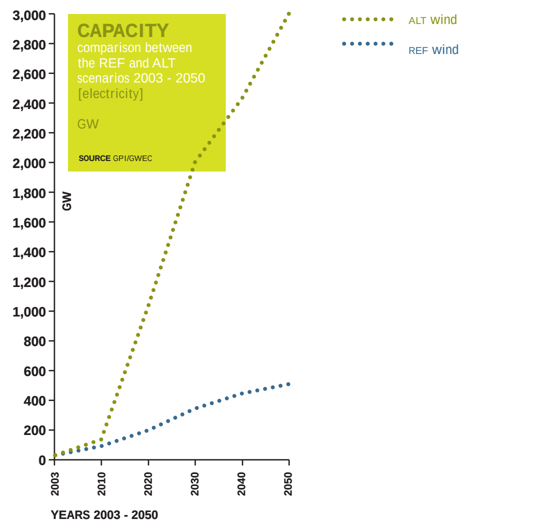
EAST ASIA

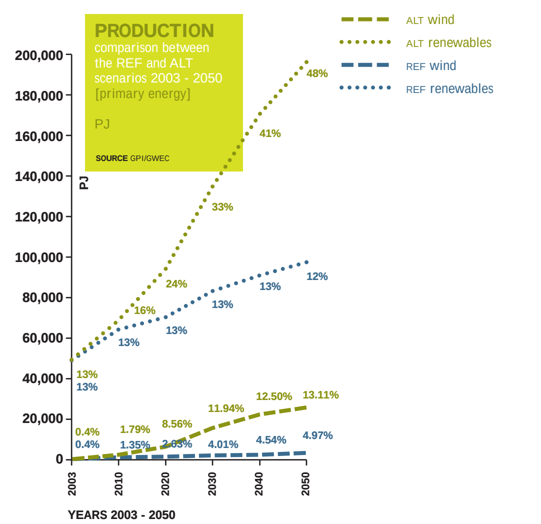
	REF %	REF PJ	ALT %	ALT PJ
2003	0.00L	0L		
2050	0.21	126	6.1M	1,980
		REF kWh		ALT kWh
2003		0L		
2050		39		619

OECD PACIFIC

	REF %	REF PJ	ALT %	ALT PJ
2003	0.02	6		
2050	0.69	324M	7.6	1,800
		REF kWh		ALT kWh
2003		9M		
2050		493		2,739





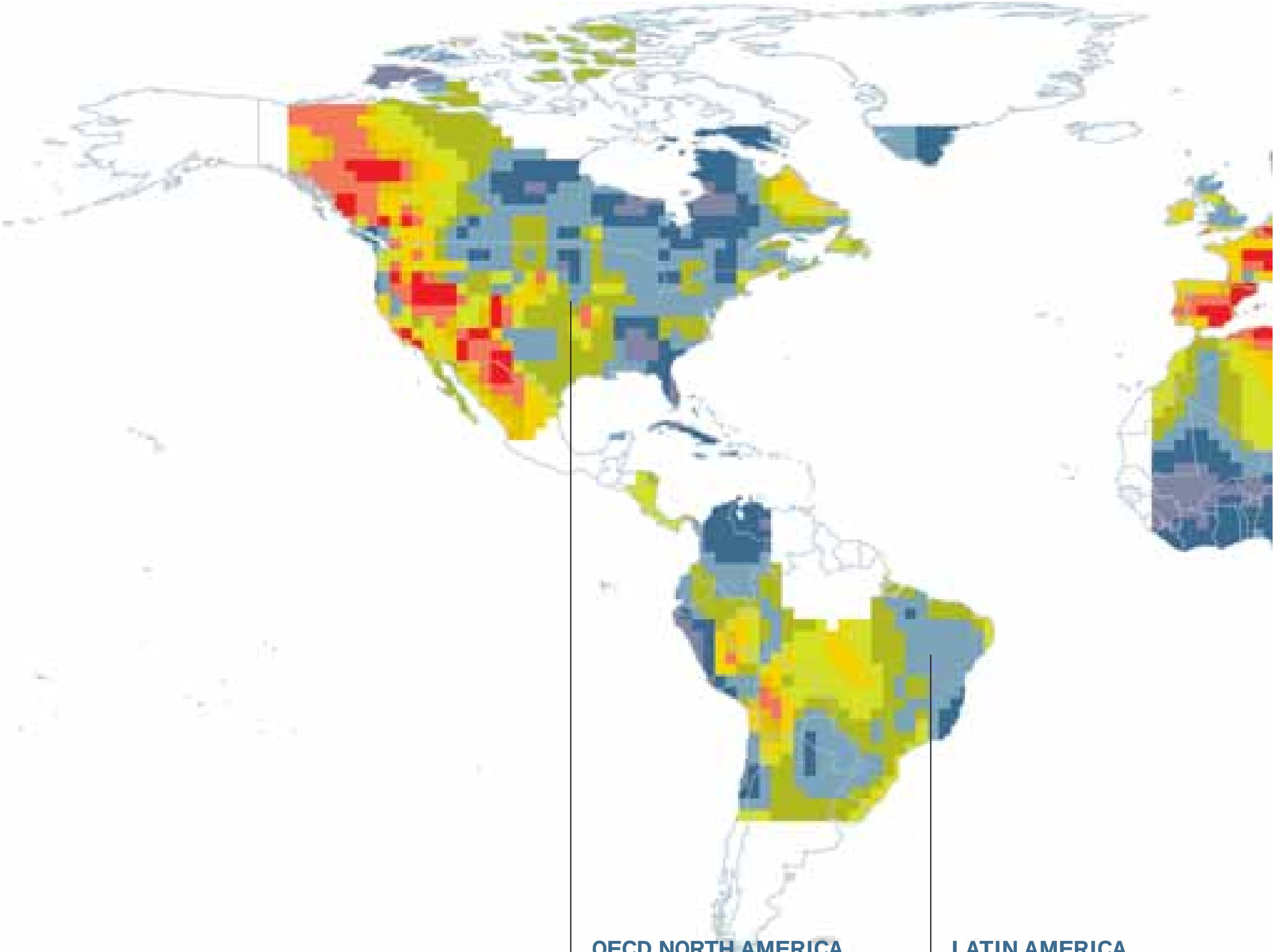


GREENPEACE

DESIGN WWW.ONEHEMISPHERE.SE **CONCEPT** SVEN TESKE/GREENPEACE INTERNATIONAL.

map 9: geothermal reference scenario and the energy [r]evolution scenario

WORLDWIDE SCENARIO



RENEWABLE RESOURCE

GEOTHERMAL

OECD NORTH AMERICA

		REF %	REF PJ	ALT %	ALT PJ
Production per region	2003	0.54H	621H		
	2050	0.78H	1,270H	5.5M	3,810
			kWh		kWh
Production per person	2003		405H		
	2050		602H		1,806

LATIN AMERICA

		REF %	REF PJ	ALT %	ALT PJ
Production per region	2003	0.31M	61		
	2050	0.54	338M	3.6	1,083
			kWh		kWh
Production per person	2003		38		
	2050		149		478

LEGEND

100 90 80 70 60 50 40 30 20 10

SURFACE HEAT FLOW IN mW/m²

SOURCE ARTEMIEVA AND MOONEY, 2001

WHITE = NO DATA

REF REFERENCE SCENARIO

ALT ALTERNATIVE SCENARIO

0 1000 KM

PRODUCTION PER REGION % OF GLOBAL SHARE | PETA JOULE [PJ]

PRODUCTION PER PERSON KILOWATT HOUR [kWh]

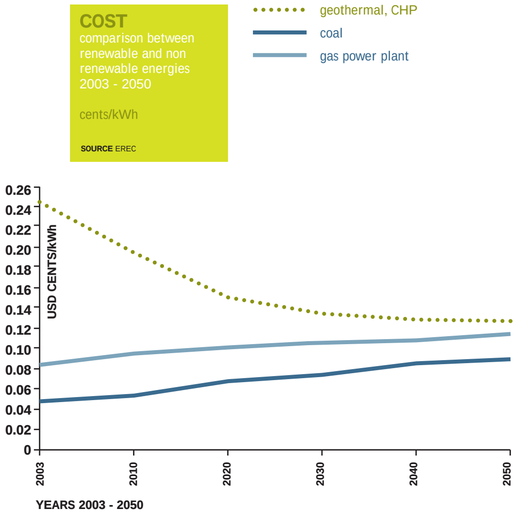
H HIGHEST | M MIDDLE | L LOWEST

COST

comparison between renewable and non renewable energies 2003 - 2050

cents/kWh

SOURCE EREC

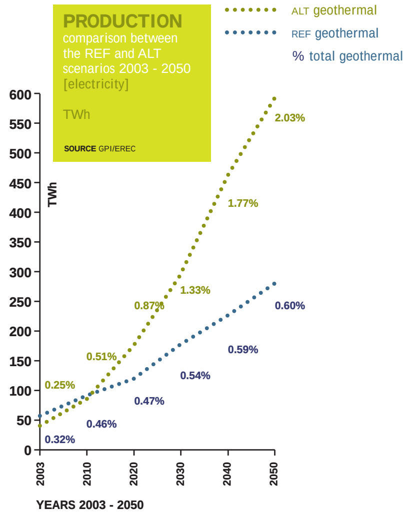


PRODUCTION

comparison between the REF and ALT scenarios 2003 - 2050 [electricity]

TWh

SOURCE GPI/EREC



share

OECD EUROPE

		REF %	REF PJ	ALT %	ALT PJ
	2003	0.20	150M		
	2050	0.61	567	8.6	4,392H
			kWh		kWh
	2003		79M		
	2050		310		2,397

MIDDLE EAST

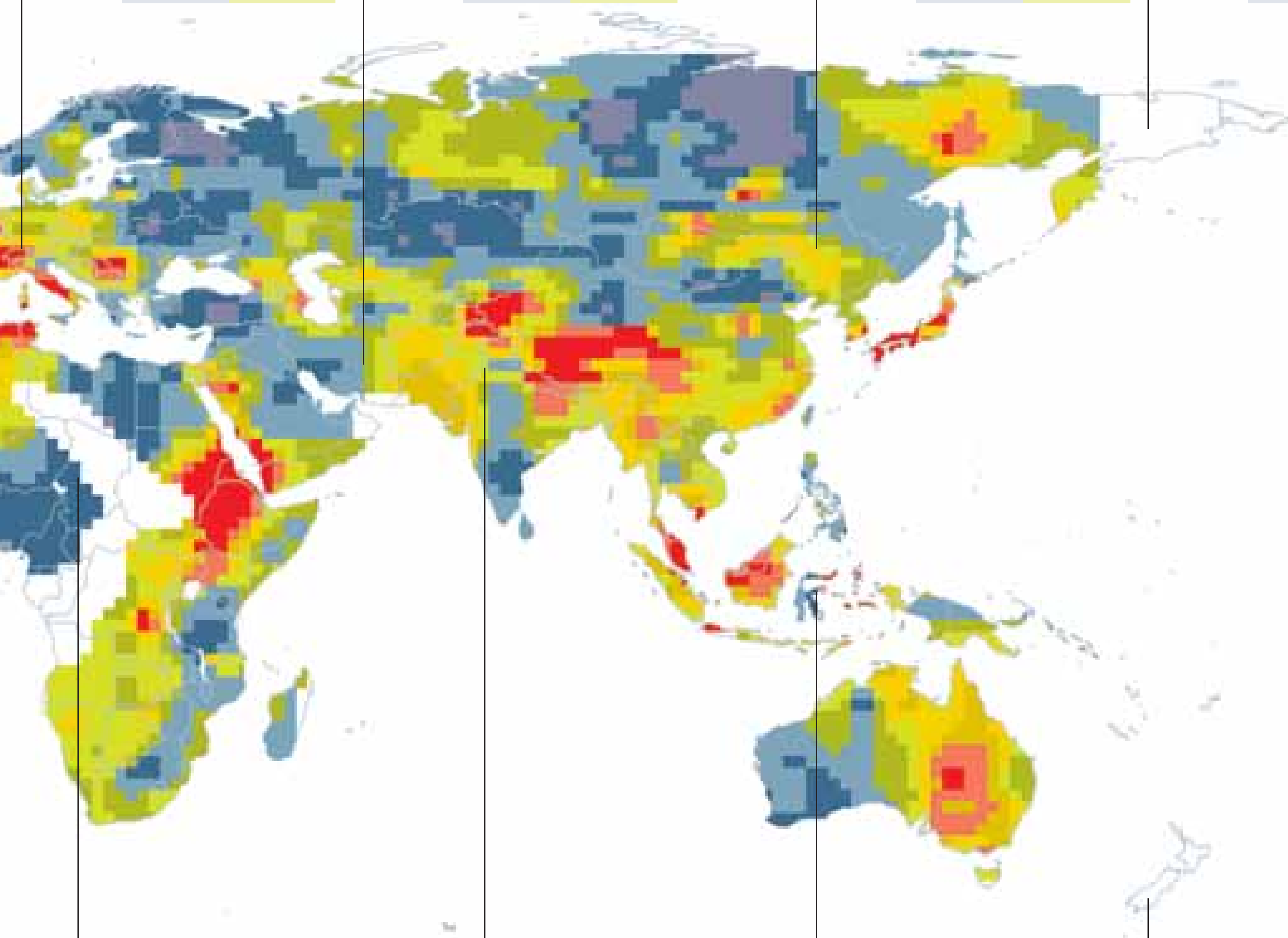
		REF %	REF PJ	ALT %	ALT PJ
	2003	0.00L	0L		
	2050	0.00L	1L	6.89	1,384
			kWh		kWh
	2003		0L		
	2050		1L		1,087M

