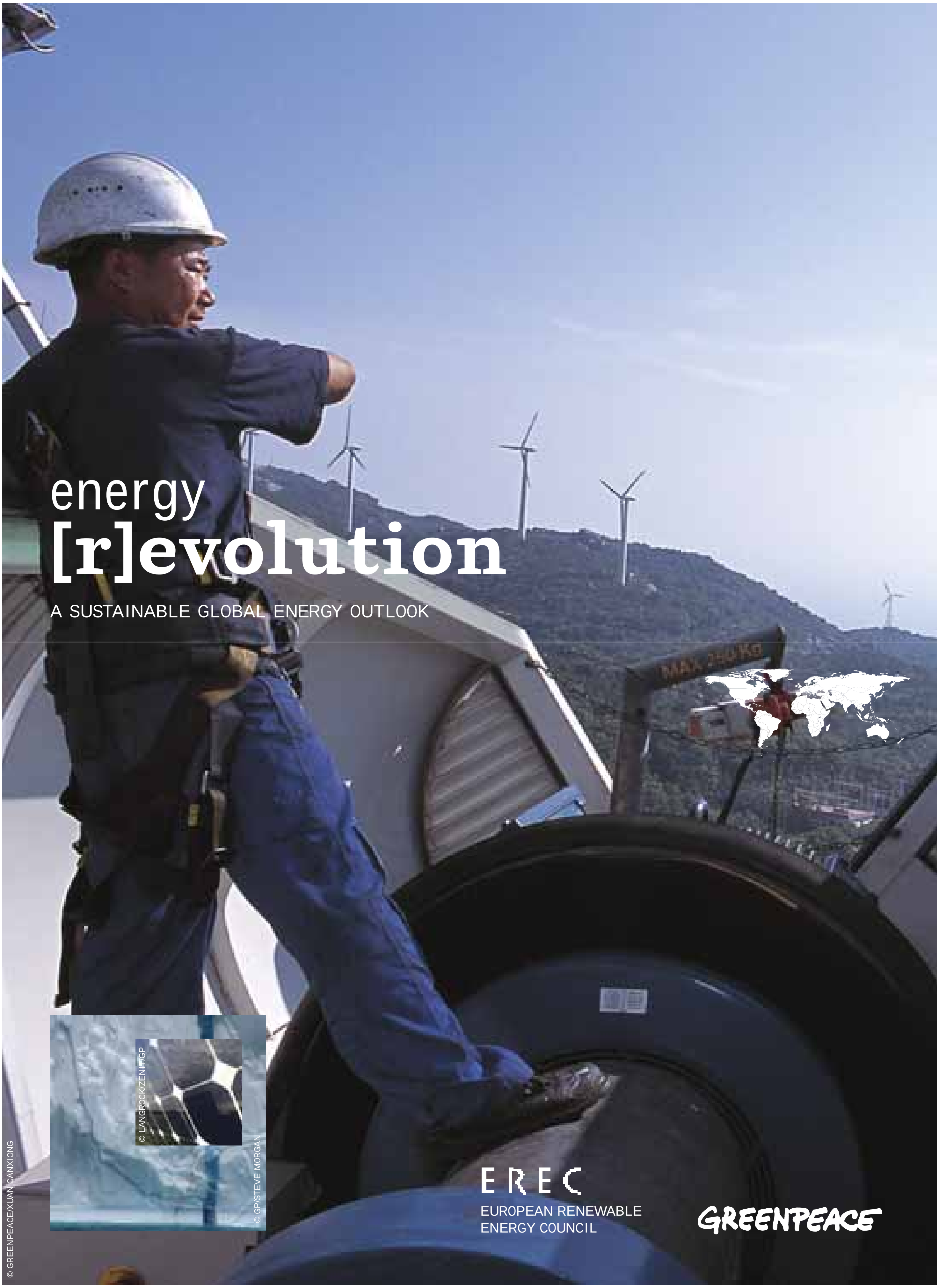

energy [r]evolution

A SUSTAINABLE GLOBAL ENERGY OUTLOOK

EREC
EUROPEAN RENEWABLE ENERGY COUNCIL

GREENPEACE

report global energy scenario

partners

Greenpeace International, European Renewable Energy Council (EREC)

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image A LOCAL TIBETAN WOMAN WHO HAS FIVE CHILDREN AND RUNS A BUSY GUEST HOUSE IN THE VILLAGE OF ZHANG ZONG USES SOLAR PANELS TO SUPPLY ENERGY FOR HER BUSINESS.
cover image A MAINTENANCE ENGINEER INSPECTS A WIND TURBINE AT THE NAN WIND FARM IN NAN'AO. GUANGDONG PROVINCE HAS ONE OF THE BEST WIND RESOURCES IN CHINA AND IS ALREADY HOME TO SEVERAL INDUSTRIAL SCALE WIND FARMS.

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

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

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

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

contents

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

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

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

Dr. R. K. Pachauri
DIRECTOR-GENERAL, THE ENERGY AND RESOURCES INSTITUTE (TERI) AND CHAIRMAN, INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE (IPCC)
OCTOBER 2008

introduction

"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."

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

Energy supply has become a subject of major universal concern. High and volatile oil and gas prices, threats to a secure and stable supply and not least climate change have all pushed it high up the international agenda. In order to avoid dangerous climate change, global CO_2 emissions must peak no later than 2015 and rapidly decrease after that. The technology to do this is available. The renewables industry is ready for take off and opinion polls show that the majority of people support this move. There are no real technical obstacles in the way of an Energy [R]evolution, all that is missing is political support. But we have no time to waste. To achieve an emissions peak by 2015 and a net reduction afterwards, we need to start rebuilding the energy sector now.

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 unchecked will have disastrous consequences. Furthermore, there is solid scientific evidence that we should act now. This is reflected in the conclusions, published in 2007, of the Intergovernmental Panel on Climate Change (IPCC), a UN institution of more than 1,000 scientists providing advice to policy makers.

The effects of climate change have in fact already begun. In 2008, the melting of the Arctic ice sheet almost matched the record set on September 16, 2007. The fact that this has now happened two years in a row reinforces the strong decreasing trend in the amount of summertime ice observed over the past 30 years.

“renewable energy, combined with the smart use of energy, can deliver half of the world’s energy needs by 2050.”

image ICEBERG MELTING ON GREENLAND’S COAST.

In response to this threat, the Kyoto Protocol has committed its signatories to reduce their greenhouse gas emissions by 5.2% from their 1990 levels by 2008-2012. The Kyoto signatories are currently negotiating the second phase of the agreement, covering the period from 2013-2017. Time is quickly running out. Signatory countries agreed a negotiating ‘mandate’, known as the Bali Action Plan, which they must complete with a final agreement on the second Kyoto commitment period by the end of 2009. 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, on the other hand, will have to reduce their emissions by up to 80%. The Energy [R]evolution concept provides a practical blueprint on how to put this into practice.

Renewable energy, combined with the smart use of energy, can deliver at least half of the world’s energy needs by 2050. This report, ‘Energy [R]evolution: A Sustainable World Energy Outlook’, shows that it is economically beneficial to cut global CO_2 emissions by over 50% within the next 42 years. It also concludes that a massive uptake of renewable energy sources is technically and economically possible. Wind power alone could produce about 40 times more power than it does today, and total global renewable energy generation could quadruple by then.

renewed energy [r]evolution

This is the second edition of the Energy [R]evolution. Since we published the first edition in January 2007, we have experienced an overwhelming wave of support from governments, the renewables industry and non-governmental organisations. Since than we have broken down the global regional scenarios into country specific plans for Canada, the USA, Brazil, the European Community, Japan and Australia, among many others.

More and more countries are seeing the environmental and economic benefits provided by renewable energy. The Brent crude oil price was at $55 per barrel when we launched the first Energy [R]evolution report. Since than the price has only headed in one direction - upwards! By mid-2008 it had reached a peak of over $140 per barrel and has subsequently stabilised at around $100. Other fuel prices have also shot up. Coal, gas and uranium have doubled or even tripled in the same timeframe. By contrast, most renewable energy sources don’t need any fuel. Once installed, they deliver energy independently from the global energy markets and at predictable prices. Every day that another community switches to renewable energy is an independence day.

The Energy [R]evolution Scenario concludes that the restructuring of the global electricity sector requires an investment of $14.7 trillion up to 2030. This compares with $11.3 trillion under the Reference Scenario based on International Energy Agency projections. While the average annual investment required to implement the Energy [R]evolution Scenario would need just under 1% of global GDP, it would lower fuel costs by 25% - saving an annual amount in the range of $750 billion.

In fact, the additional costs for coal power generation alone from today up to 2030 under the Reference Scenario could be as high as US$ 15.9 billion: this would cover the entire investment needed in renewable and cogeneration capacity to implement the Energy [R]evolution Scenario. These renewable sources will produce energy without any further fuel costs beyond 2030, while the costs for coal and gas will continue to be a burden on national and global economies.

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 an affordable energy supply on the basis of steady worldwide economic development. Both of these goals are possible at the same time. The urgent need for change in the energy sector means that this scenario is based only on proven and sustainable technologies, such as renewable energy sources and efficient decentralised cogeneration. It therefore excludes so-called ‘CO_2-free coal power plants’, which are not in fact CO_2 free and would create another burden in trying to store the gas under the surface of the Earth with unknown consequences. For multiple safety and environmental reasons, nuclear energy is also excluded.

Commissioned 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 renewables industry around the world. The new Energy [R]evolution Scenario also takes a closer look for the first time at the transport sector, including future technologies and how to implement energy efficiency.

The energy supply scenarios adopted in this report, which extend beyond and enhance projections made by the International Energy Agency, have been calculated using the MESAP/PlaNet simulation model. The demand side projection has been developed by the Ecofys consultancy to take into account the future potential for energy efficiency measures. This study envisages an ambitious development pathway 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 38% in 2050 compared to the Reference Scenario.

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

the potential for renewable energy

The good news is that the global market for renewables is booming. Decades of technical progress have seen renewable energy technologies such as wind turbines, solar photovoltaic panels, biomass power plants, solar thermal collectors and many others move steadily into the mainstream. The global market for renewable energy is growing dramatically; in 2007 its turnover was over aUS$ 70 billion, almost twice as high as the previous year. The time window for making the shift from fossil fuels to renewable energy, however, 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 or gas power plant today will result in the production of CO_2 emissions and dependency on the resource and its future costs lasting until 2050.

The power industry and utilities need to take more responsibility because today's investment decisions will define the energy supply of the next generation. We strongly believe that this should be the 'solar generation'. Politicians from the industrialised world urgently need to rethink their energy strategy, while the developing world should learn from past mistakes and build economies on the strong foundations of a sustainable energy supply.

Renewable energy could more than double its share of the world's energy supply - reaching up to 30% by 2030. All that is lacking is the political will to promote its large scale deployment in all sectors at a global level, coupled with far reaching energy efficiency measures. By 2030 about half of global electricity could come from renewable energies.

The future of renewable energy development will strongly depend on political choices made by both individual governments and the international community. At the same time 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.

In this report we have also expanded the time horizon for the Energy [R]evolution concept beyond 2050, to see when we could phase out fossil fuels entirely. Once the pathway of this scenario has been implemented, renewable energy could provide all global energy needs by 2090. A more radical scenario – which takes the advanced projections of the renewables industry into account – could even phase out coal by 2050. Dangerous climate change might force us to accelerate the development of renewables faster. We believe that this would be possible, but to achieve it more resources must go into research and development. Climate change and scarcity of fossil fuel resources puts our world as we know it at risk; we must start to think the unthinkable. To tap into the fast potential for renewables and to phase out fossil fuels as soon as possible are amongst the most pressing tasks for the next generation of engineers and scientists.

implementing the energy [r]evolution

Business as usual is not an option for future generations. The Reference Scenario based on the IEA's 'World Energy Outlook 2007' projection would almost double global CO_2 emissions by 2050 and the climate would heat up by 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, pointed out clearly in his landmark report that the countries which invest in energy saving technologies and renewable energies today will be the economic winners of tomorrow.

As Stern emphasised, inaction will be much more expensive in the long run. We therefore call on all decision makers yet again to make this vision a reality. The world cannot afford to stick to the 'business as usual' energy development path: relying on fossil fuels, nuclear energy and other outdated technologies. Renewable energy can and will play a leading role in our collective 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)

Sven Teske
CLIMATE & ENERGY UNIT
GREENPEACE INTERNATIONAL

OCTOBER 2008

"by 2030 about half of global electricity could come from renewable energies."

executive summary

"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."

© PAUL LANGROCK/ZENIT/GREENPEACE

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

climate threats and climate solutions

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

climate change and security of supply

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. The days of 'cheap oil and gas' are coming to an end. Uranium, the fuel for nuclear power, is also a finite resource. By contrast, the reserves of renewable energy that are technically accessible globally are large enough to provide about six times more power than the world currently consumes - forever.

Renewable energy technologies vary widely in their technical and economic maturity, but there are a range of sources which offer increasingly attractive options. These 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.

image IN 2005 THE WORST DROUGHT IN MORE THAN 40 YEARS DAMAGED THE WORLD'S LARGEST RAIN FOREST IN THE BRAZILIAN AMAZON, WITH WILDFIRES BREAKING OUT, POLLUTED DRINKING WATER AND THE DEATH OF MILLIONS FISH AS STREAMS DRY UP.

At the same time there is enormous potential for reducing our consumption of energy, while providing the same level of energy services. This study details a series of energy efficiency measures which together can substantially reduce demand in industry, homes, business and services.

Although nuclear power produces little carbon dioxide, there are multiple threats to people and the environment from its operations. These include the risks and environmental damage from uranium mining, processing and transport, the risk of nuclear weapons proliferation, the unsolved problem of nuclear waste and the potential hazard of a serious accident. The nuclear option is therefore discounted in this analysis. The solution to our future energy needs lies instead in greater use of renewable energy sources for both heat and power.

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 Reference Scenario published by the International Energy Agency in World Energy Outlook 2007, extrapolated forward from 2030. Compared to the 2004 IEA projections, World Energy Outlook 2007 (WEO 2007) assumes a slightly higher average annual growth rate of world Gross Domestic Product (GDP) of 3.6%, instead of 3.2%, over the period 2005-2030. At the same time, WEO 2007 expects final energy consumption in 2030 to be 4% higher than in WEO 2004.

China and India are expected to grow faster than other regions, followed by the Developing Asia group of countries, Africa and the Transition Economies (mainly the former Soviet Union). The OECD share of global purchasing power parity (PPP) adjusted GDP will decrease from 55% in 2005 to 29% by 2050.

The Energy [R]evolution Scenario has a target for worldwide carbon dioxide emissions to be reduced by 50% below 1990 levels by 2050, with per capita emissions reduced to less than 1.3 tonnes per year. This is necessary if the increase in global temperature is to remain below +2°C. A second objective is the global phasing out of nuclear energy. To achieve these targets, the scenario is characterised by significant efforts to fully exploit the large potential for energy efficiency. At the same time, all cost-effective renewable energy sources are accessed for both heat and electricity generation, as well as the production of sustainable bio fuels.

Today, renewable energy sources account for 13% of the world's primary energy demand. Biomass, which is mostly used in the heat sector, is the main renewable energy source. The share of renewable energies for electricity generation is 18%. The contribution of renewables to heat supply is around 24%, to a large extent accounted for by traditional uses such as collected firewood. About 80% of the primary energy supply today still comes from fossil fuels. The Energy [R]evolution Scenario describes a development pathway which turns the present situation into a sustainable energy supply through the following measures:

- Exploitation of the existing large energy efficiency potentials will ensure that primary energy demand increases only slightly - from the current 474,900 PJ/a (2005) to 480,860 PJ/a in 2050, compared to 867,700 PJ/a in the Reference Scenario. This dramatic reduction is a crucial prerequisite for achieving a significant share of renewable energy sources in the overall energy supply system, for compensating the phasing out of nuclear energy and for 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, the 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 77% of electricity will be produced from renewable energy sources (including large hydro). A capacity of 9,100 GW will produce 28,600 TWh/a renewable electricity in 2050.
- In the heat supply sector, the contribution of renewables will increase to 70% by 2050. Fossil fuels will be increasingly replaced by more efficient modern technologies, in particular biomass, solar collectors and geothermal.
- Before sustainable bio fuels are introduced in the transport sector, the existing large efficiency potentials have to be exploited. As biomass is mainly committed to stationary applications, the production of bio fuels is limited by the availability of sustainable raw materials. Electric vehicles powered by renewable energy sources, will play an increasingly important role from 2020 onwards.
- By 2050, 56% 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 technologies is of great importance. Such mobilisation depends on technical potentials, actual costs, cost reduction potentials and technological maturity.

image A WOMAN CLEANS SOLAR PANALS AT THE BAREFOOT COLLEGE IN TILONIA, RAJASTHAN, INDIA.

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

costs

The slightly higher electricity generation costs (compared to conventional fuels) under the Energy [R]evolution Scenario are compensated for, to a large extent, by reduced demand for electricity. Assuming average costs of 3 cents/kWh for implementing energy efficiency measures, the additional cost for electricity supply under the Energy [R]evolution Scenario will amount to a maximum of $10 billion/a in 2010. These additional costs, which represent society's investment in an environmentally benign, safe and economic energy supply, continue to decrease after 2010. By 2050 the annual costs of electricity supply will be $2,900 billion/a below those in the Reference Scenario.

It is assumed that average crude oil prices will increase from $52.5 per barrel in 2005 to $100 per barrel in 2010, and continue to rise to $140 per barrel in 2050. Natural gas import prices are expected to increase by a factor of four between 2005 and 2050, while coal prices will nearly double, reaching $360 per tonne in 2050. A CO_2 'price adder' is applied, which rises from $10 per tonne of CO_2 in 2010 to $50 per tonne of in 2050.

development of CO_2 emissions

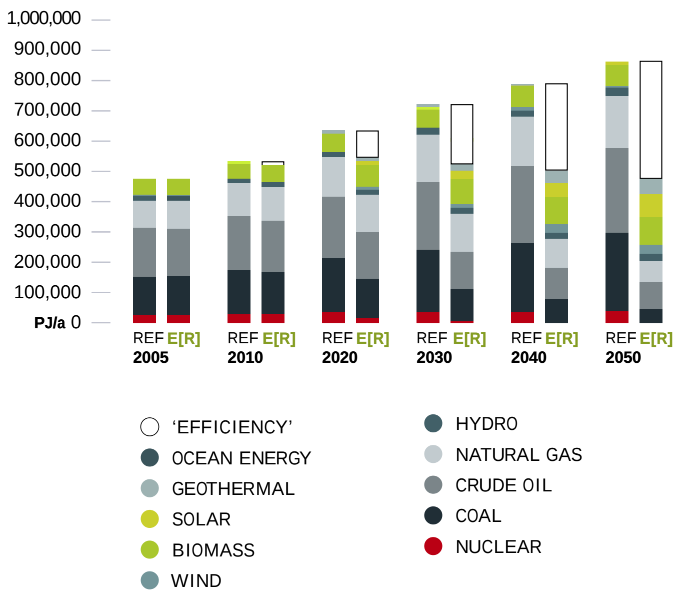
While CO_2 emissions worldwide will double under the Reference Scenario up to 2050, and are thus far removed from a sustainable development path, under the Energy [R]evolution Scenario they will decrease from 24,350 million tonnes in 2003 to 10,590 m/t in 2050. Annual per capita emissions will drop from 3.8 tonnes/capita to 1.2 t/capita. In spite of the phasing out of nuclear energy and a growing electricity demand, CO_2 emissions will decrease enormously in the electricity sector. In the long run efficiency gains and the increased use of renewable electric vehicles, as well as a sharp expansion in public transport, will even reduce CO_2 emissions in the transport sector. With a share of 35% of total emissions in 2050, the power sector will reduce significantly but remain the largest source of CO_2 emissions - followed by transport and industry.

to make the energy [r]evolution real and to avoid dangerous climate change, Greenpeace and EREC demand for the energy sector that the following policies and actions are implemented:

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

figure 0.1: global: development of primary energy consumption under the two scenarios

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



long term energy [r]evolution scenarios

The Energy [R]evolution Scenario outlines a sustainable pathway for a new way of using and producing energy up to 2050. Greenpeace, the DLR and the renewable energy industry have now developed this scenario further towards a complete phasing out of fossil fuels in the second half of this century.

A long term scenario over almost 100 years cannot be exact. Projections of economic growth rates, fossil fuel prices or the overall energy demand are of course speculative and by no means represent forecasts. A regional breakdown is also not possible as sufficient technical data, such as exact wind speed data in specific locations, is not available. The grid integration of huge percentages of fluctuating sources such as wind and solar photovoltaics equally needs further scientific and technical research. But such a long term scenario can give us an idea of by when a complete fossil fuel and CO_2 free energy supply at a global level is possible, and what long term production capacities for renewable energy sources are needed. In this context we developed two different long term scenarios: the long term Energy [R]evolution and the advanced Energy [R]evolution. The long term scenario follows the same projections until the end of this century.

By 2050, renewable energy sources will account for more than 50% of the world's primary energy demand in the Energy [R]evolution Scenario. Approximately 44% of primary energy supply in 2050 still comes from fossil fuels, mainly oil used in the transport sector, followed by gas and coal in the power sector.

The long term Energy [R]evolution Scenario continues the development pathway up to 2100 with the following outcomes:

- **demand:** Energy efficiency potentials are largely exploited and primary energy demand therefore stabilises at 2060 levels.
- **power sector:** The electricity sector will pioneer the fossil fuel phase-out. By 2070 over 93% of electricity will be produced from renewable energy sources, with the remaining gas-fired power plants mainly used for backup power. A capacity of 23,100 GW will produce 56,800 TWh of renewable electricity in 2100 – 17 times more than today.

From the currently available technologies, solar photovoltaics, followed by wind power, concentrated solar power and geothermal, have the highest potentials in the power sector. The use of ocean energy might be significantly higher, but with the current state of development, the technical and economical potential remains unclear.

- **heating and cooling:** The increased use of combined heat and power generation (CHP) in 2050 will remain at the same level up to 2070. It will then fall back slightly to its 2040 level (5,500 TWh) until the end of this century, as the decreasing demand for heat and the large potential for producing heat directly from renewable energy sources, such as solar collectors and geothermal, limits the further expansion of CHP.
- In the heat supply sector, the contribution of renewables will increase to 90% by 2080. A complete fossil fuels phase-out will be realised shortly afterwards.
- **transport:** Efficient use of transport systems will still be the main way of limiting fuel use. Public transport systems will continue to be far more energy efficient than individual vehicles. However, we assume that cars will still be needed, especially in rural areas. Between 2050 and 2085 the use of oil in cars will be phased out completely and replaced mainly by electric vehicles. The electricity will come from renewable energy sources.
- By 2080, about 90% of primary energy demand will be covered by renewable energy sources; in 2090 the renewable share will reach 98.2%.

The advanced Energy [R]evolution Scenario takes a much more radical approach to the climate crisis facing the world. In order to pull the emergency brake on global emissions it therefore assumes much shorter technical lifetimes for coal-fired power plants - 20 years instead of 40 years. This reduces global CO_2 emissions even faster and takes the latest evidence of greater climate sensitivity into account. In order to fill the resulting gap, the annual growth rates of renewable energy sources, especially solar photovoltaics, wind and concentrated solar power plants, have been increased.

Growth rates increase from 2020 onwards to 2050. These expanded growth rates are in line with the current projections of the wind and solar industry (see Global Wind Energy Outlook 2008, Solar Generation 2008). So in the advanced scenario the capacities for solar and wind power generation appear 10 to 15 years earlier than projected in the Energy [R]evolution Scenario. The expansion of geothermal co-generation has also been moved 20 years ahead of its expected take-off. All other results remain the same as in the Energy [R]evolution Scenario, with the only changes affecting the power sector.

The main change for the power sector in the advanced Energy [R]evolution Scenario is that all conventional coal-fired power plants are phased out by 2050. Between 2020 and 2050 a total of about 1,200 GW of capacity will be replaced by solar photovolatics, on- and offshore wind and concentrated solar power plants. By 2050, 86% of electricity will be produced from renewable energy sources and 96% by 2070. Again the remaining fossil fuel-based power production is from gas. Compared to the basic Energy [R]evolution Scenario the expected capacity of renewable energy will emerge 15 years ahead of schedule, while the overall level of renewable power generation from 2085 onwards will be the same.

image THE HUGE SHADOW OF A 60-METRE-HIGH WIND TURBINE EXTENDS ACROSS THE GOBI DESERT FLOOR AT THE HE LAN SHAN WIND FARM IN THE NINGXIA PROVINCE, CHINA.

From the renewables industry perspective, these larger quantities are able to be delivered. However, the advanced scenario requires more research and development into the large scale grid integration of renewable energies as well as better regional meteorological data to optimise the mix of different sources.

It is important to highlight that in the Energy [R]evolution Scenario the majority of remaining coal power plants – which will be replaced 20 years before the end of their technical lifetime – are in China and India. This means that in practice all coal power plants built between 2005 and 2020 will be replaced by renewable energy sources. To support the building of capacity in developing countries significant new public financing, especially from industrialised countries, will be needed. It is vital that specific funding mechanisms are developed under the international climate negotiations that can assist the transfer of financial support to climate change mitigation, including technology transfer. Greenpeace International has developed one option for how such a funding mechanism could work (see Chapter 2).

almost zero CO_2 emissions by 2080

While worldwide CO_2 emissions will decrease under the Energy [R]evolution Scenario from 10,589 million tonnes in 2050 (51% below 1990 levels) down to 425 m/t in 2090, the advanced scenario would reduce emissions even faster. By 2050, the advanced Energy [R]evolution version would reduce CO_2 emissions by 61% below 1990 levels, and 80% below by the year 2075. Annual per capita emissions would drop below 1 t/capita in 2050 under the advanced scenario, compared with around 2060 under the basic Energy [R]evolution.

Further CO_2 reductions between 2040 and 2080 are only possible in the transport sector, as the major remaining emitters are combustion engines in cars. It is not possible to replace the remaining fossil fuelled cars with electric vehicles as this would drive electricity demand up again. The increased demand cannot be met by renewables in this timeframe since this would exceed growth rates and grid capacities based on today's knowledge. The only way to cut vehicle emissions further would be to reduce kilometres driven by about 40% between 2040 and 2080.

figure 0.2: global: primary energy demand in energy [r]evolution scenario until 2100

FOSSIL FUEL PHASED OUT BY 2095

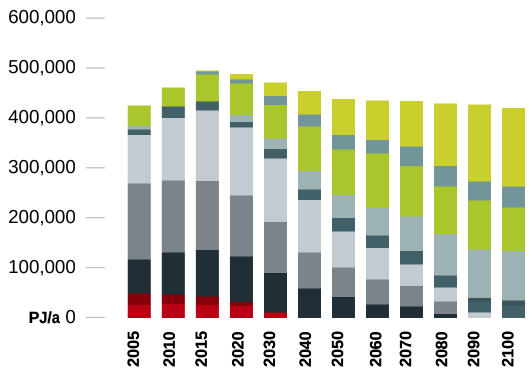
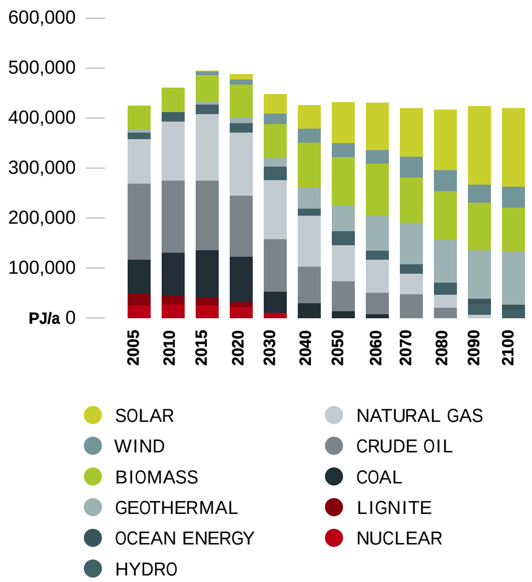


figure 0.3: global: primary energy demand in the advanced energy [r]evolution scenario until 2100

COAL POWER PLANTS PHASED OUT BY 2050



"forward-thinking governments can act now to maximize employment and investment opportunities as we move to a renewable energy future."

figure 0.4: global: electricity generation energy [r]evolution scenario until 2100

COAL POWER PLANTS PHASED OUT BY 2085 (40 YEARS LIFETIME)

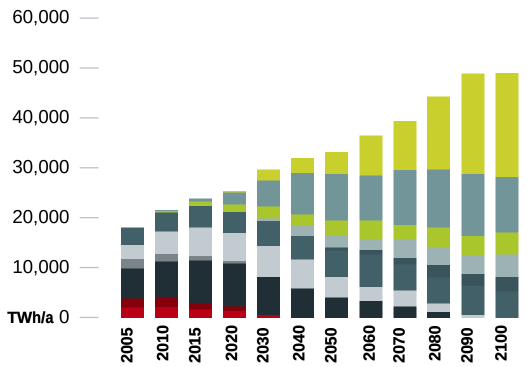


figure 0.6: global: CO_2 emissions energy [r]evolution scenario until 2100

80% GLOBAL CO_2 REDUCTION BY 2085

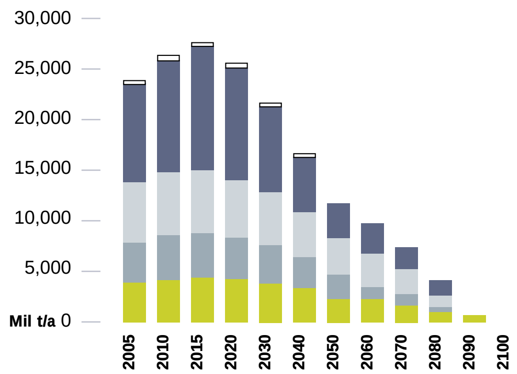


figure 0.5: global: electricity generation advanced energy [r]evolution scenario until 2100

COAL POWER PLANTS PHASED OUT BY 2050 (20 YEARS LIFETIME)

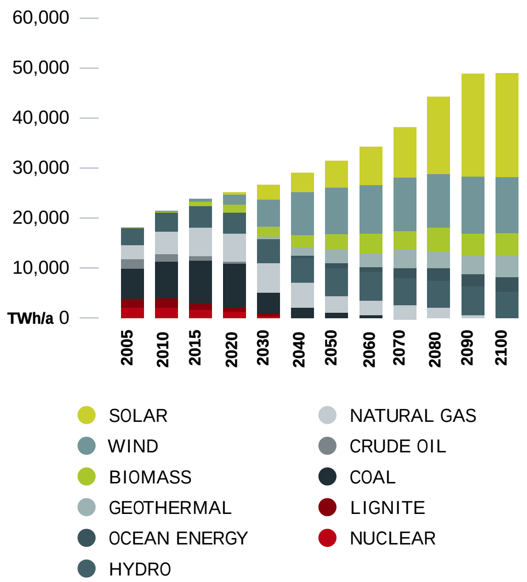
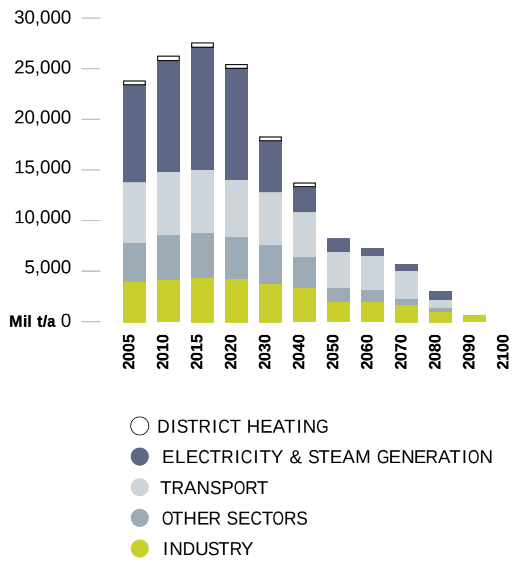


figure 0.7: global: CO_2 emissions advanced energy [r]evolution scenario until 2100

80% GLOBAL CO_2 REDUCTION BY 2075



climate protection

GLOBAL

THE KYOTO PROTOCOL
INTERNATIONAL ENERGY POLICY

RENEWABLE ENERGY TARGETS
DEMANDS FOR THE ENERGY SECTOR

1

image THE LOCAL ALASKAN TELEVISION STATION BROADCASTS A WARNING FOR HIGH TIDES AND EROSION ALONG THE SEASIDE DURING A 2006 OCTOBER STORM WHICH IMPACTS ON THE VILLAGE OF SHISHMAREF. © GP/ROBERT KNOTH

"never before has humanity been forced to grapple with such an immense environmental crisis."

GREENPEACE INTERNATIONAL
CLIMATE CAMPAIGN

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' has enhanced 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 from agriculture, 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.

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°C. 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 greater risk of more extreme weather events such as heatwaves, 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 and Andean South America as well as small islands least able to protect themselves from increasing droughts, rising sea levels, the spread of disease and decline in agricultural production.

longer term catastrophic effects Warming from emissions may trigger the irreversible meltdown of the Greenland ice sheet, adding up to seven metres of sea level rise over several centuries. New evidence 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.

image A MELT POOL NEAR SERMALIK FJORD, EAST GREENLAND, MADE BY THE HELHEIM GLACIER WHICH HAS RECEDED AND MELTED AWAY. THE LINES IN THE EARTH BANK ARE SCULPTED BY THE MOVEMENT OF THE GLACIER'S RETREAT.

images 1. THE AFTERMATH OF HURRICANE STAN IN MEXICO. ACCORDING TO THE MEXICAN GOVERNMENT FIGURES THERE ARE MORE THAN 1 MILLION, 100 THOUSAND PEOPLE WHO HAVE BEEN DIRECTLY AFFECTED BY THE FLOODS WITH AN UNKNOWN NUMBER WHO HAVE DISAPPEARED. IN CHIAPAS ALONE, 650 MM RAIN FELL IN A SHORT PERIOD OF TIME CAUSING EXTENSIVE DAMAGE TO ROADS AND HOUSES. **2.** CHILDREN LIVING NEXT TO THE SEA PLAY IN SEA WATER THAT HAS SURGED INTO THEIR VILLAGE CAUSED BY THE 'KING TIDES', BUOTA VILLAGE, TARAWA ISLAND, KIRIBATI, PACIFIC OCEAN. GREENPEACE AND SCIENTISTS ARE CONCERNED THAT LOW LYING ISLANDS FACE PERMANENT INUNDATION FROM RISING SEAS DUE TO CLIMATE CHANGE. **3.** PREECHA BUATHO, 49, IS A RESIDENT OF A VILLAGE IN LAEM TALUMPUK CAPE. HIS FAMILY, HOUSE AND VILLAGE ARE BEING THREATENED BY SEA LEVEL RISE DUE TO CLIMATE CHANGE. LAEM TALUMPUK IS IN PAK PANANG DISTRICT IN THE SOUTHERN PROVINCE OF NAKHON SI THAMMARAT, ON THE EASTERN SHORE OF THE GULF OF THAILAND. CLIMATE CHANGE-INDUCED WIND PATTERNS HAVE INTENSIFIED THE SPEED OF COASTAL EROSION IN BOTH THE GULF OF THAILAND AND THE ANDAMAN SEA. ON AVERAGE, 5 METRES OF COASTAL LANDS IN THE REGION ARE LOST EACH YEAR. **4.** THE DARK CLOUDS OF AN ADVANCING TORNADO, NEAR FORT DODGE, IOWA, USA. **5.** WOMEN FARMERS FROM LILONGWE, MALAWI STAND IN THEIR DRY, BARREN FIELDS CARRYING ON THEIR HEADS AID ORGANISATION HANDOUTS. THIS AREA, THOUGH EXTREMELY POOR HAS BEEN SELF-SUFFICIENT WITH FOOD. NOW THESE WOMEN'S CHILDREN ARE SUFFERING FROM MALNUTRITION.

the kyoto protocol

Recognising these threats, the signatories to the 1992 UN Framework Convention on Climate Change agreed the Kyoto Protocol in 1997. The 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 one major industrialised nation, the United States, has 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 help 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% for 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.

Negotiators are running out of time, however. Signatory countries agreed a negotiating 'mandate', known as the Bali Action Plan, in December 2007, but they must complete these negotiations with a final agreement on the second Kyoto commitment period by the end of 2009 at the absolute latest. Forward-thinking nations can move ahead of the game by implementing strong domestic targets now, building the industry and skills bases that will deliver the transition to a low-carbon society, and thereby provide a strong platform from which to negotiate the second commitment period.

"we have to fully acknowledge the significance and urgency of climate change."

HU JINTAO
PRESIDENT OF CHINA

image OFF SHORE WINDFARM, MIDDELGRUNDEN, COPENHAGEN, DENMARK.

international energy policy

At present, renewable energy generators have to compete with old nuclear and fossil fuel 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 for renewable energy technologies to compete.

At a time when governments around the world are in the process of liberalising their electricity markets, the increasing competitiveness of renewable energy should lead to higher demand. Without political support, however, renewable energy remains at a disadvantage, marginalised by distortions in the world's electricity markets created by decades of massive financial, political and structural support to conventional technologies. Developing renewables will therefore require strong political and economic efforts, especially through laws that guarantee stable tariffs over a period of up to 20 years. Renewable energy will also contribute to sustainable economic growth, high quality jobs, technology development, global competitiveness and industrial and research leadership.

renewable energy targets

In recent years, in order to reduce greenhouse emissions as well as increase energy security, a growing 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. These targets have served as important catalysts for increasing the share of renewable energy throughout the world.

A time period of just a few years is not long enough in the electricity sector, however, 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 feed-in tariffs for renewable electricity generation. 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 be complemented by policies that develop the skills and manufacturing bases to deliver the agreed quantity of renewable energy.

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

demands for the energy sector

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

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

Conventional energy sources receive an estimated $250-300 billion[4] in subsidies per year worldwide, resulting in heavily distorted markets. Subsidies artificially reduce the price of power, keep renewable energy out of the market place and prop up non-competitive technologies and fuels. Eliminating direct and indirect subsidies to fossil fuels and nuclear power would help move us towards a level playing field across the energy sector. Renewable energy would not need special provisions if markets factored in the cost of climate damage from greenhouse gas pollution. Subsidies to polluting technologies are perverse in that they are economically as well as environmentally detrimental. Removing subsidies from conventional electricity would not only save taxpayers' money. It would also dramatically reduce the need for renewable energy support.

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1 SOLAR GENERATION, SEPTEMBER 2007
2 CONCENTRATED SOLAR POWER –NOW! NOVEMBER 2005
3 GLOBAL WIND ENERGY OUTLOOK, OCTOBER 2008
4 'WORLD ENERGY ASSESSMENT: ENERGY AND THE CHALLENGE OF SUSTAINABILITY', UNITED NATIONS DEVELOPMENT PROGRAMME, 2000

implementing the energy [r]evolution

GLOBAL

BANKABLE SUPPORT SCHEMES
LEARNING FROM EXPERIENCE
FIXED FEED-IN TARIFFS
EMISSIONS TRADING
THE FFET FUND

2

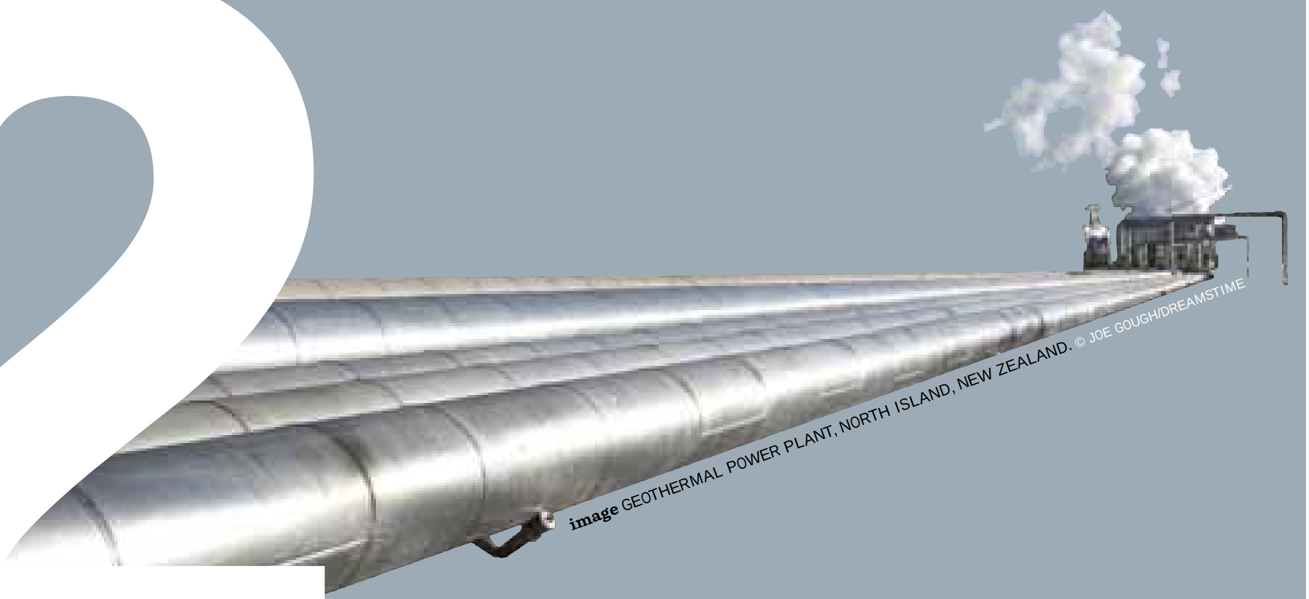


image GEOTHERMAL POWER PLANT, NORTH ISLAND, NEW ZEALAND. © JOE GOUGH/DREAMSTIME

"bridging the gap."

GREENPEACE INTERNATIONAL
CLIMATE CAMPAIGN

This chapter outlines a Greenpeace proposal for a feed-in tariff system in developing countries financed by emissions trading from OECD countries.

The Energy [R]evolution Scenario shows that renewable electricity generation has huge environmental and economic benefits. However its generation costs, especially in developing countries, will remain higher than those of existing coal or gas-fired power stations for the next five to ten years. To bridge this gap between conventional fossil fuel-based power generation and renewables, a support mechanism is needed.

The Feed in Tariff Fund Emissions Trading model (FFET) is a concept conceived by Greenpeace International[5]. The aim is the expansion of renewable energy in developing countries with financial support from industrialised nations – a mechanism to implement renewable energy technology transfer via future Joint Implementation, Clean Development Mechanism projects or Technology Transfer programmes under the Kyoto Protocol. With the Kyoto countries currently negotiating the second phase of their agreement, covering the period from 2013-2017, the proposed FFET mechanism could be used under all the existing flexible mechanisms, auctioning cap & trade schemes or linked to technology transfer projects.

The thinking behind the FFET in a nutshell is to link the feed-in tariff system, as it has been successfully applied in countries like Germany and Spain, with emissions trading schemes such as the ETS in Europe through already established international funding channels such as development aid banks or the Kyoto Protocol mechanisms.

bankable support schemes

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

Although the organisational form of these tariffs differs from country to country, there are certain clear criteria which emerge as essential for creating a successful renewable energy policy. At the heart of these is a reliable, bankable support scheme for renewable energy projects which provides long term stability and certainty[6]. Bankable support schemes result in lower cost projects because they lower the risk for both investors and equipment suppliers. The cost of wind-powered electricity in Germany is up to 40% cheaper than in the United Kingdom[7], for example, because the support system is more secure and reliable.

For developing countries, feed-in laws would be an ideal mechanism for the implementation of new renewable energies. The extra costs, however, which are usually covered in Europe, for example, by a very minor increase in the overall electricity price for consumers, are still seen as an obstacle. In order to enable technology transfer from Annex 1 countries to developing countries, a mix of a feed-in law, international finance and emissions trading could be used to establish a locally based renewable energy infrastructure and industry with the assistance of OECD countries.

learning from experience

The FFET program brings together three different support mechanisms and builds on the experience from 20 years of renewable energy support programmes.

experience of feed-in tariffs

- Feed-in tariffs are seen as the best way forward and very popular, especially in developing countries.
- The main argument against them is the increase in electricity prices for households and industry, as the extra costs are shared across all customers. This is particularly difficult for developing countries, where many people can't afford to spend more money for electricity services.

experience of emissions trading Emissions trading (between countries which need to make emissions reductions and countries where renewable energy projects can be more easily or cheaply implemented) already plays a role in achieving CO_2 reductions under the Kyoto Protocol. The experience so far is that:

- The CO_2 market is unstable, with the price per tonne varying significantly.
- The market is still a 'virtual' market, with only limited actual flow of money.
- Putting a price on CO_2 emissions makes fossil fuelled power more expensive, but due to the unstable and fluctuating prices it will not help to make renewable energy projects more economic within the foreseeable future.
- Most systems are not yet delivering real cuts in emissions.

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

combining existing programmes

The basic aims of the Feed-in Tariff Fund Emissions Trading scheme are to facilitate the implementation of feed-in laws for developing countries, to use existing emissions trading schemes to link CO_2 prices directly with the uptake of renewable energy, and to use the existing infrastructure,of international financial institutions to secure investment for projects and lower the risk factor. The FFET concept will have three parts – fixed feed-in tariffs, emissions trading and a funding arrangement.

references
5 IMPLEMENTING THE ENERGY [R]EVOLUTION, OCTOBER 2008, SVEN TESKE, GREENPEACE INTERNATIONAL
6 'THE SUPPORT OF ELECTRICITY FROM RENEWABLE ENERGY SOURCES', EUROPEAN COMMISSION, 2005
7 SEE ABOVE REPORT, P. 27, FIGURE 4

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

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

© GP/RODRIGO BALÉIA

© GP/COBBING

1. fixed feed-in tariffs

Feed-in tariffs will provide bankable and long term stable support for the development of a local renewable energy market in developing countries. The tariffs should bridge the gap between conventional power generation costs and those of renewable energy generation.

The key parameters for feed-in tariffs under FFET are:

- Variable tariffs for different renewable energy technologies, depending on their costs and technology maturity, paid for 20 years.
- Payments based on actual generation in order to achieve properly maintained projects with high performance ratios.
- Any additional finance required over the (20 year) period will be secured through a public fund, which could generate some capital income, for example via interest rates, from a soft loan programme to finance renewable energy projects (see below).
- Payment of the 'additional costs' for renewable generation will be based on the Spanish system of the wholesale electricity price plus a fixed premium.

A developing country which wants to apply for funding to operate renewable energy projects under the FFET scheme will need to establish clear regulations for the following:

- Guaranteed access to the electricity grid for renewable electricity projects.
- Establishment of a feed-in law based on successful examples.
- Transparent access to all data needed to establish the feed-in tariff, including full records of generated electricity.
- Clear planning and licencing procedures.

2. emissions trading

The traded CO_2 emissions will come from OECD countries on top of any commitment under their national emission reduction targets. Every tonne of CO_2 will be connected to a specific amount of electricity form renewable energy. A simple approach would be to use a factor of 1kg CO_2 for 1 kWh of renewable electricity, which equals the amount of avoided CO_2 emissions from an older coal power plant. A more complex method would be to use the average CO_2 emissions per kilowatt-hour in the specific country or the world's average, which is currently 0.6kg CO_2/kWh. The Energy [R]evolution Scenario shows that the average additional costs (under the proposed energy mix) between 2008 and 2015 are between 1 and 4 cents per kilowatt-hour so the price per tonne of CO_2 would be between €10 and €40.

The key parameters for emissions trading under FFET will be:

- 1 tonne CO_2 = 1,000 kWh renewable electricity (emissions factor: 1kg CO_2/kWh)
- 1 tonne CO_2 represents a 20 year 'package' of renewable electricity (1,000 kWh = 20 years x annual 50 kWh renewable electricity production)

3. the FFET fund

The FFET fund will act as a buffer between fluctuating CO_2 emissions prices and stable long term feed-in tariffs. The fund will secure the payment of the required feed-in tariffs during the whole period (about 20 years) for each project. This fund could be managed by intrernational financial institutions operating in Europe and Central Asia or by Multilateral Development Banks. In order to provide access to finance for small-scale businesses, a co-operation with a local bank with a local presence in villages or cities would be desirable.

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

The key parameters for the FFET fund will be:

- The fund will guarantee the payment of the total feed-in tariffs over a period of 20 years if the project is operated properly.
- The fund will receive annual income from emissions trading under FFET.
- The fund can provide soft loans to finance renewable energy projects.
- The fund will generate income from interest rates only.
- The fund will pay feed-in tariffs annually only on the basis of generated electricity.
- The operator of a FFET project is required to transmit all relevant data about generation to a central database. This database will also be used to evaluate the performance of the project.
- Every FFET project must have a professional maintenance company to ensure high availability.
- The grid operator must do its own monitoring and send generation data to the FFET fund. Data from the project and grid operators will be compared regularly to check consistency.

figure 2.1: ffet scheme

FFET
roles and responsibilities

developing country:

Legislation:
- feed-in law
- guaranteed grid access
- licensing

(inter-) national finance institute(s)

Organising and Monitoring:
- organize financial flow
- monitoring
- providing soft loans
- guarantee the payment of the feed-in tariff

OECD country

Legislation:
- CO_2 credits under CDM
- tax from Cap & Trade
- auctioning CO_2 Certificates

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

nuclear power and climate protection

GLOBAL

NUCLEAR PROLIFERATION
NUCLEAR WASTE
SAFETY RISKS

3

image SIGN ON A RUSTY DOOR AT CHERNOBYL ATOMIC STATION.

"safety and security risks, radioactive waste, nuclear proliferation..."

GREENPEACE INTERNATIONAL
CLIMATE CAMPAIGN

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.

Nuclear energy is a relatively small industry with big problems. It covers just one sixteenth of the world's primary energy consumption, a share set to decline over the coming decades. The average age of operating commercial nuclear reactors is 23 years, so more power stations are being shut down than started. In 2007, world nuclear production fell by 1.8 % and the number of operating reactors was 439, five less than the historical peak of 2002.

In terms of new power stations, the amount of nuclear capacity added annually between 2000 and 2007 was 2,500 MWe on average. This was six times less than wind power (13,300 MWe per annum between 2000 and 2007). In 2007, newly constructed renewable energy power plants in Germany generated 13 TWh of electricity – as much as two large nuclear units.

Despite the rhetoric of a 'nuclear renaissance', the industry is struggling with a massive increase in costs and construction delays as well as safety and security problems linked to reactor operation, radioactive waste and nuclear proliferation.

a solution to climate protection?

The promise of nuclear energy to contribute to both climate protection and energy supply needs to be checked against reality. In the most recent Energy Technology Perspectives report published by the International Energy Agency[8], for example, its Blue Map scenario outlines a future energy mix which would halve global carbon emissions by the middle of this century. To reach this goal the IEA assumes a massive expansion of nuclear power between now and 2050, with installed capacity increasing four-fold and electricity generation reaching 9,857 TWh/year, compared to 2,608 TWh in 2007. In order to achieve this, the report says that 32 large reactors (1,000 MWe) would have to be built every year from now until 2050. This would be unrealistic, expensive, hazardous and too late to make a difference.

unrealistic: Such a rapid growth is practically impossible given the technical limitations. This scale of development was achieved in the history of nuclear power for only two years at the peak of the state-driven boom of the mid-1980s. It is unlikely to be achieved again, not to mention maintained for 40 consecutive years. While 1984 and 1985 saw 31 GW of newly added nuclear capacity, the decade average was 17 GW annually. In the past ten years, only three large reactors have been brought on line each year, and the current production capacity of the global nuclear industry cannot deliver more than an annual six units.

expensive: The IEA scenario assumes very optimistic investment costs of $2,100/kWe installed, in line with what the industry has been recently promising. The reality indicates three times that much. Recent estimates by US business analysts Moody's (June 2008) put the cost of nuclear investment as high as $7,000/kWe. Price quotes for projects under preparation in the US cover a range from $5,200 to 8,000/kWe[9]. The latest cost estimate for the first French EPR pressurised water reactor being built in Finland is $5,200/kWe, a figure likely to increase for later reactors as prices escalate. The Wall Street Journal has reported that the cost index for nuclear components has risen by 173 % since 2000 – a near tripling over the past eight years[10]. Building 1,400 large reactors (1,000 MWe), even at the current cost of about $7,000/kWe, would require an investment of US$9.8 trillion.

hazardous: Massive expansion of nuclear energy would necessarily lead to a large increase in related hazards, such as serious reactor accidents, growing stockpiles of deadly high level nuclear waste which will need to be safeguarded for thousands of years and potential proliferation of both nuclear technologies and materials that can be diverted to military or terrorist use. The 1,400 large operating reactors in 2050 would generate an annual 35,000 tons of spent fuel (assuming they are light water reactors, the most common design for most new projects). This also means the production of 350,000 kilograms of plutonium each year, enough to build 35,000 crude nuclear weapons.

Most of the expected electricity demand growth by 2050 will occur in non-OECD countries. This means that a large proportion of the new reactors would need to be built in those countries in order to have a global impact on emissions. At the moment, the list of countries with announced nuclear ambitions is long and worrying in terms of their political situation and stability, especially with the need to guarantee against the hazards of accidents and proliferation for many decades. The World Nuclear Association listed the Emerging Nuclear Energy Countries in May 2008 as Albania, Belarus, Italy, Portugal, Turkey, Norway, Poland, Estonia, Latvia, Ireland, Iran, the Gulf states, Yemen, Israel, Syria, Jordan, Egypt, Tunisia, Libya, Algeria, Morocco, Azerbaijan, Georgia, Kazakhstan, Mongolia, Bangladesh, Indonesia, Philippines, Vietnam, Thailand, Malaysia, Australia, New Zealand, Chile, Venezuela, Nigeria, Ghana and Namibia.

slow: Climate science says that we need to reach a peak of global greenhouse gas emissions in 2015 and reduce them by 20 % in 2020. Even in developed countries with an established nuclear infrastructure it takes at least a decade from the decision to build a reactor to the delivery of its first electricity, and often much longer. Out of 35 reactors officially listed as under construction by the IEA in mid-July 2008, one third had been in this category for two decades or more, indicating that these projects are not progressing. This means that even if the world's governments decided to implement strong nuclear expansion now, only a few reactors would start generating electricity before 2020. The contribution from nuclear power towards reducing emissions would come too late to help.

references
8 'ENERGY TECHNOLOGY PERSPECTIVES 2008- SCENARIOS & STRATEGIES TO 2050', IEA
9 PLATTS, 2008; ENERGY BIZ, MAY/JUNE 2008
10 WALL STREET JOURNAL, 29 MAY 2008

image NUCLEAR REACTOR IN LIANYUNGANG, CHINA.

image CHERNOBYL NUCLEAR POWER STATION, UKRAINE.

nuclear power blocks solutions

Even if the ambitious nuclear scenario is implemented, regardless of costs and hazards, the IEA concludes that the contribution of nuclear power to reductions in greenhouse gas emissions from the energy sector would be only 4.6 % - less than 3 % of the global overall reduction required.

There are other technologies that can deliver much larger emission reductions, and much faster. Their investment costs are lower and they do not create global security risks. Even the IEA finds that the combined potential of efficiency savings and renewable energy to cut emissions by 2050 is more than ten times larger than that of nuclear.

The world has limited time, finance and industrial capacity to change our energy sector and achieve a large reduction in greenhouse emissions. Choosing the pathway by spending $10 trillion on nuclear development would be a fatally wrong decision. It would not save the climate but it would necessarily take resources away from solutions described in this report and at the same time create serious global security hazards. Therefore new nuclear reactors are a clearly dangerous obstacle to the protection of the climate.

nuclear power in the energy [r]evolution scenario

For the reasons explained above, the Energy [R]evolution Scenario envisages a nuclear phase-out. Existing reactors would be closed at the end of their average operational lifetime of 35 years. We assume that no new construction is started after 2008 and only two thirds of the reactors currently under construction will be finally put into operation.

the dangers of nuclear power

Although the generation of electricity through nuclear power produces much less carbon dioxide than fossil fuels, there are multiple threats to people and the environment from its operations. The main risks are:

- Nuclear Proliferation
- Nuclear Waste
- Safety Risks

These are the background to why nuclear power has been discounted as a future technology in the Energy [R]evolution Scenario.

1. 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 all 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[11].”

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"[12]. 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.

references
11 MOHAMED ELBARADEI, ‘TOWARDS A SAFER WORLD’, ECONOMIST, 18 OCTOBER 2003
12 IPCC WORKING GROUP II, ‘IMPACTS, ADAPTATIONS AND MITIGATION OF CLIMATE CHANGE: SCIENTIFIC-TECHNICAL ANALYSES’, 1995

2. 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. It points to nuclear dumping proposals in Finland, Sweden or the United States to underline its argument.

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[13]. No country in the world has a solution for high level waste.

The IAEA recognises that, despite its international safety requirements, "…radiation doses to individuals in the future can only be estimated and that the uncertainties associated with these estimates will increase for times farther into the future."

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.

3. 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 simple power failure at a Swedish nuclear plant in 2006 highlighted our vulnerability to nuclear catastrophe. Emergency power systems at the Forsmark plant failed for 20 minutes during a power cut and four of Sweden's 10 nuclear power stations had to be shut down. If power was not restored there could have been a major incident within hours. A former director of the Forsmark 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.

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.

"… reactors with gravity fed emergency cooling water and air cooling can make them more vulnerable to terrorist attacks."

references

13 REFERENCE: WASTE MANAGEMENT IN THE NUCLEAR FUEL CYCLE, WORLD NUCLEAR ASSOCIATION, INFORMATION AND ISSUE BRIEF, FEBRUARY 2006. HTTP://WWW.WORLD-NUCLEAR.ORG/INFO/INF04.HTM

image FISHERMEN IN FRONT OF THE MIHAMA NUCLEAR POWER PLANT, JAPAN AFTER AN ACCIDENT AT THE PLANT IN 1991.

figure 3.1: **the nuclear fuel cycle**

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 is rejected 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.

4

DECOUPLE GROWTH FROM FOSSIL FUEL USE. © G. POROPAT/DREAMSTIME

"half the solution to climate change is the smart use of power."

GREENPEACE INTERNATIONAL
CLIMATE CAMPAIGN

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

The climate change imperative demands nothing short of an energy revolution. The expert consensus is that this fundamental change must begin very soon and be well underway within the next ten years in order to avert the worst impacts. What we need is a complete transformation in the way we produce, consume and distribute energy and at the same time maintain economic growth. Nothing short of such a revolution will enable us to limit global warming to less than a rise in temperature of 2°C, 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 there therefore needs to be a change in the way that energy is both produced and distributed.

key principles

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

1. **respect natural limits – phase out fossil fuels by the end of this century** We must learn to respect natural limits. There is only so much carbon that the atmosphere can absorb. Each year we emit over 25 billion tonnes of carbon equivalent; we are literally filling up the sky. Geological resources of coal could provide several hundred years of fuel, but we cannot burn them and keep within safe limits. Oil and coal development must be ended.

   The Energy [R]evolution Scenario has a target to reduce energy related CO_2 emissions to a maximum of 10 Gt (Giga tonnes) by 2050 and phase out fossil fuels by 2085.

2. **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 wellbeing.

   The Energy [R]evolution Scenario has a target to achieve energy equity as soon as technically possible. By 2050 the average per capita emission should be between 1 and 2 tonnes of CO_2.

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

   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.

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

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

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

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

5. **phase out dirty, unsustainable energy** 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.

from principles to practice

In 2005, renewable energy sources accounted for 13% of the world's primary energy demand. Biomass, which is mostly used for heating, is the main renewable energy source. The share of renewable energy in electricity generation was 18%. The contribution of renewables to primary energy demand for heat supply was around 24%. About 80% of primary energy supply today still comes from fossil fuels, and 6% from nuclear power[14].

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.

references
14 'ENERGY BALANCE OF NON-OECD COUNTRIES' AND 'ENERGY BALANCE OF OECD COUNTRIES', IEA, 2007

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 cogeneration – on a large scale and through decentralised, smaller units – have to grow faster than overall global energy demand. Both approaches must replace old generating technologies and deliver the additional energy required in the developing world.

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, and able to drive cost-effective decentralisation of the energy infrastructure. With warmer summers, tri-generation, which incorporates heat-fired absorption chillers to deliver cooling capacity in addition to heat and power, will become a particularly valuable means to achieve emissions reductions.

a development pathway

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

step 1: energy efficiency The Energy [R]evolution is aimed at the ambitious exploitation of the potential for energy efficiency. It focuses on current best practice and technologies which will become available in the future, assuming continuous innovation. The energy savings are fairly equally distributed over the three sectors – industry, transport and domestic/business. Intelligent use, not abstinence, is the basic philosophy 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 industrialised countries towards a fairer worldwide distribution of efficiently used supply.

A dramatic reduction in primary energy demand compared to the IEA's "Reference Scenario" (see Chapter 6) – 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, for example heat pumps, solar thermal panels or 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 proportion 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% annually 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. Expected growth of electricity use in transport will further promote the effective use of renewable power generation technologies.

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

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

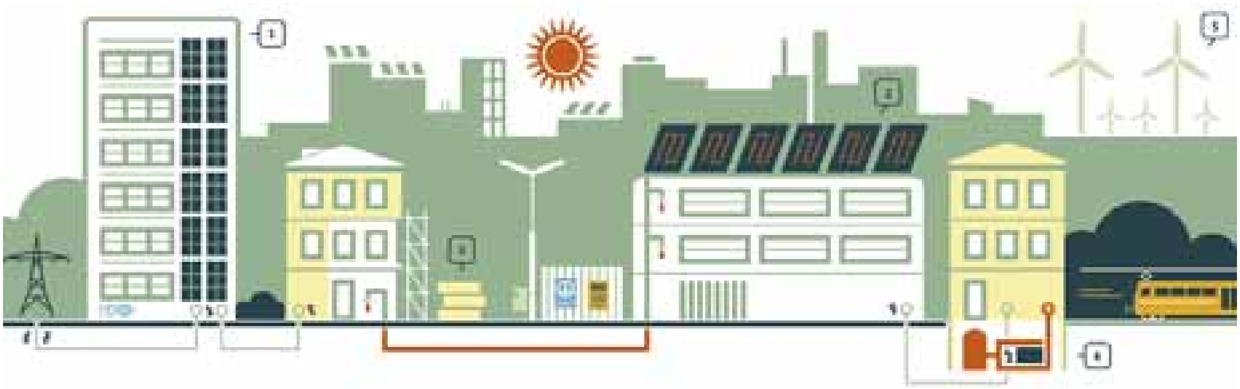
transport Before new technologies such as hybrid or electric cars or new fuels such as bio fuels can play a substantial role in the transport sector, the existing large efficiency potentials have to be exploited. In this study, biomass is primarily committed to stationary applications; the use of bio fuels for transport is limited by the availability of sustainably grown biomass[15]. Electric vehicles will therefore play an even more important role in improving energy efficiency in transport and substituting for fossil fuels.

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

figure 4.1: a decentralised energy future

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

city



1. PHOTOVOLTAIC, SOLAR 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.

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references
15 SEE CHAPTER 13

figure 4.2: 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

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. At certain times, 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 operating 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.

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.

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

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 by the use of 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 become considerably more accurate in recent years and are still being improved. The demand for balancing supply will therefore decrease in the future.

the "virtual power station" [16]

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 station 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 available 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.

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

references
16 'RENEWABLE ENERGIES - INNOVATIONS FOR THE FUTURE', GERMAN MINISTRY FOR THE ENVIRONMENT, NATURE CONSERVATION AND NUCLEAR SAFETY (BMU), 2006

future power grids

The **power grid network** must also change in order to realise decentralised structures with a high share of renewable energy. Today's grids are designed to transport power from a few centralised power stations out to the passive consumers. A future system must enable an active integration of consumers and decentralised power generators and thus realise real time two-way power and information flows. 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 (see box), a limited number of new high voltage transmission lines will 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 10% of total electricity generation by 2020 and about 35% by 2050.

case 1: a north sea electricity grid

A new Greenpeace report shows how a regionally integrated approach to the large-scale development of offshore wind in the North Sea could deliver reliable clean energy for millions of homes. The 'North Sea Electricity Grid [R]evolution' report (September 2008) calls for the creation of an offshore network to enable the smooth flow of electricity generated from renewable energy sources into the power systems of seven different countries - the United Kingdom, France, Germany, Belgium, The Netherlands, Denmark and Norway – at the same time enabling significant emissions savings. The cost of developing the grid is expected to be between €15 and 20 billion. This investment would not only allow the broad integration of renewable energy but also unlock unprecedented power trading opportunities and cost efficiency. In a recent example, a new 600 kilometre-long power line between Norway and the Netherlands cost €600 million to build, but is already generating a daily cross-border trade valued at €800,000.

The grid would enable the efficient integration of renewable energy into the power system across the whole North Sea region. By aggregating power generation from wind farms spread across the whole area, periods of very low or very high power flows would be reduced to a negligible amount. A dip in wind power generation in one area would be 'balanced' by higher production in another area, even hundreds of kilometres away. Over a year, an installed offshore wind power capacity of 68.4 GW in the North Sea would be able to generate an estimated 247 TWh of electricity.

An offshore grid in the North Sea would also allow, for example, the import of electricity from hydro power generation in Norway to the British and UCTE (Central European) network. This could replace thermal baseload plants and increase flexibility within a portfolio. In addition, increased liquidity and trading facilities on the European power markets will allow for a more efficient portfolio management. The value of such an offshore therefore lies in its contribution to increased security of supply, its function in aggregating the dispatch of power from offshore wind farms and its role as a facilitator for power exchange and trade between regions and power systems.

"a future system must enable an active integration of consumers and decentralised power generators..."

image OFFSHORE WINDFARM, MIDDELGRUNDEN, COPENHAGEN, DENMARK.

image CONSTRUCTION OF WIND TURBINES.

figure 4.3: offshore grid topology proposal and offshore wind power installed capacity scenario

* MAP IS INDICATIVE. NO ENVIRONMENTAL IMPACT ASSESSMENT OF LOCATIONS AND SITING OF WINDFARMS AND CABLES HAS BEEN DONE.

Wind energy is booming in the EU. In 2007 alone, no less than 8550MW of wind turbines were installed in the EU, which is 40% of all newly-installed capacity. By 2020–2030, offshore wind energy in the North Sea could grow to 68,000MW and supply 13 per cent of all current electricity production of seven North Sea countries. In order to integrate the electricity from the offshore wind farms, an offshore grid will be required. Greenpeace demands that the governments of these seven countries and the European Commission cooperate to make this happen.

INSTALLED AND PLANNED CAPACITY [MW]

	[MW]	[TWh]
BELGIUM	3,850	13.1
DENMARK	1,580	5.6
FRANCE	1,000	3.4
GERMANY	26,420	97.5
UNITED KINGDOM	22,240	80.8
NETHERLANDS	12,040	41.7
NORWAY	1,290	4.9
TOTAL	68,420	247

LEGEND

- **GRID:** PROPOSED OR DISCUSSED IN THE PUBLIC DOMAIN
- **GRID:** IN OPERATION OR PLANNING
- **PRINCIPLE HVDC SUBSTATIONS**
- **WIND FARMS:** INSTALLED PLANNED CAPACITY < 1000 MW
- **WIND FARMS:** INSTALLED PLANNED CAPACITY > 1000 MW

rural electrification[17]

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 adequate 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.

references
17 'SUSTAINABLE ENERGY FOR POVERTY REDUCTION: AN ACTION PLAN', IT POWER/GREENPEACE INTERNATIONAL, 2002

scenario principles in a nutshell

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

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

scenarios for a future energy supply

GLOBAL

5

image WIND TURBINE IN SAMUT SAKHON, THAILAND. © GP/VINAI DITHAJOHN

"towards a sustainable global energy supply system."

GREENPEACE INTERNATIONAL
CLIMATE CAMPAIGN

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 2007 (WEO 2007)[18]. This only takes existing international energy and environmental policies into account. The assumptions include, for example, continuing progress in electricity and gas market reforms, the liberalisation of cross-border energy trade and recent policies designed to combat environmental pollution. The Reference Scenario does not include additional policies to reduce greenhouse gas emissions. As the IEA's scenario only covers a time horizon up to 2030, it has been extended by extrapolating its key macroeconomic indicators. This provides a baseline for comparison with the Energy [R]evolution Scenario.

The **energy [r]evolution scenario** has a key target for the reduction of worldwide carbon dioxide emissions down to a level of around 10 Gigatonnes per year by 2050 in order for the increase in global temperature to remain under +2°C. A second objective is the global phasing out of nuclear energy. To achieve these targets, the scenario is characterised by significant efforts to fully exploit the large potential for energy efficiency. At the same time, all cost-effective renewable energy sources are used for heat and electricity generation as well as the production of bio fuels. The general framework parameters for population and GDP growth remain unchanged from the Reference Scenario.

These scenarios by no means claim to predict the future; they simply describe two potential development paths out of the broad range of possible 'futures'. The Energy [R]evolution Scenario is designed to indicate the efforts and actions required to achieve its ambitious objectives and to illustrate the options we have at hand to change our energy supply system into one that is sustainable.

scenario background The scenarios in this report were jointly commissioned by Greenpeace and the European Renewable Energy Council from the Institute of Technical Thermodynamics, part of the German Aerospace Center (DLR). The supply scenarios were calculated using the MESAP/PlaNet simulation model used for the previous Energy [R]evolution study[19]. Energy demand projections were developed by Ecofys Netherlands, based on an analysis of the future potential for energy efficiency measures. The biomass potential, using Greenpeace sustainability criteria, has been developed especially for this scenario by the German Biomass Research Centre. The future development pathway for car technologies is based on a special report produced in 2008 by the Institute of Vehicle Concepts, DLR for Greenpeace International.

energy efficiency study

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

Under the low energy demand scenario, worldwide final energy demand is reduced by 38% in 2050 in comparison to the Reference Scenario, resulting in a final energy demand of 350 EJ (ExaJoules). 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. Chapter 11 provides more details about this study.

"moving from principles to action.."

references
18 INTERNATIONAL ENERGY AGENCY, 'WORLD ENERGY OUTLOOK 2007', 2007
19 'ENERGY [R]EVOLUTION: A SUSTAINABLE WORLD ENERGY OUTLOOK', GREENPEACE INTERNATIONAL, 2007

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

the future for cars

The Institute of Vehicle Concepts in Stuttgart, Germany has developed a global scenario for cars covering ten world regions. The aim was to produce a demanding but feasible scenario to lower global car CO_2 emissions within the context of the overall objectives of this report. The approach takes into account a vast range of technical measures to reduce the energy consumption of vehicles, but also considers the dramatic increase in vehicle ownership and annual mileage taking place in developing countries. The major parameters are vehicle technology, alternative fuels, changes in sales of different vehicle sizes (segment split) and changes in vehicle kilometres travelled (modal split).

The scenario assumes that a large share of renewable electricity will be available in the future. A combination of ambitious efforts towards higher efficiency in vehicle technologies, a major switch to grid-connected electric vehicles and incentives for vehicle users to save carbon dioxide lead to the conclusion that it is possible to reduce CO_2 emissions from 'well-to-wheel' in 2050 by roughly 25%[20] compared to 1990 and 40% compared to 2005.

By 2050, 60% of the final energy used in transport will still come from fossil sources, mainly gasoline and diesel. Renewable electricity will cover 25%, bio fuels 13% and hydrogen 2%. Total energy consumption in 2050 will be similar to the consumption in 2005, however, in spite of enormous increases in fuel use in some regions of the world.

The peak in global CO_2 emissions from transport occurs between 2010 and 2015. From 2010 onwards, new legislation in the US and Europe will contribute to breaking the upwards trend in emissions. From 2020, the effect of introducing grid-connected electric cars can be clearly seen. Chapter 13 provides more details about this report.

the global potential for sustainable bio energy

As part of the Energy [R]evolution Scenario, Greenpeace commissioned the German Biomass Research Centre (the former Institute for Energy and Environment) to look at the worldwide potential for energy crops up to 2050. A summary of this report can be found in Chapter 8.

references

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

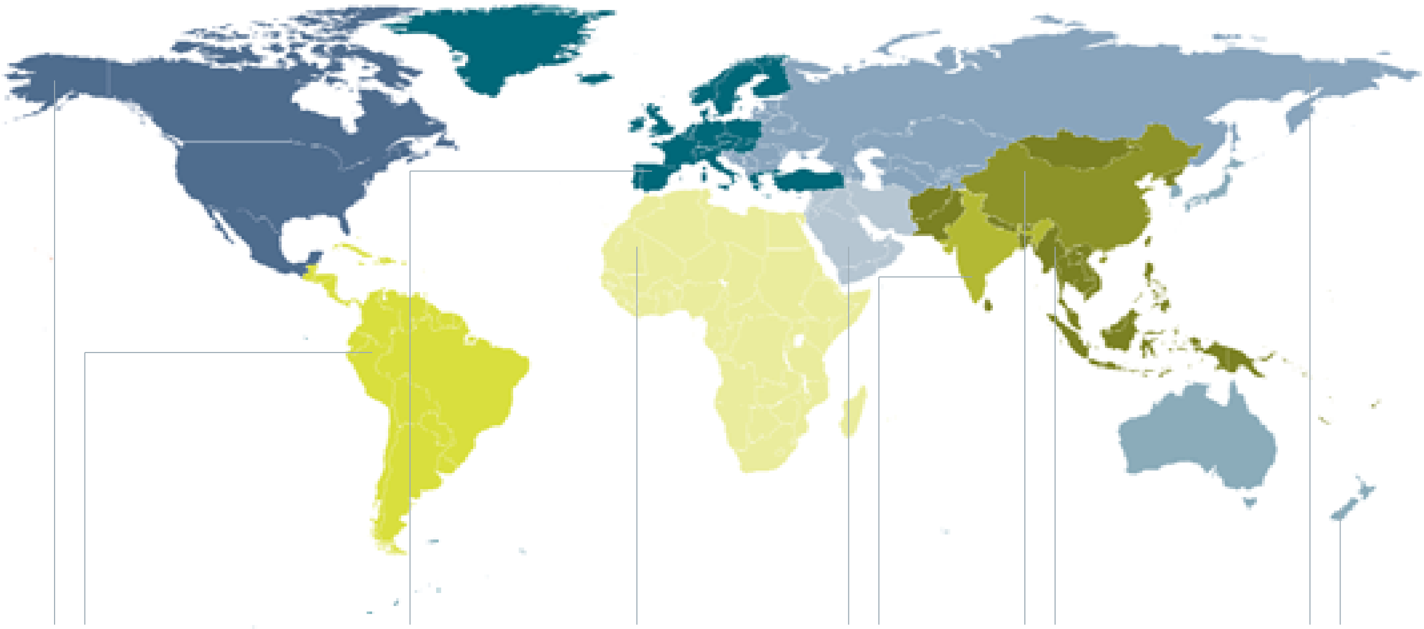
image GREENPEACE DONATES A SOLAR POWER SYSTEM TO A COASTAL VILLAGE IN ACEH, INDONESIA, ONE OF THE WORST HIT AREAS BY THE TSUNAMI IN DECEMBER 2004.

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 Agency 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[21].

The previous Energy [R]evolution Scenario used three regions to cover Asia: East Asia, South Asia and China. In line with WEO 2007, this new edition maintains the three region approach, but assesses China and India separately and aggregates the remaining Non-OECD countries in Asia under 'Developing Asia'. The loss of comparability with the previous study is outweighed by the ability to compare the new results with current IEA reports and still provides a reasonable analysis of Asia in terms of population and economic development. The definitions of the world regions are shown in Figure 5.1.

figure 5.1: definition of world regions
WEO 2007



oecd north america

Canada, Mexico, United States

latin america

Antigua and Barbuda, Argentina, Bahamas, Barbados, Belize, Bermuda, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Dominica, Dominican Republic, Ecuador, El Salvador, French Guiana, Grenada, Guadeloupe, Guatemala, Guyana, Haiti, Honduras, Jamaica, Martinique, Netherlands Antilles, Nicaragua, Panama, Paraguay, Peru, St. Kitts-Nevis-Anguila, Saint Lucia, St. Vincent and Grenadines, 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, Comoros, 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, Malawi, Mali, Mauritania, Mauritius, Morocco, Mozambique, Namibia, Niger, Nigeria, Reunion, 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

india

India

china

People's Republic of China including Hong Kong

developing asia

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

transition economies

Albania, Armenia, Azerbaijan, Belarus, Bosnia-Herzegovina, Bulgaria, Croatia, Estonia, Serbia and Montenegro, the former Republic of Macedonia, Georgia, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Moldova, Romania, Russia, Slovenia, Tajikistan, Turkmenistan, Ukraine, Uzbekistan, Cyprus* , Malta*

oecd pacific

Australia, Japan, Korea (South), New Zealand

* CYPRUS AND MALTA ARE ALLOCATED TO THE TRANSITION ECONOMIES FOR STATISTICAL REASONS

image GROUP OF YOUNG PEOPLE TOUCHING SOLAR PANELS IN BRAZIL.

1. population development

One important underlying factor in energy scenario building is future population development. Population growth affects the size and composition of energy demand, directly and through its impact on economic growth and development. World Energy Outlook 2007 uses the United Nations Development Programme (UNDP) projections for population development. For this study the most recent population projections from UNDP up to 2050 are applied[22].

Table 5.1 summarises this study's assumptions on world population development. The world's population is expected to grow by 0.77 % on average over the period 2005 to 2050, from 6.5 billion people in 2005 to more than 9.1 billion in 2050. Population growth will slow over the projection period, from 1.2% during 2005-2010 to 0.4% during 2040-2050. However, the updated projections show an increase in population of almost 300 million compared to the previous edition. This will further increase the demand for energy. The population of the developing regions will continue to grow most rapidly. The Transition Economies will face a continuous decline, followed after a short while by the OECD Pacific countries. OECD Europe and OECD North America are expected to maintain their population, with a peak in around 2020/2030 and a slight decline afterwards. The share of the population living in today's Non-OECD countries will increase from the current 82% to 86% in 2050. China's contribution to world population will drop from 20% today to 15% in 2050. Africa will remain the region with the highest growth rate, leading to a share of 21% of world population in 2050.

Satisfying the energy needs of a growing population in the developing regions of the world in an environmentally friendly manner is a key challenge for achieving a global sustainable energy supply.

2. economic growth

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

Although PPP assessments are still relatively imprecise compared to statistics based on national income and product trade and national price indexes, they are considered to provide a better basis for global scenario development.[23] Thus all data on economic development in WEO 2007 refers to purchasing power adjusted GDP. However, as WEO 2007 only covers the time period up to 2030, the projections for 2030-2050 are based on our own estimates.

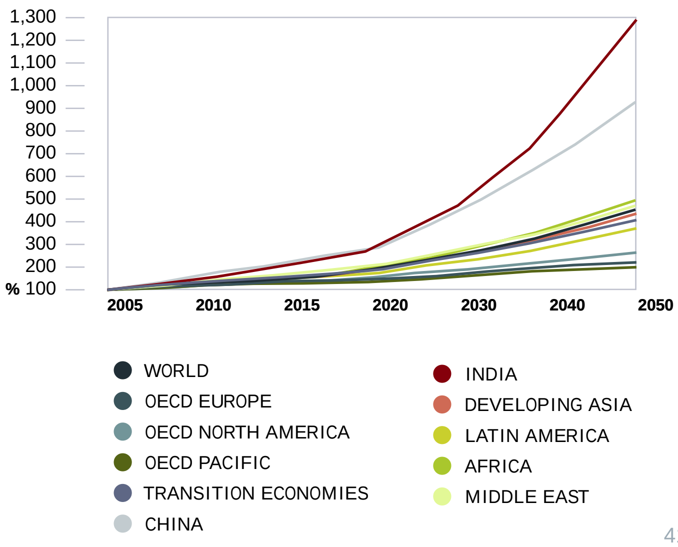
Prospects for GDP growth have increased considerably compared to the previous study, whilst underlying growth trends continue much the same. GDP growth in all regions is expected to slow gradually over the coming decades. World GDP is assumed to grow on average by 3.6% per year over the period 2005-2030,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

table 5.1: GDP development projections
(AVERAGE ANNUAL GROWTH RATES)

REGION World	2005 - 2010	2010 - 2020	2020 - 2030	2030 - 2040	2040 - 2050	**2005 - 2050**
OECD Europe	4.6%	3.6%	3.2%	3.0%	2.9%	**3.3%**
OECD North America	2.6%	2.1%	1.7%	1.3%	1.1%	**1.7%**
OECD Pacific	2.7%	2.4%	2.2%	2.0%	1.8%	**2.2%**
Transition Economies	2.5%	1.8%	1.5%	1.3%	1.2%	**1.6%**
India	5.6%	3.6%	2.7%	2.5%	2.4%	**3.1%**
China	8.0%	6.2%	5.7%	5.4%	5.0%	**5.8%**
Developing Asia	9.2%	5.7%	4.7%	4.2%	3.6%	**5.0%**
Latin America	5.1%	3.8%	3.1%	2.7%	2.4%	**3.2%**
Africa	4.3%	3.2%	2.8%	2.6%	2.4%	**2.9%**
Middle East	5.0%	3.9%	3.5%	3.2%	3.0%	**3.6%**
	5.1%	4.2%	3.2%	2.9%	2.6%	**3.4%**

source (2005-2030, IEA 2007; 2030-2050, OWN ASSUMPTIONS)

figure 5.2: relative GDP_{PPP} growth by world regions



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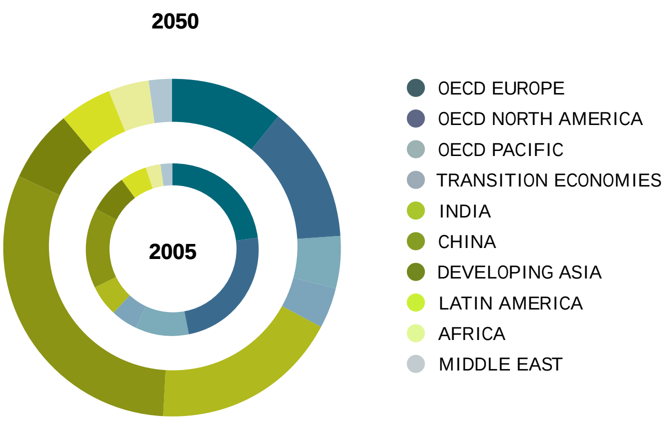
21 'ENERGY BALANCE OF NON-OECD COUNTRIES' AND 'ENERGY BALANCE OF OECD COUNTRIES', IEA, 2007
22 'WORLD POPULATION PROSPECTS: THE 2006 REVISION', UNITED NATIONS, POPULATION DIVISION, DEPARTMENT OF ECONOMIC AND SOCIAL AFFAIRS (UNDP), 2007
23 NORDHAUS, W, 'ALTERNATIVE MEASURES OF OUTPUT IN GLOBAL ECONOMIC-ENVIRONMENTAL MODELS: PURCHASING POWER PARITY OR MARKET EXCHANGE RATES?', REPORT PREPARED FOR IPCC EXPERT MEETING ON EMISSION SCENARIOS, US-EPA WASHINGTON DC, JANUARY 12-14, 2005

figure 5.3: development of world GDP_{PPP} by regions



3. fossil fuel and biomass price projections

The recent dramatic increase in global oil prices has resulted in much higher forward price projections for fossil fuels. Under the 2004 'high oil and gas price' scenario from the European Commission, for example, an oil price of just $34 per barrel was assumed in 2030. More recent projections of oil prices in 2030 range from the IEA's $\$_{2006}$62/bbl ($\$_{2005}$60/bbl) (WEO 2007) up to $\$_{2006}$119/bbl ($\$_{2005}$115/bbl) in the 'high price' scenario of the US Energy Information Administration's Annual Energy Outlook 2008.

Since the last Energy [R]evolution study was published, however, the price of oil has moved over $100/bbl for the first time (at the end of 2007), and in July 2008 reached a record high of more than $140/bbl. Although oil prices fell back to $100/bbl in September 2008, the above projections might still 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 $120/bbl by 2030 and $140/bbl in 2050.