CHINA

		REF %	REF PJ	ALT %	ALT PJ
	2003	0.00	0		
	2050	0.06	76	0.12L	93L
			kWh		kWh
	2003		0		
	2050		15		18L

TRANSITION ECONOMIES

		REF %	REF PJ	ALT %	ALT PJ
	2003	0.00	2		
	2050	0.30	201	7.8	2,930
			kWh		kWh
	2003		2		
	2050		196M		2,866H



AFRICA

		REF %	REF PJ	ALT %	ALT PJ
	2003	0.10	22		
	2050	0.05	34	2.26	981
			kWh		kWh
	2003		7		
	2050		5		148

SOUTH ASIA

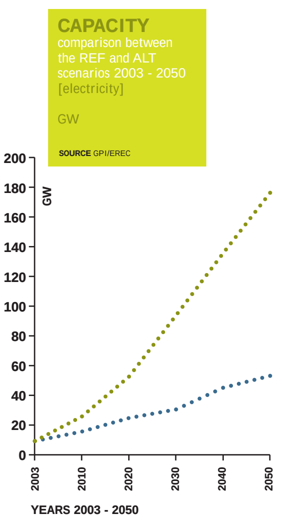
		REF %	REF PJ	ALT %	ALT PJ
	2003	0.00	0		
	2050	0.17	122	4.02	1,480M
			kWh		kWh
	2003		0		
	2050		15		186

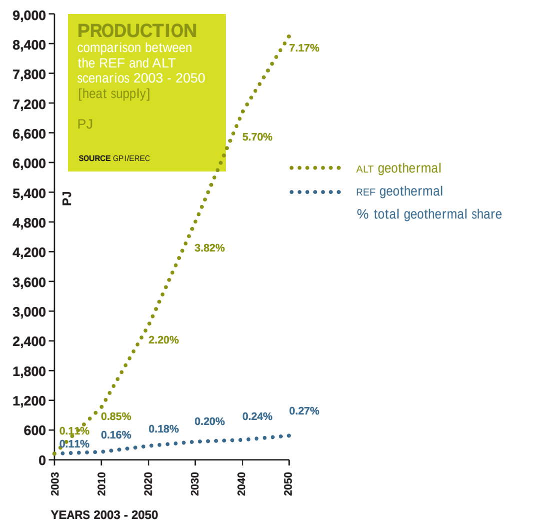
EAST ASIA

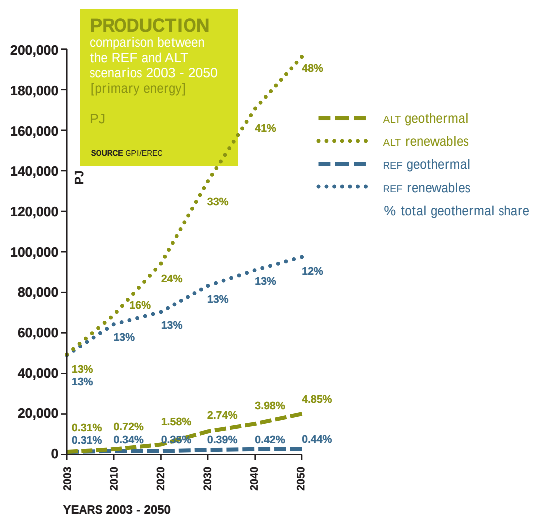
		REF %	REF PJ	ALT %	ALT PJ
	2003	2.00	446		
	2050	1.33	798	9.2H	2,978
			kWh		kWh
	2003		199		
	2050		249		931

OECD PACIFIC

		REF %	REF PJ	ALT %	ALT PJ
	2003	0.10	34		
	2050	0.38M	176	2.81	654
			kWh		kWh
	2003		48		
	2050		268		995







DESIGN WWW.ONEHEMISPHERE.SE CONCEPT SVEN TESKE/GREENPEACE INTERNATIONAL.

energy technologies

"THE ENERGY [R]EVOLUTION SCENARIO IS FOCUSED ON THE POTENTIAL FOR ENERGY SAVINGS AND RENEWABLE SOURCES, PRIMARILY IN THE ELECTRICITY AND HEAT GENERATING SECTORS."

7

This chapter describes the range of technologies available now and in the future to satisfy the world's energy demand. The energy [r]evolution scenario is focused on the potential for energy savings and renewable sources, primarily in the electricity and heat generating sectors. Although fuel use in transport is accounted for in the scenarios of future energy supply, no detailed description is given here of technologies, such as bio fuels for vehicles, which offer an alternative to the currently predominant oil.

fossil fuel technologies

The most commonly used fossil fuels for power generation around the world are coal and gas. Oil is still used where other fuels are not readily available, for example islands or remote sites, or where there is an indigenous resource. Together, coal and gas currently account for over half of global electricity supply.

coal combustion technologies

In a conventional coal-fired power station, pulverised or powdered coal is blown into a combustion chamber where it is burnt at high temperature. The hot gases and heat produced converts water flowing through pipes lining the boiler into steam. This drives a steam turbine and generates electricity. Over 90% of global coal-fired capacity uses this system. Coal power stations can vary in capacity from a few hundred megawatts up to several thousand.

A number of technologies have been introduced to improve the environmental performance of conventional coal combustion. These include coal cleaning (to reduce the ash content) and various 'bolt-on' or 'end-of-pipe' technologies to reduce emissions of particulates, sulphur dioxide and nitrogen oxide, the main pollutants resulting from coal firing apart from carbon dioxide. Flue gas desulphurisation (FGD), for example, most commonly involves 'scrubbing' the flue gases using an alkaline sorbent slurry, which is predominantly lime or limestone based.

More fundamental changes have been made to the way coal is burned to both improve its efficiency and further reduce emissions of pollutants. These include:

- **integrated gasification combined cycle:** Coal is not burnt directly but reacted with oxygen and steam to form a 'syngas' composed mainly of hydrogen and carbon monoxide, which is cleaned and then burned in a gas turbine to generate electricity and produce steam to drive a steam turbine. IGCC improves the efficiency of coal combustion from 38-40% up to 50%.
- **supercritical and ultrasupercritical:** These power plants operate at higher temperatures than conventional combustion, again increasing efficiency towards 50%.
- **fluidised bed combustion:** Coal is burned in a reactor comprised of a bed through which gas is fed to keep the fuel in a turbulent state. This improves combustion, heat transfer and recovery of waste products. By elevating pressures within a bed, a high-pressure gas stream can be used to drive a gas turbine, generating electricity. Emissions of both sulphur dioxide and nitrogen oxide can be reduced substantially.
- **pressurised pulverised coal combustion:** Mainly being developed in Germany, this is based on the combustion of a finely ground cloud of coal particles creating high pressure, high temperature steam for power generation. The hot flue gases are used to generate electricity in a similar way to the combined cycle system.

Other potential future technologies involve the increased use of coal gasification. Underground Coal Gasification, for example, involves converting deep underground unworked coal into a combustible gas which can be used for industrial heating, power generation or the manufacture of hydrogen, synthetic natural gas or other chemicals. The gas can be processed to remove CO_2 before it is passed on to end users. Demonstration projects are underway in Australia, Europe, China and Japan.

gas combustion technologiess

Natural gas can be used for electricity generation through the use of either gas turbines or steam turbines. For the equivalent amount of heat, gas produces about 45% less carbon dioxide during its combustion than coal.

gas turbine plants use the heat from gases to directly operate the turbine. Natural gas fulled turbines can start rapidly, and are therefore often used to supply energy during periods of peak demand, although at higher cost than baseload plants.

Particularly high efficiencies can be achieved through combining gas turbines with a steam turbine in combined cycle mode. In a combined cycle gas turbine (CCGT) plant, a gas turbine generator generates electricity and the exhaust gases from the gas turbine are then used to make steam to generate additional electricity. The efficiency of modern CCGT power stations can be more than 50%. Most new gas power plants built since the 1990s have been of this type.

At least until the recent increase in global gas prices, CCGT power stations have been the cheapest option for electricity generation in many countries. Capital costs have been substantially lower than for coal and nuclear plants and construction time shorter.

carbon storage technologies

Whenever coal or gas is burned, carbon dioxide (CO_2) is produced. Depending on the type of power plant, a large quantity of the gas will dissipate into the atmosphere and contribute to climate change. A coal power plant discharges roughly 720 grammes of carbon dioxide per kilowatt hour, a modern gas-fired plant releases about 370g CO_2/kWh. Some coal advocates are proposing a new technique for reducing the carbon dioxide released by power plants. In this scheme the CO_2 is separated, and then pumped underground. Both methods - capture and storage - have limitations. Even after employing proposed capture technologies, a residual amount of carbon dioxide - between 60 and 150g CO_2/kWh - will continue to be emitted.

carbon dioxide storage

CO_2 captured at the point of incineration has to be stored somewhere. Current thinking is that it can be trapped in the oceans or under the earth's surface at a depth of over 3,000 feet. As with nuclear waste, however, the question is whether this will just displace the problem elsewhere.

dangers of ocean storage

Ocean storage could result in greatly accelerated acidification (reduction of pH) of large areas and would be detrimental to a great many organisms, if not entire ecosystems, in the vicinity of injection sites. CO_2 disposed of in this way is likely to get back into the atmosphere in a relative short time. The oceans are both productive resources and a common natural endowment for this and future generations worthy of safekeeping. Given the diversity of other options available for dealing with CO_2 emissions, direct disposal of CO_2 to the ocean, sea floor, lakes and other open reservoir structures must be ruled out.

dangers of underground storage

Empty oil and gas fields are riddled with holes drilled during their exploration and production phases. These holes have to be sealed over. Normally special cement is used, but carbon dioxide is relatively reactive with water and attacks metals or cement, so that even sealed drilling holes present a safety hazard. To many experts the question is not if but when leakages will occur.

Because of the lack of experience with CO_2 storage, its safety is often compared to the storage of natural gas. This technology has been tried and tested for decades and is appraised by industry to be low risk. Greenpeace does not share this assessment. A number of serious leaks from gas storage installations have occurred around the world, sometimes requiring evacuation of nearby residents.

Sudden leakage of CO_2 can be fatal. Carbon dioxide is not itself poisonous, and is contained (approx. 0.04 per cent) in the air we breathe. But as concentrations increase it displaces the vital oxygen in the air. Air with concentrations of 7 to 8% CO_2 by volume causes death by suffocation after 30 to 60 minutes.

There are also health hazards when large amounts of CO_2 are explosively released. Although the gas normally disperses quickly after leaking, it can accumulate in depressions in the landscape or closed buildings, since carbon dioxide is heavier than air. It is equally dangerous when it escapes more slowly and without being noticed in residential areas, for example in cellars below houses.

The dangers from such leaks are known from natural volcanic CO_2 degassing. Gas escaping at the Lake Nyos crater lake in Cameroon, Africa in 1986 killed over 1,700 people. At least 10 people have died in the Lazio region of Italy in the last 20 years as a result of CO_2 being released.

carbon storage and climate change targets

Can carbon storage contribute to climate change reduction targets? In order to avoid dangerous climate change, we need to reduce CO_2 globally by 50% in 2050. Power plants that store CO_2 are still being developed, however, and will not be widely available more than a decade. This means they will not make any substantial contribution towards protecting the climate until the year 2020 at the earliest.

Nor is CO_2 storage of any great help in attaining the goal of an 80% reduction by 2050 in OECD countries. If it does become available in 2020, most of the world's new power plants will have just finished being modernised. All that could then be done would be for existing power plants to be retrofitted and CO_2 captured from the waste gas flow. As retrofitting existing power plants is highly expensive, a high carbon price would be needed.

Employing CO_2 capture will also increase the price of electricity from fossil fuels. Although the costs of storage depend on a lot of factors, including the technology used for separation, transport and the kind of storage installation, experts from the UN Intergovernmental Panel on Climate Change calculate the additional costs at between 3.5 and 5.0 cents/kWh of power. Since modern wind turbines in good wind locations are already cost competitive with new build coal-fired power plants today, the costs will probably be at the top end. This means the technology would more than double the cost of electricity today.

conclusion

Renewable energy sources are already available, in many cases cheaper, and without the negative environmental impacts that are associated with fossil fuel exploitation, transport and processing. It is renewable energy together with energy efficiency and energy conservation – and NOT carbon capture and storage – that has to increase world-wide so that the primary cause of climate change – the burning of fossil fuels like coal, oil and gas – is stopped. Greenpeace opposes any CCS efforts which lead to:

- the undermining or threats to undermine existing global and regional regulations governing the disposal of wastes at sea (in the water column, at or beneath the seabed).
- continued or increasing finance to the fossil fuel sector at the expense of renewable energy and energy efficiency.
- the stagnation of renewable energy, energy efficiency and energy conversation improvements
- the promotion of this possible future technology as the only major solution to climate change, thereby leading to new fossil fuel developments – especially lignite and black coal-fired power plants, and the increase of emissions in the short to medium term

nuclear technologies

Generating electricity from nuclear power involves transferring the heat produced by a controlled nuclear fission reaction into a conventional steam turbine generator. The nuclear reaction takes place inside a core and surrounded by a containment vessel of varying design and structure. Heat is removed from the core by a coolant (gas or water) and the reaction controlled by a moderating element or "moderator".

Across the world over the last two decades there has been a general slowdown in building new nuclear power stations. This has been caused by a variety of factors: fear of a nuclear accident, following the events at Three Mile Island, Chernobyl and Monju, increased scrutiny of economics and environmental factors, such as waste management and radioactive discharges.

nuclear reactor designs: evolution and safety issues

At the beginning of 2005 there were 441 nuclear power reactors operating in 31 countries around the world. Although there are dozens of different reactor designs and sizes, there are three broad categories either currently deployed or under development. These are:

generation I: Prototype commercial reactors developed in the 1950s and 1960s as modified or enlarged military reactors, originally either for submarine propulsion or plutonium production.

generation II: Mainstream reactor designs in commercial operation worldwide.

generation III: Generation III reactors include the so-called "Advanced Reactors", three of which are already in operation in Japan, with more under construction or planned. About 20 different designs are reported to be under development[14], most of them "evolutionary" designs developed from Generation II reactor types with some modifications, but without introducing drastic changes. Some of them represent more innovative approaches. According to the World Nuclear Association, reactors of Generation III are characterised by the following:

- a standardised design for each type to expedite licensing, reduce capital cost and construction time
- a simpler and more rugged design, making them easier to operate and less vulnerable to operational upsets
- higher availability and longer operating life, typically 60 years
- reduced possibility of core melt accidents
- minimal effect on the environment
- higher burn-up to reduce fuel use and the amount of waste
- burnable absorbers ("poisons") to extend fuel life

To what extent these goals address issues of higher safety standards, as opposed to improved economics, remains unclear.