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

4. cost of CO_2 emissions

Assuming that a CO_2 emissions trading system is 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 emissions costs are even more uncertain than energy prices, and available studies span a broad range of future CO_2 cost estimates. As in the previous Energy [R]evolution study we assume CO_2 costs of $10/t$CO_2$ in 2010, rising to $50/t$CO_2$ in 2050. Additional CO_2 costs are applied in Kyoto Protocol Non-Annex B (developing) countries only after 2020.

table 5.3: assumptions on CO_2 emissions cost 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 5.2: assumptions on fuel price development

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

image TRANSPORT POLLUTION.

5. power plant investment costs

fossil fuel technologies and carbon capture and storage (CCS)
While the fossil fuel power technologies in use today for coal, gas, lignite and oil are established and at an advanced stage of market development, further cost reduction potentials are assumed. The potential for cost reductions is limited, however, and will be achieved mainly through an increase in efficiency, bringing down investment costs[24].

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

CCS is a means of trapping CO_2 from fossil fuels, either before or after they are burned, and 'storing' (effectively disposing of) it in the sea or beneath the surface of the Earth. There are currently three different methods of capturing CO_2: 'pre-combustion', 'post-combustion' and 'oxyfuel combustion'. However, development is at a very early stage and CCS will not be implemented - in the best case - before 2020 and will probably not become commercially viable as a possible effective mitigation option until 2030.

Cost estimates for CCS vary considerably, depending on factors such as power station configuration, technology, fuel costs, size of project and location. One thing is certain, however, CCS is expensive. It requires significant funds to construct the power stations and the necessary infrastructure to transport and store carbon. The IPCC assesses costs at $15-75 per ton of captured CO_2[25], while a recent US Department of Energy report found installing carbon capture systems to most modern plants resulted in a near doubling of costs[26]. These costs are estimated to increase the price of electricity in a range from 21-91%[27].

Pipeline networks will also need to be constructed to move CO_2 to storage sites. This is likely to require a considerable outlay of capital[28]. Costs will vary depending on a number of factors, including pipeline length, diameter and manufacture from corrosion-resistant steel, as well as the volume of CO_2 to be transported. Pipelines built near population centres or on difficult terrain, such as marshy or rocky ground, are more expensive[29].

The IPCC estimates a cost range for pipelines of $1-8/ton of CO_2 transported. A United States Congressional Research Services report calculated capital costs for an 11 mile pipeline in the Midwestern region of the US at approximately $6 million. The same report estimates that a dedicated interstate pipeline network in North Carolina would cost upwards of $5 billion due to the limited geological sequestration potential in that part of the country[30]. Storage and subsequent monitoring and verification costs are estimated by the IPCC to range from $0.5-8/t$CO_2$ injected and $0.1-0.3/t$CO_2$ injected, respectively. The overall cost of CCS could therefore serve as a major barrier to its deployment[31].

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

Table 5.4 summarises our assumptions on the technical and economic parameters of future fossil-fuelled power plant technologies. In spite of growing raw material prices, we assume that further technical innovation will result in a moderate reduction of future investment costs as well as improved power plant efficiencies. These improvements are, however, outweighed by the expected increase in fossil fuel prices, resulting in a significant rise in electricity generation costs.

references
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31 RUBIN ET AL., 2005B, PG 4444

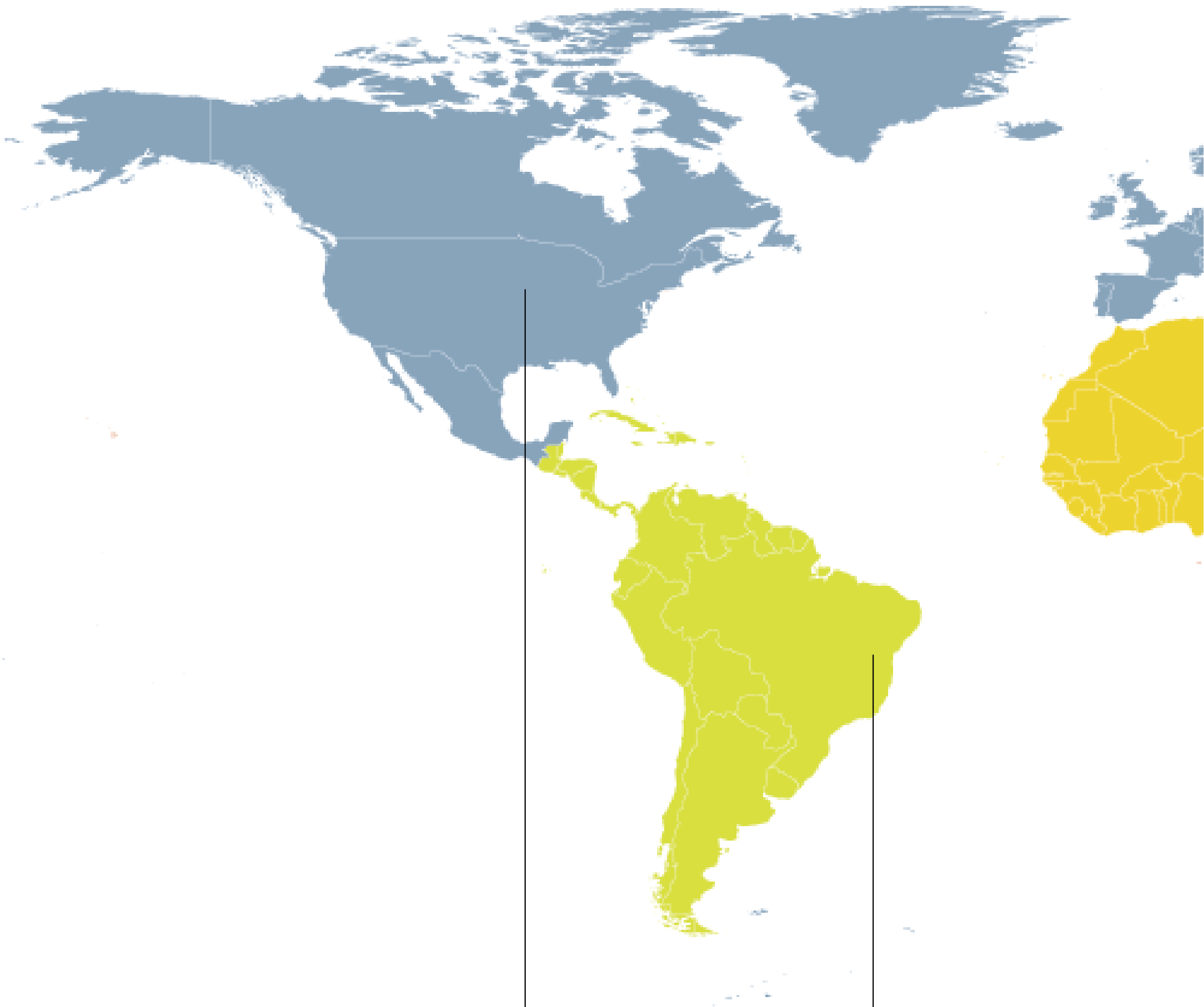
table 5.4: development of efficiency and investment costs for selected power plant technologies

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

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

map 5.1: CO_2 emissions reference scenario and the energy [r]evolution scenario

WORLDWIDE SCENARIO



EMISSIONS

CO_2

OECD NORTH AMERICA

		REF mio t	REF %	E[R] mio t	E[R] %
CO_2	2005	6,433 H	111	6,433	111
	2050	9,135	158	1,058 M	18
		t		**t**	
Per person	2005	14.74 H		14.74	
	2050	15.82 H		1.83	

LATIN AMERICA

		REF mio t	REF %	E[R] mio t	E[R] %
CO_2	2005	827	125	827	125
	2050	2,350	354	369 L	56
		t		**t**	
Per person	2005	1.84		1.84	
	2050	3.72		0.58	

LEGEND

300-200 | 200-100 | 100-50 | 50-0 — % OF 1990 EMISSIONS IN THE 2050 ENERGY [R]EVOLUTION SCENARIO

REF — REFERENCE SCENARIO

E[R] — ENERGY [R]EVOLUTION SCENARIO

0 — 1000 KM

CO_2 — **EMISSIONS TOTAL** MILLION TONNES [mio t] | % OF 1990 EMISSIONS

EMISSIONS PER PERSON TONNES [t]

H HIGHEST | M MIDDLE | L LOWEST

OECD EUROPE

		REF mio t	REF %	E[R] mio t	E[R] %
CO_2	2005	4,062	99	4,062	99
	2050	4,553M	111	884	22
		t		t	
per capita	2005	7.57		7.57	
	2050	8.08M		1.57M	

MIDDLE EAST

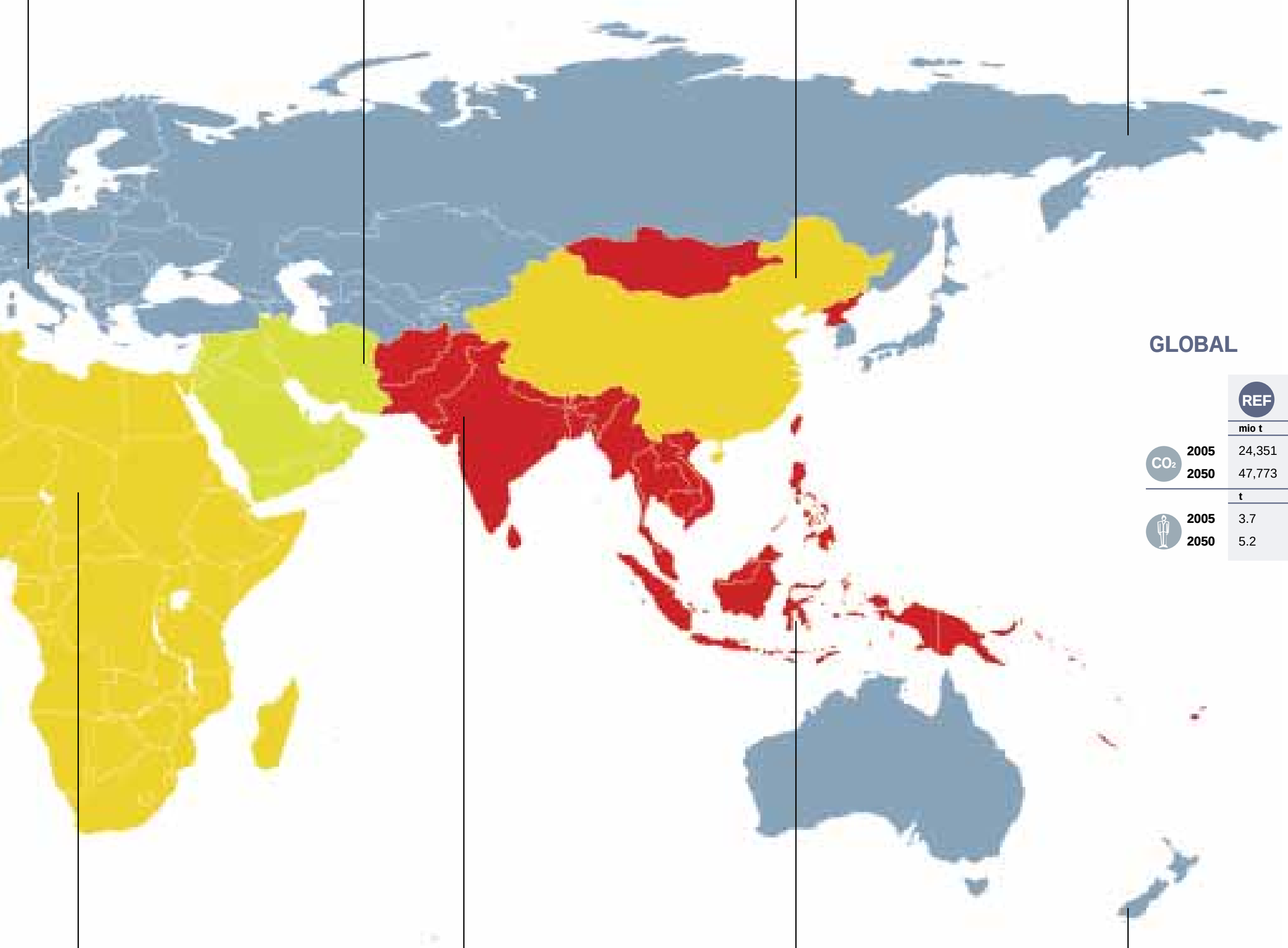
		REF mio t	REF %	E[R] mio t	E[R] %
CO_2	2005	1,173	162	1,173	162
	2050	2,929	403	393	54
		t		t	
per capita	2005	6.23M		6.23	
	2050	8.44		1.13	

CHINA

		REF mio t	REF %	E[R] mio t	E[R] %
CO_2	2005	4,429	198	4,429	198
	2050	12,572H	561	3,209H	143
		t		t	
per capita	2005	3.35		3.35	
	2050	8.86		2.26	

TRANSITION ECONOMIES

		REF mio t	REF %	E[R] mio t	E[R] %
CO_2	2005	2,375M	53	2,375	53
	2050	3,003	67	539	12
		t		t	
per capita	2005	6.96		6.96	
	2050	10.22		1.83	



GLOBAL

		REF mio t	REF %	E[R] mio t	E[R] %
CO_2	2005	24,351	114	24,351	114
	2050	47,773	223	10,589	49
		t		t	
per capita	2005	3.7		3.7	
	2050	5.2		1.2	

AFRICA

		REF mio t	REF %	E[R] mio t	E[R] %
CO_2	2005	780L	109	780	109
	2050	2,064L	287	895	125
		t		t	
per capita	2005	0.85L		0.85	
	2050	1.03L		0.45L	

INDIA

		REF mio t	REF %	E[R] mio t	E[R] %
CO_2	2005	1,074	187	1,074	187
	2050	5,776	1,005	1,662	289
		t		t	
per capita	2005	0.98		0.98	
	2050	3.62		1.04	

DEVELOPING ASIA

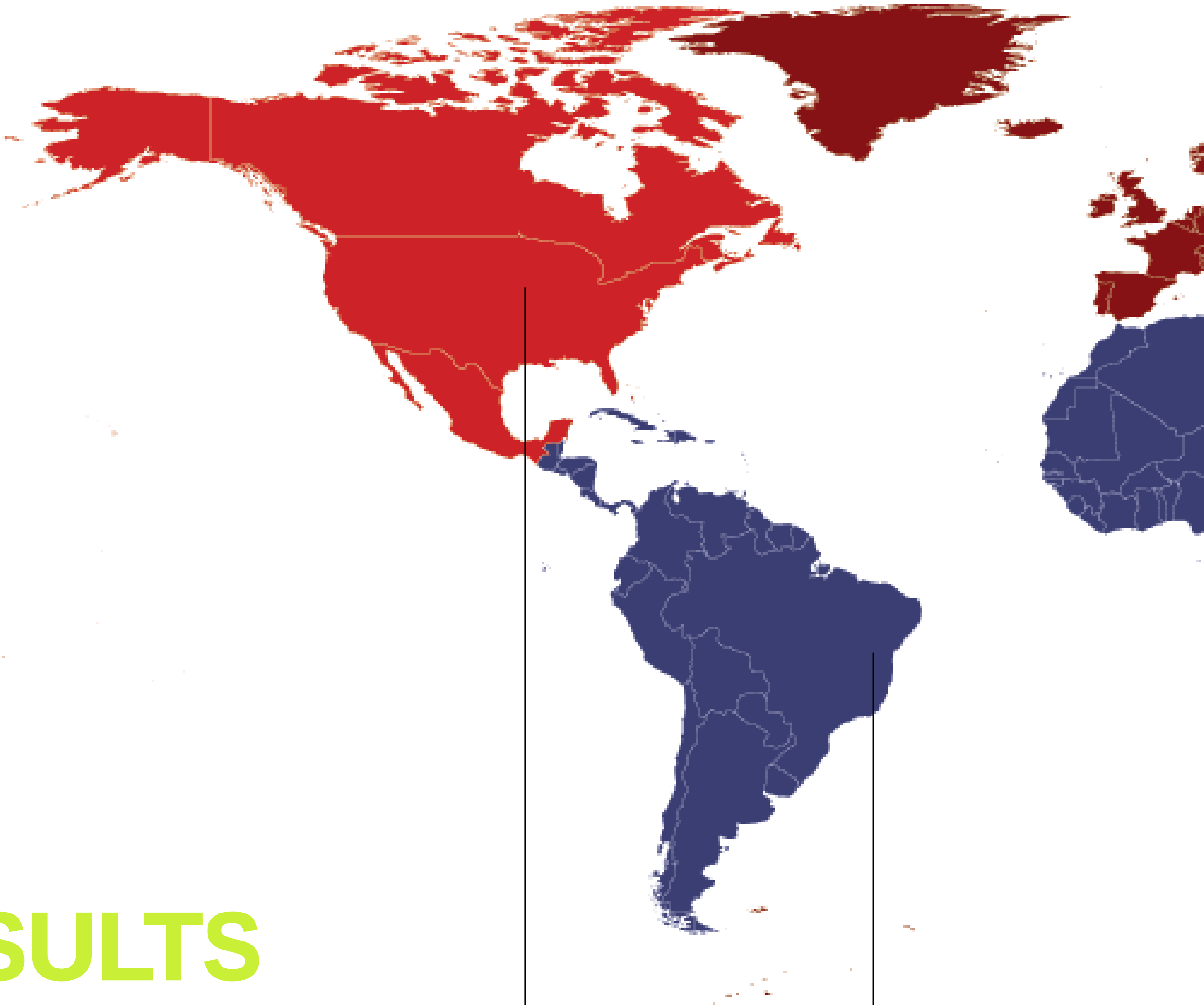
		REF mio t	REF %	E[R] mio t	E[R] %
CO_2	2005	1,303	268	1,303	268
	2050	3,265	673	1,148	236
		t		t	
per capita	2005	1.34		1.34	
	2050	2.17		0.76	

OECD PACIFIC

		REF mio t	REF %	E[R] mio t	E[R] %
CO_2	2005	1,895	123	1,895	123
	2050	2,127	138	433	28
		t		t	
per capita	2005	9.47		9.47	
	2050	11.94		2.43H	

map 5.2: 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 ENERGY [R]EVOLUTION SCENARIO 2050 COMPARED TO CURRENT CONSUMPTION 2005

REF REFERENCE SCENARIO

E[R] ENERGY [R]EVOLUTION 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		E[R]	
		PE PJ	EL TWh	PE PJ	EL TWh
	2005	115,888H	5,118	115,888H	5,118
	2050	164,342	9,378	77,697	6,756
		%		%	
Share of renewables	2005	6	15	6	15
	2050	9	17	66	93
		%		%	
Share of fossil fuels	2005	85	67M	85	67M
	2050	84	72M	31	7
		%		%	
Share of nuclear energy	2005	9	18	NUCLEAR POWER PHASED OUT BY 2040	
	2050	7	11		

LATIN AMERICA

		REF		E[R]	
		PE PJ	EL TWh	PE PJ	EL TWh
	2005	21,143L	906	21,143L	906
	2050	52,268	3,258	32,484	2,615
		%		%	
Share of renewables	2005	29	71H	29	71H
	2050	23	47H	71H	95
		%		%	
Share of fossil fuels	2005	70L	27L	70L	27L
	2050	76	52L	26L	5
		%		%	
Share of nuclear energy	2005	1	2	NUCLEAR POWER PHASED OUT BY 2030	
	2050	1	2		

OECD EUROPE

	REF PE PJ	REF EL TWh	E[R] PE PJ	E[R] EL TWh
2005	81,482	3,481	81,482	3,481
2050	90,284	5,618M	48,918M	3,252M
	%		%	
2005	8	19	8	19
2050	15M	30	60	86
	%		%	
2005	79M	53	79M	53
2050	79M	62	43	14
	%		%	
2005	13	28	NUCLEAR POWER PHASED OUT BY 2030	
2050	5M	8M		

MIDDLE EAST

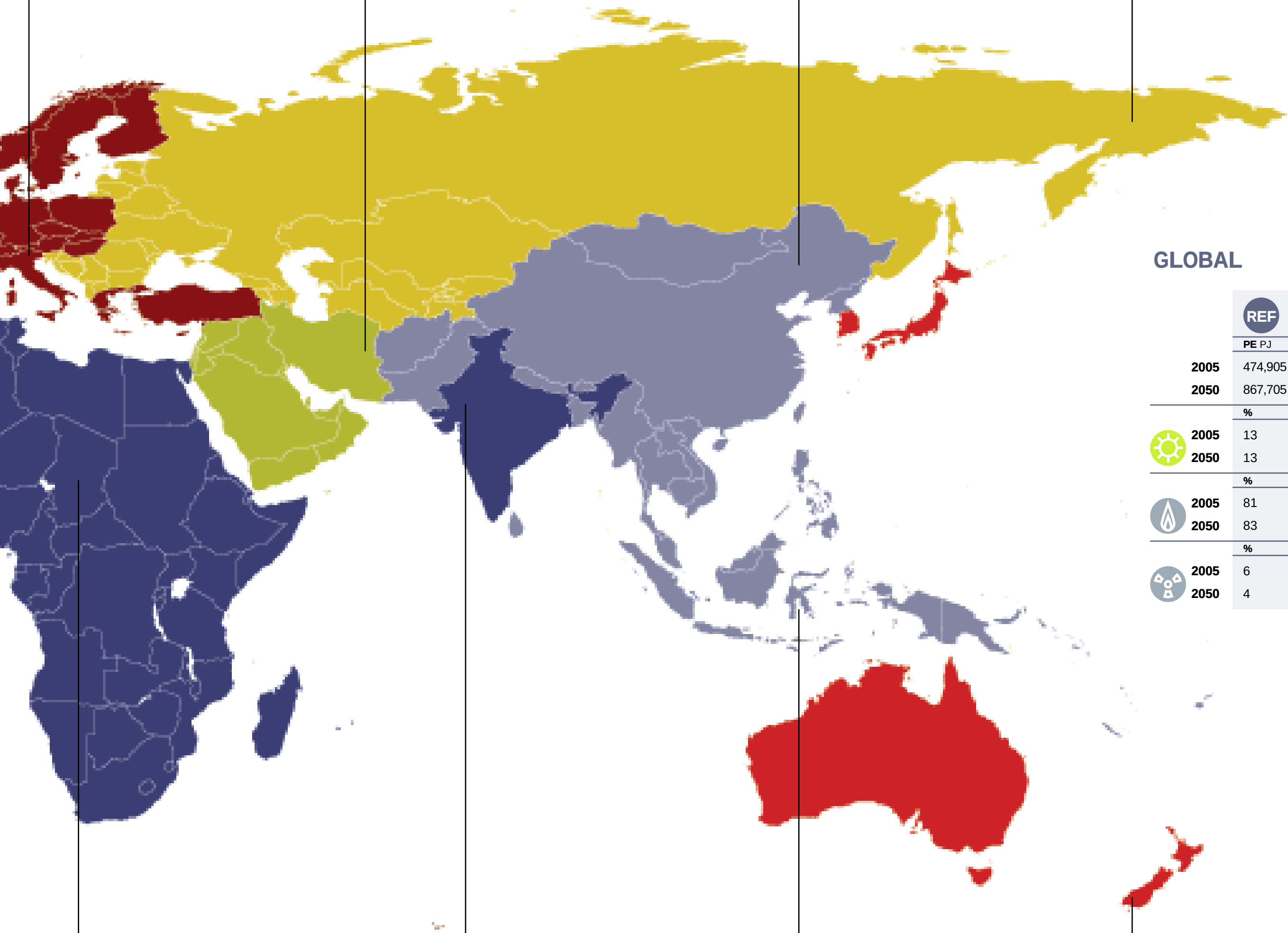
	REF PE PJ	REF EL TWh	E[R] PE PJ	E[R] EL TWh
2005	21,416	640	21,416	640
2050	54,982	2,432	27,590	2,171L
	%		%	
2005	1L	3L	1L	3L
2050	2L	4L	62	96H
	%		%	
2005	99H	97H	99H	97H
2050	98H	95H	37	4
	%		%	
2005	0L	0L	NO NUCLEAR ENERGY DEVELOPMENT	
2050	0L	0L		

CHINA

	REF PE PJ	REF EL TWh	E[R] PE PJ	E[R] EL TWh
2005	73,007	2,539	73,007	2,539
2050	185,017H	12,607H	99,152H	9,261H
	%		%	
2005	15M	16	15M	16
2050	8	15	47L	63
	%		%	
2005	84	82	84	82
2050	89	81	53H	37H
	%		%	
2005	1	2	NUCLEAR POWER PHASED OUT BY 2045	
2050	3	4		

TRANSITION ECONOMIES

	REF PE PJ	REF EL TWh	E[R] PE PJ	E[R] EL TWh
2005	46,254M	1,598	46,254M	1,598
2050	63,933	2,934	35,764	2,083
	%		%	
2005	4	20M	4	20M
2050	9	21M	62	81
	%		%	
2005	89	63	89	63
2050	83	63	38	19
	%		%	
2005	7M	17	NUCLEAR POWER PHASED OUT BY 2045	
2050	8	16		



GLOBAL

	REF PE PJ	REF EL TWh	E[R] PE PJ	E[R] EL TWh
2005	474,905	18,226	474,905	18,226
2050	867,705	50,606	480,861	37,116
	%		%	
2005	13	18	1,297	18
2050	13	19	5,611	77
	%		%	
2005	81	67	81	67
2050	83	74	44	23
	%		%	
2005	6	15	NUCLEAR POWER PHASED OUT BY 2045	
2050	4	7		

AFRICA

	REF PE PJ	REF EL TWh	E[R] PE PJ	E[R] EL TWh
2005	25,243	564L	25,243	564L
2050	53,286	2,339L	38,347	2,076L
	%		%	
2005	49H	17	49H	17
2050	38H	22	56M	73
	%		%	
2005	50	81	50	81
2050	62L	78	42M	27
	%		%	
2005	0L	2	NUCLEAR POWER PHASED OUT BY 2025	
2050	0L	1		

INDIA

	REF PE PJ	REF EL TWh	E[R] PE PJ	E[R] EL TWh
2005	22,344	699	22,344	699
2050	89,090M	6,012	52,120	4,435
	%		%	
2005	31	15	31	15
2050	12	10	48	60L
	%		%	
2005	68	82	68	82
2050	85	87	52	40
	%		%	
2005	1	3	NUCLEAR POWER PHASED OUT BY 2045	
2050	3	3		

DEVELOPING ASIA

	REF PE PJ	REF EL TWh	E[R] PE PJ	E[R] EL TWh
2005	31,095	901	31,095	901
2050	67,414	3,283	43,838	2,356
	%		%	
2005	26	16	26	16
2050	22	21	49	67
	%		%	
2005	72	79	72	79
2050	77	76	51	33
	%		%	
2005	1	5M	NUCLEAR POWER PHASED OUT BY 2045	
2050	1	3		

OECD PACIFIC

	REF PE PJ	REF EL TWh	E[R] PE PJ	E[R] EL TWh
2005	37,035	1,780M	37,035	1,780M
2050	47,024L	2,744	24,952L	2,111
	%		%	
2005	3	9	3	9
2050	8	12	55	78M
	%		%	
2005	83	66	83	66
2050	75	61	45	22M
	%		%	
2005	13H	25H	NUCLEAR POWER PHASED OUT BY 2045	
2050	17H	27H		

6. cost projections for renewable energy technologies

The range of renewable energy technologies available today display marked differences in terms of their technical maturity, costs and development potential. 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 being generated and used locally to the consumer - the future will also see large-scale applications in the form of offshore wind parks, photovoltaic power plants or concentrating solar power 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 transport fuels.

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

To identify long-term cost developments, learning curves have been applied which reflect the correlation between cumulative production volumes of a particular technology and a reduction in its costs. For many technologies, the learning factor (or progress ratio) falls in the range between 0.75 for less mature systems to 0.95 and higher for well-established technologies. A learning factor of 0.9 means that costs are expected to fall by 10% every time the cumulative output from the technology doubles. Empirical data shows, for example, that the learning factor for PV solar modules has been fairly constant at 0.8 over 30 years whilst that for wind energy varies from 0.75 in the UK to 0.94 in the more advanced German market.

Assumptions on future costs for renewable electricity technologies in the Energy [R]evolution Scenario are derived from a review of learning curve studies, for example by Lena Neij and others[32], from the analysis of recent technology foresight and road mapping studies, including the European Commission funded NEEDS (New Energy Externalities Developments for Sustainability)[33] project or the IEA Energy Technology Perspectives 2008, and a discussion with experts from the renewable energy industry.

"large cost reductions can be achieved through technical advances, manufacturing improvements and large-scale production."

references
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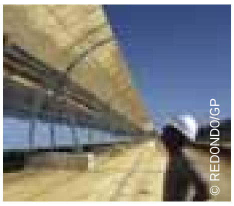


image THE PS10 SOLAR TOWER PLANT AT SAN LUCAR LA MAYOR OUTSIDE SEVILLE, SPAIN, APRIL 29, 2008.

photovoltaics (pv)

The worldwide photovoltaics (PV) market has been growing at over 35% per annum in recent years and the contribution it can make to electricity generation is starting to become significant. Development work is focused on improving existing modules and system components by increasing their energy efficiency and reducing material usage. Technologies like PV thin film (using alternative semiconductor materials) or dye sensitive solar cells are developing quickly and present a huge potential for cost reduction. The mature technology crystalline silicon, with a proven lifetime of 30 years, is continually increasing its cell and module efficiency (by 0.5% annually), whereas the cell thickness is rapidly decreasing (from 230 to 180 microns over the last five years). Commercial module efficiency varies from 14 to 21% depending on silicon quality and fabrication process.

The learning factor for PV modules has been fairly constant over the last 30 years, with a cost reduction of 20% each time the installed capacity doubles, indicating a high rate of technical learning. Assuming a globally installed capacity of 1,600 GW by between 2030 and 2040, and with an electricity output of 2,600 TWh, we can expect that generation costs of around 5-10 cents/kWh (depending on the region) will be achieved. During the following five to ten years, PV will become competitive with retail electricity prices in many parts of the world and competitive with fossil fuel costs by 2050. The importance of photovoltaics comes from its decentralised/centralised character, its flexibility for use in an urban environment and huge potential for cost reduction.

concentrating solar power (csp)

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

Thermal storage systems are a key component for reducing CSP electricity generation costs. The Spanish Andasol 1 plant, for example, is equipped with molten salt storage with a capacity of 7.5 hours. A higher level of full load operation can be realised by using a thermal storage system and a large collector field. Although this leads to higher investment costs, it reduces the cost of electricity generation.

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

table 5.5: photovoltaics (pv)

	2005	2010	2020	2030	2040	**2050**
Global installed capacity (GW)	5.2	21	269	921	1,799	**2,911**
Investment costs ($/kW)	6,600	3,760	1,660	1,280	1,140	**1,080**
Operation & maintenance costs ($/kWa)	66	38	16	13	11	**10**

table 5.6: concentrating solar power (csp)

	2005	2010	2020	2030	2040	**2050**
Global installed capacity (GW)	0.53	5	83	199	468	**801**
Investment costs ($/kW)	7,530	6,340	5,240	4,430	4,360	**4,320**
Operation & maintenance costs ($/kWa)	300	250	210	180	160	**155**

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. While favourable policy incentives have made Europe the main driver for the global wind market, in 2007 more than half of the annual market was outside Europe. This trend is likely to continue. The boom in demand for wind power technology has nonetheless led to supply constraints. As a consequence, the cost of new systems has stagnated or even increased. Because of the continuous expansion of production capacities, the industry expects to resolve the bottlenecks in the supply chain over the next few years. Taking into account market development projections, learning curve analysis and industry expectations, we assume that investment costs for wind turbines will reduce by 30% for onshore and 50% for offshore installations up to 2050.

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 (based on credit for waste disposal costs avoided) through inexpensive residual materials to the more expensive energy crops. The resulting spectrum of energy generation costs is correspondingly broad. One of the most economic options is the use of waste wood in steam turbine combined heat and power (CHP) plants. Gasification of solid biomass, on the other hand, which 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, the USA and Europe. Processes for obtaining synthetic fuels from biogenic synthesis gases will also play a larger role.

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

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

table 5.7: wind power

	2005	2010	2020	2030	2040	**2050**
Installed capacity (on+offshore)	59	164	893	1,622	2,220	**2,733**
Wind onshore						
Global installed capacity (GW)	59	162	866	1,508	1,887	**2,186**
Investment costs ($/kW)	1,510	1,370	1,180	1,110	1,090	**1,090**
O&M costs ($/kWa)	58	51	45	43	41	**41**
Wind offshore						
Global installed capacity (GW)	0,3	1,6	27	114	333	**547**
Investment costs ($/kW)	3,760	3,480	2,600	2,200	1,990	**1,890**
O&M costs ($/kWa)	166	153	114	97	88	**83**

table 5.8: biomass

	2005	2010	2020	2030	2040	**2050**
Biomass (electricity only)						
Global installed capacity (GW)	21	35	56	65	81	**99**
Investment costs ($/kW)	3,040	2,750	2,530	2,470	2,440	**2,415**
O&M costs ($/kWa)	183	166	152	148	147	**146**
Biomass (CHP)						
Global installed capacity (GW)	32	60	177	275	411	**521**
Investment costs ($/kW)	5,770	4,970	3,860	3,380	3,110	**2,950**
O&M costs ($/kWa)	404	348	271	236	218	**207**

image 100 KW PV GENERATING PLANT NEAR BELLINZONA-LOCARNO RAILWAY LINE. GORDOLA, SWITZERLAND.

image THE POWER OF THE OCEAN.

geothermal

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

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

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

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

ocean energy

Ocean energy, particularly offshore wave energy, is a significant resource, and has the potential to satisfy an important percentage of electricity supply worldwide. Globally, the potential of ocean energy has been estimated at around 90,000 TWh/year. The most significant advantages are the vast availability and high predictability of the resource and a technology with very low visual impact and no CO_2 emissions. Many different concepts and devices have been developed, including taking energy from the tides, waves, currents and both thermal and saline gradient resources. Many of them are in an advanced phase of R&D, large scale prototypes have been deployed in real sea conditions and some have reached pre-market deployment. There are a few grid connected, fully operational commercial wave and tidal generating plants.

The cost of energy from initial tidal and wave energy farms has been estimated to be in the range of 15-55 €cents/kWh, and for initial tidal stream farms in the range of 11-22 €cents/kWh. Generation costs of 10-25 €cents/kWh are expected by 2020. Key areas for development will include concept design, optimisation of the device configuration, reduction of capital costs by exploring the use of alternative structural materials, economies of scale and learning from operation. According to the latest research findings, the learning factor is estimated to be 10-15% for offshore wave and 5-10% for tidal stream. In the medium term, ocean energy has the potential to become one of the most competitive and cost effective forms of generation. In the next few years a dynamic market penetration is expected, following a similar curve to wind energy.

Because of the early development stage any future cost estimates for ocean energy systems are uncertain, and no learning curve data is available. Present cost estimates are based on analysis from the European NEEDS project[34].

table 5.9: geothermal

	2005	2010	2020	2030	2040	**2050**
Geothermal (electricity only)						
Global installed capacity (GW)	8.7	12	33	71	120	**152**
Investment costs ($/kW)	17,440	15,040	11,560	10,150	9,490	**8,980**
O&M costs ($/kWa)	645	557	428	375	351	**332**
Geothermal (CHP)						
Global installed capacity (GW)	0.24	1.7	13	38	82	**124**
Investment costs ($/kW)	17,500	13,050	9,510	7,950	6,930	**6,310**
O&M costs ($/kWa)	647	483	351	294	256	**233**

table 5.10: ocean energy

	2005	2010	2020	2030	2040	**2050**
Global installed capacity (GW)	0.27	0.9	17	44	98	**194**
Investment costs ($/kW)	9,040	5,170	2,910	2,240	1,870	**1,670**
Operation & maintenance costs ($/kWa)	360	207	117	89	75	**66**

references
34 WWW.NEEDS-PROJECT.ORG

image BENMORE HYDRO DAM, NEW ZEALAND.

hydro power

Hydropower is a mature technology with a significant part of its potential already exploited. There is still, however, some potential left both for new schemes (especially small scale run-of-river projects with little or no reservoir impoundment) and for repowering of existing sites. The significance of hydropower is also likely to be encouraged by the increasing need for flood control and maintenance of water supply during dry periods. The future is in sustainable hydropower which makes an effort to integrate plants with river ecosystems while reconciling ecology with economically attractive power generation.

table 5.11: hydro

	2005	2010	2020	2030	2040	**2050**
Global installed capacity (GW)	878	978	1178	1300	1443	**1565**
Investment costs ($/kW)	2760	2880	3070	3200	3320	**3420**
Operation & maintenance costs ($/kWa)	110	115	123	128	133	**137**

summary of renewable energy cost development

Figure 5.4 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 70% of current levels by 2020, and to between 20% and 60% 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 5.5. Generation costs today are around 8 to 25 €cents/kWh (10-25 $cents/kWh) for the most important technologies, with the exception of photovoltaics. In the long term, costs are expected to converge at around 4 to 10 €cents/kWh (5-12 $cents/kWh). These estimates depend on site-specific conditions such as the local wind regime or solar irradiation, the availability of biomass at reasonable prices or the credit granted for heat supply in the case of combined heat and power generation.

figure 5.4: future development of investment costs
(NORMALISED TO CURRENT COST LEVELS) FOR RENEWABLE ENERGY TECHNOLOGIES

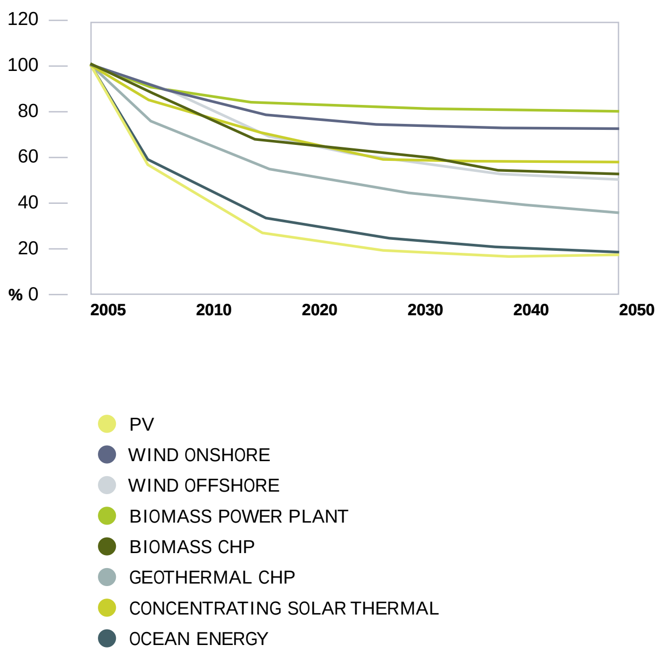
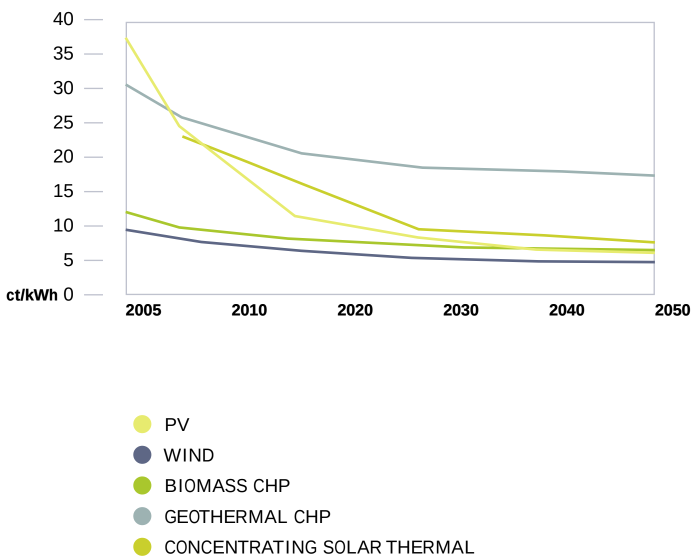


figure 5.5: expected development of electricity generation costs from fossil fuel and renewable options
EXAMPLE FOR OECD NORTH AMERICA



6

image SOLAR PANEL. © BERND JUERGENS/DREAMSTIME

"for us to develop in a sustainable way, strong measures have to be taken to combat climate change."

HU JINTAO
PRESIDENT OF CHINA

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

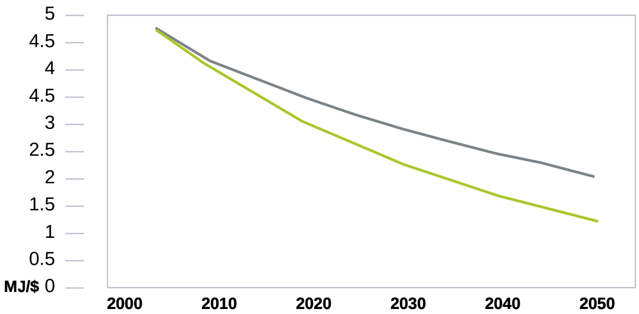
- Population development: the number of people consuming energy or using energy services.
- Economic development, for which Gross Domestic Product (GDP) is the most commonly used indicator. In general, an increase in GDP triggers an increase in energy demand.
- Energy intensity: how much energy is required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

global: 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 1.25% on average per year, leading to a reduction in final energy demand per unit of GDP of about 56% between 2005 and 2050. Under the Energy [R]evolution Scenario, it is assumed that active policy and technical support for energy efficiency measures will lead to an even higher reduction in energy intensity of almost 73%.

figure 6.1: global: projection of average energy intensity under the reference and energy [r]evolution scenarios



ENERGY [R]EVOLUTION SCENARIO
REFERENCE SCENARIO

figure 6.2: global: energy intensity by world region under the reference scenario

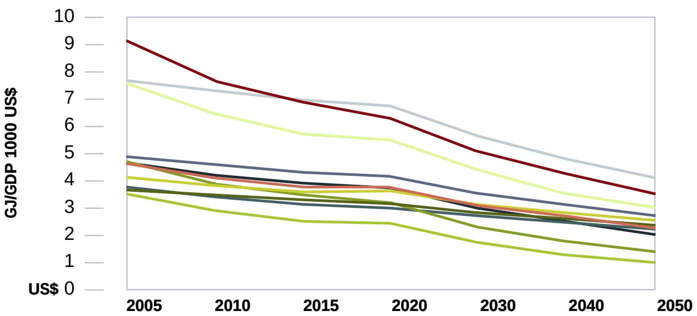


figure 6.3: global: energy intensity by world region under the energy [r]evolution scenario

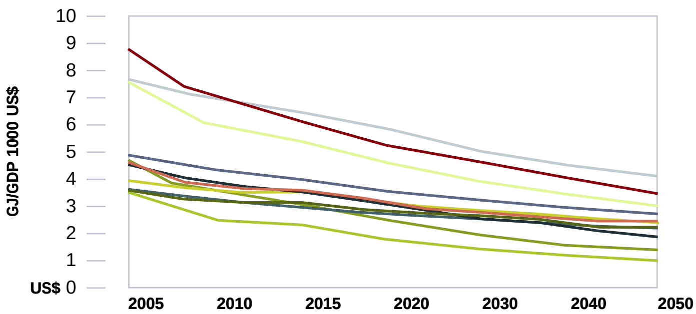


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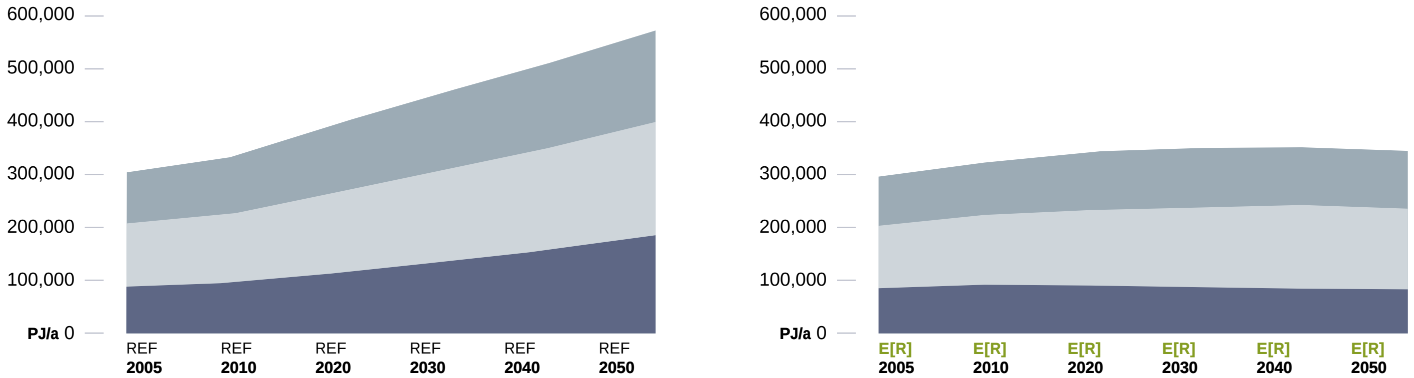
image BERLINER GEOSOL INSTALLING THE SOLAR ENERGY PLANT (PHOTOVOLTAIK) "LEIPZIGER LAND" OWNED BY SHELL SOLAR IN A FORMER BROWN COAL AREA NEAR LEIPZIG, SACHSEN, GERMANY.

global: development of energy demand by sector

Combining the projections on population development, GDP growth and energy intensity results in future development pathways for the world's energy demand. These are shown in Figure 6.4 for both the Reference and Energy [R]evolution Scenarios. Under the Reference Scenario, total primary energy demand almost doubles from 474,900 PJ/a in 2005 to 867,700 PJ/a in 2050. In the Energy [R]evolution Scenario, demand increases up to 2015 by 16% and decreases to close to today's level of 480,860 PJ in 2050.

The accelerated increase in energy efficiency, which is a crucial prerequisite for achieving a sufficiently large share of renewable energy sources in our energy supply, is beneficial not only for the environment but also for economics. Taking into account the full service life, in most cases the implementation of energy efficiency measures saves costs compared to an additional energy supply. The mobilisation of cost-effective energy saving potential leads directly to a reduction in costs. A dedicated energy efficiency strategy thus also helps to compensate in part for the additional costs required during the market introduction phase of renewable energy sources.

figure 6.4: global: projection of final energy demand by sector for the two scenarios



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 6.5). With the exploitation of efficiency measures, however, an even higher increase can be avoided, leading to electricity demand of around 30,800 TWh/a in the year 2050. Compared to the Reference Scenario, efficiency measures avoid the generation of about 12,800 TWh/a. This reduction in energy demand can be achieved in particular by introducing highly efficient electronic devices using the best available technology in all demand sectors. Employment of solar architecture in both residential and commercial buildings will help to curb the growing demand for active air-conditioning.

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 6.6). Compared to the Reference Scenario, consumption equivalent to 46,000 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, it is assumed under the Energy [R]evolution Scenario that energy demand will increase by 12 % to around 94,000 PJ/a in 2015 and will fall slightly afterwards down to 83,300 PJ/a in 2050, saving 100,000 PJ 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 6.5: global: development of electricity demand by sector

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

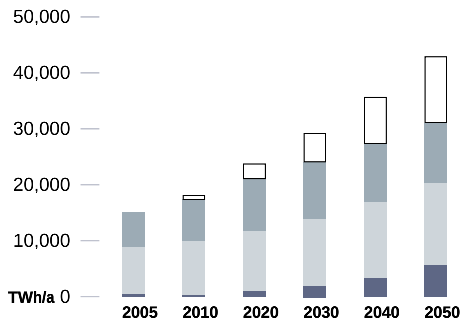
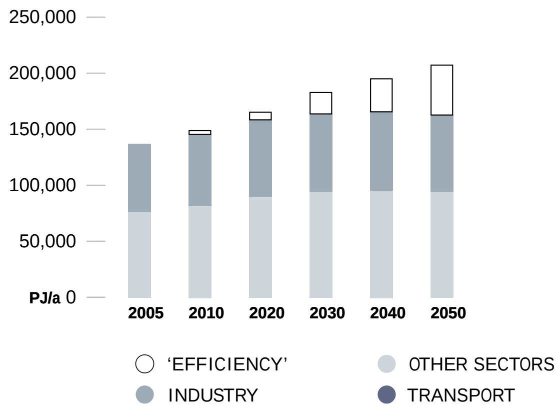


figure 6.6: global: development of heat demand by sector

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



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global: 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, 77% of the electricity produced worldwide will come from renewable energy sources. 'New' renewables – mainly wind, solar thermal energy and PV – will contribute over 60% 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, biomass, concentrating solar power plants and solar photovoltaics. 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 1,000 GW to 9,100 GW in 2050. Increasing renewable capacity by a factor of nine within the next 42 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 21 shows the comparative evolution of the different renewable technologies over time. Up to 2020, hydro-power and wind will remain the major contributors to the growing market share. After 2020, the continuing growth of wind will be complemented by electricity from biomass, photovoltaic and solar thermal (CSP) energy.

table 6.1: global: projection of renewable electricity generation capacity under the energy [r]evolution scenario

IN GW

	2005	2010	2020	2030	2040	2050
Hydro	878	978	1,178	1,300	1,443	1,565
Biomass	52	95	233	341	492	619
Wind	59	164	893	1,622	2,220	2,911
Geothermal	9	14	46	108	203	276
PV	2	21	269	921	1,799	2,911
Solarthermal	0.5	5	83	199	468	801
Ocean energy	0.3	1	17	44	98	194
Total	**1,001**	**1,276**	**2,719**	**4,536**	**6,723**	**9,100**

figure 6.7: global: development of electricity supply structure under the two scenarios

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

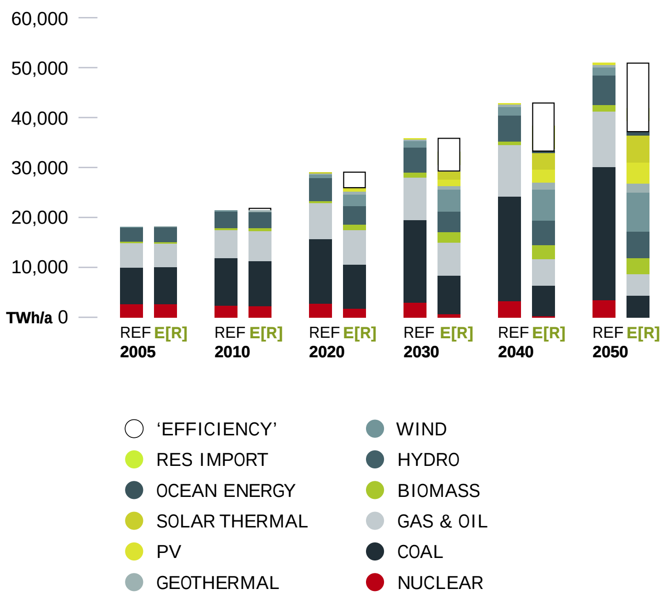


figure 6.8: global: growth of renewable electricity generation under the energy [r]evolution scenario

BY INDIVIDUAL SOURCE

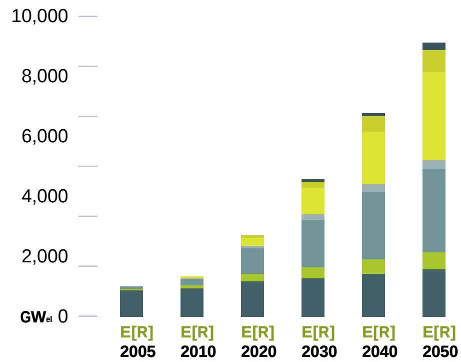


image TEST WIND MILL N90 2500, BUILD BY GERMAN COMPANY NORDEX, IN THE HARBOUR OF ROSTOCK. THIS WIND MILL PRODUCES 2,5 MEGA WATT AND AT LEAST 10 FACILITIES OF THIS TYPE WILL BE ERECTED 20 KM OFF THE ISLAND DARSS IN THE BALTIC SEA.

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

global: future costs of electricity generation

Figure 27 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 0.2 cents/kWh up to 2020. Note that any increase in fossil fuel prices beyond the projection given in Table 6.1 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 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 $1,750 billion per year to more than $7,300 bn in 2050. Figure 28 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.

global: heat and cooling supply

Development of renewables in the heat supply sector raises different issues. Today, renewables provide 24%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.

In the Energy [R]evolution Scenario, renewables satisfy more than 70% of the total global heating demand in 2050.

- Energy efficiency measures can decrease the current per capita demand for heat supply by 30% in spite of improving living standards.
- For direct heating, solar collectors, biomass/biogas as well as geothermal energy will increasingly substitute 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 6.9: global: development of specific electricity generation costs under the two scenarios

(CO_2 EMISSION COSTS IMPOSED FROM 2010, WITH AN INCREASE FROM 15 $/$T_{CO_2}$ IN 2010 TO 50 $/$T_{CO_2}$ IN 2050)

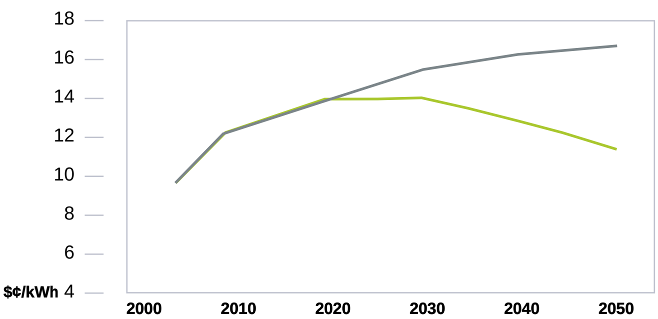


figure 6.10: global: development of total electricity supply costs

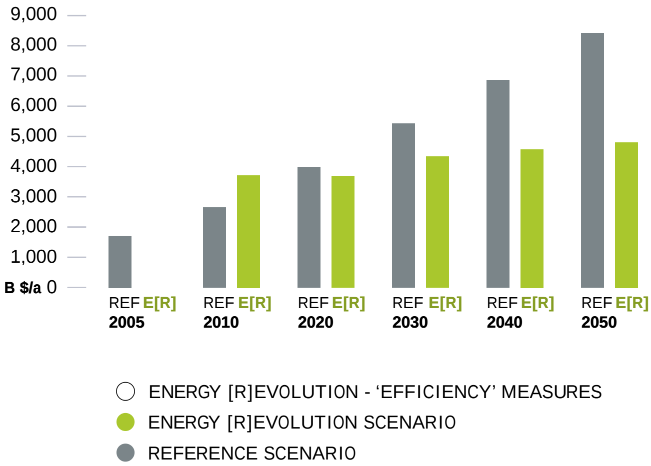
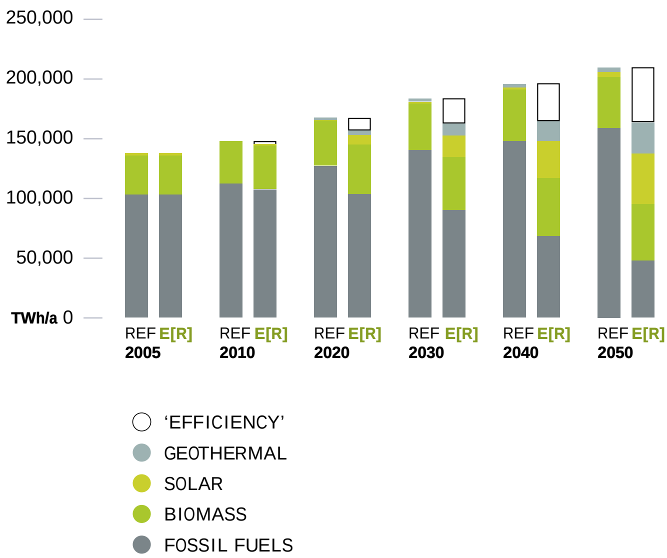


figure 6.11: global: development of heat supply structure under the two scenarios

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



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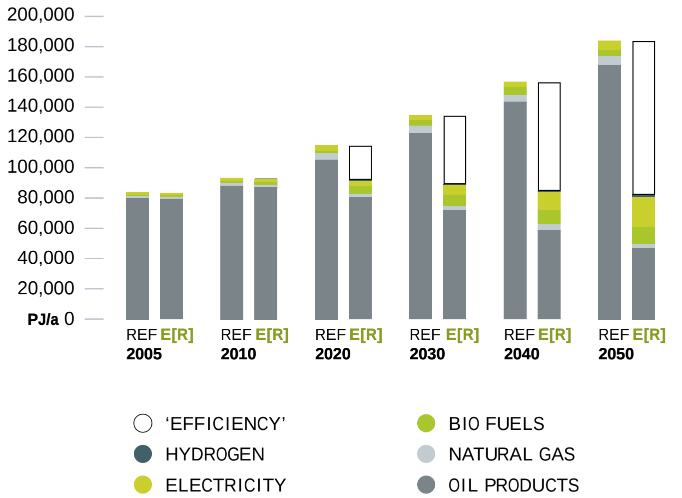
global: transport

In the transport sector, it is assumed that under the Energy [R]evolution Scenario, due to fast growing demand for services, energy demand will further increase up to 2015. After that demand will decrease, falling to below its current level in 2050. Compared to the Reference Scenario, energy demand is reduced by 54%. 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. By implementing attractive alternatives to individual cars, the amount of cars will grow more slowly than in the Reference Scenario. In 2050, electricity will provide 24% of the transport sector's total energy demand, while 61% of the demand will be covered by fossil fuels.

figure 6.12: global: transport under the two scenarios

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



development of global 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 24,350 million tonnes in 2005 to 10,600 m/t in 2050. Annual per capita emissions will drop from 3.7 tonnes to 1.15 t. In spite of the phasing out of nuclear energy and increasing demand, CO_2 emissions will decrease in the electricity sector. In the long run efficiency gains and the increased use of renewable electricity will even reduce CO_2 emissions in the transport sector. With a share of 35% of total CO_2 in 2050, the power sector will fall significantly but remain the largest source of emissions, followed by transport.

global: 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 6.13. Compared to the Reference Scenario, overall energy demand will be reduced by almost 45% in 2050. More than 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.

figure 6.13: global: development of primary energy consumption under the two scenarios

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

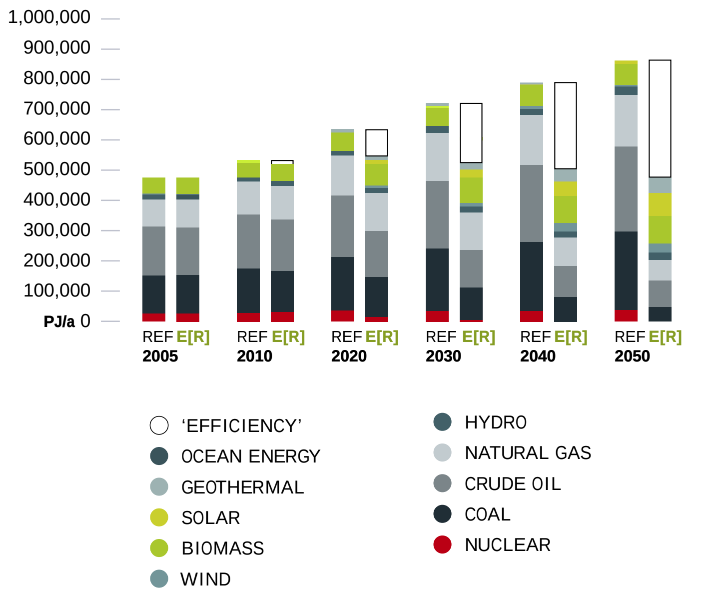


figure 6.14: global: development of CO_2 emissions by sector under the energy [r]evolution scenario

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

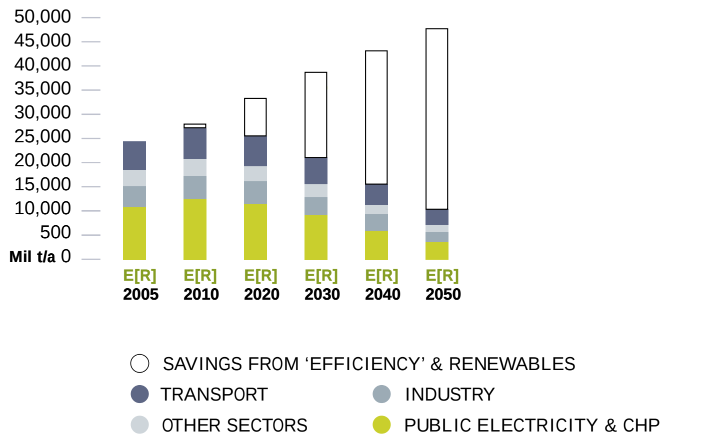


image HIGH MARNHAM COAL-FIRED POWER STATION ON THE RIVER TRENT IN NOTTINGHAMSHIRE, UK.

global: regional breakdown of CO_2 emissions in 2050

With effective efficiency standards OECD countries can reduce their per capita energy consumption significantly while developing countries could slow down their massive increase in energy demand. At the same time renewable energy sources can increase there share in the energy mix to over 50 % globally. In some regions, the renewable energy share will be well above 80%, while economic growth is still maintained over the entire scenario period.

With this shift, annual per capita CO_2 emissions will fall from their current level of about 3.6 tonnes to 1.15 tonnes in 2050. OECD countries will be able to reduce their CO_2 emissions by about 80%. The Energy [R]evolution Scenario for the USA shows that it is possible to reduce per capita CO_2 emissions from 19 tonnes now to 3 tonnes by 2050. For the EU-27 countries, per capita emissions will fall from 8 to just under 2 tonnes per capita. Developing countries such as the Philippines could even keep per capita emissions at their current level of about 1 tonne of CO_2 until 2050, while maintaining economic growth. A combination of efficiency standards and renewable energy development proves to be the most cost effective way to cut CO_2 emissions and increase security of supply by reducing dependence on fossil fuel imports.

Under the global Energy [R]evolution Scenario, China and India will emit almost half of the remaining CO_2 emissions in 2050, while all OECD countries together will have a share of about 22%.

global: CO_2 emissions by source

In 2050, coal will be by far the largest source of CO_2, mainly from coal-fired power stations in China and India as well as power stations in other developing countries. Since those emissions are mainly from power stations built between 2000 and 2015, and the average lifetime of a coal-fired power plant is calculated at 40 years, in order to achieve the projected reduction, the construction of new coal power stations must end across most of the world by 2015 and in developing countries by 2020.

The second biggest emitter is oil, mainly from the remaining oil used in the transport sector.

figure 6.16: global: CO_2 emissions electricity & steam generation in 2050

4,35Gt

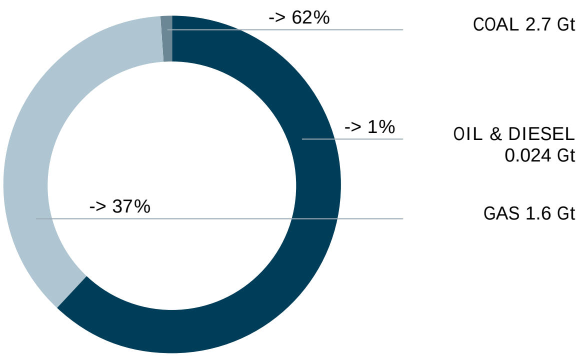


figure 6.15: global: CO_2 emissions in 2050

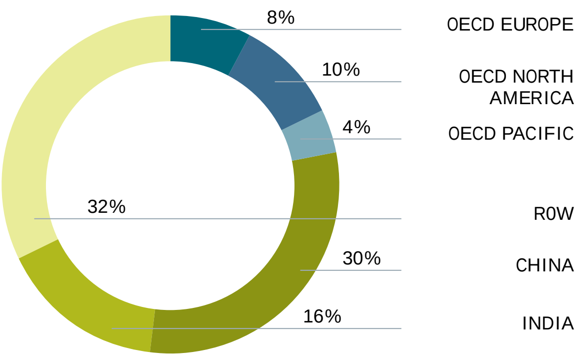
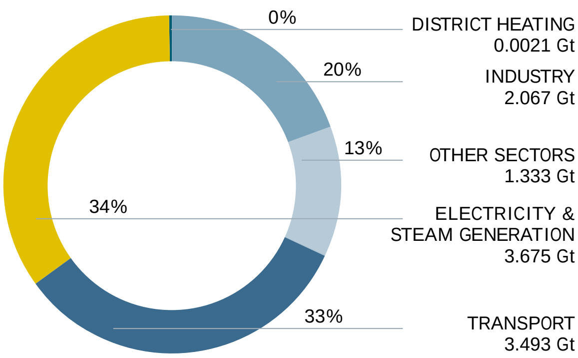


figure 6.17: global: CO_2 emissions in 2050

10,5 Gt -> BREAKDOWN BY SECTOR



regional breakdown of energy [r]evolution scenario The outcome of the Energy [R]evolution Scenario for each region of the world shows how the global pattern is adapted to regional circumstances in terms of predicted demand and the potential for developing different sources of future energy generation.

oecd north america

oecd north america: energy demand by sector

Combining the projections on population development, GDP growth and energy intensity results in future development pathways for North America's energy demand. These are shown in Figure 6.18 for both the Reference and Energy [R]evolution Scenarios. Under the Reference Scenario, total primary energy demand increases by more than 40% from the current 115,900 PJ/a to 164,300 PJ/a in 2050. In the Energy [R]evolution Scenario, primary energy demand decreases by 33% compared to current consumption and is expected by 2050 to reach 77,700 PJ/a.

Under the Energy [R]evolution Scenario, electricity demand is expected to decrease in the industry sector, but to grow in the transport as well as in the residential and service sectors (see Figure 6.19). Total electricity demand will rise to 5,730 TWh/a in the year 2050. Compared to the Reference Scenario, efficiency measures avoid the generation of about 2,460 TWh/a. This reduction in energy demand can be achieved in particular by introducing highly efficient electronic devices using the best available technology in all demand sectors. Employment of solar architecture in both residential and commercial buildings will help to curb the growing demand for active air-conditioning.

Efficiency gains in the heat supply sector are even larger. Under the Energy [R]evolution Scenario, demand for heat supply will grow up to 2030, but after that can even be reduced to below the current level (see Figure 6.20). Compared to the Reference Scenario, consumption equivalent to 7,850 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, it is assumed under the Energy [R]evolution Scenario that energy demand will decrease by half to 16,720 PJ/a by 2050, saving 65% 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 6.18: oecd north america: projection of total final energy demand by sector for the two scenarios

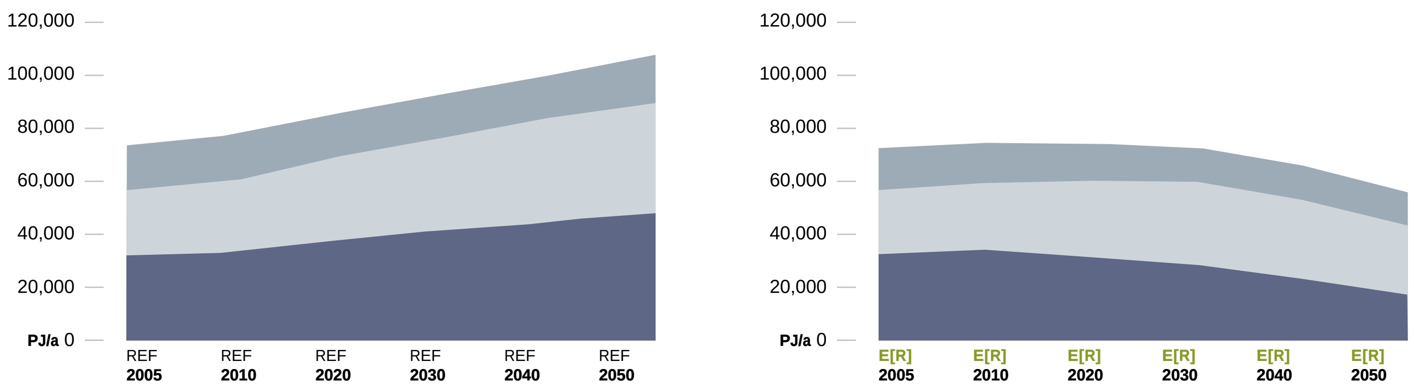


figure 6.19: oecd north america: development of electricity demand by sector

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

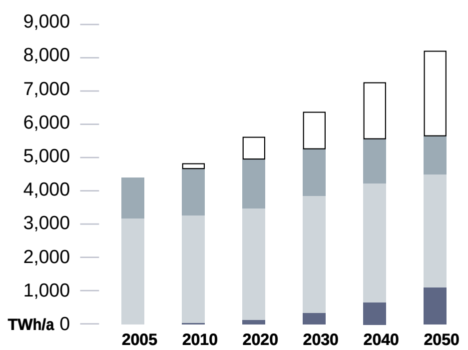


figure 6.20: oecd north america: development of heat demand by sector

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

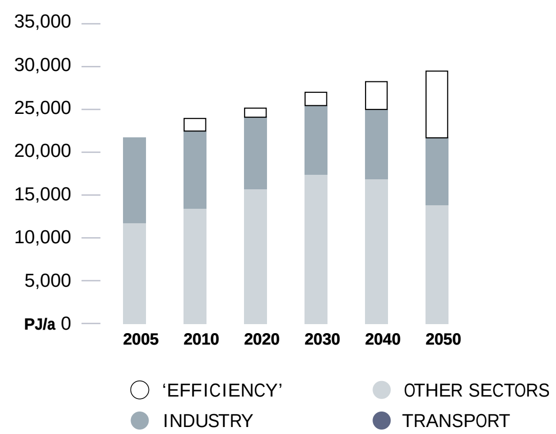


image SUN SETTING OFF THE GULF OF MEXICO.

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

oecd north america: 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, 94% of the electricity produced in OECD North America will come from renewable energy sources. 'New' renewables – mainly wind, solar thermal energy and PV – will contribute over 85% of electricity generation.

Figure 6.22 shows the comparative evolution of the different renewable technologies in OECD North America 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.

table 6.2: oecd north america: projection of renewable electricity generation capacity under the energy [r]evolution scenario

IN GW

	2005	2010	2020	2030	2040	2050
Hydro	187	192	217	230	239	246
Biomass	17	15	52	90	130	153
Wind	9	35	284	414	469	504
Geothermal	3	6	22	55	96	118
PV	0.04	2	77	227	410	577
Solarthermal	0.3	2	34	62	118	164
Ocean energy	0	0.6	5	15	34	51
Total	**217**	**263**	**693**	**1092**	**1496**	**1814**

figure 6.21: oecd north america: development of electricity generation structure under the two scenarios

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

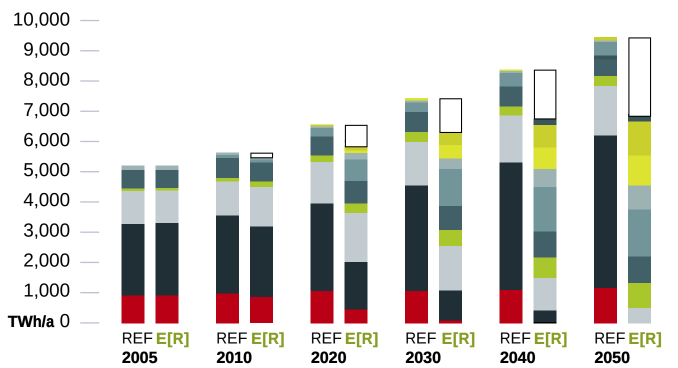
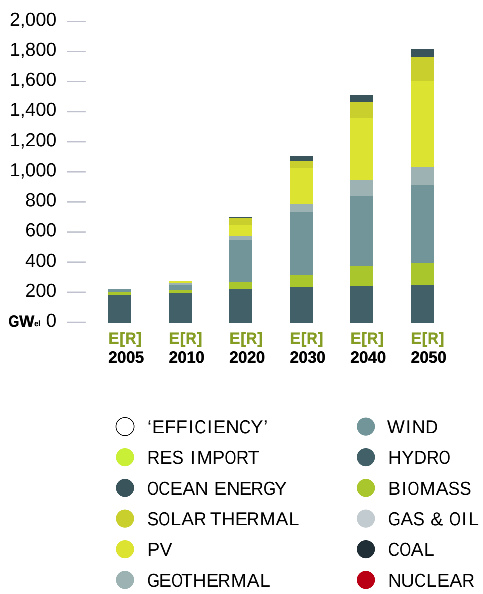


figure 6.22: oecd north america: growth of renewable electricity generation capacity under the energy [r]evolution scenario

BY INDIVIDUAL SOURCE



oecd north america

oecd north america: future costs of electricity generation

Figure 6.23 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 0.4 cents/kWh up to 2020. 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 5 cents/kWh below those in the Reference Scenario.

Under the Reference Scenario, on the other hand, unchecked growth in demand, the increase in fossil fuel prices and the cost of CO_2 emissions result in total electricity supply costs rising from today's $420 billion per year to more than $1,350 bn in 2050. Figure 6.24 shows that the Energy [R]evolution Scenario not only complies with OECD North America 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.

oecd north america: heat and cooling supply

Today, renewables provide 11% of North America's primary energy demand for heat supply, the main contribution coming from the use of biomass. The lack of district heating networks is a severe structural barrier to the large scale utilisation of geothermal and solar thermal energy. Dedicated support instruments are required to ensure a dynamic development.

In the Energy [R]evolution Scenario, renewables provide 69% of North America's total heating demand in 2050.

- Energy efficiency measures help to reduce the currently growing demand for heating and cooling, in spite of improving living standards.
- For direct heating, solar collectors, biomass/biogas as well as geothermal energy 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 6.23: oecd north america: development of specific electricity generation costs under the two scenarios

(CO₂ EMISSION COSTS IMPOSED FROM 2010, WITH AN INCREASE FROM 15 $/T$_{CO_2}$ IN 2010 TO 50 $/T$_{CO_2}$ IN 2050)

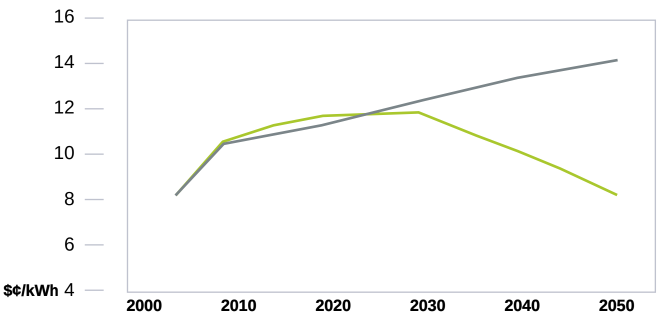


figure 6.24: oecd north america: development of total electricity supply costs

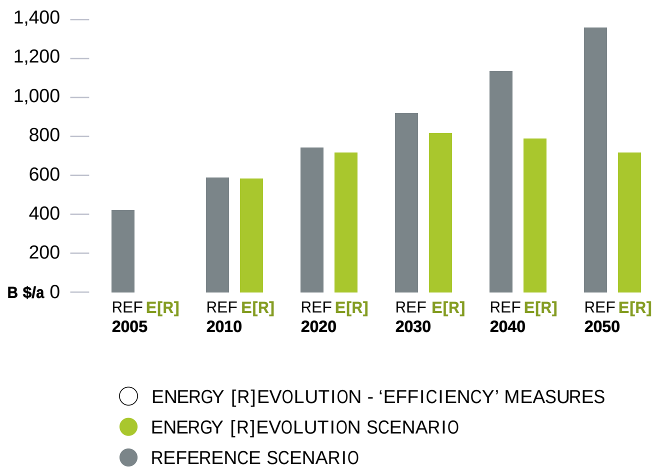


figure 6.25: oecd north america: development of heat supply structure under the two scenarios

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

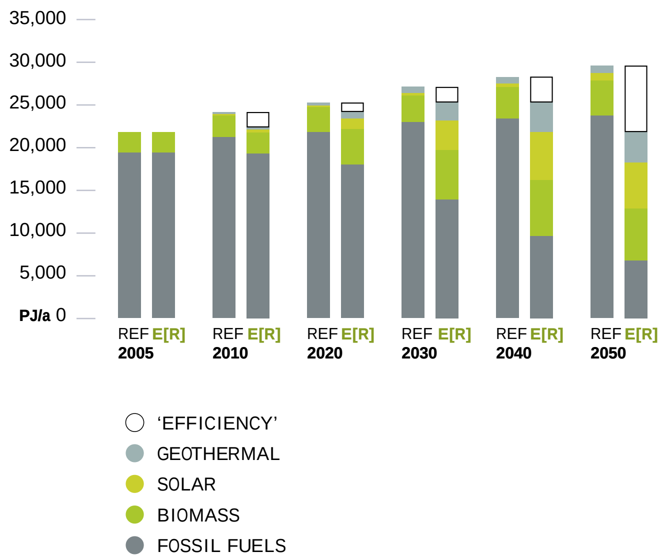


image CONCENTRATING SOLAR POWER (CSP) AT A SOLAR FARM IN DAGGETT, CALIFORNIA, USA.

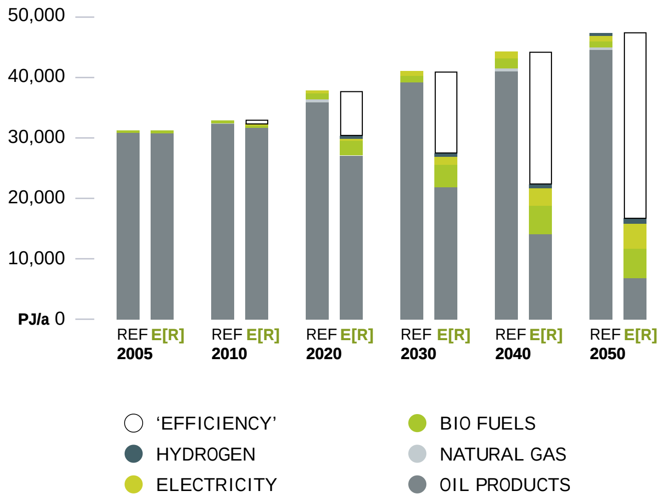
image AN OFFSHORE DRILLING RIG DAMAGED BY HURRICANE KATRINA, GULF OF MEXICO.

oecd north america: transport

A key initiative in North America is to introduce incentives to drive smaller cars, which today are virtually non-existant. In addition, a shift to efficient modes of transport like rail, light rail and bus is important, especially in the expanding large metropolitan areas. Together with the rising price of fossil fuels, these changes reduce the huge growth in car sales projected by the Reference Scenario. In the Energy [R]evolution Scenario, the car fleet still grows by 20% from the year 2000 to 2050. However the energy demand of the transport sector is reduced by 47%. Highly efficient propulsion technology, including hybrid, plug-in hybrid and battery-electric powertrains, will bring large efficiency gains. A quarter of the transport energy demand by 2050 is covered by electricity, 30% by bio fuels.

figure 6.26: oecd north america: transport under the two scenarios

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



oecd north america: development of CO_2 emissions

Whilst North America's emissions of CO_2 will increase by 42% under the Reference Scenario, under the Energy [R]evolution Scenario they will decrease from 6,430 million tonnes in 2005 to 1,060 m/t in 2050. Annual per capita emissions will drop from 14.7 tonnes to 1.8 t. In spite of the phasing out of nuclear energy and increasing demand, CO_2 emissions will decrease in the electricity sector. In the long run efficiency gains and the increased use of renewable electricity in the transport sector will even reduce CO_2 emissions there. With a share of 46% of total CO_2, the transport sector will be the largest source of emissions in 2050.

oecd north america: 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 6.27. Compared to the Reference Scenario, overall primary energy demand will be reduced by 53% in 2050. Around 66% of the remaining demand in North America will be covered by renewable energy sources.

figure 6.27: oecd north america: development of primary energy consumption under the two scenarios

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

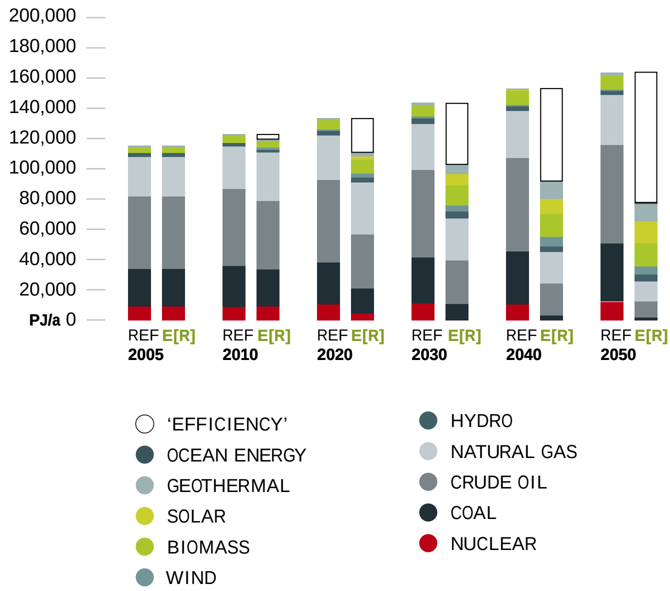
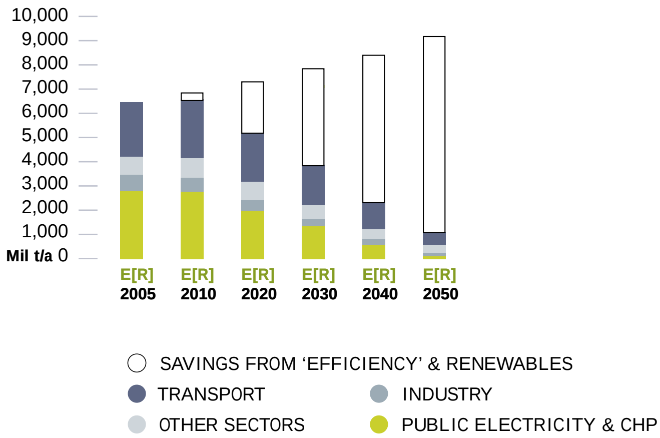


figure 6.28: oecd north america: development of CO_2 emissions by sector under the energy [r]evolution scenario ('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)



latin america

GLOBAL SCENARIO

OECD NORTH AMERICA
LATIN AMERICA
OECD EUROPE
AFRICA

MIDDLE EAST
TRANSITION ECONOMIES
INDIA

DEVELOPING ASIA
CHINA
OECD PACIFIC

latin america: energy demand by sector

Combining the projections on population development, GDP growth and energy intensity results in future development pathways for Latin America's energy demand. These are shown in Figure 6.29 for both the Reference and Energy [R]evolution Scenarios. Under the Reference Scenario, total primary energy demand more than doubles from the current 21,140 PJ/a to 52,300 PJ/a in 2050. In the Energy [R]evolution Scenario, a smaller 54% increase on current consumption is expected by 2050, reaching 32,500 PJ/a.

Under the Energy [R]evolution Scenario, electricity demand is expected to increase disproportionately, with households and services the main source of growing consumption. This is due to wider access to energy services in developing countries (see Figure 6.30). With the exploitation of efficiency measures, however, an even higher increase can be avoided, leading to electricity demand of around 2,150 TWh/a in 2050. Compared to the Reference Scenario, efficiency measures avoid the generation of about 660 TWh/a. This reduction can be achieved in particular by introducing highly efficient electronic devices. Employment of solar architecture in both residential and commercial buildings will help to curb the growing demand for air-conditioning.