The **european pressurised water reactor (EPR)** has been developed from the most recent Generation II designs to start operation in France and Germany[15]. Its stated goals are to improve safety levels - in particular, reduce the probability of a severe accident by a factor of ten, achieve mitigation of severe accidents by restricting their consequences to the plant itself, and reduce costs. Compared to its predecessors, however, the EPR displays several modifications which constitute a reduction of safety margins, including:

- The volume of the reactor building has been reduced by simplifying the layout of the emergency core cooling system, and by using the results of new calculations which predict less hydrogen development during an accident.
- The thermal output of the plant was increased by 15% relative to the French reactor by increasing core outlet temperature, letting the main coolant pumps run at higher capacity and modifying the steam generators.
- The EPR has fewer redundant trains in safety systems than a Germany Generation II reactor.

Several other modifications are hailed as substantial safety improvements, including a "core catcher" system to control a meltdown accident. Nonetheless, in spite of the changes being envisaged, there is no guarantee that the safety level of the EPR actually represents a significant improvement. In particular, reduction of the expected core melt probability by a factor of ten is not proven. Furthermore, there are serious doubts as to whether the mitigation and control of a core melt accident with the "core catcher" concept will actually work.

Finally, **generation IV** reactors are currently being developed with the aim of commercialisation in 20-30 years.

references
14 IAEA 2004; WNO 2004a
15 HAINZ 2004.

renewable energy technologies

Renewable energy covers a range of natural sources which are constantly renewed and therefore, unlike fossil fuels and uranium, will never be exhausted. Most of them derive from the effect of the sun and moon on the earth's weather patterns. They also produce none of the harmful emissions and pollution associated with "conventional" fuels. Although hydroelectric power has been used on an industrial scale since the middle of the last century, the serious exploitation of other renewable sources has a more recent history.

solar power (photovoltaics)

There is more than enough solar radiation available all over the world to satisfy a vastly increased demand for solar power systems. The sunlight which reaches the earth's surface is enough to provide 2,850 times as much energy as we can currently use. On a global average, each square metre of land is exposed to enough sunlight to produce 1,700 kWh of power every year. The average irradiation in Europe is about 1,000 kWh per square metre, however, compared with 1,800 kWh in the Middle East.

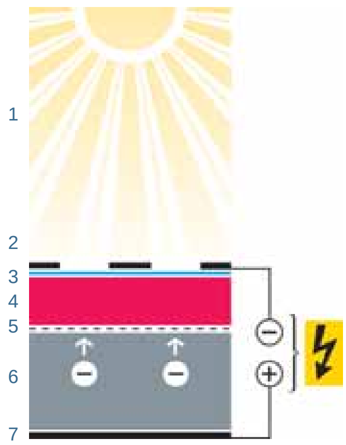
Photovoltaic (PV) technology involves the generation of electricity from light. The secret to this process is the use of a semiconductor material which can be adapted to release electrons, the negatively charged particles that form the basis of electricity. The most common semiconductor material used in photovoltaic cells is silicon, an element most commonly found in sand. All PV cells have at least two layers of such semiconductors, one positively charged and one negatively charged. When light shines on the semiconductor, the electric field across the junction between these two layers causes electricity to flow. The greater the intensity of the light, the greater the flow of electricity. A photovoltaic system does not therefore need bright sunlight in order to operate, and can generate electricity even on cloudy days. Solar PV is different from a solar thermal collecting system (see below) where the sun's rays are used to generate heat, usually for hot water in a house, swimming pool etc.

The most important parts of a PV system are the cells which form the basic building blocks, the modules which bring together large numbers of cells into a unit, and, in some situations, the inverters used to convert the electricity generated into a form suitable for everyday use. When a PV installation is described as having a capacity of 3 kWp (peak), this refers to the output of the system under standard testing conditions, allowing comparison between different modules. In central Europe a 3 kWp rated solar electricity system, with a surface area of approximately 27 square metres, would produce enough power to meet the electricity demand of an energy conscious household.

types of PV system

- **grid connected** The most popular type of solar PV system for homes and businesses in the developed world. Connection to the local electricity network allows any excess power produced to be sold to the utility. Electricity is then imported from the network outside daylight hours. An inverter is used to convert the DC power produced by the system to AC power for running normal electrical equipment.
- **grid support** A system can be connected to the local electricity network as well as a back-up battery. Any excess solar electricity produced after the battery has been charged is then sold to the network. This system is ideal for use in areas of unreliable power supply.
- **off-grid** Completely independent of the grid, the system is connected to a battery via a charge controller, which stores the electricity generated and acts as the main power supply. An inverter can be used to provide AC power, enabling the use of normal appliances. Typical off-grid applications are repeater stations for mobile phones or rural electrification. Rural electrification means either small solar home systems (SHS) covering basic electricity needs or solar mini grids, which are larger solar electricity systems providing electricity for several households.
- **hybrid system** A solar system can be combined with another source of power - a biomass generator, a wind turbine or diesel generator - to ensure a consistent supply of electricity. A hybrid system can be grid connected, stand alone or grid support.

figure 31: **photovoltaics technology**



1. LIGHT (PHOTONS)
2. FRONT CONTACT GRID
3. ANTI-REFLECTION COATING
4. N-TYPE SEMICONDUCTOR
5. BOARDER LAYOUT
6. P-TYPE SEMICONDUCTOR
7. BACKCONTACT

concentrating solar power plants(CSP)

Concentrating solar power (CSP) plants, also called solar thermal power plants, produce electricity in much the same way as conventional power stations. The difference is that they obtain their energy input by concentrating solar radiation and converting it to high temperature steam or gas to drive a turbine or motor engine. Large mirrors concentrate sunlight into a single line or point. The heat created there is used to generate steam. This hot, highly pressurised steam is used to power turbines which generate electricity. In sun-drenched regions, CSP plants can guarantee large shares of electricity production.

Four main elements are required: a concentrator, a receiver, some form of transfer medium or storage, and power conversion. Many different types of system are possible, including combinations with other renewable and non-renewable technologies, but the three most promising solar thermal technologies are:

- **parabolic trough** Trough-shaped mirror reflectors are used to concentrate sunlight on to thermally efficient receiver tubes placed in the trough's focal line. A thermal transfer fluid, such as synthetic thermal oil, is circulated in these tubes. Heated to approximately 400°C by the concentrated sun's rays, this oil is then pumped through a series of heat exchangers to produce superheated steam. The steam is converted to electrical energy in a conventional steam turbine generator, which can either be part of a conventional steam cycle or integrated into a combined steam and gas turbine cycle.

  This is the most mature technology, with 354 MWe of plants connected to the Southern California grid since the 1980s and more than 2 million square metres of parabolic trough collectors installed worldwide.

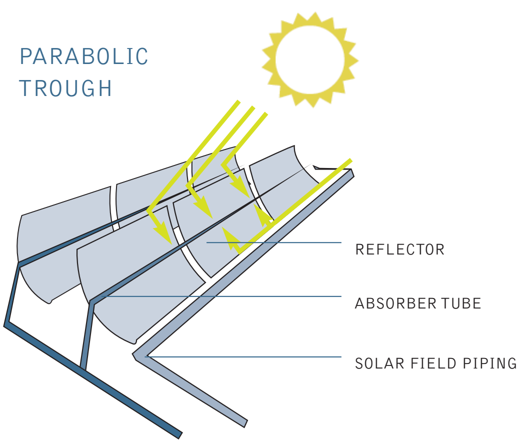
- **central receiver or solar tower** A circular array of heliostats (large individually tracking mirrors) is used to concentrate sunlight on to a central receiver mounted at the top of a tower. A heat-transfer medium absorbs the highly concentrated radiation reflected by the heliostats and converts it into thermal energy to be used for the subsequent generation of superheated steam for turbine operation. To date, the heat transfer media demonstrated include water/steam, molten salts, liquid sodium and air. If pressurised gas or air is used at very high temperatures of about 1,000°C or more as the heat transfer medium, it can even be used to directly replace natural gas in a gas turbine, thus making use of the excellent efficiency (60%+) of modern gas and steam combined cycles.

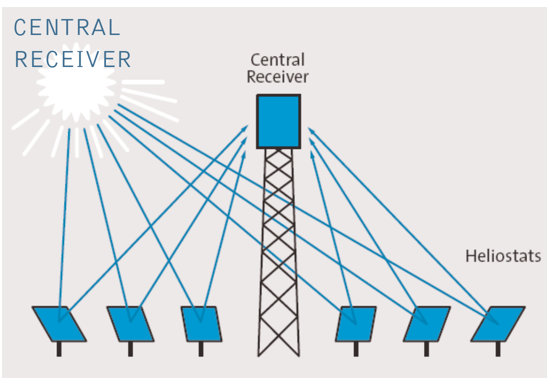
  After an intermediate scaling up to 30 MW capacity, solar tower developers now feel confident that grid-connected tower power plants can be built up to a capacity of 200 MWe solar-only units. Use of heat storage will increase their flexibility. Although solar tower plants are considered to be further from commercialisation than parabolic trough systems, they have good longer-term prospects for high conversion efficiencies. Projects are being developed in Spain, South Africa and Australia.

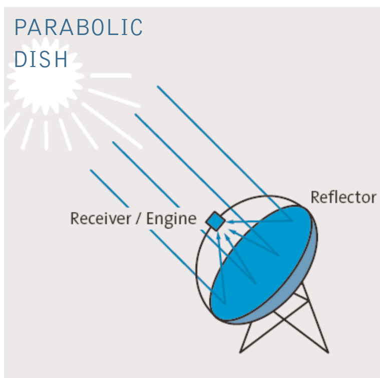
- **parabolic dish** A dish-shaped reflector is used to concentrate sunlight on to a receiver located at its focal point. The concentrated beam radiation is absorbed into the receiver to heat a fluid or gas (air) to approximately 750°C. This is then used to generate electricity in a small piston, Stirling engine or a micro turbine, attached to the receiver.

  The potential of parabolic dishes lies primarily in decentralised power supply and remote, stand-alone power systems. Projects are currently planned in the United States, Australia and Europe.

figures 32 - 34: parabolic trough/central receiver or solar tower/parabolic dish technology







solar thermal collectors

Solar thermal collecting systems are based on a centuries-old principle: the sun heats up water contained in a dark vessel. Solar thermal technologies on the market now are efficient and highly reliable, providing energy for a wide range of applications - from domestic hot water and space heating in residential and commercial buildings to swimming pool heating, solar-assisted cooling, industrial process heat and the desalination of drinking water.

solar domestic hot water and space heating

Domestic hot water production is the most common application. Depending on the conditions and the system's configuration, most of a building's hot water requirements can be provided by solar energy. Larger systems can additionally cover a substantial part of the energy needed for space heating. There are two main types of technology:

- **vacuum tubes:** The absorber inside the vacuum tube absorbs radiation from the sun and heats up the fluid inside. Additional radiation is picked up from the reflector behind the tubes. Whatever the angle of the sun, the round shape of the vacuum tube allows it to reach the absorber. Even on a cloudy day, when the light is coming from many angles at once, the vacuum tube collector can still be effective.
- **flat panel:** This is basically a box with a glass cover which sits on the roof like a skylight. Inside is a series of copper tubes with copper fins attached. The entire structure is coated in a black substance designed to capture the sun's rays. These rays heat up a water and antifreeze mixture which circulates from the collector down to the building's boiler.

solar assisted cooling

Solar chillers use thermal energy to produce cooling and/or dehumidify the air in a similar way to a refrigerator or conventional air-conditioning. This application is well-suited to solar thermal energy, as the demand for cooling is often greatest when there is most sunshine. Solar cooling has been successfully demonstrated and large-scale use can be expected in the future.

figure 35: **flat panel solar technology**

wind power

Over the last 20 years, wind energy has become the world's fastest growing energy source. Today's wind turbines are produced by a sophisticated mass production industry employing a technology that is efficient, cost effective and quick to install. Turbine sizes range from a few kW to over 5,000 kW, with the largest turbines reaching more than 100m in height. One large wind turbine can produce enough electricity for about 5,000 households. State-of-the-art wind farms today can be as small as a few turbines and as large as several hundred MW.

The global wind resource is enormous, capable of generating more electricity than the world's total power demand, and well distributed across the five continents. Wind turbines can be operated not just in the windiest coastal areas but in countries which have no coastlines, including regions such as central Eastern Europe, central North and South America, and central Asia. The wind resource out at sea is even more productive than on land, encouraging the installation of offshore wind parks with foundations embedded in the ocean floor. In Denmark, a wind park built in 2002 uses 80 turbines to produce enough electricity for a city with a population of 150,000.

Smaller wind turbines can produce power efficiently in areas that otherwise have no access to electricity. This power can be used directly or stored in batteries. New technologies for using the wind's power are also being developed for exposed buildings in densely populated cities.

wind turbine design

Significant consolidation of wind turbine design has taken place since the 1980s. The majority of commercial turbines now operate on a horizontal axis with three evenly spaced blades. These are attached to a rotor from which power is transferred through a gearbox to a generator. The gearbox and generator are contained within a housing called a nacelle. Some turbine designs avoid a gearbox by using direct drive. The electricity output is then channelled down the tower to a transformer and eventually into the local grid.

Wind turbines can operate from a wind speed of 3-4 metres per second up to about 25 m/s. Limiting their power at high wind speeds is achieved either by "stall" regulation – reducing the power output – or "pitch" control – changing the angle of the blades so that they no longer offer any resistance to the wind. Pitch control has become the most common method. The blades can also turn at a constant or variable speed, with the latter enabling the turbine to follow more closely the changing wind speed.

The main design drivers for current wind technology are:

- high productivity at both low and high wind sites
- grid compatibility
- acoustic performance

• aerodynamic performance

• visual impact

• offshore expansion

Although the existing offshore market is only 0.4% of the world's land-based installed wind capacity, the latest developments in wind technology are primarily driven by this emerging potential. This means that the focus is on the most effective ways to make very large turbines.