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 6.31). Compared to the Reference Scenario, consumption equivalent to 2,400 PJ/a is avoided through efficiency gains by 2050. In the transport sector, it is assumed under the Energy [R]evolution Scenario that energy demand will increase by a fifth to 6,100 PJ/a by 2050, saving 50% compared to the Reference Scenario.

figure 6.29: latin america: projection of total final energy demand by sector for the two scenarios

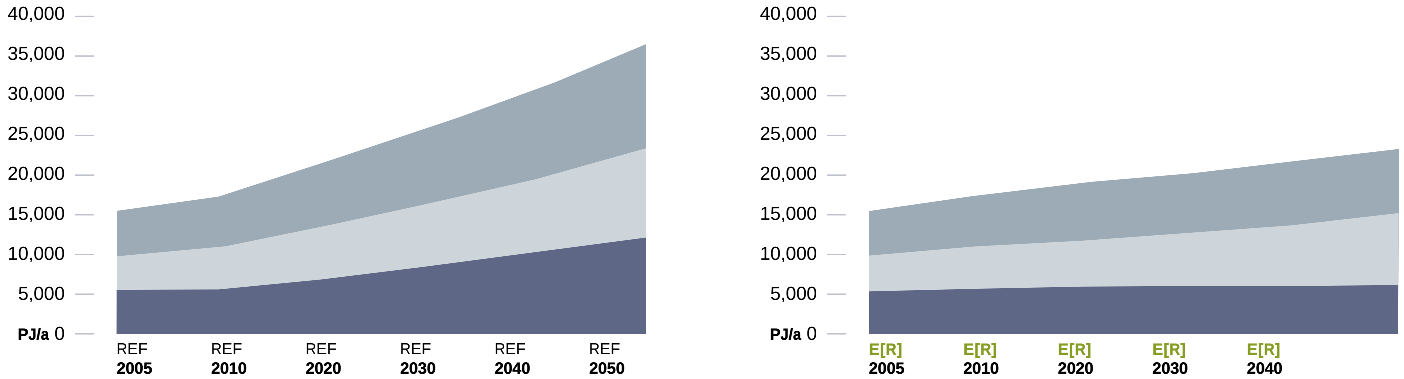


figure 6.30: latin america: development of electricity demand by sector

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

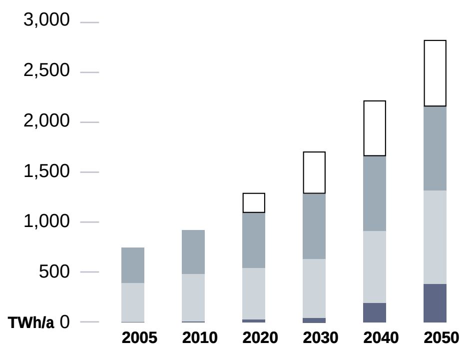


figure 6.31: latin america: development of heat demand by sector

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

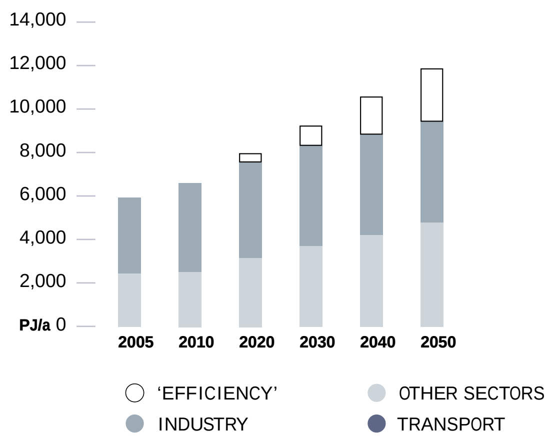


image VOLUNTEERS CHECK THE SOLAR PANELS ON TOP OF GREENPEACE POSITIVE ENERGY TRUCK, BRAZIL.

image WIND TURBINES IN FORTALEZ, CEARÀ, BRAZIL.

latin america: electricity generation

The development of the electricity supply sector is characterised by an increasing share of renewable electricity. By 2050, 95% of the electricity produced in Latin America will come from renewable energy sources. 'New' renewables – mainly wind, solar thermal energy and PV – will contribute more than 60% of electricity generation. The installed capacity of renewable energy technologies will grow from the current 139 GW to 695 GW in 2050 - increasing renewable capacity by a factor of five within the next 42 years.

Figure 6.33 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.

table 6.3: latin america: projection of renewable electricity generation capacity under the energy [r]evolution scenario

IN GW

	2005	2010	2020	2030	2040	2050
Hydro	135	159	167	171	174	179
Biomass	4	11	33	45	59	75
Wind	0.2	3	47	88	179	274
Geothermal	0.4	1	3	5	9	16
PV	0	0.5	10	57	79	114
Solarthermal	0	0	3	5	9	16
Ocean energy	0	0	0.6	1	3	7
Total	**139**	**174**	**264**	**372**	**515**	**695**

figure 6.32: latin america: development of electricity generation structure under the two scenarios

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

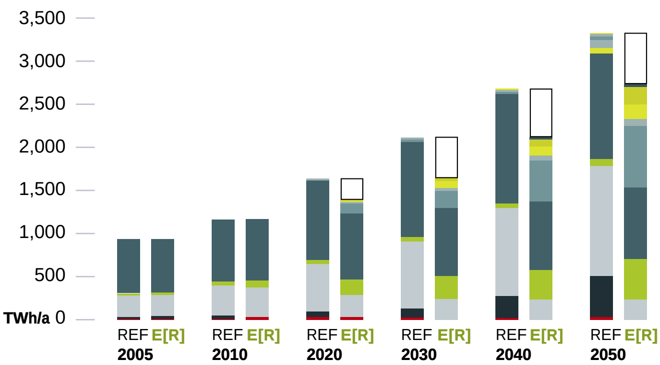
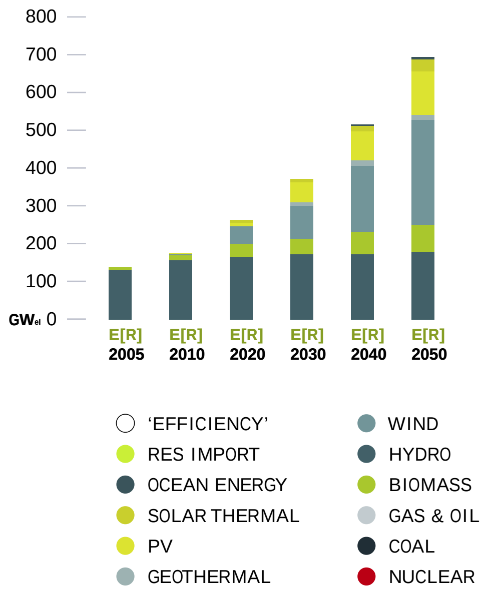


figure 6.33: latin america: growth of renewable electricity generation capacity under the energy [r]evolution scenario

BY INDIVIDUAL SOURCE



latin america

latin america: future costs of electricity generation

Figure 6.34 shows that the introduction of renewable technologies under the Energy [R]evolution Scenario significantly decreases the future costs of electricity generation compared to the Reference Scenario. Because of the lower CO_2 intensity of electricity generation, costs will become economically favourable under the Energy [R]evolution Scenario. By 2050 generation costs will be more than 8 cents/kWh below those in the Reference Scenario.

Under the Reference Scenario, on the other hand, unchecked growth in demand, the increase in fossil fuel prices and the cost of CO_2 emissions result in total electricity supply costs rising from today's $70 billion per year to more than $551 bn in 2050. Figure 6.35 shows that the Energy [R]evolution Scenario not only complies with Latin America's CO_2 reduction targets but also helps to stabilise energy costs and relieve the economic pressure on society. Increasing energy efficiency and shifting energy supply to renewables leads to long term costs for electricity supply that are one third lower than in the Reference Scenario.

latin america: heat and cooling supply

Today, renewables provide around 40% of primary energy demand for heat supply in Latin America, the main contribution coming from the use of biomass. The availability of less efficient but cheap appliances is a severe structural barrier to efficiency gains. Large-scale utilisation of geothermal and solar thermal energy for heat supply will be largely restricted to the industrial sector.

In the Energy [R]evolution Scenario, renewables provide 83% of Latin America's total heating and cooling demand in 2050.

- Energy efficiency measures restrict the future primary energy demand for heat and cooling supply to a 60% increase, in spite of improving living standards.
- In the industry sector solar collectors, biomass/biogas as well as geothermal energy are increasingly replacing conventional fossil fuel-fired heating systems.
- A shift from coal and oil to natural gas in the remaining conventional applications leads to a further reduction of CO_2 emissions.

figure 6.34: latin america: development of specific electricity generation costs under the two scenarios

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

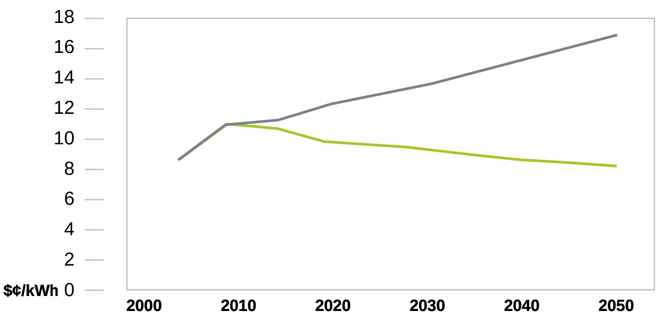


figure 6.35: latin america: development of total electricity supply costs

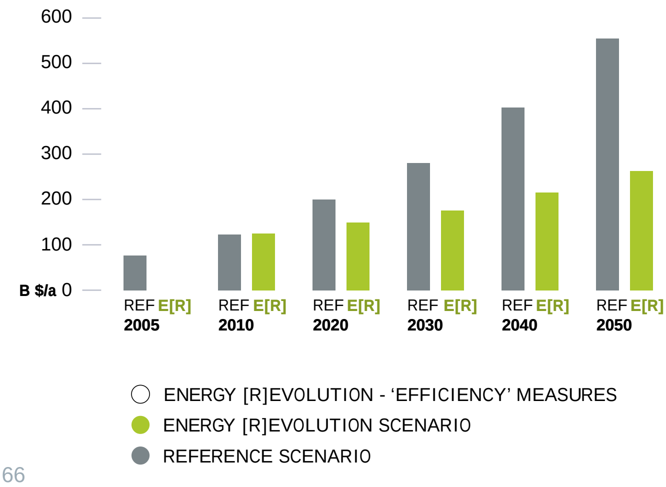


figure 6.36: latin america: development of heat supply structure under the two scenarios

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

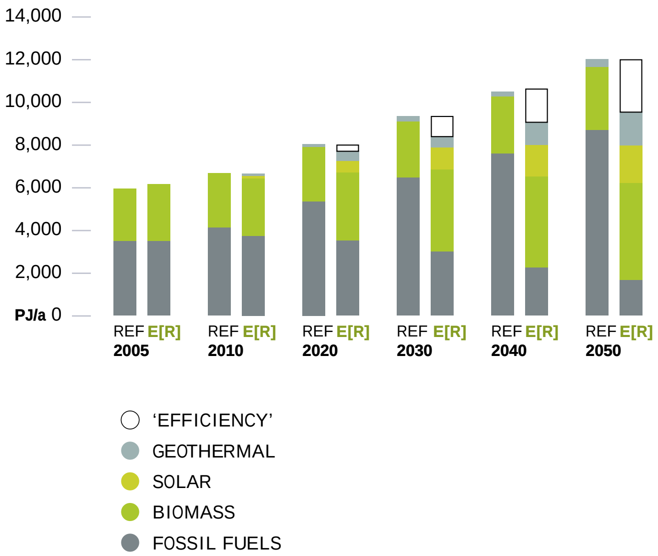


image GROUP OF YOUNG PEOPLE FEEL THE HEAT GENERATED BY A SOLAR COOKING STOVE IN BRAZIL.

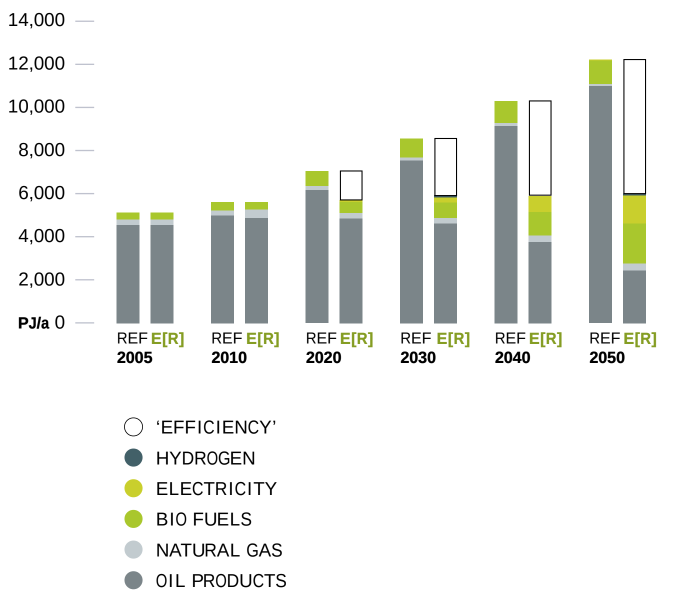
image IN 2005 THE WORST DROUGHT IN MORE THAN 40 YEARS DAMAGED THE WORLD'S LARGEST RAIN FOREST IN THE BRAZILIAN AMAZON, WITH WILDFIRES BREAKING OUT, POLLUTED DRINKING WATER AND THE DEATH OF MILLIONS FISH AS STREAMS DRY UP.

latin america: transport

Despite a huge growth in services, the increase in energy consumption in the transport sector by 2050 can be limited to 19% under the Energy [R]evolution Scenario. Current 90% dependency on fossil fuels is transformed into a 30% contribution from bio fuels and 22% from electricity. The market for cars will grow by a factor of five less than in the Reference Scenario. Measures are taken to keep the car sales split by segment like its present breakdown, with one third represented by medium-sized vehicles and more than half by small vehicles. Technological progress increases the share of hybrid vehicles to 65% in 2050. Incentives to use more efficient transport modes reduces vehicle kilometre travelled to in average 11.000 km per annum.

figure 6.37: latin america: transport under the two scenarios

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

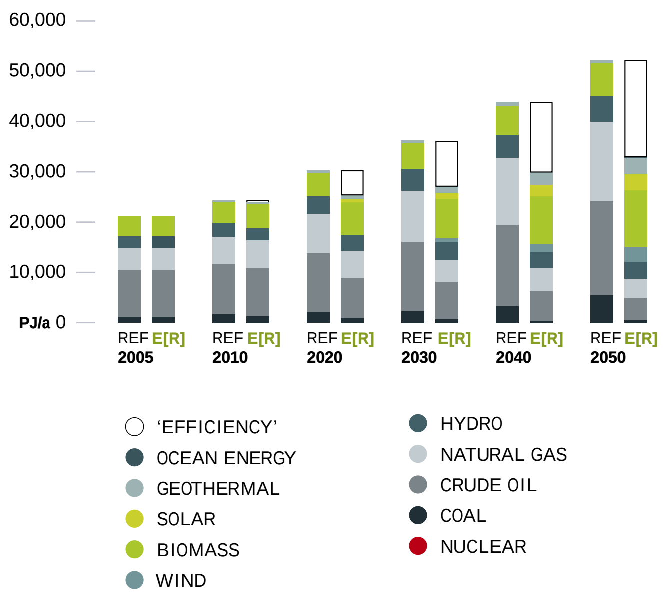


latin america: primary energy consumption

Taking into account the assumptions discussed above, the resulting primary energy consumption under the Energy [R]evolution Scenario is shown in Figure 6.38. Compared to the Reference Scenario, overall energy demand will be reduced by about 38% in 2050. Latin America's energy demand will increase from 21,000 PJ/a to 32,500 PJ/a. Around 70% of this will be covered by renewable energy sources.

figure 6.38: latin america: development of primary energy consumption under the two scenarios

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

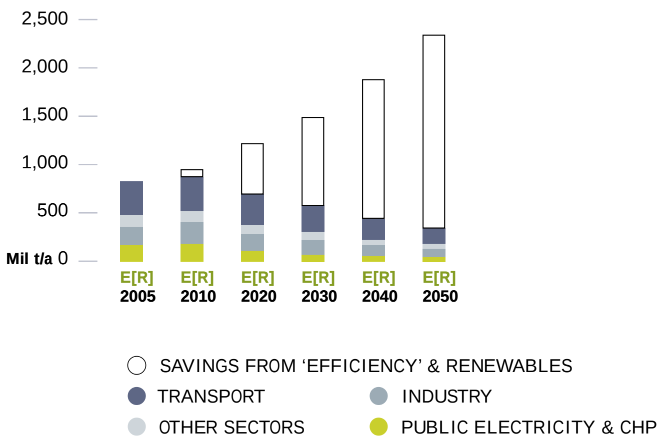


latin america: development of CO_2 emissions

Whilst Latin America's emissions of CO_2 will almost triple under the Reference Scenario, under the Energy [R]evolution Scenario they will decrease from 830 million tonnes in 2005 to 370 m/t in 2050. Annual per capita emissions will drop from 1.8 tonnes to 0.6 t. In spite of the phasing out of nuclear energy and increasing demand, CO_2 emissions will decrease in the electricity sector. In the long run efficiency gains and the increased use of renewable electricity in vehicles will even reduce CO_2 emissions in the transport sector. With a share of 53% of total CO_2 in 2050, the transport sector will remain the largest source of emissions.

figure 6.39: latin america: development of CO_2 emissions by sector under the energy [r]evolution scenario

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



oecd europe

GLOBAL SCENARIO

OECD NORTH AMERICA
LATIN AMERICA
OECD EUROPE
AFRICA

MIDDLE EAST
TRANSITION ECONOMIES
INDIA

DEVELOPING ASIA
CHINA
OECD PACIFIC

oecd europe: energy demand by sector

The future development pathways for Europe's energy demand are shown in Figure 6.40 for both the Reference and Energy [R]evolution Scenarios. Under the Reference Scenario, total primary energy demand in OECD Europe increases by more than 10% from the current 81,500 PJ/a to 90,300 PJ/a in 2050. In the Energy [R]evolution Scenario, demand decreases by 40% compared to current consumption, reaching 48,900 PJ/a by the end of the scenario period.

Under the Energy [R]evolution Scenario, electricity demand in all three sectors is expected to decrease after 2015 (see Figure 6.41). Because of the growing use of electric vehicles, however, electricity use for transport increases to 3,520 TWh/a in the year 2050. Compared to the Reference Scenario, efficiency measures avoid the generation of about 1,460 TWh/a. This reduction in energy demand can be achieved in particular by introducing highly efficient electronic devices using the best available technology.

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 6.42). Compared to the Reference Scenario, consumption equivalent to 7,350 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 new 'passive houses', enjoyment of the same comfort and energy services will be accompanied by a much lower future energy demand.

In the transport sector, it is assumed under the Energy [R]evolution Scenario that energy demand will decrease by almost half to 8700 PJ/a by 2050, saving 58% 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 6.40: oecd europe: projection of total final energy demand by sector for the two scenarios

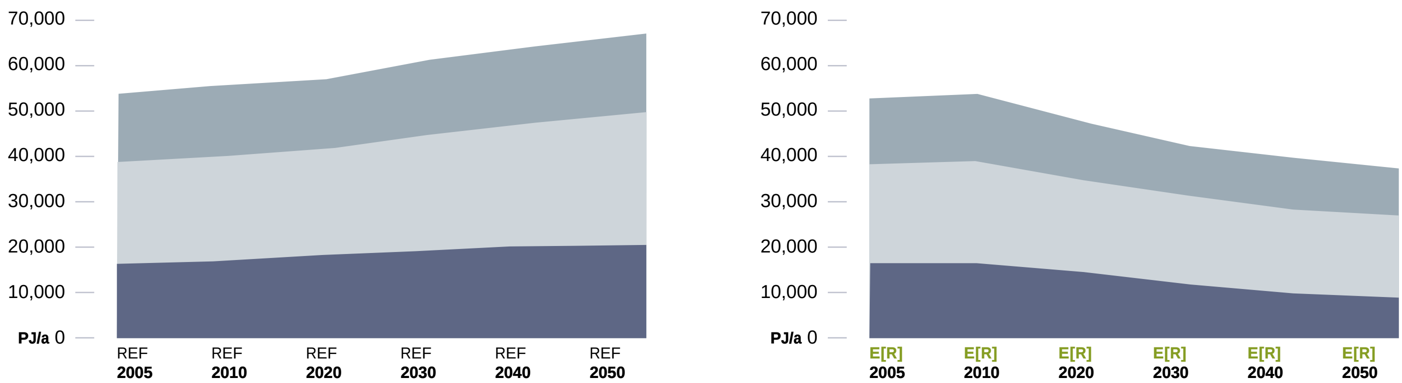


figure 6.41: oecd europe: development of electricity demand by sector

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

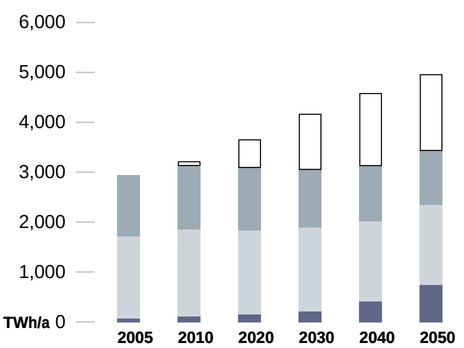


figure 6.42: oecd europe: development of heat demand by sector

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

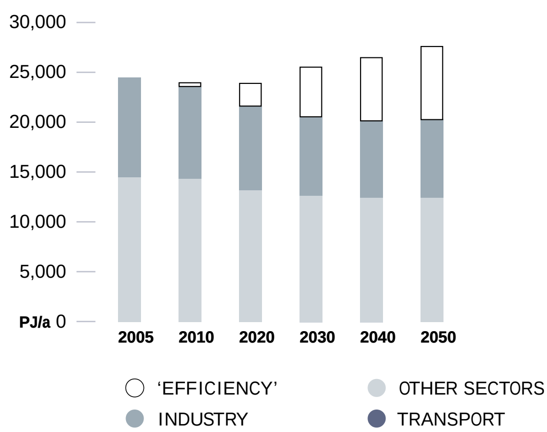


image OFFSHORE WINDFARM, MIDDELGRUNDEN, COPENHAGEN, DENMARK.

image MAN USING METAL GRINDER ON PART OF A WIND TURBINE MAST IN THE VESTAS FACTORY, CAMBELTOWN, SCOTLAND, GREAT BRITAIN.

oecd europe: electricity generation

The development of the electricity supply sector is characterised by a dynamically growing renewable energy market. 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, 86% of the electricity produced in OECD Europe will come from renewable energy sources. 'New' renewables – mainly wind, solar thermal energy and PV – will contribute 67%.

The installed capacity of renewable energy technologies will grow from the current 250 GW to 1,030 GW in 2050, increasing renewables capacity by a factor of four. Figure 6.44 shows the evolution of the different renewable technologies. 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.

None of these numbers describe a maximum feasibility, but a possible balanced approach. With the right policy development, the solar industry believes that a much further uptake could happen. This is particularly true for concentrated solar power (CSP) which could unfold to 30GW already by 2020 and more than 120GW in 2050. The photovoltaic industry believes in a possible electricity generation capacity of 350GW by 2020 in Europe alone, assuming the necessary policy changes.

table 6.4: oecd europe: projection of renewable electricity generation capacity under the energy [r]evolution scenario

IN GW

	2005	2010	2020	2030	2040	2050
Hydro	184	174	179	181	182	182
Biomass	22	37	61	69	82	88
Wind	42	87	215	254	309	333
Geothermal	1	1.5	3	8	18	26
PV	1.5	10	96	187	287	357
Solarthermal	0	0.7	9	17	27	31
Ocean energy	0	0	1	5	10	15
Total	**251**	**312**	**564**	**720**	**915**	**1033**

figure 6.43: oecd europe: development of electricity generation structure under the two scenarios

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

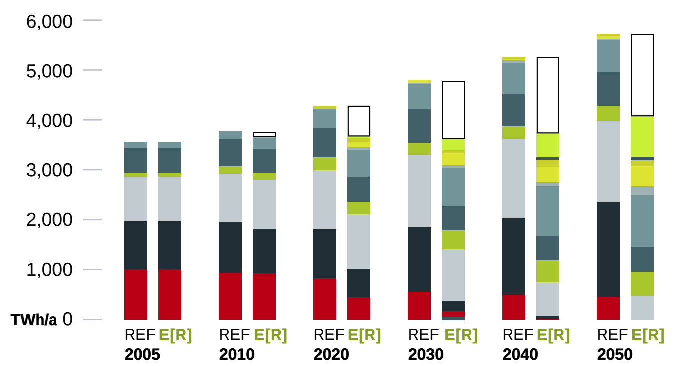
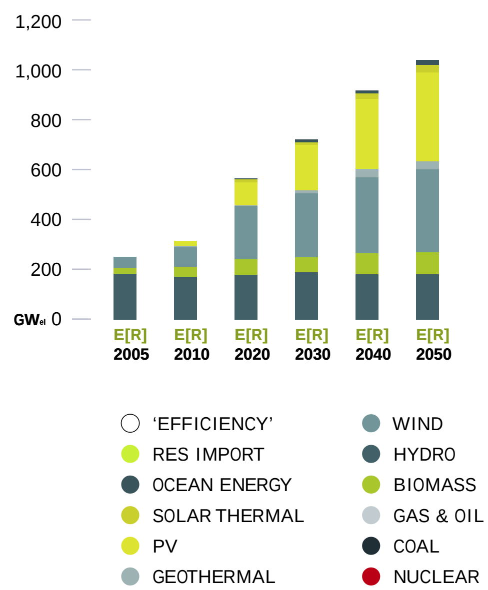


figure 6.44: oecd europe: growth of renewable electricity generation capacity under the energy [r]evolution scenario

BY INDIVIDUAL SOURCE



oecd europe

oecd europe: future costs of electricity generation

Figure 6.45 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 0.4 cents/kWh up to 2020, however. Because of the lower CO_2 intensity of electricity generation, electricity generation costs will become economically favourable under the Energy [R]evolution Scenario by 2020, and by 2050 costs will be more than 3 cents/kWh below those in the Reference Scenario.

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 $330 billion per year to more than $800 bn in 2050. Figure 6.46 shows that the Energy [R]evolution Scenario not only complies with OECD Europe 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.

figure 6.45: oecd europe: development of specific electricity generation costs under the two scenarios

(CO_2 EMISSION COSTS IMPOSED FROM 2010, WITH AN INCREASE FROM 15 $/$T_{CO_2}$ IN 2010 TO 50 $/$T_{CO_2}$ IN 2050)

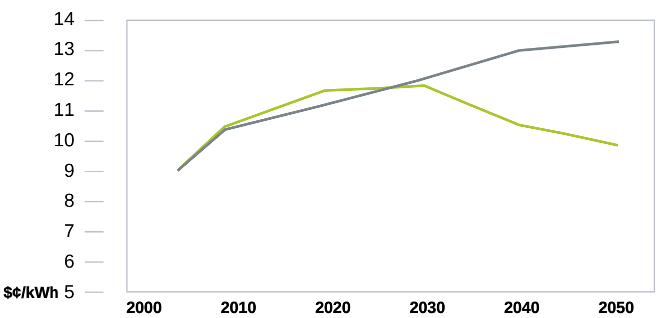
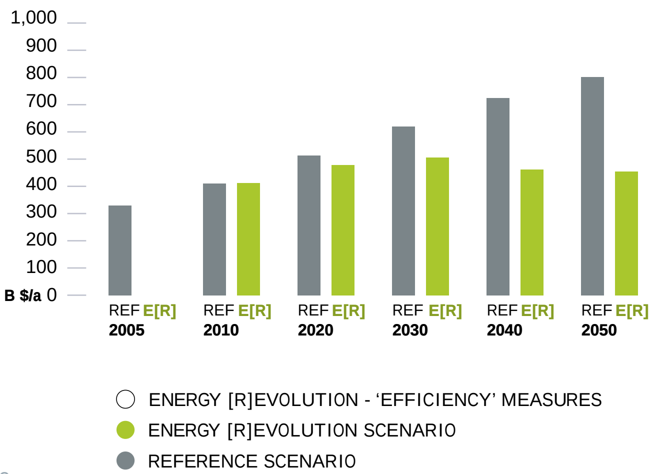


figure 6.46: oecd europe: development of total electricity supply costs



oecd europe: heat and cooling supply

Renewables currently provide 11% of OECD Europe's primary energy demand for heat supply, the main contribution coming from the use of biomass. The lack of district heating networks is a severe structural barrier to the large scale utilisation of geothermal and solar thermal energy.

In the Energy [R]evolution Scenario, renewables provide 61% of OECD Europe's total heating and cooling demand in 2050.

- Energy efficiency measures can decrease the current demand for heat supply by 18%, in spite of improving living standards.
- For direct heating, solar collectors, biomass/biogas as well as geothermal energy are increasingly substituting for fossil fuel-fired systems.

figure 6.47: oecd europe: development of heat supply structure under the two scenarios

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

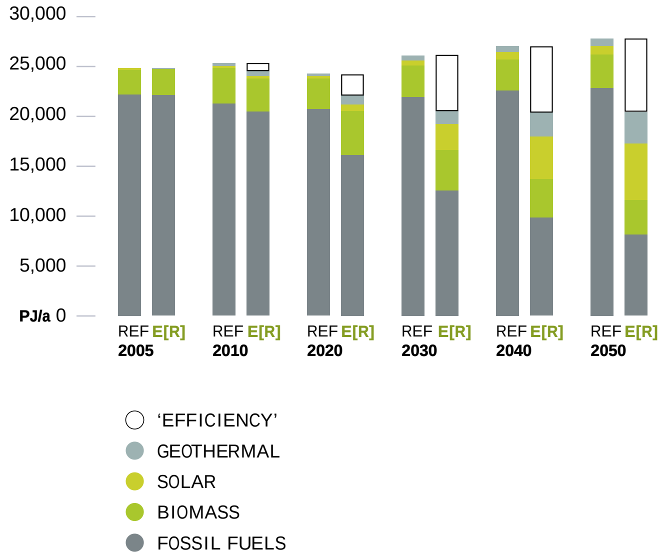


image PLANT NEAR REYKJAVIK WHERE ENERGY IS PRODUCED FROM THE GEOTHERMAL ACTIVITY.

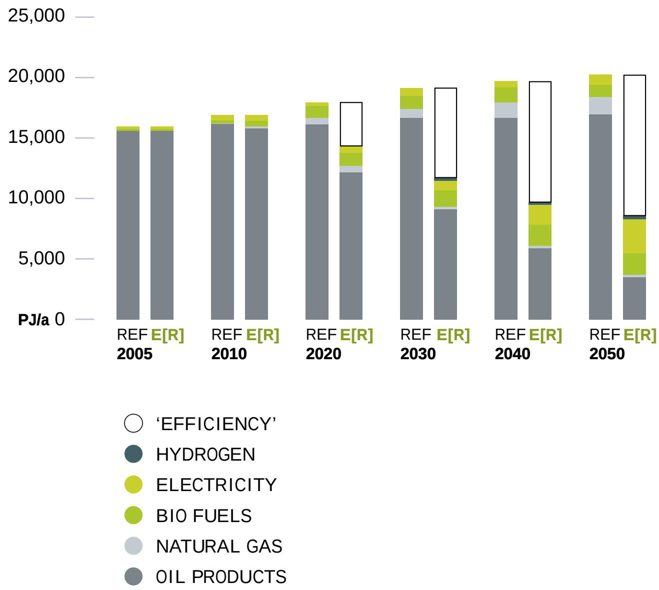
image WORKERS EXAMINE PARABOLIC TROUGH COLLECTORS IN THE PS10 SOLAR TOWER PLANT AT SAN LUCAR LA MAYOR OUTSIDE SEVILLE, SPAIN, 2008.

oecd europe: transport

In the transport sector, it is assumed under the Energy [R]evolution Scenario that energy demand will decrease by almost half to 8,700 PJ/a by 2050, saving 57% 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 behaviour patterns. By implementing attractive alternatives to individual cars, the car fleet will grow more slowly than in the Reference Scenario, reaching 235 million cars in 2050. A slight shift towards smaller cars - triggered by economic incentives coupled with a significant move towards electrified power trains and a reduction of vehicle kilometres travelled by 0.25% per year - leads to 60% final energy savings. In 2050, electricity will provide 35% of the transport sector's total energy demand, while 21% of the demand will be covered by bio fuels.

figure 6.48: oecd europe: transport under the two scenarios

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



oecd europe: development of CO_2 emissions

While CO_2 emissions in OECD Europe will increase by 12% under the Reference Scenario by 2050, in the Energy [R]evolution Scenario they will decrease from 4,060 million tonnes in 2005 to 880 m/t in 2050. Annual per capita emissions will drop from 7.6 tonnes to 1.6 t. In spite of the phasing out of nuclear energy and increasing demand, CO_2 emissions will decrease in the electricity sector. In the long run efficiency gains and the increased use of renewable electricity in vehicles will reduce emissions in the transport sector. With a share of 14% of total CO_2 in 2050, the power sector will drop below transport as the largest source of emissions.

oecd europe: 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 6.49. Compared to the Reference Scenario, overall energy demand will be reduced by 46% in 2050. Around 60% of the remaining demand will be covered by renewable energy sources.

figure 6.49: oecd europe: development of primary energy consumption under the two scenarios

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

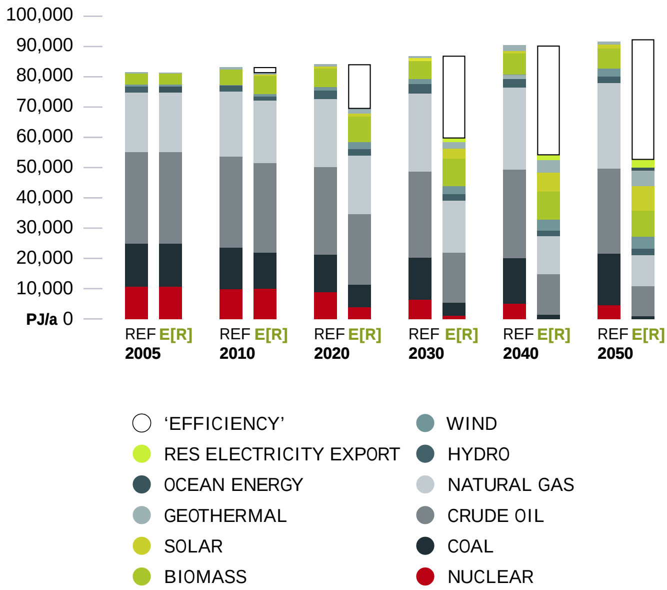
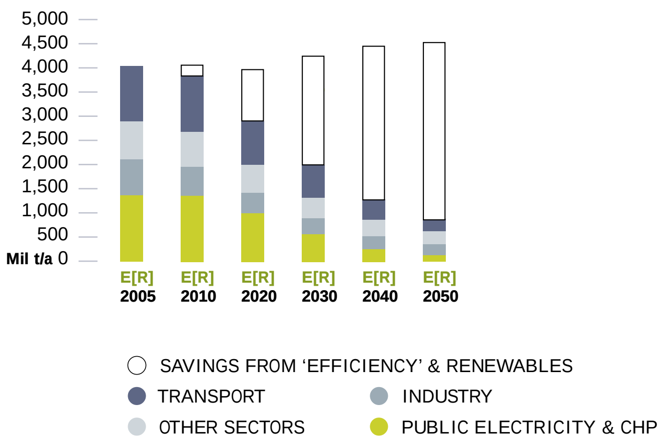


figure 6.50: oecd europe: development of CO_2 emissions by sector under the energy [r]evolution scenario

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



africa

GLOBAL SCENARIO

OECD NORTH AMERICA
LATIN AMERICA
OECD EUROPE
AFRICA

MIDDLE EAST
TRANSITION ECONOMIES
INDIA

DEVELOPING ASIA
CHINA
OECD PACIFIC

africa: energy demand by sector

Future development pathways for Africa's energy demand are shown in Figure 6.51 for both the Reference and Energy [R]evolution Scenarios. Under the Reference Scenario, total primary energy demand more than doubles from the current 25,200 PJ/a to 53,300 PJ/a in 2050. In the Energy [R]evolution Scenario, a much smaller 50% increase on current consumption is expected by 2050 to reach 38,300 PJ/a.

Under the Energy [R]evolution Scenario, electricity demand in Africa is expected to increase disproportionately, with households and services the main source of growing consumption (see Figure 6.52). With the exploitation of efficiency measures, however, an even higher increase can be avoided, leading to electricity demand of around 1,340 TWh/a in the year 2050. Compared to the Reference Scenario, efficiency measures avoid the generation of about 620 TWh/a.

Efficiency gains in the heat supply sector are also significant. Under the Energy [R]evolution Scenario, final demand for heat supply can even be reduced (see Figure 6.53). Compared to the Reference Scenario, consumption equivalent to 550 PJ/a is avoided through efficiency gains by 2050.

In the transport sector, it is assumed under the Energy [R]evolution Scenario that energy demand will almost double to 5,300 PJ/a by 2050, still saving 46% 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.

figure 6.51: africa: projection of total final energy demand by sector for the two scenarios

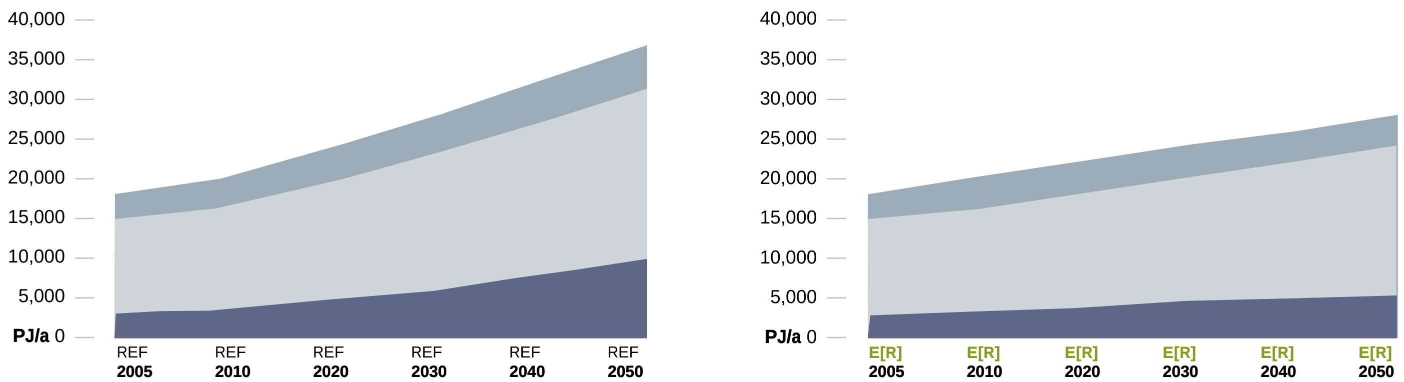


figure 6.52: africa: development of electricity demand by sector

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

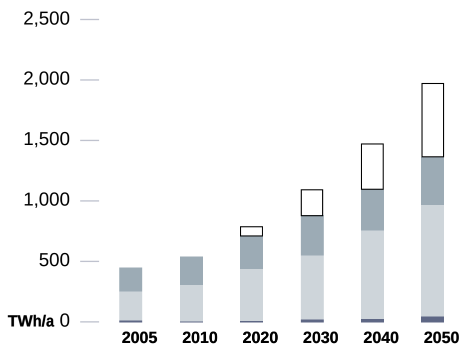


figure 6.53: africa: development of heat demand by sector

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

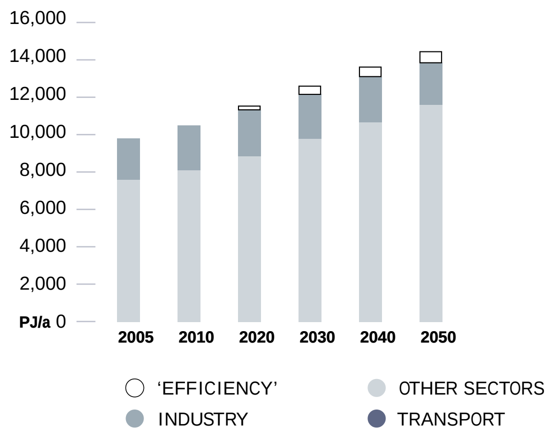
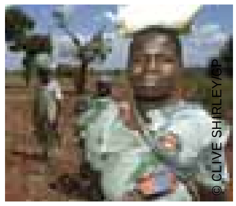


image GARIEP DAM, FREE STATE, SOUTH AFRICA.

image WOMEN FARMERS FROM LILONGWE, MALAWI STAND IN THEIR DRY, BARREN FIELDS CARRYING ON THEIR HEADS AID ORGANISATION HANDOUTS. THIS AREA, THOUGH EXTREMELY POOR HAS BEEN SELF-SUFFICIENT WITH FOOD. NOW THESE WOMEN'S CHILDREN ARE SUFFERING FROM MALNUTRITION.



africa: 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. By 2050, 73% of the electricity produced in Africa will come from renewable energy sources. A main driver for the development of solar power generation capacities will be the export of solar electricity to OECD Europe. 'New' renewables – mainly wind, solar thermal energy and PV – will contribute more than 60% of electricity generation.

The installed capacity of renewable energy technologies will grow from the current 21 GW to 388 GW in 2050, increasing renewable capacity by a factor of 18 over the next 42 years. More than 60 GW CSP plants will produce electricity for export to Europe.

Figure 6.55 shows the comparative evolution of 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.

table 6.5: africa: projection of renewable electricity generation capacity under the energy [r]evolution scenario

IN GW

	2005	2010	2020	2030	2040	2050
Hydro	21	24	30	34	39	45
Biomass	0.1	0.6	3	5	7	8
Wind	0.4	1.4	10	21	31	51
Geothermal	0.1	0.2	1	3	4	6
PV	0	0.5	8	55	105	175
Solarthermal	0	1	10	14	58	100
Ocean energy	0	0	0.6	2	3	4
Total	**21**	**28**	**62**	**134**	**246**	**388**

figure 6.54: africa: development of electricity generation structure under the two scenarios

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

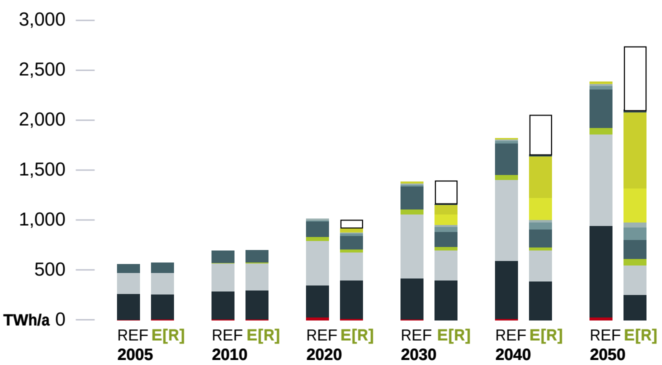
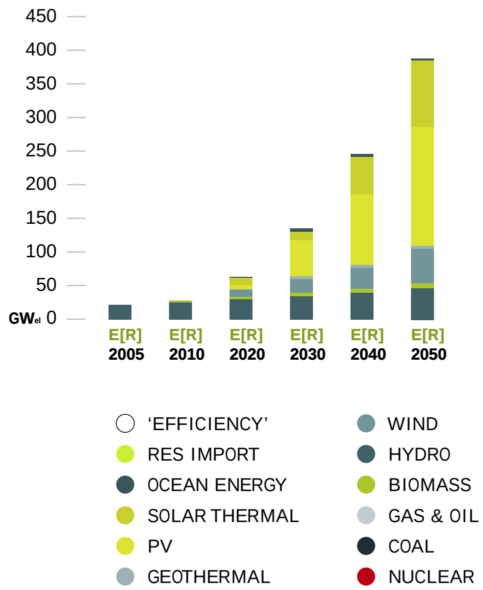


figure 6.55: africa: growth of renewable electricity generation capacity under the energy [r]evolution scenario

BY INDIVIDUAL SOURCE



africa

GLOBAL SCENARIO

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AFRICA

MIDDLE EAST
TRANSITION ECONOMIES
INDIA

DEVELOPING ASIA
CHINA
OECD PACIFIC

africa: future costs of electricity generation

Figure 6.56 shows that the introduction of renewable technologies under the Energy [R]evolution Scenario significantly decreases the future costs of electricity generation. Because of the lower CO_2 intensity, electricity generation costs will steadily become more economic under the Energy [R]evolution Scenario and by 2050 will be more than 9 cents/kWh below those in the Reference Scenario.

Under the Reference Scenario, by contrast, unchecked demand growth, the increase in fossil fuel prices and the cost of CO_2 emissions result in total electricity supply costs rising from today's $59 billion per year to more than $468 bn in 2050. Figure 6.57 shows that the Energy [R]evolution Scenario not only complies with Africa's CO_2 reduction targets but also helps to stabilise energy costs. 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.

figure 6.56: africa: development of specific electricity generation costs under the two scenarios

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

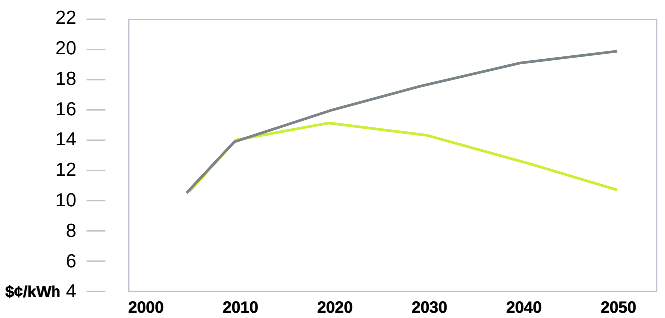
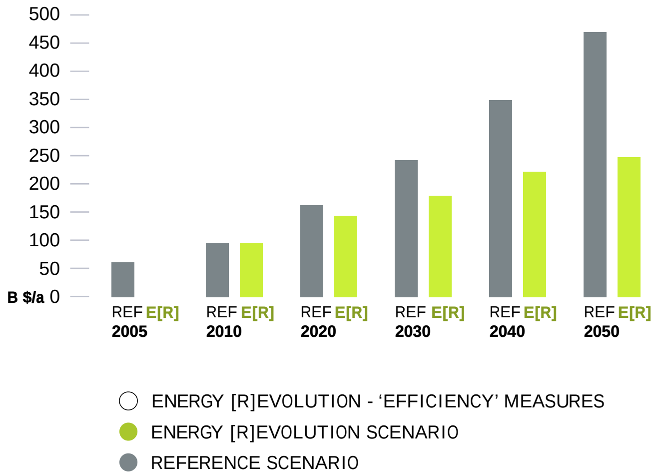


figure 6.57: africa: development of total electricity supply costs



africa: heat and cooling supply

Today, renewables provide around 75% of primary energy demand for heat supply in Africa, the main contribution coming from the use of biomass. The availability of less efficient but cheap appliances is a severe structural barrier to efficiency gains. Large-scale utilisation of geothermal and solar thermal energy for heat supply is restricted to the industrial sector. Dedicated support instruments are required to ensure a continuously dynamic development of renewables in the heat market.

In the Energy [R]evolution Scenario, renewables provide 72% of Africa's total heating and cooling demand in 2050.

- Energy efficiency measures can restrict the future energy demand for heat and cooling supply to a 50% increase, in spite of improving living standards.
- In the industry sector solar collectors, biomass/biogas as well as geothermal energy are increasingly substituting for conventional fossil-fired heating systems.
- A shift from coal and oil to natural gas in the remaining conventional applications leads to a further reduction of CO_2 emissions.

figure 6.58: africa: development of heat supply structure under the two scenarios

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

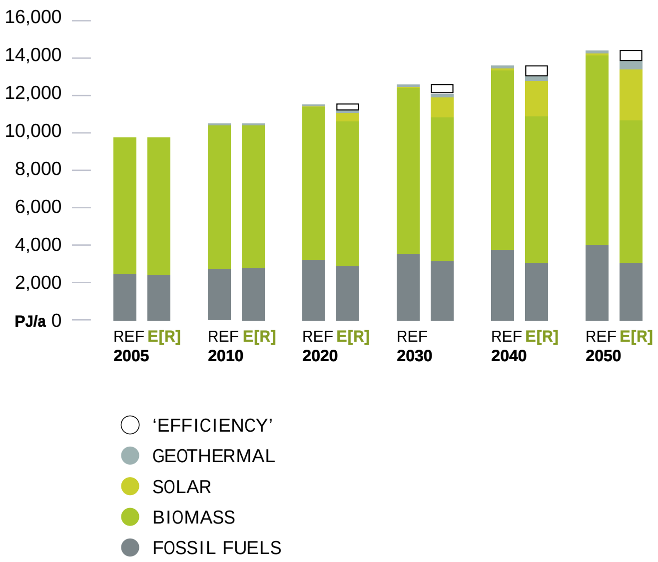
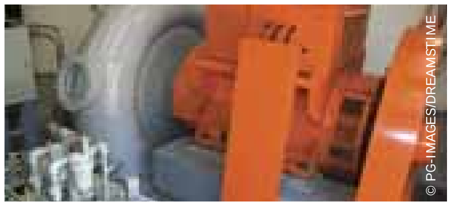


image FLOWING WATERS OF THE TUGELA RIVER IN NORTHERN DRAKENSBERG IN SOUTH AFRICA.

image A SMALL HYDRO ELECTRIC ALTERNATOR MAKES ELECTRICITY FOR A SMALL AFRICAN TOWN.

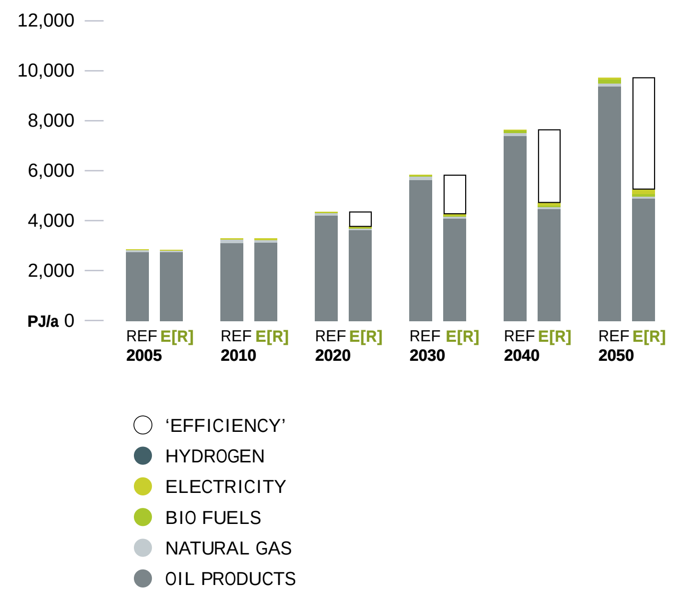


africa: transport

In the transport sector, it is assumed under the Energy [R]evolution Scenario that energy demand will almost double to 5,300 PJ/a by 2050, still saving 46% 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. The African car fleet is projected to grow by a factor of 6 to roughly 100 million vehicles. Development of fuel efficiency is delayed by 20 years compared to other world regions for economic reasons. By 2050, Africa will still have the lowest average fuel consumption.

figure 6.59: africa: transport under the two scenarios

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

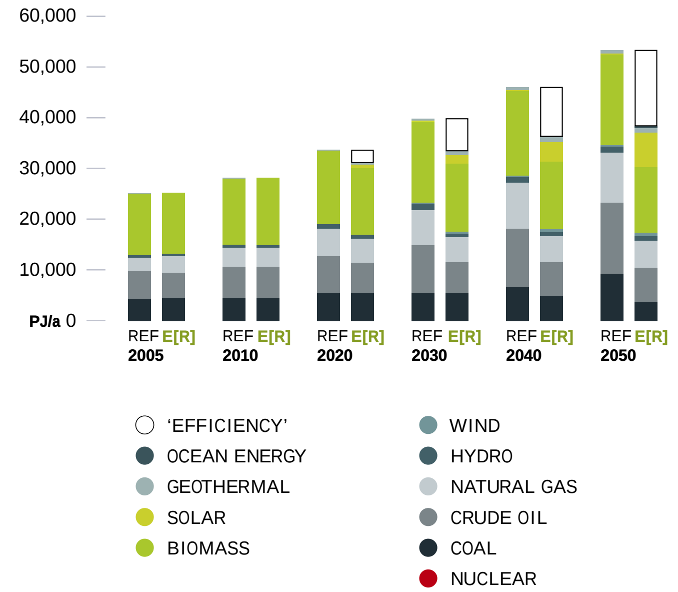


africa: primary energy consumption

Taking into account the assumptions discussed above, the resulting primary energy consumption under the Energy [R]evolution Scenario is shown in Figure 6.60. Compared to the Reference Scenario, overall energy demand will be reduced by about 30% in 2050. Under the Energy [R]evolution Scenario, Africa's energy demand will increase from 25,200 PJ/a to 38,300 PJ/a in 2050. Around 56% of this demand will be covered by renewable energy sources.

figure 6.60: africa: development of primary energy consumption under the two scenarios

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

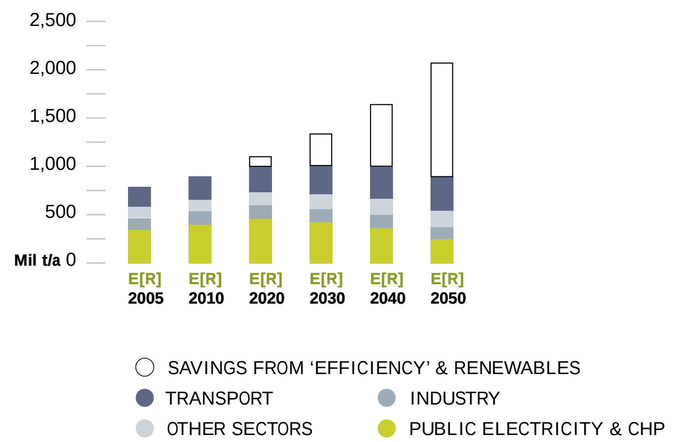


africa: development of CO_2 emissions

While Africa's emissions of CO_2 will almost triple under the Reference Scenario, under the Energy [R]evolution Scenario they will increase from 780 million tonnes in 2003 to 895 m/t in 2050. Annual per capita emissions will drop from 0.8 tonnes to 0.45 t. In spite of increasing demand, CO_2 emissions will decrease in the electricity sector. In the long run efficiency gains and the increased use of bio fuels and electricity will reduce CO_2 emissions in the transport sector. With a share of 28% of total CO_2 in 2050, the power sector will drop below transport as the largest source of emissions.

figure 6.61: africa: development of CO_2 emissions by sector under the energy [r]evolution scenario

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



middle east

middle east: energy demand by sector

The future development pathways for the Middle East's energy demand are shown in Figure 6.62 for both the Reference and Energy [R]evolution Scenarios. Under the Reference Scenario, total primary energy demand more than doubles from the current 21,400 PJ/a to 54,980 PJ/a in 2050. In the Energy [R]evolution Scenario, a much smaller 28% increase on current consumption is expected by 2050, reaching 27,600 PJ/a.

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 6.63), leading to an electricity demand of around 1,620 TWh/a in the year 2050. Compared to the Reference Scenario, efficiency measures avoid the generation of about 390 TWh/a.

Efficiency gains in the heat supply sector are even larger. Under the Energy [R]evolution Scenario (see Figure 6.64), consumption equivalent to 2,650 PJ/a is avoided through efficiency gains by 2050.

In the transport sector, it is assumed under the Energy [R]evolution Scenario that energy demand will be slightly reduced compared to today's level, reaching 3,990 PJ/a by 2050, a saving of 49% 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 6.62: middle east: projection of total final energy demand by sector for the two scenarios

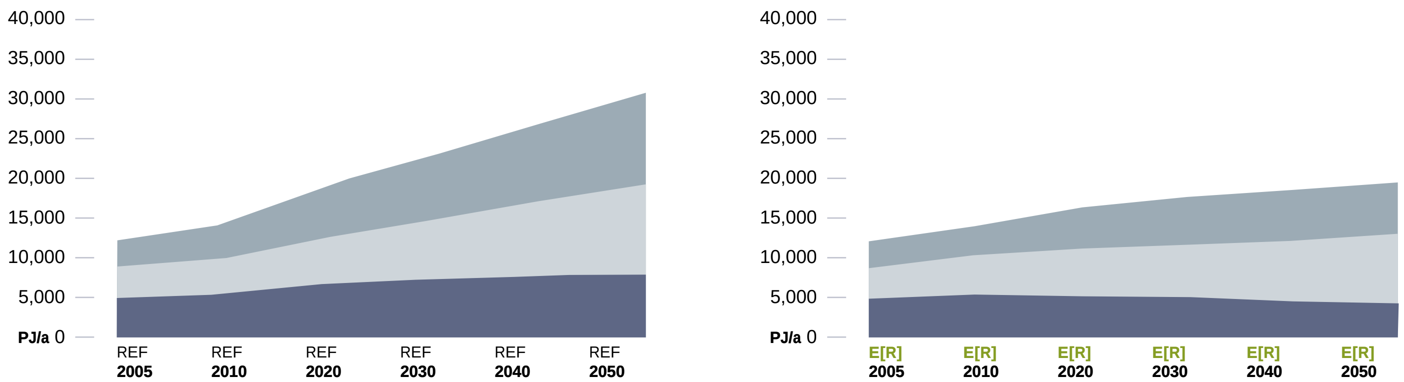


figure 6.63: middle east: development of electricity demand by sector

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

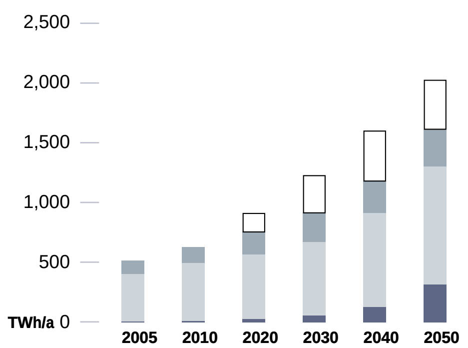


figure 6.64: middle east: development of heat demand by sector

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

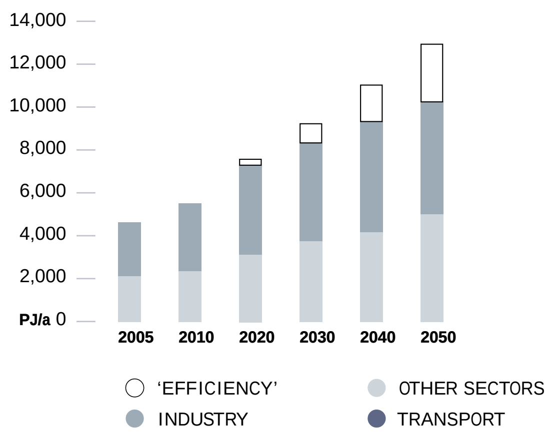


image A LARGE POWER PLANT ALONG THE ROCKY COASTLINE IN CAESAREA, ISRAEL.

image WIND TURBINES IN THE GOLAN HEIGHTS IN ISRAEL.

middle east: electricity generation

The development of the electricity supply sector is characterised by an increasing share of renewable electricity. By 2050, 95% of the electricity produced in the Middle East will come from renewable energy sources. 'New' renewables – mainly wind, solar thermal energy and PV – will contribute about 90% of electricity generation.

The installed capacity of renewable energy technologies will grow from the current 10 GW to 556 GW in 2050, a very large increase over the next 42 years requiring political support and well-designed policy instruments. Figure 6.66 shows the comparative evolution of the different technologies over the period up to 2050.

table 6.6: middle east: projection of renewable electricity generation capacity under the energy [r]evolution scenario IN GW

	2005	2010	2020	2030	2040	2050
Hydro	10	12	18	20	20	20
Biomass	0	0.4	3	4	6	8
Wind	0	0.9	25	61	72	87
Geothermal	0	0	2	5	8	12
PV	0	0.3	3	31	128	233
Solarthermal	0	0.8	10	48	100	194
Ocean energy	0	0	0	0	1	1
Total	**10**	**14**	**62**	**168**	**335**	**556**

figure 6.65: middle east: development of electricity generation structure under the two scenarios

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

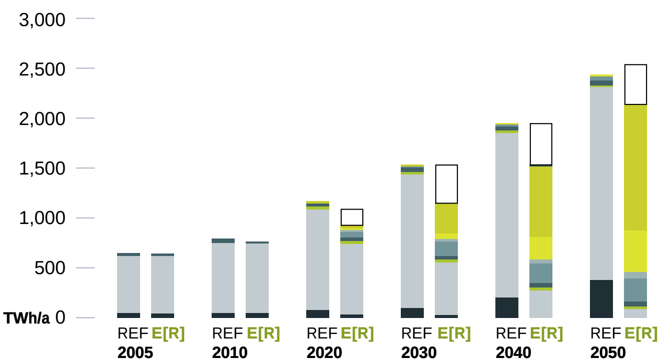
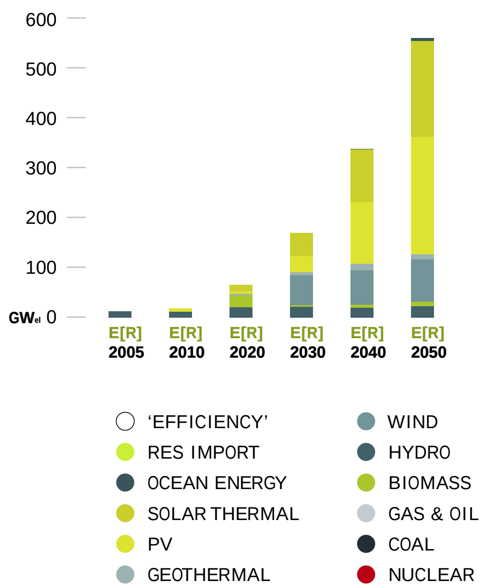


figure 6.66: middle east: growth of renewable electricity generation capacity under the energy [r]evolution scenario

BY INDIVIDUAL SOURCE



middle east

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middle east: future costs of electricity generation

Figure 6.67 shows that the introduction of renewable technologies under the Energy [R]evolution Scenario will lead to a significant reduction of electricity generation costs. Under the Reference Scenario, on the other hand, the unchecked growth in demand, increase in fossil fuel prices and the cost of CO_2 emissions result in total electricity supply costs rising from today's $133 billion per year to more than $870 bn in 2050. Figure 6.68 shows that the Energy [R]evolution Scenario not only meets the Middle East's CO_2 reduction targets but also helps to stabilise energy costs. Long term costs for electricity supply are one third lower than in the Reference Scenario.

middle east: heat and cooling supply

Renewables currently provide only 1% of primary energy demand for heat and cooling in the Middle East, the main contribution coming from the use of biomass and solar collectors. Dedicated support instruments are required to ensure a continuously dynamic development of renewables in the heat market.

In the Energy [R]evolution Scenario, renewables satisfy 83% of the Middle East's total heating and cooling demand in 2050.

- Energy efficiency measures can restrict the future primary energy demand for heat and cooling supply to a doubling rather than tripling, in spite of improving living standards.
- In the industry sector solar collectors, biomass/biogas as well as geothermal energy are increasingly substituting for conventional fossil-fired heating systems.

figure 6.67: middle east: development of specific electricity generation costs under the two scenarios

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

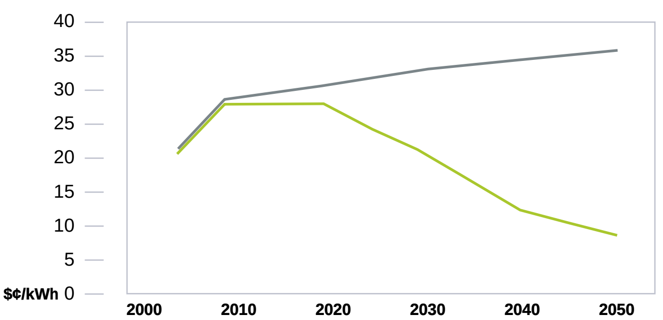


figure 6.68: middle east: development of total electricity supply costs

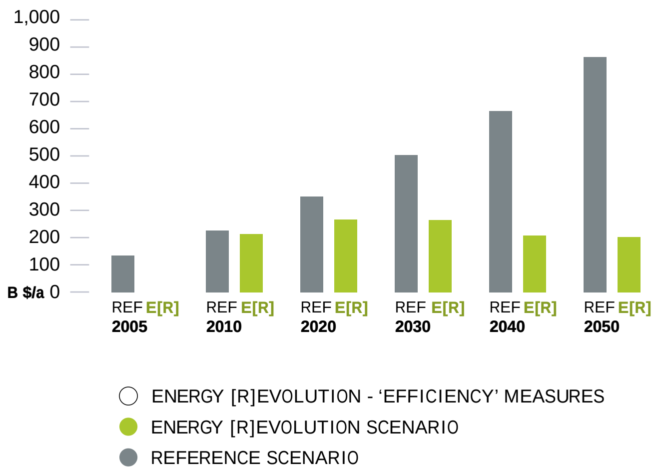


figure 6.69: middle east: development of heat supply structure under the two scenarios

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

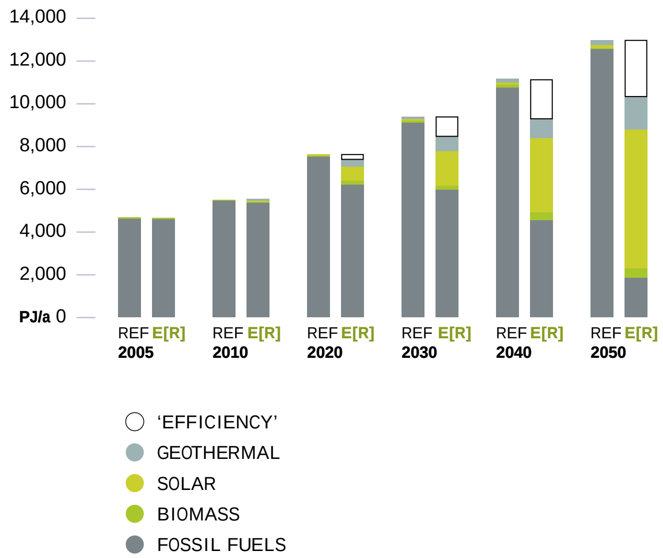
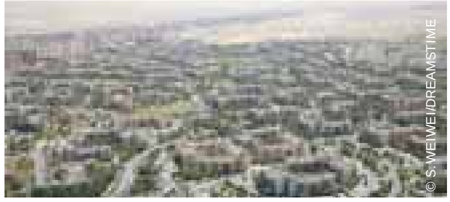


image THE BAHRAIN WORLD TRADE CENTER IN MANAMA GENERATES PART OF ITS OWN ENERGY USING WIND TURBINES.

image SUBURBS OF DUBAI, UNITED ARAB EMIRATES.



middle east: transport

Traditionally, in a region with major oil resources, transport has been powered 100% by fossil fuels. Rising prices, together with other incentives, lead to a projected share of 27% of renewable electricity in this sector. Highly efficient electrified cars – plug-in-hybrid and battery vehicles – contribute to a total energy saving of 16%, although the car fleet is still projected to grow by a factor of 5 by 2050. The further promotion of energy efficient transport modes will help to reduce annual vehicle kilometres travelled by 0.25% p.a.

middle east: primary energy consumption

Taking into account these assumptions, the resulting primary energy consumption under the Energy [R]evolution Scenario is shown in Figure 6.71. Compared to the Reference Scenario, overall energy demand will be reduced by more than 50% in 2050., so the Middle East's demand will increase from 21,420 PJ/a to just 27,590 PJ/a. Over 62% of this will be covered by renewable energy sources.

figure 6.70: middle east: transport under the two scenarios

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

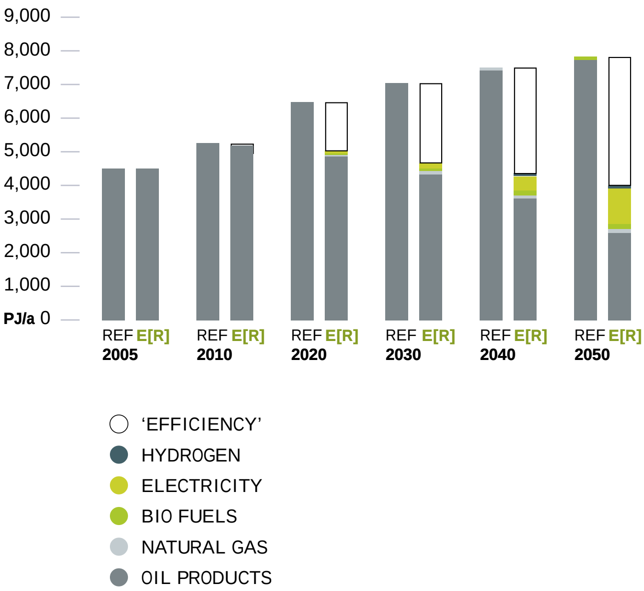
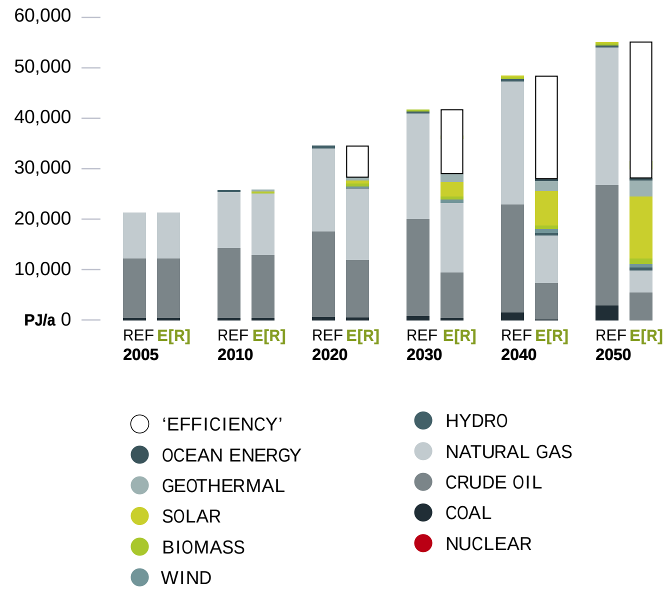


figure 6.71: middle east: development of primary energy consumption under the two scenarios

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

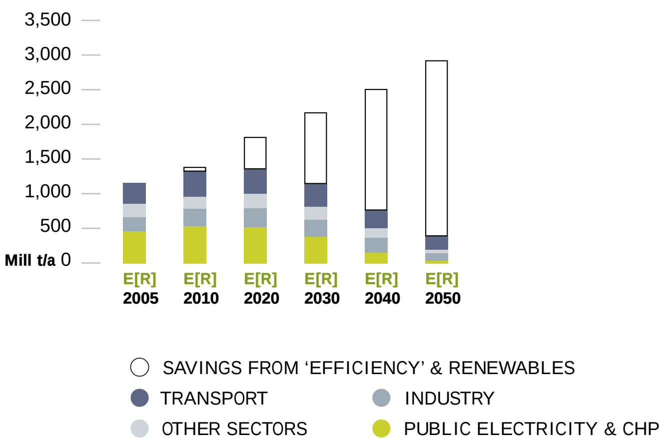


middle east: development of CO_2 emissions

While CO_2 emissions in the Middle East will triple under the Reference Scenario by 2050, and are thus far removed from a sustainable development path, under the Energy [R]evolution Scenario they will decrease from 1,170 million tonnes in 2005 to 390 m/t in 2050. Annual per capita emissions will drop from 6.2 tonnes/capita to 1.1 t. In spite of an increasing electricity demand, CO_2 emissions will decrease strongly in the electricity sector. In the long run efficiency gains and the increased use of renewable electricity in vehicles will even reduce CO_2 emissions in the transport sector.

figure 6.72: middle east: development of CO_2 emissions by sector under the energy [r]evolution scenario

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



transition economies

GLOBAL SCENARIO
OECD NORTH AMERICA
LATIN AMERICA
OECD EUROPE
AFRICA
MIDDLE EAST
TRANSITION ECONOMIES
INDIA
DEVELOPING ASIA
CHINA
OECD PACIFIC

transition economies: energy demand by sector

Future development pathways for energy demand in the Transition Economies are shown in Figure 6.73 for both the Reference and Energy [R]evolution Scenarios. Under the Reference Scenario, total primary energy demand increases by 38 % from the current 46,250 PJ/a to 63,930 PJ/a in 2050. In the Energy [R]evolution Scenario, demand decreases by 23% compared to current consumption and is expected to reach 35,760 PJ/a by 2050.

Under the Energy [R]evolution Scenario, electricity demand is expected to increase disproportionately, with transport and the households and services sectors being the main source of growing consumption (see Figure 6.74). With the exploitation of efficiency measures, however, an even higher increase can be avoided, leading to electricity demand of around 1,550 TWh/a in 2050. Compared to the Reference Scenario, efficiency measures avoid the generation of about 560 TWh/a.

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 after 2030 (see Figure 6.75). Compared to the Reference Scenario, consumption equivalent to 5,990 PJ/a is avoided through efficiency gains.

In the transport sector, it is assumed under the Energy [R]evolution Scenario that energy demand will decrease by 28% to 4,240 PJ/a by 2050, saving 57% compared to the Reference Scenario.

figure 6.73: transition economies: projection of total final energy demand by sector for the two scenarios

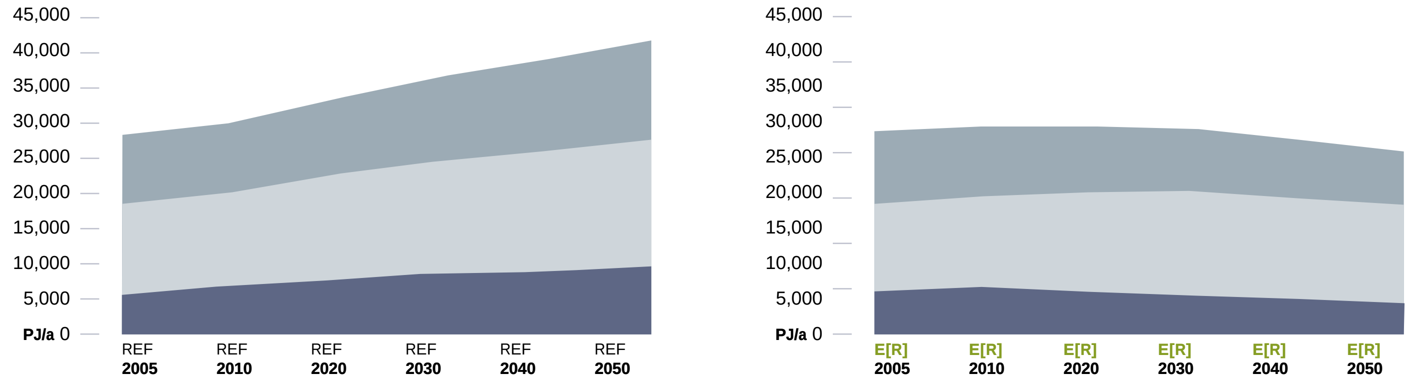


figure 6.74: transition economies: development of electricity demand by sector

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

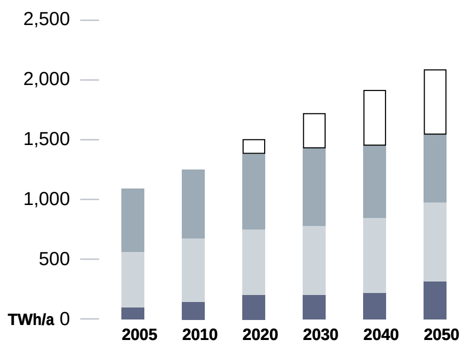


figure 6.75: transition economies: development of heat demand by sector

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

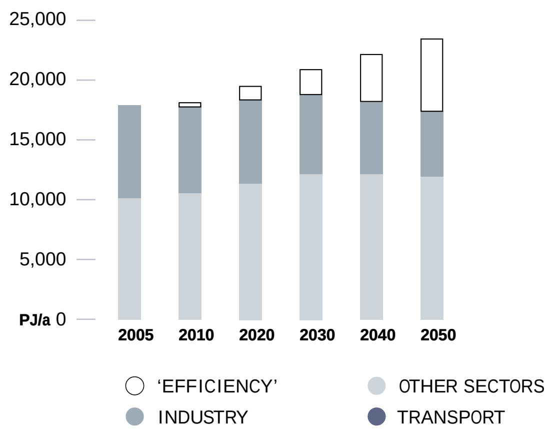


image LAKE BAIKAL, RUSSIA.

image SOLAR PANELS IN A NATURE RESERVE IN CAUCASUSU, RUSSIA.

transition economies: electricity generation

The development of the electricity supply sector is characterised by a growing renewable energy market. 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, 81% of the electricity produced in the Transition Economy countries will come from renewable energy sources. 'New' renewables – mainly wind, solar thermal energy and PV – will contribute 65% of electricity generation.

The installed capacity of renewable energy technologies will grow from the current 93 GW to 550 GW in 2050, increasing capacity by a factor of six over the next 42 years. This will require political support and well-designed policy instruments.

Figure 6.77 shows the expansion rate of the different renewable technologies over time. Up to 2020, hydro-power and wind will remain the main contributors. After 2020, the continuing growth of wind will be complemented by electricity from biomass, photovoltaics and geothermal energy.

table 6.7: transition economies: projection of renewable electricity generation capacity under the energy [r]evolution scenario

IN GW

	2005	2010	2020	2030	2040	2050
Hydro	89	94	103	106	109	110
Biomass	3	9	40	49	61	68
Wind	0.1	0.4	10	72	169	245
Geothermal	0.1	0.3	2	8	16	17
PV	0	0.1	2	42	100	100
Solarthermal	0	0	0	2	3	3
Ocean energy	0	0	4	6	7	9
Total	**93**	**104**	**162**	**285**	**466**	**551**

figure 6.76: transition economies: development of electricity generation structure under the two scenarios

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

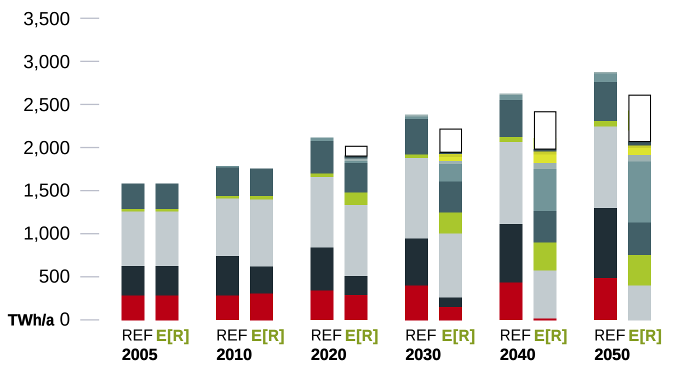
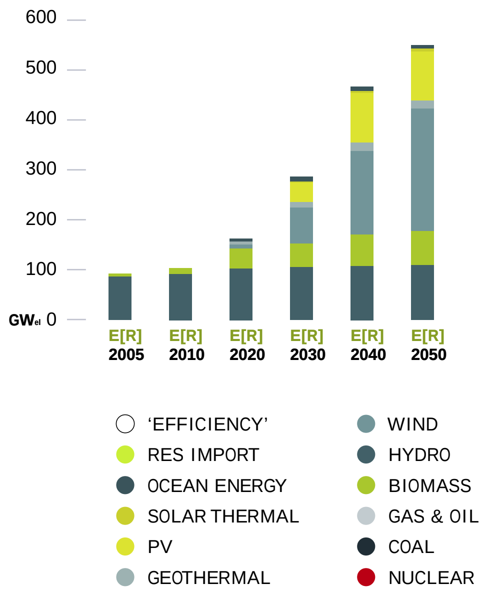


figure 6.77: transition economies: growth of renewable electricity generation capacity under the energy [r]evolution scenario

BY INDIVIDUAL SOURCE



transition economies

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transition economies: future costs of electricity generation

Figure 6.78 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 about 0.5 cents/kWh in 2015. Because of the lower CO_2 intensity of electricity generation, by 2020 these costs will become economically favourable under the Energy [R]evolution Scenario and by 2050 will be more than 5 cents/kWh below those in the Reference Scenario.

Due to growing demand, there will be a significant increase in society's expenditure on electricity supply. Under the Reference Scenario, total electricity supply costs will rise from today's $190 billion per year to $520 bn in 2050. Figure 6.79 shows that the Energy [R]evolution Scenario not only complies with the Transition Economies' CO_2 reduction targets but also helps to stabilise energy costs and relieve the economic pressure on society. Long term costs for electricity supply are one third lower than in the Reference Scenario.

figure 6.78: transition economies: development of specific electricity generation costs under the two scenarios

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

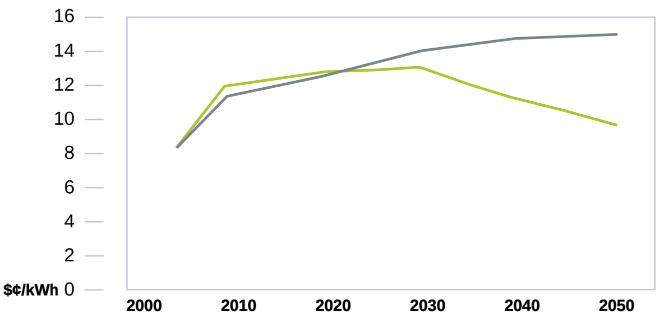
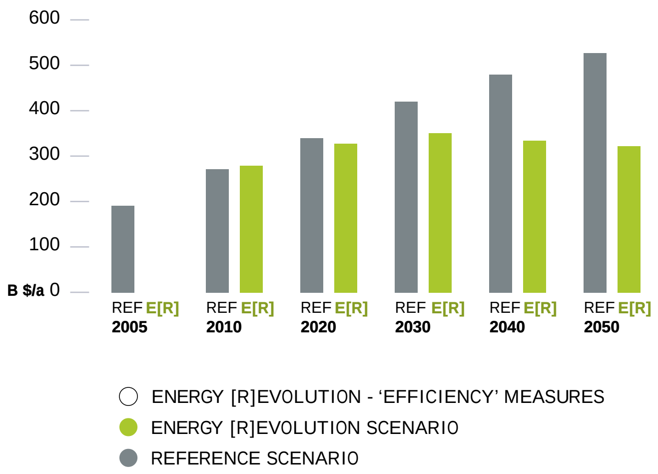


figure 6.79: transition economies: development of total electricity supply costs



transition economies: heat and cooling supply

Renewables currently provide just 3% of the Transition Economies' primary energy demand for heat supply, the main contribution coming from the use of biomass. The lack of available infrastructure for modern and efficient district heating networks is a barrier to the large scale utilisation of biomass, geothermal and solar thermal energy. Dedicated support instruments are required to ensure a dynamic development.

In the Energy [R]evolution Scenario, renewables provide 75% of the Transition Economies' total heating demand in 2050.

- Energy efficiency measures can moderate the increase in heat demand, and in spite of improving living standards after 2030 lead to a decrease in demand, which in 2050 is slightly lower than at present.
- 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 6.80: transition economies: development of heat supply structure under the two scenarios

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

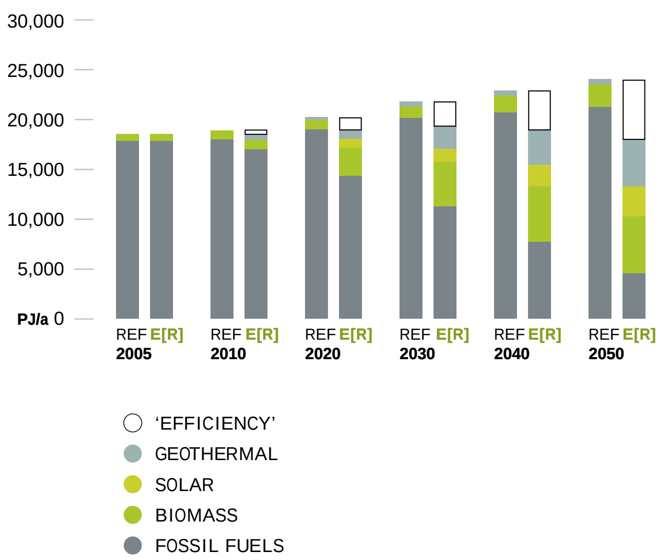


image CHERNOBYL NUCLEAR POWER STATION, UKRAINE.