Modern wind technology is available for a range of sites - low and high wind speeds, desert and arctic climates. European wind farms operate with high availability, are generally well integrated with the environment and accepted by the public. In spite of repeated predictions of a levelling off at an optimum mid-range size, and the fact that wind turbines cannot get larger indefinitely, turbine size has increased year on year - from units of 20-60 kW in California in the 1980s up to the latest multi-MW machines with rotor diameters over 100 m. The average size of turbine installed around the world during 2005 was 1,282 kW, whilst the largest machine in operation is the Enercon E112, with a capacity of up to 6 MW. This is targeted at the developing offshore market.

This growth in turbine size has been matched by the expansion of both markets and manufacturers. More than 80,000 wind turbines now operate in over 50 countries around the world. The German market is the largest, but there has also been impressive growth in Spain, Denmark, India and the United States.

biomass energy

Biomass is a broad term used to describe material of recent biological origin that can be used as a source of energy. This includes wood, crops, algae and other plants as well as agricultural and forest residues. Biomass can be used for a variety of end uses: heating, electricity generation or as fuel for transportation. The term 'bio energy' is used for biomass energy systems that produce heat and/or electricity and 'bio fuels' for liquid fuels for transport. Biodiesel manufactured from various crops has become increasingly used as vehicle fuel, especially as the cost of oil has risen.

Biological power sources are renewable, easily stored, and, if sustainably harvested, CO_2 neutral. This is because the gas emitted during their transfer into useful energy is balanced by the carbon dioxide absorbed when they were growing plants.

Electricity generating biomass power plants work just like natural gas or coal power stations, except that the fuel must be processed before it can be burned. These power plants are generally not as large as coal power stations because their fuel supply needs to grow as near as possible to the power plant. Heat generation from biomass power plants can result either from utilising the heat produced in a Combined Heat and Power plant (CHP), piping the heat to nearby homes or industry, or through dedicated heating systems. Small heating systems using specially produced pellets made from waste wood, for example, can be used to heat single family homes instead of natural gas or oil.

figure 36: wind turbine technology

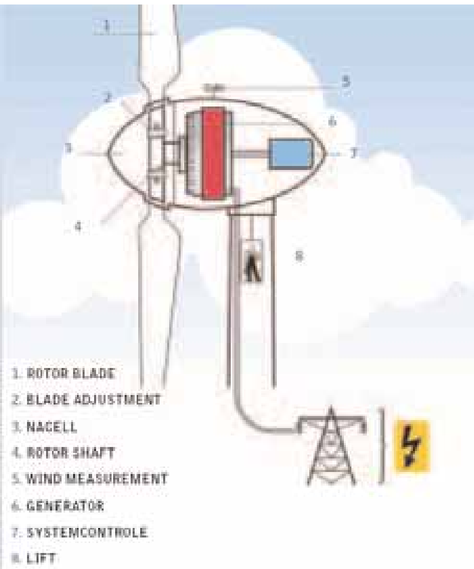
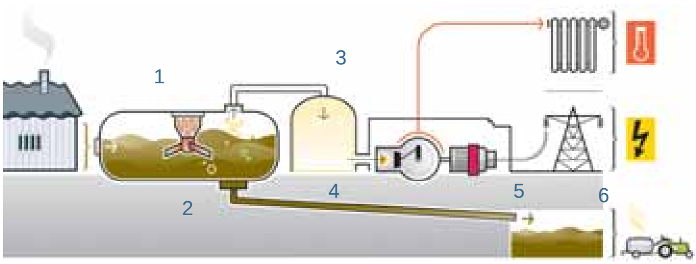


figure 37: biomass technology



1. HEATED MIXER
2. CONTAINMENT FOR FERMENTATION
3. BIOGAS STORAGE
4. COMBUSTION ENGINE
5. GENERATOR
6. WASTE CONTAINMENT

biomass technology

A number of processes can be used to convert energy from biomass. These divide into thermal systems, which involve direct combustion of either solids, liquids or a gas via pyrolysis or gasification, and biological systems, which involve decomposition of solid biomass to liquid or gaseous fuels by processes such as anaerobic digestion and fermentation.

thermal systems

- **direct combustion** Direct combustion is the most common way of converting biomass to energy, for heat as well as electricity. Worldwide it accounts for over 90% of biomass generation. Technologies can be distinguished as either fixed bed, fluidised bed or entrained flow combustion. In fixed bed combustion, such as a grate furnace, primary air passes through a fixed bed, in which drying, gasification and charcoal combustion takes place. The combustible gases produced are burned after the addition of secondary air, usually in a zone separated from the fuel bed. In fluidised bed combustion, the primary combustion air is injected from the bottom of the furnace with such high velocity that the material inside the furnace becomes a seething mass of particles and bubbles. Entrained flow combustion is suitable for fuels available as small particles, such as sawdust or fine shavings, which are pneumatically injected into the furnace.

- **gasification** Biomass fuels are increasingly being used with advanced conversion technologies, such as gasification systems, which offer superior efficiencies compared with conventional power generation. Gasification is a thermochemical process in which biomass is heated with little or no oxygen present to produce a low energy gas. The gas can then be used to fuel a gas turbine or a combustion engine to generate electricity. Gasification can also decrease emission levels compared to power production with direct combustion and a steam cycle.

- **pyrolysis** Pyrolysis is a process whereby biomass is exposed to high temperatures in the absence of air, causing the biomass to decompose. The products of pyrolysis always include gas (‘biogas’), liquid (‘bio-oil’) and solid (‘char’), with the relative proportions of each depending on the fuel characteristics, the method of pyrolysis and the reaction parameters, such as temperature and pressure. Lower temperatures produce more solid and liquid products and higher temperatures more biogas.

biological systems

These processes are suitable for very wet biomass materials such as food or agricultural wastes, including slurry.

- **anaerobic digestion** Anaerobic digestion means the breakdown of organic waste by bacteria in an oxygen-free environment. This produces a biogas typically made up of 65% methane and 35% carbon dioxide. Purified biogas can then be used both for heating or electricity generation.

- **fermentation** Fermentation is the process by which plants of high sugar and starch content are broken down with the help of micro-organisms to produce ethanol and methanol. The end product is a combustible fuel that can be used in vehicles.

  Biomass power station capacities typically range up to 15 MW, but larger plants are possible of up to 400 MW capacity, with part of the fuel input potentially being fossil fuel, for example pulverised coal. The world’s largest biomass fuelled power plant is located at Pietarsaari in Finland. Built in 2001, this is an industrial CHP plant producing steam (100 MWth) and electricity (240 MWe) for the local forest industry and district heat for the nearby town. The boiler is a circulating fluidised bed boiler designed to generate steam from bark, sawdust, wood residues, commercial bio fuel and peat.

  A 2005 study commissioned by Greenpeace Netherlands concluded that it was technically possible to build and operate a 1,000 MWe biomass fired power plant using fluidised bed combustion technology and fed with wood residue pellets.[16]

reference
16 OPPORTUNITIES FOR 1,000 MWE BIOMASS-FIRED POWER PLANT IN THE NETHERLANDS”, GREENPEACE NETHERLANDS, MARCH 2005

geothermal energy

Geothermal energy is heat derived from deep underneath the earth's crust. In most areas, this heat reaches the surface in a very diffuse state. However, due to a variety of geological processes, some areas, including the western part of the USA, west and central eastern Europe, Iceland, Asia and New Zealand are underlain by relatively shallow geothermal resources. These are classified as low temperature (less than 90°C), moderate temperature (90° - 150°C) and high temperature (greater than 150°C). The uses to which these resources can be put depends on the temperature. The highest temperature is generally used only for electric power generation. Current global geothermal generation capacity totals approximately 8,000 MW. Uses for low and moderate temperature resources can be divided into two categories: direct use and ground-source heat pumps.

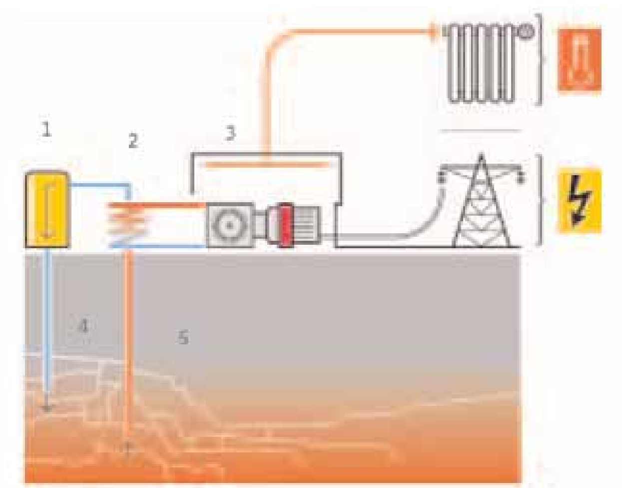
Geothermal power plants use the earth's natural heat to vapourise water or an organic medium. The steam created powers a turbine which produces electricity. In New Zealand and Iceland, this technique has been used extensively for decades. In Germany, where it is necessary to drill many kilometres down to reach the necessary temperatures, it is only in the trial stages. Geothermal heat plants require lower temperatures and the heated water is used directly.

hydro power

Water has been used to produce electricity for about a century. Today, around one fifth of the world's electricity is produced from hydro power. Large unsustainable hydroelectric power plants with concrete dams and extensive collecting lakes often have very negative effects on the environment, however, requiring the flooding of habitable areas. Smaller 'run-of-the-river' power stations, which are turbines powered by one section of running water in a river, can produce electricity in an environmentally friendly way.

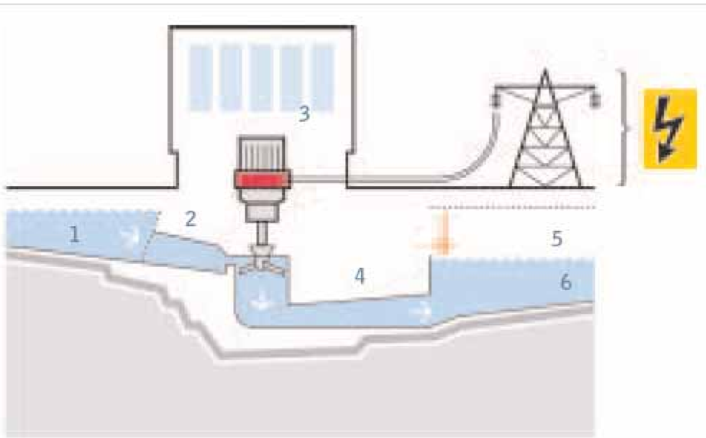
The main requirement for hydro power is to create an artificial head so that water, diverted through an intake channel or pipe into a turbine, discharges back into the river downstream. Small hydro power is mainly 'run-of-the-river' and does not collect significant amounts of stored water, requiring the construction of large dams and reservoirs. There are two broad categories of turbines: impulse turbines (notably the Pelton) in which a jet of water impinges on the runner designed to reverse the direction of the jet and thereby extract momentum from the water. This turbine is suitable for high heads and 'small' discharges. Reaction turbines (notably Francis and Kaplan) run full of water and in effect generate hydrodynamic 'lift' forces to propel the runner blades. These turbines are suitable for medium to low heads, and medium to large discharges.

figure 38: geothermal technology



1. PUMP
2. HEAT EXCHANGER (PRODUCES STEAM)
3. GAS TURBINE
4. DRILLING HOLE FOR COLDWATER INJECTION
5. GENERATOR
6. WASTE CONTAINMENT

figure 39: hydro technology



1. INLET
2. SIEVE
3. GENERATOR
4. TURBINE
5. HEAD
6. OUTLET

ocean energy

tidal power

Tidal power can be harnessed by constructing a dam or barrage across an estuary or bay with a tidal range of at least 5 metres. Gates in the barrage allow the incoming tide to build up in a basin behind it. The gates then close so that when the tide flows out the water can be channelled through turbines to generate electricity. Tidal barrages have been built across estuaries in France, Canada and China but a mixture of high cost projections coupled with environmental objections to the effect on estuarial habitats has limited the technology's further expansion.

wave and tidal stream power

In wave power generation, a structure interacts with the incoming waves, converting this energy to electricity through a hydraulic, mechanical or pneumatic power take-off system. The structure is kept in position by a mooring system or placed directly on the seabed/seashore. Power is transmitted to the seabed by a flexible submerged electrical cable and to shore by a sub-sea cable.

Wave power converters can be made up from connected groups of smaller generator units of 100 – 500 kW, or several mechanical or hydraulically interconnected modules can supply a single larger turbine generator unit of 2 – 20 MW. The large waves needed to make the technology more cost effective are mostly found at great distances from the shore, however, requiring costly sub-sea cables to transmit the power. The converters themselves also take up large amounts of space. Wave power has the advantage of providing a more predictable supply than wind energy and can be located in the ocean without much visual intrusion.

There is no commercially leading technology on wave power conversion at present. Different systems are being developed at sea for prototype testing. These include a 50 kW PowerBuoy floating buoy device installed in Hawaii, a 750 kW Pelamis device, with linked semi-submerged cyclindrical sections, operating in Scotland, a 300 kW underwater tidal current turbine operating in south-west England, a 150 kW seabed-mounted Stingray, also using tidal currents, and a 500 kW coastline wave energy generator operating on the island of Islay, Scotland. Most development work has been carried out in the UK.

energy efficiency

Energy efficiency often has multiple positive effects. For example, an efficient clothes washing machine or dishwasher uses less power and less water. Efficiency also usually provides a higher level of comfort. For example, a well-insulated house will feel warmer in the winter, cooler in the summer and be healthier to live in. An efficient refrigerator will make less noise, have no frost inside, no condensation outside and will probably last longer. Efficient lighting will offer you more light where you need it. Efficiency is thus really: 'more with less'.

Efficiency has an enormous potential. There are very simple steps a householder can take, such as putting additional insulation in the roof, using super-insulating glazing or buying a high-efficiency washing machine when the old one wears out. All of these examples will save both money and energy. But the biggest savings will not be found in such incremental steps. The real gains come from rethinking the whole concept, e.g. 'the whole house', 'the whole car' or even 'the whole transport system'. When you do this, surprisingly often energy needs can be cut back by four to ten times what is needed today.

Take the example of a house: by insulating the whole outer shell (from roof to basement) properly, which requires an additional investment, the demand for heat will be so low that you can install a smaller and cheaper heating system – offsetting the cost of the extra insulation. The result is a house that only needs one third of the energy without being any more expensive to build. By insulating even further and installing a high efficiency ventilation system, heating demand is reduced to one tenth. Thousands of these super-efficient houses have been successfully built in Europe over the last ten years. This is no dream for the future, but part of everyday life.

Here is another example: imagine you are the manager of an office. Throughout the hot summer months, air-conditioning pumps cold air on your staff's shoulders to keep them productive. As this is fairly expensive, you could ask a clever engineer to improve the efficiency of the cooling pumps. But why not take a step back instead and look at the whole system. If we first improve the building to keep the sun from heating the office like an oven, then install more energy-efficient computers, copiers and lights (which save electricity and generate less heat), and then install passive cooling systems such as ventilation at night – you may well find that the air-conditioning system is no longer necessary. Then, of course, if the building had been properly planned and built, you would not have bought the air-conditioner in the first place.

electricity

There is a huge potential to save electricity in a relatively short period of time. By simply switching off the standby mode and changing to energy efficient light bulbs, consumers would save electricity and money in every household. If the majority of households did this, several large power plants could be switched off almost immediately. The following table provides a brief overview of medium-term measures for industry and household appliances:

table 13: examples of electricity saving potential

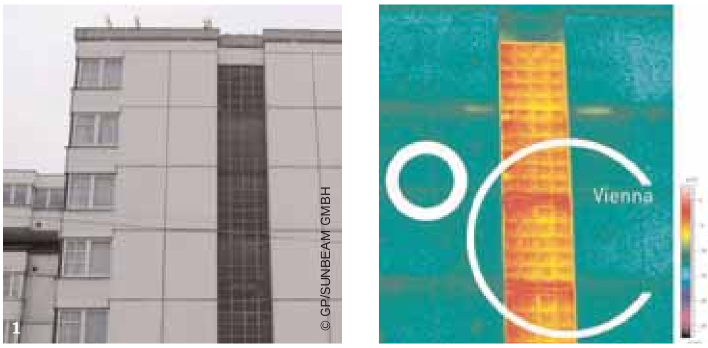
SECTOR	EFFICIENCY MEASURE	ELECTRICITY SAVINGS
Industry	Efficient motor systems	30-40%
	Higher aluminium recycling rate	35-45%
Other sectors	Efficient household appliances	30-80%
	Efficient office appliances	50-75%
	Efficient cooling systems	30-60%
	Efficient lighting	30-50%
	Reduced stand by losses	50-70%
	Reduced electricity use during non-office hours	up to 90%

source ECOFYS 2006, GLOBAL ENERGY DEMAND SCENARIOS

heating

Insulation and thermal design can dramatically reduce heat loss and help stop climate change. Energy demand for heating in existing buildings can be reduced on average by 30-50%. In new buildings it can be reduced by 90-95% using widely available and competitive technology and design.

Heat losses can be easily detected with thermographic photos (see example below). A thermographic camera shows details the eye cannot detect. Parts of the building that have a higher surface temperature than the rest appear in yellow and red. This means that in these areas heat is leaking through gaps and poor insulating materials, and valuable energy is being lost. This results both in damage to the environment through a waste of energy resources and to unnecessary costs for home owners and tenants. Typical weak points are window panes and frames and thin walls below windows, where radiators are commonly positioned and insulation should be optimal.



images 1. VIENNA AM SCHÖPFWERK RESIDENTIAL ESTATE. AS WELL AS LOSSES OF HEAT ENERGY THROUGH THE WINDOWS THERE ARE DIVERSE HEAT BRIDGES IN THE FABRIC OF THE BUILDING. **2.** LUXEMBOURG TWINERG GAS POWER PLANT. THE PLUME OF WASTE GAS IS NORMALLY NOT VISIBLE. THE THERMOGRAM SHOWS THE WASTE OF ENERGY THROUGH THE CHIMNEY.

energy efficiency in the energy [r]evolution Scenario

A range of options has been considered in this study for reducing the demand for energy in the period up to 2050. The analysis focuses on best practice technologies. The scenario assumes continuous innovation in the field of energy efficiency, so that best practice technologies keep improving. The table below shows those which have been applied in the three sectors – industry, transport and households/services. A few examples are elaborated here.

table 14: energy efficiency measures

SECTOR	REDUCTION OPTION
Industry	
General	Efficient motor systems
General	Heat integration/pinch analysis
General	Improved process control
Aluminium	Increase secondary aluminium
Iron and steel	Blast furnace - coal injection
Iron and steel	BOF (Basic Oxygen Furnace) gas + heat recovery
Iron and steel	Thin slab casting
Chemical industry	Membrane product separation
Transport	Efficient passenger cars (hybrid fuel)
Passenger cars	Efficient freight vehicles
Freight	Efficient buses
Buses	
Others	Efficient electric appliances
Households & services	Efficient cooling equipment
Services	Efficient lighting
Households & services	Reduce stand-by losses
Households & services	Improved heat insulation
Households & services	Reduce electricity use during non-office hours
Services	Energy efficiency improvement
Agriculture & non-specified others	

industry

Approximately 65% of electricity consumption by industry is used to drive electric motor systems. This can be reduced by employing variable speed drives, high efficiency motors and using efficient pumps, compressors and fans. The savings potential is up to 40%.

The production of primary aluminium from alumina (which is made out of bauxite) is a very energy-intensive process. It is produced by passing a direct current through a bath with alumina dissolved in a molten cryolite electrode. Another option is to produce aluminium out of recycled scrap. This is called secondary production. Secondary aluminium uses only 5 to 10% of the energy demand for primary production because it involves remelting the metal instead of an electrochemical reduction process. If recycling increases from 22% of aluminium production in 2005 to 60% in 2050 this would save 45% of current electricity use.

transport

Use of hybrid vehicles (electric/combustion) and other efficiency measures could reduce energy consumption in passenger cars by up to 80% in 2050.

households/services

Energy use by household appliances such as washing machines, dishwashers, TVs and refrigerators can be reduced by 30% using the best available options and by 80% with advanced technologies. Energy use by office appliances can be reduced by 50-75% through a combination of power management and energy efficient computer systems.

Use of stand-by mode for appliances is on average responsible for 5-13% of electricity use by households in OECD countries. Replacement of existing appliances by those with the lowest losses would reduce standby power consumption by 70%.

Better building design and effective heat insulation could save up to 80% of the average heat demand for buildings.

policy recommendations

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

8

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 and the failure to internalise environmental and social costs in price of energy. Developing renewables will therefore require strong political and economic efforts, especially through laws that guarantee stable tariffs over a period of up to 20 years.

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.

The following is an overview of current political frameworks and barriers that need to be overcome 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, from Europe to the Far East to the USA.

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 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, the European Solar Thermal Power Industry Association and the European Wind Energy Association[17], Greenpeace and EREC have documented the development of those industries from 1990 onwards and outlined a prognosis for growth up to 2020.

reference
17 SOLAR GENERATION (EPIA), CONCENTRATED SOLAR THERMAL POWER - NOW! (GREENPEACE), WINDFORCE 12 (EWEA), GLOBAL WIND ENERGY OUTLOOK 2006, GWEC

demands for the energy sector

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

- 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[18] 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. The 2001 report of the G8 Renewable Energy Task Force argued that "re-addressing them [subsidies] and making even a minor re-direction of these considerable financial flows toward renewables, provides an opportunity to bring consistency to new public goals and to include social and environmental costs in prices." The Task Force recommended that "G8 countries should take steps to remove incentives and other supports for environmentally harmful energy technologies, and develop and implement market-based mechanisms that address externalities, enabling renewable energy technologies to compete in the market on a more equal and fairer basis."

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.

This is a fuller description of what needs to be done to eliminate or compensate for current distortions in the energy market.

1. removal of energy market distortions

A major barrier preventing renewable energy from reaching its full potential is the lack of pricing structures in the energy markets that reflect the full costs to society of producing energy. For more than a century, power generation was characterised by national monopolies with mandates to finance investments in new production capacity through state subsidies and/or levies on electricity bills. As many countries are moving in the direction of more liberalised electricity markets, these options are no longer available, which puts new generating technologies, such as wind power, at a competitive disadvantage relative to existing technologies. This situation requires a number of responses.

internalisation of the social and environmental costs of polluting energy

The real cost of energy production by conventional energy includes expenses absorbed by society, such as health impacts and local and regional environmental degradation - from mercury pollution to acid rain – as well as the global negative impacts from climate change. Hidden costs include the waiving of nuclear accident insurance that is too expensive to be covered by the nuclear power plant operators. The Price- Anderson Act, for instance, limits the liability of US nuclear power plants in the case of an accident to an amount of up to US$ 98 million per plant, and only 15 million per year per plant, with the rest being drawn from an industry fund for up to US$ 10 billion – an after that taxpayer pays[19]. Environmental damage should as a priority be rectified at source. Translated into energy generation that would mean that, ideally, production of energy should not pollute and that it is the energy producers' responsibility to prevent it. If they do pollute they should pay an amount equal to the damage the production causes to society as a whole. The environmental impacts of electricity generation can be difficult to quantify, however. How do we put a price on lost homes on Pacific Islands as a result of melting icecaps or on deteriorating health and human lives?

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

reference
18 UNDP REPORT
19 HTTP://EN.WIKIPEDIA.ORG/WIKI/PRICE-ANDERSON_NUCLEAR_INDUSTRIES_INDEMNITY_ACT

introduce the "polluter pays" principle

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

2. electricity market reform

Renewable energy technologies could already be competitive if they had received the same attention as other sources in terms of R&D funding and subsidies, and if external costs were reflected in power prices. Essential reforms in the electricity sector are necessary if new renewable energy technologies are to be accepted on a larger scale. These reforms include:

removal of electricity sector barriers

Complex licensing procedures and bureaucratic hurdles constitute one of the most difficult obstacles faced by renewable energy projects in many countries. A clear timetable for approving projects should be set for all administrations at all levels. Priority should be given to renewable energy projects. Governments should propose more detailed procedural guidelines to strengthen the existing legislation and at the same time streamline the licensing procedure for renewable energy projects.

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

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

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

The reforms needed to address market barriers to renewables include:

- Streamlined and uniform planning procedures and permitting systems and integrated least cost network planning;
- Fair access to the grid at fair, transparent prices and removal of discriminatory access and transmission tariffs;
- Fair and transparent pricing for power throughout a network, with recognition and remuneration for the benefits of embedded generation;
- Unbundling of utilities into separate generation and distribution companies;
- The costs of grid infrastructure development and reinforcement must be carried by the grid management authority rather than individual renewable energy projects;
- Disclosure of fuel mix and environmental impact to end users to enable consumers to make an informed choice of power source.

priority grid access

Rules on grid access, transmission and cost sharing are very often inadequate. Legislation must be clear, especially concerning cost distribution and transmission fees. Renewable energy generators should be guaranteed priority access. Where necessary, grid extension or reinforcement costs should be borne by the grid operators, and shared between all consumers, because the environmental benefits of renewables are a public good and system operation is a natural monopoly.

support mechanisms for renewables

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

Overall, there are broadly speaking two types of incentive to promote deployment of renewable electricity. Others exist for renewable heating, but the experiences in this sector are unfortunately not as long as in the electricity sector. These are Fixed Price Systems where the government dictates the electricity price (or premium) paid to the producer and lets the market determine the quantity, and Renewable Quota Systems (in the USA referred to as Renewable Portfolio Standards) where the government dictates the quantity of renewable electricity and leaves it to the market to determine the price. Both systems create a protected market against a background of subsidised, depreciated conventional generators whose external environmental costs are not accounted for. Their aim is to provide incentives for technology improvements and cost reductions, leading to cheaper renewables that can compete with conventional sources in the future.

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

fixed price systems

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

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

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

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

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

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

renewable quota systems

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

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

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

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

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

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

It is too early to draw final conclusions on the potential impacts of the full range of policy options available since more complex systems, such as those based on tradable green certificates, are still at an experimental phase. More time and experience are needed to draw credible conclusions on their ability to attract investments and deliver new capacity. The choice of framework at a national level also depends on the culture and history of the individual countries, the stage of development for renewables and the political will to produce results.

appendix

BREAKDOWN OF THE GLOBAL ENERGY SCENARIO BY WORLD REGION

OECD north america

development of energy demand

population: The population of OECD North America will increase from 425 million now to 585 million by 2050.

GDP: The PPP adjusted Gross Domestic Product is expected to grow on average by 2.1% per year, leading to a fivefold increase by 2050. Per capita GDP will remain one of the highest in the world, almost triple the global average.

energy intensity: Under the reference scenario, energy intensity will reduce by 1.1% 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, energy intensity will fall by 70%.

final energy demand: Under the reference scenario, energy demand will increase by more than 60% from the current 70,000 PJ/a to 114,000 PJ/a in 2050. Under the energy [r]evolution scenario, there will be a steady decrease to 56,000 PJ/a in 2050, half of projected consumption under the reference scenario.

electricity demand: Under the energy [r]evolution scenario, efficiency measures will result in electricity demand of about 3,400 TWh/a by 2050. Compared to the reference scenario, this would avoid the generation of 4,400 TWh/a.

heat demand: Under the energy [r]evolution scenario, a steep decline in demand for heating will mean that, compared to the reference scenario, the consumption of 15,000 PJ/a is avoided through efficiency gains.

development of energy supply

primary energy supply: Under the energy [r]evolution scenario, renewable energy sources will cover almost 50% of primary energy demand by 2050, an increase from 6% now.

electricity generation: Under the energy [r]evolution scenario, renewables will generate about 80% of electricity supply by 2050, an increase from 16% now. Growing from the current output of 195 GW, a renewable generating capacity of 1,150 GW will by then produce 23,700 TWh/a.

heat supply: Under the energy [r]evolution scenario, renewables will satisfy 60% of heating supply by 2050, an increase from 9% now. The CHP share will be more than 20%.

development of CO_2 emissions

CO_2 emissions will increase by 40% up to 2050 under the reference scenario. Under the energy [r]evolution scenario they will decrease from 6,600 million tonnes to 1,800 million tonnes. Annual per capita emissions will drop from 15.6 t to 3.0 t.

future costs of electricity generation

The growth in renewables under the energy [r]evolution scenario will increase the costs of electricity generation compared to the reference scenario by around 0.4 cents/kWh in 2020 up to 1.8 cents/kWh in 2050.

latin america

development of energy demand

population: The population of Latin America will grow slowly compared to other developing regions, increasing to 630 million by 2050.