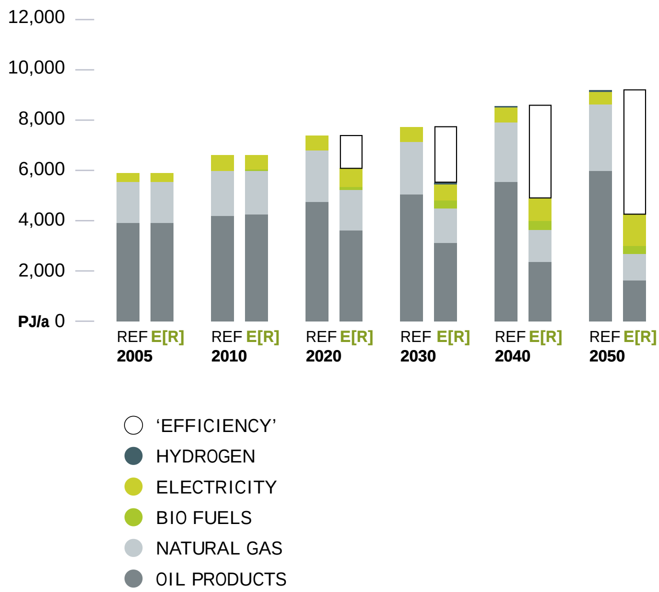
image THE SUN OVER LAKE BAIKAL, RUSSIA.

transition economies: transport

Development of the transport sector is characterised by the diversification of energy sources towards bio fuels (9%) and electricity (28%) up to 2050. The time taken to reach reference target levels for efficient vehicles is delayed by ten years compared to the most other industrialised countries. Although the light duty vehicle stock will triple by 2050, increasingly attractive and highly efficient suburban and long distance rail services, as well as growing fuel prices, will lead to the vehicle kilometres travelled falling by 10% between 2010 and 2050. These measures and incentives, together with highly efficient cars, will result in nearly 30% energy savings in the transport sector.

figure 6.81: transition economies: transport under the two scenarios

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

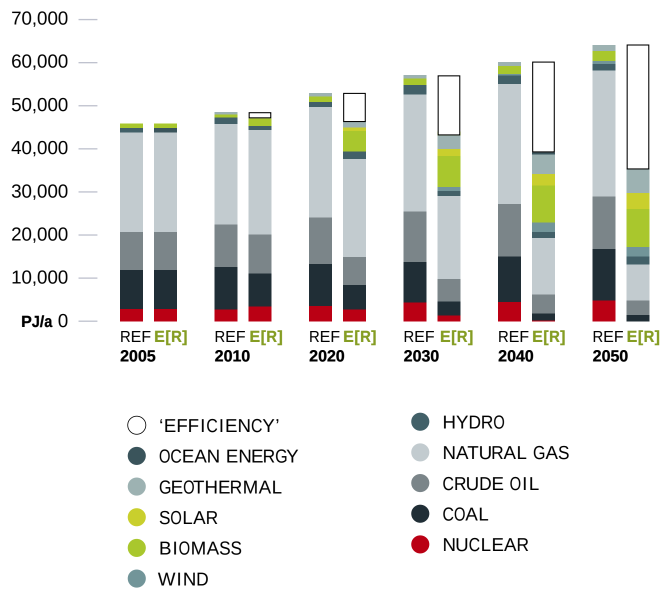


transition economies: primary energy consumption

Taking into account the changes outlined above, the resulting primary energy consumption under the Energy [R]evolution Scenario is shown in Figure 6.82. Compared to the Reference Scenario, overall energy demand will be reduced by 44% in 2050. Around 60% of the remaining demand will be covered by renewable energy sources.

figure 6.82: transition economies: development of primary energy consumption under the two scenarios

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

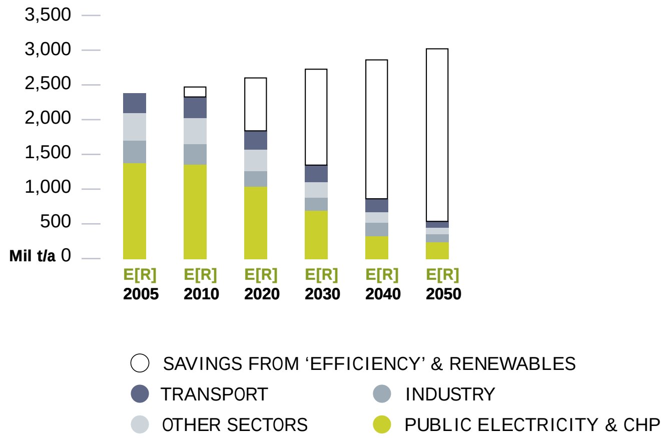


transition economies: development of CO_2 emissions

Whilst emissions of CO_2 will increase by 11% under the Reference Scenario, under the Energy [R]evolution Scenario they will decrease from 2,380 million tonnes in 2005 to 540 m/t in 2050. Annual per capita emissions will drop from 7.0 tonnes to 1.8 t. In spite of the phasing out of nuclear energy and increasing demand, CO_2 emissions will decrease in the electricity sector.

figure 6.83: transition economies: development of CO_2 emissions by sector under the energy [r]evolution scenario

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



india

india: energy demand by sector

The potential future development pathways for India's primary energy demand are shown in Figure 6.84 for both the Reference and Energy [R]evolution Scenarios. Under the Reference Scenario, total primary energy demand quadruples from the current 22,300 PJ/a to 89,100 PJ/a in 2050. In the Energy [R]evolution Scenario, by contrast, demand will increase by about 230 % and is expected to reach 52,000 PJ/a by 2050.

Under the Energy [R]evolution Scenario, electricity demand is expected to increase substantially (see Figure 6.85). With the exploitation of efficiency measures, however, a higher increase can be avoided, leading to demand of around 3,500 TWh/a in 2050. Compared to the Reference Scenario, efficiency measures avoid the generation of about 1,410 TWh/a. This reduction can be achieved in particular by introducing highly efficient electronic devices using the best available technology in all demand sectors.

Efficiency gains for heat and cooling supply are also significant. Under the Energy [R]evolution Scenario, final demand for heating and cooling can even be reduced (see Figure 6.86). Compared to the Reference Scenario, consumption equivalent to 3,130 PJ/a is avoided through efficiency gains by 2050.

In the transport sector it is assumed that a fast growing economy will see energy demand, even under the Energy [R]evolution Scenario, increase dramatically - from 1,550 PJ/a in 2005 to 8,700 PJ/a by 2050. This still saves 50% compared to the Reference Scenario. This reduction can be achieved by the introduction of highly efficient vehicles, shifting freight transport from road to rail and by changes in travel behaviour.

figure 6.84: india: projection of total final energy demand by sector for the two scenarios

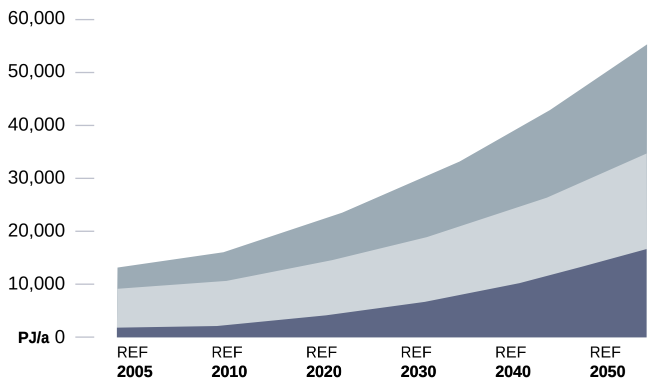


figure 6.85: india: development of electricity demand by sector

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

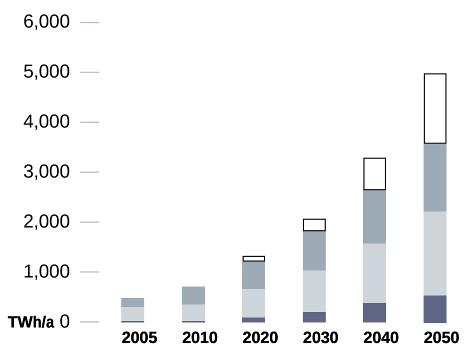


figure 6.86: india: development of heat demand by sector

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

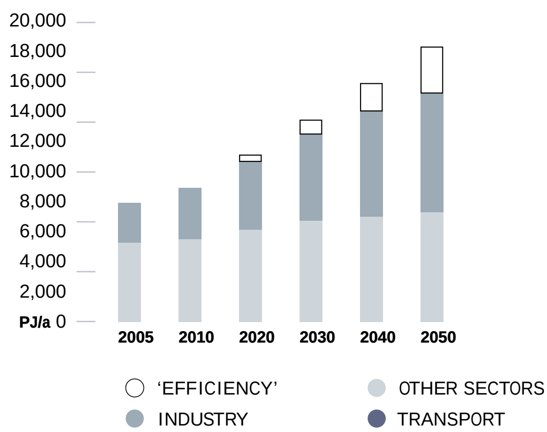


image NANLINIKANT BISWAS, FARMER AGE 43. FIFTEEN YEARS AGO NANLINIKANT'S FAMILY ONCE LIVED WHERE THE SEA IS NOW. THEY WERE AFFLUENT AND OWNED 4 ACRES OF LAND. BUT RISING SEAWATER INCREASED THE SALINITY OF THE SOIL UNTIL THEY COULD NO LONGER CULTIVATE IT, KANHAPUR, ORISSA, INDIA.

image A SOLAR DISH WHICH IS ON TOP OF THE SOLAR KITCHEN AT AUROVILLE,TAMIL NADU, INDIA.

india: electricity generation

By 2050, about 60% of the electricity produced in India will come from renewable energy sources. 'New' renewables – mainly wind, solar thermal energy and PV – will contribute almost 50%. The installed capacity of renewable energy technologies will grow from the current 38 GW to 915 GW in 2050, a substantial increase over the next 42 years.

Figure 6.88 shows the comparative evolution of different renewable technologies over time. Up to 2030, hydro-power and wind will remain the main contributors. After 2020, the continuing growth of wind will be complemented by electricity from biomass, photovoltaics and solar thermal (CSP) energy.

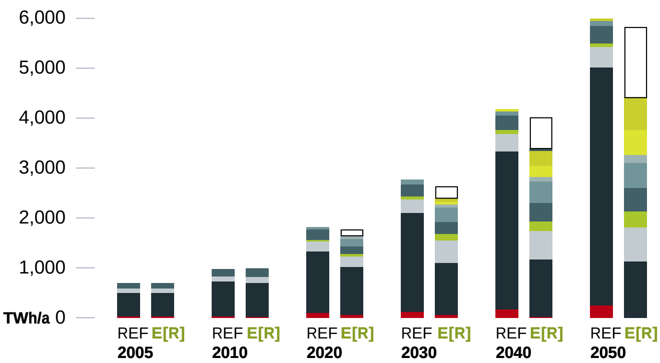
table 6.8: india: projection of renewable electricity generation capacity under the energy [r]evolution scenario

IN GW

	2005	2010	2020	2030	2040	2050
Hydro	34	43	62	85	129	156
Biomass	0.4	0.7	8	19	41	70
Wind	4	11	69	127	170	212
Geothermal	0	0	2	6	17	29
PV	0	0.2	10	51	136	343
Solarthermal	0	0	3	10	48	97
Ocean energy	0	0	1	2	4	7
Total	**38**	**55**	**155**	**299**	**545**	**915**

figure 6.87: india: development of electricity generation structure under the two scenarios

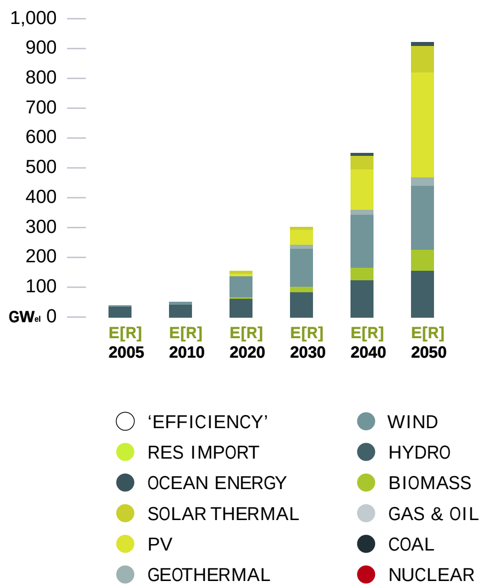
('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)



note GREENPEACE COMISSIONED ANOTHER SCENARIO FOR INDIA WITH HIGHER GDP DEVELOPMENT PROJECTIONS UNTIL 2030. FOR MORE INFORMATION PLEASE VISIT THE ENERGY [R]EVOLUTION WEBSITE WWW.ENERGYBLUEPRINT.INFO/

figure 6.88: india: growth of renewable electricity generation capacity under the energy [r]evolution scenario

BY INDIVIDUAL SOURCE



india

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CHINA
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india: future costs of electricity generation

Figure 6.89 shows that the introduction of renewable technologies under the Energy [R]evolution Scenario significantly decreases the future costs of electricity generation compared to the Reference Scenario. Because of the lower CO_2 intensity, electricity generation costs will become economically favourable under the Energy [R]evolution Scenario and by 2050 will be more than 4.5 cents/kWh below those in the Reference Scenario.

Under the Reference Scenario, a massive growth in demand, increased fossil fuel prices and the cost of CO_2 emissions result in total electricity supply costs rising from today's $64 billion per year to more than $930 bn in 2050. Figure 6.90 shows that the Energy [R]evolution Scenario not only complies with India's CO_2 reduction targets but also helps to stabilise energy costs. Increasing energy efficiency and shifting energy supply to renewables leads to long term costs that are one third lower than in the Reference Scenario.

india: heat and cooling supply

Renewables presently provide 63% of primary energy demand for heat and cooling supply in India, the main contribution coming from the use of biomass. Dedicated support instruments are required to ensure a continuously dynamic development of renewables in the heat market.

In the Energy [R]evolution Scenario, renewables will provide 71% of India's heating and cooling demand by 2050.

- Energy efficiency measures will restrict future primary energy demand for heat and cooling supply to an increase of 90% by 2005, in spite of improving living standards. This compares to 130% in the Reference Scenario.
- In the industry sector solar collectors, biomass/biogas and geothermal energy are increasingly replacing conventional fossil-fired heating systems.
- A shift from coal and oil to natural gas in the remaining conventional applications leads to a further reduction of CO_2 emissions.

figure 6.89: india: development of specific electricity generation costs under the two scenarios

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

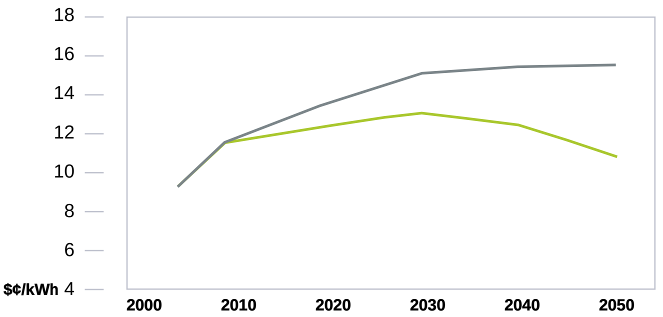


figure 6.90: india: development of total electricity supply costs

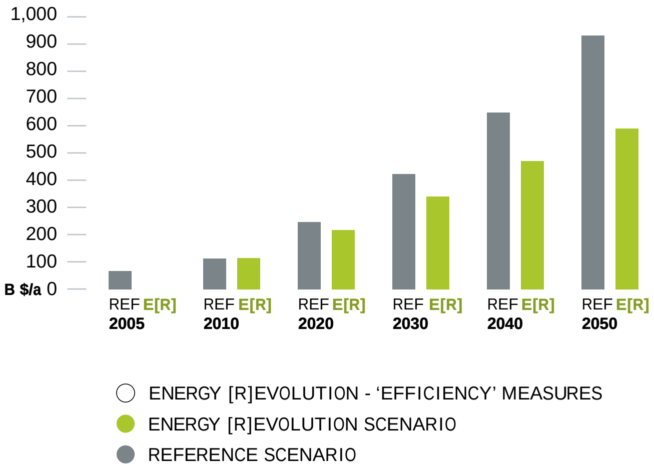


figure 6.91: india: development of heat supply structure under the two scenarios

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

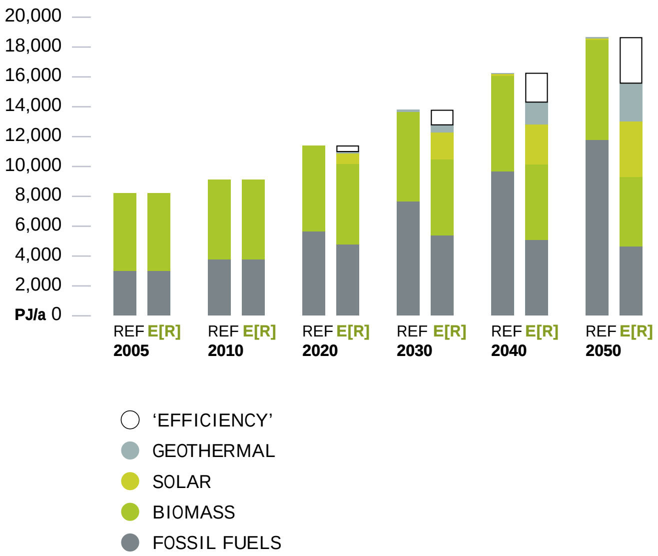


image A LOCAL BENGALI WOMAN PLANTS A MANGROVE (SUNDARI) SAPLING ON SAGAR ISLAND IN THE ECOLOGICALLY SENSITIVE SUNDERBANS RIVER DELTA REGION, IN WEST BENGAL. THOUSANDS OF LOCAL PEOPLE WILL JOIN THE MANGROVE PLANTING INITIATIVE LED BY PROFESSOR SUGATA HAZRA FROM JADAVAPUR UNIVERSITY, WHICH WILL HELP TO PROTECT THE COAST FROM EROSION AND WILL ALSO PROVIDE NUTRIENTS FOR FISH AND CAPTURE CARBON IN THEIR EXTENSIVE ROOT SYSTEMS.

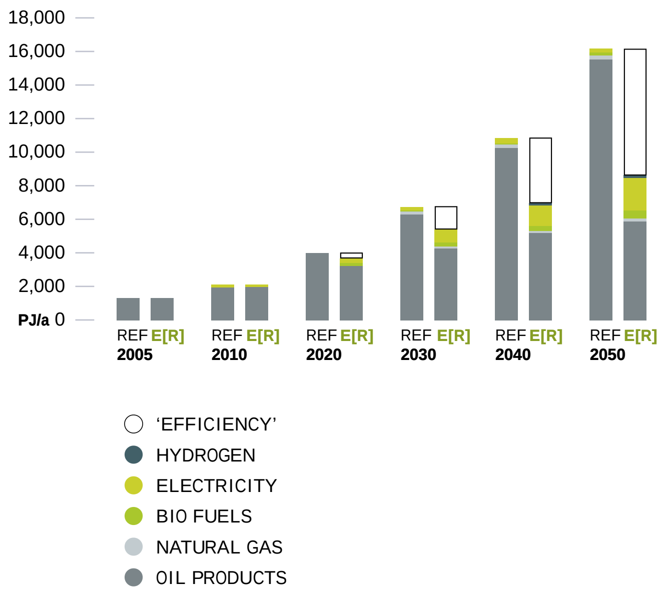
image FEMALE WORKER CLEANING A SOLAR OVEN AT A COLLEGE IN TILONIA, RAJASTHAN, INDIA.

india: transport

India's car fleet is projected to grow by a factor of 16 from 2000 to 2050. Presently characterised by small cars (70%), this will stay the same up to 2050. Although India will remain a low price car market, the key to efficiency lies in electrified powertrains (hybrid, plug-in and battery electric). Biofuels will take over 6% and electricity 22% of total transport energy demand. Stringent energy efficiency measures will help limit growth of transport energy demand by 2050 to about a factor of 5.5 compared to 2005.

figure 6.92: india: transport under the two scenarios

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

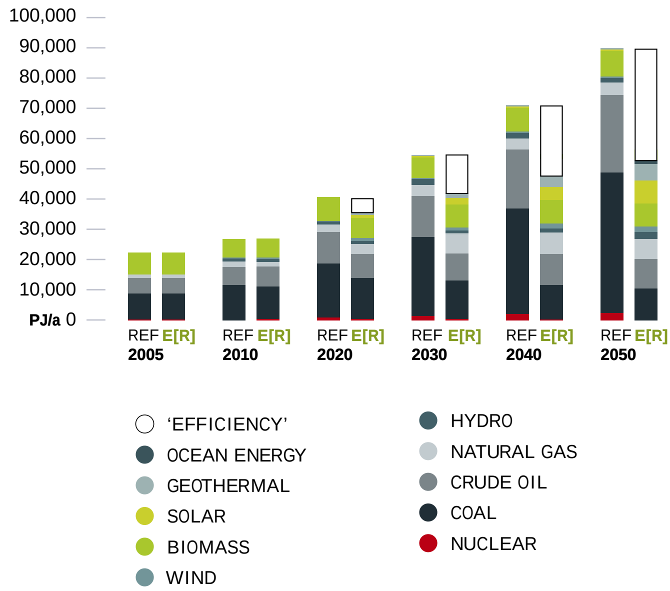


india: primary energy consumption

Taking into account the above assumptions, the resulting primary energy consumption under the Energy [R]evolution Scenario is shown in Figure 6.93. Compared to the Reference Scenario, overall demand will be reduced by about 40% in 2050. Around half of this will be covered by renewable energy sources.

figure 6.93: india: development of primary energy consumption under the two scenarios

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



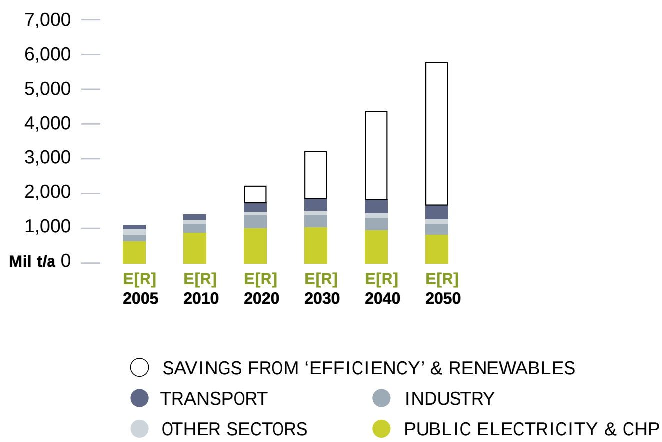
india: development of CO_2 emissions

While CO_2 emissions in India will increase under the Reference Scenario by a factor of 5.4 up to 2050, and are thus far removed from a sustainable development path, under the Energy [R]evolution Scenario they will increase from the current 1,074 million tonnes in 2005 to reach a peak of 1,820 m/t in 2030. After that they will decrease to 1,660 m/t in 2050. Annual per capita emissions will increase to 1.3 tonnes/capita in 2030 and fall again to 1.0 t/capita in 2050. In spite of the phasing out of nuclear energy and increasing electricity demand, CO_2 emissions will decrease in the electricity sector.

After 2030, efficiency gains and the increased use of renewables in all sectors will soften the still increasing CO_2 emissions in transport, the power sector and industry. Although its share is decreasing, the power sector will remain the largest source of emissions in India, contributing 50% of the total in 2050, followed by transport.

figure 6.94: india: development of CO_2 emissions by sector under the energy [r]evolution scenario

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



developing asia

GLOBAL SCENARIO
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LATIN AMERICA
OECD EUROPE
AFRICA
MIDDLE EAST
TRANSITION ECONOMIES
INDIA
DEVELOPING ASIA
CHINA
OECD PACIFIC

developing asia: energy demand by sector

The future development pathways for Developing Asia's primary energy demand are shown in Figure 6.95 for both the Reference and Energy [R]evolution Scenarios. Under the Reference Scenario, total primary energy demand more than doubles from the current 31,100 PJ/a to 67,400 PJ/a in 2050. In the Energy [R]evolution Scenario, a much smaller 40% increase in consumption is expected by 2050, reaching 43,800 PJ/a.

Under the Energy [R]evolution Scenario, electricity demand is expected to increase disproportionately in Developing Asia (see Figure 6.96). With the introduction of serious efficiency measures, however, an even higher increase can be avoided, leading to electricity demand of around 1,965 TWh/a in 2050. Compared to the Reference Scenario, efficiency measures avoid the generation of about 860 TWh/a.

Efficiency gains in the heat supply sector are also significant (see Figure 6.97). Compared to the Reference Scenario, consumption equivalent to 2,900 PJ/a is avoided through efficiency measures by 2050. In the transport sector, it is assumed under the Energy [R]evolution Scenario that energy demand will rise to 8,300 PJ/a by 2050, saving 90% compared to the Reference Scenario.

figure 6.95: developing asia: projection of total final energy demand by sector for the two scenarios

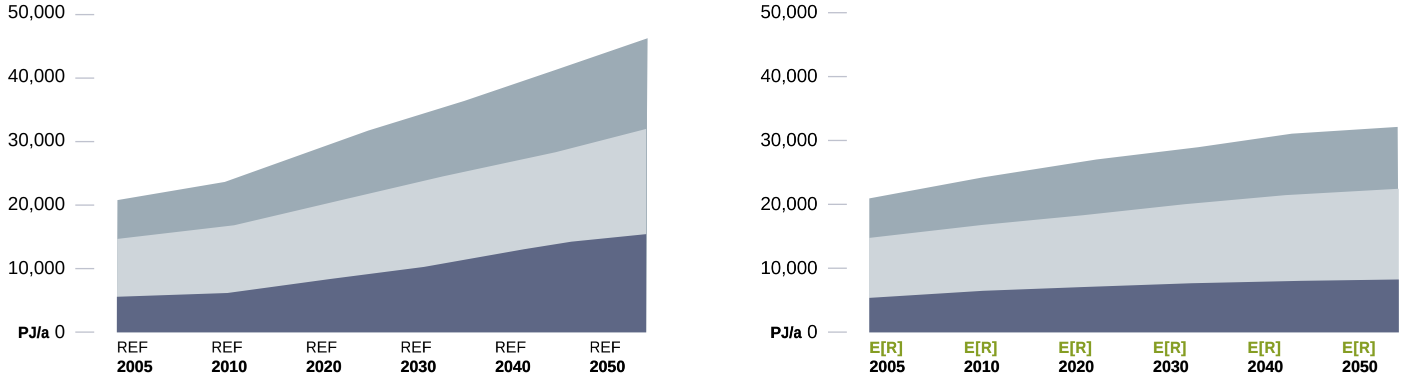


figure 6.96: developing asia: development of electricity demand by sector

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

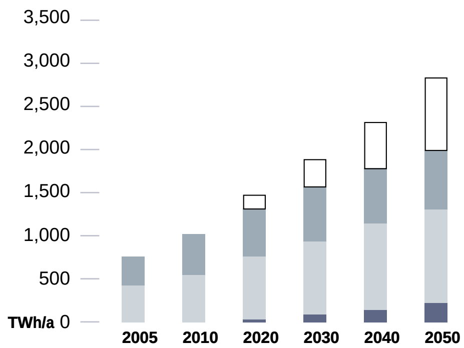
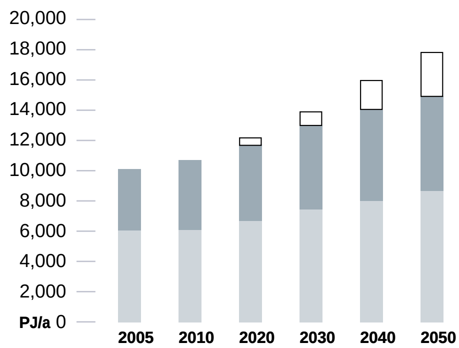


figure 6.97: developing asia: development of heat demand by sector

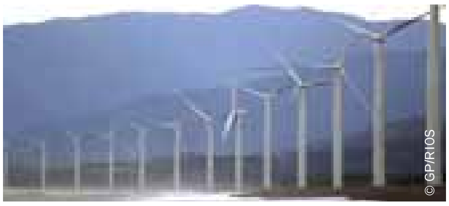
('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)



'EFFICIENCY'
INDUSTRY
OTHER SECTORS
TRANSPORT

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

image AMIDST SCORCHING HEAT, AN ELDERLY FISHERWOMAN GATHERS SHELLS IN LAM TAKONG DAM, WHERE WATERS HAVE DRIED UP DUE TO PROLONGED DROUGHT. GREENPEACE LINKS RISING GLOBAL TEMPERATURES AND CLIMATE CHANGE TO THE ONSET OF ONE OF THE WORST DROUGHTS TO HAVE STRUCK THAILAND, CAMBODIA, VIETNAM AND INDONESIA IN RECENT MEMORY. SEVERE WATER SHORTAGE AND DAMAGE TO AGRICULTURE HAS AFFECTED MILLIONS.



developing asia: electricity generation

The development of the electricity supply sector is characterised by 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. By 2050, 67% of the electricity produced in Developing Asia will come from renewable energy sources. 'New' renewables – mainly wind, solar thermal energy and PV – will contribute 55%.

The installed capacity of renewable energy technologies will grow from the current 51 GW to 590 GW in 2050, increasing capacity by a factor of more than ten.

Figure 6.99 shows the comparative evolution of the different technologies over time. Up to 2020, hydro-power and wind will remain the main contributors. After 2020, the continuing growth of wind will be complemented by electricity from biomass, photovoltaics and geothermal sources.

table 6.9: developing asia: projection of renewable electricity generation capacity under the energy [r]evolution scenario

IN GW

	2005	2010	2020	2030	2040	2050
Hydro	46	51	70	79	81	82
Biomass	2	3	7	11	17	20
Wind	0	2	40	127	171	202
Geothermal	3	3.6	7	13	20	26
PV	0	0.7	13	68	139	232
Solarthermal	0	0	3	5	14	25
Ocean energy	0	0	1	2	3	5
Total	**51**	**61**	**141**	**305**	**446**	**590**

figure 6.98: developing asia: development of electricity generation structure under the two scenarios

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

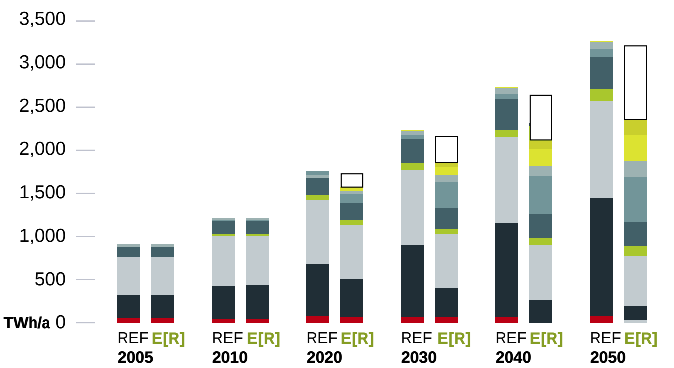
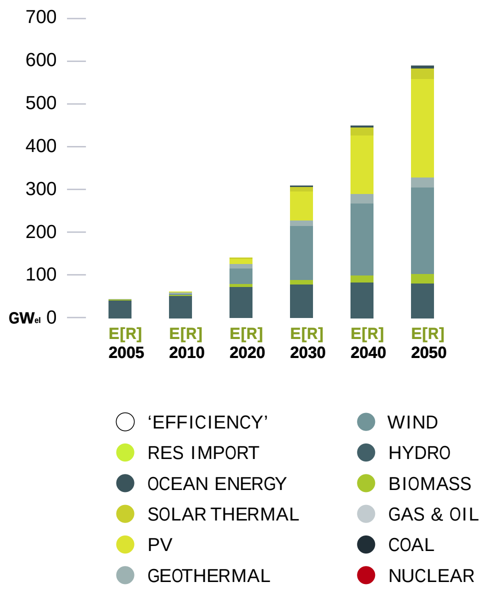


figure 6.99: developing asia: growth of renewable electricity generation capacity under the energy [r]evolution scenario

BY INDIVIDUAL SOURCE



developing asia

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INDIA
DEVELOPING ASIA
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developing asia: future costs of electricity generation

Figure 6.100 shows that the introduction of renewable technologies under the Energy [R]evolution Scenario significantly decreases the future costs of electricity generation compared to the Reference Scenario. Because of lower CO_2 intensity in electricity generation, costs will become economically favourable under the Energy [R]evolution Scenario. By 2050 they will be more than 5 cents/kWh below those in the Reference Scenario.

Under the Reference Scenario, unchecked growth in demand, an increase in fossil fuel prices and the cost of CO_2 emissions result in total electricity supply costs rising from today's $98 billion per year to more than $566 bn in 2050. Figure 6.101 shows that the Energy [R]evolution Scenario not only complies with Developing Asia's CO_2 reduction targets but also helps to stabilise energy costs. Increasing energy efficiency and shifting supply to renewables leads to long term costs that are almost one third lower than in the Reference Scenario.

figure 6.100: developing asia: development of specific electricity generation costs under the two scenarios

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

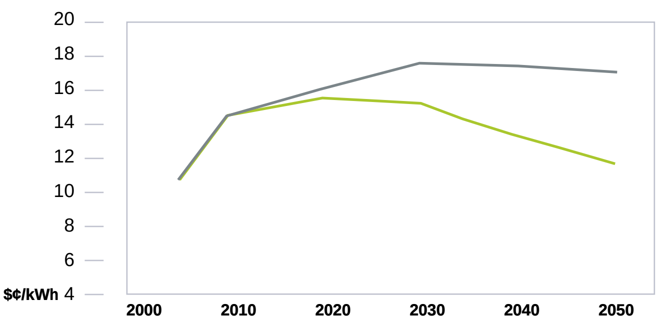
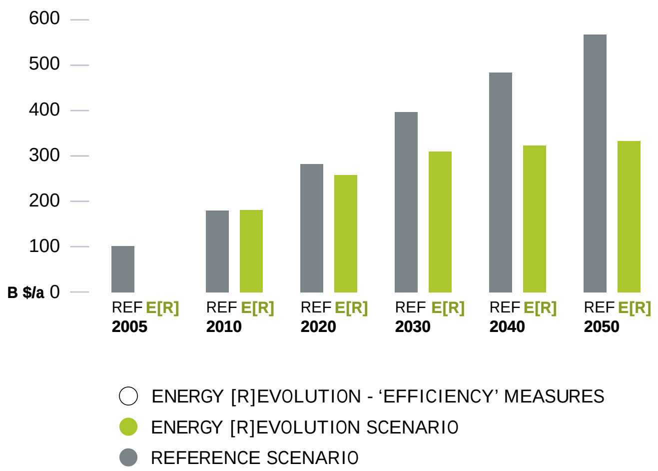


figure 6.101: developing asia: development of total electricity supply costs



developing asia: heat and cooling supply

The starting point for renewables in the heat supply sector is quite different from the power sector. Today, renewables provide 53% of primary energy demand for heat and cooling supply in Developing Asia, the main contribution coming from biomass. Dedicated support instruments are still required to ensure a continuously dynamic development of renewables in the heat market.

In the Energy [R]evolution Scenario, renewables provide 70% of Developing Asia's heating and cooling demand in 2050.

- Energy efficiency measures can restrict the future primary energy demand for heat and cooling supply to a increase of 48%, compared to 77% in the Reference Scenario, in spite of improving living standards.
- In the industry sector solar collectors, biomass/biogas and geothermal energy are increasingly replacing conventional fossil fuel-fired heating systems.
- A shift from coal and oil to natural gas in the remaining conventional applications leads to a further reduction of CO_2 emissions.

figure 6.102: developing asia: development of heat supply structure under the two scenarios

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

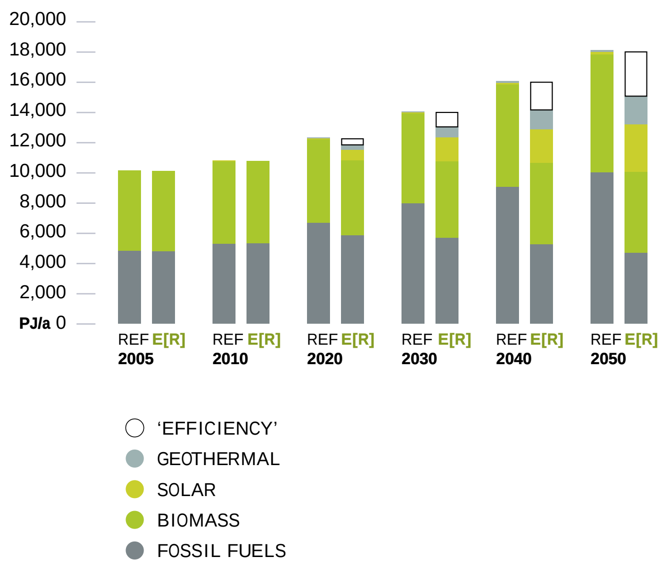


image GREENPEACE DONATES A SOLAR POWER SYSTEM TO A COASTAL VILLAGE IN ACEH, INDONESIA, ONE OF THE WORST HIT AREAS BY THE TSUNAMI IN DECEMBER 2004. IN COOPERATION WITH UPLINK, A LOCAL DEVELOPMENT NGO, GREENPEACE OFFERED ITS EXPERTISE ON ENERGY EFFICIENCY AND RENEWABLE ENERGY AND INSTALLED RENEWABLE ENERGY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

image A WOMAN GATHERS FIREWOOD ON THE SHORES CLOSE TO THE WIND FARM OF ILOCOS NORTE, AROUND 500 KILOMETERS NORTH OF MANILA.

developing asia: transport

This region's light duty vehicle stock is projected to grow by a factor of 10 from 2000 to 2050. Biofuels will reach a share of 7%, electricity 9% of the energy needed in the total transport sector. Highly efficient hybrid car technologies, together with plug-in and battery electric vehicles, will lead to significant gains in energy efficiency.

developing asia: 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 6.104. Compared to the Reference Scenario, overall demand will be reduced by almost 35% in 2050. Around half of the remaining demand will be covered by renewables.

figure 6.103: developing asia: transport under the two scenarios

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

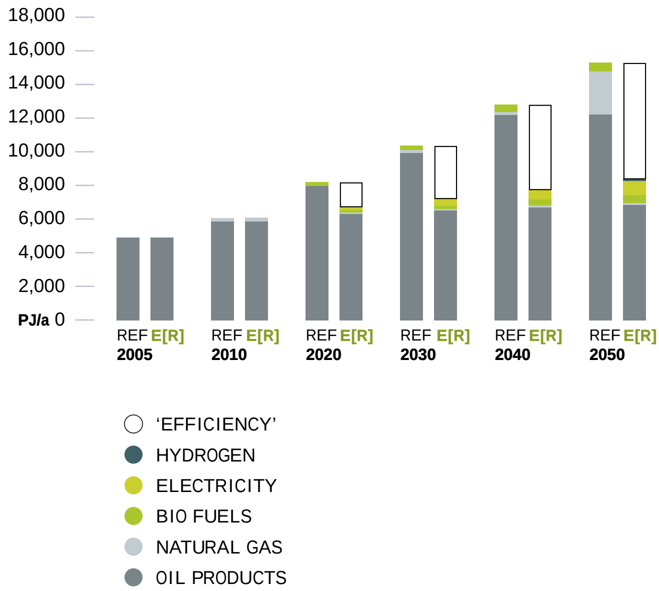
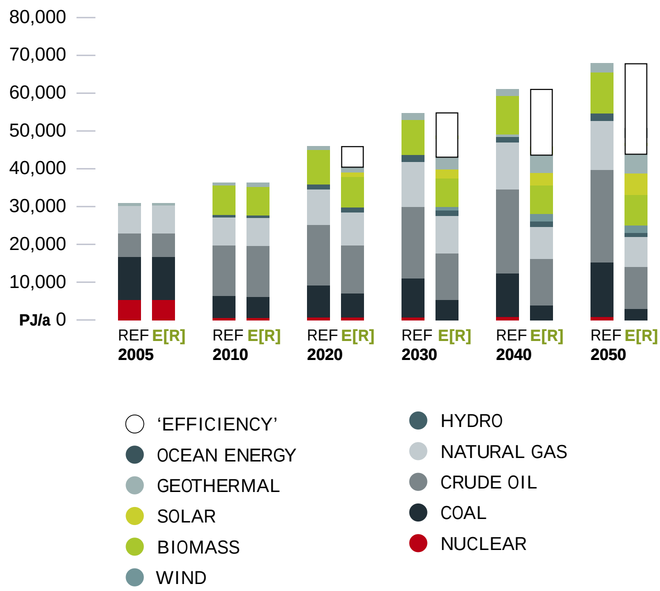


figure 6.104: developing asia: development of primary energy consumption under the two scenarios

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

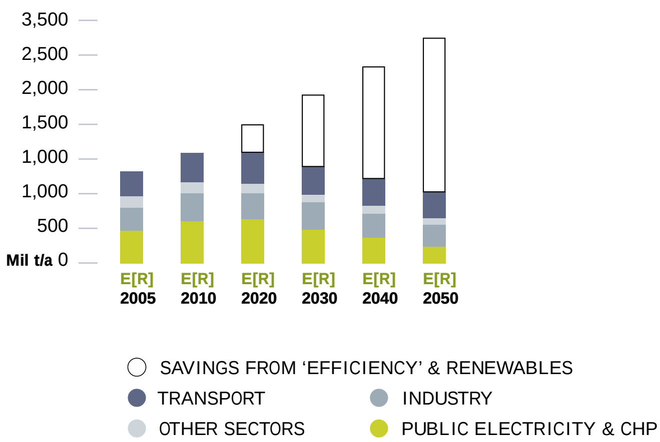


developing asia: development of CO_2 emissions

Whilst Developing Asia's CO_2 emissions will increase by a factor of 2.5 under the Reference Scenario, in the Energy [R]evolution Scenario they will decrease from 1,300 million tonnes in 2005 to 1,150 m/t in 2050. Annual per capita emissions will drop from 1.3 tonnes to 0.8 t. In spite of the phasing out of nuclear energy and increasing demand, CO_2 emissions will decrease in the electricity sector. In the long run efficiency gains and the increased use of renewable electricity in vehicles will stabilise CO_2 emissions in the transport sector. With a share of 22% of total CO_2 in 2050, the power sector will drop below transport as the largest source of emissions.

figure 6.105: developing asia: development of CO_2 emissions by sector under the energy [r]evolution scenario

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



china

china: energy demand by sector

The future development pathways for China's primary energy demand are shown in Figure 6.106 for both the Reference and Energy [R]evolution Scenarios. Under the Reference Scenario, total primary energy demand will increase by a factor of 2.5 from the current 73,000 PJ/a to 185,020 PJ/a in 2050. In the Energy [R]evolution Scenario, primary energy demand increases up to 2030 by 60% and decreases to a level of 99,150 PJ/a in 2050.

Under the Energy [R]evolution Scenario, electricity demand is expected to increase disproportionately (see Figure 6.107). With the exploitation of efficiency measures, however, an even higher increase can be avoided, leading to demand of around 7,500 TWh/a in 2050. Compared to the Reference Scenario, efficiency measures avoid the generation of about 3,160 TWh/a.

Efficiency gains in the heat supply sector are large as well. Under the Energy [R]evolution Scenario, final demand for heat supply can even be reduced (see Figure 6.108). Compared to the Reference Scenario, consumption equivalent to 10,300 PJ/a is avoided through efficiency gains by 2050.

In the transport sector, it is assumed under the Energy [R]evolution Scenario that energy demand will increase considerably, from 5,100 PJ/a in 2005 to 17,300 PJ/a by 2050. However this still saves 50% compared to the Reference Scenario.

figure 6.106: china: projection of total final energy demand by sector for the two scenarios

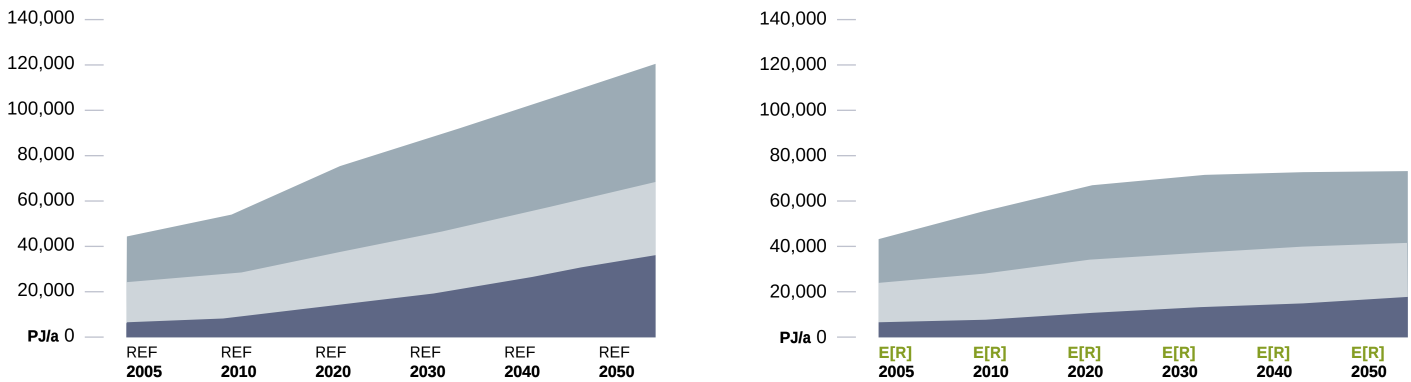


figure 6.107: china: development of electricity demand by sector

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

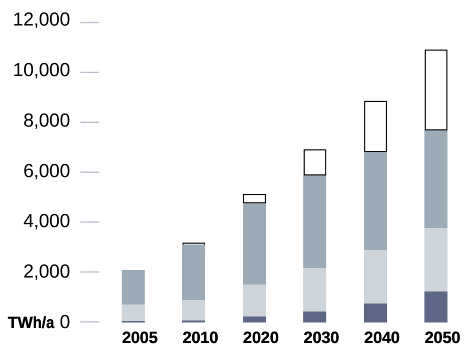


figure 6.108: china: development of heat demand by sector

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

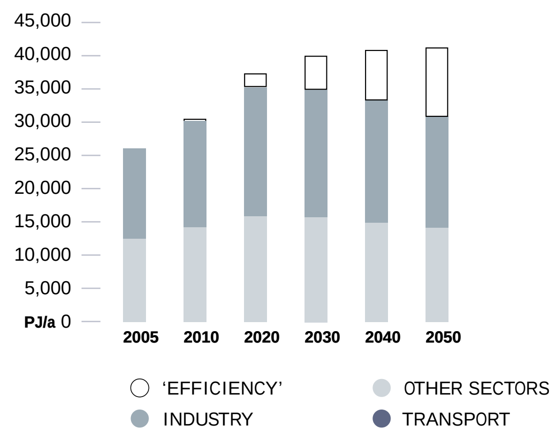


image A MAINTENANCE ENGINEER INSPECTS A WIND TURBINE AT THE NAN WIND FARM IN NAN'AO. GUANGDONG PROVINCE HAS ONE OF THE BEST WIND RESOURCES IN CHINA AND IS ALREADY HOME TO SEVERAL INDUSTRIAL SCALE WIND FARMS. MASSIVE INVESTMENT IN WIND POWER WILL HELP CHINA OVERCOME ITS RELIANCE ON CLIMATE DESTROYING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

image image A LOCAL TIBETAN WOMAN WHO HAS FIVE CHILDREN AND RUNS A BUSY GUEST HOUSE IN THE VILLAGE OF ZHANG ZONG USES SOLAR PANELS TO SUPPLY ENERGY FOR HER BUSINESS.

china: electricity generation

A dynamically growing renewable energy market 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, 63% of the electricity produced in China will come from renewable energy sources. 'New' renewables – mainly wind, solar thermal energy and PV – will contribute 46% of electricity generation. The following strategy paves the way for a future renewable energy supply:

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-power and biomass will also make substantial contributions.

The installed capacity of renewable energy technologies will grow from the current 119 GW to 1,950 GW in 2050, an enormous increase resulting in a considerable demand for investment over the next 20 years. Figure 6.110 shows the comparative evolution of the different renewable technologies over time. Up to 2020, hydro-power and wind will remain the main contributors. After 2020, the continuing growth of wind will be complemented by electricity from biomass, photovoltaics and solar thermal energy.

table 6.10: china: projection of renewable electricity generation capacity under the energy [r]evolution scenario

IN GW

	2005	2010	2020	2030	2040	2050
Hydro	117	166	254	313	385	457
Biomass	0.6	3	17	36	68	96
Wind	1	17	151	380	506	574
Geothermal	0	0.2	1	3	8	20
PV	0,1	0,4	16	136	300	579
Solarthermal	0	0	9	33	83	150
Ocean energy	0	0	1	7	21	74
Total	**119**	**186**	**450**	**909**	**1370**	**1950**

figure 6.109: china: development of electricity generation structure under the two scenarios

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

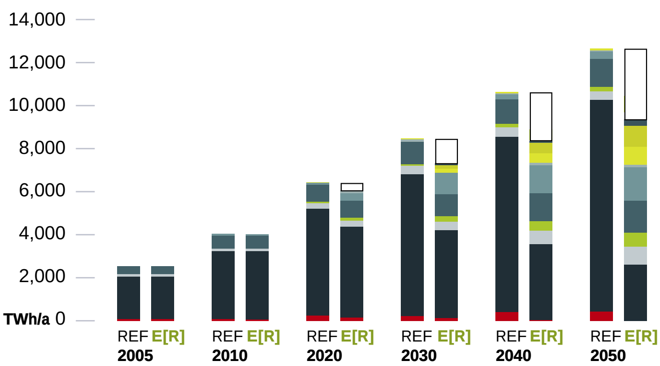
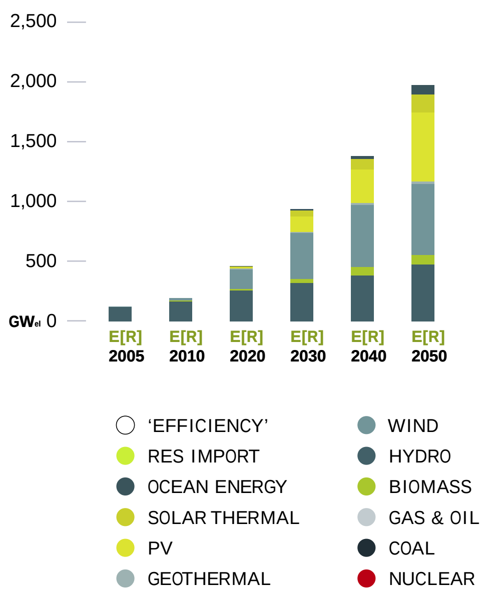


figure 6.110: china: growth of renewable electricity generation capacity under the energy [r]evolution scenario

BY INDIVIDUAL SOURCE



china

china: future costs of electricity generation

Figure 6.111 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. The difference will be less than 1 cents/kWh up to 2020. Because of the lower CO_2 intensity, by 2020 electricity generation costs in China will become economically favourable under the Energy [R]evolution Scenario, and by 2050 will be more than 5 cents/kWh below those in the Reference Scenario.

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 $ 205 billion per year to more than $ 1,940 bn in 2050. Figure 6.112 shows that the Energy [R]evolution Scenario not only complies with China's CO_2 reduction targets but also helps to stabilise energy costs. 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.

china: heat and cooling supply

Today, renewables provide 28% of primary energy demand for heat and cooling supply in China, the main contribution coming from the use of biomass.

In the Energy [R]evolution Scenario, renewables provide 65% of China's total heating and cooling demand by 2050.

- Energy efficiency measures will restrict the future primary energy demand for heat and cooling supply to an increase of 21%, compared to 61% in the Reference Scenario, in spite of improving living standards.
- In the industry sector solar collectors, biomass/biogas as well as geothermal energy are increasingly substituting for conventional fossil-fired heating systems.
- A shift from coal and oil to natural gas in the remaining conventional applications leads to a further reduction of CO_2 emissions.

figure 6.111: china: development of specific electricity generation costs under the two scenarios

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

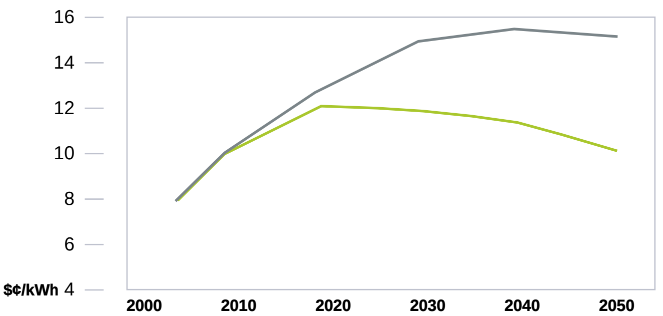


figure 6.112: china: development of total electricity supply costs

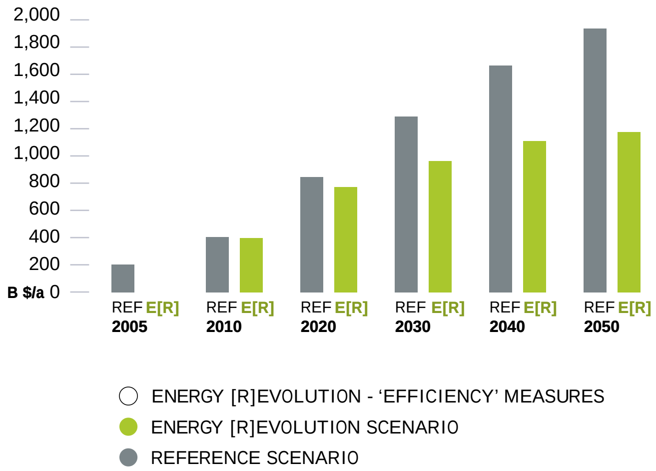


figure 6.113: china: development of heat supply structure under the two scenarios

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

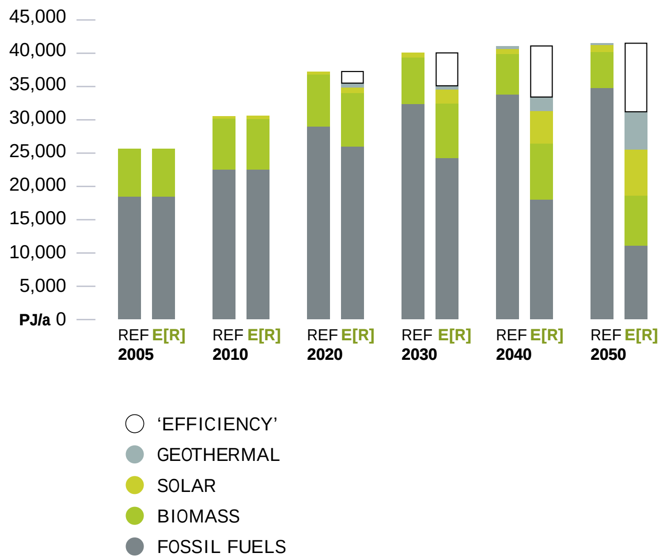
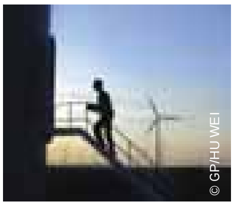


image A WORKER ENTERS A TURBINE TOWER FOR MAINTENANCE AT DABANCHENG WIND FARM. CHINA'S BEST WIND RESOURCES ARE MADE POSSIBLE BY THE NATURAL BREACH IN TIANSHAN (TIAN MOUNTAIN).

image WOMEN WEAR MASKS AS THEY RIDE BIKES TO WORK IN THE POLLUTED TOWN OF LINFEN. LINFEN, A CITY OF ABOUT 4.3 MILLION, IS ONE OF THE MOST POLLUTED CITIES IN THE WORLD. CHINA'S INCREASINGLY POLLUTED ENVIRONMENT IS LARGELY A RESULT OF THE COUNTRY'S RAPID DEVELOPMENT AND CONSEQUENTLY A LARGE INCREASE IN PRIMARY ENERGY CONSUMPTION, WHICH IS ALMOST ENTIRELY PRODUCED BY BURNING COAL.

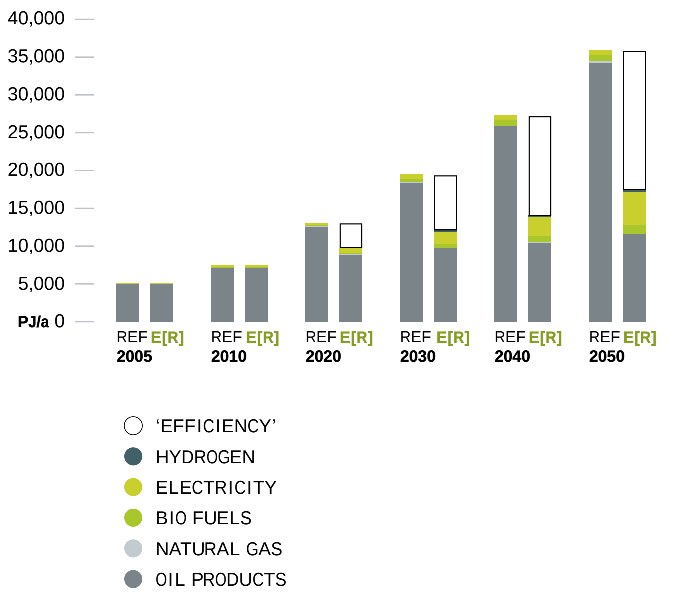


china: transport

In 2050, the light duty vehicle stock in China will be 20 times larger than today. Today, more medium to large sized cars are driven in China, with an unusually high annual mileage. With growing individual mobility, an increasing share of small efficient cars is projected, with vehicle kilometres driven converging with industrialised country averages. More efficient propulsion technologies, including hybrid-electric powertrains and lightweight construction, will help limit the increase in total transport energy demand to a factor of 3.4, reaching 17,300 PJ/a in 2050. As China already has a large fleet of electric vehicles, this will grow to the point where almost 25% of total transport energy is covered by electricity. Bio fuels will contribute about 7%.

figure 6.114: china: transport under the two scenarios

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

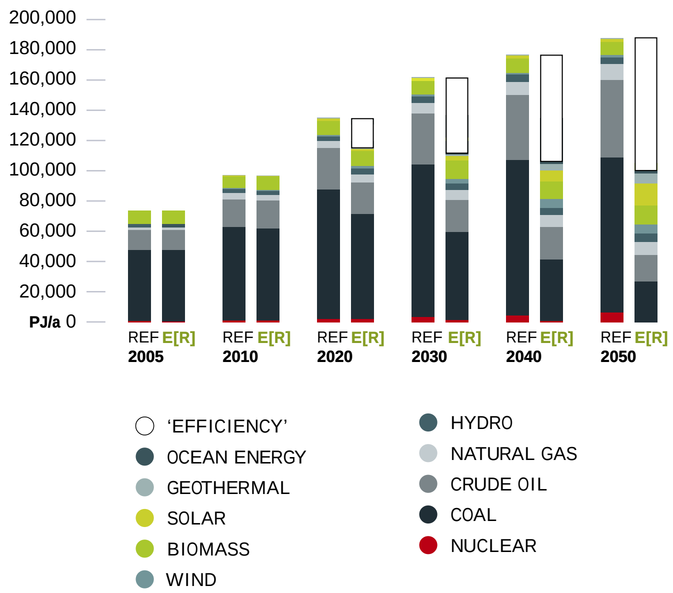


china: primary energy consumption

Taking into account the above assumptions, the resulting primary energy consumption under the Energy [R]evolution Scenario is shown in Figure 6.115. Compared to the Reference Scenario, overall energy demand will be reduced by almost 47 in 2050. Around 47% of the remaining demand will be covered by renewable energy sources.

figure 6.115: china: development of primary energy consumption under the two scenarios

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

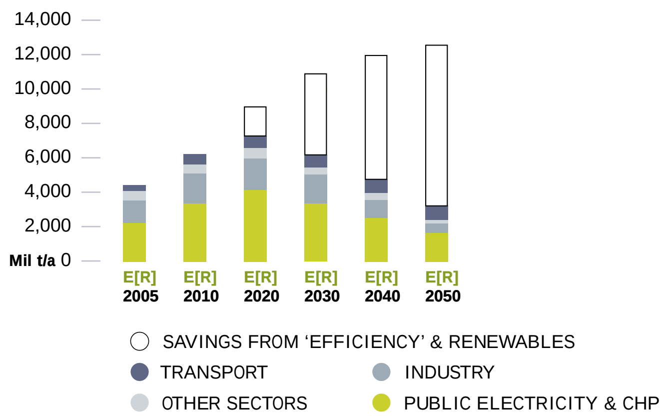


china: development of CO_2 emissions

Whilst China's emissions of CO_2 will almost triple under the Reference Scenario, under the Energy [R]evolution Scenario they will decrease from 4,400 million tonnes in 2005 to 3,200 m/t in 2050. Annual per capita emissions will drop from 3.4 tonnes to 2.3 t. In spite of increasing demand, CO_2 emissions will decrease in the electricity sector. In the long run efficiency gains and the increased use of renewable electricity in vehicles will even reduce CO_2 emissions in the transport sector. With a share of 50% of total CO_2 in 2050, the power sector will remain the largest source of emissions.

figure 6.116: china: development of CO_2 emissions by sector under the energy [r]evolution scenario

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



oecd pacific

oecd pacific: energy demand by sector

The future development pathways for the OECD Pacific's primary energy demand are shown in Figure 6.117 for both the Reference and Energy [R]evolution Scenarios. Under the Reference Scenario, total primary energy demand increases by 27% - from the current 37,040 PJ/a to 47,020 PJ/a in 2050. In the Energy [R]evolution Scenario, by contrast, primary energy demand decreases by 33% compared to current consumption and is expected by 2050 to reach 24,950 PJ/a.

Under the Energy [R]evolution Scenario, electricity demand in the industry as well as the residential and services sectors is expected to fall slightly below the current level of demand (see Figure 6.118). The growing use of electric vehicles however leads to an increase in electricity demand, reaching 1,920 TWh/a in 2050. Overall demand is still 560 TWh/a lower than in the Reference Scenario.

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 6.119). Compared to the Reference Scenario, consumption equivalent to 2,860 PJ/a is avoided through efficiency gains by 2050.

In the transport sector, it is assumed under the Energy [R]evolution Scenario that energy demand will decrease by 40% to 4,000 PJ/a by 2050, saving about 50% compared to the Reference Scenario.

figure 6.117: oecd pacific: projection of total final energy demand by sector for the two scenarios

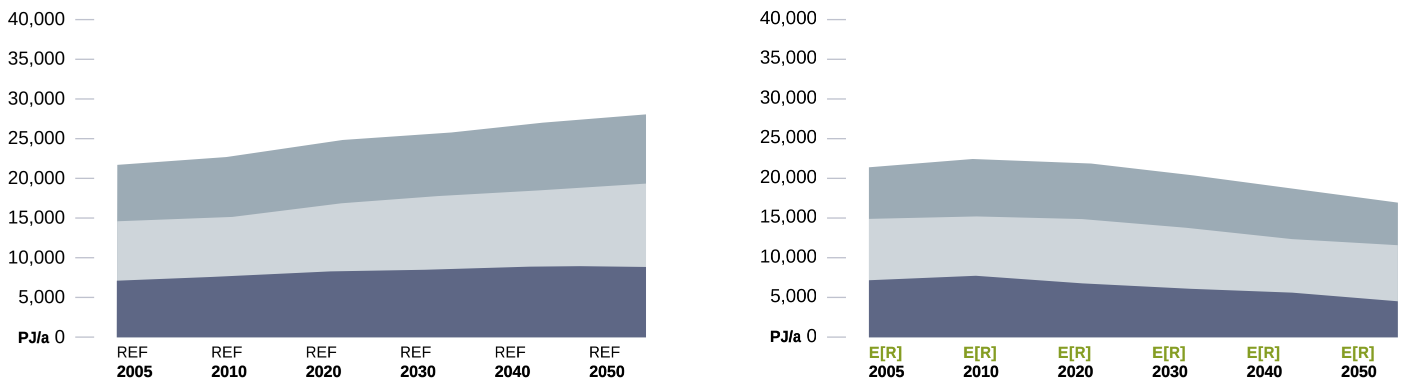


figure 6.118: oecd pacific: development of electricity demand by sector

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

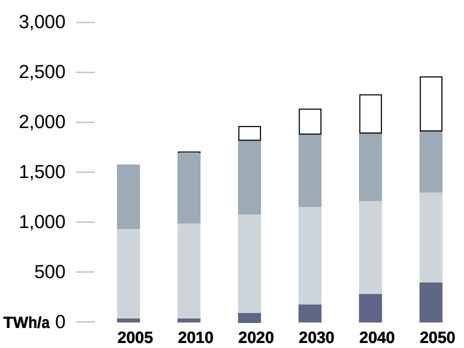


figure 6.119: oecd pacific: development of heat demand by sector

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

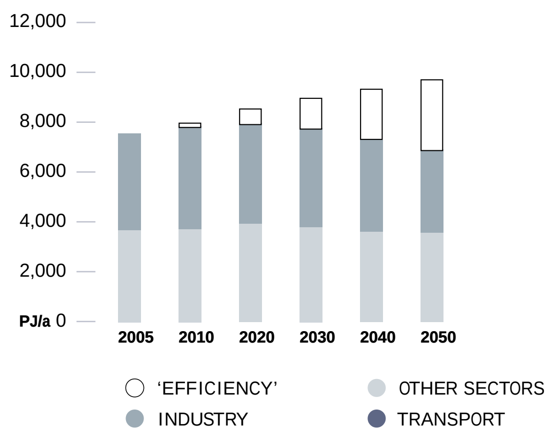


image GEOTHERMAL POWER STATION, NORTH ISLAND, NEW ZEALAND.

image WIND FARM LOOKING OVER THE OCEAN AT CAPE JERVIS, SOUTH AUSTRALIA.

oecd pacific: electricity generation

A dynamically growing renewable energy market 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, 78% of the electricity produced in the OECD Pacific will come from renewable energy sources. 'New' renewables – mainly wind, solar thermal energy and PV – will contribute 68%.

The installed capacity of renewable energy technologies will grow from the current 62 GW to more than 600 GW in 2050, an increase by a factor of ten.

To achieve an economically attractive growth in renewable energy sources, a balanced and timely mobilisation of all technologies is of great importance. Figure 6.121 shows the comparative evolution of the different renewables over time. Up to 2020, hydro-power and wind will remain the main contributors. After 2020, the continuing growth of wind will be complemented by electricity from biomass, photovoltaic and solar thermal energy.

table 6.11: oecd pacific: projection of renewable electricity generation capacity under the energy [r]evolution scenario

IN GW

	2005	2010	2020	2030	2040	2050
Hydro	55	64	76	81	86	89
Biomass	3	5	8	13	22	33
Wind	2	5	35	68	116	201
Geothermal	1	1	2	3	5	7
PV	0.02	5	35	68	116	201
Solarthermal	0	0	3	3	6	7
Ocean energy	0	0	1	4	11	21
Total	**62**	**80**	**166**	**252**	**389**	**609**

figure 6.120: oecd pacific: development of electricity generation structure under the two scenarios

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

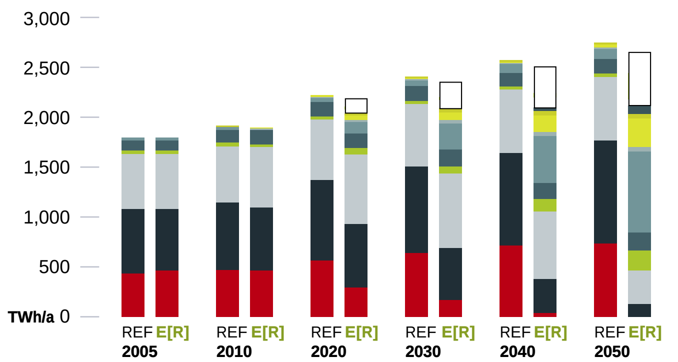
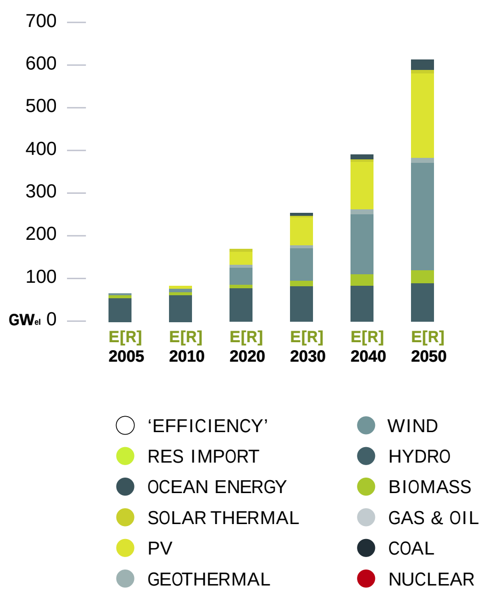


figure 6.121: oecd pacific: growth of renewable electricity generation capacity under the energy [r]evolution scenario

BY INDIVIDUAL SOURCE



oecd pacific

GLOBAL SCENARIO

OECD NORTH AMERICA
LATIN AMERICA
OECD EUROPE
AFRICA

MIDDLE EAST
TRANSITION ECONOMIES
INDIA

DEVELOPING ASIA
CHINA
OECD PACIFIC

oecd pacific: future costs of electricity generation

Figure 6.122 shows that the introduction of renewable technologies under the Energy [R]evolution Scenario slightly increases the costs of electricity generation in the OECD Pacific compared to the Reference Scenario. The difference will be less than 1.5 cents/kWh up to 2030. Because of the lower CO_2 intensity, by 2020 electricity generation costs will become economically favourable under the Energy [R]evolution Scenario, and by 2050 they will be more than 4 cents/kWh below those in the Reference Scenario.

Under the Reference Scenario, by contrast, unchecked growth in demand, an increase in fossil fuel prices and the cost of CO_2 emissions result in total electricity supply costs rising from today's $160 billion per year to more than $400 bn in 2050. Figure 6.123 shows that the Energy [R]evolution Scenario not only complies with the OECD Pacific's CO_2 reduction targets but also helps to stabilise energy costs. 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.

oecd pacific: heat and cooling supply

Renewables currently provide 5% of OECD Pacific's primary energy demand for heat supply, the main contribution coming from biomass. Dedicated support instruments are required to ensure a future dynamic development.

In the Energy [R]evolution Scenario, renewables provide 73% of OECD Pacific's total heating and cooling demand by 2050.

- Energy efficiency measures can decrease the current demand for heat supply by 10%, in spite of improving living standards.
- 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 6.122: oecd pacific: development of specific electricity generation costs under the two scenarios

(CO_2 EMISSION COSTS IMPOSED FROM 2010, WITH AN INCREASE FROM 15 $/$T_{CO_2}$ IN 2010 TO 50 $/$T_{CO_2}$ IN 2050)

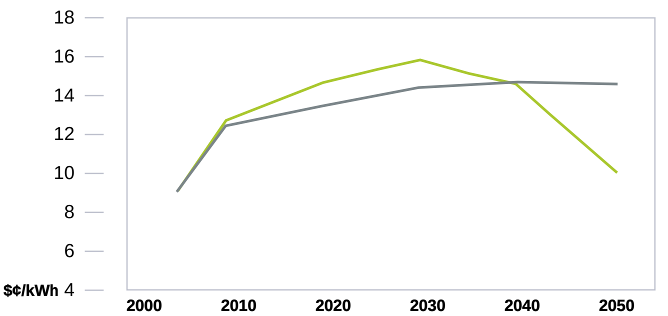


figure 6.123: oecd pacific: development of total electricity supply costs

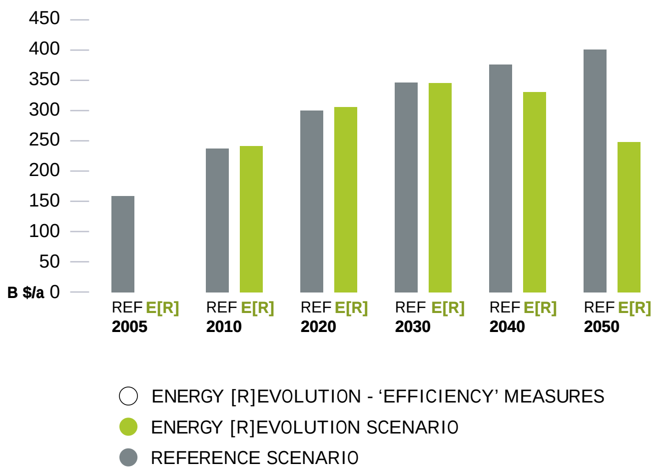


figure 6.124: oecd pacific: development of heat supply structure under the two scenarios

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

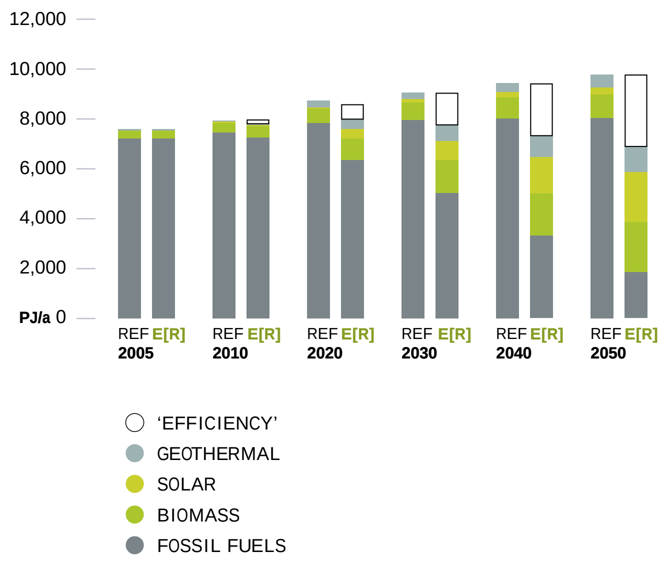


image SOLAR PANELS ON CONISTON STATION, NORTH WEST OF ALICE SPRINGS, NORTHERN TERRITORY.

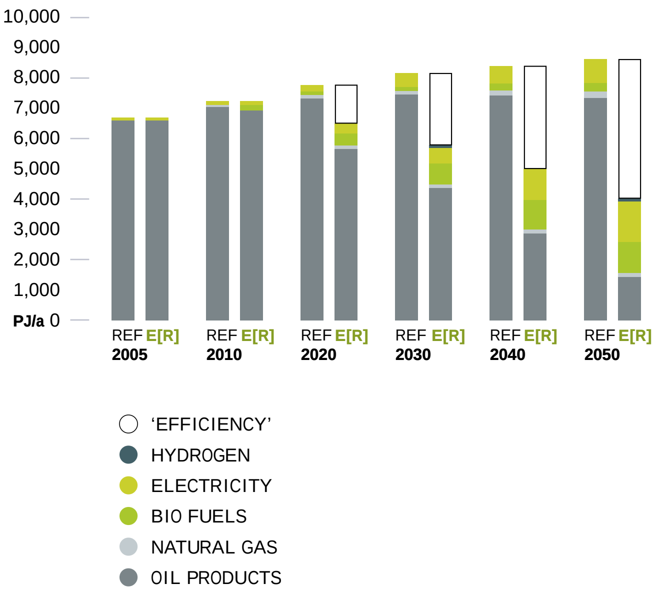
image THE "CITIZENS' WINDMILL" IN AOMORI, NORTHERN JAPAN. PUBLIC GROUPS, SUCH AS CO-OPERATIVES, ARE BUILDING AND RUNNING LARGE-SCALE WIND TURBINES IN SEVERAL CITIES AND TOWNS ACROSS JAPAN.

oecd pacific: transport

The low duty vehicles (LDV) market in OECD Pacific is driven by Japan, with a unique share of small cars and a fuel consumption average of 6.45 litres/100 km in the new car fleet. Other countries in the region typically drive larger cars, and incentives to encourage smaller cars will be crucial. The LDV stock is projected to grow by a factor of 1.4 to 119 million vehicles. While 94% of all LDVs use petrol today, electrified vehicles will play a key role, especially in Japan's well suited small cars, in reducing energy demand. By 2050, 35% of total transport energy is covered by electricity and 25% by bio fuels.

figure 6.125: oecd pacific: transport under the two scenarios

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

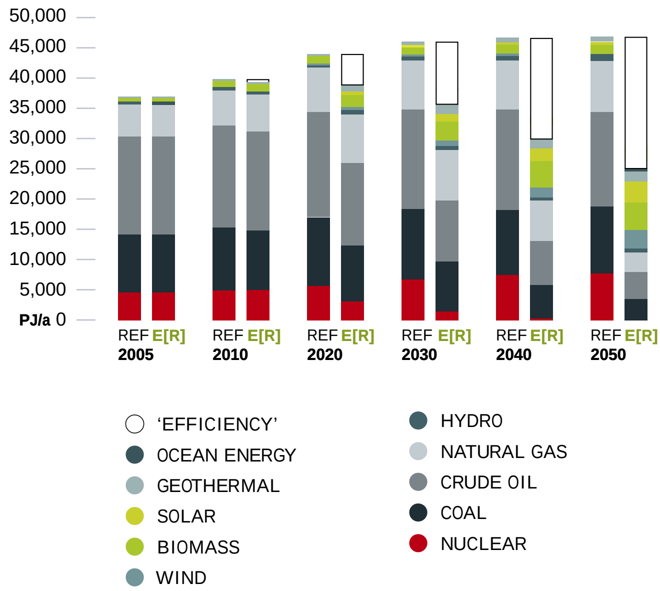


oecd pacific: primary energy consumption

Taking into account the above assumptions, the resulting primary energy consumption under the Energy [R]evolution Scenario is shown in Figure 6.126. Compared to the Reference Scenario, overall energy demand will be reduced by 47% in 2050. Around 55% of the remaining demand will be covered by renewable energy sources.

figure 6.126: oecd pacific: development of primary energy consumption under the two scenarios

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

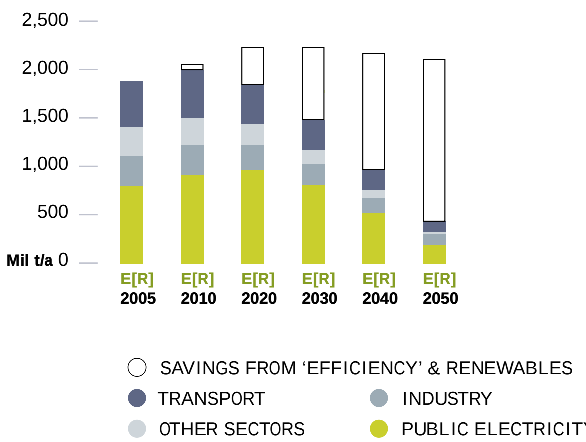


oecd pacific: development of CO_2 emissions

Whilst the OECD Pacific's emissions of CO_2 will increase by 20% under the Reference Scenario, under the Energy [R]evolution Scenario they will decrease from 1,900 million tonnes in 2005 to 430 m/t in 2050. Annual per capita emissions will fall from 9.5 tonnes to 2.4 t. In the long run efficiency gains and the increased use of renewable electricity in vehicles will even reduce CO_2 emissions in the transport sector. With a share of 45% of total CO_2 in 2050, the power sector will remain the largest source of emissions.

figure 6.127: oecd pacific: development of CO_2 emissions by sector under the energy [r]evolution scenario

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



INVESTMENT IN NEW POWER PLANTS   FOSSIL FUEL POWER GENERATION INVESTMENT
RENEWABLE POWER GENERATION INVESTMENT

7

image PRODUCING WIND ROTORS FOR OFFSHORE WIND ENERGY IN RINGKOBING, DENMARK.

"I often ask myself why this whole question needs to be so difficult, why governments have to be dragged kicking and screaming even when the cost is miniscule."

LYN ALLISON
LEADER OF THE AUSTRALIAN DEMOCRATS, SENATOR 2004-2008

image TEST WINDMILL N90 2500, BUILT BY THE GERMAN COMPANY NORDEX, IN THE HARBOUR OF ROSTOCK. THIS WINDMILL PRODUCES 2,5 MEGA WATT AND IS TESTED UNDER OFFSHORE CONDITIONS. TWO TECHNICIANS WORKING INSIDE THE TURBINE.

global market overview

source FOR PAGE 101+102: RENEWABLE 2007 - GLOBAL STATUS REPORT, REN 21, ERIC MARTINOT

The global market for renewable energy has been expanding in recent years at a record rate, an indication of its potential to realise the future targets outlined in the Energy [R]evolution Scenario.

- **Renewable electricity generation capacity** reached an estimated 240 Gigawatts (GW) worldwide in 2007, an increase of 50 % over 2004. Renewables represent 5 % of global power capacity and 3.4 % of global power generation. These figures exclude large hydropower, which alone accounted for 15 % of global power generation.
- Renewable energy (excluding large hydropower) generated as much **electric power** worldwide in 2006 as one-quarter of the world's nuclear power plants.
- The largest component of renewable generation capacity is wind power, which grew by 28 % worldwide in 2007 to reach 95 GW. The annual capacity growth rate is even higher: 40 % more in 2007 than the year before.
- The fastest growing energy technology in the world is **grid-connected solar photovoltaics (PV)**, with a 50 % annual increase in cumulative installed capacity in both 2006 and 2007 to reach 7.7 GW. This translates into 1.5 million homes with rooftop solar PV feeding into the grid.
- Rooftop **solar heat collectors** provide hot water to nearly 50 million households worldwide, and space heating to a growing number of homes. Existing solar hot water/heating capacity increased by 19 % in 2006 to reach 105 Gigawatts thermal (GWth) globally.
- The use of **biomass and geothermal energy** for both power and heating has been increasing in a number of countries, including for district heating networks. More than 2 million ground source heat pumps are now used in 30 countries to heat (and cool) buildings.
- **Renewable energy**, in particular small hydropower, biomass and solar PV, is providing electricity, heat, motive power and water pumping for tens of millions of people in the rural areas of developing countries, serving agriculture, small industry, homes and schools. 25 million households cook and light their homes with biogas and 2.5 million households use solar lighting systems.
- **Developing countries** account for more than 40 % of existing renewable power capacity, more than 70 % of solar hot water capacity and 45 % of bio fuels production.

In terms of investment, an estimated $71 billion was invested in new renewable power and heating capacity worldwide in 2007 (excluding large hydropower). Of this, 47 % was for wind power and 30 % for solar PV. Investment in large hydropower, the most established renewable energy source, added a further $15–20 billion. The total amount invested in new renewable energy capacity, manufacturing plants and research and development during 2007 is estimated to have reached a record $100 billion.

Investment flows have also became more diversified and mainstream, with funding flowing from a wide range of sources, including major commercial and investment banks, venture capital and private equity investors, multilateral and bilateral development organisations as well as smaller local financiers. The renewable energy industry has seen many new companies launched, huge increases in company valuations and numerous initial public offerings. The 140 highest-valued publicly traded renewable energy companies now have a combined market capitalisation of over $100 billion.

Major industrial growth is occurring in a number of emerging renewable technologies, including thin-film solar PV, concentrating solar thermal power generation and advanced or second generation bio fuels. Worldwide employment in renewable energy manufacturing, operation and maintenance exceeded 2.4 million jobs in 2006, including some 1.1 million in bio fuels production.

The main reason for this industrial expansion is that national targets for renewable energy have been adopted in at least 66 countries worldwide, including all 27 European Union member states, 29 US states and nine Canadian provinces. Most targets are for a percentage of electricity production or primary energy to be achieved by a specific future year. There is now an EU-wide target, for example, for 20 % of energy to come from renewables by 2020 and a Chinese target of 15 %. Targets for bio fuel use in transport energy also now exist in several countries, including an EU-wide target for 10 % by 2020.

Specific policies to promote renewables have also mushroomed in recent years. At least 60 countries - 37 developed and transition countries and 23 developing countries - have adopted some type of policy to promote renewable power generation. The most common is the feed-in law, through which a set premium price is paid for each unit of renewable power generation. By 2007, at least 37 countries and nine states or provinces had adopted feed-in policies, more than half of which have been enacted since 2002. At least 44 states, provinces and countries have enacted renewable portfolio standards (RPS), which place an obligation on energy companies to source a rising percentage of their power from renewable sources. Other forms of support for renewable power generation include capital investment subsidies or rebates, tax incentives and credits, sales tax and value-added tax exemptions, net metering, public investment or financing and public competitive bidding.