GDP: The PPP adjusted Gross Domestic Product is expected to grow on average by 2.9% per year, leading to a quadrupling by 2050. Per capita GDP will still be below the world average and just one third of that in Europe or North America.

energy intensity: Under the reference scenario, energy intensity will reduce by 0.4% per year, leading to a reduction in final energy demand per unit of GDP of about 20% between 2003 and 2050. Under the energy [r]evolution scenario, energy intensity will fall by more than 50%.

final energy demand: Under the reference scenario, energy demand will more than triple from the current 14,000 PJ/a to 45,000 PJ/a in 2050. Under the energy [r]evolution scenario, there will be a much slower increase to 25,000 PJ/a in 2050, just over half of projected consumption under the reference scenario.

electricity demand: Under the energy [r]evolution scenario, energy efficiency measures will result in electricity demand of about 1,900 TWh/a by 2050. Compared to the reference scenario this will avoid the generation of 1,400 TWh/a.

heat demand: Under the energy [r]evolution scenario, demand for heating will remain relatively stable. Compared to the reference scenario, the consumption of 6,800 PJ/a will still be avoided through efficiency gains.

development of energy supply

primary energy supply: Under the energy [r]evolution scenario, renewable energy sources will cover 65% of primary energy demand by 2050, an increase from 27% now.

electricity generation: Under the energy [r]evolution scenario, renewables will generate 90% of electricity supply by 2050, an increase from 70% now. Growing from a current output of 130 GW, a renewable generating capacity of 660 GW will by then produce 2,070 TWh/a.

heat supply: Under the energy [r]evolution scenario, renewables will satisfy 70% of heating supply by 2050, an increase from 36% now.

development of CO_2 emissions

CO_2 emissions will increase by a factor of four up to 2050 under the reference scenario. Under the energy [r]evolution scenario they will decrease from 800 million tonnes to 440 million tonnes. Annual per capita emissions will drop from 1.8 t to 0.7 t. Whereas today the power sector is the largest source of CO_2 emissions, it will contribute less than 15% of the total in 2050.

future costs of electricity generation

The growth in renewables under the energy [r]evolution scenario will decrease the costs of electricity generation compared to the reference scenario by around 1.5 cents/kWh in 2020 and up to 3.5 cents/kWh by 2050.

OECD europe

development of energy demand

population: The population of OECD Europe will peak at almost 550 million in about 2030. After that it will decrease to 510 million by 2050.

GDP: The PPP adjusted Gross Domestic Product is expected to grow on average by 1.7% per year, leading to a tripling by 2050. Per capita GDP will remain one of the highest in the world, more than double the global average.

energy intensity: Under the reference scenario, energy intensity will reduce by 1.1% 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, energy intensity will fall by almost 75%.

final energy demand: Under the reference scenario, energy demand will increase by more than 30% from the current 50,000 PJ/a to 68,000 PJ/a in 2050. Under the energy [r]evolution scenario, there will be a steady decrease to 41,000 PJ/a in 2050, two thirds of projected consumption under the reference scenario.

electricity demand: Under the energy [r]evolution scenario, electricity demand is expected to increase up to 2040, then fall to about 3,300 TWh/a by 2050. Compared to the reference scenario, efficiency measures therefore avoid the generation of 1,100 TWh/a.

heat demand: Under the energy [r]evolution scenario, demand for heating will be almost halved. Compared to the reference scenario, the consumption of 13,000 PJ/a is avoided through efficiency gains.

development of energy supply

primary energy supply: Under the energy [r]evolution scenario, renewable energy sources will cover 50% of primary energy demand by 2050, an increase from 7% now.

electricity generation: Under the energy [r]evolution scenario, renewables will generate 80% of electricity supply by 2050, an increase from 18% now. Growing from a current output of 160 GW, a renewable generating capacity of 865 GW will by then produce 2,500 TWh/a.

heat supply: Under the energy [r]evolution scenario, renewables will satisfy 50% of heating supply by 2050, an increase from 10% now. The CHP share will be more than 20%.

development of CO_2 emissions

CO_2 emissions will increase by one third up to 2050 under the reference scenario. Under the energy [r]evolution scenario they will decrease from 3,900 million tonnes to 1,200 million tonnes. Annual per capita emissions will drop from 7.4 t to 2.3 t.

future costs of electricity generation

The growth in renewables under the energy [r]evolution scenario will increase the costs of electricity generation compared to the reference scenario by around 0.5 cents/kWh between 2010 and 2030. Because of lower CO_2 intensity, costs will then start to decrease, falling by 2050 to 0.7 cents/kWh below those in the reference scenario.

africa

development of energy demand

population: The population of Africa will triple to 1,840 million by 2050.

GDP: The PPP adjusted Gross Domestic Product is expected to grow on average by 3.6% per year. By 2050 it will have increased fivefold. Per capita GDP will still only be a tenth of that in Europe or North America.

energy intensity: Under the reference scenario, energy intensity will reduce by 1% 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, energy intensity will fall even further.

final energy demand: Under the reference scenario, energy demand will triple from the current 17,000 PJ/a to 54,000 PJ/a in 2050. Under the energy [r]evolution scenario, demand will grow much slower to reach 35,000 PJ/a by 2050, double today's figure but one third less than projected consumption under the reference scenario.

electricity demand: Under the energy [r]evolution scenario, efficiency measures will result in electricity demand of about 2,000 TWh/a by 2050. Compared to the reference scenario, this will avoid the generation of 1,100 TWh/a.

heat demand: Under the energy [r]evolution scenario, demand for heating will be reduced. Compared to the reference scenario, the consumption of 8,600 PJ/a is avoided through efficiency gains.

development of energy supply

primary energy supply: Under the energy [r]evolution scenario, renewable energy sources will cover 60% of primary energy demand by 2050, an increase from 47% now.

electricity generation: Under the energy [r]evolution scenario, renewables will generate 55% of electricity supply by 2050, an increase from 17% now. Growing from a current output of 25 GW, a renewable generating capacity of 480 GW will by then produce 1,500 TWh/a.

heat supply: Under the energy [r]evolution scenario, renewables will satisfy 88% of heating supply by 2050, an increase from 78% now. Traditional biomass will be replaced by more efficient modern technologies.

development of CO_2 emissions

Whilst CO_2 emissions will increase "by a factor five" under the reference scenario, under the energy [r]evolution scenario they will be restricted to a 60% increase from their 2003 level of 750 million tonnes to 1,100 million tonnes by 2050. Annual per capita emissions will fall from 0.9 t to 0.6 t. Whilst the power sector will still the largest source of CO_2 emissions in 2050, it will also register the largest reduction.

future costs of electricity generation

The growth in renewables under the energy [r]evolution scenario will decrease costs compared to the reference scenario by 2 cents/kWh in 2020 and by about 3 cents/kWh in 2050.

appendix - *continued*

BREAKDOWN OF THE GLOBAL ENERGY SCENARIO BY WORLD REGION

middle east

development of energy demand

population: The population of the Middle East will double to 350 million by 2050.

GDP: The PPP adjusted Gross Domestic Product is expected to grow on average by 2.6% per year. By 2050 it will have increased by a factor of four. Per capita GDP will still only be a fifth of that in Europe or North America.

energy intensity: Under the reference scenario, energy intensity will reduce by 0.9% per year, leading to a reduction in final energy demand per unit of GDP of about 50% between 2003 and 2050. Under the energy [r]evolution scenario, energy intensity will fall by almost 60%.

final energy demand: Under the reference scenario, energy demand will more than double from the current 11,000 PJ/a to 25,000 PJ/a in 2050. Under the energy [r]evolution scenario, demand will grow much slower, to reach 15,000 PJ/a by 2050, a third more than today but 40% less than projected consumption under the reference scenario.

electricity demand: Under the energy [r]evolution scenario, efficiency measures will result in electricity demand of about 1,000 TWh/a by 2050. Compared to the reference scenario, this will avoid the generation of 500 TWh/a.

heat demand: Under the energy [r]evolution scenario, demand for heating will be reduced. Compared to the reference scenario, the consumption of 4,700 PJ/a is avoided through efficiency gains.

development of energy supply

primary energy supply: Under the energy [r]evolution scenario, renewable energy sources will cover 50% of primary energy demand by 2050, an increase from 1% now.

electricity generation: Under the energy [r]evolution scenario, renewables will generate 86% of electricity supply by 2050, an increase from 3% now. Growing from a current output of 7 GW, a renewable generating capacity of 450 GW will by then produce 1,400 TWh/a.

heat supply: Under the energy [r]evolution scenario, renewables will satisfy 67% of heating supply by 2050, an increase from 1% now.

development of CO_2 emissions

Whilst CO_2 emissions will double under the reference scenario, under the energy [r]evolution scenario they will decrease from their 2003 level of 1,000 million tonnes to 480 million tonnes by 2050. Annual per capita emissions will fall from 5.5 t to 1.4 t. Whilst the power sector is now the largest source of CO_2 emissions, it will only account for only a fifth in 2050.

future costs of electricity generation

The growth in renewables under the energy [r]evolution scenario will decrease costs compared to the reference scenario by 1 cent/kWh in 2020 and by about 9 cents/kWh in 2050.

transition economies

development of energy demand

population: The population of the Transition Economies will reduce from 345 million now to 285 million by 2050.

GDP: The PPP adjusted Gross Domestic Product is expected to grow on average by 3.2% per year. By 2050 it will have increased by a factor of five. Per capita GDP will be about half of that in Europe or North America.

energy intensity: Under the reference scenario, energy intensity will reduce by 1.8% per year, leading to a reduction in final energy demand per unit of GDP of about 60% between 2003 and 2050. Under the energy [r]evolution scenario, energy intensity will fall by almost 80%.

final energy demand: Under the reference scenario, energy demand will more than double from the current 27,000 PJ/a to 51,000 PJ/a in 2050. Under the energy [r]evolution scenario, demand is expected to remain stable at current levels up to 2050, 50% less than projected consumption under the reference scenario.

electricity demand: Under the energy [r]evolution scenario, efficiency measures will result in electricity demand of about 1,900 TWh/a by 2050. Compared to the reference scenario, this will avoid the generation of 640 TWh/a.

heat demand: Under the energy [r]evolution scenario, demand for heating will be reduced. Compared to the reference scenario, the consumption of 13,600 PJ/a is avoided through efficiency gains.

development of energy supply

primary energy supply: Under the energy [r]evolution scenario, renewable energy sources will cover 60% of primary energy demand by 2050, an increase from 4% now.

electricity generation: Under the energy [r]evolution scenario, renewables will generate 80% of electricity supply by 2050, an increase from 18% now. Growing from a current output of 90 GW, a renewable generating capacity of 635 GW will by then produce 1,900 TWh/a.

heat supply: Under the energy [r]evolution scenario, renewables will satisfy 60% of heating supply by 2050, an increase from 3% now. The CHP share will be more than 20%.

development of CO_2 emissions

While CO_2 emissions will increase by one third under the reference scenario, under the energy [r]evolution scenario they will decrease from their 2003 level of 2,700 million tonnes to 700 million tonnes by 2050. Annual per capita emissions will fall from 7.8 t to 2.5 t. With a share of 30% of total CO_2 emissions in 2050, the power sector will fall behind transport as the largest source.

future costs of electricity generation

The growth in renewables under the energy [r]evolution scenario will decrease costs compared to the reference scenario by about 1.8 cents/kWh in 2050.

south asia

development of energy demand

population: The population of South Asia is expected to grow to 2,200 million by 2050, 25% of the world total.

GDP: The PPP adjusted Gross Domestic Product is expected to grow on average by 3.9% per year. By 2050 it will have increased by a factor of six. Per capita GDP will still be only 20% of that in Europe or North America.

energy intensity: Under the reference scenario, energy intensity will reduce by 2% 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, energy intensity will fall by almost 80%.

final energy demand: Under the reference scenario, energy demand will more than double from the current 19,000 PJ/a to 47,000 PJ/a in 2050. Under the energy [r]evolution scenario, there will be a slower increase to 29,000 PJ/a in 2050, 50% more than today's figure but 40% less than projected consumption under the reference scenario.

electricity demand: Under the energy [r]evolution scenario, efficiency measures will result in electricity demand of about 2,400 TWh/a by 2050. Compared to the reference scenario, this will avoid the generation of 1,000 TWh/a.

heat demand: Under the energy [r]evolution scenario, demand for heating will be reduced. Compared to the reference scenario, the consumption of 10,000 PJ/a is avoided through efficiency gains.

development of energy supply

primary energy supply: Under the energy [r]evolution scenario, renewable energy sources will cover 50% of primary energy demand by 2050, an increase from 40% now.

electricity generation: Under the energy [r]evolution scenario, renewables will generate 60% of electricity supply by 2050, an increase from 15% now. Growing from a current output of 31 GW, a renewable generating capacity of 600 GW will by then produce 1,700 TWh/a.

heat supply: Under the energy [r]evolution scenario, renewables will satisfy 70% of heating supply by 2050, a similar proportion to now, although traditional biomass will increasingly be replaced by more efficient technologies, in particular solar collectors and geothermal energy.

development of CO_2 emissions

CO_2 emissions will increase fourfold by 2050 under the reference scenario. Under the energy [r]evolution scenario they will remain at the 2003 level of about 1,000 million tonnes. Annual per capita emissions will only fall slightly from 0.8 t to 0.5 t. Although its share will decrease, the power sector will remain the largest source of CO_2 emissions in South Asia, contributing 50% of the total in 2050.

future costs of electricity generation

The growth in renewables under the energy [r]evolution scenario will decrease costs compared to the reference scenario by about 1 cent/kWh from 2020, increasing to 2 cents/kWh in 2050.

east asia

development of energy demand

population: The population of East Asia is expected to grow to 800 million by 2050, although its expansion will stabilise after 2040.

GDP: The PPP adjusted Gross Domestic Product is expected to grow on average by 3.2% per year. By 2050 it will have increased by a factor of 4.5. Per capita GDP will still be about a quarter of that in Europe or North America.

energy intensity: Under the reference scenario, energy intensity will reduce by 1.1% 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, energy intensity will fall by almost 70%.

final energy demand: Under the reference scenario, energy demand will more than double from the current 15,000 PJ/a to 39,000 PJ/a in 2050. Under the energy [r]evolution scenario, there will be a steady increase to 23,000 PJ/a in 2050, 50% more than today's figure but 40% less than projected consumption under the reference scenario.

electricity demand: Under the energy [r]evolution scenario, efficiency measures will result in electricity demand of about 1,800 TWh/a by 2050. Compared to the reference scenario, this will avoid the generation of 1,000 TWh/a.

heat demand: Under the energy [r]evolution scenario, demand for heating will be reduced. Compared to the reference scenario, the consumption of 5,000 PJ/a is avoided through efficiency gains.

development of energy supply

primary energy supply: Under the energy [r]evolution scenario, renewable energy sources will cover almost half of primary energy demand by 2050, an increase from 23% now.

electricity generation: Under the energy [r]evolution scenario, renewables will generate 70% of electricity supply by 2050, an increase from 14% now. Growing from a current output of 29 GW, a renewable generating capacity of 560 GW will by then produce 1,600 TWh/a.

heat supply: Under the energy [r]evolution scenario, renewables will satisfy 80% of heating supply by 2050, an increase from 50% now.

development of CO_2 emissions

CO_2 emissions will increase fourfold by 2050 under the reference scenario. Under the energy [r]evolution scenario they will fall from the 2003 level of about 1,000 million tonnes to 830 million tonnes. Annual per capita emissions will only fall slightly from 1.7 t to 0.9 t. Whilst the power sector is today the largest source of CO_2 emissions in East Asia, it will contribute less than 30% in 2050.

future costs of electricity generation

The growth in renewables under the energy [r]evolution scenario will decrease costs compared to the reference scenario by about 1.5 cents/kWh from 2020, increasing to 3 cents/kWh in 2050.

appendix - *continued*

BREAKDOWN OF THE GLOBAL ENERGY SCENARIO BY WORLD REGION

china

development of energy demand

population: The population of China will peak at 1,460 million in about 2030. After that it will decrease to 1,400 million by 2050.

GDP: The PPP adjusted Gross Domestic Product is expected to grow on average by 4.1% per year, the highest growth of all the world regions. By 2050 it will have increased seven-fold. Per capita GDP will still be about half of that in Europe or North America.

energy intensity: Under the reference scenario, energy intensity will reduce by 2.3% per year, leading to a reduction in final energy demand per unit of GDP of about 65% between 2003 and 2050. Under the energy [r]evolution scenario, energy intensity will fall by almost 80%.

final energy demand: Under the reference scenario, energy demand will more than double from the current 35,000 PJ/a to 81,000 PJ/a in 2050. Under the energy [r]evolution scenario, there will be a steady increase to 53,000 PJ/a in 2050, 50% more than today's figure but a third less than projected consumption under the reference scenario.

electricity demand: Under the energy [r]evolution scenario, efficiency measures will result in electricity demand of about 6,300 TWh/a by 2050. Compared to the reference scenario, this will avoid the generation of 1,200 TWh/a.

heat demand: Under the energy [r]evolution scenario, demand for heating will be reduced. Compared to the reference scenario, the consumption of 12,500 PJ/a is avoided through efficiency gains.

development of energy supply

primary energy supply: Under the energy [r]evolution scenario, renewable energy sources will cover 33% of primary energy demand by 2050, an increase from 20% now.

electricity generation: Under the energy [r]evolution scenario, renewables will generate 50% of electricity supply by 2050, an increase from 15% now. Growing from a current output of 84 GW, a renewable generating capacity of 1,300 GW will by then produce 4,000 TWh/a.

heat supply: Under the energy [r]evolution scenario, renewables will satisfy 43% of heating supply by 2050, an increase from 35% now. The CHP share will be more than 30%.

development of CO_2 emissions

CO_2 emissions will triple by 2050 under the reference scenario. Under the energy [r]evolution scenario they will remain stable at the 2003 level of about 3,300 million tonnes. Annual per capita emissions will only fall slightly from 2.5 t to 2.3 t. The increasing electricity supply, the power sector will remain the largest source of CO_2 emissions in China, accounting for 50% in 2050.

future costs of electricity generation

The growth in renewables under the energy [r]evolution scenario will hardly increase costs and they will fall to almost 1 cent/kWh below those in the reference scenario by 2050.

OECD pacific

development of energy demand

population: The population of OECD Pacific will peak in 2020 at about 200 million and then decrease to 180 million by 2050.

GDP: The PPP adjusted Gross Domestic Product is expected to grow on average by 1.8% per year, leading to a fivefold increase by 2050. Per capita GDP is increasing strongly, making this the leading world region by 2050.

energy intensity: Under the reference scenario, energy intensity will reduce by 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, energy intensity will fall by 75%.

final energy demand: Under the reference scenario, energy demand will increase by more than 40% from the current 21,000 PJ/a to 30,000 PJ/a in 2050. Under the energy [r]evolution scenario, energy demand will peak in 2010, then fall back to 17,300 PJ/a by 2050, which is about 85% of today's figure and 40% less than projected consumption under the reference scenario.

electricity demand: Under the energy [r]evolution scenario, efficiency measures will result in electricity demand of about 1,600 TWh/a by 2050. Compared to the reference scenario, this would avoid the generation of 800 TWh/a.

heat demand: Under the energy [r]evolution scenario, a steep decline in demand for heating will mean that, compared to the reference scenario, the consumption of 4,900 PJ/a is avoided through efficiency gains.

development of energy supply

primary energy supply: Under the energy [r]evolution scenario, renewable energy sources will cover one third of primary energy demand by 2050, an increase from 3% now.

electricity generation: Under the energy [r]evolution scenario, renewables will generate about 70% of electricity supply by 2050, an increase from 10% now. Growing from the current output of 60 GW, a renewable generating capacity of 410 GW will by then produce 1,130 TWh/a.

heat supply: Under the energy [r]evolution scenario, renewables will satisfy 60% of heating supply by 2050, an increase from 4% now.

development of CO_2 emissions

CO_2 emissions will increase by 20% up to 2050 under the reference scenario. Under the energy [r]evolution scenario they will decrease from 1,900 million tonnes to 700 million tonnes. Annual per capita emissions will drop from 9.4 t to 3.8 t.

future costs of electricity generation

The growth in renewables under the energy [r]evolution scenario will increase the costs of electricity generation compared to the reference scenario up to 2030, but by 2050 they will be 1 cent/kWh lower.

reference scenario

tables 15: electricity generation

TWh/a

	2003	2010	2020	2030	2040	2050
Power plants	**14,988**	**18,170**	**23,451**	**29,000**	**35,377**	**43,426**
Coal	5,451	6,554	8,644	11,148	14,530	19,214
Lignite	572	615	656	705	752	821
Gas	2,380	3,273	5,396	7,507	9,736	12,475
Oil	1,031	1,073	1,128	1,070	1,026	1,011
Nuclear	2,641	2,984	2,975	2,867	2,797	2,730
Biomass	137	189	243	316	384	432
Hydro	2,659	3,148	3,714	4,199	4,591	4,872
Wind	64	237	535	918	1,174	1,370
PV	1	9	30	73	108	139
Geothermal	53	85	113	160	210	257
Solar thermal power plants	1	4	13	31	61	98
Ocean energy	1	1	4	6	8	9
Combined heat & power production	**1,674**	**1,860**	**2,167**	**2,589**	**2,868**	**3,074**
Coal	390	440	519	691	800	880
Lignite	142	132	115	103	91	78
Gas	915	1,007	1,195	1,415	1,561	1,662
Oil	134	133	126	101	78	65
Biomass	91	142	204	268	324	368
Geothermal	1	7	9	11	15	21
CHP by producer						
Main acitivity producers	1,215	1,279	1,348	1,450	1,500	1,578
Autoproducers	459	581	819	1,139	1,367	1,497
Total generation	**16,662**	**20,030**	**25,617**	**31,589**	**38,245**	**46,501**
Fossil	11,015	13,226	17,778	22,714	28,574	36,206
Coal	5,841	6,993	9,163	11,839	15,329	20,094
Lignite	714	746	771	808	843	899
Gas	3,295	4280	6,591	8,922	11,297	14,137
Oil	1,165	1,206	1,254	1,172	1,104	1,076
Nuclear	2,641	2,984	2,975	2,867	2,797	2,730
Renewables	3,007	3,821	4,864	5,981	6,875	7,564
Hydro	2,659	237	3,714	4,199	4,591	4,872
Wind	64	9	535	918	1,174	1,370
PV	1	331	30	73	108	139
Biomass	228	92	447	584	708	800
Geothermal	54	4	122	170	226	278
Solar thermal	1	1	13	31	61	98
Ocean energy	1		4	6	8	9
Import	557	598	630	620	580	530
Import RES	79	87	95	98	94	86
Export	558	583	611	609	566	528
Distribution losses	1,520	1,852	2,370	2,952	3,609	4,467
Own consumption electricity	1,467	1,625	1,988	2,366	2,698	3,028
Final energy consumption (electricity)	**13,675**	**16,568**	**21,279**	**26,282**	**31,951**	**39,008**
Fluctuating RES (PV, Wind, Ocean)	65	247	569	997	1,289	1,517
Share of fluctuating RES	0.4%	1,2%	2,2%	3,2%	3,4%	3,3%
RES share	18%	19,1%	19,0%	18,9%	18,0%	16,3%

table 17: primary energy demand converted

	2003	2010	2020	2030	2040	2050
coal in Mill t	5,367	5,499	6,006	6,884	7,916	9,356
crude oil in Mill barrel	24,089	28,887	33,720	37,784	41,841	46,407
gas in E+9 m³	2453.4	2666.9	3255.0	3839.5	4369.3	4986.1
Conversion factors						
Coal	23.03	kJ/t				
Lignite	8.45	kJ/t				
oil	6.12	GJ/barrel				
gas	38000.00	kJ/m³				

tables 16: installed capacity

GW

	2003	2010	2020	2030	2040	2050
Power plants	**3,152**	**3,888**	**5,046**	**6,252**	**7,463**	**8,973**
Coal	902	1,091	1,452	1,871	2,440	3,212
Lignite	73	80	86	94	103	115
Gas	626	857	1,327	1,775	2,205	2,735
Oil	414	451	489	502	495	511
Nuclear	347	392	391	377	370	365
Biomass	20	28	35	46	55	61
Hydro	728	857	999	1,118	1,213	1,280
Wind	30	108	218	375	449	525
PV	1	6	22	55	81	104
Geothermal	10	16	22	30	40	49
Solar thermal power plants	0	1	2	4	8	13
Ocean energy	0	0	2	3	4	4
Combined heat & power production	**581**	**598**	**678**	**777**	**840**	**899**
Coal	163	171	174	210	239	264
Lignite	65	56	42	30	26	23
Gas	244	266	355	443	485	519
Oil	80	67	61	42	29	24
Biomass	28	36	45	50	57	64
Geothermal	0	1	2	2	3	4
CHP by producer						
Main activity producers	465	465	498	531	553	585
Autoproducers	117	132	180	247	287	314
Total generation≈	**3,733**	**4,485**	**5,724**	**7,029**	**8,303**	**9,872**
Fossil	2,570	3,039	3,986	4,969	6,023	7,403
Coal	1,066	1,262	1,626	2,082	2,679	3,477
Lignite	139	136	128	125	129	137
Gas	871	1,123	1,682	2,218	2,690	3,254
Oil	494	518	550	545	524	535
Nuclear	346.7	392.1	391.0	377.5	369.8	364.6
Renewables	817	1,054	1,347	1,683	1,910	2,105
Hydro	728	857	999	1,118	1,213	1,280
Wind	30	108	218	375	449	525
PV	1	6	22	55	81	104
Biomass	48	64.5	80.0	95.2	111.9	125.4
Geothermal	10	18	23	33	43	53
Solar thermal	0	1	2	4	8	13
Ocean energy	0	0	2	3	4	4
Fluctuating RES (PV, Wind, Ocean)	31.1	114.4	242.5	432.1	533,8	633,5
Share of fluctuating RES	0.8%	2,6%	4.2%	6.1%	6.4%	6.4%
RES share	21.9%	23.5%	23.5%	23.9%	23.0%	21.3%

tables 18: primary energy demand

PJ/A

	2003	2010	2020	2030	2040	2050
Total	**435,116**	**487,635**	**563,236**	**638,789**	**715,803**	**807,747**
Fossil	**348,558**	**391,127**	**456,328**	**523,527**	**592,155**	**676,274**
Hard coal	98,797	105,077	119,291	139,346	162,956	195,453
Lignite	9,106	7,915	6,981	7,041	7,097	7,341
Natural gas	93,230	101,344	123,691	145,903	166,033	189,471
Crude oil	147,425	176,791	206,365	231,237	256,069	284,010
Nuclear	**28,805**	**32,554**	**32,463**	**31,281**	**30,509**	**29,785**
Renewables	**57,755**	**63,954**	**74,445**	**83,981**	**93,139**	**101,687**
Hydro	9,572	11,332	13,369	15,115	16,528	17,537
Wind	231	853	1,926	3,305	4,225	4,931
Solar	162	386	694	1,243	1,769	2,265
Biomass	46,454	49,715	56,490	61,861	67,591	73,371
Geothermal	1,336	1,668	1,967	2,457	3,026	3,582
Ocean Energy	2	5	21	39	57	68

reference scenario

tables 19: heat supply

PJ/A

	2003	2010	2020	2030	2040	2050
District heating plants	**2,765**	**4,029**	**6,522**	**7,667**	**8,417**	**9,139**
Fossil fuels	2,622	3,659	5,450	5,828	5,960	6,191
Biomass	141	365	1,060	1,823	2,437	2,922
Solar collectors	0	1	4	7	10	16
Geothermal	2	5	8	9	10	11
Heat from CHP	**13,471**	**11,731**	**10,671**	**11,024**	**11,097**	**11,416**
Fossil fuels	12,846	10,870	9,606	9,841	9,883	10,106
Biomass	617	812	1,004	1,108	1,118	1,184
Geothermal	8	49	61	75	96	126
Direct heating[1]	**116,034**	**128,577**	**145,486**	**160,437**	**173,029**	**184,893**
Fossil fuels	82,523	93,492	106,318	118,467	127,775	136,018
Biomass	33,222	34,572	38,409	40,831	43,757	47,057
Solar collectors	158	340	535	861	1,151	1,400
Geothermal	131	173	224	278	346	418
Total heat supply[1]	**132,271**	**144,337**	**162,678**	**179,129**	**192,544**	**205,448**
Fossil fuels	97,992	108,021	121,373	134,135	143,618	152,315
Biomass	33,979	35,749	40,473	43,762	47,312	51,163
Solar collectors	158	341	539	869	1,161	1,415
Geothermal	142	226	293	363	453	556
RES share (including RES electricity)	26%	25%	25%	25%	25%	26%