Beneath a national and state level, municipalities around the world are also setting targets for future shares of renewable energy, typically in the range of 10–20 %. Some cities have established carbon dioxide reduction targets, others are enacting policies to promote solar hot water and solar PV or introducing urban planning rules which incorporate renewable energy. Market facilitation organisations are supporting the growth of renewable energy markets and policies through networking, market research, training, project facilitation, consulting, financing, policy advice and other technical assistance. There are now hundreds of such organisations around the world, including industry associations, non-governmental organisations, multilateral and bilateral development agencies, international partnerships and government agencies.

table 7.1: selected indicators

	2005	2006	2007
Investment in new renewable capacity (ANNUAL)	$40	$55	$71 billion
Renewables power capacity (EXISTING, EXCL. LARGE HYDRO)	182	207	240 GW
Renewables power capacity (EXISTING, INCL. LARGE HYDRO)	930	970	1,010 GW
Wind power capacity (EXISTING)	59	74	95 GW
Grid-connected solar PV capacity (EXISTING)	3.5	5.1	7.8 GW
Solar PV production (ANNUAL)	1.8	2.5	3.8 GW
Solar hot water capacity (EXISTING)	88	105	128 GWth
Ethanol production (ANNUAL)	33	39	46 bill. litrs
Biodiesel production (ANNUAL)	3.9	6	8 bill. litrs
Countries with policy targets	52		66
States/provinces/countries with feed-in policies	41		46
States/provinces/countries with RPS policies	38		44
States/provinces/countries with bio fuels mandates	38		53

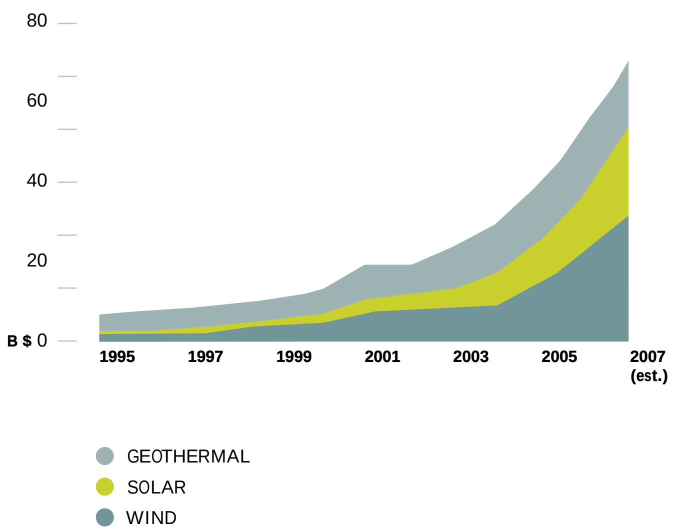
source REN21

growth rates of the renewable energy industry

Figure 7.2 shows that many renewable energy technologies grew at rates of 15–30 % annually during the five year period 2002–2006, including wind power, solar hot water, geothermal heating and off-grid solar PV. Grid-connected solar PV eclipsed all of these, with a 60 % annual average growth rate for the period. Bio fuels also grew rapidly during the period, at a 40 % annual average for biodiesel and 15 % for ethanol. Other technologies are growing more slowly, at 3–5 %, including large hydropower, biomass power and heat, and geothermal power, although in some countries these technologies are growing much more rapidly than the global average.

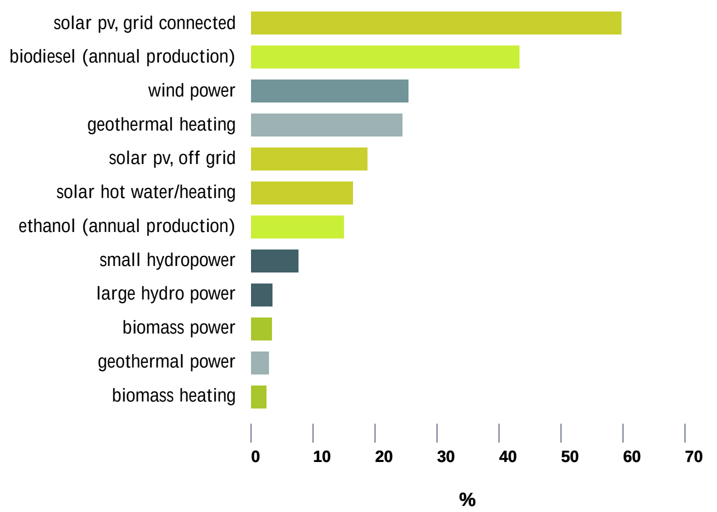
These expansion rates compare with the global growth rates for fossil fuels of 2–4 % in recent years (higher in some developing countries)[35].

figure 7.1: annual investment in renewable energy capacity, 1995-2007 EXCLUDES LARGE HYDROPOWER



source REN21

figure 7.2: average annual growth rates of renewable energy capacity, 2002-2006



source REN21

references
35 'RENEWABLE ENERGY STATUS REPORT 2007', REN 21, WWW.REN21.NET

image GREENPEACE DONATES A SOLAR POWER SYSTEM TO A COASTAL VILLAGE IN ACEH, INDONESIA, ONE OF THE WORST HIT AREAS BY THE TSUNAMI IN DECEMBER 2004.

image A LOCAL WOMAN WORKS WITH TRADITIONAL AGRICULTURE PRACTICES JUST BELOW 21ST CENTURY ENERGY TECHNOLOGY. THE JILIN TONGYU TONGFA WIND POWER PROJECT, WITH A TOTAL OF 118 WIND TURBINES, IS A GRID CONNECTED RENEWABLE ENERGY PROJECT.

future growth rates

In order to get a better understanding of what different technologies can deliver, however, it is necessary to examine more closely how future production capacities can be achieved from the current baseline. The wind industry, for example, has a current annual production capacity of about 25,000 MW. If this output were not expanded, total capacity would reach 650 GW by the year 2050. This includes the need for "repowering" of older wind turbines after 20 years. But according to this scenario the share of wind electricity in global production by 2050 would need to grow from today's 1% to 4.5% under the Reference Scenario and 6.5% under the Energy [R]evolution pathway.

A relatively modest expansion from today's 25 GW production capacity, however, to about 80 GW by 2020 and 100 GW in 2040 would lead to a total installed capacity of 1,800 GW in 2050, providing between 12% and 18% of world electricity demand.

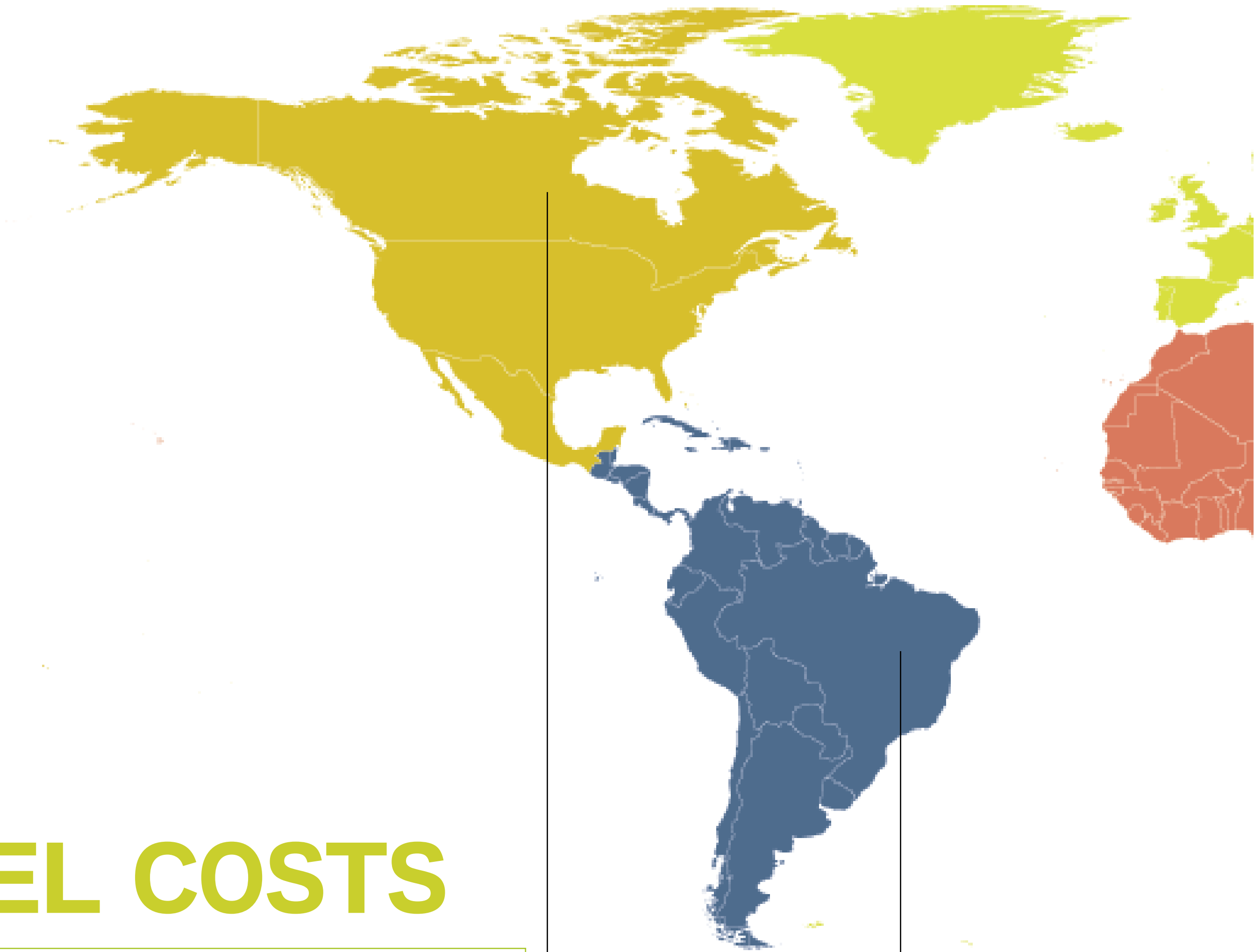
The tables below provide an overview of current generation levels, the capacities required under the Energy [R]evolution Scenario and industry projections of a more advanced market growth. The good news is that the scenario does not even come close to the limit of the renewable industries' own projections. However, the scenario assumes that at the same time strong energy efficiency measures are taken in order to save resources and develop a more cost optimised energy supply.

table 7.2: required production capacities for renewable energy technologies in different scenarios

NEW RENEWABLE ELECTRICITY GENERATION TECHNOLOGIES	2010	2020	2030	2040	2050	TOTAL INSTALLED CAPACITY IN 2050	ELECTRICITY SHARE UNDER E[R] DEMAND PROJECTION IN 2050
			INCLUDES PRODUCTION CAPACITY FOR REPOWERING				
	GW/a	GW/a	GW/a	GW/a	GW/a	GW	%
Solar Photovoltaics PRODUCTION CAPACITY IN 2007 (APPROX. 5-7 GW)							
Reference	2	5	5	5	5	153	0
Energy [R]evolution	4	40	65	100	125	2,911	10
Advanced	4	45	165	165	165	3,835	13
Concentrated Solar Power PRODUCTION CAPACITY IN 2007 (APPROX. 2-3 GW)							
Reference	0.5	0.5	0.5	0.5	0.5	17	0
Energy [R]evolution	1	12	17	27	33	801	12
Advanced	1	15	32	65	105	2,100	32
Wind PRODUCTION CAPACITY IN 2007 (APPROX. 25 GW)							
Reference	25	25	25	25	25	593	4
Energy [R]evolution	30	82	85	100	100	2,733	18
Advanced	36	142	165	165	165	3,500	23
Geothermal PRODUCTION CAPACITY IN 2007 (APPROX. 1-2 GW)							
Reference	1	1	1	1	1	36	1
Energy [R]evolution	1	5	6	10	10	276	4
Advanced - not available							
Ocean PRODUCTION CAPACITY IN 2007 (APPROX. >1 GW)							
Reference	0.2	0.2	0.2	0.3	0.3	9	0
Energy [R]evolution	0	2	3	5	10	194	2
Advanced - not available							
Total PRODUCTION CAPACITIES PRODUCTION CAPACITY IN 2007 (APPROX.)							
Reference	28	32	31	31	31	808	5
Energy [R]evolution	36	141	176	242	278	6,916	46
Advanced	41	202	362	395	435	9,435	68

map 7.2: fuel costs in the reference and the energy [r]evolution scenario

WORLDWIDE SCENARIO



SCENARIO

FUEL COSTS

LEGEND

> 0 | > 5 | > 10 | > 15 | > 20 | > 25 | > 30 | > 35 | > 40 | > 45 | > 50

% FUEL COST SAVING IN THE E[R] SCENARIO COMPARED TO THE REFERENCE SCENARIO 2005-2030. GLOBAL FUEL SAVING IS 23.25%

REF REFERENCE SCENARIO

E[R] ALTERNATIVE SCENARIO

DIF DIFFERENCE BETWEEN SCENARIOS

0 1000 KM

COST OF COAL BILLION $

COST OF GAS BILLION $

COST OF OIL BILLION $

OECD NORTH AMERICA

		REF	E[R]	DIF
COAL	2005-2010	1,275	1,231	43
	2011-2020	3,307	2,603	703
	2021-2030	4,048	2,159	1,889
	2005-2030	8,629	5,994	2,636
GAS	2005-2010	389	409	-20
	2011-2020	1,076	1,320	-244
	2021-2030	1,466	1,692	-226
	2005-2030	2,931	3,421	-490
OIL	2005-2010	146	135	11
	2011-2020	292	177	115
	2021-2030	244	74	170
	2005-2030	681	386	295
TOTAL ALL FUELS	2005-2010	1,809	1,775	34
	2011-2020	4,674	4,100	574
	2021-2030	5,758	3,925	1,833
	2005-2030	12,242	9,801	2,441

OECD LATIN AMERICA

		REF	E[R]	DIF
COAL	2005-2010	25	22	3
	2011-2020	76	30	46
	2021-2030	231	19	112
	2005-2030	233	71	162
GAS	2005-2010	89	81	8
	2011-2020	395	225	170
	2021-2030	749	234	514
	2005-2030	1,233	540	692
OIL	2005-2010	54	56	-2
	2011-2020	106	81	25
	2021-2030	87	16	72
	2005-2030	247	152	95
TOTAL ALL FUELS	2005-2010	168	158	10
	2011-2020	577	336	241
	2021-2030	967	269	698
	2005-2030	1,712	763	949

OECD EUROPE

		REF	E[R]	DIF
	2005-2010	628	582	46
	2011-2020	1,563	1,155	408
	2021-2030	1,922	579	1,343
	2005-2030	4,113	2,316	1,797
	2005-2010	307	311	-4
	2011-2020	928	981	-54
	2021-2030	1,493	1,266	227
	2005-2030	2,726	2,558	168
	2005-2010	124	119	5
	2011-2020	192	124	69
	2021-2030	124	56	68
	2005-2030	440	298	141
TOTAL ALL FUELS	2005-2010	1,058	1,011	47
	2011-2020	2,682	2,260	422
	2021-2030	3,539	1,901	1,637
	2005-2030	7,279	5,172	2,107

MIDDLE EAST

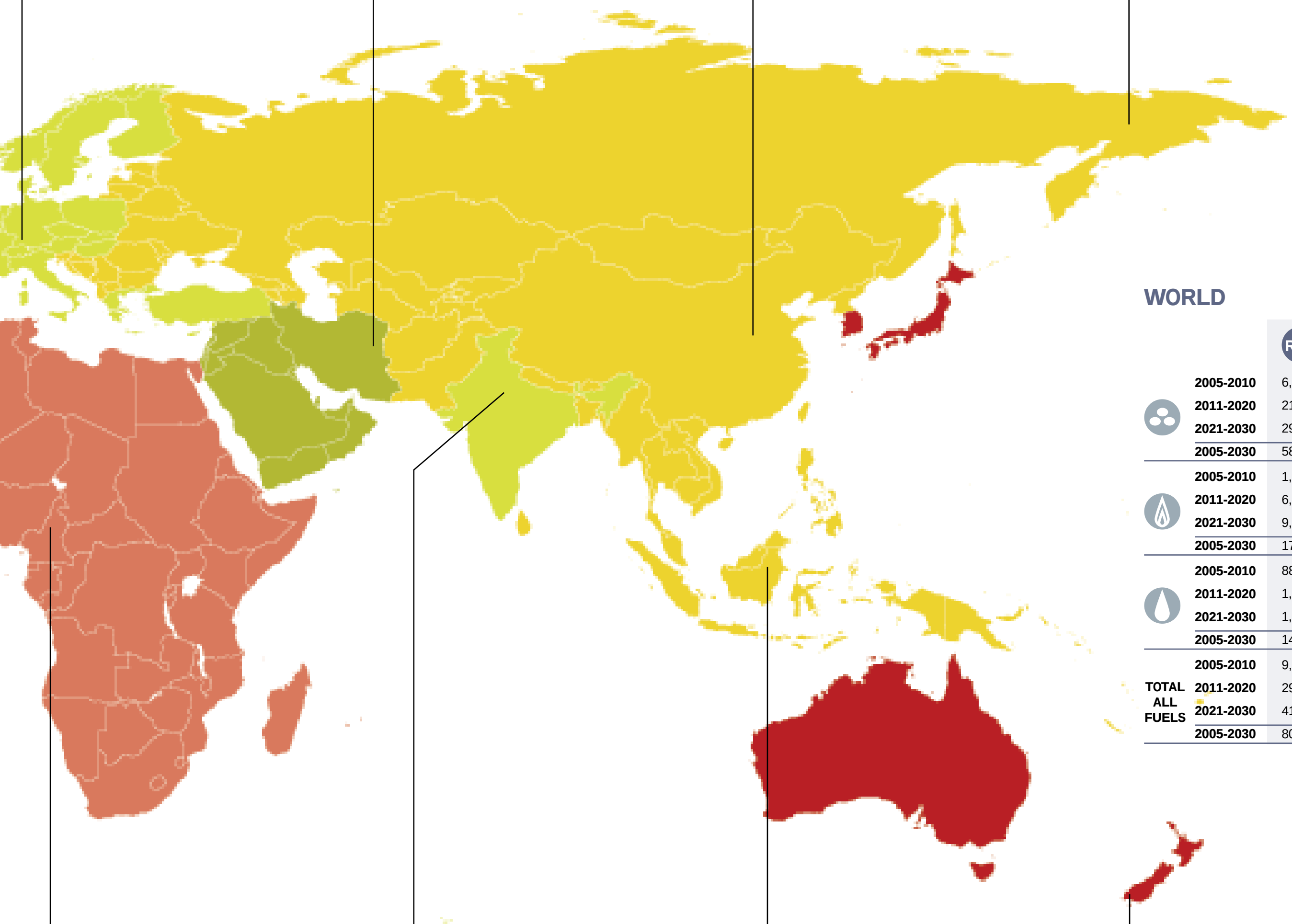
		REF	E[R]	DIF
	2005-2010	33	31	2
	2011-2020	103	56	48
	2021-2030	148	42	106
	2005-2030	284	128	156
	2005-2010	223	230	-7
	2011-2020	771	665	106
	2021-2030	1,422	821	601
	2005-2030	2,416	1,716	700
	2005-2010	227	215	13
	2011-2020	601	461	140
	2021-2030	715	327	388
	2005-2030	1,544	1,002	542
TOTAL ALL FUELS	2005-2010	483	475	8
	2011-2020	1,476	1,182	294
	2021-2030	2,285	1,89	1,095
	2005-2030	4,244	2,846	1,397

CHINA

		REF	E[R]	DIF
	2005-2010	2,834	2,817	17
	2011-2020	10,370	9,097	1,272
	2021-2030	14,908	9,242	5,666
	2005-2030	28,112	21,156	6,956
	2005-2010	27	28	0
	2011-2020	145	204	-59
	2021-2030	348	495	-147
	2005-2030	520	726	-206
	2005-2010	46	44	2
	2011-2020	93	81	13
	2021-2030	86	57	29
	2005-2030	225	182	43
TOTAL ALL FUELS	2005-2010	2,907	2,889	19
	2011-2020	10,608	9,382	1,226
	2021-2030	15,342	9,793	5,548
	2005-2030	28,857	22,064	6,793

TRANSITION ECONOMIES

		REF	E[R]	DIF
	2005-2010	389	320	68
	2011-2020	933	508	425
	2021-2030	910	300	610
	2005-2030	2,232	1,128	1,104
	2005-2010	510	535	-26
	2011-2020	1,270	1,347	-77
	2021-2030	1,687	1,487	191
	2005-2030	3,458	3,369	89
	2005-2010	52	55	-4
	2011-2020	84	81	4
	2021-2030	69	22	47
	2005-2030	205	158	47
TOTAL ALL FUELS	2005-2010	950	911	39
	2011-2020	2,288	1,936	352
	2021-2030	2,657	1,808	848
	2005-2030	5,894	4,655	1,239



WORLD

		REF	E[R]	DIF
	2005-2010	6,890	6,698	192
	2011-2020	21,577	18,001	3,576
	2021-2030	29,731	17,254	12,477
	2005-2030	58,198	41,953	16,244
	2005-2010	1,989	2,047	-59
	2011-2020	6,136	6,283	-147
	2021-2030	9,686	8,396	1,291
	2005-2030	17,811	16,727	1,085
	2005-2010	883	855	27
	2011-2020	1,902	1,465	438
	2021-2030	1,811	862	949
	2005-2030	14,596	3,181	1,415
TOTAL ALL FUELS	2005-2010	9,761	9,600	161
	2011-2020	29,616	25,749	3,866
	2021-2030	41,228	26,511	14,716
	2005-2030	80,605	61,861	18,744

AFRICA

		REF	E[R]	DIF
	2005-2010	247	247	0
	2011-2020	626	632	-6
	2021-2030	793	753	40
	2005-2030	1,666	1,632	34
	2005-2010	82	82	0
	2011-2020	317	258	59
	2021-2030	594	347	247
	2005-2030	993	687	307
	2005-2010	37	37	0
	2011-2020	75	72	4
	2021-2030	74	52	22
	2005-2030	186	161	26
TOTAL ALL FUELS	2005-2010	366	366	0
	2011-2020	1,018	962	57
	2021-2030	1,461	1,252	309
	2005-2030	2,845	2,479	366

INDIA

		REF	E[R]	DIF
	2005-2010	705	706	0
	2011-2020	2,302	1,987	315
	2021-2030	3,938	2,240	1,699
	2005-2030	6,947	4,933	2,014
	2005-2010	33	33	0
	2011-2020	152	157	-5
	2021-2030	321	440	-119
	2005-2030	506	630	-124
	2005-2010	26	26	0
	2011-2020	59	40	19
	2021-2030	56	12	43
	2005-2030	140	78	62
TOTAL ALL FUELS	2005-2010	764	764	0
	2011-2020	2,514	2,184	330
	2021-2030	4,315	2,693	1,622
	2005-2030	7,593	5,641	1,952

DEVELOPING ASIA

		REF	E[R]	DIF
	2005-2010	289	289	1
	2011-2020	868	732	137
	2021-2030	1,308	718	590
	2005-2030	2,466	1,738	727
	2005-2010	175	175	0
	2011-2020	581	524	56
	2021-2030	856	667	189
	2005-2030	1,612	1,367	245
	2005-2010	61	61	0
	2011-2020	173	150	23
	2021-2030	191	133	58
	2005-2030	425	344	81
TOTAL ALL FUELS	2005-2010	526	526	1
	2011-2020	1,622	1,406	216
	2021-2030	2,355	1,518	837
	2005-2030	4,503	3,450	1,053

OECD PACIFIC

		REF	E[R]	DIF
	2005-2010	466	455	11
	2011-2020	1,428	1,202	227
	2021-2030	1,624	1,203	421
	2005-2030	3,517	2,859	659
	2005-2010	154	163	-9
	2011-2020	504	603	-99
	2021-2030	759	946	-187
	2005-2030	1,417	1,712	-296
	2005-2010	110	108	2
	2011-2020	226	198	28
	2021-2030	166	113	53
	2005-2030	502	419	89
TOTAL ALL FUELS	2005-2010	729	725	4
	2011-2020	2,158	2,003	156
	2021-2030	2,549	2,262	287
	2005-2030	5,437	4,990	446

investment in new power plants

The overall global level of investment required in new power plants up to 2030 will be in the region of $ 11 to 14 trillion. The main driver for investment in new generation capacity in OECD countries will be the ageing power plant fleet. Utilities will make their technology choices within the next five to ten years based on national energy policies, in particular market liberalisation, renewable energy and CO_2 reduction targets. Within Europe, the EU emissions trading scheme may have a major impact on whether the majority of investment goes into fossil fuel power plants or renewable energy and co-generation. In developing countries, international financial institutions will play a major role in future technology choices.

The investment volume required to realise the Energy [R]evolution Scenario is $ 14.7 trillion, approximately 30% higher than in the Reference Scenario, which will require $ 11.3 trillion. Whilst the levels of investment in renewable energy and fossil fuels are almost equal under the Reference Scenario, with about $ 4.5 trillion each up to 2030, the Energy [R]evolution Scenario shifts about 80% of investment towards renewable energy. The fossil fuel share of power sector investment is focused mainly on combined heat and power and efficient gas-fired power plants.

The average annual investment in the power sector under the Energy [R]evolution Scenario between 2005 and 2030 is approximately $ 590 billion. This is equal to the current amount of subsidies for fossil fuels globally in less than two years. Most investment in new power generation will take place in China, followed by North America and Europe. South Asia, including India, and East Asia, including Indonesia, Thailand and the Philippines, will also be 'hot spots' of new power generation investment.

figure 7.4: change in cumulative power plant investment in the energy [r]evolution scenario

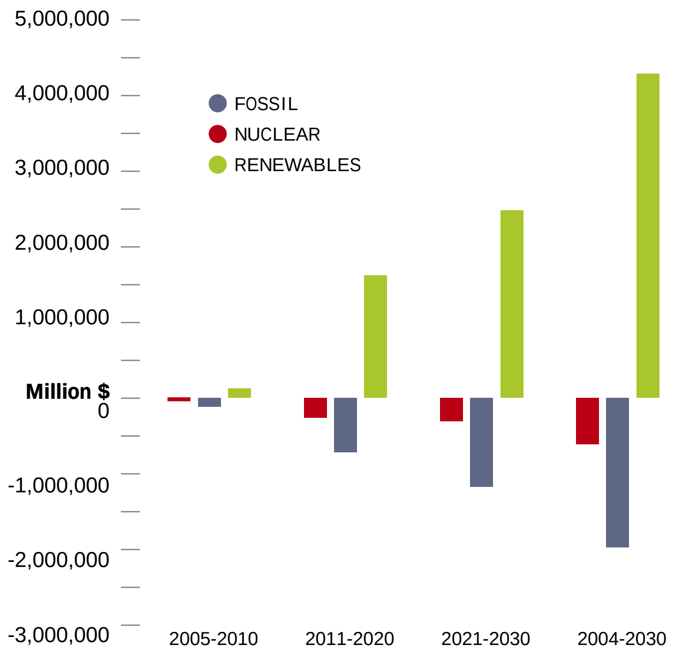


figure 7.3: investment shares - reference versus energy [r]evolution

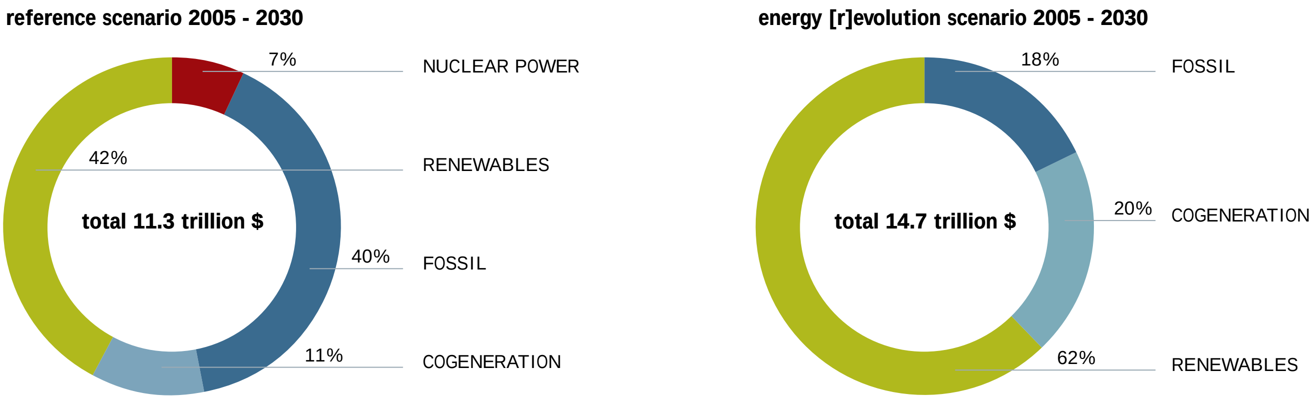
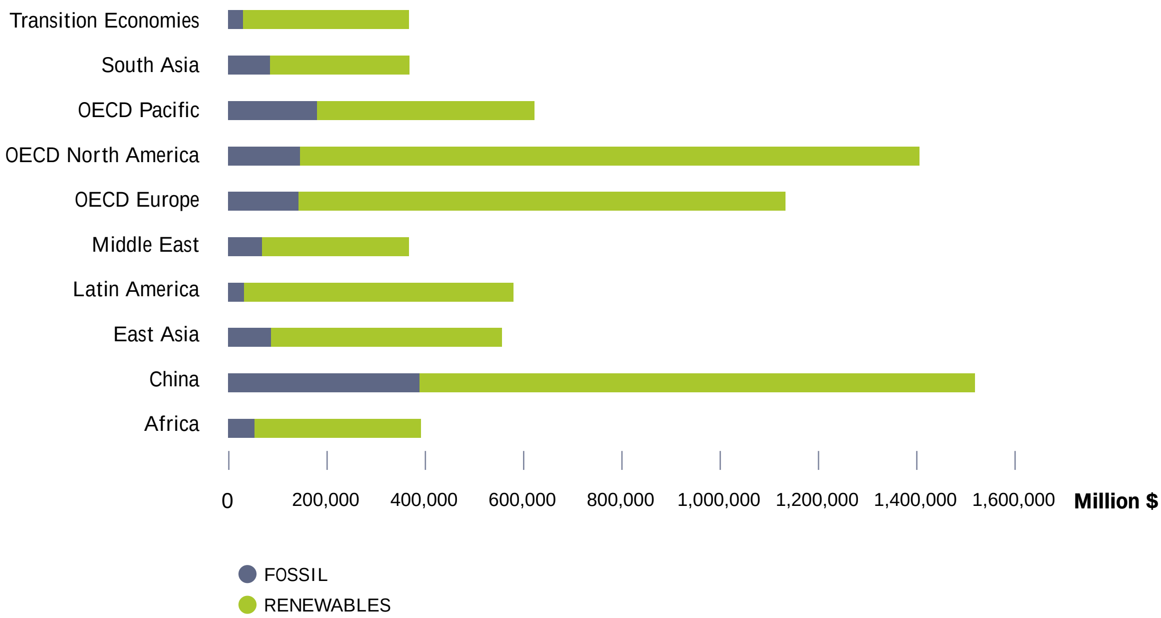


image WORKERS BUILD A WIND TURBINE IN A FACTORY IN PATHUM THANI, THAILAND. THE IMPACTS OF SEA-LEVEL RISE DUE TO CLIMATE CHANGE ARE PREDICTED TO HIT HARD ON COASTAL COUNTRIES IN ASIA, AND CLEAN RENEWABLE ENERGY IS A SOLUTION.

figure 7.5: cumulative power plant investments by region 2004-2030 in the energy [r]evolution scenario



renewable power generation investment

Under the Reference Scenario the investment expected in renewable electricity generation will be $ 4.7 trillion. This compares with $ 8.9 trillion in the Energy [R]evolution Scenario. The regional distribution in the two scenarios, however, is almost the same.

How investment is divided between the different renewable power generation technologies depends on their level of technical development. Technologies like wind power, which in some regions with good wind resources is already cost competitive with conventional fuels, will take a larger investment volume and a bigger market share. The market volume by technology and region also depends on the local resources and policy framework.

For solar photovoltaics, the main market will remain for some years in Europe and the US, but will soon expand across China and India. Because solar PV is a highly modular and decentralised technology which can be used almost everywhere, its market will eventually be spread across the entire world.

Concentrated solar power systems, on the other hand, can only be operated within the world's sunbelt regions. The main investment in this technology will therefore take place in North Africa, the Middle East, parts of the USA and Mexico, as well as south-west China, India, Australia and southern Europe.

The main development of the wind industry will take place in Europe, North America and China. Offshore wind technology will take a larger share from roughly 2015 onwards. The main offshore wind development will take place in North Europe and North America.

The market for geothermal power plants will be mainly in North America and East Asia. The USA, Indonesia and the Philippines, and some countries of central and southern Africa, have the highest potential over the next 20 years. After 2030, geothermal generation will expand to other parts of the world, including Europe and India.

Bio energy power plants will be distributed across the whole world as there is potential almost everywhere for biomass and/or biogas (cogeneration) power plants.

fossil fuel power generation investment

Under the Reference Scenario, the main market expansion for new fossil fuel power plants will be in China, followed by North America, which will have a volume equal to India and Europe combined. In the Energy [R]evolution Scenario the overall investment in fossil fuel power stations up to 2030 will be $ 2,600 billion, significantly lower than the Reference Scenario's $ 4,500 billion.

China will be by far the largest investor in coal power plants in both scenarios. While in the Reference Scenario the growth trend of the current decade (2000–2010) will continue towards 2030, the Energy [R]evolution Scenario assumes that in the second and third decades (2011-2030) growth slows down significantly. In the Reference Scenario the massive expansion of coal firing is due to activity in China, followed by the USA, India, East Asia and Europe.

The total cost for fossil fuel investment in the Reference Scenario between 2005 and 2030 amounts to $ 80.6 trillion, compared to $ 61.8 trillion in the Energy [R]evolution Scenario. This means that fuel costs in the Energy [R]evolution Scenario are already about 25% lower by 2030 and will be 50% lower by 2050. Although the investment in gas-fired power stations and cogeneration plants is about the same in both scenarios, the finance committed to oil and coal for electricity generation in the Energy [R]evolution Scenario is almost 30% below the Reference version.

fuel cost savings with renewables

Because renewable energy has no fuel costs, the total fuel cost savings in the Energy [R]evolution Scenario reach a total of $18.7 trillion, or $ 750 billion per year. A comparison between the extra fuel costs associated with the Reference Scenario and the extra investment costs of the Energy [R]evolution version shows that the average annual additional fuel costs are about five times higher than the additional investment requirements of the alternative scenario. In fact, the additional costs for coal fuel from today until the year 2030 are as high as $ 15.9 trillion: this would cover the entire investment in renewable and cogeneration capacity required to implement the Energy [R]evolution Scenario. These renewable energy sources will produce electricity without any further fuel costs beyond 2030, while the costs for coal and gas will continue to be a burden on national economies.

table 7.3: fuel and investment costs in the reference and the energy [r]evolution scenario

INVESTMENT COST	DOLLAR	2005-2010	2011-2020	2021-2030	2005-2030	2005-2030 AVERAGE PER YEAR
REFERENCE SCENARIO						
Total Nuclear	billion $ 2005	225	310	286	821	33
Total Fossil	billion $ 2005	1,190	1,659	1,693	4,535	181
Total Renewables	billion $ 2005	1,193	1,837	1,702	4,702	188
Total Cogeneration	billion $ 2005	271	523	464	1,257	50
Total	billion $ 2005	2,849	4,322	4,144	11,315	453
E[R] SCENARIO						
Total Fossil	billion $ 2005	1,314	995	536	2,845	114
Total Renewables	billion $ 2005	1,299	3,475	4,216	8,989	360
Total Cogeneration	billion $ 2005	360	1,200	1,365	2,926	117
Total	billion $ 2005	2,973	5,670	6,117	14,761	590
DIFFERENCE E[R] VERSUS REF						
Total Fossil & Nuclear	billion $ 2005	-101	-967	-1,443	-2,511	-100
Total Cogeneration	billion $ 2005	89	678	902	1,669	67
Total Renewables	billion $ 2005	136	1,637	2,514	4,287	171
Total	billion $ 2005	124	1,348	1,973	3,445	138
FUEL COSTS						
REFERENCE SCENARIO						
Total Fuel Oil	billion $/a	883	1,902	1,811	4,595	184
Total Gas	billion $/a	1,989	6,136	9,686	17,811	712
TotalCoal	billion $/a	6,742	21,296	29,420	57,458	2,298
Total Lignite	billion $/a	148	281	311	740	30
Total Fossil Fuels	billion $/a	9,761	29,616	41,228	80,605	3,224
E[R] SCENARIO						
Total Fuel Oil	billion $/a	855	1,464	862	3,181	127
Total Gas	billion $/a	2,047	6,283	8,396	16,727	669
Total Coal	billion $/a	6,557	17,820	17,179	41,556	1,662
Total Lignite	billion $/a	141	181	75	397	16
Total Fossil Fuels	billion $/a	9,600	25,749	26,511	61,861	2,474
SAVINGS REF VERSUS E[R]						
Fuel Oil	billion $/a	27	438	949	1,415	57
Gas	billion $/a	-59	-147	1,291	1,085	43
Coal	billion $/a	185	3,476	12,241	15,901	636
Lignite	billion $/a	7	100	236	343	14
Total Fossil Fuel Savings	billion $/a	161	3,866	14,716	18,744	750

energy resources & security of supply

GLOBAL

NUCLEAR
THE GLOBAL POTENTIAL FOR SUSTAINABLE BIOMASS

8

AROUND 80% OF GLOBAL ENERGY DEMAND IS MET BY FINITE FOSSIL FUELS. © R. KASPRZAK/DREAMSTIME

"the issue of security of supply is now at the top of the energy policy agenda."

GREENPEACE INTERNATIONAL
CLIMATE CAMPAIGN

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, on the other hand, 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'[36].

oil

Oil is the lifeblood 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.

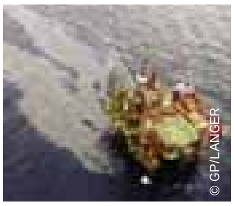
Historically, private oil companies have consistently underestimated their reserves to comply with conservative stock exchange rules and through natural commercial caution. Whenever a discovery was made, only a portion of the geologist's estimate of recoverable resources was reported; subsequent revisions would then increase the reserves from that same oil field over time. National oil companies, mostly 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.

references
36 'PLUGGING THE GAP - A SURVEY OF WORLD FUEL RESOURCES AND THEIR IMPACT ON THE DEVELOPMENT OF WIND ENERGY', GLOBAL WIND ENERGY COUNCIL/RENEWABLE ENERGY SYSTEMS, 2006

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

image ON A LINFEN STREET, TWO MEN LOAD UP A CART WITH COAL THAT WILL BE USED FOR COOKING. LINFEN, A CITY OF ABOUT 4.3 MILLION, IS ONE OF THE MOST POLLUTED CITIES IN THE WORLD. CHINA'S INCREASINGLY POLLUTED ENVIRONMENT IS LARGELY A RESULT OF THE COUNTRY'S RAPID DEVELOPMENT AND CONSEQUENTLY A LARGE INCREASE IN PRIMARY ENERGY CONSUMPTION, WHICH IS ALMOST ENTIRELY PRODUCED BY BURNING COAL.



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 an 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, and a few massive fields make up 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, with ambiguities arising over the amount produced partly because flared and vented gas is not always accounted for. As opposed to published reserves, the technical ones have been almost constant since 1980 because discoveries have roughly matched production.

coal

Coal was the world's largest source of 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 forward, the world will consume 20% of its current reserves by 2030 and 40% by 2050. Hence, if current trends are maintained, coal would still last several hundred years.

table 8.1: overview of fossil fuel reserves and resources

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

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

source SEE TABLE [a)] INCLUDING GAS HYDRATES

table 8.2: assumptions on fossil fuel use in the energy [r]evolution scenario

Oil	2005	2010	2020	2030	2040	2050
Reference [PJ]	161.739	175.865	201.402	224.854	250.093	278.527
Reference [million barrels]	26.428	28.736	32.909	36.741	40.865	45.511
Alternative [PJ]	161.751	168.321	147.531	126.088	102.912	83.927
Alternative [million barrels]	26.430	27.503	24.106	20.603	16.816	13.714

Gas	2005	2010	2020	2030	2040	2050
Reference [PJ]	99.741	111.600	135.291	157.044	170.244	180.559
Reference [billion cubic metres = 10E9m³]	2624,8	2936,8	3560,3	4132,7	4480,1	4751,5
Alternative [PJ]	99.746	115.011	128.402	122.884	100.682	74.596
Alternative [billion cubic metres = 10E9m³]	2624,9	3026,6	3379,0	3233,8	2649,5	1963,1

Coal	2005	2010	2020	2030	2040	2050
Reference [PJ]	121.639	146.577	179.684	209.482	232.422	257.535
Reference [million tonnes]	6.640	7.742	9.182	10.554	11.659	12.839
Alternative [PJ]	121.621	139.439	133.336	106.493	77.675	51.438
Alternative [million tonnes]	6.639	7.299	6.367	4.784	3.392	2.234

nuclear

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

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

A joint report by the OECD Nuclear Energy Agency[37] and the International Atomic Energy Agency estimates that all existing nuclear power plants will have used up their nuclear fuel, employing current technology, within less than 70 years. Given the range of scenarios for the worldwide development of nuclear power, it is likely that uranium supplies will be exhausted sometime between 2026 and 2070. This forecast includes the use of mixed oxide fuel (MOX), a mixture of uranium and plutonium.

references
37 'URANIUM 2003: RESOURCES, PRODUCTION AND DEMAND'

image OLD NUCLEAR PLANT. CRIMEA, UKRAINE.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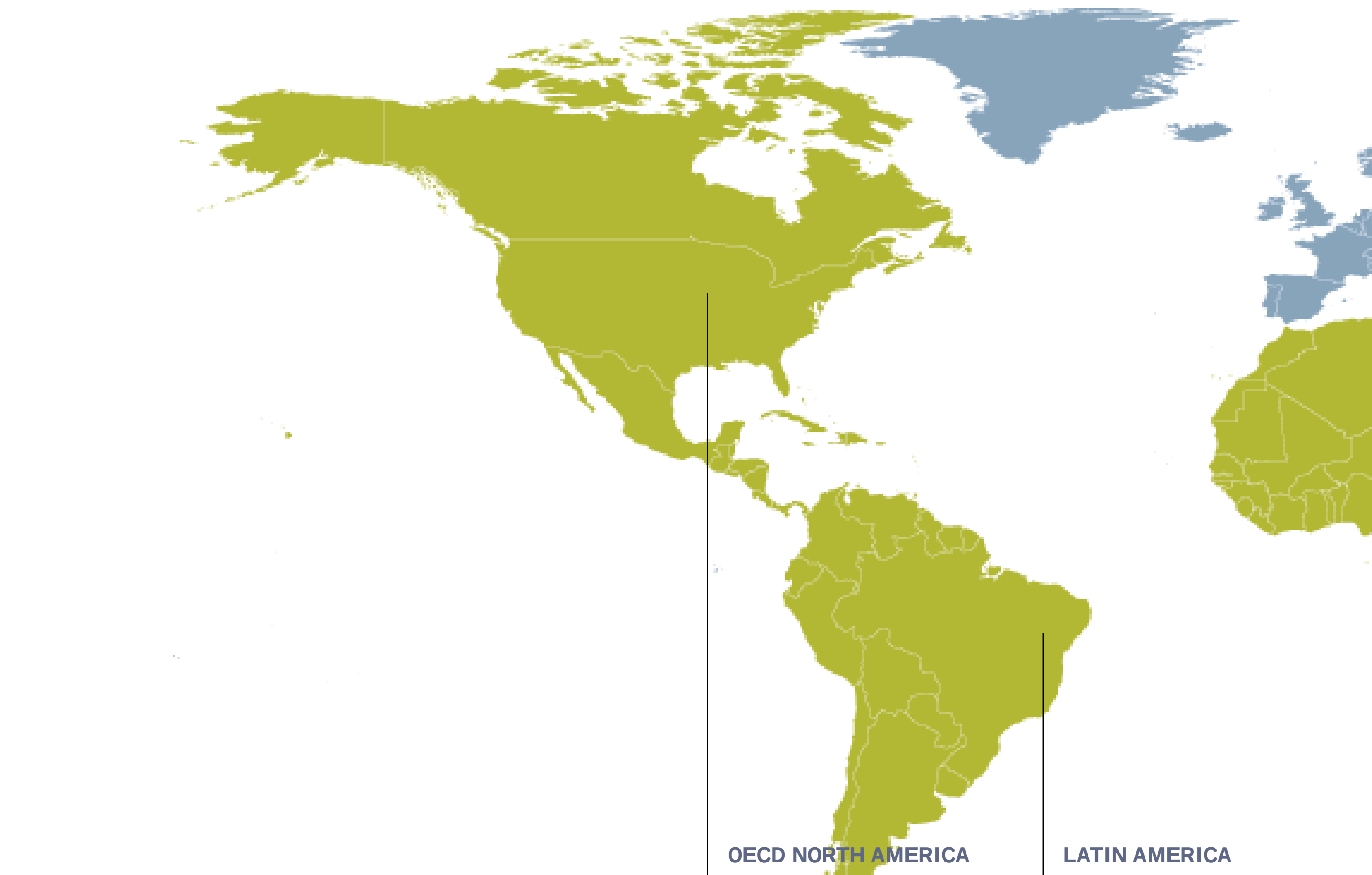
images 1. SCIENTIST FROM THE LOS ALAMOS NUCLEAR LABORATORY, NEW MEXICO, (USA). WEAPONS-GRADE PLUTONIUM IS TRANSPORTED FROM LOS ALAMOS (USA) TO CADARACHE (FRANCE) VIA SEVERAL DESTINATIONS FOR TRANSFORMATION INTO PLUTONIUM FUEL OR MOX (URANIUM-PLUTONIUM OXIDE) THEN DESTINED FOR SHIPMENT BACK TO USA FOR TESTS IN REACTOR. **2.** DSUNUSOVA GULSUM (43) IS SUFFERING FROM A BRAIN TUMOUR. SHE LIVES IN THE NUCLEAR BOMB TESTING AREA IN THE EAST KAZAKH REGION OF KAZAKHSTAN. **3.** DOCTOR PEI HONGCHUAN EXAMINES ZHAI LISHENG, A YOUNG BOY WHO IS SUFFERING FROM A RESPIRATORY ILLNESS DUE TO THE HEAVY POLLUTION IN LINFEN. LINFEN, A CITY OF ABOUT 4.3 MILLION, IS ONE OF THE MOST POLLUTED CITIES IN THE WORLD. CHINA'S INCREASINGLY POLLUTED ENVIRONMENT IS LARGELY A RESULT OF THE COUNTRY'S RAPID DEVELOPMENT AND CONSEQUENTLY A LARGE INCREASE IN PRIMARY ENERGY CONSUMPTION, WHICH IS ALMOST ENTIRELY PRODUCED BY BURNING COAL. **4.** GREENPEACE SURVEY OF GULF WAR OIL POLLUTION IN KUWAIT. AERIAL VIEW OF OIL IN THE SEA. **5.** AERIAL VIEW OF THE CHEVRON EMPIRE, SITUATED IN PLAQUEMINES PARISH NEAR THE MOUTH OF THE MISSISSIPPI RIVER, AN AREA DEVASTATED BY HURRICANE KATRINA. AROUND 991,000 GALLONS OF OIL WERE RELEASED. AROUND 4,000 GALLONS WERE RECOVERED AND A FURTHER 3,600 GALLONS WERE CONTAINED DURING THE HURRICANE. 19 DAYS AFTER HURRICANE KATRINA HIT THE DEVASTATION IS EVIDENT, WITH VILLAGES AND TOWNS STILL FLOODED WITH CONTAMINATED WATER FROM THE OIL INDUSTRIES. LOCAL RESIDENTS AND OFFICIALS BLAME A RUPTURED SHELL PIPELINE FOR SPREADING OIL THROUGH MARSHES AND COMMUNITIES DOWN RIVER FROM NEW ORLEANS.

map 8.1: oil reference scenario and the energy [r]evolution scenario

WORLDWIDE SCENARIO



NON RENEWABLE RESOURCE

OIL

OECD NORTH AMERICA

		REF		E[R]	
		TMB	%	TMB	%
Reserves	2007	69.3	5.6%	69.3	5.6%
		MB	PJ	MB	PJ
Consumption per region	2005	7,891H	48,290H	7,891H	48,290H
	2050	10,554H	64,590H	1,884	11,531
		L		L	
Consumption per person	2005	2,875H		2,875H	
	2050	2,906H		519	

LATIN AMERICA

		REF		E[R]	
		TMB	%	TMB	%
Reserves	2007	111.2	9.0%	111.2	9.0%
		MB	PJ	MB	PJ
Consumption per region	2005	1,554	9,511	1,554	9,511
	2050	3,102	18,985	691	4,229
		L		L	
Consumption per person	2005	550		550	
	2050	780		174	

LEGEND

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

REF REFERENCE SCENARIO

E[R] ENERGY [R]EVOLUTION SCENARIO

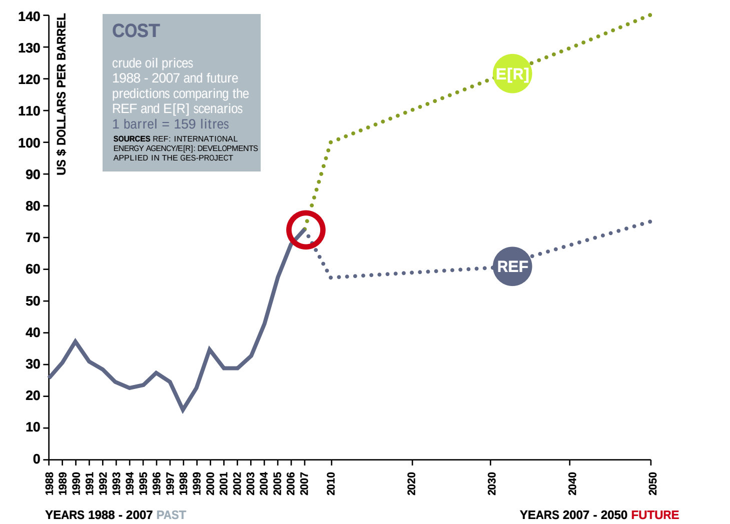
0 1000 KM

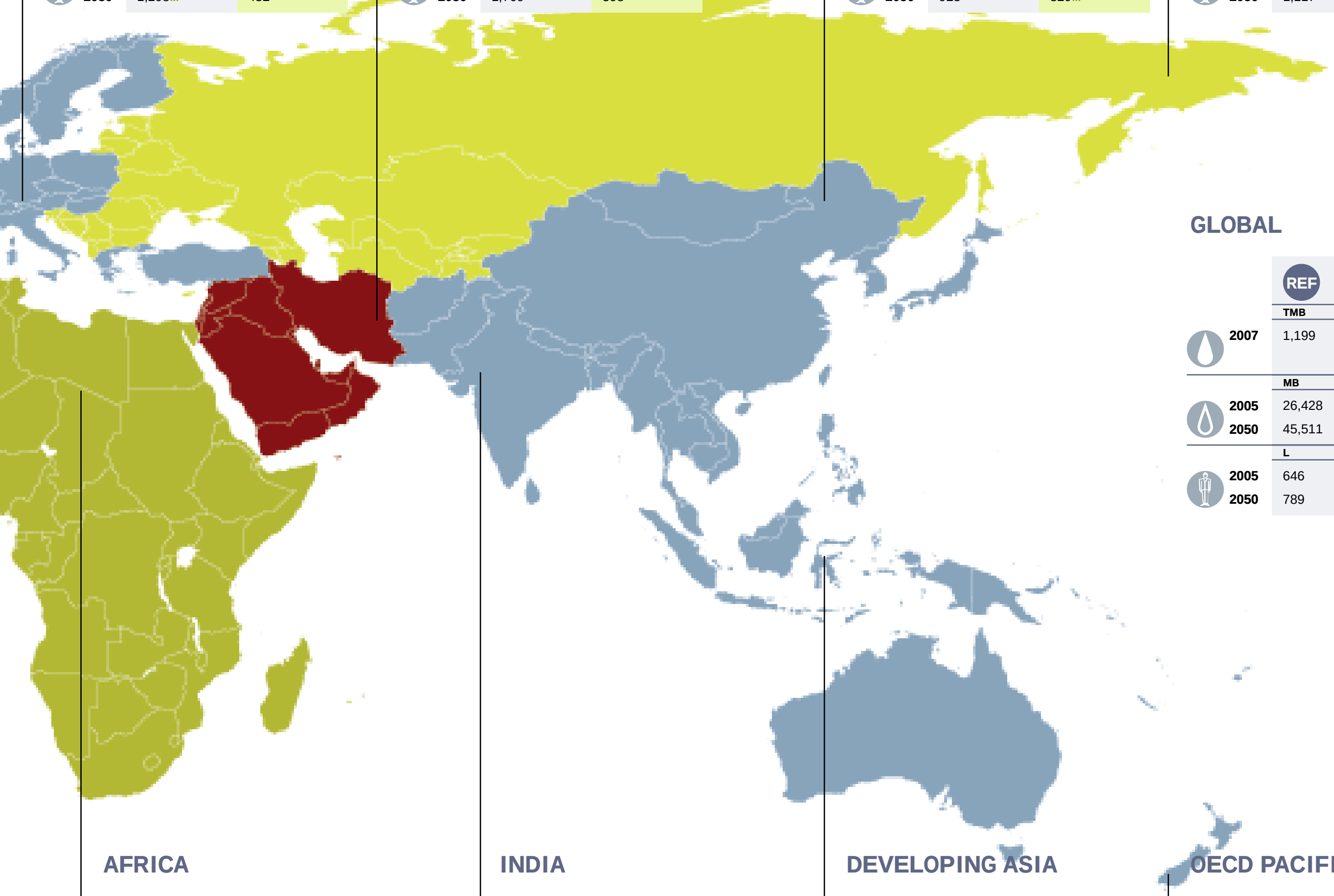
RESERVES TOTAL THOUSAND MILLION BARRELS [TMB] | SHARE IN % OF GLOBAL TOTAL [END OF 2007]

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

CONSUMPTION PER PERSON LITERS [L]

H HIGHEST | M MIDDLE | L LOWEST





OECD EUROPE

	REF		E[R]	
	TMB	%	TMB	%
2007	16.9	1.4%M	16.9	1.4%M
	MB	PJ	MB	PJ
2005	4,969	30,411	4,969	30,411
2050	4,597M	28,134M	1,530M	9,361M
	L		L	
2005	1,473		1,473	
2050	1,298M		432	

MIDDLE EAST

	REF		E[R]	
	TMB	%	TMB	%
2007	755.3H	61.0%H	755.3H	61.0%H
	MB	PJ	MB	PJ
2005	1,931	11,815	1,931	11,815
2050	3,859	23,614	868	5,312
	L		L	
2005	1,632		1,632	
2050	1,769		398	

CHINA

	REF		E[R]	
	TMB	%	TMB	%
2007	15.5	1.3%	15.5	1.3%
	MB	PJ	MB	PJ
2005	2,267	13,872	2,267	13,872
2050	8,237	50,409	2,933H	17,950H
	L		L	
2005	273		273	
2050	923		329M	

TRANSITION ECONOMIES

	REF		E[R]	
	TMB	%	TMB	%
2007	87.6	10.1%L	87.6	10.1%L
	MB	PJ	MB	PJ
2005	1,503	9,199	1,503	9,199
2050	2,063L	12,628L	480L	2,939L
	L		L	
2005	700M		700M	
2050	1,117		260	

GLOBAL

	REF		E[R]	
	TMB	%	TMB	%
2007	1,199	100%	1,199	100%
	MB	PJ	MB	PJ
2005	26,428	161,739	26,428	161,739
2050	45,511	278,527	13,714	83,927
	L		L	
2005	646		646	
2050	789		238	

AFRICA

	REF		E[R]	
	TMB	%	TMB	%
2007	117.5M	9.5%	117.5M	9.5%
	MB	PJ	MB	PJ
2005	893	5,465	893	5,465
2050	2,238	13,697	1,131	6,923
	L		L	
2005	154		154	
2050	178L		90L	

INDIA

	REF		E[R]	
	TMB	%	TMB	%
2007	5.5	0.5%	5.5	0.5%
	MB	PJ	MB	PJ
2005	861L	5,272L	861	5,272
2050	4,220	25,824	1,591	9,738
	L		L	
2005	121L		121L	
2050	405		153	

DEVELOPING ASIA

	REF		E[R]	
	TMB	%	TMB	%
2007	14.8	1.2%	14.8	1.2%
	MB	PJ	MB	PJ
2005	1,871	11,450	1,871	11,450
2050	4,073	24,928	1,846	11,297
	L		L	
2005	305		305	
2050	431		195	

OECD PACIFIC

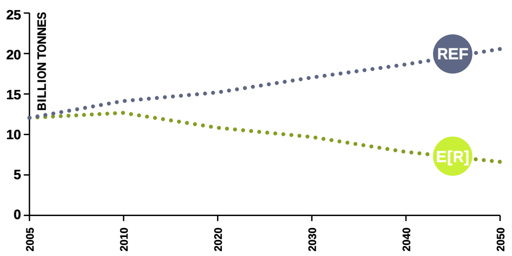
	REF		E[R]	
	TMB	%	TMB	%
2007	5.1L	0.4%	5.1L	0.4%
	MB	PJ	MB	PJ
2005	2,689M	16,454M	2,689	16,454
2050	2,568	15,718	759	4,647
	L		L	
2005	2,136		2,136	
2050	2,293		678H	

CO_2 EMISSIONS FROM OIL

comparison between the REF and E[R] scenarios 2005 - 2050

billion tonnes

SOURCE GPI/EREC



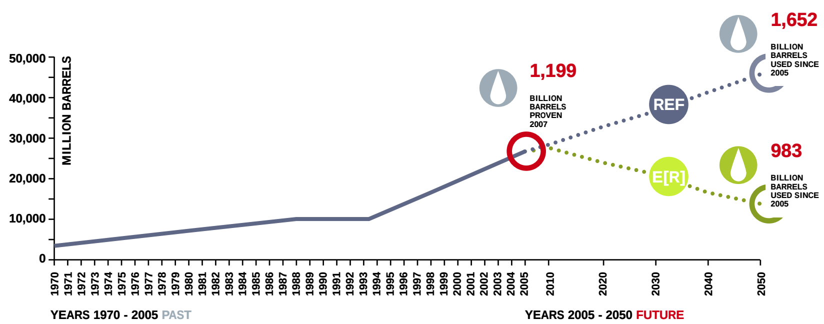
RESERVES AND CONSUMPTION

oil reserves versus global demand, production and consumption. global consumption comparison between the REF and E[R] scenarios.

million barrels. 1 barrel = 159 litres

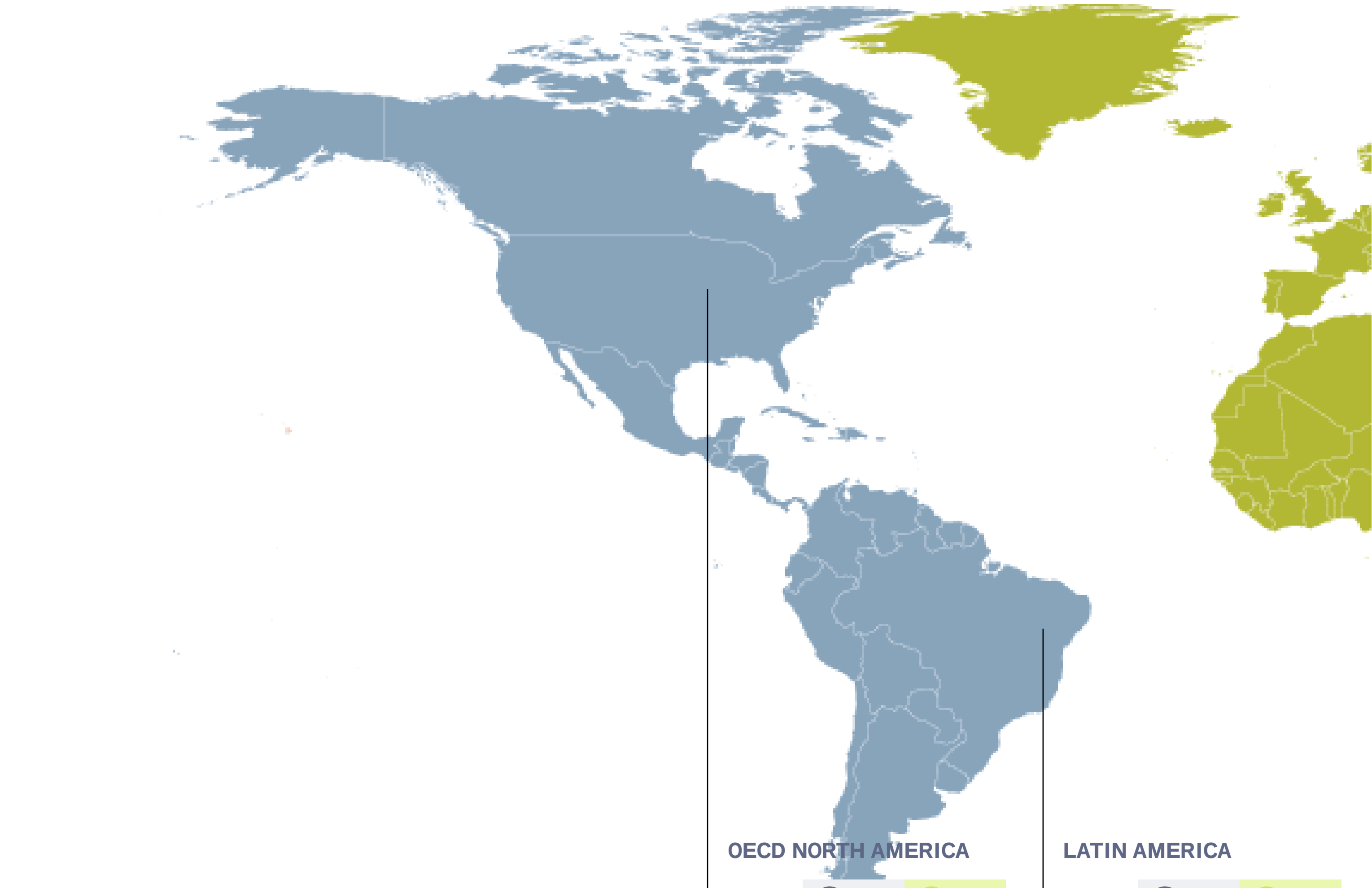
SOURCE BP 2008

REF global consumption
E[R] global consumption



map 8.2: gas reference scenario and the energy [r]evolution scenario

WORLDWIDE SCENARIO



OECD NORTH AMERICA

		REF		E[R]	
		tn m³	%	tn m³	%
Reserves	2007	8.0	4.4%	8.0	4.4%
		bn m³	PJ	bn m³	PJ
Consumption per region	2005	691H	26,259H	691H	26,259H
	2050	878H	33,354H	366H	13,911H
		m³		m³	
Consumption per person	2005	1,584		1,584	
	2050	1,520		634	

LATIN AMERICA

		REF		E[R]	
		tn m³	%	tn m³	%
Reserves	2007	7.7	4.3%	7.7	4.3%
		bn m³	PJ	bn m³	PJ
Consumption per region	2005	112	4,246	112	4,246
	2050	420M	15,955M	105	3,986
		m³		m³	
Consumption per person	2005	249		249	
	2050	664		166	

NON RENEWABLE RESOURCE

GAS

LEGEND

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

REF REFERENCE SCENARIO

E[R] ENERGY [R]EVOLUTION SCENARIO

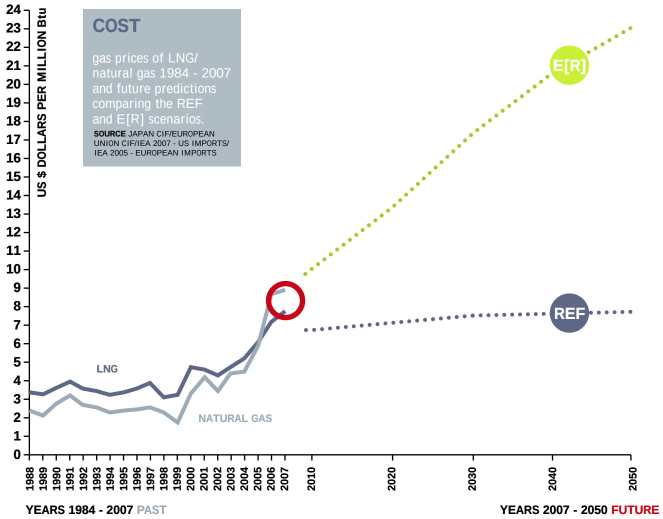
0 1000 KM

RESERVES TOTAL TRILLION CUBIC METRES [tn m³] | SHARE IN % OF GLOBAL TOTAL [END OF 2007]

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 tn m³	%	E[R] tn m³	%
2007	9.8	5.4%	9.8	5.4%
	bn m³	**PJ**	**bn m³**	**PJ**
2005	520	19,773	520	19,773
2050	736	27,965	276	10,494
	m³		**m³**	
2005	970		970	
2050	1,307M		490	

MIDDLE EAST

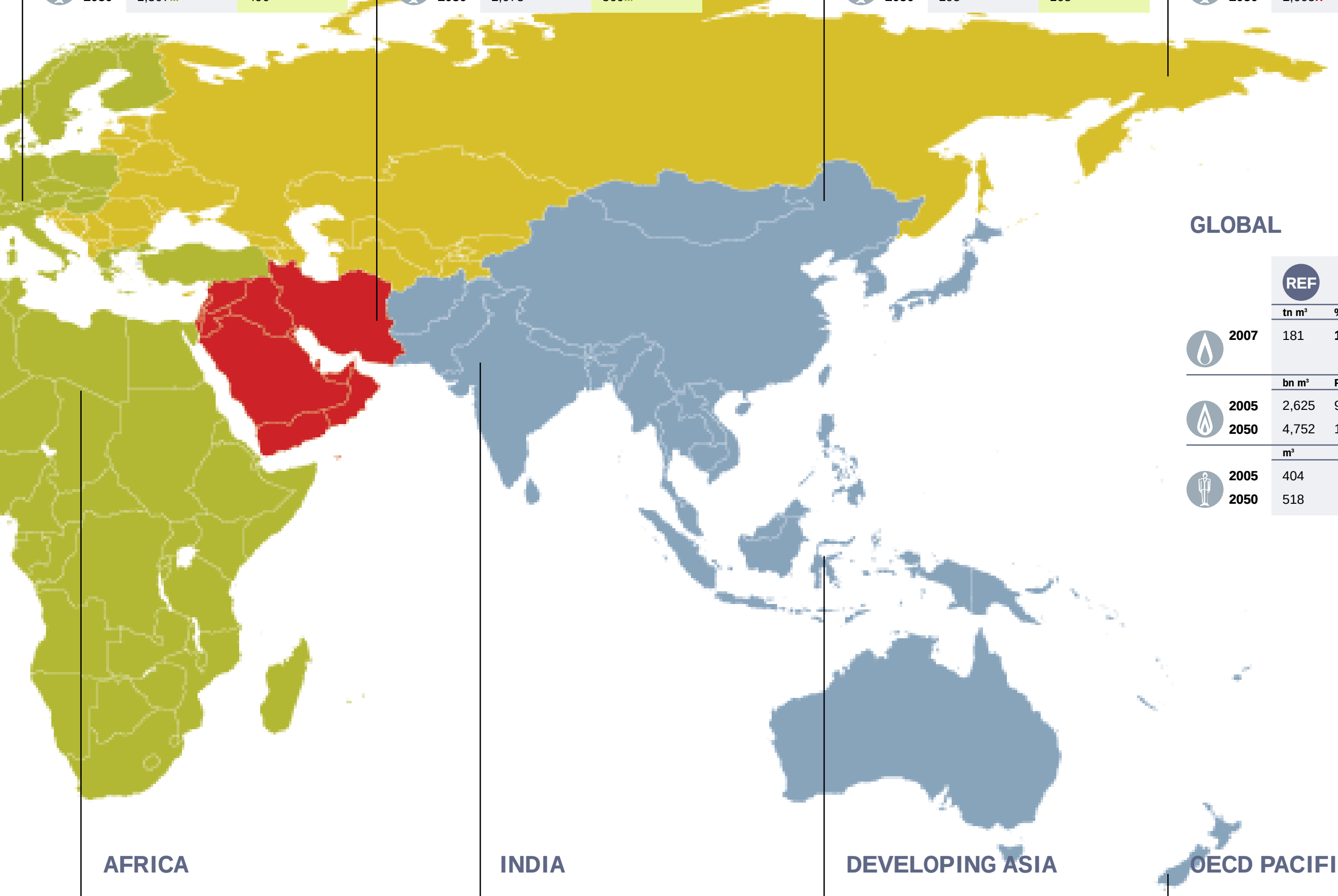
	REF tn m³	%	E[R] tn m³	%
2007	73.2H	40.4%H	73.2H	40.4%H
	bn m³	**PJ**	**bn m³**	**PJ**
2005	239M	9,075M	239	9,075
2050	719	27,323	125	4,742
	m³		**m³**	
2005	1,270		1,270	
2050	2,073		360M	

CHINA

	REF tn m³	%	E[R] tn m³	%
2007	1.9	1.0%	1.9	1.0%
	bn m³	**PJ**	**bn m³**	**PJ**
2005	47	1,805	47	1,805
2050	277	10,519	234	8,886
	m³		**m³**	
2005	36		36	
2050	195		165	

TRANSITION ECONOMIES

	REF tn m³	%	E[R] tn m³	%
2007	53.3	29.4%	53.3	29.4%
	bn m³	**PJ**	**bn m³**	**PJ**
2005	611	23,234	611	23,234
2050	766	29,089	231	8,790
	m³		**m³**	
2005	1,791H		1,791H	
2050	2,605H		787H	



GLOBAL

	REF tn m³	%	E[R] tn m³	%
2007	181	100%	181	100%
	bn m³	**PJ**	**bn m³**	**PJ**
2005	2,625	99,741	2,625	99,741
2050	4,752	180,559	1,963	180,559
	m³		**m³**	
2005	404		404	
2050	518		214	

AFRICA

	REF tn m³	%	E[R] tn m³	%
2007	14.6M	8.0%M	14.6M	8.0%M
	bn m³	**PJ**	**bn m³**	**PJ**
2005	80	3,024	80	3,024
2050	268	10,184	142	5,384
	m³		**m³**	
2005	86		86	
2050	134		71L	

INDIA

	REF tn m³	%	E[R] tn m³	%
2007	1.1L	0.6%L	1.1L	0.6%L
	bn m³	**PJ**	**bn m³**	**PJ**
2005	32L	1,208L	32L	1,208L
2050	124L	4,693L	187M	7,116M
	m³		**m³**	
2005	28L		28L	
2050	74L		113	

DEVELOPING ASIA

	REF tn m³	%	E[R] tn m³	%
2007	8.6	4.8%	8.6	4.8%
	bn m³	**PJ**	**bn m³**	**PJ**
2005	159	6,047	159	6,047
2050	341	12,956	213	8,109
	m³		**m³**	
2005	163		163	
2050	227		142	

OECD PACIFIC

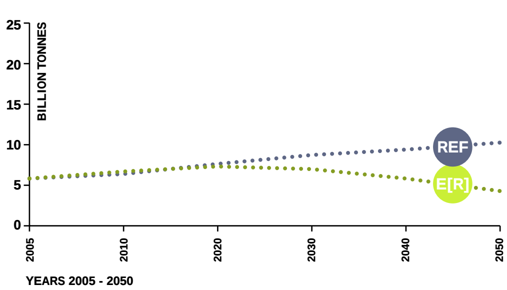
	REF tn m³	%	E[R] tn m³	%
2007	2.9	1.6%	2.9	1.6%
	bn m³	**PJ**	**bn m³**	**PJ**
2005	133	5,070	133	5,070
2050	224	8,521	84L	3,177L
	m³		**m³**	
2005	667M		667M	
2050	1,259		469	

CO_2 EMISSIONS FROM GAS

comparison between the REF and E[R] scenarios 2005 - 2050

billion tonnes

SOURCE GPI/EREC



RESERVES AND CONSUMPTION

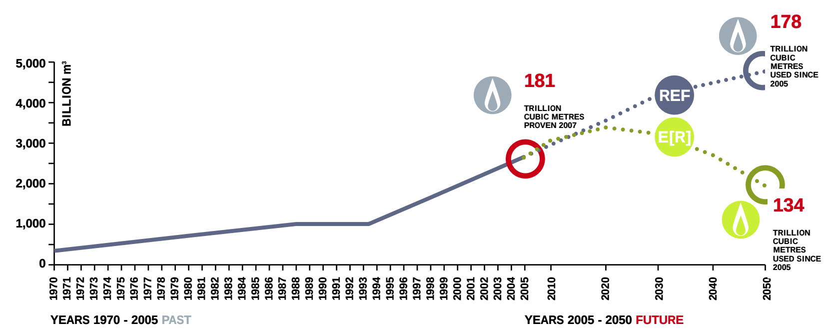
gas reserves versus global demand, production and consumption. global consumption comparison between the REF and E[R] scenarios.

billion cubic metres

SOURCE 1970-2008 BP, 2007-2050 GPI/EREC

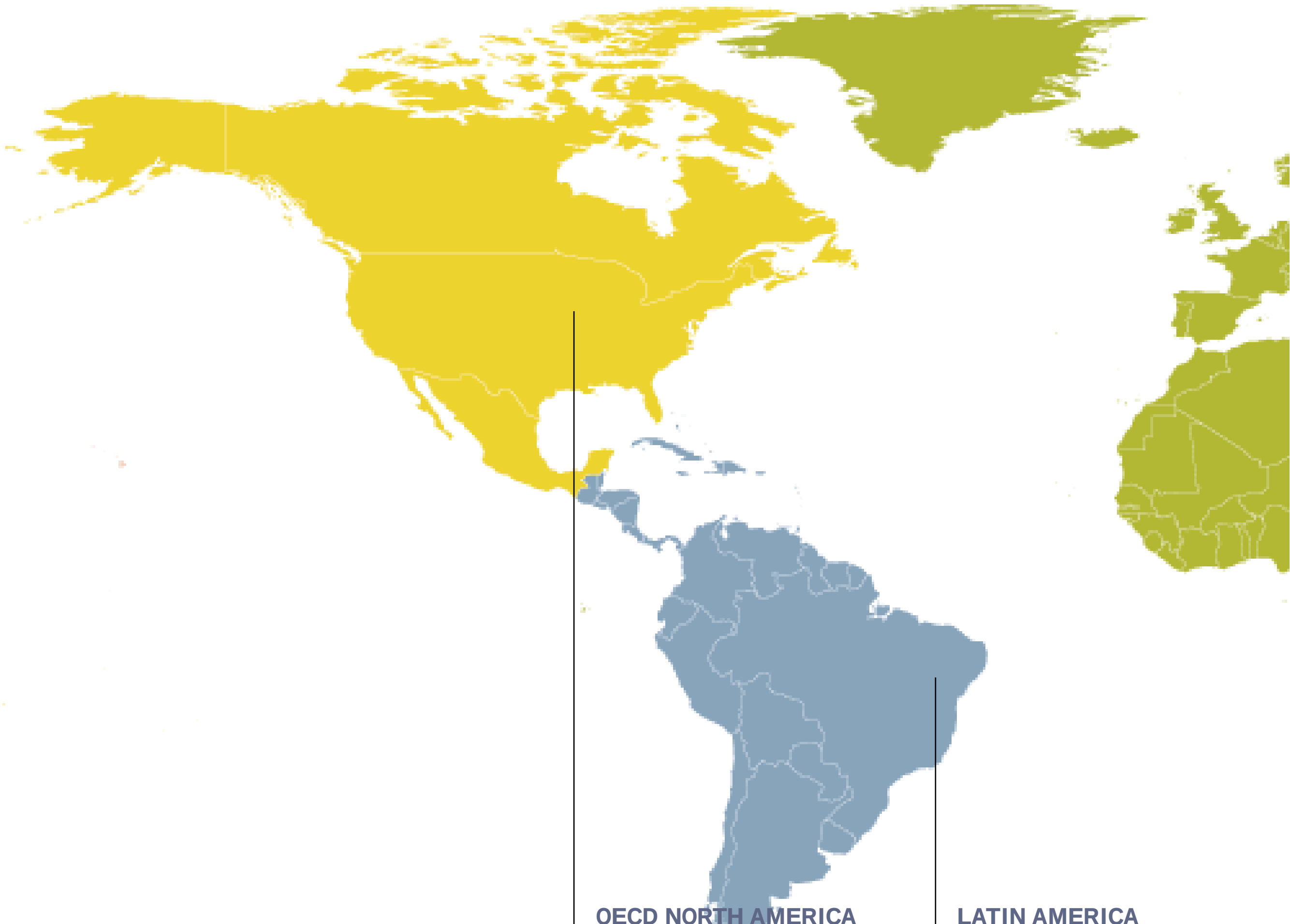
REF global consumption

E[R] global consumption



map 8.3: coal reference scenario and the energy [r]evolution scenario

WORLDWIDE SCENARIO



OECD NORTH AMERICA

		REF		E[R]	
		mn t	%	mn t	%
Reserves	2007	250,510	29.6% H	250,510	29.6% H
		mn t	PJ	mn t	PJ
Consumption per region	2005	1,823	24,342	1,823	24,342
	2050	2,616	39,621	51	1,175
		t		t	
Consumption per person	2005	2.4		2.4	
	2050	3.0 H		0.1 M	

LATIN AMERICA

		REF		E[R]	
		mn t	%	mn t	%
Reserves	2007	16,276	1.9%	16,276	1.9%
		mn t	PJ	mn t	PJ
Consumption per region	2005	48	972	48	972
	2050	247	4,926	15	355
		t		t	
Consumption per person	2005	0.1		0.1	
	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

E[R] ENERGY [R]EVOLUTION SCENARIO

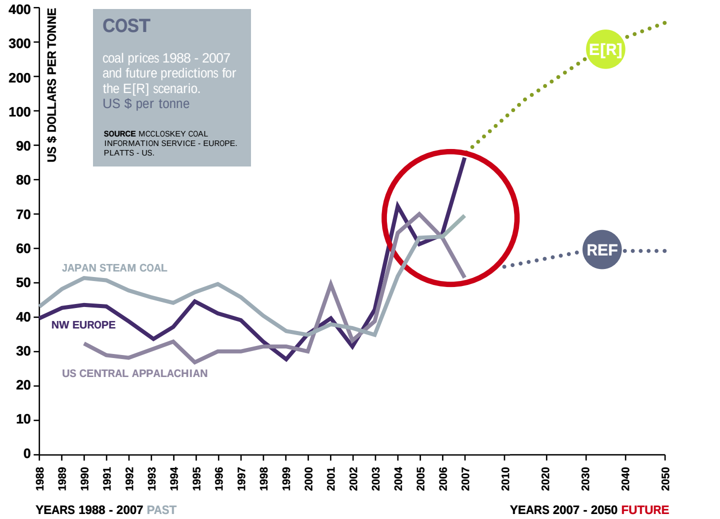
0 1000 KM

RESERVES TOTAL MILLION TONNES [mn t] | SHARE IN % OF GLOBAL TOTAL [END OF 2007]

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

CONSUMPTION PER PERSON TONNES [t]

H HIGHEST | M MIDDLE | L LOWEST



OECD EUROPE

	REF		E[R]	
	mn t	%	mn t	%
2007	50,063	5.9%	50,063	5.9%
	mn t	PJ	mn t	PJ
2005	865	14,031	865	14,031
2050	831	15,598	50	1,145
	t		t	
2005	1.1		1.1	
2050	1.2		0.1	

MIDDLE EAST

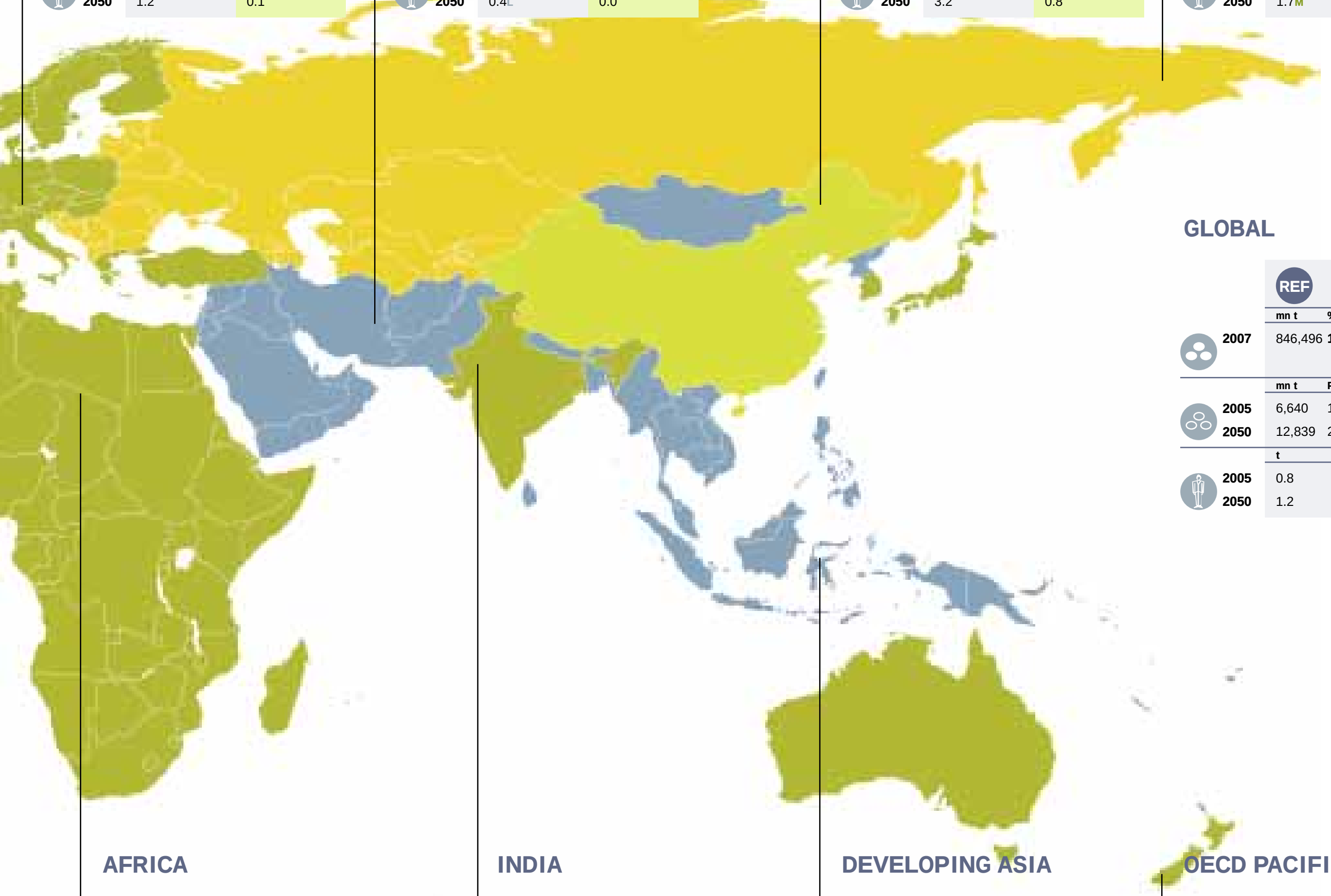
	REF		E[R]	
	mn t	%	mn t	%
2007	1,386	0.2%L	1,386	0.2%L
	mn t	PJ	mn t	PJ
2005	16	371	16	371
2050	132L	3,037	1L	34
	t		t	
2005	0.1		0.1	
2050	0.4L		0.0	

CHINA

	REF		E[R]	
	mn t	%	mn t	%
2007	114,500	13.5%	114,500	13.5%
	mn t	PJ	mn t	PJ
2005	1,995	45,951	1,995	45,951
2050	4,498H	103,595	1,136H	26,160
	t		t	
2005	1.5		1.5	
2050	3.2		0.8	

TRANSITION ECONOMIES

	REF		E[R]	
	mn t	%	mn t	%
2007	222,183	26%	222,183	26%
	mn t	PJ	mn t	PJ
2005	562	8,809	562	8,809
2050	816	11,320	82	1,896
	t		t	
2005	1.1		1.1	
2050	1.7M		0.3	



GLOBAL

	REF		E[R]	
	mn t	%	mn t	%
2007	846,496	100%	846,496	100%
	mn t	PJ	mn t	PJ
2005	6,640	121,639	6,640	121,639
2050	12,839	257,535	2,234	51,438
	t		t	
2005	0.8		0.8	
2050	1.2		0.2H	

AFRICA

	REF		E[R]	
	mn t	%	mn t	%
2007	49,605	5.9%	49,605	5.9%
	mn t	PJ	mn t	PJ
2005	182	4,198	182	4,198
2050	400	9,207	163	3,749
	t		t	
2005	0.2		0.2	
2050	0.2		0.1	

INDIA

	REF		E[R]	
	mn t	%	mn t	%
2007	56,498	6.7%M	56,498	6.7%M
	mn t	PJ	mn t	PJ
2005	393	8,671	393	8,671
2050	2,076	45,550	455M	10,478
	t		t	
2005	0.3		0.3	
2050	1.2		0.3	

DEVELOPING ASIA

	REF		E[R]	
	mn t	%	mn t	%
2007	7,814	0.9%	7,814	0.9%
	mn t	PJ	mn t	PJ
2005	237	4,986	237	4,986
2050	655M	13,777	132	3,043
	t		t	
2005	0.2		0.2	
2050	0.4		0.1	

OECD PACIFIC

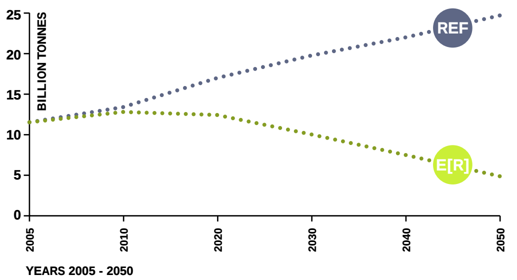
	REF		E[R]	
	mn t	%	mn t	%
2007	77,661	9%	77,661	9%
	mn t	PJ	mn t	PJ
2005	517	9,307	517	9,307
2050	568	10,902	148	3,402
	t		t	
2005	2.0		2.0	
2050	2.7		0.8H	

CO_2 EMISSIONS FROM COAL

comparison between the REF and E[R] scenarios 2005 - 2050

billion tonnes

SOURCE GPI/EREC

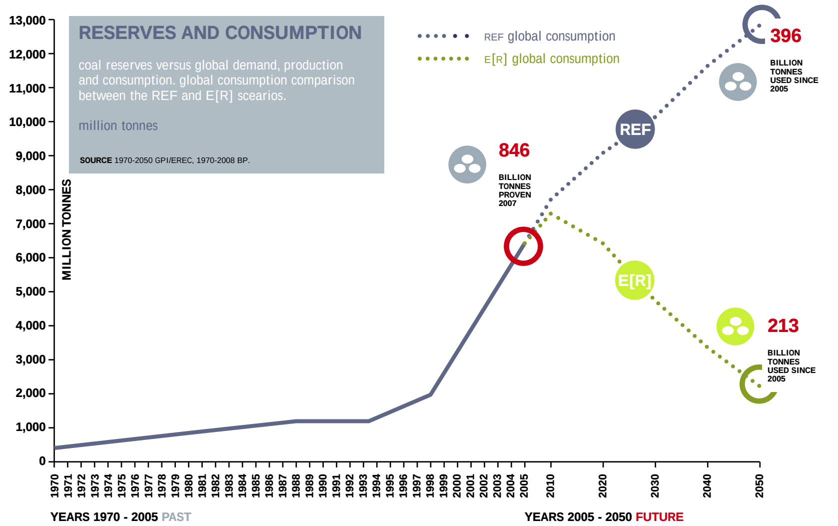


RESERVES AND CONSUMPTION

coal reserves versus global demand, production and consumption. global consumption comparison between the REF and E[R] scearios.

million tonnes

SOURCE 1970-2050 GPI/EREC, 1970-2008 BP.

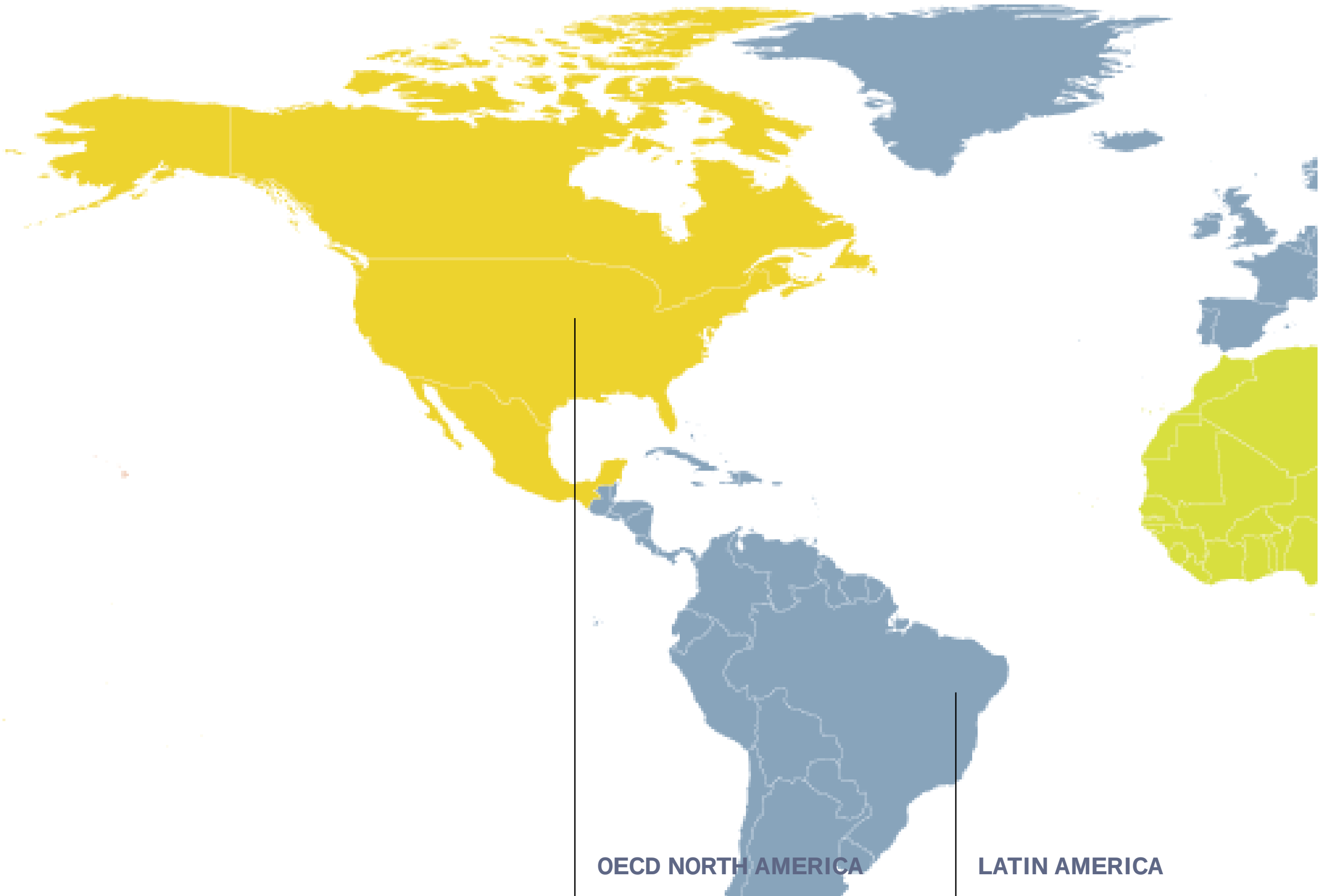


GREENPEACE

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

map 8.4: nuclear reference scenario and the energy [r]evolution scenario

WORLDWIDE SCENARIO



OECD NORTH AMERICA

		REF		E[R]	
		t	%	t	%
Reserves	2007	680,109	**21.5%**	680,109	**21.5%**
		TWh		TWh	
Generation	2005	914		NUCLEAR POWER PHASED OUT BY 2040	
	2050	1,098 H			
		PJ		PJ	
Consumption per region	2005	9,968		9,968	
	2050	11,980 H		0	
		kWh		kWh	
Consumption per person	2005	2,094		2,094	
	2050	1,901		0	

LATIN AMERICA

		REF		E[R]	
		t	%	t	%
Reserves	2007	95,045	**3%**	95,045	**3%**
		TWh		TWh	
Generation	2005	17		PHASED OUT BY 2030	
	2050	30			
		PJ		PJ	
Consumption per region	2005	183		183	
	2050	327		0	
		kWh		kWh	
Consumption per person	2005	37		37	
	2050	47		0	

NON RENEWABLE RESOURCE

NUCLEAR

LEGEND

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

REF — REFERENCE SCENARIO

E[R] — ENERGY [R]EVOLUTION SCENARIO

0 — 1000 KM

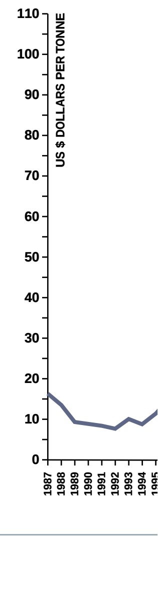
RESERVES TOTAL TONNES | SHARE IN % OF GLOBAL TOTAL [END OF 2007]

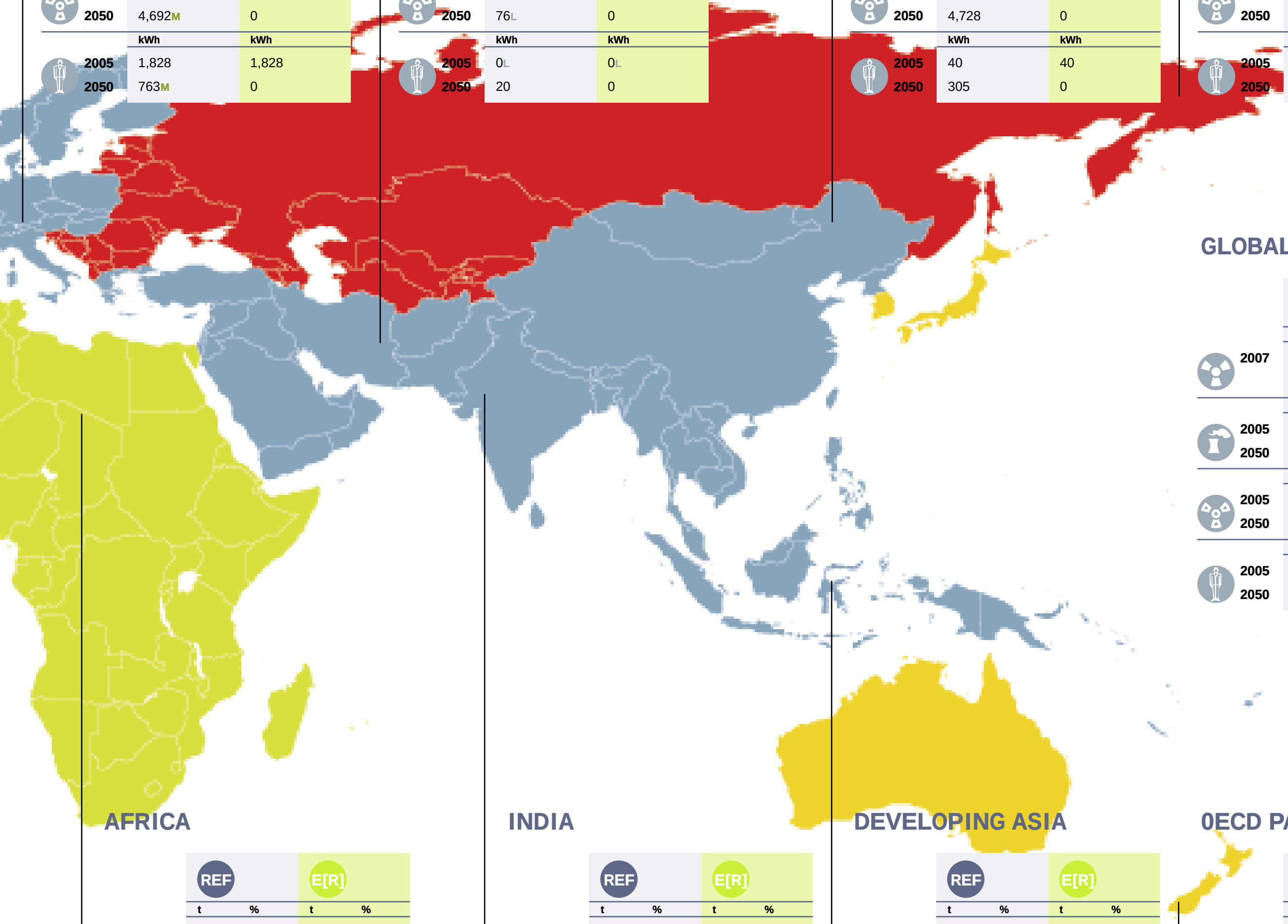
GENERATION PER REGION TERAWATT HOURS [TWh]

CONSUMPTION PER REGION PETA JOULE [PJ]

CONSUMPTION PER PERSON KILOWATT HOURS [kWh]

H HIGHEST | M MIDDLE | L LOWEST





OECD EUROPE

	REF t	REF %	E[R] t	E[R] %
2007	56,445	1.8%	56,445	1.8%
	TWh		**TWh**	
2005	981H		PHASED OUT BY 2030	
2050	430M			
	PJ		**PJ**	
2005	10,699H		10,699H	
2050	4,692M		0	
	kWh		**kWh**	
2005	1,828		1,828	
2050	763M		0	

MIDDLE EAST

	REF t	REF %	E[R] t	E[R] %
2007	370L	0%L	370L	0%L
	TWh		**TWh**	
2005	0L		NO NUCLEAR ENERGY DEVELOPMENT	
2050	7L			
	PJ		**PJ**	
2005	0L		0L	
2050	76L		0	
	kWh		**kWh**	
2005	0L		0L	
2050	20		0	

CHINA

	REF t	REF %	E[R] t	E[R] %
2007	35,060	1.1%	35,060	1.1%
	TWh		**TWh**	
2005	53		NUCLEAR POWER PHASED OUT BY 2045	
2050	433			
	PJ		**PJ**	
2005	579		579	
2050	4,728		0	
	kWh		**kWh**	
2005	40		40	
2050	305		0	

TRANSITION ECONOMIES

	REF t	REF %	E[R] t	E[R] %
2007	1,043,687H	32.9%H	1,043,687H	32.9%H
	TWh		**TWh**	
2005	281M		NUCLEAR POWER PHASED OUT BY 2045	
2050	475			
	PJ		**PJ**	
2005	3,070M		3,070M	
2050	5,183		0	
	kWh		**kWh**	
2005	824M		824M	
2050	1,617		0	

GLOBAL

	REF t	REF %	E[R] t	E[R] %
2007	3,169,238	100%	3,169,238	100%
	TWh		**TWh**	
2005	2,768		NUCLEAR POWER PHASED OUT BY 2045	
2050	3,517			
	PJ		**PJ**	
2005	30,201		30,201	
2050	38,372		0	
	kWh		**kWh**	
2005	426		426	
2050	384		0	

AFRICA

	REF t	REF %	E[R] t	E[R] %
2007	470,312M	14.8%M	470,312M	14.8%M
	TWh		**TWh**	
2005	11		NUCLEAR POWER PHASED OUT BY 2025	
2050	15			
	PJ		**PJ**	
2005	123		123	
2050	164		0	
	kWh		**kWh**	
2005	12		12	
2050	8L		0	

INDIA

	REF t	REF %	E[R] t	E[R] %
2007	40,980	1.3%	40,980	1.3%
	TWh		**TWh**	
2005	17		NUCLEAR POWER PHASED OUT BY 2045	
2050	219			
	PJ		**PJ**	
2005	189		189	
2050	2,386		0	
	kWh		**kWh**	
2005	15		15	
2050	132		0	

DEVELOPING ASIA

	REF t	REF %	E[R] t	E[R] %
2007	5,630	0.2%	5,630	0.2%
	TWh		**TWh**	
2005	42		NUCLEAR POWER PHASED OUT BY 2045	
2050	76			
	PJ		**PJ**	
2005	463		463	
2050	829		0	
	kWh		**kWh**	
2005	44		44	
2050	51		0	

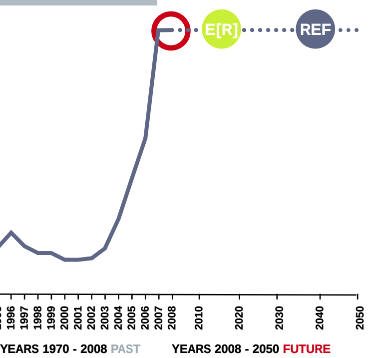
OECD PACIFIC

	REF t	REF %	E[R] t	E[R] %
2007	741,600	23.4%	741,600	23.4%
	TWh		**TWh**	
2005	452		NUCLEAR POWER PHASED OUT BY 2045	
2050	734			
	PJ		**PJ**	
2005	4,927		4,033	
2050	8,007		0	
	kWh		**kWh**	
2005	2,256H		2,256H	
2050	4,122H		0	

COST

yellow cake prices
1987 - 2008 and future predictions comparing the REF and E[R] scenarios
tonnes

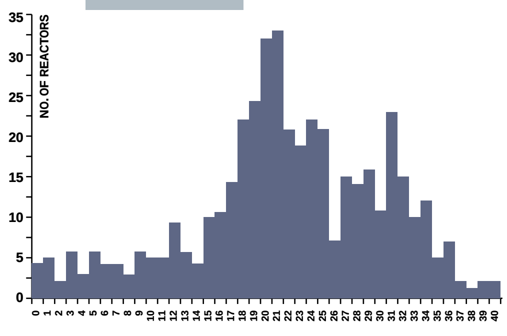
SOURCES REF: INTERNATIONAL ENERGY AGENCY/E[R]: DEVELOPMENTS APPLIED IN THE GES-PROJECT



REACTORS

age and number of reactors worldwide

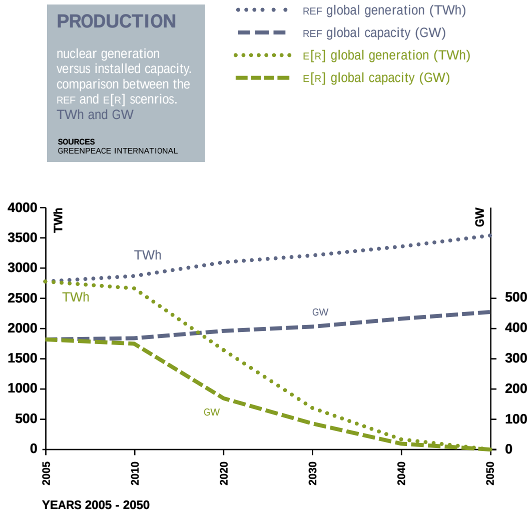
SOURCES WISE



PRODUCTION

nuclear generation versus installed capacity. comparison between the REF and E[R] scenrios. TWh and GW

SOURCES GREENPEACE INTERNATIONAL



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

renewable energy

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

On average, the energy in the sunshine that reaches the Earth is about one kilowatt per square 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. In one day, the sunlight which reaches the Earth produces enough energy to satisfy the world's current power requirements for eight years. Even though only a percentage of that potential is technically accessible, this is still enough to provide just under six times more power than the world currently requires.

definition of types of energy resource potential38

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

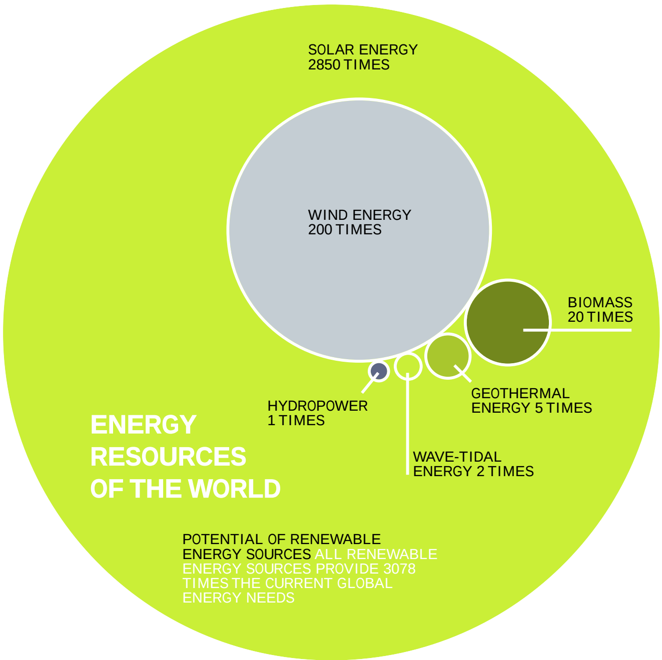
conversion potential This is derived from the annual efficiency of the respective conversion technology. It is therefore not a strictly defined value, since the efficiency of a particular technology depends on technological progress.

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.

figure 8.1: energy resources of the world



source WBGU

table 8.3: technically accessible today

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

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

source DR. JOACHIM NITSCH

references
38 WBGU (GERMAN ADVISORY COUNCIL ON GLOBAL CHANGE)'

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

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

renewable energy potential by region and technology

Based on the report 'Renewable Energy Potentials' from REN 21, a global policy network[39], we can provide a more detailed overview of renewable energy prospects by world region and technology. The table below focuses on large economies, which consume 80 % of the world's primary energy and produce a similar share of the world's greenhouse gas emissions.

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

In terms of heating and cooling, apart from using biomass, there is the option of using direct geothermal energy. The potential is extremely large and could cover 20 times the current world energy demand for heat. The potential for solar heating, including passive solar building design, is virtually limitless. However, heat is costly to transport and one should only consider geothermal heat and solar water heating potentials which are sufficiently close to the point of consumption. Passive solar technology, which contributes enormously to the provision of heating services, is not considered as a (renewable energy) supply source in this analysis but as an efficiency factor to be taken into account in the demand forecasts.

table 8.4: technical renewable energy potential by region

EXCL. BIO ENERGY

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

source REN21

references
39 'RENEWABLE ENERGY POTENTIALS: OPPORTUNITIES FOR THE RAPID DEPLOYMENT OF RENEWABLE ENERGY IN LARGE ENERGY ECONOMIES', REN 21, 2007

the global potential for sustainable biomass

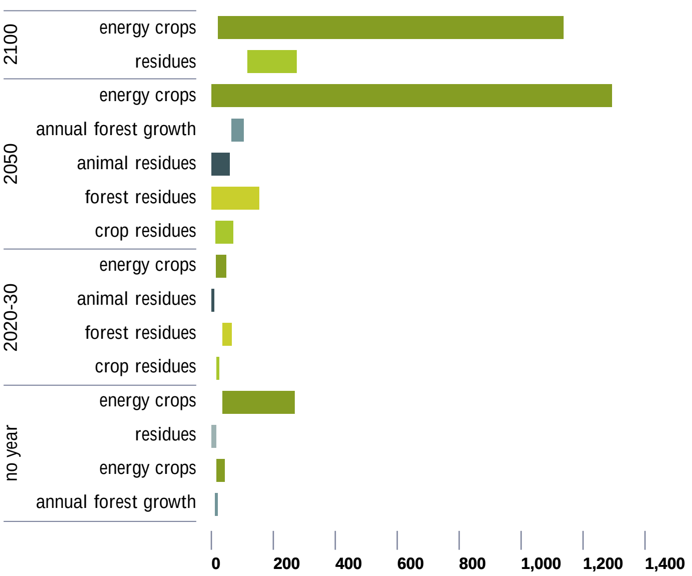
As part of background research for the Energy [R]evolution Scenario, Greenpeace commissioned the German Biomass Research Centre, the former Institute for Energy and Environment, to investigate the worldwide potential for energy crops in different scenarios up to 2050. In addition, information has been compiled from scientific studies of the worldwide potential and from data derived from state of the art remote sensing techniques such as satellite images. A summary of the report's findings is given below; references can be found in the full report.

assessment of biomass potential studies

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

Data from 18 studies has been examined, with a concentration on those studies which report the potential for biomass residues. Among these there were ten comprehensive assessments with more or less detailed documentation of the methodology. The majority focus on the long-term potential for 2050 and 2100. Little information is available for 2020 and 2030. Most of the studies were published within the last ten years. Figure 8.2 shows the variations in potential by biomass type from the different studies.

figure 8.2: ranges of potentials for different resource categories

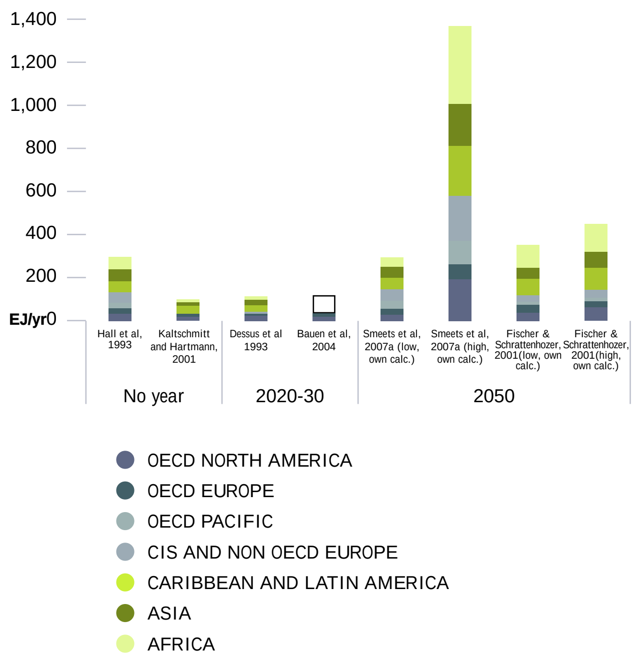


source GERMAN BIOMASS RESEARCH CENTRE (DBFZ)

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

figure 8.3: bio energy potential analysis from different authors

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



source GERMAN BIOMASS RESEARCH CENTRE (DBFZ)

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

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

potential of energy crops

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

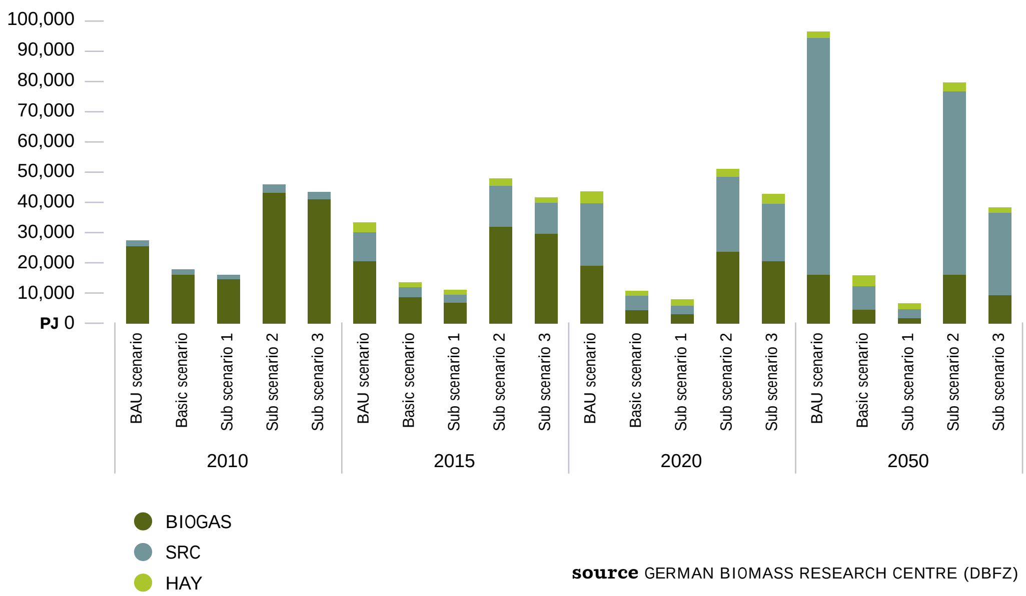
- Business as usual (BAU) scenario: Present agricultural activity continues for the foreseeable future
- Basic scenario: No forest clearing; reduced use of fallow areas for agriculture
- Sub-scenario 1: Basic scenario plus expanded ecological protection areas and reduced crop yields
- Sub-scenario 2: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

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

The result is that the global biomass potential from energy crops in 2050 falls within a range from 6 EJ in Sub-scenario 1 up to 97 EJ in the BAU scenario.

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

figure 8.4: world wide energy crop potentials in different scenarios



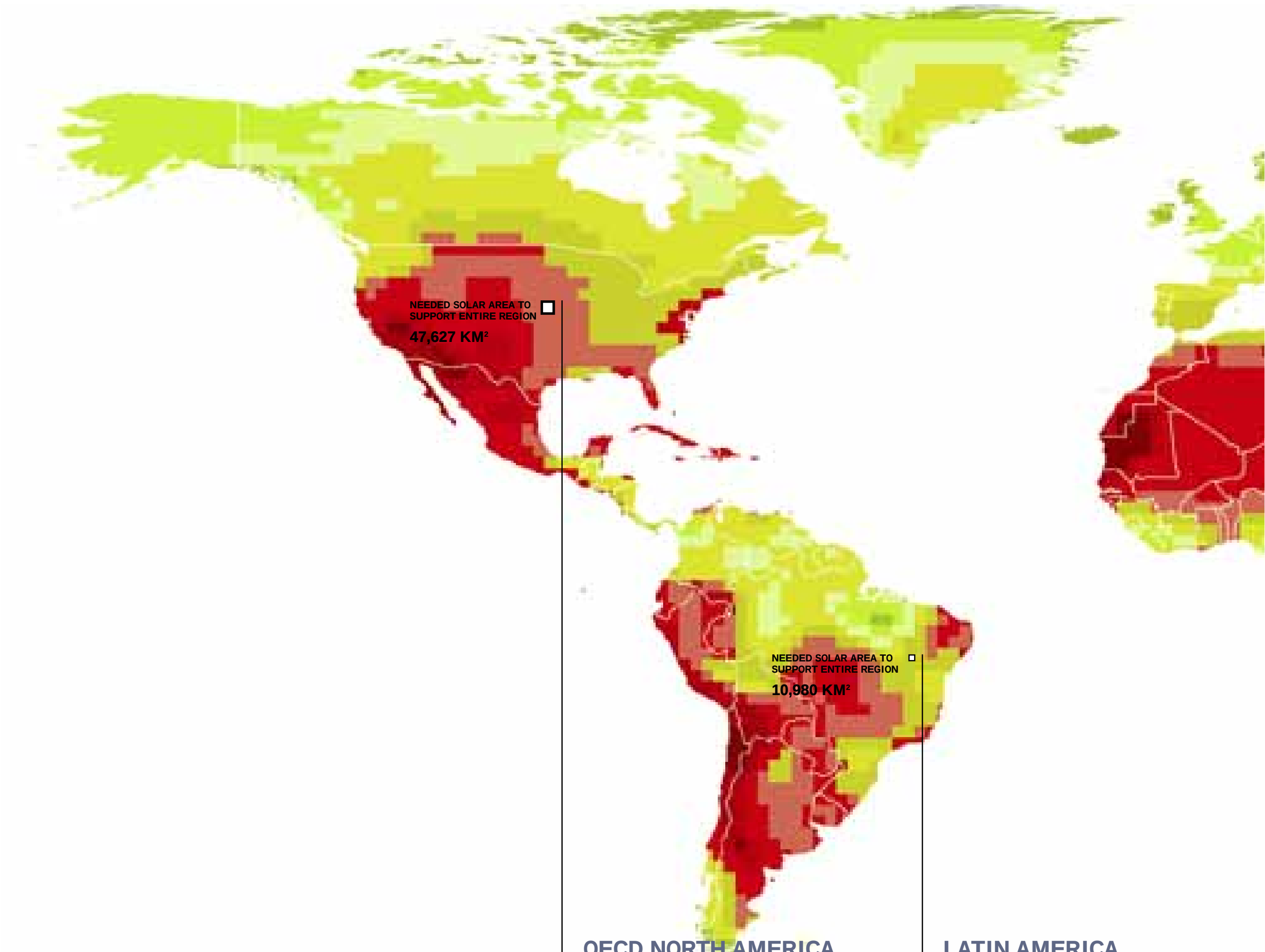
source GERMAN BIOMASS RESEARCH CENTRE (DBFZ)

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

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

map 8.5: solar reference scenario and the energy [r]evolution scenario

WORLDWIDE SCENARIO



OECD NORTH AMERICA

		REF %	REF PJ	E[R] %	E[R] PJ
Production per region	2005	0.05M	58H		
	2050	0.65M	1,075	17.03M	13,230
			kWh		kWh
Production per person	2005		37		
	2050		517		6,364

LATIN AMERICA

		REF %	REF PJ	E[R] %	E[R] PJ
Production per region	2005	0.01	2		
	2050	0.10	50	9.39L	3,050L
			kWh		kWh
Production per person	2005		1		
	2050		22		1,340

RENEWABLE RESOURCE

SOLAR

LEGEND

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

RADIATION IN kW/h PER SQUARE METER
SOURCE DLR

REF REFERENCE SCENARIO

E[R] ENERGY [R]EVOLUTION SCENARIO

0 1000 KM

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

PRODUCTION PER PERSON KILOWATT HOUR [kWh]

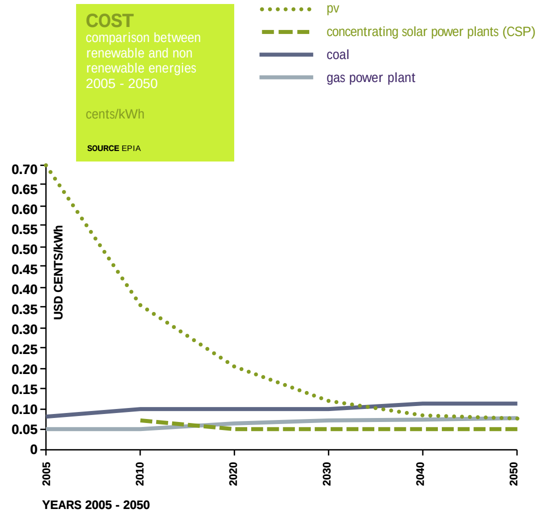
H HIGHEST | M MIDDLE | L LOWEST

COST

comparison between renewable and non renewable energies 2005 - 2050

cents/kWh

SOURCE EPIA

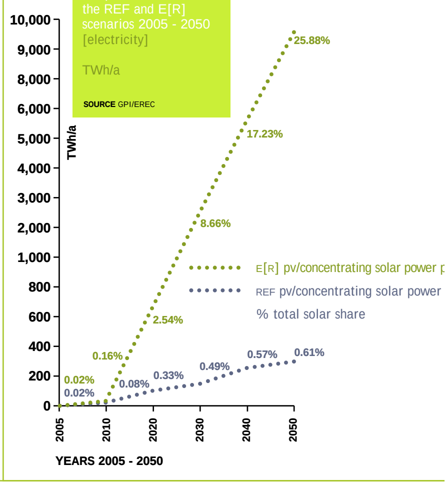


PRODUCTION

comparison between the REF and E[R] scenarios 2005 - 2050 [electricity]

TWh/a

SOURCE GPI/EREC



OECD EUROPE

		REF %	REF PJ	E[R] %	E[R] PJ
solar	2005	0.06M	50		
	2050	1.42H	1,279	16	7,850
			kWh		kWh
per capita	2005		26M		
	2050		631		3,872M

MIDDLE EAST

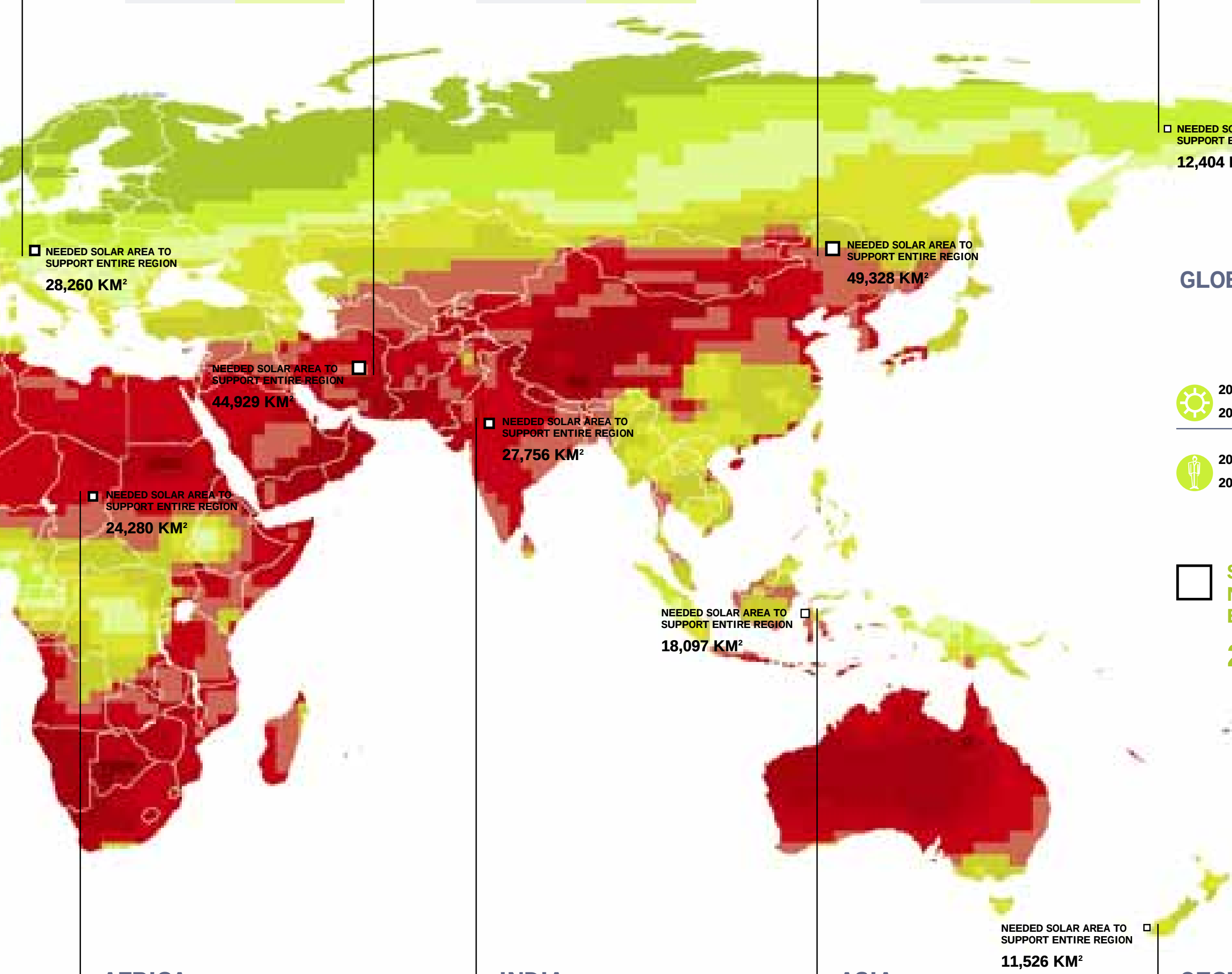
		REF %	REF PJ	E[R] %	E[R] PJ
solar	2005	0.16H	33		
	2050	0.27	149	45H	12,480
			kWh		kWh
per capita	2005		49H		
	2050		120		9,996H

CHINA

		REF %	REF PJ	E[R] %	E[R] PJ
solar	2005	0.00L	0L		
	2050	0.71	1,307H	13.82	13,702H
			kWh		kWh
per capita	2005		0		
	2050		256M		2,684

TRANSITION ECONOMIES

		REF %	REF PJ	E[R] %	E[R] PJ
solar	2005	0.00L	2		
	2050	0.03L	18L	9.63	3,446
			kWh		kWh
per capita	2005		1		
	2050		17		3,257



GLOBAL

		REF %	REF PJ	E[R] %	E[R] PJ
solar	2005	0.04	176		
	2050	0.55	4,775	15.98	76,441
			kWh		kWh
per capita	2005		8		
	2050		145		2,316

SOLAR AREA NEEDED TO SUPPORT E[R] 2050 SCENARIO

275,189 KM²

AFRICA

		REF %	REF PJ	E[R] %	E[R] PJ
solar	2005	0.01	2		
	2050	0.21	110	17.59	6,744
			kWh		kWh
per capita	2005		1		
	2050		15L		938

INDIA

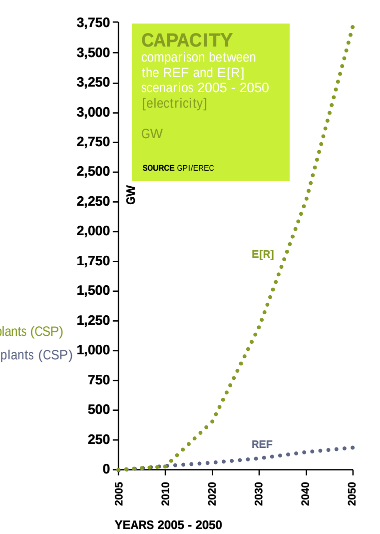
		REF %	REF PJ	E[R] %	E[R] PJ
solar	2005	0.00L	0L		
	2050	0.15	137	14.79	7,710M
			kWh		kWh
per capita	2005		0		
	2050		23		1,292

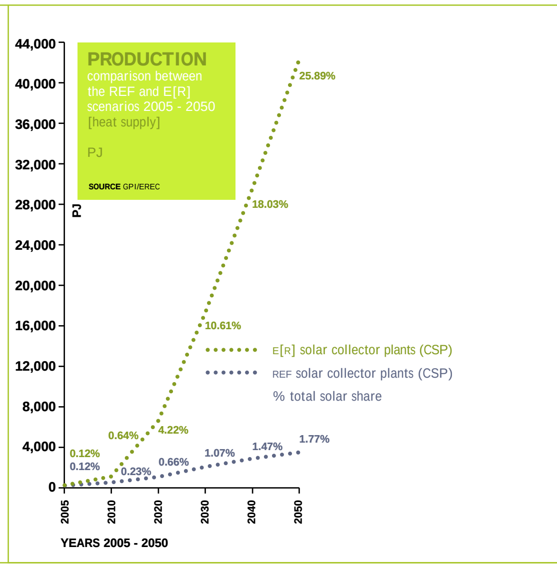
ASIA

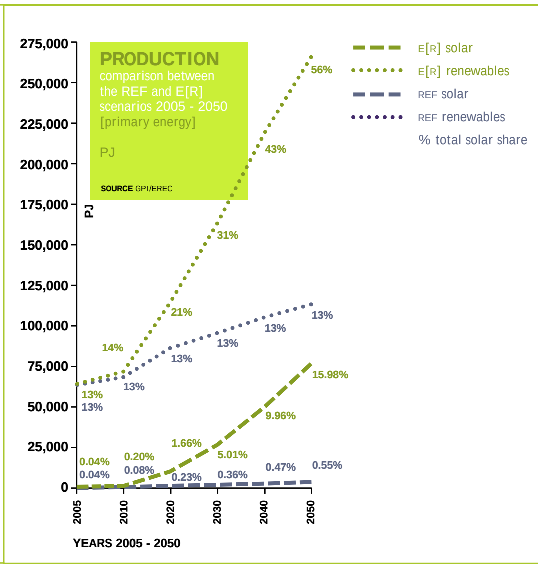
		REF %	REF PJ	E[R] %	E[R] PJ
solar	2005	0.00L	0L		
	2050	0.20	138	11.47	5,027
			kWh		kWh
per capita	2005		0L		
	2050		25		929L

OECD PACIFIC

		REF %	REF PJ	E[R] %	E[R] PJ
solar	2005	0.07	28M		
	2050	1.09	512M	12.83	3,202
			kWh		kWh
per capita	2005		38		
	2050		798H		4,994

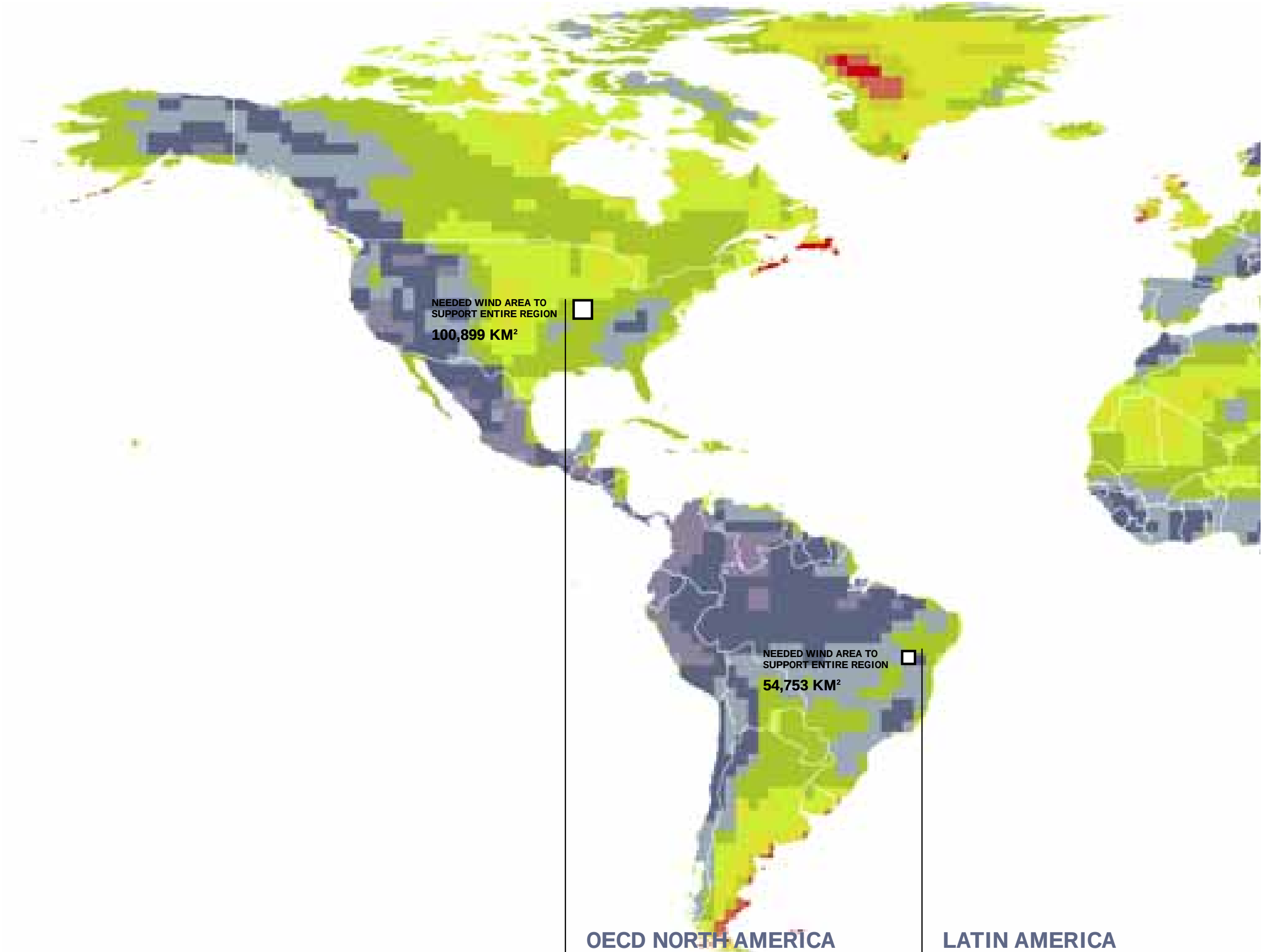






map 8.6: wind reference scenario and the energy [r]evolution scenario

WORLDWIDE SCENARIO



OECD NORTH AMERICA

	REF %	REF PJ	E[R] %	E[R] PJ
2005	0.06M	70		
2050	0.91	1,494	7.11	5,522H
		kWh		kWh
2005		44		
2050		719		2,656

LATIN AMERICA

	REF %	REF PJ	E[R] %	E[R] PJ
2005	0.01	1		
2050	0.28	147	7.98	2,592
		kWh		kWh
2005		1		
2050		64		1,138

RENEWABLE RESOURCE

WIND

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

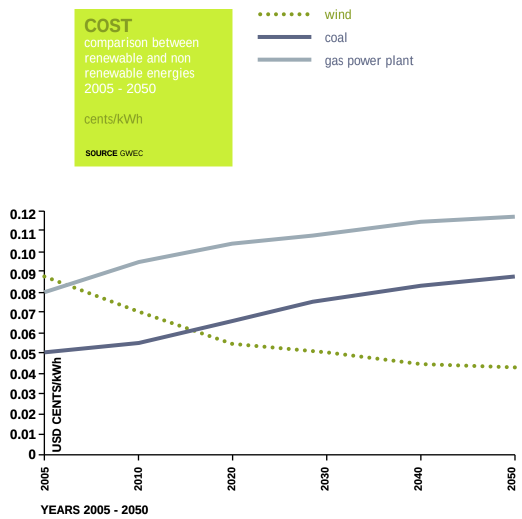
E[R] ENERGY [R]EVOLUTION SCENARIO

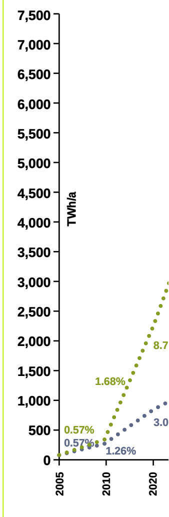
0 1000 KM

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	E[R] %	E[R] PJ
	2005	0.31H	255H		
	2050	2.57H	2,322H	7.65	3,744
			kWh		kWh
	2005		132H		
	2050		1,145H		1,846M

MIDDLE EAST

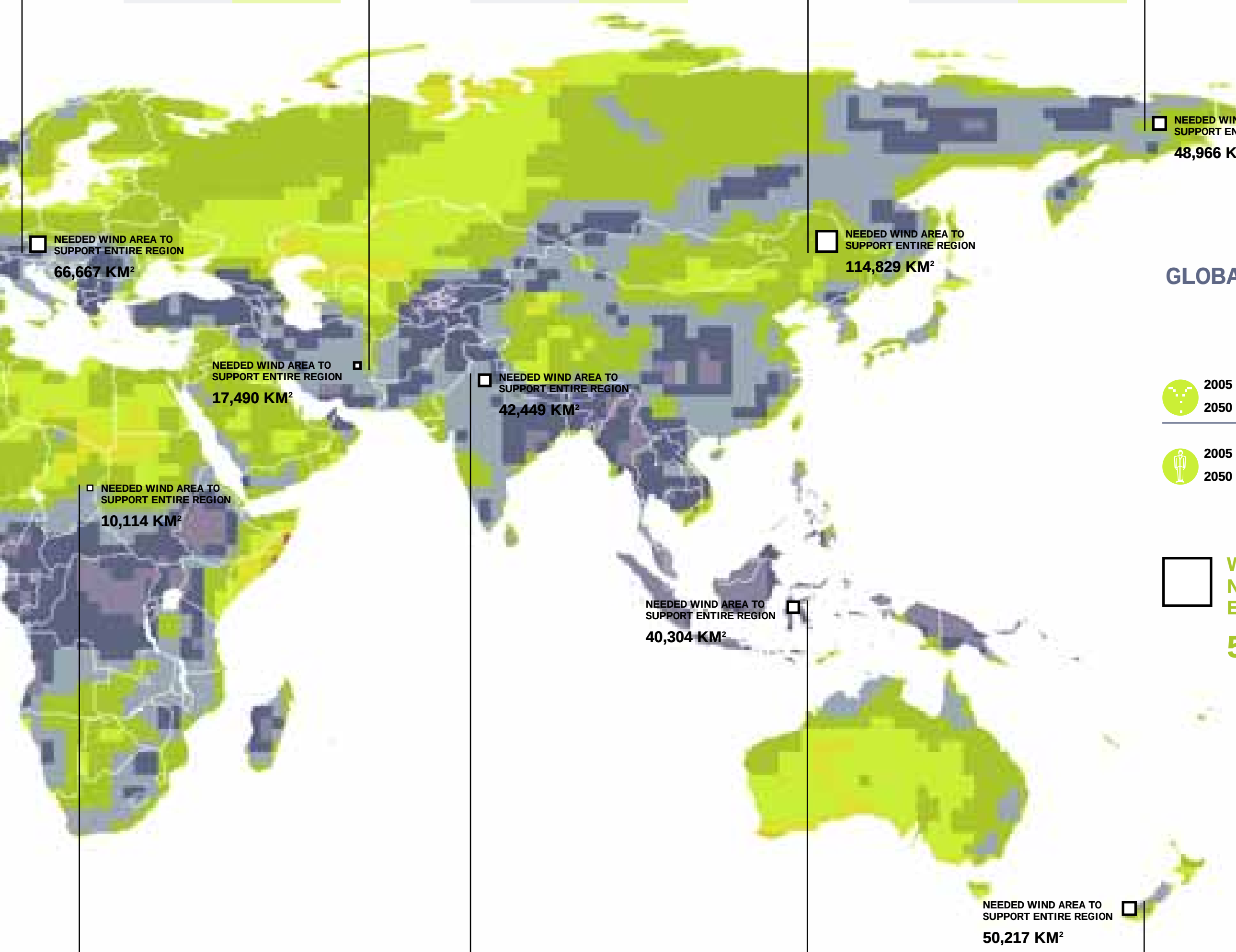
		REF %	REF PJ	E[R] %	E[R] PJ
	2005	0.00L	0L		
	2050	0.13	69L	3.0	828
			kWh		kWh
	2005		0L		
	2050		56		663

CHINA

		REF %	REF PJ	E[R] %	E[R] PJ
	2005	0.01	8		
	2050	0.48	882M	5.48M	5,436
			kWh		kWh
	2005		2		
	2050		173		1,064

TRANSITION ECONOMIES

		REF %	REF PJ	E[R] %	E[R] PJ
	2005	0.00L	1		
	2050	0.36	228	7.15	2,556
			kWh		kWh
	2005		0		
	2050		215M		2,416



GLOBAL

		REF %	REF PJ	E[R] %	E[R] PJ
	2005	0.08	372		
	2050	0.72	6,251	5.82	27,857
			kWh		kWh
	2005		16		
	2050		189		844

WIND AREA NEEDED TO SUPPORT E[R] 2050 SCENARIO

546,688 KM²

AFRICA

		REF %	REF PJ	E[R] %	E[R] PJ
	2005	0.01	3		
	2050	0.21	111	1.25L	479L
			kWh		kWh
	2005		1		
	2050		15L		67L

INDIA

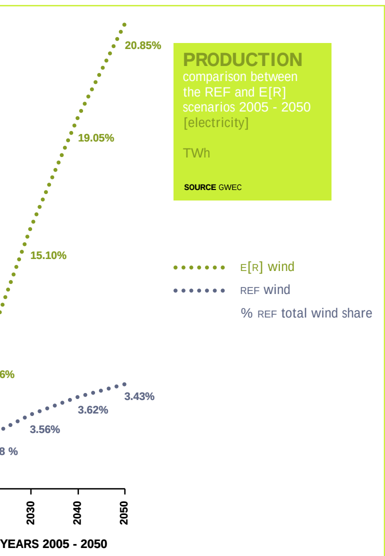
		REF %	REF PJ	E[R] %	E[R] PJ
	2005	0.10	22M		
	2050	0.42	373	3.59	1,872
			kWh		kWh
	2005		5		
	2050		63		314

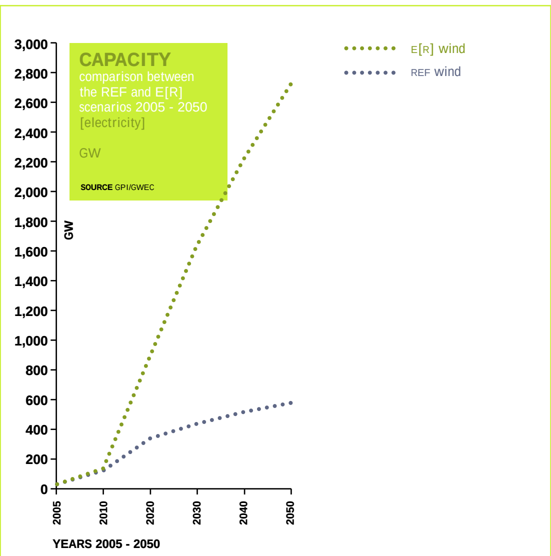
ASIA

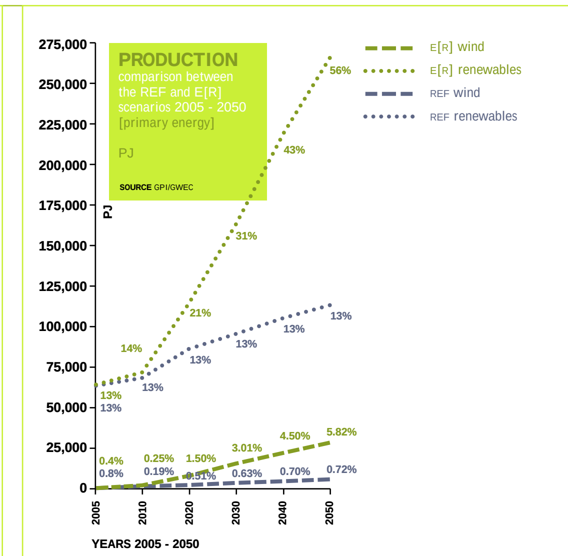
		REF %	REF PJ	E[R] %	E[R] PJ
	2005	0.00L	0L		
	2050	0.48	327	4.35	1,908
			kWh		kWh
	2005		0L		
	2050		60		352

OECD PACIFIC

		REF %	REF PJ	E[R] %	E[R] PJ
	2005	0.03	12		
	2050	0.64M	299	11.7H	2,920M
			kWh		kWh
	2005		17M		
	2050		466		4,554H



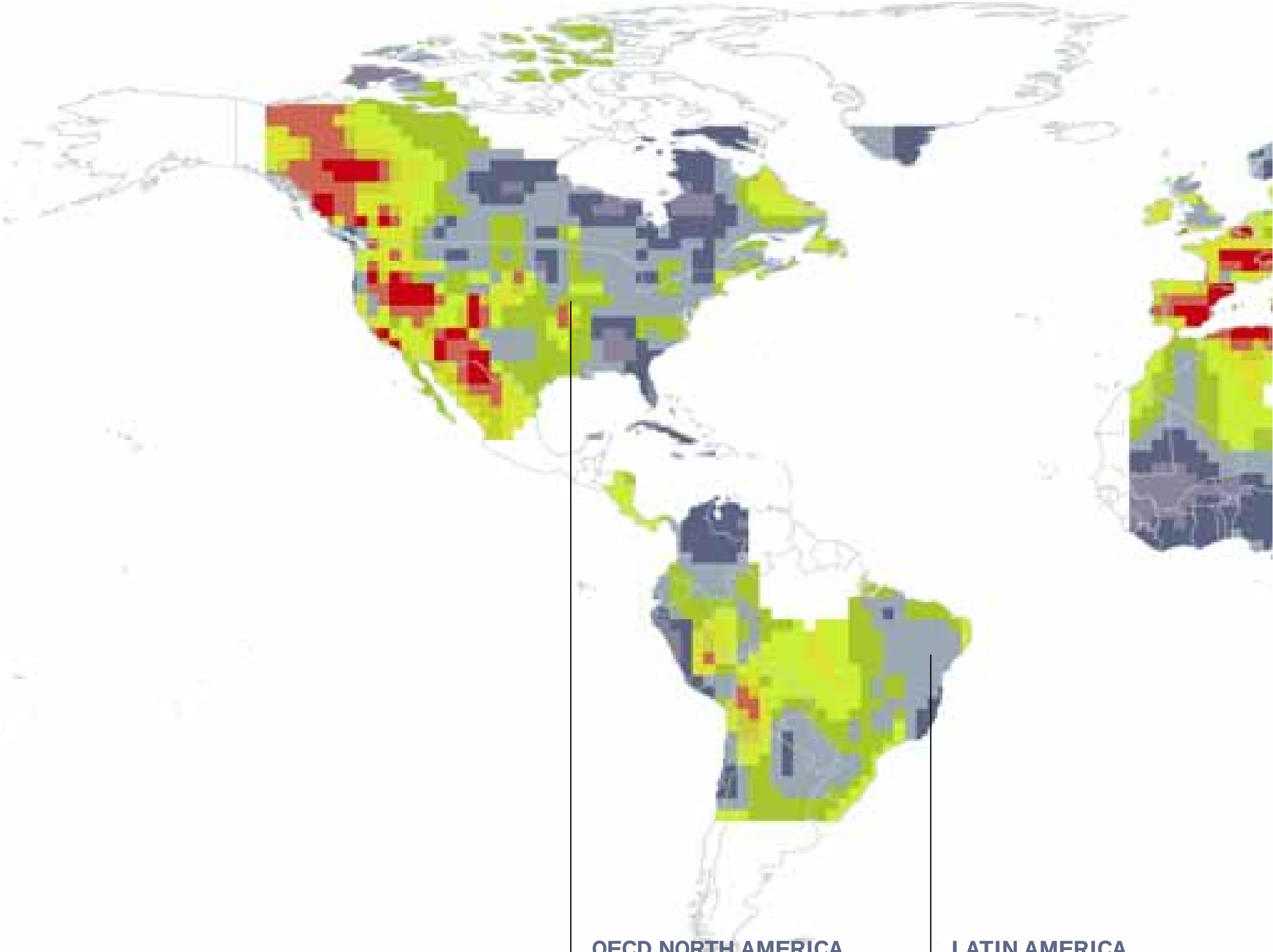




GREENPEACE DESIGN WWW.ONEHEMISPHERE.SE CONCEPT SVEN TESKE/GREENPEACE INTERNATIONAL.

map 8.7: geothermal reference scenario and the energy [r]evolution scenario

WORLDWIDE SCENARIO



OECD NORTH AMERICA

		REF %	REF PJ	E[R] %	E[R] PJ
Production per region	2005	0.54	625H		
	2050	1.03M	1,695H	16.15H	12,547H
			kWh		kWh
Production per person	2005		398H		
	2050		815		6,036H

LATIN AMERICA

		REF %	REF PJ	E[R] %	E[R] PJ
Production per region	2005	0.42M	89		
	2050	1.29	675	9.96M	3,237
			kWh		kWh
Production per person	2005		55M		
	2050		297		1,422

RENEWABLE RESOURCE

GEOTHERMAL

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

E[R] ENERGY [R]EVOLUTION SCENARIO

0 1000 KM

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

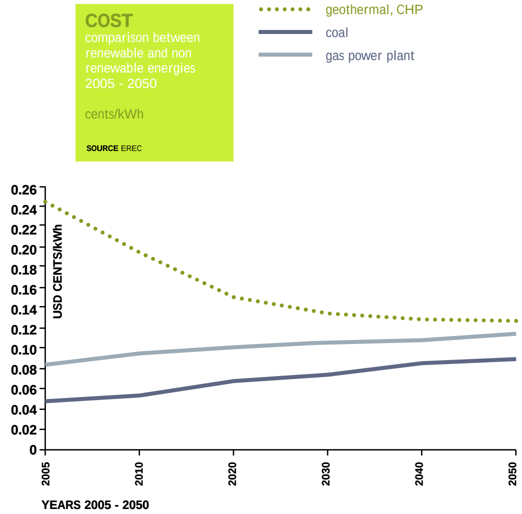
PRODUCTION PER PERSON KILOWATT HOUR [kWh]

H HIGHEST | M MIDDLE | L LOWEST

COST
comparison between renewable and non renewable energies 2005 - 2050

cents/kWh

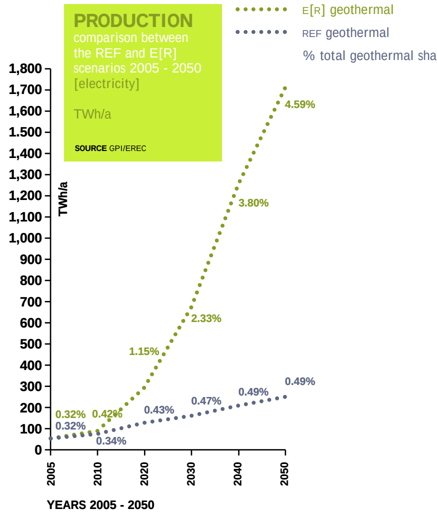
SOURCE EREC



PRODUCTION
comparison between the REF and E[R] scenarios 2005 - 2050 [electricity]

TWh/a

SOURCE GPI/EREC



OECD EUROPE

	REF %	REF PJ	E[R] %	E[R] PJ
2005	0.44	360		
2050	1.15	1,036	10.77	5,271M
		kWh		kWh
2005		186		
2050		511M		2,600

MIDDLE EAST

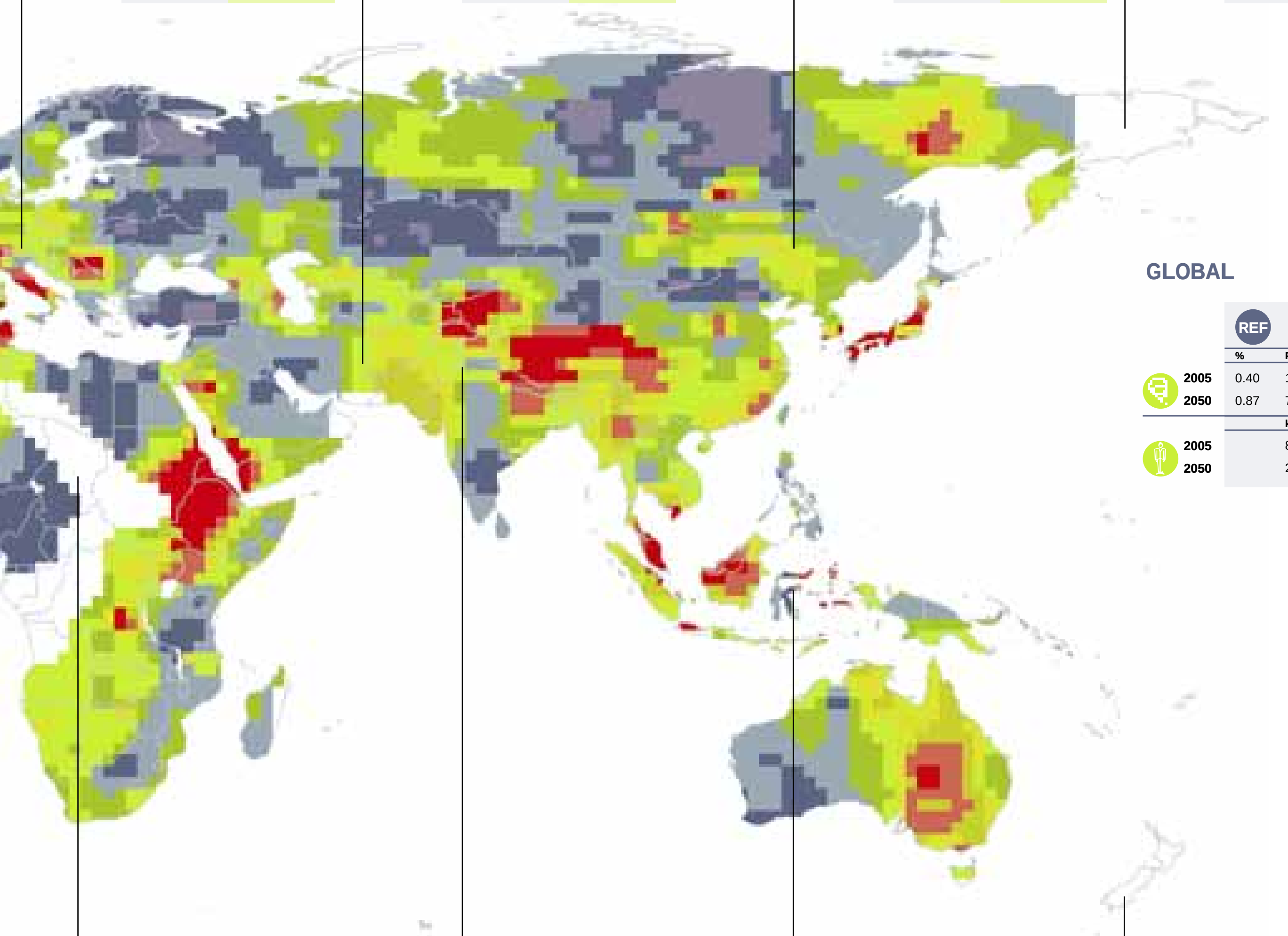
	REF %	REF PJ	E[R] %	E[R] PJ
2005	0.00L	0L		
2050	0.26	145	10.72	2,958
		kWh		kWh
2005		0L		
2050		116		2,369M

CHINA

	REF %	REF PJ	E[R] %	E[R] PJ
2005	0.00L	0L		
2050	0.19	345	6.71	6,652
		kWh		kWh
2005		0L		
2050		68		1,303

TRANSITION ECONOMIES

	REF %	REF PJ	E[R] %	E[R] PJ
2005	0.05	21		
2050	1.35	863	15.8	5,649
		kWh		kWh
2005		17		
2050		816		5,341



GLOBAL

	REF %	REF PJ	E[R] %	E[R] PJ
2005	0.40	1,921		
2050	0.87	7,540	10.48	50,131
		kWh		kWh
2005		82		
2050		228		1,519

AFRICA

	REF %	REF PJ	E[R] %	E[R] PJ
2005	0.13	32		
2050	0.62	333	2.43L	930L
		kWh		kWh
2005		10		
2050		46		129L

INDIA

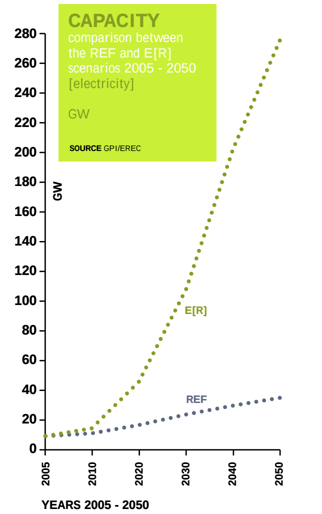
	REF %	REF PJ	E[R] %	E[R] PJ
2005	0.00L	0L		
2050	0.15L	138L	10.69	5,870M
		kWh		kWh
2005		0L		
2050		23L		933

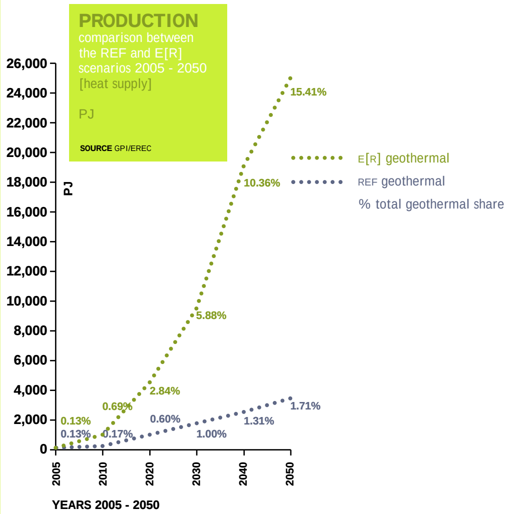
ASIA

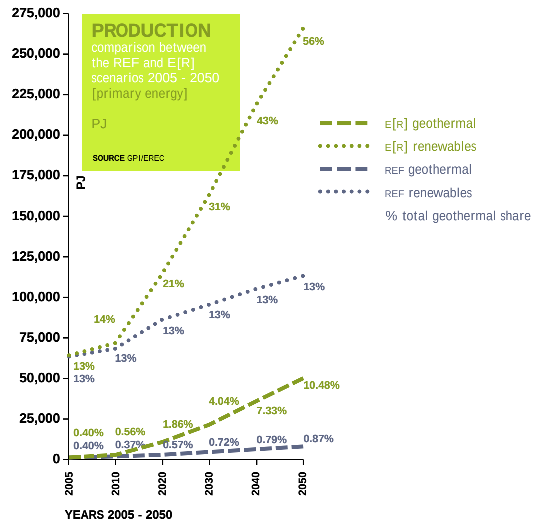
	REF %	REF PJ	E[R] %	E[R] PJ
2005	1.91H	594		
2050	2.32H	1,567	12.29	5,390
		kWh		kWh
2005		169		
2050		290		996

OECD PACIFIC

	REF %	REF PJ	E[R] %	E[R] PJ
2005	0.54	200M		
2050	1.58	743M	7.72	1,927
		kWh		kWh
2005		277		
2050		1,159H		3,005







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GLOBAL

FOSSIL FUEL TECHNOLOGIES
NUCLEAR TECHNOLOGIES
RENEWABLE ENERGY TECHNOLOGIES

9

"the technology is here, all we need is political will."

CHRIS
SUPORTER, AUSTRALIA

image BIOGAS FACILITY "SCHRADEN BIOGAS" IN GROEDEN NEAR DRESDEN, GERMANY. © LANGROCK/ZENIT/GP

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

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 fuel sources, 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 synthetic gas composed mainly of hydrogen and carbon monoxide. This 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 the 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 technologies 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 fuelled 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 produces electricity and the exhaust gases from the 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 reduction 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 hard coal power plant discharges roughly 720 grammes of carbon dioxide per kilowatt hour, a modern gas-fired plant about 370g CO_2/kWh. To ensure that no CO_2 emerges from the power plant chimney, the gas must first be removed, and then stored somewhere. Both carbon capture and storage (CCS) 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.

Ocean storage could result in greatly accelerated acidification of large sea 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 relatively short time. The oceans are both productive resources and a common natural endowment for this and future generations. Given the diversity of other options available for dealing with CO_2 emissions, direct disposal to the ocean, sea floor, lakes and other open reservoir structures must be ruled out.

Among the options available for 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 considered 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 ten 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 could only become reality in 15 years at the earliest. This means they will not make any substantial contribution towards protecting the climate until the year 2020 at the earliest. They are thus irrelevant to the goals of the Kyoto Protocol.

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 many factors, including the technology used for separation, transport and the 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.

The conclusion reached in the Energy [R]evolution Scenario is that 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 worldwide 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 conservation 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 an increase in emissions in the short to medium term.

image SELLAFIELD NUCLEAR PLANT, CUMBRIA, UK.

image TEMELÍN NUCLEAR POWER PLANT IN THE CZECH REPUBLIC.

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: New generation reactors now being built.

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[40], 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.

Of the new reactor types, the European Pressurised Water Reactor (EPR) has been developed from the most recent Generation II designs to start operation in France and Germany[41]. 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 has been increased by 15% relative to existing French reactors by increasing core outlet temperature, letting the main coolant pumps run at higher capacity and modifying the steam generators.
- The EPR has fewer redundant pathways in its safety systems than a German 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
40 IAEA 2004; WNO 2004A
41 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 pv) 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.

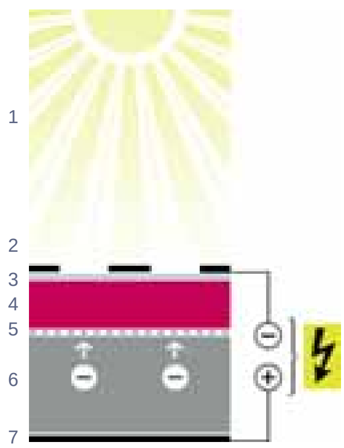
Photovoltaic (PV) technology involves the generation of electricity from light. The secret to this process is the use of a semiconductor material which can be adapted to release electrons, the negatively charged particles that form the basis of electricity. The most common semiconductor material used 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 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 9.1: 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

image SOLAR PROJECT IN PHITSANULOK, THAILAND. SOLAR FACILITY OF THE INTERNATIONAL INSTITUTE AND SCHOOL FOR RENEWABLE ENERGY.

image SOLAR PANELS ON CONISTON STATION, NORTH WEST OF ALICE SPRINGS, NORTHERN TERRITORY.

concentrating solar power (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 a large proportion 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.

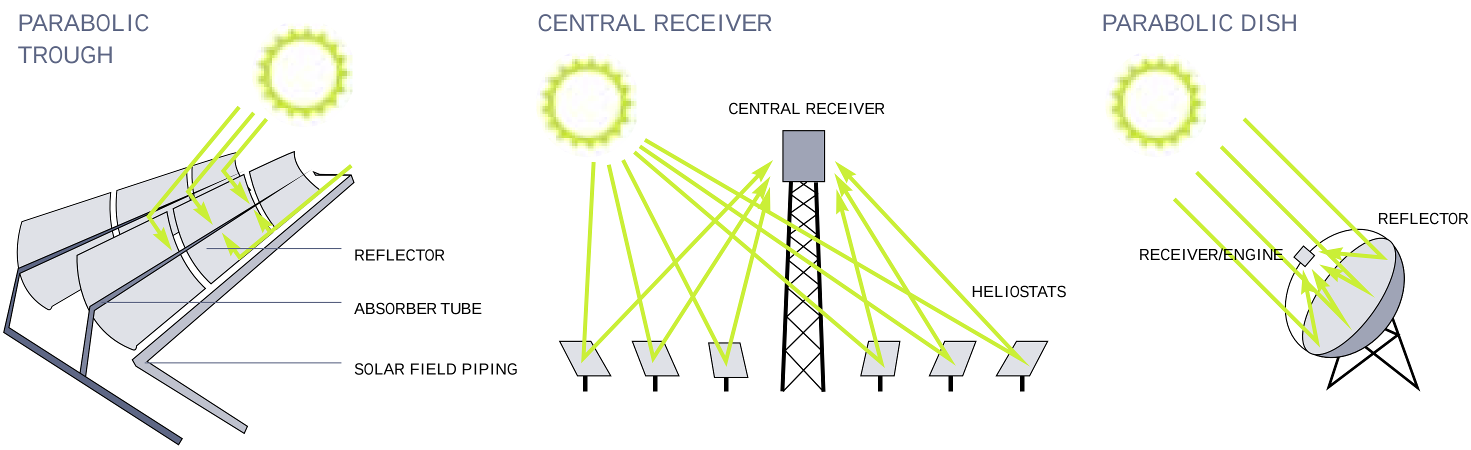
- **central receiver or solar tower** A circular array of heliostats (large individually tracking mirrors) is used to concentrate sunlight on to a central receiver mounted at the top of a tower. A heat-transfer medium absorbs the highly concentrated radiation reflected by the heliostats and converts 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 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 for decentralised power supply and remote, stand-alone power systems. Projects are currently planned in the United States, Australia and Europe.

figures 9.2: parabolic trough/central receiver or solar tower/parabolic dish technology



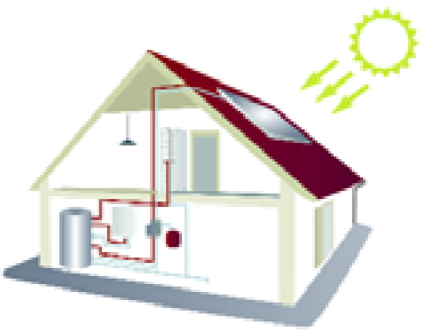
solar thermal collectors Solar thermal collecting systems are based on a centuries-old principle: the sun heats up water contained in a dark vessel. Solar thermal technologies on the market now are efficient and highly reliable, providing energy for a wide range of applications - from domestic hot water 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 9.3: 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 network.

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.

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

image VESTAS VM 80 WIND TURBINES AT AN OFFSHORE WIND PARK IN THE WESTERN PART OF DENMARK.

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 just over 1% 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 2007 was 1,492 kW, whilst the largest machine in operation is the Enercon E126, with a rotor diameter of 126 metres and a power capacity of 6 MW.

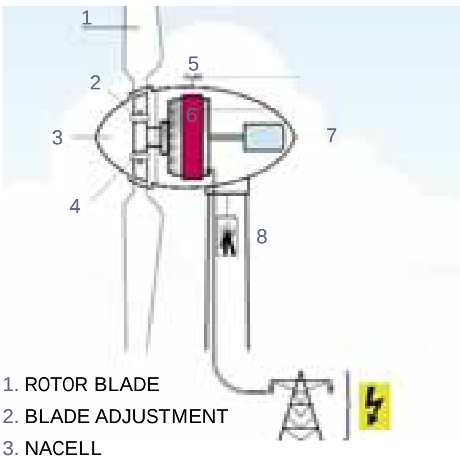
This growth in turbine size has been matched by the expansion of both markets and manufacturers. Almost 100,000 wind turbines now operate in over 50 countries around the world. The German market is the largest, but there has also been impressive growth in Spain, Denmark, India, China and the United States.

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 used in 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.

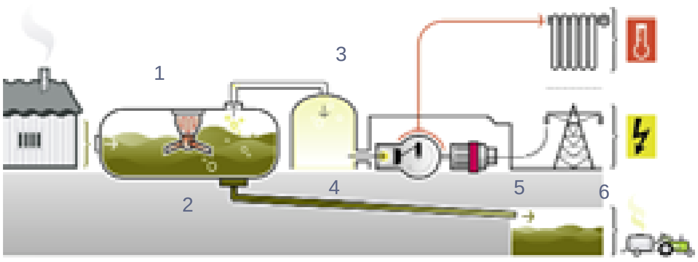
Electricity generating biomass power plants work just like natural gas or coal power stations, except that the fuel must be processed before it can be burned. These power plants are generally not as large as coal power stations because their fuel supply needs to grow as near as possible to the plant. Heat generation from biomass power plants can result either from utilising a Combined Heat and Power (CHP) system, 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 9.4: wind turbine technology



1. ROTOR BLADE
2. BLADE ADJUSTMENT
3. NACELL
4. ROTOR SHAFT
5. WIND MEASUREMENT
6. GENERATOR
7. SYSTEM CONTROL
8. LIFT

figure 9.5: 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 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 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 combustion engine to generate electricity. Gasification can also decrease emission levels compared to power production with direct combustion and a steam cycle.

  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 farm animal slurry.

  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 and electricity generation.

  Fermentation Fermentation is the process by which growing plants with a 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[42].

bio fuels Converting crops into ethanol and bio diesel made from rapeseed methyl ester (RME) currently takes place mainly in Brazil, the USA and Europe. Processes for obtaining synthetic fuels from 'biogenic synthesis' gases will also play a larger role in the future. Theoretically bio fuels can be produced from any biological carbon source, although the most common are photosynthetic plants. Various plants and plant-derived materials are used for bio fuel production. Globally bio fuels are most commonly used to power vehicles, but can also be used for other purposes. The production and use of bio fuels must result in a net reduction in carbon emissions compared to the use of traditional fossil fuels to have a positive effect in climate change mitigation. Sustainable bio fuels can reduce the dependency on petroleum and thereby enhance energy security.

Bio ethanol is a fuel manufactured through the fermentation of sugars. This is done by accessing sugars directly (sugar cane or beet) or by breaking down starch in grains such as wheat, rye, barley or maize. In the European Union bio ethanol is mainly produced from grains, with wheat as the dominant feedstock. In Brazil the preferred feedstock is sugar cane, whereas in the USA it is corn (maize). Bio ethanol produced from cereals has a by-product, a protein-rich animal feed called Dried Distillers Grains with Solubles (DDGS). For every tonne of cereals used for ethanol production, on average one third will enter the animal feed stream as DDGS. Because of its high protein level this is currently used as a replacement for soy cake. Bio ethanol can either be blended into gasoline (petrol) directly or be used in the form of ETBE (Ethyl Tertiary Butyl Ether).

Bio diesel is a fuel produced from vegetable oil sourced from rapeseed, sunflower seeds or soybeans as well as used cooking oils or animal fats. Bio diesel comes in a standard form as 'mono-alkyl ester' and other kinds of diesel-grade fuels of biological origin are not included. In specific cases, used vegetable oils can be recycled as feedstock for bio diesel production. This can reduce the loss of used oils in the environment and provides a new way of transforming a waste into transport energy. Blends of bio diesel and conventional hydrocarbon-based diesel are the most common products distributed in the retail transport fuel market.

Most countries use a labelling system to explain the proportion of bio diesel in any fuel mix. Fuel containing 20% biodiesel is labelled B20, while pure bio diesel is referred to as B100. Blends of 20 % bio diesel with 80 % petroleum diesel (B20) can generally be used in unmodified diesel engines. Used in its pure form (B100) an engine may require certain modifications. Bio diesel can also be used as a heating fuel in domestic and commercial boilers. Older furnaces may contain rubber parts that would be affected by bio diesel's solvent properties, but can otherwise burn it without any conversion.

references

42 'OPPORTUNITIES FOR 1,000 MWE BIOMASS-FIRED POWER PLANT IN THE NETHERLANDS', GREENPEACE NETHERLANDS, 2005

image GEOTHERMAL POWER STATION, NORTH ISLAND, NEW ZEALAND.

image GEOTHERMAL ACTIVITY.