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

tables 20: CO_2 emissions

MILL t/a

	2003	2010	2020	2030	2040	2050
Condensation power plants	**8,185**	**9,321**	**11,484**	**13,652**	**16,204**	**19,859**
Coal	5,491	6,270	7,676	9,232	11,248	14,143
Lignite	709	685	644	671	688	729
Gas	1,208	1,567	2,345	2,985	3,548	4,289
Oil	777	799	820	763	720	698
Combined heat & power production	**2,374**	**1,794**	**1,367**	**1,445**	**1,541**	**1,607**
Coal	784	595	472	570	638	691
Lignite	302	194	131	111	100	86
Gas	1,149	891	674	698	753	790
Oil	139	114	90	67	49	40
CO_2 emissions electricity & steam generation	**10,559**	**11,115**	**12,851**	**15,097**	**17,745**	**21,466**
Coal	6,276	6,865	8,148	9,802	11,886	14,834
Lignite	1,011	879	775	782	788	815
Gas	2,356	2,458	3,019	3,683	4,302	5,079
Oil & diesel	916	914	909	830	769	738
CO_2 emissions by sector	**23,124**	**26,604**	**29,913**	**34,545**	**39,401**	**45,489**
% of 2000 emissions	100%	111%	129%	149%	170%	197%
Industry	3,738	4,188	4,736	5,290	5,726	6,087
Other sectors	3,257	3,666	4,123	4,602	4,881	5,085
Transport	5,635	6,582	8,085	9,546	11,096	12,925
Electricity & steam generation	10,198	10,790	12,453	14,590	17,181	20,872
District heating	296	379	515	517	518	520
Population (Mill.)	6,310	6,849	7,562	8,139	8,594	8,888
CO_2 emissions per capita (t/capita)	3.7	3.7	4.0	4.2	4.6	5.1

alternative scenario

tables 21: electricity generation

TWh/a

	2003	2010	2020	2030	2040	2050
Power plants	**14,989**	15,264	17,560	19,805	22,694	25,909
Coal	5,451	5,226	4,541	3,398	2,937	2,661
Lignite	572	456	266	117	24	0
Gas	2,380	3,029	4,191	4,981	4,875	4,580
Oil	1,031	693	379	171	55	7
Diesel	0	0	0	0	0	0
Nuclear	2,641	2,094	1,331	65	0	0
Biomass	137	171	251	340	437	547
Hydro	2,659	3,127	3,656	4,035	4,402	4,709
Wind	64	346	2,327	4,494	5,866	7,149
PV	1	28	269	1,003	1,835	2,835
Geothermal	53	80	124	188	262	338
Solar thermal power plants	1	9	196	949	1,891	2,933
Ocean energy	1	5	31	64	111	151
Combined heat & power production	**1,674**	2,044	2,673	3,487	4,325	5,026
Coal	390	337	218	102	37	34
Lignite	142	124	96	43	11	0
Gas	915	1,150	1,475	1,777	2,046	2,195
Oil	134	95	49	35	18	14
Biomass	91	311	750	1,356	1,918	2,395
Geothermal	1	27	86	174	294	388
CHP by producer						
Main acitivity producers	1,215	1,328	1,473	1,724	2,034	2,324
Autoproducers	459	716	1,200	1,763	2,290	2,702
Total generation	**16,662**	17,308	20,234	23,292	27,018	30,935
Fossil	11,015	11,110	11,215	10,624	10,003	9,491
Coal	5,841	5,563	4,759	3,500	2,974	2,695
Lignite	714	580	362	160	35	0
Gas	3,295	4,179	5,666	6,758	6,921	6,775
Oil	1,165	788	428	206	73	21
Nuclear	2,641	2,094	1,331	65	0	0
Renewables	3,007	4,104	7,688	12,603	17,015	21,444
Hydro	2,659	3,127	3,656	4,035	4,402	4,709
Wind	64	346	2,327	4,494	5,866	7,149
PV	1	28	269	1,003	1,835	2,835
Biomass	228	482	1,000	1,696	2,355	2,942
Geothermal	54	107	209	362	556	726
Solar thermal	1	9	196	949	1,891	2,933
Ocean energy	1	5	31	64	111	151
Import	557	595	620	672	789	1,008
Import RES	79	65	161	377	630	894
Export	558	580	618	695	764	997
Distribution losses	1,520	1,590	1,827	2,063	2,340	2,665
Own consumption electricity	1,467	1,545	1,795	2,017	2,187	2,271
Final energy consumption (electricity)	**13,675**	14,188	16,614	19,189	22,516	26,009
Fluctuating RES (PV, Wind, Ocean)	65	379	2,627	5,561	7,812	10,134
Share of fluctuating RES	0.4%	2.2%	13%	23.9%	28.9%	32.8%
RES share	18%	23.7%	38%	54.1%	63%	69.3%
'Efficiency' savings (compared to REF.)	0	2,380	4,665	7,093	9,435	13,000

table 23: primary energy demand converted

	2003	2010	2020	2030	2040	2050
coal in Mill t	5,368	4,380	3,325	2,343	1,748	1,382
crude oil in Mill barrel	24,089	23,543	21,014	18,115	16,149	14,238
gas in E+9 m³	2453.4	2605.1	2736.2	2816.4	2653.2	2448.8

Conversion factors		
Coal	23.03	kJ/t
Lignite	8.45	kJ/t
oil	6.12	GJ/barrel
gas	38000.00	kJ/m³

tables 22: installed capacity

GW

	2003	2010	2020	2030	2040	2050
Power plants	**3,152**	**3,392**	**4,481**	**5,881**	**7,002**	**8,329**
Coal	902	885	783	590	507	457
Lignite	73	59	35	16	3	0
Gas	626	792	1,057	1,269	1,284	1,239
Oil	414	304	185	94	30	4
Nuclear	347	275	175	9	0	0
Biomass	20	25	36	48	60	75
Hydro	728	855	994	1,091	1,183	1,257
Wind	30	156	950	1,834	2,242	2,731
PV	1	23	199	728	1,330	2,033
Geothermal	10	15	24	36	49	63
Solar thermal power plants	0	2	29	138	267	405
Ocean energy	0	2	14	28	46	63
Combined heat & power production	**581**	**626**	**754**	**897**	**1,063**	**1,209**
Coal	163	135	76	33	10	9
Lignite	65	52	34	12	3	0
Gas	244	306	433	548	640	690
Oil	80	43	19	11	4	3
Biomass	28	85	176	258	348	430
Geothermal	0	5	17	35	58	77
CHP by producer						
Main acitivity producers	464	464	499	538	617	689
Autoproducers	117	162	255	359	445	520
Total Generation	**3,733**	**4,018**	**5,235**	**6,778**	**8,064**	**9,537**
Fossil	2,569	2,574	2,622	2,573	2,481	2,402
Coal	1,066	1,020	859	623	517	466
Lignite	139	111	69	28	6	0
Gas	871	1,097	1,490	1,818	1,923	1,929
Oil	494	346	204	105	34	7
Nuclear	346.7	275.2	175.4	9	0	0
Renewables	817	1,169	2,438	4,196	5,584	7,135
Hydro	728	855	994	1,091	1,183	1,257
Wind	30	156	950	1,834	2,242	2,731
PV	1	23	199	728	1,330	2,033
Biomass	48	110	211	306	408	505
Geothermal	10	21	41	70	107	140
Solar thermal	0	2	29	138	267	405
Ocean energy	0	2	14	28	46	63
Fluctuating RES (PV, Wind, Ocean)	31.1	181.1	1,162.2	2,590.2	3,617.5	4,828.1
Share of fluctuating RES	0.8%	4.5%	22.2%	38.2%	44.9%	50.6%
RES share	21.9%	29.1%	46.6%	61.9%	69.2%	74.8%

tables 24: primary energy demand

PJ/A

	2003	2010	2020	2030	2040	2050
Total	**435,116**	**428,049**	**421,446**	**414,573**	**420,512**	**421,904**
Fossil	**348,558**	**333,205**	**303,439**	**269,418**	**239,370**	**212,011**
Hard coal	98,797	83,902	67,550	50,124	39,409	31,822
Lignite	9,106	6,224	3,308	1,406	308	0
Natural gas	93,230	98,994	103,975	107,023	100,822	93,055
Crude oil	147,425	144,085	128,606	110,865	98,832	87,135
Nuclear	**28,805**	**22,844**	**14,520**	**709**	**0**	**0**
Renewables	**57,755**	**72,000**	**103,487**	**144,446**	**181,142**	**209,893**
Hydro	9,572	11,255	13,160	14,524	15,846	16,951
Wind	231	1,246	8,377	16,178	21,118	25,735
Solar	162	1,743	6,916	17,909	30,231	42,284
Biomass	46,454	54,704	68,467	84,727	97,679	105,136
Geothermal	1,336	3,052	6,567	11,108	16,268	19,787
Ocean Energy	2	18	111	232	398	542
'Efficiency' savings (compared to Ref.)	0	59,263	141,744	224,873	296,208	386,780

alternative scenario

tables 25: heat supply

PJ/A

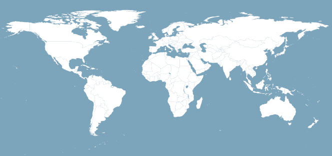
	2003	2010	2020	2030	2040	2050
District heating plants	**2,766**	**4,278**	**5,686**	**6,678**	**7,647**	**7,229**
Fossil fuels	2,623	3.588	3,836	3,260	2,565	1,630
Biomass	141	385	893	1,498	2,033	2,096
Solar collectors	0	278	758	1,508	2,378	2,725
Geothermal	2	27	198	412	671	777
Heat from CHP	**13,470**	**12,708**	**13,303**	**15,172**	**16,950**	**18,884**
Fossil fuels	12,845	10,750	8,966	8,258	8,180	8,367
Biomass	617	1,717	3,576	5,374	6,250	7,275
Geothermal	8	241	762	1,540	2,520	3,242
Direct heating[1]	**116,034**	**111,832**	**106,796**	**104,229**	**100,048**	**93,333**
Fossil fuels	82,523	75,426	63,791	52,877	42,080	31,330
Biomass	33,222	34,247	36,708	39,115	39,616	38,666
Solar collectors	158	1,330	4,484	9,374	14,439	18,794
Geothermal	131	829	1,814	2,863	3,914	4,542
Total heat supply[1]	**132,271**	**128,817**	**125,785**	**126,079**	**124,645**	**119,446**
Fossil fuels	97,992	89,764	76,592	64,395	52,825	41,327
Biomass	33,979	36,348	41,176	45,987	47,898	48,038
Solar collectors	158	1,608	5,243	10,882	16,817	21,519
Geothermal	142	1,097	2,774	4,815	7,104	8,562
RES share (including RES electricity)	26%	30%	39%	49%	58%	65%
'Efficiency' savings (compared to Ref.)	0	15,514	36,890	53,048	67,899	86,005

tables 26: CO_2 emissions

MILL t/a

	2003	2010	2020	2030	2040	2050
Condensation power plants	**8,185**	**7,471**	**6,419**	**5,061**	**4,170**	**3,587**
Coal	5,492	5,000	4,070	2,851	2,298	1,977
Lignite	709	508	257	110	22	0
Gas	1,208	1,453	1,821	1,982	1,812	1,605
Oil	777	510	271	118	37	5
Combined heat & power production	**2,374**	**1,697**	**1,162**	**1,025**	**1,034**	**1,072**
Coal	784	453	201	85	26	23
Lignite	302	183	110	46	12	0
Gas	1,148	983	818	872	986	1,042
Oil	139	79	34	22	10	8
CO_2 emissions electricity & steam generation	**10,559**	**9,168**	**7,581**	**6,086**	**5,204**	**4,659**
Coal	6,276	5,452	4,271	2,936	2,324	2,000
Lignite	1,011	691	367	156	34	0
Gas	2,356	2,436	2,639	2,854	2,797	2,646
Oil & diesel	916	589	305	140	48	13
CO_2 emissions by sector	**23,124**	**21,379**	**18,798**	**15,917**	**13,608**	**11,594**
% of 2000 emissions	100%	92%	81%	69%	59%	50%
Industry	3,738	3,115	2,519	2,161	1,817	1,488
Other sectors	3,257	3,118	2,752	2,208	1,636	1,097
Transport	5,635	5,961	5,964	5,552	5,106	4,604
Electricity & steam generation	10,198	8,824	7,187	5,677	4,779	4,217
District heating	296	362	375	319	269	187
Population (Mill.)	6,310	6,849	7,562	8,139	8,594	8,888
CO_2 emissions per capita (t/capita)	3.7	3.1	2.5	2.0	1.6	1.3
'Efficiency' savings (compared to REF.)	0	4,224	11,115	18,628	25,794	33,895

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 north 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 international
Ottho Heldringstraat 5, 1066 AZ Amsterdam, The Netherlands
t +31 20 718 2000 f +31 20 514 8151
sven.teske@int.greenpeace.org
www.greenpeace.org

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)
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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