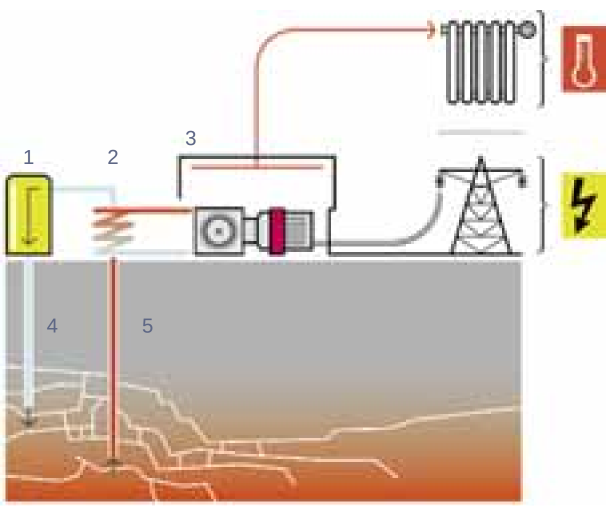
geothermal energy Geothermal energy is heat derived from deep underneath the Earth's crust. In most areas, this heat reaches the surface in a very diffuse state. However, due to a variety of geological processes, some areas, including the western part of the USA, west and central eastern Europe, Iceland, Asia and New Zealand are underlain by relatively shallow geothermal resources. These are classified as either low temperature (less than 90°C), moderate temperature (90° - 150°C) or high temperature (greater than 150°C). The uses to which these resources can be put depend 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 then 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 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.

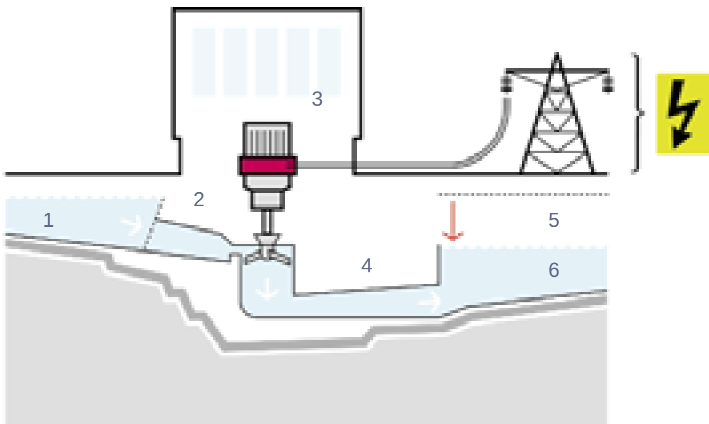
The main requirement for hydro power is to create an artificial head so that water, diverted through an intake channel or pipe into a turbine, discharges back into the river downstream. Small hydro power is mainly 'run-of-the-river' and does not collect significant amounts of stored water, requiring 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 extracts 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 9.6: geothermal technology



1. PUMP
2. HEAT EXCHANGER
3. GAS TURBINE & GENERATOR
4. DRILLING HOLE FOR COLD WATER INJECTION
5. DRILLING HOLE FOR WARM WATER EXTRACTION

figure 9.7: 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 five 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. The largest grid-connected system installed so far is the 2.25 MW Pelamis, with linked semi-submerged cyclindrical sections, operating off the coast of Portugal. Most development work has been carried out in the UK.


1 © USCHI HERING/DREAMSTIME


2 © MCDONNELL/ISTOCK


3 © MAXFX/DREAMSTIME

images 1. BIOMASS CROPS. **2.** OCEAN ENERGY. **3.** CONCENTRATING SOLAR POWER (CSP).

energy efficiency – more with less

10

IN NORTH AMERICA ALONE WE COULD SHUT DOWN 16 DIRTY POWERPLANTS BY CHANGING TO CFLS AND LEDS. IN EUROPE WE COULD SHUT DOWN 11.

“today, we are wasting two thirds (61%) of the electricity we consume, mostly due to bad product design.”

GREENPEACE INTERNATIONAL
CLIMATE CAMPAIGN

Using energy efficiently is cheaper than producing fresh energy and often has multiple positive effects. An efficient clothes washing machine or dishwasher, for example uses less power and less water. Efficiency also usually provides a higher level of comfort. A well-insulated house, for instance, 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'.

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 - 'the whole house', 'the whole car' or even 'the whole transport system'. When you do this, energy needs can often be cut back by four to ten times.

In order to find out the global and regional energy efficiency potential, the Dutch institute Ecofys developed energy demand scenarios for this update of the Greenpeace Energy [R]evolution analysis. These scenarios cover energy demand over the period 2005-2050 for ten world regions. Two low energy demand scenarios for energy efficiency improvements have been defined. The first is based on the best technical energy efficiency potentials and is called 'Technical'. The second is based on more moderate energy savings taking into account implementation constraints in terms of costs and other barriers. This scenario is called 'Revolution'. The main results of the study are summarised below.

The starting point for the Ecofys analysis is that worldwide final energy demand is expected to grow by 95%, from 290 EJ in 2005 to 570 EJ in 2050, if we continue with business as usual. In the light of increasing fossil fuel prices, depleting resources and climate change, business as usual is simply not an option.

Growth in the transport sector is projected to be the largest, with energy demand expected to grow from 84 EJ in 2005 to 183 EJ in 2050. Demand for buildings and agriculture is expected to grow the least, from 91 EJ in 2005 to 124 EJ in 2050.

Under the energy [r]evolution scenario, however, growth in energy demand can be limited to an increase of 28% up to 2050 in comparison to the 2005 level, whilst taking into account implementation constraints in terms of costs and other barriers.

In Figure 10.2 the potential for energy efficiency improvements under this scenario are presented. The baseline is 2005 final energy demand per region. Table 10.1 shows that total worldwide energy demand has reduced to 376 PJ by 2050, with a breakdown by sector.

figure 10.1: reference scenario (business as usual) for worldwide final energy demand by sector

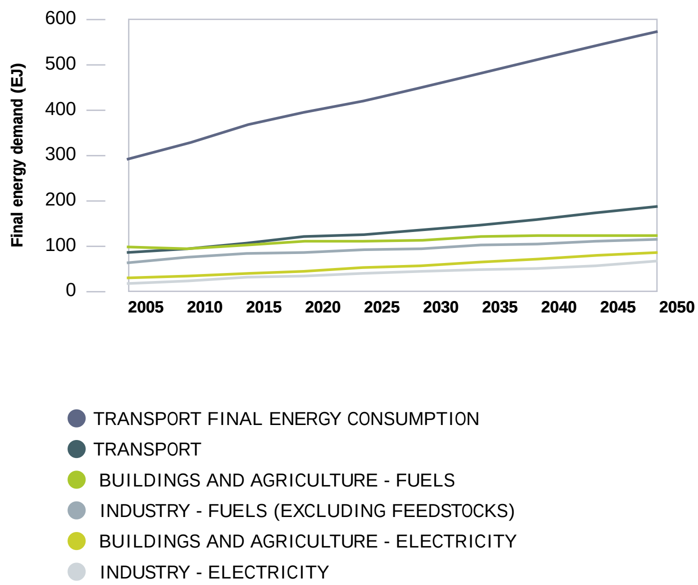


image STANDBY.

image WORK TEAM APPLYING STYROFOAM WALL INSULATION TO A NEWLY CONSTRUCTED BUILDING.

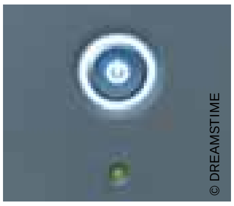


figure 10.2: potential for energy efficiency improvements per region in energy [r]evolution scenario

ENERGY DEMAND FOR ALL SECTORS (NORMALISED BASED ON 2005 PJ)

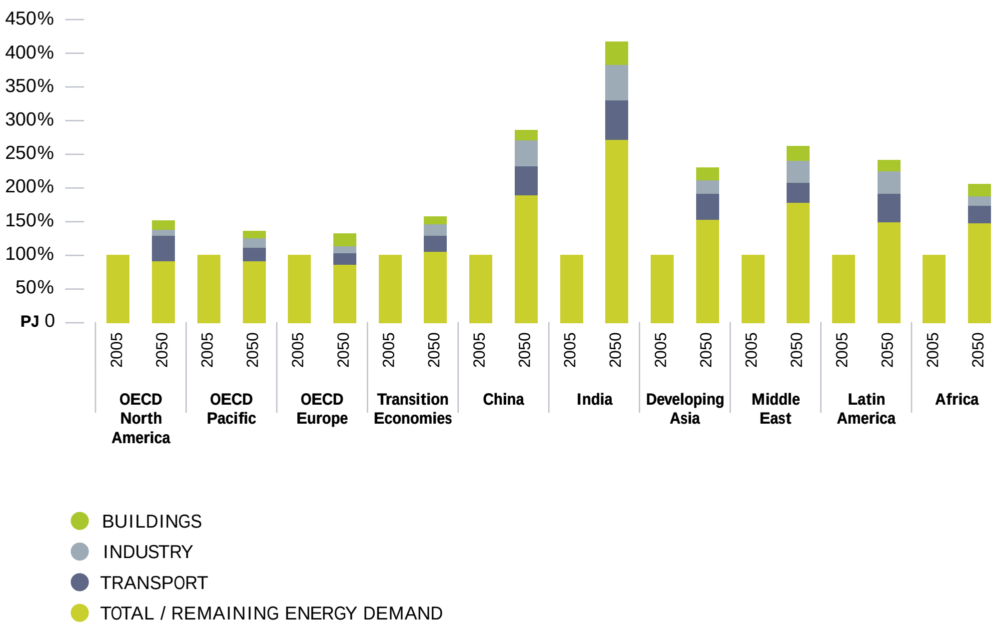


table 10.1: change in energy demand by 2050 in comparison to 2005 level

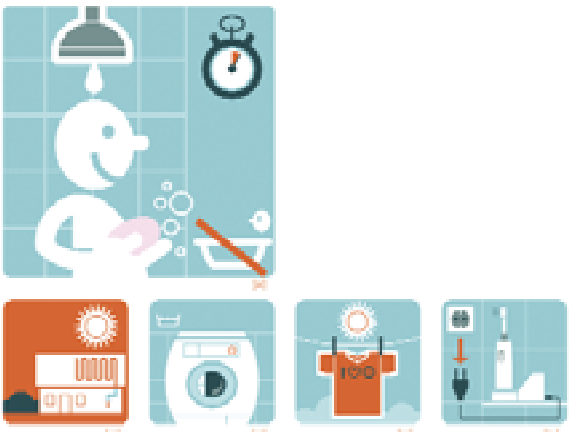
SECTOR	[R]EVOLUTION SCENARIO	REFERENCE SCENARIO
Industry	+32%	+101%
Transport	+11%	+119%
Buildings and Agriculture	+38%	+74%
Total	**+28%**	**+95%**

figure 10.3: energy efficient households

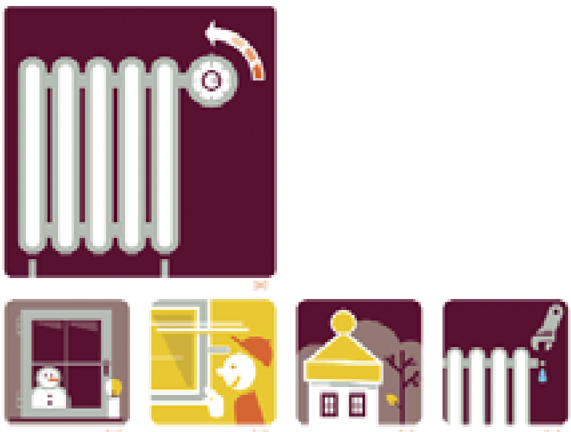
SAVE ENERGY – IN YOUR HOME

SAVE ENERGY – IN YOUR KITCHEN

SAVE ENERGY – IN YOUR BATHROOM



GET SMART ABOUT HEATING



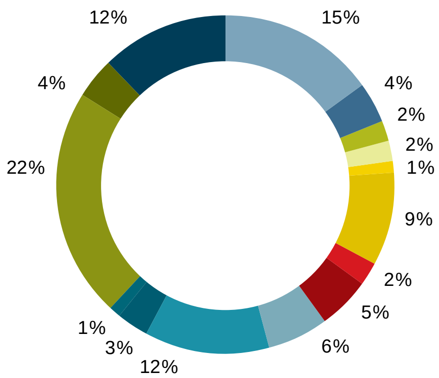
images POWER SOCKETS AND SWITCH.

Since homes account for the largest share of energy demand from buildings, this section examines in detail the savings potential in households. Breakdowns of electricity use in the core EU-15 countries and the new member states are given in Figure 10.4 and Figure 10.5. A breakdown of electricity demand in the services sector can be found in Figure 10.6.

Based on the results from three studies[43], we have assumed the following breakdowns for energy use (fuel and electricity) under the Reference Scenario in 2050. Insufficient information is available to make a breakdown by world region. We assume however that the pattern for different regions will converge over the years.

figure 10.4: breakdown of electricity use for residential end-use equipment in EU-15 countries in 2004

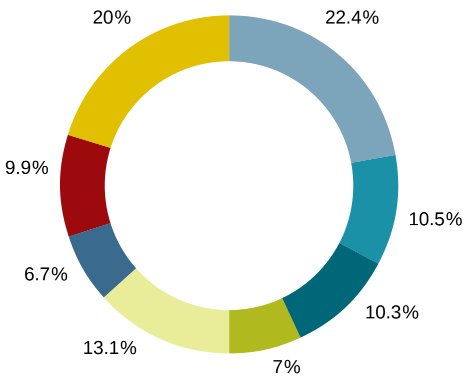
(BERTOLDI & ATANASIU, 2006)



- REFRIGERATORS & FREEZERS
- WASHING MACHINES
- DISHWASHERS
- DRIERS
- ROOM AIR-CONDITIONERS
- ELECTRIC STORAGE & WATER HEATER
- ELECTRIC OVENS
- ELECTRIC HOBS
- CONSUMER ELECTRONICS & OTHER EQUIPMENT STAND-BY
- LIGHTING
- TV ON MODE
- OFFICE EQUIPMENT
- RESIDENTIAL ELECTRIC HEATING
- CENTRAL HEATING CIRCULATION PUMPS
- MISCELLANEOUS

figure 10.5: breakdown of electricity use for residential end-use equipment in EU new member states in 2004

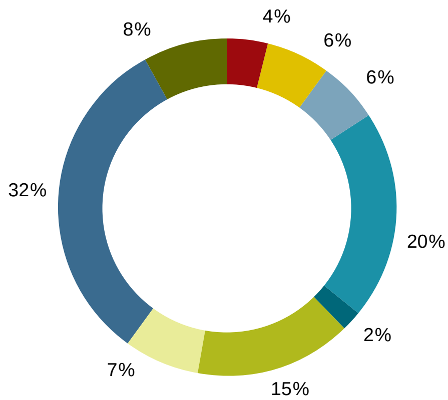
(BERTOLDI & ATANASIU, 2006)



- HEATING & COOLING
- LIGHTING
- REFRIGERATORS/FREEZERS
- WASHING MACHINES
- COOKING DISHWASHER
- ELECTRIC STORAGE & WATER HEATER
- CONSUMER ELECTRONICS & STAND-BY
- MISCELLANEOUS

figure 10.6: breakdown of electricity consumption in the EU services sector

(BERTOLDI & ATANASIU, 2006)



- CONVEYORS
- COOKING
- PUMPS
- SPACE & WATER HEATING
- MISCELLANEOUS
- COOLING & VENTILATION
- COMMERCIAL REFRIGERATION
- COMMERCIAL & STREET LIGHTING
- OFFICE EQUIPMENT

references

43 BERTOLDI, P. AND B. ATANASIU. 'ELECTRICITY CONSUMPTION AND EFFICIENCY TRENDS IN THE ENLARGED EUROPEAN UNION - STATUS REPORT 2006', INSTITUTE FOR ENVIRONMENT AND SUSTAINABILITY, OECD/IEA (2006) AND WBCSD (2005)

table 10.2: break down of energy use in households

FUEL USE 2050	ELECTRICITY USE 2050
Hot water (15%)	Air conditioning (8%)
Cooking (5%)	Lighting (15%)
Space heating (80%)	Standby (8%)
	Cold appliances (15%)
	Appliances (30%)
	Other (e.g. electric heating) (24%)

Since an estimated 80% of fuel use in buildings is for space heating, the energy efficiency improvement potential here is considered to be large. In order to determine the potential for efficiency improvement in space heating we looked at the energy demand per m^2 floor area per heating degree day (HDD). Heating degree days indicate the number of degrees that a day's average temperature is under 18°C, the temperature below which buildings need to be heated.

The typical current heating demand for dwellings is 70-120 kJ/m^2 [44]. Dwellings with a low energy use consume below 32 kJ/m^2/, however, more than 70% less than the current level.

the low energy household

Technologies to reduce energy demand applied in this typical household are[45]:

- Triple-glazed windows with low emittance coatings. These windows greatly reduce heat loss to 40% compared to windows with one layer. The low emittance coating prevents energy waves in sunlight coming through, reducing the need for cooling.
- Insulation of roofs, walls, floors and basement. Proper insulation reduces heating and cooling demand by 50% in comparison to typical energy demand.
- Passive solar techniques make use of solar energy through the building's design - siting and window orientation. The term 'passive' indicates that no mechanical equipment is used. All solar gains come through the windows.
- Balanced ventilation with heat recovery means that heated indoor air is channelled to a heat recovery unit and used to heat incoming outdoor air.

Current space heating demands in kJ per square metre per heating degree day for OECD dwellings are given in the table below.

table 10.3: space heating demands in OECD dwellings in 2004

REGION	SPACE HEATING (KJ/M²/HDD)
OECD Europe	113
OECD North America	78
OECD Pacific	52

source OECD/IEA, 2007

references
44 BERTOLDI, P. AND B. ATANASIU. 'ELECTRICITY CONSUMPTION AND EFFICIENCY TRENDS IN THE ENLARGED EUROPEAN UNION - STATUS REPORT 2006', INSTITUTE FOR ENVIRONMENT AND SUSTAINABILITY, OECD/IEA (2006) AND WBCSD (2005)
45 BASED ON WBCSD (2005), IEA (2006), JOOSEN ET AL (2002)

image A ROOM AT A NEWLY CONSTRUCTED HOME IS SPRAYED WITH LIQUID INSULATING FOAM BEFORE THE DRYWALL IS ADDED.

image FUTURISTIC SOLAR HEATED HOME MADE FROM CEMENT AND PARTIALLY COVERED IN THE EARTH.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space heating savings for new buildings We have assumed under the Energy [R]evolution Scenario that from 2010 onwards, all new dwellings will be low energy buildings using 48 kJ/m²/HDD. Since there is no data on current average energy consumption for dwellings in non-OECD countries, we have had to make assumptions for these regions. The potential for fuel savings[46] is considered to be small in developing regions and about the same as the OECD in the Transition Economies. From this study we have taken the potential for developing regions to be equal to a 1.4% energy efficiency improvement per year, including replacing existing homes with more energy efficient housing (retrofitting). For the Transition Economies we have assumed the average OECD savings potential. For new homes, the savings compared to the average current dwelling are given in Table 10.4.

space heating savings by retrofit As well as constructing efficient new buildings there is a large savings potential to be found in retrofitting existing buildings. Important retrofit options are more efficient windows and insulation. According to the OECD/IEA, the first can save 39% of space heating energy demand while the latter can save 32% of space heating or cooling. Energy consumption in existing buildings in Europe could therefore decrease by more than 50%[47]. In OECD Europe and for the other regions we assume the same relative reductions as for new buildings, to take into account current average efficiency of dwellings in the regions. For existing homes, the savings compared to the average current dwelling are given in the table below.

table 10.4: savings for space heating in new buildings in comparison to typical current dwellings

REGION	[R]EVOLUTION SCENARIO
OECD Europe	58%
OECD North America	38%
OECD Pacific	8%
EIT	35%

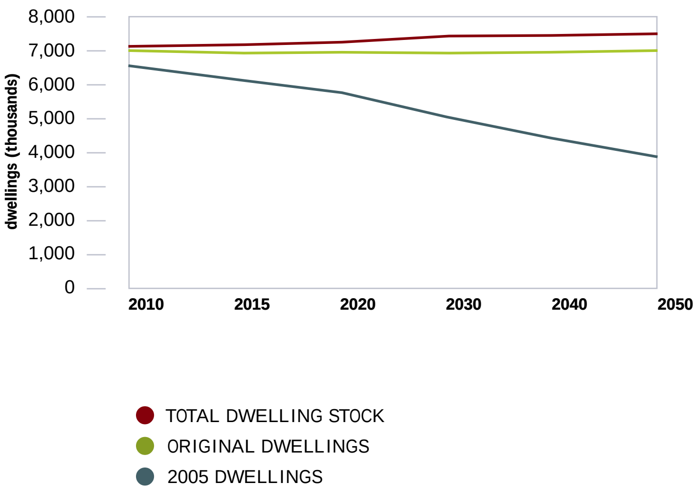
table 10.5: savings for space heating in existing buildings in comparison to a current average dwelling

REGION	[R]EVOLUTION SCENARIO
OECD Europe	40%
OECD North America	26%
OECD Pacific	5%
EIT	24%

In order to calculate the overall potential we need to know the share of new and existing buildings in 2050. The United Nations Economic Commission for Europe database[48] contains data on the total housing stock, the increase from new construction and population. We have assumed that the total housing stock grows along with the population. The number of existing dwellings also decreases each year due to a certain level of replacement. On average this is about 1.3% of the total housing stock per year, meaning a 40% replacement over 40 years, the equivalent of an average house lifetime of 100 years. Figure 10.6 shows how the future housing stock could develop in The Netherlands.

references
46 ÜRGE-VORSATZ & NOVIKOVA (2008)
47 OECD/IEA,2006
48 UNECE, 'HUMAN SETTLEMENT DATABASE', 2008

figure 10.7: future housing stock development in the netherlands



This example illustrates that new dwellings in The Netherlands (and therefore OECD Europe) make up 7% of the total housing stock in 2050 and retrofits account for 41%. Although the UNECE database does not have data for countries in all regions of the world, the percentages of new and retrofit houses in 2050 are not dependent on the absolute number of dwellings but only on the rate of population growth and the 1.3% assumption. This means that we can use the population growth to make forecasts for other regions (see Table 10.6).

table 10.6: forecast share of new dwellings in the housing stock in 2050

REGION	EXISTING BUILDINGS	NEW DWELLINGS DUE TO REPLACEMENT OF OLD BUILDINGS AS SHARE OF TOTAL DWELLINGS IN 2050	NEW DWELLINGS DUE TO POPULATION GROWTH AS SHARE OF TOTAL IN 2050
OECD Europe	52%	41%	7%
OECD North America	36%	29%	35%
OECD Pacific	55%	44%	1%
Transition Economies	55%	45%	0%
India	32%	25%	43%
China	49%	39%	12%
Developing Asia	29%	23%	48%
Latin America	33%	27%	40%
Middle East	22%	17%	61%
Africa	16%	13%	71%

Total savings for space heating energy demand are calculated by multiplying the savings potentials for new and existing houses by the forecast share of dwellings in 2050 to get a weighed percentage reduction. For fuel use for hot water we have assumed the same annual percentage reduction as for space heating. For cooking we have assumed a 1.5% per year efficiency improvement.

electricity savings by application

In order to determine savings for electricity demand in buildings, we examined the energy use and potential savings for the following different elements of power consumption:

- Standby
- Lighting
- Set-top boxes
- Freezers/fridges
- Computers/servers
- Air conditioning

1. standby power consumption Standby power consumption is the "lowest power consumption which cannot be switched off (influenced) by the user and may persist for an indefinite time when an appliance is connected to the mains electricity supply"[49]. In other words, the energy available when an appliance is connected to the power supply is not being used. Some appliances also consume energy when they are not on standby and are also not being used for their primary function, for example when an appliance has reached the end of a cycle but the 'on' button is still engaged. This consumption does not fit into the definition of standby power but could still account for a substantial amount of energy use.

Reducing standby losses provides a major opportunity for cost-effective energy savings. Nowadays, many appliances can be remotely and/or instantly activated or have a continuous digital display, and therefore require a standby mode. Standby power accounts for 20–90W per home in developed nations, ranging from 4 to 10% of total residential electricity use[50] and 3-12% of total residential electricity use worldwide[51]. Printers use 30-40% of their full power requirement when idle, as do televisions and music equipment. Set-top boxes used in conjunction with televisions tend to consume even more energy on standby than in use. Typical standby use of different types of electrical devices is shown in Figure 10.8.

references
49 UNITED KINGDOM MARKET TRANSFORMATION PROGRAMME, 'BNXS15: STANDBY POWER CONSUMPTION - DOMESTIC APPLIANCES', 2008
50 MEIER, A., J. LIN, J. LIU, T. LI, 'STANDBY POWER USE IN CHINESE HOMES', ENERGY AND BUILDINGS 36, PP. 1211-1216, 2004
51 MEIER, A, 'A WORLDWIDE REVIEW OF STANDBY POWER IN HOMES', LAWRENCE BERKELEY NATIONAL LABORATORY, UNIVERSITY OF CALIFORNIA, 2001

image FRIDGE.

image POWER PLUGS.

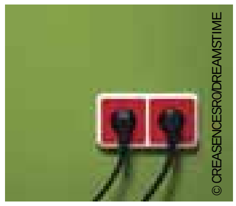


figure 10.8: electricity use of standby power for different devices

(HARMELINK ET AL., 2005)

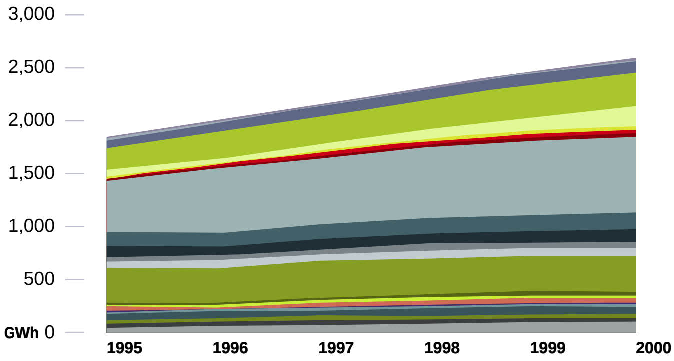
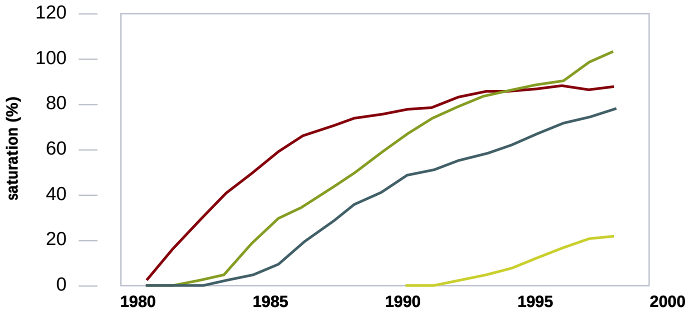


figure 10.9: level of saturation in population for major appliances in china

(MEIER ET AL., 2004)



In developing nations, the amount of appliances per household is growing (see Figure 10.9 for China). In China, standby energy use accounts for 50–200 kWh per year in an average urban home.

Overall, residential standby power consumption in China requires the electrical output equivalent to at least six 500 MW power plants.

Levels of standby power use in Chinese homes (on average 29W) are below those in developed countries but still high because Chinese appliances have a higher level of standby operation. Existing technologies are available to greatly reduce standby power at a low cost.

By 2050, standby use is expected to be responsible for 8% of total electricity demand across all regions of the world. The World Business Council for Sustainable Development has assessed that a worldwide savings potential of between 72% and 82% is feasible. This is confirmed by research in The Netherlands[52] which showed that reducing the amount of power available for standby in all devices to just 1W would lead to a saving of approximately 77%. We have adopted these reduction percentages for the Technical scenario (82% reduction) and the [R]evolution Scenario (72% reduction). This means an energy efficiency improvement of 4.2% per year in the Technical scenario and 3.1% per year in the [R]evolution Scenario.

references

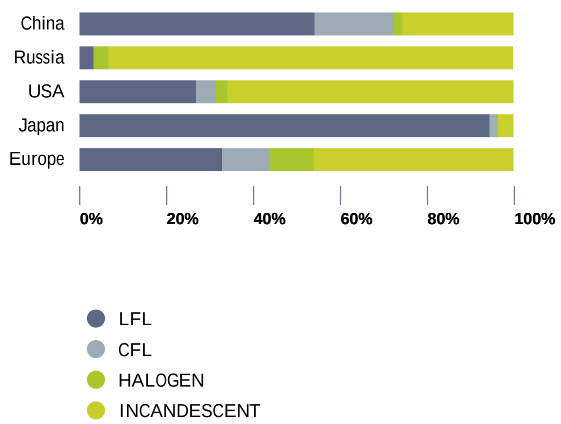
52 HARMELINK M., K. BLOK, M. CHANG, W. GRAUS, S. JOOSEN, 'OPTIONS TO SPEED UP ENERGY SAVINGS IN THE NETHERLANDS (MOGELIJKHEDEN VOOR VERSNELLING VAN ENERGIEBESPARING IN NEDERLAND)', ECOFYS, UTRECHT, 2005

2. lighting Incandescent bulbs have been the most common lamps for a more than 100 years. These are the most inefficient type of lighting, however, since up to 95% of the electricity is converted into heat[53]. Incandescent lamps have a relatively short life-span (average of approximately 1,000 hours) but have a low initial cost and optimal colour rendering. CFLs (Compact Fluorescent Lamps) are more expensive than incandescent bulbs but they use about 75% less energy, produce 75% less heat and last about ten times longer[54]. CFLs are available in different sizes and shapes, for indoors and outdoors.

The usage pattern for different lighting technologies in different countries is shown in Figure 10.10 (LFL = Linear Fluorescent Lamp).

figure 10.10: share of residential lighting taken up by different lighting technologies

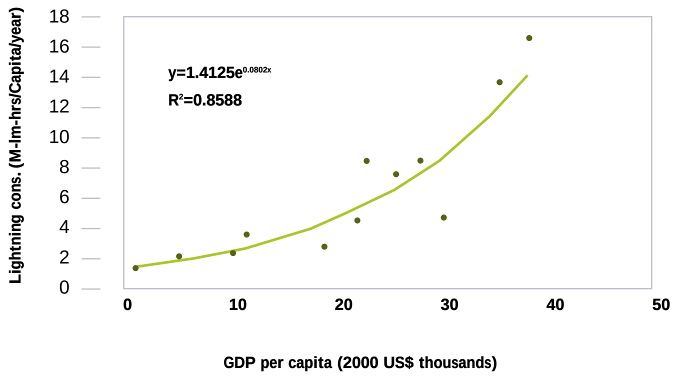
(WAIDE, 2006)



Globally, people consume 3 Mega-lumen-hrs (Mlmh) of residential electric light per capita/year. The average North American uses 13.2 Mlmh, the average Chinese 1.5 Mlmh - still 300 times the average artificial per capita light use in England in the nineteenth century. The average Japanese uses 18.5 Mlmh and the average European or Australian 2.7Mlmh. There is a clear relationship between GDP per capita and lighting consumption in Mlmh/cap/yr (see Figure 10.11).

figure 10.11: lighting consumption Mlmh/capita/yr as a function of GDP per capita

(WAIDE, 2006)



It is important to realise that lighting energy savings are not just a question of using more efficient lamps but also involve other approaches. These include making smarter use of daylight, reducing light absorption by luminaires (the fixture in which the lamp is housed), optimising lighting levels (levels in OECD countries commonly exceed recommended values), using automatic controls (turn off when no one is present, dim artificial light in response to rising daylight) and retrofitting buildings to make better use of daylight. Buildings designed to optimise daylight can receive up to 70% of their annual illumination needs from daylight, while a typical building will only get 20 to 25%[55]. In a study by Bertoldi & Atanasiu (2006), national lighting consumption and CFL penetration data is presented for the EU-27 countries (and candidate country Croatia). We used this data as the basis for household penetration rates and lighting electricity consumption in OECD Europe. As well as standby, lighting is an important source of cost-effective savings. The IEA publication "Light's Labour's Lost" (2006) projects that the cost-effective savings potential from energy efficient lighting in 2030 is at least 38% of lighting electricity consumption, even disregarding newer and promising solid state lighting technologies such as light emitting diodes (LEDs). In order to determine the savings potential for lighting, it is important to know the percentage of households with energy efficient lamps and the penetration level of these lamps. Based on Bertoldi & Atanasiu (2006) and Waide (2006) we calculated the shares shown in Table 10.7.

references
53 HENDEL-BLACKFORD ET AL., 2007
54 ENERGY STAR, 'COMPACT FLUORESCENT LIGHT BULBS', 2008
55 IEA, 2006

image COMPACT FLUORESCENT LAMP LIGHT BULB.

image WASHING MACHINE.

table 10.7: current penetration of energy efficient lamps

REGION	% OF ENERGY EFFICIENT LAMPS
OECD Europe	15%
OECD Pacific	60% (average North America and Japan)
OECD North America	30%
Transition Economies (TE)	5%
China	75%
Developing Regions	No information, 5% assumed, as for TE

Based on the studies already cited we calculate that a maximum of 80% savings can result from the introduction of efficient residential lighting in the Technical scenario and 70% in the [R]evolution Scenario. These savings not only include using energy efficient lamps but behavioural changes and maximising daylight use. Since the penetration of energy efficient lamps differs per household, we have assumed that the savings potential is the maximum saving multiplied by 1 minus the penetration rate. The resulting savings are given in Table 10.8.

table 10.8: energy savings from implementing energy efficient lighting

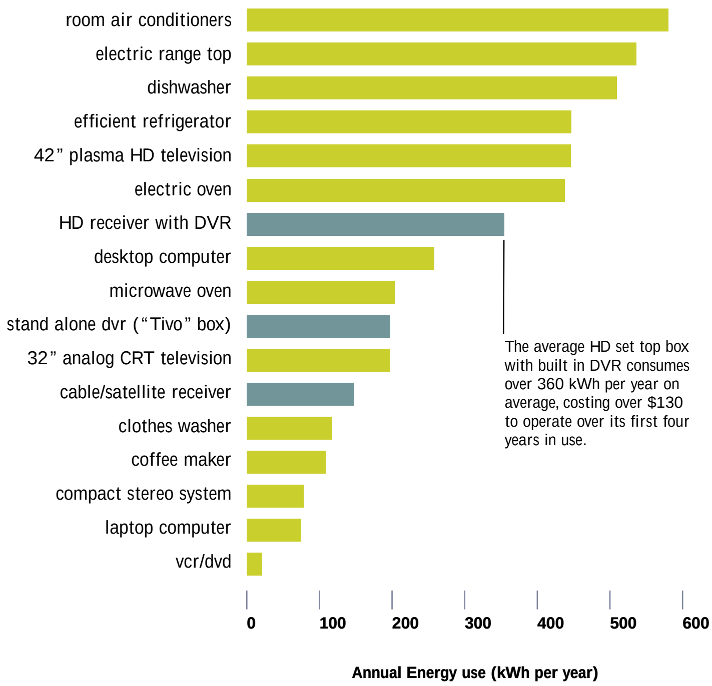
REGION	[R]EVOLUTION SCENARIO
OECD Europe	60%
OECD North America	49%
OECD Pacific	42%
Transition Economies	67%
China	18%
Other Developing Regions	67%

3. Set-top boxes Set-top boxes (STBs) are used to decode satellite or cable television programmes and are a major new source of energy demand. More than a billion are projected to be purchased worldwide over the next decade. The energy use of an average set-top box is 20-30 W, but it uses nearly the same amount of energy when switched off[56]. In the USA, STB energy use is estimated at 15 TWh/year, or about 1.3% of residential electricity use[57]. With more advanced uses, for instance digital video recorders (DVRs), STB energy use is forecast to triple to 45 TWh/year by 2010 – an 18% annual growth rate and 4% of 2010 residential electricity use.

Because of their short lifetimes (on average five years) and high ownership growth rates, STBs provide an opportunity for significant short term energy savings. Cable/satellite boxes without DVRs use 100 to 200 kWh of electricity per year, whilst combined with DVRs they use between 200 and 400 kWh per year. Media receiver boxes use less energy (around 35 kWh per year) but must be used in conjunction with existing audiovisual equipment and computers, thus adding another 35 kWh to the annual energy use of existing home electronics. Figure 10.12 shows the annual energy use of common household appliances. This shows that the energy use of some set-top boxes approaches that of the major energy consuming household appliances.

figure 10.12: annual energy use of common household appliances

(HOROWITZ, 2007)



Reducing the energy use of set-top boxes is complicated by their complex operating and communication modes. Although improvements in power supply design and efficiency will be effective in reducing energy use, the major savings will be obtained through energy management measures. The study by Rainer et al (2004) reports a savings potential of between 32% and 54% over five years (2005-2010). Assuming that these drastic measures have not yet been applied and due to lack of data on other regions, we have taken these reduction percentages as the global potential up to 2050.

references
56 OECD/IEA, 2006; HOROWITZ, 2007
57 RAINER ET AL., 2004

4. cold appliances The average household in OECD Europe consumed 700 kWh/year of electricity for food refrigeration in 2000 compared with 1,034 kWh/year in Japan, 1 216 kWh/year in OECD Australasia and 1,294 kWh/year in OECD North America. These figures illustrate differences in average household storage capacities, the ratio of frozen to fresh food use, ambient temperatures and humidity, and food storage temperatures and control[58]. European households typically either have a refrigerator-freezer in the kitchen (sometimes with an additional freezer or refrigerator), or they have a refrigerator and a separate freezer. Practical height and width limits place constraints on the available internal storage space for an appliance. Similar constraints apply in Japanese households, where ownership of a single refrigerator-freezer is the norm, but are less pressing in OECD North America and Australia. In these countries almost all households have a refrigerator-freezer and many also have a separate freezer and occasionally a separate refrigerator.

Looking in detail at the situation in the European Union, we found that in 2003, 103 TWh of electricity was consumed by household cold appliances alone (15% of total 2004 residential end use). A cold appliance with an energy use rating of A++ uses 120 kWh per year, while a comparable appliance with energy rating B uses 300 kWh per year and with rating C 600 kWh per year[59]. The average energy rating of appliances sold in the EU-15 countries is still B. If only A++ appliances were sold, energy consumption would be 60% less. The average lifetime of a cold appliance is 15 years, which means that 15 years from the introduction of only A++ labelled appliances, 60% less energy would be used in the EU-15. According to the European Commission (see Table 10.9), consumption in TWh/y could decrease from 103 in 2003 to 80 in 2010 with additional policies to encourage efficient appliances. This means that the energy efficiency of cold appliances could increase by about 3.5% each year.

table 10.9: energy consumption of household appliances in the EU-15 residential sector (european commission, 2005)

APPLIANCES	ELECTRICITY SAVINGS ACHIEVED IN THE PERIOD 1992-2003 [TWH/YEAR]	CONSUMPTION IN 2003 [TWH/YEAR]	CONSUMPTION IN 2010 (WITH CURRENT POLICIES) [TWH/YEAR]	CONSUMPTION IN 2010 AVAILABLE POTENTIAL TO 2010 (WITH ADDITIONAL POLICIES) [TWH/YEAR]
Washing machines	10-11	26	23	14
Refrigerators and freezers	12-13	103	96	80
Electric ovens	-	17	17	15.5
Standby	1-2	44	66	46
Lighting	1-5	85	94	79
Dryers	-	13.8	15	12
DESWH	-	67	66	64
Air-conditioners	-	5.8	8.4	6.9
Dishwashers	0.5	16.2	16.5	15.7
Total	**24.5-31.5**	**377.8**	**401.9**	**333.1**

Based on this analysis, we have assumed for the Technical scenario an energy efficiency improvement of 3.5% per year from 2010 onwards. This would lead to an efficiency improvement of 77% in 2050. For the [R]evolution Scenario we have assumed a 2.5% per year efficiency improvement, corresponding to 64% in 2050.

references
58 IEA, 2003
59 EUROTOPTEN, 2008

images COMPUTERS.

5. computers and servers The average desktop computer uses about 120 W per hour - the monitor 75 W and the central processing unit 45 W - and the average laptop 30 W per hour. Current best practice monitors[60] use only 18 W (15 inch screen), which is 76% less than the average. Savings for computers are especially important in the commercial sector. According to a 2006 US study, computers and monitors have the highest energy consumption in an office after lighting. In Europe, office equipment use is considered to be less important (see Figure 4), but estimates differ widely[61]. Some studies have shown that automatic and/or manual power management of computers and monitors can significantly reduce their energy consumption.

A power managed computer consumes less than half the energy of a computer without power management[62], depending on how your computer is used; power management can reduce the annual energy consumption of a computer and monitor by as much as 80%[63]. Approximately half of all office computers are left on overnight and at weekends (75% of the time). Apart from switching off at night, using LCD (liquid crystal display) monitors requires less energy than CRT (cathode ray tube). An average LCD screen uses 79% less energy than an average CRT monitor if both are power-managed[64]. Further savings can be made by ensuring computers enter low power mode when they are idle during the day. Another benefit of decreasing the power consumption of computers and monitors is that it reduces the load for air conditioning. According to a 2002 study by Roth et al, office equipment increases the air conditioning load by 0.2-0.5 kW per kW of office equipment power consumption.

The average computer with a CRT monitor in constant operation uses 1,236 kWh/y (482kWh/y for the computer and 754kWh/y for the monitor). With power management this reduces to 190kWh/y (86+104). Effective power management can save 1,046kWh per computer and CRT monitor per year, a reduction of 84%, or 505kWh per computer and LCD monitor per year. These examples illustrate that power management can have a greater effect than just more efficient equipment. The German website EcoTopten, for example, says that more efficient computers save 50-70% compared with older models and efficient flat-screens use 70% less energy than CRTs.

Servers are multiprocessor systems running commercial workloads[65]. The typical breakdown of peak power server use is shown in Table 10.10.

table 10.10: peak power breakdown by component for a typical server

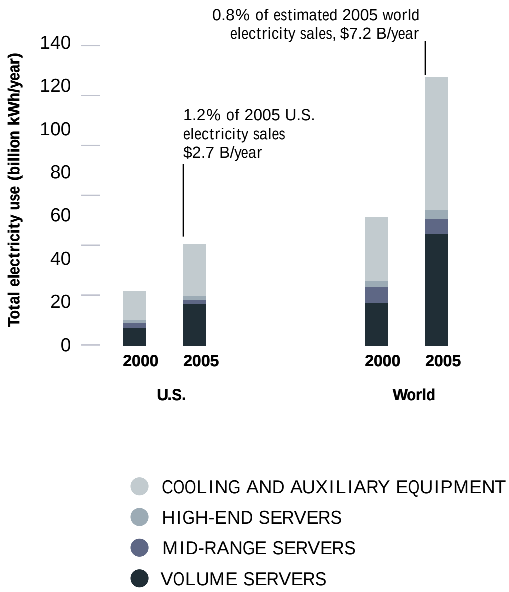
COMPONENT	PEAK POWER (WATTS)
CPU	80
Memory	36
Disks	12
Peripheral slots	50
Motherboard	25
Fan	10
PSU losses	38
Total	**251**

source (FAN ET AL., 2007, US EPA, 2007A). PSU = POWER SUPPLY UNIT

Data centres are facilities that primarily contain electronic equipment used for data processing, data storage and communications networking[66]. 80% of servers are located in these data centres[67]. Worldwide, about three million data centres and 32 million servers are in operation. Approximately 25% of servers are located in the EU, but only 10% of data centres, meaning that on average each data centre hosts a relatively large number of servers (Fichter, 2007). The installed base of servers is growing rapidly due to an increasing demand for data processing and storage. New digital services such as music downloads, video-on-demand, online banking, electronic trading, satellite navigation and internet telephony spur this rapid growth, as well as the increasing penetration of computers and the internet in developing countries. Since systems have become more and more complex to handle increasingly large amounts of data, power and energy consumption (about 50% used for cooling[68]) have grown in parallel. The power density of data centres is rising by approximately 15% each year[69]. Aggregate electricity use for servers doubled over the period 2000 to 2005 both in the US and worldwide (see Figure 10.13). Data centres accounted for roughly 1% of global electricity use in 2005 (14 GW) (Koomey, 2007).

figure 10.13: total electricity use for servers in the US and world in 2000 and 2005, including associated cooling and auxiliary equipment

(KOOMEY, 2007)



references
60 BEST OF EUROPE, 2008
61 SEE BERTOLDI & ATANASIU, 2006 FOR A MORE ELABORATE ACCOUNT
62 WEBBER ET AL., 2006
63 WEBBER ET AL., 2006
64 WEBBER ET AL., 2006
65 LEFURGY ET AL., 2003
66 US EPA, 2007A
67 FICHTER, 2007
68 US EPA, 2007A
69 HUMPHREYS & SCARAMELLA, 2006

Power and energy consumption are key concerns for internet data centres and there is a significant potential for energy efficiency improvements. Existing technologies and design strategies have been shown to reduce the energy use of a typical server by 25% or more[70]. Energy management efforts in existing data centres could reduce their energy usage by around 20%, according to the US Environmental Protection Agency (EPA).

The US EPA scenario for reducing server energy use includes measures such as enabling power management, consolidating servers and storage, using liquid instead of air cooling, improving the efficiency of chillers, pumps, fans and transformers and using combined heat and power. This bundle of measures could reduce electricity use by up to 56% compared to current efficiency trends (or 60% compared to historical trends), the EPA concludes, representing the maximum technical potential by 2011. This assumes that only 50% of current data centres can introduce these measures. A significant savings potential is therefore available for servers and data centres around the world by 2050. For computers and servers we have based the savings potential on the WBCSD 2005 report and other sources mentioned in this section. For the Technical scenario this would result in 70% savings, for the [R]evolution Scenario 55% savings.

6. air conditioning Today in the USA, some 14 % of total electrical consumption is used to air condition buildings[71]. Increasing use of small air conditioning units (less than 12 kW output cooling power) in southern European cities, mainly during the summer months, is also driving up electricity consumption. Total residential electricity consumption for air conditioners in the EU-25 in 2005 was estimated to be between 7 and 10 TWh per year[72]. However, we should not underestimate the consumption in developing countries. Many of these are located in warm climatic zones. With the rapid development of its economy and improving living standards, central air conditioning units are now widely used in China, for example. They currently account for about 20% of total Chinese electricity consumption[73].

There are several options for technological savings in air conditioning equipment. One is to use a different refrigerant. Tests with the refrigerant Ikon B show possible energy consumption reductions of 20-25% compared to the commonly used liquids[74]. However, behavioural changes should not be overlooked. One example of a smart alternative to cooling a whole house was developed by the company Evening Breeze. This combined a mosquito net, bed and air conditioning so that only the bed had to be cooled instead of the whole bedroom.

There are also other options for cooling, such as geothermal cooling by heat pumps. This uses the same principle as geothermal heating, namely that the temperature at a certain depth below the Earth's surface remains constant year round. In the winter we can use this relatively high temperature to warm our houses. Conversely, we can use the relatively cold temperature in the summer to cool our houses. There are several technical concepts available, but all rely on transferring the heat from the air in the building to the Earth. A refrigerant is used as the heat transfer medium. This concept is cost-effective[75]. Heat pumps have been gaining market share in a number of countries[76].

Solar energy can also be used for cooling through the use of solar thermal energy or solar electricity to power a cooling appliance. Basic types of solar cooling technologies include absorption cooling (uses solar thermal energy to vapourise the refrigerant); desiccant cooling (uses solar thermal energy to regenerate (dry) the desiccant); vapour compression cooling (uses solar thermal energy to operate a Rankine-cycle heat engine); evaporative cooling; and heat pumps and air conditioners that can be powered by solar photovoltaic systems. To drive the pumps only 0.05 kWh of electricity is needed, instead of 0.35 kWh for regular air conditioning[77], representing a savings potential of 85%.

Not only is it important to use efficient air conditioning equipment, it is equally important to reduce the need for air conditioning in the first place. Important ways to reduce cooling demand are to use insulation to prevent heat from entering the building, to reduce the amount of inefficient appliances present in the house, such as incandescent lamps or old refrigerators that give off unusable heat, to use cool exterior finishes, such as 'cool roof' technology or light-coloured wall paint, to improve windows and use vegetation to reduce the amount of heat that comes into the house, and to use ventilation instead of air conditioning units.

For air conditioning we have assumed that the savings potential based on the 2005 WBCSD study and other sources mentioned in this section will amount to 70% savings under the Technical scenario and 55% savings under the [R]evolution Scenario.

references
70 US EPA, 2007A
71 US DOE/EIA, 2007
72 BERTOLDI & ATANASIU, 2006
73 LU, 2007
74 US DOE EERE, 2008
75 DUFFIELD & SASS, 2004
76 OECD/IEA, 2006
77 AUSTRIAN ENERGY AGENCY, 2006

image WASHING MACHINE.

image AIR CONDITIONING UNIT AND INSULATED WINDOWS.

total household savings

Total savings from the previous sections are summarised here. Table 10.11 shows the total savings in percentages up to 2050. These need to be translated into energy efficiency improvements per year to compare them with the Reference Scenario. Since it is not clear what assumptions this is based on, we have assumed an efficiency improvement of 1% per year. Subtracting this from the reduction potentials in Table 10.12 shows the energy efficiency improvements per year measured against the Reference Scenario. Electricity use in the 'Other' sector is assumed to decline at the same rate as residential electricity use (lighting, appliances, cold appliances, computers/servers and air conditioning). We have assumed a minimum energy efficiency improvement of 1.2% in the Technical scenario and 1.1% in the [R]evolution Scenario, including autonomous improvements.

table 10.11: savings potential for different types of energy use in the buildings sector

(REVOLUTION POTENTIAL IN BRACKETS)

	HEATING NEW	HEATING RETROFIT	STANDBY	LIGHTING	APPLIANCES	COLD APPLIANCES	AIR CONDITIONING	COMPUTER/ SERVER	OTHER
OECD Europe	72 (58)	50 (40)	82 (72)	68 (60)	70 (50)	77 (64)	70 (55)	70 (55)	71 (57)
OECD North America	59 (38)	41 (26)		48 (42)					67 (53)
OECD Pacific	38 (8)	26 (5)		56 (49)					69 (55)
Transition Economies	56 (35)	39 (24)		76 (67)					73 (58)
China	43 (38)			20 (18)					61 (48)
India				76 (67)					73 (58)
Rest dev. Asia									
Middle East									
Latin America									
Africa									

table 10.12: savings potential for different types of energy use in the buildings sector

(REVOLUTION POTENTIAL IN BRACKETS). PERCENTAGES ARE TOTAL EFFICIENCY IMPROVEMENT PER YEAR (INCLUDING 1% AUTONOMOUS IMPROVEMENT)

	HEATING NEW	HEATING RETROFIT	STANDBY	LIGHTING	APPLIANCES	COLD APPLIANCES	AIR CONDITIONING	COMPUTER/ SERVER	OTHER
OECD Europe	3.1 (2.1)	1.7 (1.3)	4.2 (3.1)	2.8 (2.3)	3.0 (1.7)	3.5 (2.5)	3.0 (2.0)	3.0 (2.0)	3.1 (2.1)
OECD North America	2.2 (1.2)	1.3 (1.1)		2.0 (1.7)					2.9 (2.0)
OECD Pacific	1.2 (1.1)	1.2 (1.1)		1.6 (1.4)					2.8 (1.9)
Transition Economies	2.2 (1.4)	1.2 (1.1)		3.5 (2.7)					3.2 (2.2)
China	1.4 (1.2)			1.2 (1.1)					2.8 (1.9)
India				3.5 (2.7)					3.2 (2.2)
Rest dev. Asia									
Middle East									
Latin America									
Africa									

For services and agriculture we have assumed the same percentage savings potential as for the household sector.

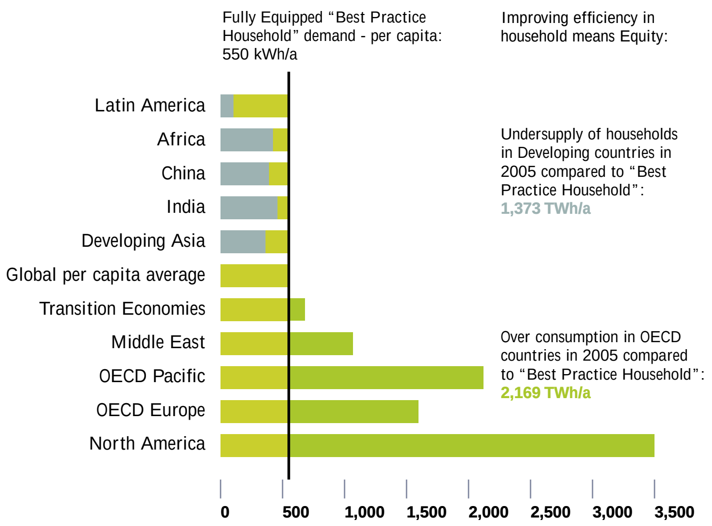
energy efficiency standards - steps towards an energy equity

the standard household

In order to enable a specific level of energy demand as a basic "right" for all people in the world, we have developed the model of an efficient Standard Household. A fully equipped OECD household (including fridge, oven, TV, radio, music centre, computer, lights etc.) currently consumes between 1,500 and 3,400 kWh/a per person. With an average of two to four people per household the total consumption is therefore between 3,000 and 12,000 kWh/a. This demand could be reduced to about 550 kWh/a per person just by using the most efficient appliances available on the market today. This does not even include any significant lifestyle changes. Based on this assumption, the 'over-consumption' of all households in OECD countries totals more than 2,100 billion kilowatt-hours. Comparing this figure with the current per capita consumption in developing countries, they would have the right to use about 1,350 billion kilowatt-hours more. The 'oversupply' of OECD households could therefore fill the gap in energy supply to developing countries one and a half times over.

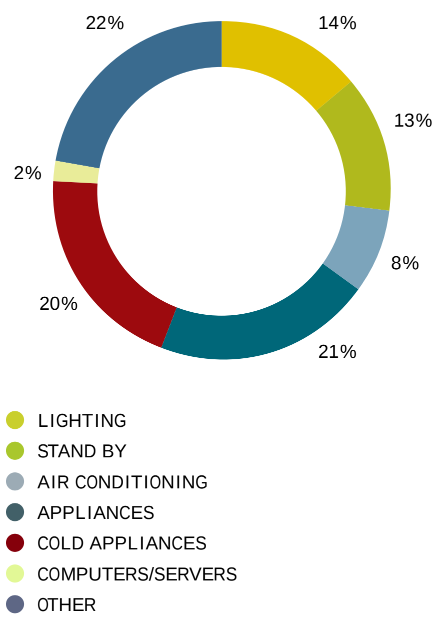
By implementing a strict technical standard for all electrical appliances, in order to achieve a level of 550 kWh/a per capita consumption, it would be possible to switch off more than 340 coal power plants in OECD countries.

figure 10.14: energy equity through efficiency standards



source SVEN TESKE/WINA GRAUS

figure 10.15: electricity savings in households [energy [r]evolution versus reference] in 2050



source ECOFYS

image DISHWASHER AND OTHER KITCHEN APPLIANCES.

energy efficiency standards - the potential is huge

Setting energy efficiency standards for electrical equipment could have a huge impact on the world's power sector. A large number of power plants could be switched off if strict technical standards were brought into force. The table below provides an overview of the theoretical potential for using efficiency standards based on currently available technology. The Energy [R]evolution Scenario has not been calculated on the basis of this theoretical potential. However, this overview illustrates how many power plants producing electricity would not be needed if all global appliances were brought up to the highest efficiency standards overnight.

table 10.13: effect on number of global operating power plants introducing strict energy efficiency standards*

BASED ON CURRENTLY AVAILABLE TECHNOLOGY

	ELECTRICITY LIGHTING	ELECTRICITY STAND BY	ELECTRICITY AIR CONDITIONING	ELECTRICITY SET TOP BOXES	ELECTRICITY OTHER APPLIANCES	ELECTRICITY COLD APPLIANCES	ELECTRICITY COMPUTERS/ SERVERS	ELECTRICITY OTHER
	HOUSEHOLDS							
OECD Europe	16	11	11	2	27	15	2	23
OECD North America	32	19	19	3	47	26	4	42
OECD Pacific	5	5	5	1	13	7	1	11
China	3	3	3	1	7	4	1	6
Latin America	5	2	3	0	6	3	1	6
Africa	3	2	2	0	4	2	0	4
Middle East	5	2	3	0	6	3	1	6
Transition Economies	6	3	3	1	7	4	1	7
India	2	1	1	0	3	2	0	3
Rest dev. Asia	4	2	2	0	6	3	1	5
World	80	50	52	9	126	69	11	113

* 1 POWER PLANT = 750 MW
source WINA GRAUS/ECOFYS

table 10.14: effect on number of global operating power plants introducing strict energy efficiency standards*

BASED ON CURRENTLY AVAILABLE TECHNOLOGY

	ELECTRICITY SERVICES COMPUTERS	ELECTRICITY SERVICES LIGHTING	ELECTRICITY SERVICES AIR CONDITIONING	ELECTRICITY SERVICES COLD APPLIANCES	ELECTRICITY SERVICES OTHER APPLIANCES	ELECTRICITY AGRICULTURE	TOTAL NUMBER OF COAL FIRED POWER PLANTS PHASED OUT DUE TO STRICT EFFICIENCY STANDARDS	INDUSTRY	**TOTAL INCL INDUSTRY**
OECD Europe	8	30	18	6	33	7	209	106	315
OECD North America	15	62	34	11	60	21	397	107	503
OECD Pacific	5	11	10	3	18	1	69	52	148
China	1	3	3	1	5	21	61	144	205
Latin America	2	8	4	1	7	3	52	39	90
Africa	1	3	1	0	2	6	30	23	53
Middle East	1	6	3	1	5	10	51	8	59
Transition Economies	2	9	4	1	7	8	62	63	125
India	0	2	1	0	1	14	31	23	54
Rest dev. Asia	2	7	3	1	6	6	50	33	83
World	3	140	81	27	144	98	1,038	613	1,651

* 1 POWER PLANT = 750 MW
source WINA GRAUS/ECOFYS

GLOBAL

REFERENCE SCENARIO
FUTURE OF TRANSPORT IN THE
ENERGY [R]EVOLUTION SCENARIO

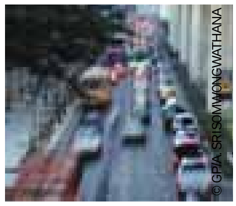
11

HALF THE SOLUTION TO CLIMATE CHANGE IS THE SMART USE OF POWER.

"...a mix of lifestyle changes and new technologies."

WINA GRAUS
ECOFYS, THE NETHERLANDS

image TRAFFIC JAM IN BANGKOK, THAILAND.



Transport is a key element in reducing the level of greenhouse gases produced by energy consumption. 28% of current energy use comes from the transport sector – road, rail and sea. In order to assess the present status of global transport, including its carbon footprint, a special study was undertaken by Ecofys.

This chapter gives an overview of how the Ecofys Reference Scenario was originated and the changes expected under the Energy [R]evolution Scenario. The following chapter looks specifically at the technical efficiency potential for cars. The main actions proposed in the Energy [R]evolution Scenario are: increasing the use of public transport, especially trains, reducing the number of kilometres driven each year by private cars, and introducing more efficient vehicles.

the reference scenario for transport

In order to calculate possible savings in the transport sector, we first need to construct a detailed Reference Scenario. This needs to include detailed shares and energy intensity data per mode of transport and per region up to 2050. Although this data cannot be found in the IEA WEO, input is available from the WBCSD (World Business Council for Sustainable Development) mobility database. This database was completed in 2004 after collaboration between the IEA and the WBCSD's Sustainable Mobility Project to develop a global transport model. Those transport options have been selected which can be expected to result in a substantial reduction in energy demand up to 2050.

In order to estimate the energy demand per transport sub-sector, we need the modal shares per region up to 2050. These can be calculated by using the WBCSD final energy use per mode, adding them together and working out the share per mode in % by region from 2005-2050. In the OECD, for example, light duty vehicles (LDVs) account for 57% of total energy use, heavy trucks for 15%.

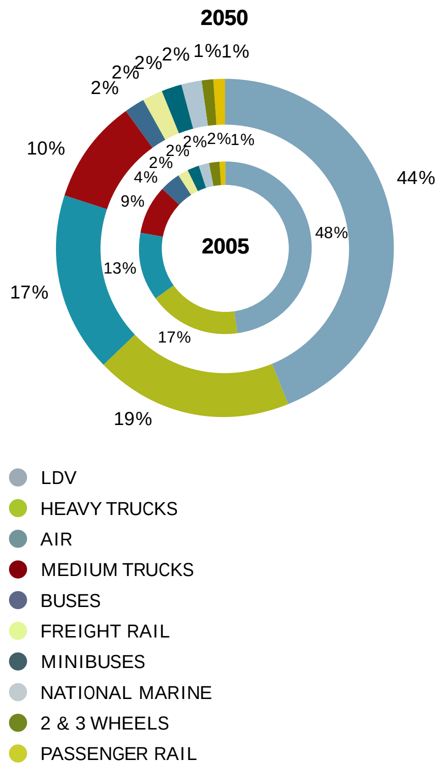
Since international shipping spreads across all regions of the world, it has been left out whilst calculating the baseline figures. The total is therefore made up of LDVs, heavy and medium duty freight, two to three wheel vehicles, buses, minibuses, rail, air and national marine transport. Although energy use from international marine bunkers (international shipping fuel suppliers) is not included in these calculations, it is still estimated to account for 9% of worldwide transport final energy demand in 2005 and 7% by 2050. A recent UN report concluded that carbon dioxide emissions from shipping are much greater than initially thought and increasing at an alarming rate. It is therefore very important to improve the energy efficiency of international shipping. Possible options are examined later in this chapter.

The definitions of different transport modes for this scenario[78] are:

- Light-duty vehicles (LDVs) are defined as four-wheel vehicles used primarily for personal passenger road travel. These are typically cars, SUVs (Sports Utility Vehicles), small passenger vans (up to eight seats) and personal pickup trucks. Within this report we will sometimes call light-duty vehicles simply 'cars'.
- Heavy duty trucks are defined here as long haul trucks operating almost exclusively on diesel fuel. These trucks carry large loads with lower energy intensity (energy use per tonne-kilometre of haulage) than medium duty trucks such as delivery trucks.
- Medium duty trucks include medium haul trucks and delivery vehicles.
- Buses have been divided into two size classes - full size buses and minibuses - with the latter roughly encompassing the range of small buses and large passenger vans prevalent around the developing world and typically used for informal transit services.
- All air travel in each region (domestic and international) is treated together.

The Figures below show the breakdown of final energy demand for transport by mode in 2005 and 2050.

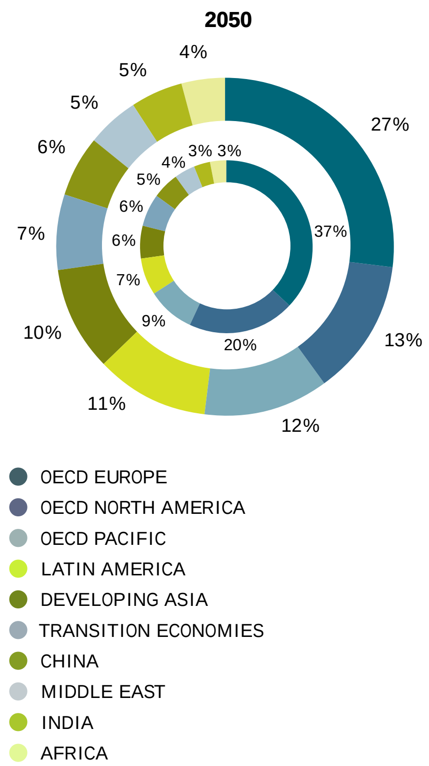
figure 11.1: world final energy use per transport mode 2005/2050 - reference



As can be seen from the above figures, the largest share of energy demand comes from cars, although it slightly decreases from 48% in 2005 to 44% in 2050. The share of air transport increases from 13% to 19%. Of particular note is the high share of road transport in total transport energy demand: 82% in 2005 and 74% in 2050. The Figures below show world final energy use for the transport sector by region in 2005 and 2050.

references
78 FULTON & EADS (2004)

figure 11.2: world transport final energy use per region 2005/2050 - reference



As we can see, OECD Europe has the highest final energy use, followed by OECD North America and OECD Pacific. Over time, the shares of these regions will decrease while the shares of all other regions will increase. In 2050, OECD Europe will still be the largest final energy user, but now followed by China. Figure 11.3 and Figure 11.4 show the forecast worldwide growth of different passenger and freight transport modes. Light duty vehicles will remain the most important mode of passenger transport, air, passenger rail and two wheeled transport are expected to grow considerably, while three wheeled transport is expected to grow only slightly. Buses and minibus passenger transport is expected to decline a little. Heavy duty trucks will remain the most important mode of freight transport. Freight rail, inland navigation and medium duty trucks will also increase, but will remain 'inferior' modes in the Reference Scenario.

image ITALIAN EUROSTAR TRAIN.

image TRUCK.

figure 11.3: time series of growth by mode for passenger transport in passenger-km per year
SCALE IS LOGARITHMIC

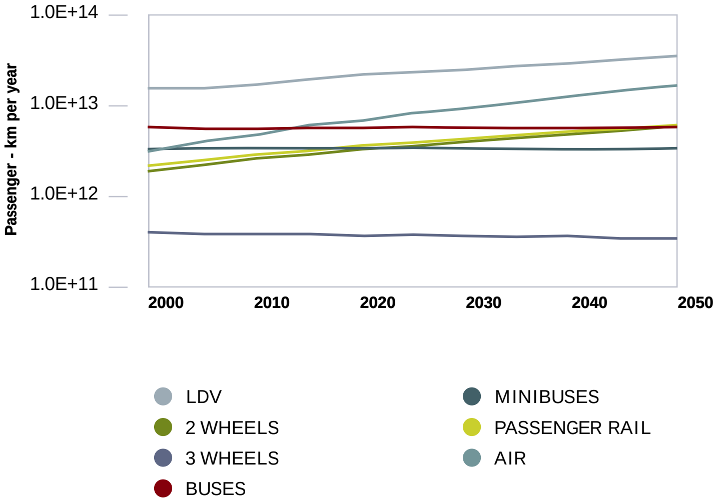
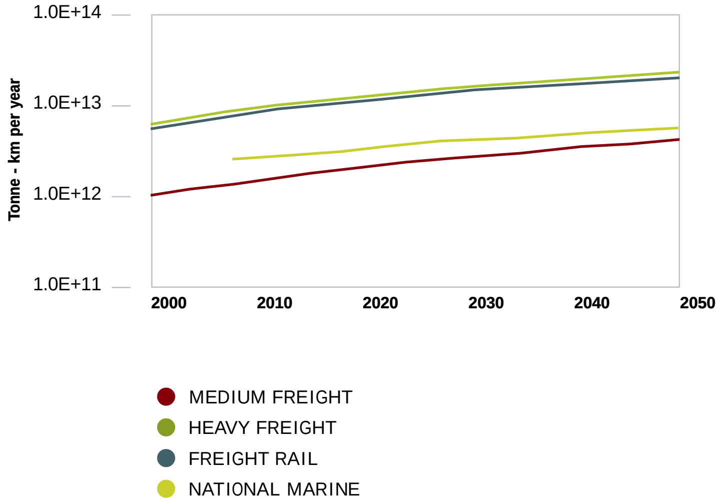


figure 11.4: time series of growth by mode for freight transport in tonne-km per year
SCALE IS LOGARITHMIC



The growth per mode and region between 2005 and 2050 can be seen in Table 11.1. This shows very large growth percentages for almost all modes in China and India. The highest forecast growth is predicted for LDV transport in China and India. We can also see that in all regions air transport is expected to grow significantly up to 2050.

table 11.1: percentage growth of passenger-km or tonne-km between 2005 and 2050 for different regions and transport mode THE HIGHEST GROWTH PERCENTAGES ARE INDICATED IN COLOUR.

	LDV	2 WHEELS	3 WHEELS	BUSES	MINI BUSES	PASS RAIL	AIR	MEDIUM TRUCKS	HEAVY TRUCKS	FREIGHT RAIL	NAT. MARINE
OECD North America	41%	64%		0%	0%	44%	212%	119%	119%	93%	109%
OECD Europe	9%	7%		0%	0%	66%	185%	87%	87%	66%	97%
OECD Pacific	16%	14%		0%	0%	81%	184%	119%	119%	68%	110%
Transition Economies	166%	96%		-5%	4%	115%	618%	288%	302%	148%	217%
China	**1149%**	174%	-9%	-5%	4%	**254%**	**706%**	**550%**	**550%**	**269%**	**310%**
Other Dev. Asia	608%	136%	-9%	-5%	4%	183%	543%	400%	400%	132%	258%
India	**956%**	**226%**	-9%	-5%	4%	**222%**	**778%**	**560%**	**560%**	**281%**	**315%**
Middle East	313%	165%		-5%	4%	166%	313%	189%	189%	128%	
Latin America	340%	**226%**		-5%	4%	47%	734%	267%	267%	91%	204%
Africa	418%	**447%**		-5%	4%	172%	615%	351%	351%	188%	238%
World Average (stock-weighted)	120%	150%	-9%	-3%	4%	165%	318%	224%	190%	156%	145%

the future of the transport sector in the energy [r]evolution scenario

The Reference Scenario shows that changes in patterns of passenger travel are partly a consequence of growing wealth. As GDP per capita increases, people tend to migrate towards faster, more flexible and more expensive travel modes (from buses and trains to cars and air). With faster modes, people also tend to travel further and do not reduce the amount of time spent travelling[79]. There is also a strong correlation between GDP growth and increases in freight transport. More economic activity will mean more transport of raw materials, intermediary products and final consumer goods.

All the above figures and tables illustrate the importance of both a modal shift and a slowing of growth in forecast transport if emissions reductions are to be achieved. Furthermore, it is very important to make the remaining transport as clean as possible, signalling the role of energy efficiency improvements. Unlimited growth in the transport sector is simply not an option. A shift towards a sustainable energy system, which respects natural limits and saves the world's climate, requires a mix of lifestyle changes and new technologies. We basically need to use our cars less, fly less and use more public transport, as well as cutting down the transport kilometres for freight transport whilst introducing more new and highly efficient vehicles.

technical potentials We have looked at three options for decreasing energy demand in the transport sector:

- Reduction of transport demand.
- Modal shift from high energy intensive transport modes to low energy intensity.
- Energy efficiency improvements.

table 11.2: selection of measures and indicators

MEASURE	REDUCTION OPTION	INDICATOR
Reduction of transport demand	Reduction in volume of passenger transport in comparison to the Reference Scenario	Passenger km/capita
	Reduction in volume of freight transport in comparison to Reference Scenario	Tonne-km/unit of GDP
Modal shift	Modal shift from trucks to rail	MJ/tonne km
	Modal shift from cars to public transport	MJ/passenger km
Energy efficiency improvements	Efficient passenger cars (hybrid fuel cars)	MJ/vehicle km
	Efficient buses	MJ/passenger km
	Efficiency improvements in aircraft	MJ/passenger km
	Efficient freight vehicles	MJ/tonne km
	Efficiency improvements in ships	MJ/tonne km

step 1: reduction of transport demand
A reduction in transport demand involves reducing passenger-km per capita and reducing freight transport demand. The amount of freight transport is to a large extent linked to GDP development and therefore difficult to influence. However, by improved logistics, for example optimal load profiles for trucks, the demand can be limited.

passenger transport First we must look at reducing passenger transport demand. For this we need to examine the transport demand per capita in the Reference Scenario, as shown in Table 11.3. This shows that transport demand is highest in OECD North America, followed by the OECD Pacific. Demand per capita is lowest in Africa and India.

The potential for reducing passenger transport demand is very difficult to determine. For OECD countries we have assumed that transport demand per capita can be reduced by 10% by 2050 in comparison to the Reference Scenario. For the non-OECD countries we have assumed in the [R]evolution Scenario – as a matter of equity - no reduction in transport demand per capita because the current demand is already quite low in comparison to the OECD. We have made an exception for the Transition Economies, where we assume that transport demand per capita can be reduced by 5% in 2050.

The table below shows the profile of passenger transport demand per capita in 2005, development under the Reference Scenario by 2050 and the reduced transport demand under the [R]evolution Scenario, broken down by region.

table 11.3: passenger transport demand per capita

(P-KM PER CAPITA)

REGION	REFERENCE SCENARIO 2005	REFERENCE SCENARIO 2050	[R]EVOLUTION SCENARIO 2050
OECD North America	20,800	27,800	26,400
OECD Pacific	15,200	23,400	22,200
OECD Europe	12,900	17,000	16,100
Transition Economies	6,700	15,600	14,800
Latin America			
China			
Middle East			
Rest dev. Asia			
India			
Africa			

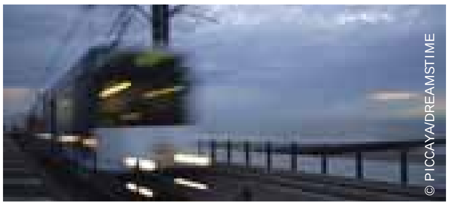
Policy measures for reducing passenger transport demand could include:

- Price incentives that increase transport costs
- Incentives for working from home
- Stimulating the use of video conferencing in businesses
- Improved cycle paths in cities

references
79 OECD/IEA, 2007

image BELGIAN COASTAL TRAMWAY.

image HIGHWAY IN ISRAEL.



freight transport In the Reference Scenario the largest absolute increase in freight transport demand is expected in the Transition Economies, whilst the largest percentage increase is forecast in China (383%). The potential for reducing demand for freight transport by improved logistics is difficult to estimate. For the [R]evolution Scenario we have assumed that freight transport demand can be reduced by 5% in comparison to the Reference Scenario, although only through measures in the OECD and Transition Economies.

figure 11.5: demand for freight transport in the reference scenario

(IN TONNE-KM PER CAPITA)

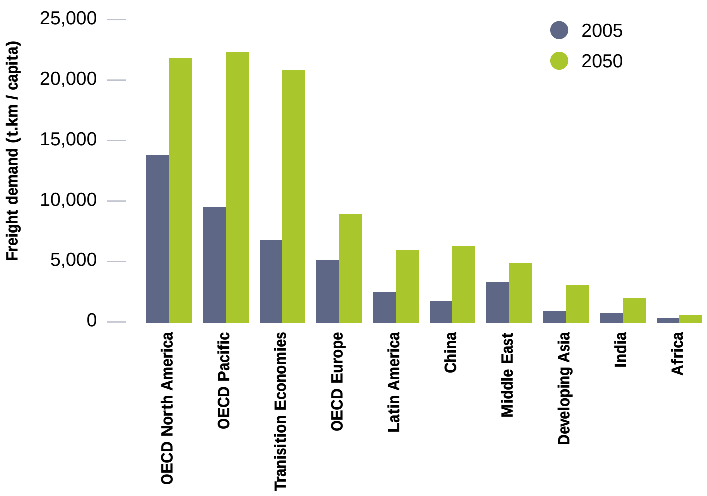
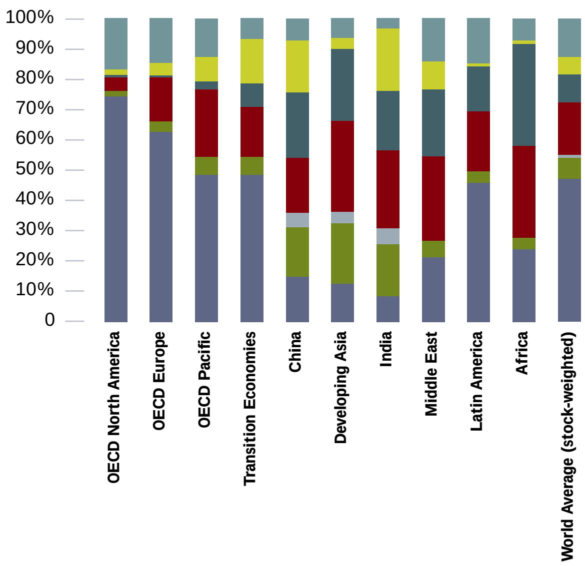


figure 11.6: breakdown of passenger transport by mode in 2005

(IN % SHARE OF PASSENGER KM)



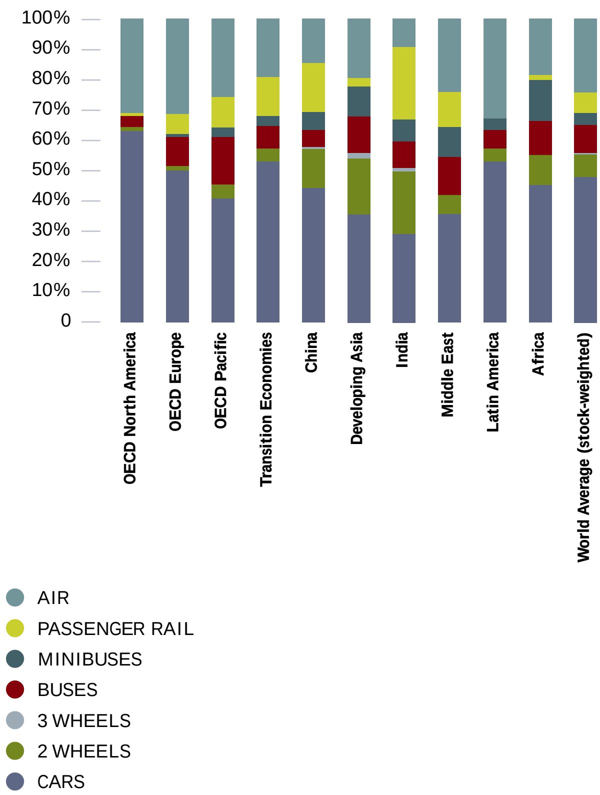
step 2: changes in transport mode
In order to decide which vehicles or transport systems are the most effective for each purpose, an analysis of the different technologies is needed. To calculate the energy savings achieved by shifting transport mode we need to know the energy use and intensity for each type of transport[80]. The following information is needed:

- Passenger transport: Energy demand per passenger kilometre, measured in MJ/p-km.
- Freight transport: Energy demand per kilometre of transported tonne of goods, measured in MJ/ tonne-km.

development of passenger transport Passenger transport includes cars, minibuses, two and three wheelers, buses, passenger rail and air transport. Freight transport includes medium trucks, heavy trucks, national marine and freight rail. The figures below show a breakdown of passenger transport by mode in the Reference Scenario for 2005 and 2050 (as % of total passenger-km). The global demand for air transport is expected to grow from 12% in 2005 to 23% in 2050.

figure 11.7: breakdown of passenger transport by mode in 2050

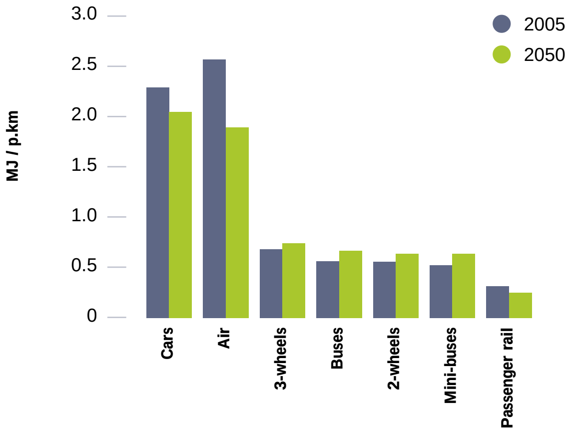
(IN % SHARE OF PASSENGER KM)



references
80 WBCSD PROVIDES ESTIMATES FOR ENERGY INTENSITIES PER MODE

travelling by rail is the most efficient Figure 11.8 shows the worldwide average specific energy consumption by transport mode under the Reference Scenario in 2005 and 2050. This data differs for each region. As can be seen, the difference in specific energy consumption for each transport mode is large. Passenger transport by rail will consume 85% less energy in 2050 than car transport and by bus nearly 70% less energy. This means that there is a large energy savings potential to be realised by a modal shift.

figure 11.8: world average (stock-weighted) passenger transport energy intensity for 2005 and 2050.



modal shift for passengers in the energy [r]evolution scenario From the figures above we can conclude that in order to reduce transport energy demand by modal shift, passengers have to move from cars and air transport to the lower intensity passenger rail and bus transport. As an indication of the action required we can take Japan as a 'best practice country'. In 2004, Japan had a large share of p-km by rail (29%) thanks to the fact that it had established a strong urban and regional rail system[81]. Comparing different regions with the example of Japan, and assuming that 40 years is enough time to build up an extensive rail network, the following modal shifts have been assumed:

table 11.4: passenger modal shifts assumed in [r]evolution scenario

TRANSPORT	[R]EVOLUTION SCENARIO
From air to rail (short distances)	2.5%
From car to rail	2.5%
From car to bus	2.5%

This means that in the Energy [R]evolution Scenario 2.5% of car transport shifts to rail and 2.5% to bus. In total this means a reduction in car transport of 7.5% in comparison to the Reference Scenario.

references
81 OECD/IEA, 2007

image TRAIN SIGNALS.

freight transport Figures 11.9 and 11.10 show the breakdown of freight transport in percentages of total tonnes-km per year and by region under the Reference Scenario. Both the Transition Economies and China have a very large proportion of rail transport while the Developing Asia and the Middle East have a very small share. The share of heavy and medium trucks is very large in the Developing Asia countries and OECD Europe. National marine transport plays an important role in the OECD Pacific. The figures also show that the difference between 2005 and 2050 is relatively small.

transporting goods by rail is the most efficient Figure 11.12 shows the energy intensity for world average freight transport in 2005 and 2050 under the Reference Scenario. Energy intensity for all modes of transport is expected to decrease by 2050.

figure 11.9: breakdown of freight transport by mode in 2005 (IN % SHARE OF TONNE KM)

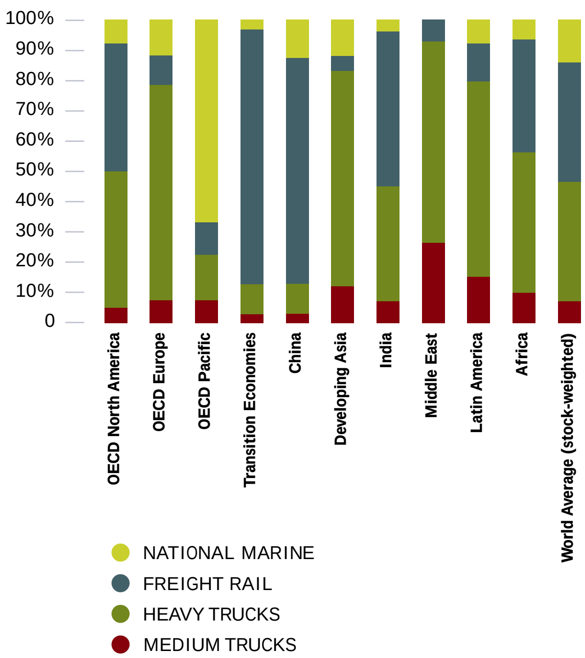


figure 11.10: breakdown of freight transport by mode in 2050 (IN % SHARE OF TONNE KM)

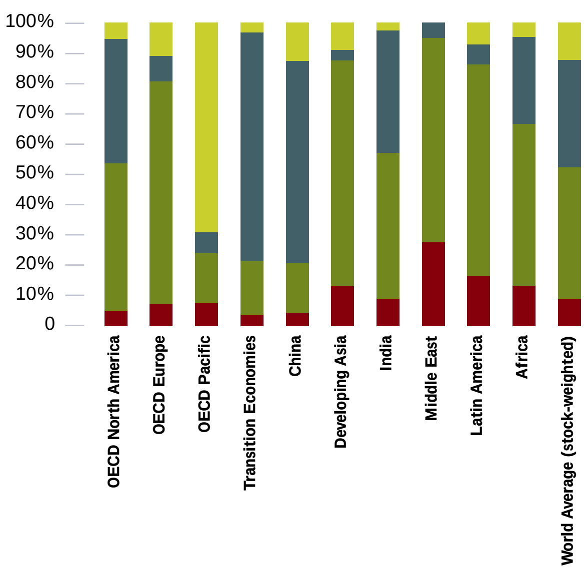
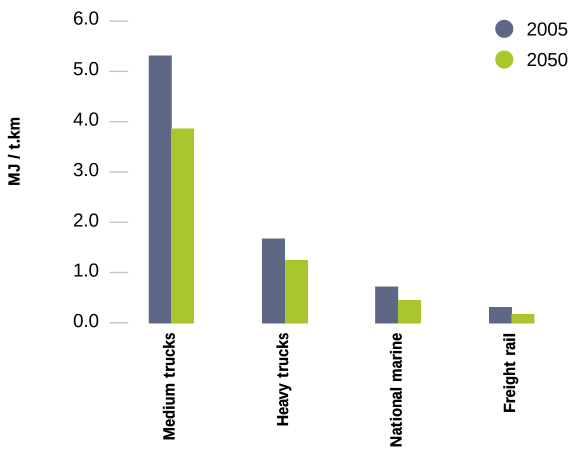


figure 11.12: world average (stock-weighted) freight transport energy intensity in 2005 and 2050



modal shift for transporting goods in the energy [r]evolution scenario From the figures above we can conclude that in order to reduce transport energy demand by modal shift, freight has to move from medium and heavy duty trucks to the less energy intensive freight rail and national marine. Canada is a ‘best practice’ country in this respect, with 29% of freight transported by trucks, 39% by rail and 32% by ships. Since the use of ships largely depends on the geography of the country, we do not propose a modal shift for national ships but instead a shift towards freight rail. China, OECD Pacific and the Transition Economies already have a low share of truck usage, so for these regions we will not assume a modal shift. For the other regions we have assumed the following changes:

table 11.5: freight modal shift in the [r]evolution scenario for all regions

EXCEPT CHINA, THE TRANSITION ECONOMIES AND OECD PACIFIC

TRANSPORT	[R]EVOLUTION SCENARIO
From medium trucks to rail	+ 5%
From heavy trucks to rail	+ 2.5%

marine transport Since the WBCSD did not provide estimates for total national marine tonnes-km per year or energy intensities per region, we have calculated these ourselves. Data for energy intensity for the year 2005 in OECD countries was found in OECD/IEA, 2007. For other regions we have assumed that the highest OECD estimate would hold. The 2050 intensities were extrapolated from 2005 data using 1% per year autonomous efficiency improvement. The amount of t-km per year could then be calculated using the Reference Scenario energy use divided by the energy intensity in MJ/t-km.

case 11.1: wind powered ships

Introduced to commercial operation in 2007, the SkySails system allows wind power, which has no fuel costs, to contribute to the motive power of large freight-carrying ships, which currently use increasingly expensive and environmentally damaging oil. Instead of a traditional sail fitted to a mast, the system uses large towing kites to contribute to the ship's propulsion. Shaped like paragliders, they are tethered to the vessel by ropes and can be controlled automatically, responding to wind conditions and the ship's trajectory.

The kites can operate at altitudes of between 100 and 300 metres, where stronger and more stable winds prevail. By means of dynamic flight patterns, the SkySails are able to generate five times more power per square metre of sail area than conventional sails. Depending on the prevailing winds, the company claims that a ship's average annual fuel costs can be reduced by 10 to 35%. Under optimal wind conditions, fuel consumption can temporarily be cut by up to 50%.

On the first voyage of the Beluga SkySails, a 133m long specially built cargo ship, the towing kite propulsion system was able to temporarily substitute for approximately 20 % of the vessel's main engine power, even in moderate winds. The company is now planning a kite twice the size of this 160m² pilot.

The designers say that virtually all sea-going cargo vessels can be retro- or outfitted with the SkySails propulsion system without extensive modifications. If 1,600 ships would be equiped with these sails by 2015 ,it would save over 146 million tonnes of CO_2 a year, equivalent to about 15% of Germany's total emissions.

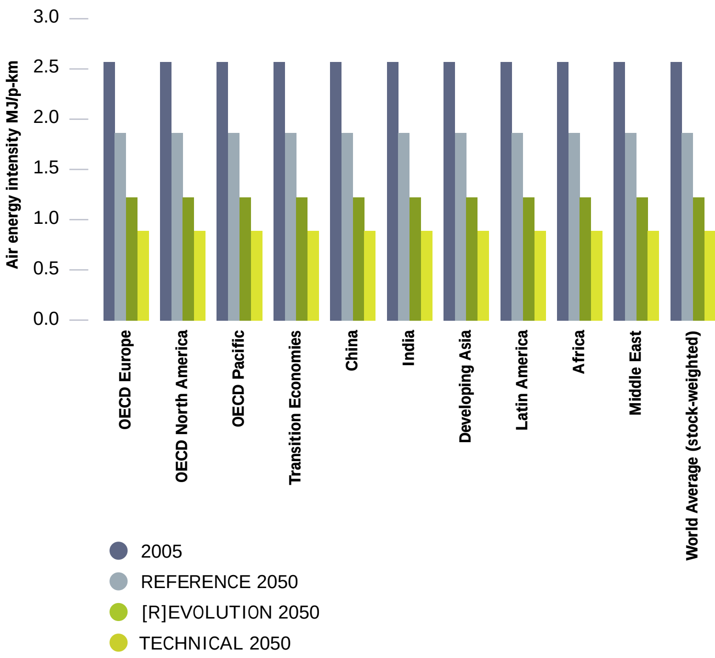
© SKYSAILS

step 3: efficiency improvements or travelling with less energy Energy efficiency improvements are the third important way of reducing transport energy demand. This section explains the different possibilities for improving energy efficiency[82] up to 2050 for each type of transport:

- Air transport
- Passenger and freight trains
- Buses and mini-buses
- Trucks
- Ships for marine transport
- Motorcycles
- Cars

air transport Savings for air transport have been taken from Akerman, 2005. He reports that a 65% reduction in fuel use is technically feasible by 2050. This has been applied to 2005 energy intensity data in order to calculate the technical potential. The figure below shows the energy intensity per region in the Reference Scenario and in the two low energy demand scenarios.

figure 11.13: energy intensities (MJ/p-km) for air transport in the reference and [r]evolution scenarios



All regions have the same energy intensities in 2005 due to lack of regionally-differentiated data. Numbers shown are a global average. The projection of future energy intensity is based on IEA data over the 1990-2000 period, when intensity improved at about 0.7% per year.

references
82 FOR THE [R]EVOLUTION SCENARIO WE BASE THE POTENTIAL ON IMPLEMENTING 80% OF THE ENERGY EFFICIENCY IMPROVEMENTS, UNLESS OTHERWISE SPECIFIED.

image CONTAINER SHIP.

image FREIGHT TRAINS.

passenger and freight trains Savings for passenger and freight rail transport have been taken from Fulton & Eads (2004). They report a historic improvement in the fuel economy of passenger rail of 1% per year and for freight rail of between 2 and 3% per year. Since no other studies are available we have assumed for the Technical scenario a 1% improvement of in energy efficiency per year for passenger rail and 2.5% for freight rail. The figure below shows the energy intensity per region in the Reference Scenario and in the two low energy demand scenarios.

freight rail Savings for freight rail are taken from the same study as for passenger rail. They report a historic improvement in the fuel economy of freight rail of between 2 and 3% per year. Since no other studies are available we have assumed for the Technical scenario a 2.5% improvement in energy efficiency per year. The figure below shows the energy intensity per region in the Reference Scenario and in the two low energy demand scenarios.

figure 11.14: energy intensities for passenger rail transport in the reference and [r]evolution scenarios

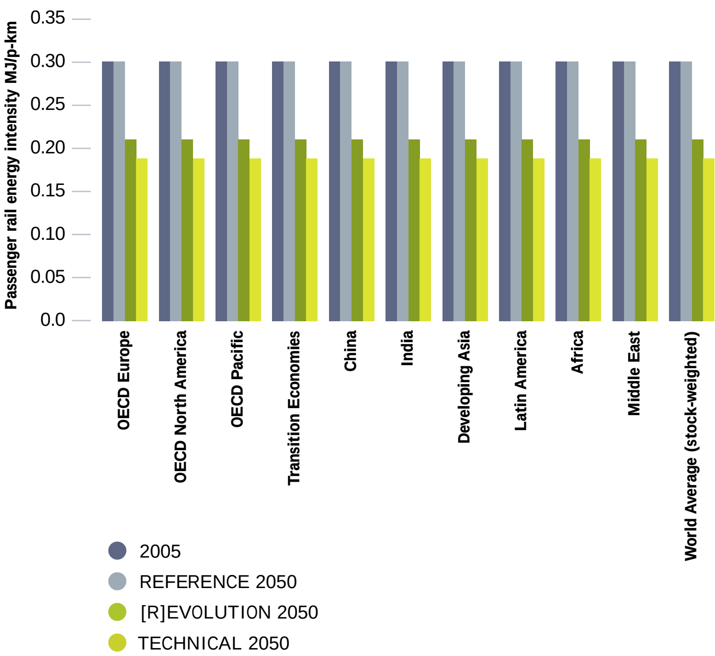
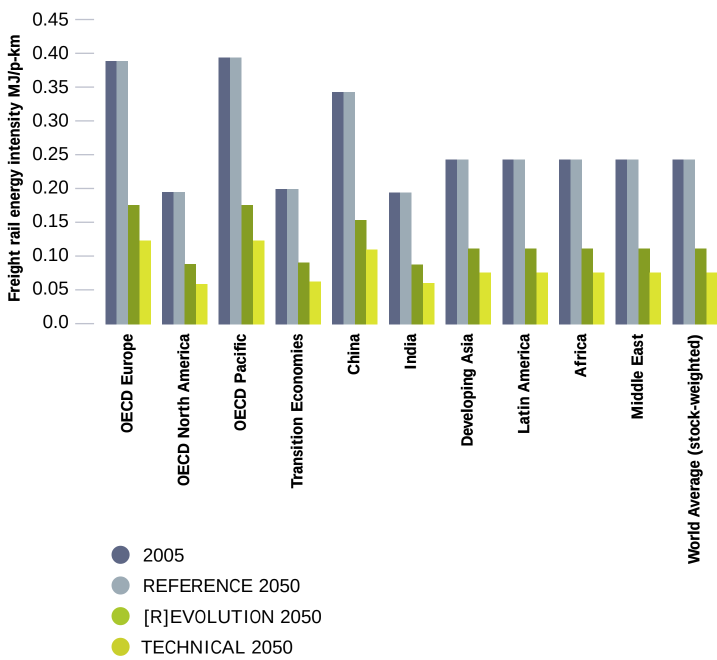


figure 11.15: reference scenario and 2050 technical potential energy intensities for different regions for freight rail transport



Energy intensities for passenger rail transport are assumed to be the same for all regions due to a lack of sufficiently detailed data. The differentiation in energy intensity for freight rail is based on the following assumption: regions with longer average distances for freight rail (such as the US and Former Soviet Union), and where more raw materials are transported (such as coal), show a lower energy intensity than other regions (Fulton & Eads, 2004). Future projections use ten year historic IEA data. Rail intensities are and will remain highest in OECD Europe and OECD Pacific and lowest in India.

buses and minibuses The company Enova Systems is promoting a 'clean bus' with a 100% improvement in fuel economy. We have adopted this improvement and applied it to 2005 energy intensity numbers per region. For minibuses the American Council for an Energy Efficient Economy reports[83] a fuel economy improvement of 55% by 2015. Since this is a very ambitious target and will most likely not be reached, we have extended it up to 2050 and adopted it as the technical potential (see Figure 11.16 and Figure 11.17). Currently, buses in North America consume far and away the most energy. The Reference Scenario predicts an increase in all regions between 2005 and 2050. Although in general more efficient buses are being produced, this is offset by increases in average bus size, weight and power. OECD buses have much more powerful engines than non-OECD buses, but the latter are likely to catch up over this period.

figure 11.16: energy intensities for buses in the reference and [r]evolution scenarios

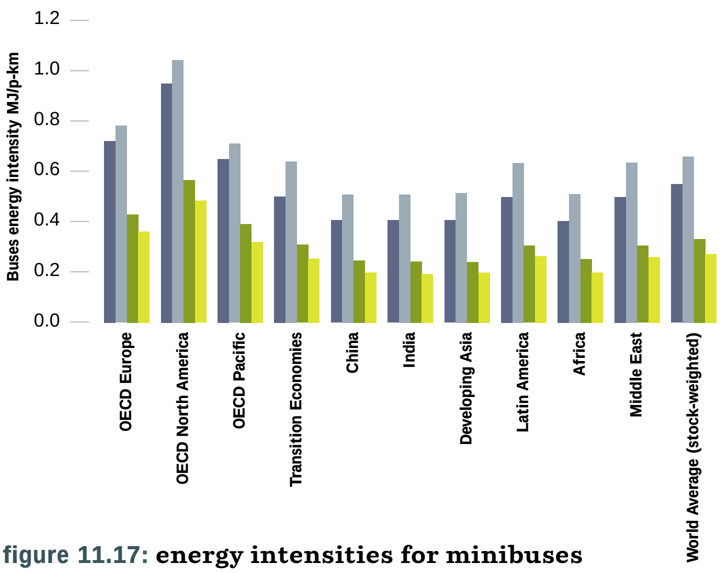
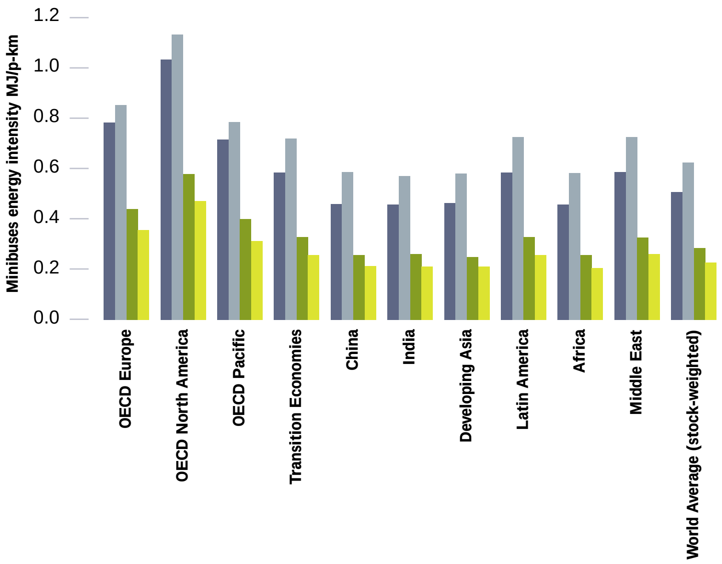


figure 11.17: energy intensities for minibuses in the reference and [r]evolution scenarios



trucks (freight by road) Elliott et al., 2006 give possible savings for heavy and medium-duty freight trucks. This list of reduction options is expanded in Lensink and De Wilde, 2007. For medium duty trucks a fuel economy saving of 50% is reported by 2030 (mainly due to hybridisation). We applied this percentage to 2005 energy intensity data, calculated the fuel economy improvement per year and extrapolated this yearly growth rate up to 2050. For heavy duty trucks we applied the same methodology, arriving at a 39% savings. Current intensities are highest in the Middle East, India and Africa and lowest in OECD North America. The Reference Scenario predicts that future values will converge, assuming past improvement percentages and assuming a higher learning rate in developing regions. The figures below show the energy intensity per region in the Reference Scenario and in the two low energy demand scenarios.

figure 11.18: reference scenario and 2050 technical potential energy intensities for different regions for medium duty freight transport

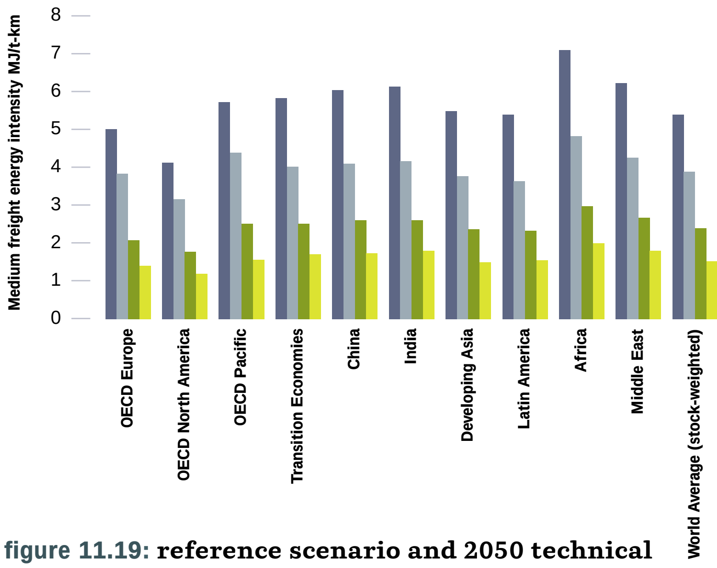
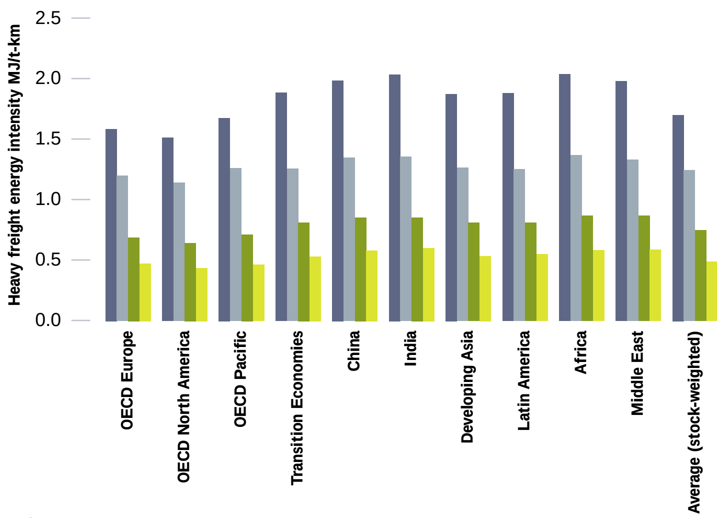


figure 11.19: reference scenario and 2050 technical potential energy intensities for different regions for heavy duty freight transport



references
83 DECICCO ET AL., 2001.

image FREIGHT TRUCK.

marine transport National marine savings have also been taken from the Lensink and De Wilde study. They report 20% savings in 2030 for inland navigation as a realistic potential with currently available technology, and ultimate efficiency savings of up to 30% for the current fleet. To arrive at the potential in 2050, we used the same approach as described for road freight above. OECD Pacific has the lowest current energy intensity due to the fact that they have a large proportion of long haul trips where larger (less energy intensive) boats can be used. All energy intensities are expected to improve by 1% per year up to 2050. Reference Scenario energy intensities and the technical potentials for national marine transport are shown in Figure 11.20.

motorcycles For two wheelers we have based the potential on IEA/SMP (2004), where 0.3 MJ/p.km is the lowest value. For three wheelers we have assumed that the technical potential is 0.5 MJ/p.km in 2050. The uncertainty in these potentials is high, although two and three wheelers only account for 1.5% of transport energy demand.

The figures below show the energy intensity per region in the Reference Scenario and in the two low energy demand scenarios.

figure 11.20: reference scenario and 2050 technical potential energy intensities for different regions for national marine transport

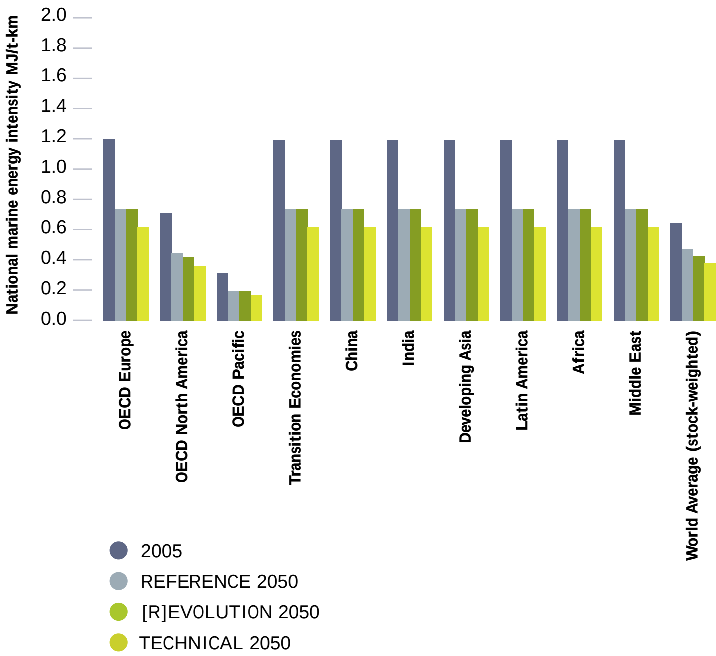


figure 11.21: energy intensities for two wheelers in the reference and [r]evolution scenarios

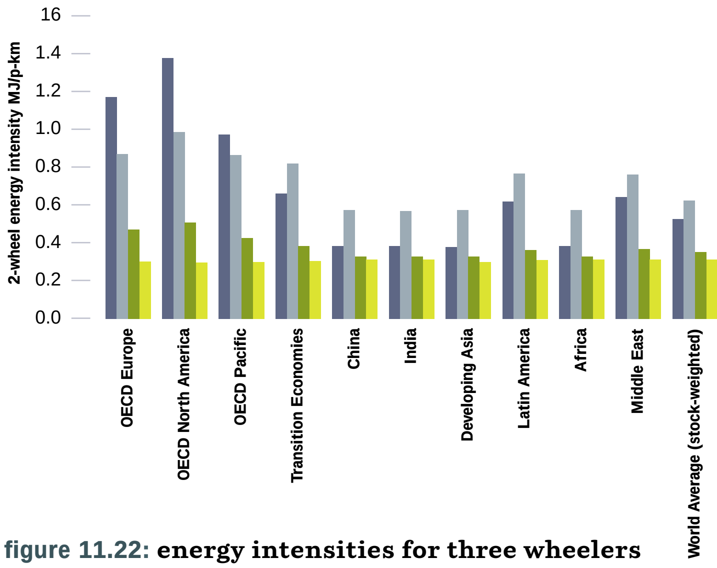
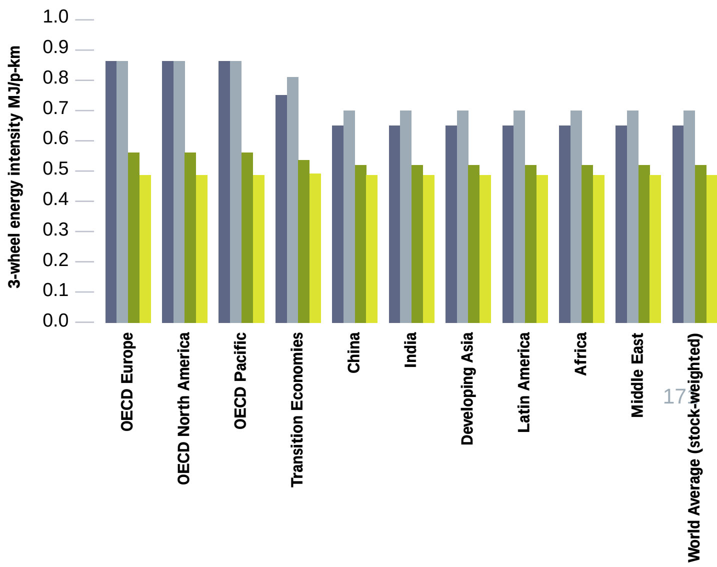


figure 11.22: energy intensities for three wheelers in the reference and [r]evolution scenarios



passenger cars This section is based on a special study conducted by the DLR's Institute for Vehicle Concepts to investigate the potential for improving the efficiency of existing cars and moving towards greater use of hybrid or electric vehicles. See Chapter 12 for a full account of this analysis.

Many technologies can be used to improve the fuel efficiency of passenger cars. Examples include improvements in engines, weight reduction and friction and drag reduction[84]. The impact of the various measures on fuel efficiency can be substantial. Hybrid vehicles, combining a conventional combustion engine with an electric engine, have relatively low fuel consumption. The most well-known is the Toyota Prius, which originally had a fuel efficiency of about five litres of gasoline-equivalent per 100 km (litre ge/100 km). Recently, Toyota presented an improved version with a lower fuel consumption of 4.3 litres ge/100 km. Further developments are underway, as shown by the presentation of new concept cars by the main US car manufacturers in 2000 with a specific fuel use as low as three litres ge/100 km. There are suggestions that applying new lightweight materials, in combination with the new propulsion technologies, can bring fuel consumption levels down to 1 litre ge/100 km.

table 11.6: efficiency of cars and new developments

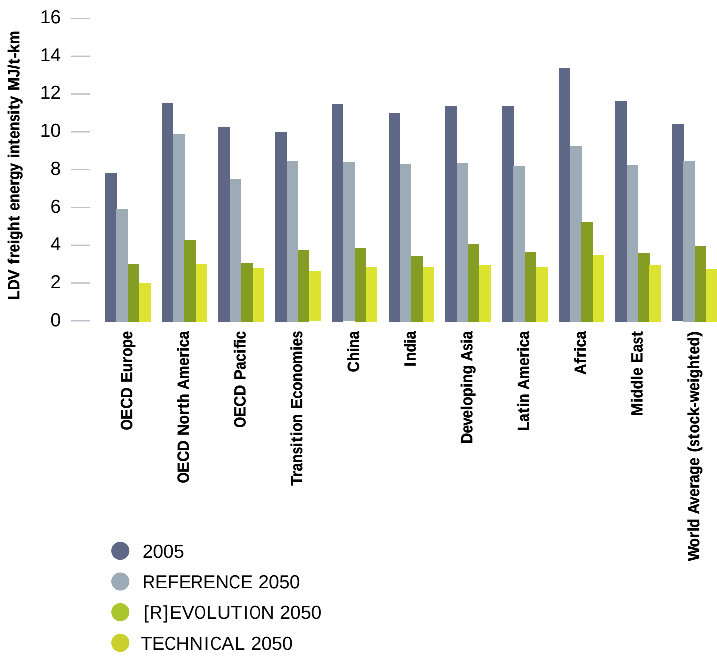
(BLOK, 2004)

BEST PRACTICE CURRENT & FUTURE EFFICIENCIES	FUEL CONSUMPTION (LITRES GE/100 KM)	SOURCE
Present average	10.4	IEA/SMP (2004)
Hybrids on the market (medium-sized cars)	~5 (1997) 4.3 (2003)	EPA (2003)
Improved hybrids or fuel cell cars (average car)	2 – 3	USCAR (2002) Weiss et al (2000)
Ultralights	0.8 - 1.6	Von Weizsäcker et al (1998)

Based on SRU (2005), the technical potential in 2050 for a diesel fuelled car is 1.6 and for a petrol car 2.0 litres ge/100 km. Based on the sources in Table 11.6, we have assumed 2.0 litres as the technical potential for Europe and adopted the same improvement in efficiency (about 3% per year) for other regions. In order to reach this target in time, these more efficient cars need to be on the market by 2030 – assuming that the maximum lifetime of a car is 20 years.

the energy [r]evolution scenario for passenger cars The figure below gives the energy intensity for cars in the Reference Scenario and in the two alternative scenarios.

figure 11.23: energy intensities (litres ge/v-km) for cars in the reference and [r]evolution scenarios



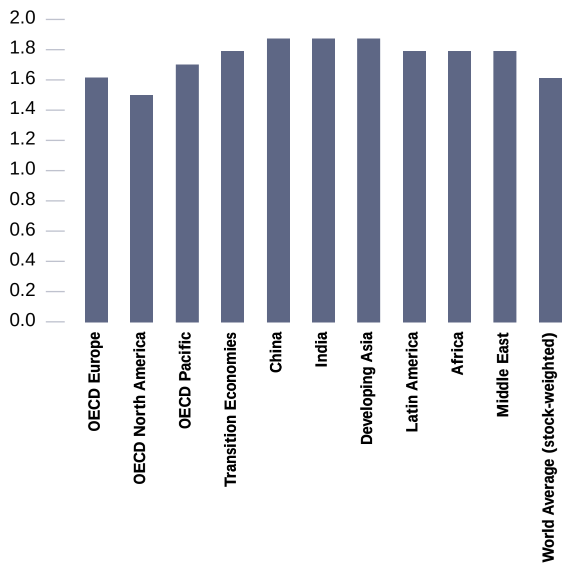
references
84 DECICCO ET AL., 2001.

image AIRPLANE FLYING OVER HIGHWAY.

image TRANSPORTING CARGO AND OIL.

The energy intensities for car passenger transport are currently highest in OECD North America and Africa and lowest in OECD Europe. The Reference Scenario shows a decrease in energy intensities in all regions, but the division between highest and lowest will remain the same, although there will be some convergence. We have assumed that the occupancy rate for cars remains the same as in 2005, as shown in the figure below.

figure 11.24: car occupancy rate in 2005



summary of energy savings in the transport sector in the energy [r]evolution scenario

The table below gives a summary of the energy efficiency improvement for passenger transport in the two low energy demand scenarios.

table 11.7: technical efficiency potential for world passenger transport

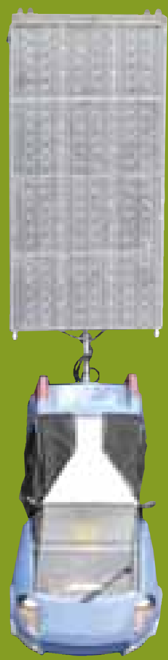
MJ/P-KM	REFERENCE SCENARIO 2005	REFERENCE SCENARIO 2050	[R]EVOLUTION SCENARIO 2050
Cars (L/100 v-km)	10.4	8.5	3.9
Cars (MJ/p-km)	2.2	2.0	0.9
Air	2.6	1.9	1.2
Buses	0.5	0.6	0.3
Mini-buses	0.5	0.6	0.3
Two wheels	0.5	0.6	0.3
Three wheels	0.7	0.7	0.5
Passenger rail	0.3	0.3	0.2

The table below gives a summary of the energy efficiency improvement for freight transport in the two low energy demand scenarios.

table 11.8: technical efficiency potential for world freight transport

MJ/P-KM	REFERENCE SCENARIO 2005	REFERENCE SCENARIO 2050	[R]EVOLUTION SCENARIO 2050
Medium trucks	5.4	3.9	2.3
Heavy trucks	1.7	1.3	0.7
Freight rail	0.2	0.2	0.1
National marine	0.7	0.5	0.5

12



MOVING TOWARDS ALTERNATIVES NO LONGER BASED ON FOSSIL FUELS.

"if we're serious about facing up to climate change, we need to improve ALL our cars."

GREENPEACE INTERNATIONAL
CLIMATE CAMPAIGN

image DESIGNS FOR A CLEVER ENGINE.

Since the global use of privately owned cars (light duty vehicles) currently accounts for more carbon dioxide emissions than any other form of transport, the DLR's Institute for Vehicle Concepts was commissioned to look specifically at the potential for reductions in this sector. At the same time, the door has already been opened for both major technological changes and shifts in personal habits. Rising oil prices, increasing concern about climate change and, in some regions, legislation on everything from bio fuels to vehicle emissions, have together combined to put pressure on international vehicle manufacturers to investigate solutions. Numerous technical fixes are already in production which can improve the efficiency of the predominant internal combustion engine, as well as moving towards alternatives no longer based on fossil fuels.

This specific study of the light duty vehicle market concludes that a number of measures could help reduce the CO_2 emissions from cars very significantly to a target level of about 80 g CO_2 per km for the European Union. These measures include a major shift to vehicles powered by (renewable) electricity, a range of efficiency improvements to the power trains of existing internal combustion engines and behavioural changes leading to an overall reduction in kilometres travelled.

methodology

The DLR developed a global scenario for cars based on a detailed bottom-up model covering ten world regions. The aim was to produce a challenging but feasible scenario which would lower global CO_2 emissions within the context of the overall emission reduction objective. Cars contribute about 45% of the greenhouse gas emissions from the entire transport sector, the largest proportion of any mode.

This approach takes into account a vast range of technical measures to reduce the energy consumption of vehicles, but also considers the dramatic increase in vehicle ownership and annual mileage taking place in developing countries. The turnover of replacement vehicles has been modelled over five year stages from 2005 to 2050. The scenario assumes that a large share of renewable electricity is available in the future. The major parameters for achieving increased efficiency are:

- vehicle technology
- alternative fuels
- changes in sales by vehicle size
- changes in vehicle kilometres travelled

This section will examine the development of the world's car fleet in more detail and is focused on non-technical as well as technical solutions. Light duty vehicles and their technologies are divided into three vehicle segments (small, medium and large) and nine categories of fuel/propulsion technology:

- conventional petrol
- petrol hybrid
- conventional diesel
- diesel hybrid
- LPG/CNG (Liquefied Petroleum Gas/Compressed Natural Gas)
- LPG/CNG hybrid
- fuel cell hydrogen
- battery electric
- plug in-hybrid electric vehicles

As a Reference Scenario for the starting point in 2005, the analysis in the IEA/SMP model[85] has been used. This is the most comprehensive and detailed model available for CO_2 emissions from the global transport sector. For those technologies not included in the SMP model, we had to decide starting points for today's performance values (see below). We then created so-called 'target reference vehicles' (TRVs), which project the energy consumption feasible for each of the main fuel conversion technologies. This is described in the section 'Future vehicle technologies'. The TRVs will be introduced in the different regions of the world over a varying timescale. In general, the technologies to achieve the TRVs are aimed to be available for sale in 2050 - 42 years from now.

In general, we have first introduced the most recent - and most expensive - technologies in the currently industrialised countries, and postponed their introduction in the rest of the world. We have then used the option to change the energy source used to fuel light duty transport. This is described in the section 'Projection of future technology mix'. Various non-technical measures are reflected in the projections for future vehicle sales (see 'Projection of vehicle segment split'), in the projection for the absolute number of vehicles sold in the future (see 'Projection of global vehicle stock development') and in the projection of how much individual vehicles are used compared to other transport means in the future (see 'Projection of kilometres driven').

reference scenario

The IEA Reference Scenario developed for the Mobility 2030 project[86] was used as the starting point for the year 2005 key data and for comparison as a 'business as usual' scenario. It is important to note that for this scenario no major new policies were assumed to be implemented beyond those already introduced by 2003. While for some areas, such as pollution control, further so called policy trajectories have been assumed, this was not the case for fuel consumption. Trends in future fuel consumption are therefore based on historical (non-policy driven) trends[87]. If the serious discussions taking place in Europe and the United States on the regulation of fuel economy in new vehicles, together with legal guidelines and proposed long term targets, were taken into account, the business as usual case would be different. However, it is beyond the scope of this project to redefine the status quo. Nevertheless, we include the most recent political targets in our scenario.

references
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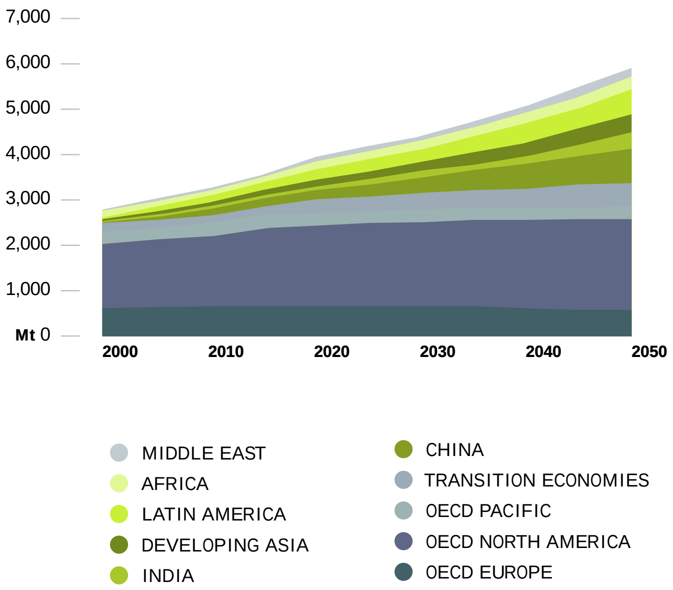
Current starting point values for the world's regions and vehicle types are presented in Figure 12.2.

figure 12.1: well-to-wheel CO_2 emissions from the light duty fleet as projected in the reference scenario



energy [r]evolution car scenario

The alternative car scenario is targeted towards high CO_2 reductions compared to today's levels. Summarised in brief, we have focused on the following proposals:

- Efficiency improvements resulting from technological development
- Renewable electricity as the primary alternative fuel
- Influencing customer behaviour in the long term

There is a huge potential for technological options to make today's vehicles more efficient while lowering their CO_2 emissions. A car today converts the energy in the fuel into mechanical energy in order to take the compartment we sit in from point A to B, but it does it in a very inefficient way. Only 25% to 35% of the chemical energy in the fuel is converted into mechanical energy by the engine. The rest is lost as waste heat. Only 10% of the fuel energy is used to overcome driving resistance. Hybrid technologies mark an important starting point for making vehicles more efficient, whilst technologies to lower energy demand, such as lightweight design, reduced rolling resistance wheels and improved aerodynamics, will contribute to the achievement of very low fuel consumptions.

Renewable electricity can be produced almost everywhere in the world, and with declining costs in the future. Taking into account the enormous development in batteries in recent years, we believe that electric mobility as offered by battery electric cars and plug-in hybrid electric vehicles is the preferred way to make major reductions in the CO_2 emissions of cars.

Consumer behaviour is the third major key to a lower carbon world for the transport sector. Here we have relied on programmes, incentives and policy measures to support a shift towards low carbon emitting vehicles as well as reducing demand in general.

figure 12.2: reference values for CO_2 emissions for 2005 sales averages per vehicle segment, gasoline and diesel, and world region

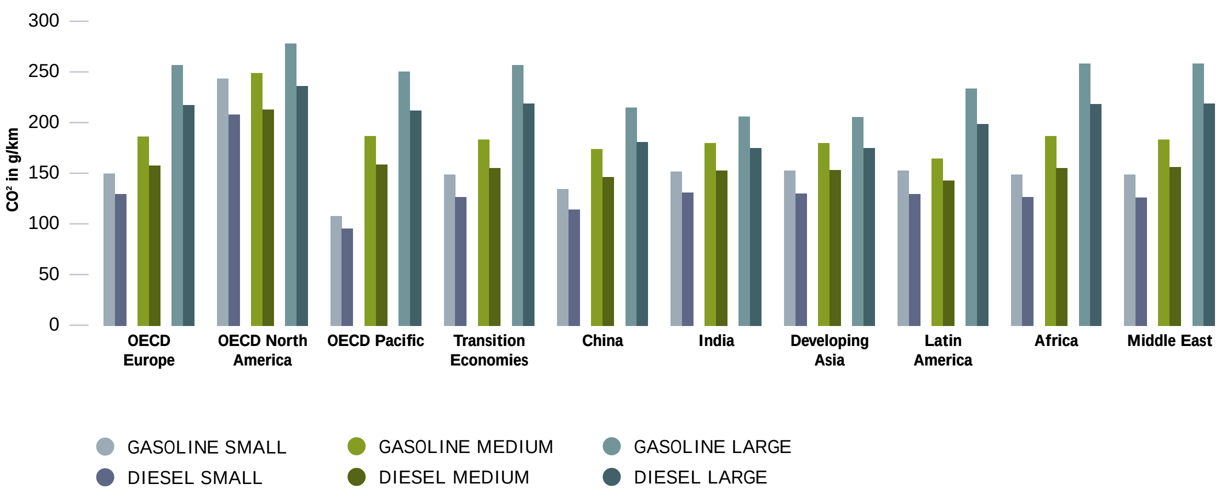


image 4 WHEEL DRIVE.

image TESTRIDE SMILE CAR, GREENPEACE HELPED PRODUCE AN ENVIRONMENTALLY FRIENDLIER CAR.

future vehicle technologies

The global vehicle market, with about 55 million vehicles sold per year, is enormous. Around 500 automobile plants produce this huge quantity. Regional markets differ in the size of vehicles and fuel type used. Depending on income, infrastructure and the spatial characteristics of the countries, people have different preferences for the size of vehicles they use.

The propulsion technology used in all new cars globally does not differ very much, however. For the sake of simplicity, therefore, we have defined the reference target vehicles, which we use throughout the world, as characterised by their energy consumption 'tank-to-wheel', independent of the fuel used. The energy consumption for the reference target vehicles are presented in Figure 12.3.

Differences in energy consumption 'tank-to-wheel' shown in Figure 12.3 reflect the different efficiencies with which vehicles convert fuel energy into movement. The various fuels and energy sources have different qualities, depending on their upstream production processes. This is taken into account in the model. In the light of high energy prices and thus growing costs for individual mobility, we foresee a market for dedicated small commuter vehicles. These cars would serve predominantly for the transport of a single person, reflecting today's car usage in industrialised countries. Although there will still be seats for three to five people, the comfort for the car passengers will be less. Therefore the 'small' passenger vehicle of the future is projected to be smaller than it is today and therefore less energy intensive[88].

Due to the differences in income level between the world's regions, which we have assumed to be still valid in 2050, the reference target vehicles are applied to new vehicle sales in the year 2050 for today's most industrialised regions: OECD Europe, North America and OECD Pacific. For all other regions, they are envisaged to enter the market in 2060, ten years later, and 20 years later in Africa.

gasoline and diesel cars

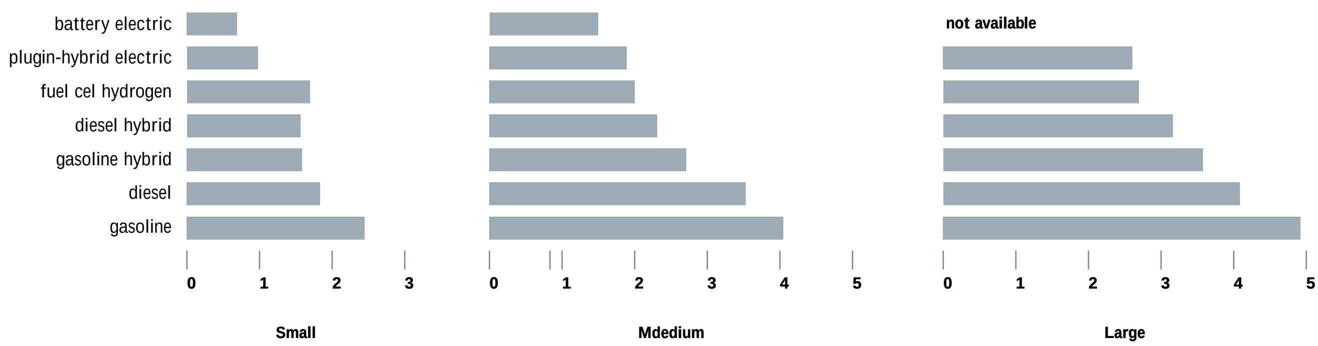
For traditional internal combustion engines, we have only allowed here for improvements in starting and stopping and no other hybrid features. Other vehicle adaptations to be introduced up to 2050 are described in more detail below.

For the small car sector we project a 1.8 litre/100 km (NEDC) four-seater diesel vehicle, as described in simulations by Friedrich[89]. We found corresponding results from our own simulations for a low-energy concept car with space for three adults and two children. For gasoline, we project 2.4 l/100 km. For the medium size sector, we project the potential for a 50% reduction in CO_2 for gasoline cars and 42% for diesel cars. Approximately half of these reductions will be derived from power train improvements (including starting and stopping) and half from an improvement in energy demand. Aerodynamics, rolling resistance and lightweight design will contribute as described below.

For the large size sector, a slightly higher 60% emissions reduction is predicted, resulting from higher mass reduction and greater downsizing potentials (due to current over-motorisation). In addition, we have assumed political measures have been introduced, such as luxury taxes, in addition to high fuel costs, to reduce the sales of very large SUVs (Sport Utility Vehicles) for passenger transport. This means that the size of vehicles within the segment will also decrease over the years. Examples of future cross-over SUVs are projected, for example by Lovins and Cramer[90].

Although considerable improvements are in sight for conventional gasoline and diesel engines without hybridisation, they will be technically hard to reach. Significant CO_2 reductions in the short to medium term will therefore be much easier and cheaper to achieve with the hybridisation of power trains.

figure 12.3: energy consumption of reference target vehicles for three size segments in litres of gasoline equivalent per 100 km (VALUES GIVEN FOR THE NEW EUROPEAN DRIVE CYCLE (NEDC) TEST CYCLE).



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hybrid vehicles

Hybrid drive trains consist of at least two different energy converters and two energy storage units. The most common is the hybrid-electric drive train, although there are also proposals for kinetic and hydraulic hybrids. Advantages of the combination of the internal combustion engine with a second source of power arise from avoiding inefficient working regimes of the internal combustion engine (ICE), recuperation of braking energy, engine displacement downsizing and automated gear switch. For hybrid-electric vehicles, there are several different architectures and levels of hybridisation proposed.

Hybrid vehicles have been available since the 1990s. In 2006, approximately 400,000 hybrid cars were sold, which is less than 1% of world car production. An increasing number of hybrid models are being announced, however. For this study we have used reference values of 4[91], 4.5[92], 8.3[93] lge/100 km respectively for small, medium and large gasoline vehicles[94].

For the reference target vehicles in 2050, we have projected the following values, depending on the vehicle segment.

small segment: As explained above, the small segment vehicles will be of the '1 litre car' type - smaller and lighter than today. A dedicated vehicle in the 500 kg class, with three seats and with a highly efficient propulsion system, will be standard by 2050, especially for commuting or other journeys were no multi-purpose family type vehicle is necessary. The fuel consumption for this type of vehicle is projected to be 1.6 lge/100 km.

medium segment: We developed our vision of reaching 60 g CO_2 per km for the medium segment following the technological building blocks described below, although this might not be the only way to reach the target.

- A 25% emissions reduction is envisaged by using turbo charging with variable turbine geometry, external cooled exhaust gas recirculation, gasoline direct injection (2nd generation) and variable valve control/cam phase shifting with respective scavenging strategies. These measures all result in a downsizing and down speeding of the engine[95].
- An additional potential for a 25% saving, related to the previous step, will come from hybridisation and the benefits in terms of start/stop improvements, regenerative braking and further downsizing. Waste heat recovery by thermoelectric generators will contribute to the on-board power supply, which saves an additional 3 to 5%[96 97].
- A reduction in the vehicle's mass from 360 kg to 1,000 kg will reduce energy demand by about 18%[98]. To achieve lightweight construction, methods such as topology optimisation, multi-material design and highly integrated components will be used. Mass reductions of 60 to 120 kg for midsized cars have already been achieved[99]. The production and recycling processes of lightweight materials such as magnesium and carbon fibres will also be improved in 30-40 years time, thus avoiding a shift in emissions from the utilisation to the production phase.
- Aerodynamic resistance, aerodynamic drag and frontal areas offer further potential for improvements. By optimising the car's underside, engine air flows and contours we project an additional lowering of energy demand by 8%.
- Rolling resistance depends on the material used for the tyre, the construction of the tyre and its radius, tyre pressures and driving speed. The tyre industry has proposed new concepts for wheels which are intended to lower rolling resistance by 50% by 2030[100 101]. Reducing the rolling coefficient by 1/1000 will lead to fuel savings of 0.08 l/100 km[102]. This results in an additional 12% CO_2 savings.
- Further potentials for energy savings will come from 'intelligent controllers' which improve energy management and drive train control strategies by recognising frequently driven journeys. Improved traffic management to help a driver find the energy optimised route might also make a contribution. Other options for hybridisation could come from free piston linear generators, which produce electricity with a constant high efficiency, at the same time avoiding part load conditions because of the variable cylinder capacity[103].

From the technologies and potentials described here, we project that within the next 40 years an improvement of 64% in energy consumption for hybrid vehicles is achievable, resulting in 2.6 l/100 km or 60 g CO_2/km for a middle sized car in the NEDC test cycle. This corresponds to an annual improvement of 2.2%. It is likely that other combinations will lead to similar results, for example by following full hybridisation first, with a potential saving of 44%[104][26] and adding complementary measures. We have also applied an 18% increase in fuel consumption based on a realistic assessment of driving patterns. The Volkswagen Golf V FSI 1.6 l, with a 1,360 kg mass and 163 g CO_2/km in NEDC was used as a starting point[105].

large segment: For large vehicles, the same technologies as described for the medium segment can be applied. We believe, however, that the potential for improvements is higher and project fuel consumption in 2050 at 3.5 lge/100 km. In addition, we assume that political measures to reduce the sales of very large SUVs for passenger transport have been introduced, so that the size of vehicles within the segment will also decrease.

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image NEW FUEL EFFICIENT HYBRID CAR DESIGN.

image CHARGING AN ELECTRIC CAR.

battery electric vehicles

Battery electric vehicles already have a long history, starting in 1881 with the first electric vehicle powered by a secondary Planté battery[106]. Considerable activity in the 1990s resulted in a number of production scale electric cars such as the EV1 (GM), Saxo electrique (Citroen), Hijet EV (Daihatsu), Th!nk City (Ford), EV Plus (Honda), Altra EV (Nissan), Clio Electric (Renault) and the RAV 4 (Toyota). At the beginning of the 21st century the Tesla Roadster is among the most prominent. There is also a continuous flow of prototype electric cars, including the Ion (Peugeot), E1 (BMW), A-Class electric (DaimlerChysler) and E-com (Toyota).

Battery electric vehicles are already very efficient. A fuel consumption of 1.7 litres gasoline equivalent /100 km is reported for the Ford e-Ka[107], 2.1 l/100 km for the Ford Ecostar and 3.4 l/100 km for the Chrysler van[108]. In the future we anticipate reference target values of 0.7 l/100 km for small size cars based on simulations for micro cars and 1.4 l/100 km for medium size vehicles based on simulations of city and compact class vehicles. We do not consider battery vehicles for the large vehicle segment.

There is a considerable gap between test cycle results and real driving experience because of auxiliary power needs, for example for heating, cooling and other electrical services. We have therefore applied a factor of 1.7 to the transfer from test cycle to real world driving based on simulation results.

Battery electric vehicles carry their energy along on board in a chemical form. The future battery technology for vehicles will most probably be based on Lithium because of good energy densities and cost prospects. Remaining issues associated with the application of batteries in vehicles are safety, long term durability and costs. However, under the most optimistic estimates for battery development, battery electric vehicles will mainly be small vehicles and those with dedicated usage profiles like urban fleets. Other problems to be solved are fast recharging and cycle stability. Technical solutions have already been proposed, and the cost reduction target for batteries in the long term is to reach 1/40th of today's figures. An enormous amount of research is being carried out, as well as production of the first vehicle-type batteries. This scenario assumes the introduction of battery electric vehicles from 2015.

plug-in-hybrid electric vehicles

Plug-in-hybrids are a combination of conventional hybrids and battery electric vehicles. They promise to provide both advantages: using low carbon and cheap energy from the grid, a wide travel range and grid independent driving when necessary. Plug-in-hybrids can be adapted from conventional hybrids by changing to a higher capacity battery, but different concepts, so-called series hybrids, are also proposed. Again, depending on the control strategy, different concepts are possible. The ICE, for example, is designed as a range-extender to recharge the battery only or a battery plus ICE/generator provides energy, depending on the power need. Fuel and energy consumption depend very much on the system layout and control strategy, combined with the distance, frequency and speed driven. We project 2.3, 2.4, 4.5 lge/100 km following the announced specification for the Volvo Recharge concept car and other input[109].

By the year 2050 we project that plug-in hybrids will use 10% more energy in electric mode compared to our projection for battery electric vehicles due to their increased weight. Once the battery is below the recharge limit, the ICE/generator will provide the energy in part or full. In this operating mode we again project 10% higher fuel consumption than their conventional hybrid counterparts. In terms of CO_2 balance the distribution of kilometres driven in electric and ICE modes is crucial. We anticipate that 80% of all kilometres will be driven in electric mode. In this scenario the introduction of plug-in-hybrid electric vehicles starts in 2015.

fuel cell hydrogen

Fuel cell vehicles have reached a high level of readiness for mass production. The polymer electrolyte membrane fuel cell provides high power density, resulting in low weight, cost and volume . Average drive cycle efficiencies have reached 3.5 lge/100 km[111]. Major problems still to be solved are durability, operating temperature range and cost reductions. Hydrogen on-board storage to provide a large driving range is a further issue not finally solved. Nevertheless, the technology seems ready to begin the transition into the mass market.

The main problem in fact is not so much the vehicles themselves as the hydrogen they need. Before the vehicles can operate, a hydrogen infrastructure needs to be established. The investment involved is risky, not least because of the competing electric systems. Because of energy losses in the hydrogen production chain, electricity appears to be cheaper, easier to handle and more environmentally friendly – at least until there is renewable electricity in abundance.

The hydrogen fuel cell vehicle might find its niche, however, where the driving range of battery electric vehicles is too low and/or locally emission free driving is demanded or the freedom from grid-connecting is valued more highly. We have projected a 35% improvement compared to today's fuel cell vehicles as the target reference value because of the potential for both fuel cell system improvement and lightweight, rolling resistance and aerodynamic vehicles, as already described.

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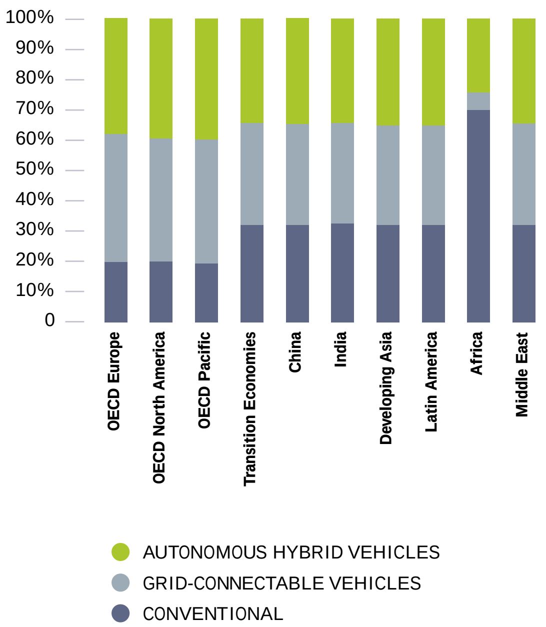
projection of future vehicle technology mix

We are convinced that the share of hybrid cars will grow enormously. For the industrialised regions, we anticipate a sales share of 65% for hybrid power trains by 2050 and for all other regions 50%, apart from Africa, with 25%. This share includes all types of non-grid connected hybrids. In 2050 the balance of different hybrids will be that in Europe, North America and OECD Pacific roughly 20% are powered by conventional ICE engines, roughly 40% are grid-connectable and 40% are autonomous hybrids. For all other regions, 34% will be conventional, a third plug-in-hybrids and a third autonomous hybrids. Africa is again treated differently.

figure 12.4: sales share of conventional ICE, autonomous hybrid and grid-connectable vehicles in 2050



To power all sizes of vehicles with the same technology does not make sense. We have therefore further projected that a large share of plug-in-electric cars in the small vehicle segment (80%) will be battery electric vehicles. Two-thirds of the medium sized vehicles and all of the large vehicles will be plug-in-hybrids, thus still having an internal combustion engine on board.

projection of vehicle segment split

We have disaggregated the light duty vehicle sales into three segments: small, medium and large vehicles. This gives us the opportunity to show the effect of 'driving smaller cars'. The size and CO_2 emissions of the vehicles are particularly interesting in the light of the enormous growth predicted in the LDV stock. For our purposes we have divided up the numerous car types as follows. The small car bracket includes city, supermini, microvans, mini SUV, minicompact cars and two seaters. The medium sized bracket includes lower medium/subcompact, medium class and compact cars, car derived vans and small station wagons, upper medium class, midsize cars and station wagons, executive class, passenger vans (subcompact, compact and standard MPV), car derived pickups, subcompact and compact SUVs, 2WD and 4WD. Within the large car bracket we have included all kinds of luxury class, luxury MPV, medium and heavy vans, compact and full-size pickup trucks (2WD, 4WD), standard and luxury SUVs.

In examining the segment split, we have focused most strongly on the two world regions which will be the largest emitters of CO_2 from cars in 2050: North America and China. In North America today the small vehicle segment is almost non-existant. We have nonetheless applied a considerable growth rate of 8% per year, triggered by rising fuel prices and possibly vehicle taxes. For China, we have anticipated the same share of the mature car market as for Europe and projected that the small segment will grow by 2.3% per year at the expenses of the larger segments in the light of rising mass mobility. The segment split is shown in Figure 12.5.

figure 12.5: vehicle sales by segment in 2005 and 2050 for ten world regions

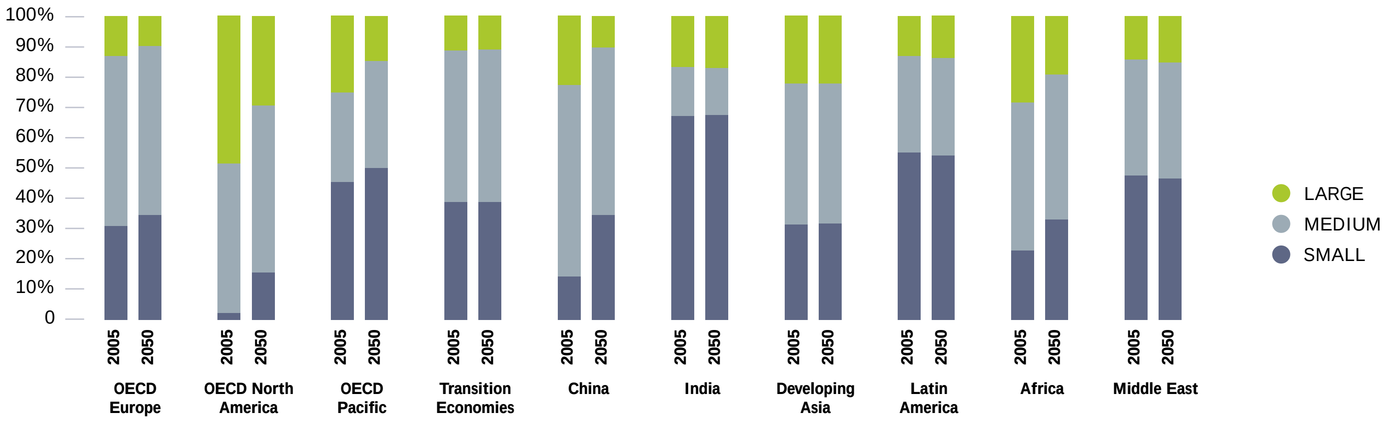


image PARKING SPACE FOR HYBRIDS ONLY.

image INTERNAL WORKINGS OF A HYBRID CAR.

projection of switch to alternative fuels

A switch to renewable fuels in the car fleet is one of the cornerstones of our low CO_2 car scenario, with the most prominent element the direct use of renewable electricity in cars. The different types of electric and hybrid cars, such as battery electric and plug-in-hybrid, are summarised as 'plug-in electric'. Their introduction will start in industrialised countries in 2015, following an s-curve pattern, and are projected to reach about 40% of total LDV sales in the EU, North America and the Pacific OECD by 2050. Due to the higher costs of the technology and renewable electricity availability, we have slightly delayed progress in other countries. More cautious targets are applied for Africa. The sales split in vehicles by fuel is presented in Figure 12.7 for 2005 and 2050.

projection of global vehicle stock development

Differences in forecasts for the growth of vehicle sales in developing countries are huge[112]. We have mainly used the projections from the Reference Scenario. Slight changes were applied to vehicle sales in saturated markets such as Europe and North America, where we believe that massive policy intervention to promote modal shift and alternative forms of car usage will show effects in vehicle sales in the long run.

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figure 12.6: development of the global car market

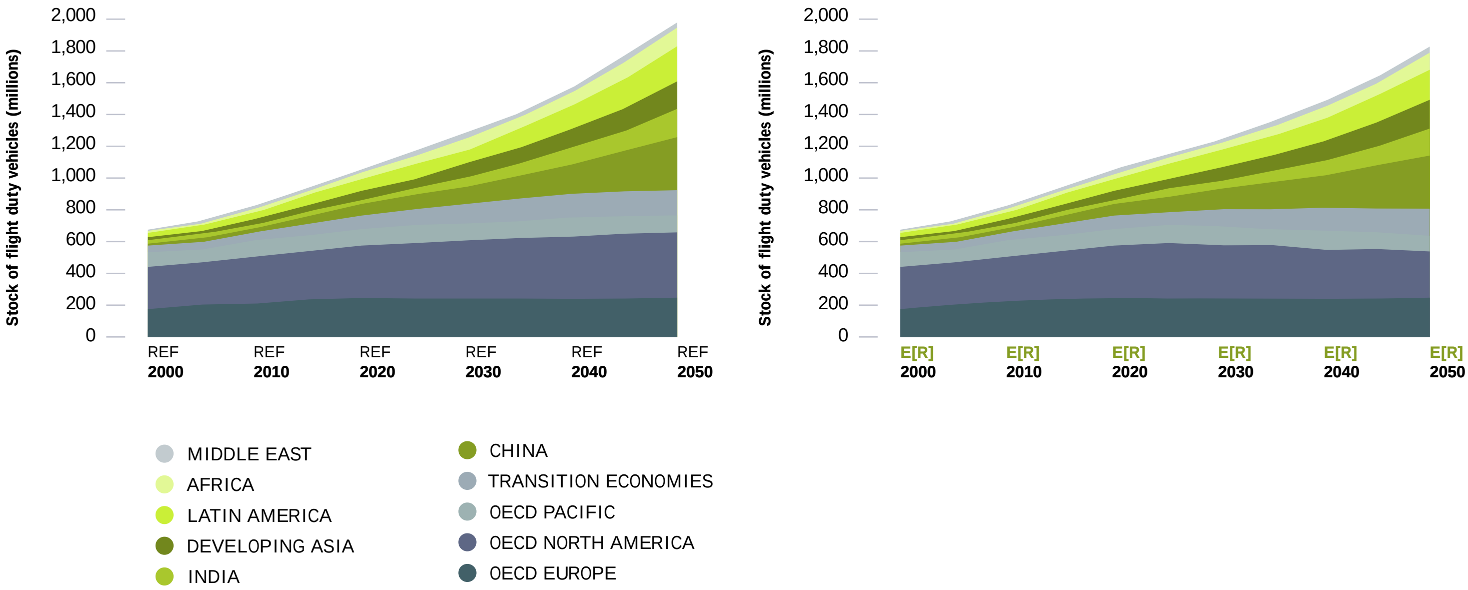
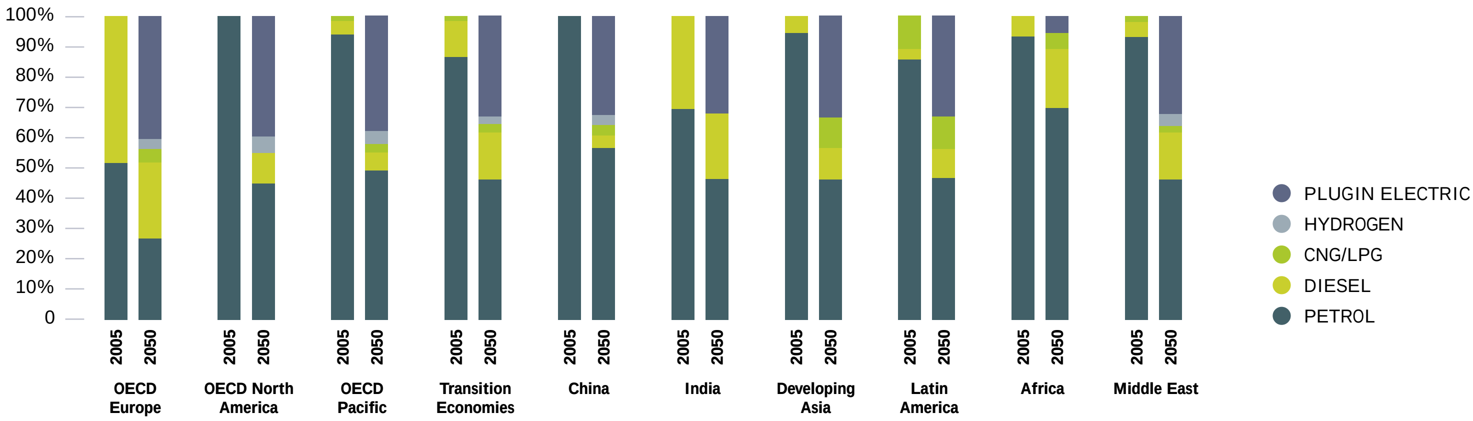


figure 12.7: fuel split in vehicle sales for 2005 and 2050 by ten world regions



projection of kilometres driven per year

Until a complete shift from fossil to renewable fuels is completed, driving on the road will be linked to CO_2 emissions. Thus driving less contributes to our target for emissions reduction. However this is not necessarily linked to less mobility because we have relied on the multitude of excellent opportunities for shifts from individual passenger road transport towards less CO_2 intense public or non-motorised transport.

In our scenario we have taken into account the effects of a variety of policy measures which could be implemented all over the world and summarised them in two indicators: numbers of vehicles (see the section above) and annual kilometres driven (AKD). For AKD we have applied a 0.25% reduction per year, assuming the first visible effect in 2010, resulting in a roughly 10% reduction by 2050. This has been coordinated into a model which projects the shift from car to rail or bus at 5%, with the additional 5% coming from LDVs as part of the predicted demand reduction for all modes of transport[113].

Figure 12.9 shows the effect of vehicle travel reduction over time by world region. China shows a less typical pattern: while in China today many vehicles are used intensively, with many kilometres travelled per year, with a growing individual mobility we assume that AKD will move towards the global average.

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115 THERE IS NO RELIABLE NUMBER FOR THE GLOBAL 1990 LDV EMISSIONS AVAILABLE, THEREFORE THIS HAS TO BE UNDERSTOOD AS A ROUGH ESTIMATE.
.

summary of scenario results[114]

A combination of ambitious efforts to introduce higher efficiency vehicle technologies, a major switch to grid-connected electric vehicles and incentives for travellers to save CO_2 all lead to the conclusion that it is possible to reduce emissions from well-to-wheel in 2050 by roughly 25%[115] compared to 1990 and 40% compared to 2005. Even so, 74% of the final energy used in cars will still come from fossil fuel sources, 70% from gasoline and diesel. Renewable electricity covers 19% of total car energy demand, bio fuels cover 5% and hydrogen 2%. Energy consumption in total is reduced by 23% in 2050 compared to 2005, in spite of tremendous increases in some world regions. The peak in global CO_2 emissions occurs between 2010 and 2015. From 2010 onwards, new legislation in the US and Europe contributes towards breaking the upwards trend in emissions. From 2020 onwards, we can see the effect of introducing grid-connected electric cars. The development of CO_2 emissions, taking into account upstream emissions, is shown in Figure 12.8.

figure 12.9: average annual kilometres driven per world region

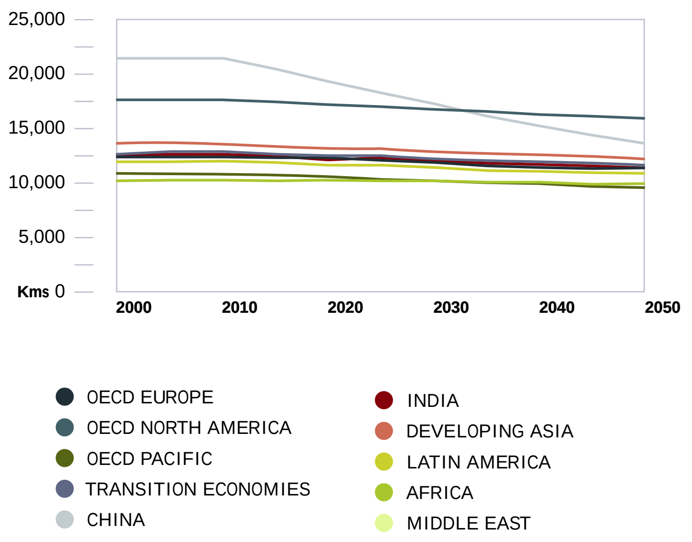
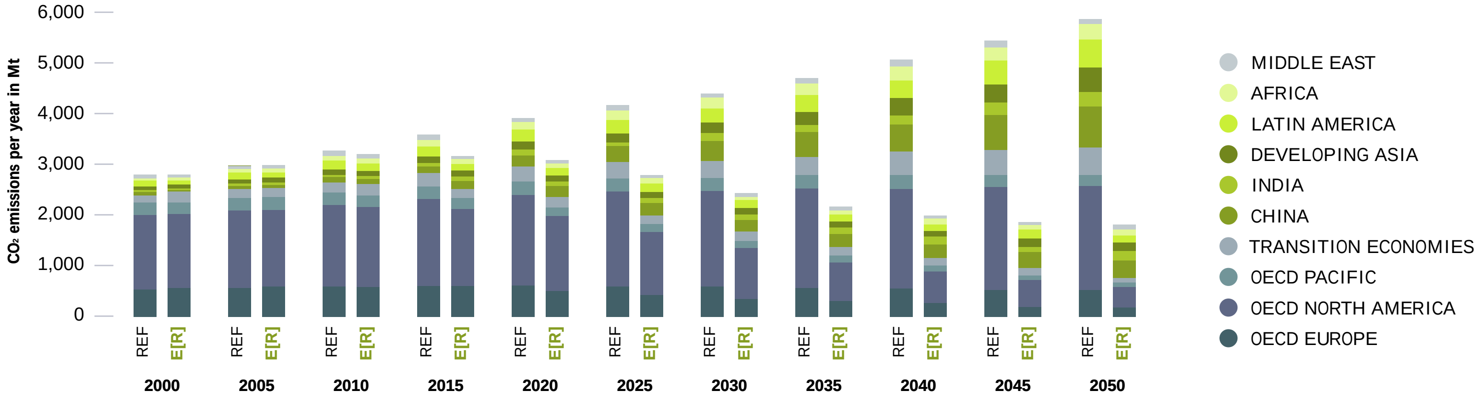


figure 12.8: well-to-wheel CO_2 emissions of light duty vehicles in the reference and energy [r]evolution scenarios from 2000 to 2050



GLOBAL

13

STANDBY POWER IS WASTED POWER. GLOBALLY, WE HAVE 50 DIRTY POWER PLANTS RUNNING JUST FOR OUR WASTED STANDBY POWER. OR: IF WE WOULD REDUCE OUR STANDBY TO JUST 1 WATT, WE CAN AVOID THE BUILDING OF 50 NEW DIRTY POWER PLANTS.
© M. DIETRICH/DREAMSTIME

"...so I urge the government to act and to act quickly."

LYN ALLISON
LEADER OF THE AUSTRALIAN DEMOCRATS, SENATOR 2004-2008

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

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.

Renewable energy technologies would already be competitive if they had received the same attention as fossil fuels and nuclear in terms of R&D funding, subsidies, and if external costs were reflected in energy prices. Removing public subsidies to fossil fuels and nuclear and applying the 'polluter pays' principle to the energy markets, would go a long way to level the playing field and drastically reduce the need for renewables support. Unless this principle is fully implemented, renewable energy technologies need to receive compensation and additional support measures in order to compete in the distorted market.

Support mechanisms for the different sectors and technologies can vary according to regional characteristics, priorities or starting points. But some general principles should apply to any kind of support mechanism. These criteria are:

effectiveness in reaching the targets The experiences in some countries show that it is possible with the right design of a support mechanism to reach agreed national targets. Any system to be adopted at a national level should focus on being effective in deploying new installed capacity and meeting the targets.

long term stability Whether price or quantity-based, policy makers need to make sure that investors can rely on the long-term stability of any support scheme. It is absolutely crucial to avoid stop-and-go markets by changing the system or the level of support frequently. Therefore market stability has to be created with a stable long-term support mechanism.

simple and fast administrative procedures Complex licensing procedures constitute one of the most difficult obstacles that renewables projects have to face. Administrative barriers have to be removed at all levels. A 'one-stop-shop' system should be introduced and a clear timetable set for approving projects.

encouraging local and regional benefits and public acceptance The development of renewable technologies can have a significant impact on local and regional areas, resulting from both installation and manufacturing. Some support schemes include public involvements that hinder or facilitate the acceptance of renewable technologies. A support scheme should encourage local/regional development, employment and income generation. It should also encourage public acceptance of renewables, including their positive impact and increased stakeholder involvement.

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[116], Greenpeace and EREC have documented the development of those industries from 1990 onwards and outlined a prognosis for growth up to 2020.

references
116 SOLAR GENERATION (EPIA), CONCENTRATED SOLAR THERMAL POWER – NOW! (GREENPEACE), WINDFORCE 12 (EWEA), GLOBAL WIND ENERGY OUTLOOK 2006, GWEC..

image LOCALS AND GREENPEACE SETTING UP WIND TURBINES IN THAILAND.

demands for the energy sector

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

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

Conventional energy sources receive an estimated $250-300[117] billion in subsidies per year worldwide, resulting in heavily distorted markets. Subsidies artificially reduce the price of power, keep renewable energy out of the market place and prop up 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.

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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 $ 98 million per plant, and only $15 million per year per plant, with the rest being drawn from an industry fund of up to $ 10 billion. After that the taxpayer becomes responsible[118].

Environmental damage should, as a priority, be rectified at source. Translated into energy generation that would mean that, ideally, production of energy should not pollute and it is the energy producers' responsibility to prevent it. If 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.

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.

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 two types of incentive to promote deployment of renewable energy. 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.

image A YOUNG BOY IS PART OF A GATHERING AT THE CLIMATE DEFENDERS CAMP WHERE LOCAL COMMUNITIES AND PRO-RENEWABLE ENERGY GROUPS PLEDGE TO CONTINUE WORK TO HELP STOP CLIMATE CHANGE. THE CAMP WAS ESTABLISHED TO OPPOSE COAL POWER PLANT CONSTRUCTION IN ILOILO CITY IN THE PHILIPPINES.

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 renewables 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, which determines its success.

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

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

Measures should stimulate the deployment of the large potential for cost effective renewable heating and cooling, available already with today's technologies. At the same time, increased R&D efforts should be undertaken, particularly in the fields of heat storage and renewable cooling.

glossary & appendix

GLOBAL

GLOSSARY
APPENDIX

14

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

GREENPEACE INTERNATIONAL
CLIMATE CAMPAIGN

image COAL FIRED POWER PLANT.
© F. FUXA/DREAMSTIME

image NEXT EXIT 'SUNSHINE', CANADA.

glossary of commonly used terms and abbreviations

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

J Joule, a measure of energy:
kJ = 1,000 Joules,
MJ = 1 million Joules,
GJ = 1 billion Joules,
PJ = 1015 Joules,
EJ = 1018 Joules

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

kWh Kilowatt-hour, measure of electrical output:
TWh = 1012 watt-hours
t/Gt Tonnes, measure of weight:
Gt = 1 billion tonnes

conversion factors - fossil fuels

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

conversion factors - different energy units

FROM \ TO: MULTIPLY BY	TJ	Gcal	Mtoe	Mbtu	GWh
TJ	1	238.8	2.388×10^{-5}	947.8	0.2778
Gcal	4.1868×10^{-3}	1	$10^{(-7)}$	3.968	1.163×10^{-3}
Mtoe		107	1	3968×10^{7}	11630
Mbtu		0.252	2.52×10^{-8}	1	2.931×10^{-4}
GWh		860	8.6×10^{-5}	3412.00	1

definition of sectors

The definition of different sectors is analog to the sectorial break down of the IEA World Energy Outlook series.

All definitions below are from the IEA Key World Energy Statistics

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

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

Transport sector: The Transport sector includes all fuels from transport such as road, railway, aviation, domestic and navigation. Fuel used for ocean, costal and inland fishing is included in "Other Sectors".

Other sectors: 'Other sectors' covers agriculture, forestry, fishing, residential, commercial and public services.

Non-energy use: This category covers use of other petroleum products such as paraffin waxes, lubricants, bitumen etc.

appendix: global reference scenario

table 14.1: global: electricity generation

TWh/a	2005	2010	2020	2030	2040	2050
Power plants	**16,311**	**19,673**	**26320**	**32,380**	**39,233**	**46,849**
Coal	5,089	6,955	9,957	13,153	17,505	22,892
Lignite	1,532	1,620	1,813	1,964	2,189	2,425
Gas	2,631	3,304	4,925	6,376	7,433	8,291
Oil	1,047	1,048	943	786	725	733
Diesel	33	28	20	17	15	14
Nuclear	2,768	2,824	3,068	3,173	3,345	3,517
Biomass	124	168	324	474	578	650
Hydro	2,923	3,362	4,164	4,833	5,440	6,027
Wind	103	274	887	1,260	1,545	1,736
PV	2	13	68	120	167	213
Geothermal	56	72	119	158	196	229
Solar thermal power plants	1	5	26	54	77	95
Ocean energy	1	1	6	12	20	28
Combined heat & power production	**1,915**	**2,107**	**2,487**	**2,989**	**3,392**	**3,757**
Coal	438	567	642	777	901	1,014
Lignite	166	141	134	137	136	136
Gas	1,088	1,142	1,331	1,597	1,780	1,917
Oil	113	104	102	103	98	60
Biomass	109	151	272	367	466	613
Geothermal	1	2	6	9	12	17
CHP by producer						
Main activity producers	1,410	1,484	1,579	1,813	1,941	2,062
Autoproducers	505	623	908	1,177	1,451	1,695
Total generation	**18,226**	**21,780**	**28,807**	**35,369**	**42,626**	**50,606**
Fossil	12,138	14,910	19,868	24,910	30,872	37,482
Coal	5,527	7,522	10,599	13,930	18,406	23,905
Gas	1,698	1,761	1,947	2,101	2,324	2,561
Lignite	3,719	4,447	6,256	7,974	9,213	10,208
Oil	1,160	1,152	1,045	889	823	793
Diesel	33	2,824	3,068	3,173	3,345	3,517
Nuclear	2,768	28	20	17	15	14
Renewables	**3,321**	**4,047**	**5,871**	**7,286**	**8,499**	**9,608**
Hydro	2,923	3,362	4,164	4,833	5,440	6,027
Wind	103	274	887	1,260	1,545	1,736
PV	2	13	68	120	167	213
Biomass	234	318	595	841	1,044	1,263
Geothermal	58	74	125	167	207	245
Solar thermal	1	5	26	54	77	95
Ocean energy	1	1	6	12	20	28
Distribution losses	1,596	1,958	2,541	2,999	3,300	3,569
Own consumption electricity	1,597	1,941	2,579	3,095	3,601	4,058
Electricity for hydrogen production	0	0	5	17	27	40
Final energy consumption (electricity)	**15,018**	**17,890**	**23,677**	**29,256**	**35,698**	**42,938**
Fluctuating RES (PV, Wind, Ocean)	106	287	961	1,392	1,731	1,978
Share of fluctuating RES	0.6%	1.3%	3.3%	3.9%	4.1%	3.9%
RES share	**18.2%**	**18.6%**	**20.4%**	**20.6%**	**19.9%**	**19.0%**

table 14.2: global: heat supply

PJ/A	2005	2010	2020	2030	2040	2050
District heating plants	**5,900**	**6,121**	**6,323**	**6,560**	**6,922**	**7,334**
Fossil fuels	5,305	5,512	5,545	5,465	5,440	5,448
Biomass	584	596	759	1,070	1,448	1,841
Solar collectors	0	0	1	2	2	3
Geothermal	11	13	19	24	32	42
Heat from CHP	**10,136**	**10,659**	**11,961**	**13,213**	**13,771**	**14,349**
Fossil fuels	9,637	9,958	10,721	11,740	12,147	12,308
Biomass	489	680	1,188	1,395	1,516	1,889
Geothermal	11	22	52	79	107	152
Direct heating[1]	**120,217**	**131,029**	**146,045**	**160,350**	**171,953**	**182,702**
Fossil fuels	88,074	97,298	110,049	122,267	131,179	139,579
Biomass	31,978	33,387	34,905	36,137	37,902	39,460
Solar collectors	165	344	1,091	1,946	2,872	3,664
Geothermal						
Total heat supply[1]	**136,402**	**148,032**	**165,256**	**181,830**	**195,064**	**207,744**
Fossil fuels	103,015	112,768	126,315	139,472	148,766	157,336
Biomass	33,050	34,663	36,851	38,601	40,867	43,189
Solar collectors	166	345	1,091	1,948	2,874	3,667
Geothermal	171	257	998	1,809	2,558	3,553
RES share (including RES electricity)	**24%**	**24%**	**24%**	**23%**	**24%**	**24%**

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

table 14.3: global: CO_2 emissions

MILL t/a	2005	2010	2020	2030	2040	2050
Condensation power plants	**8,765**	**11,043**	**14,416**	**17,364**	**19,551**	**21,901**
Coal	4,977	6,812	9,554	11,994	13,865	15,964
Lignite	1,725	1,816	1,852	1,965	2,115	2,260
Gas	1,273	1,611	2,284	2,769	2,987	3,089
Oil	743	763	694	602	557	563
Diesel	48	41	32	30	27	25
Combined heat & power production	**1,899**	**1,793**	**1,694**	**1,762**	**1,858**	**1,880**
Coal	621	677	623	642	682	716
Lignite	287	225	193	190	205	195
Gas	826	786	795	858	909	936
Oil	165	105	83	72	61	33
CO_2 emissions electricity & steam generation	**10,664**	**12,836**	**16,111**	**19,127**	**21,410**	**23,781**
Coal	5,598	7,489	10,178	12,636	14,548	16,680
Lignite	2,012	2,041	2,045	2,160	2,321	2,455
Gas	2,099	2,396	3,078	3,627	3,896	4,025
Oil & diesel	956	910	810	703	645	622
CO_2 emissions by sector	**24,351**	**27,932**	**33,541**	**38,716**	**43,095**	**47,773**
% of 1990 emissions	114%	131%	157%	181%	201%	223%
Industry	4,292	4,863	5,618	6,199	6,684	7,138
Other sectors	3,405	3,645	4,065	4,423	4,630	4,802
Transport	5,800	6,411	7,718	9,020	10,521	12,283
Electricity & steam generation	10,293	12,442	15,605	18,579	20,793	23,106
District heating	561	571	535	496	467	443
Population (Mill.)	6,503	6,894	7,652	8,300	8,803	9,169
CO_2 emissions per capita (t/capita)	**3.7**	**4.1**	**4.4**	**4.7**	**4.9**	**5.2**

table 14.4: global: installed capacity

GW	2005	2010	2020	2030	2040	2050
Power plants	**3,690**	**4,415**	**5,940**	**7,262**	**8,816**	**10,799**
Coal	874	1,209	1,758	2,342	3,104	4,060
Lignite	257	268	296	323	361	402
Gas	803	979	1,404	1,814	2,236	2,807
Oil	354	371	364	313	324	446
Diesel	65	55	37	30	25	23
Nuclear	368	369	392	405	426	452
Biomass	21	28	52	72	86	95
Hydro	878	989	1,215	1,399	1,558	1,711
Wind	59	124	346	440	526	593
PV	2	10	49	86	120	153
Geothermal	9	11	17	22	28	33
Solar thermal power plants	1	2	8	12	15	17
Ocean energy	0	0	2	4	7	9
Combined heat & power production	**565**	**605**	**683**	**815**	**912**	**995**
Coal	141	172	181	211	245	279
Lignite	54	45	38	36	35	35
Gas	281	301	360	465	518	555
Oil	56	44	35	31	27	15
Biomass	32	42	68	71	84	109
Geothermal	0	0	1	2	2	3
CHP by producer						
Main activity producers	439	460	478	556	602	636
Autoproducers	125	144	205	259	310	359
Total generation	**4,254**	**5,020**	**6,622**	**8,077**	**9,727**	**11,794**
Fossil	2,885	3,445	4,473	5,564	6,875	8,620
Coal	1,015	1,382	1,939	2,554	3,350	4,339
Lignite	311	313	333	358	396	437
Gas	1,084	1,280	1,763	2,279	2,754	3,362
Oil	410	415	399	344	351	461
Diesel	65	55	37	30	25	23
Nuclear	368	369	392	405	426	452
Renewables	**1,001**	**1,206**	**1,757**	**2,108**	**2,426**	**2,722**
Hydro	878	989	1,215	1,399	1,558	1,711
Wind	59	124	346	440	526	593
PV	2	10	49	86	120	153
Biomass	52	70	119	143	170	203
Geothermal	9	11	18	24	30	36
Solar thermal	1	2	8	12	15	17
Ocean energy	0	0	2	4	7	9
Fluctuating RES (PV, Wind, Ocean)	61	134	396	531	652	755
Share of fluctuating RES	1.4%	2.7%	6.0%	6.6%	6.7%	6.4%
RES share	**23.5%**	**24.0%**	**26.5%**	**26.1%**	**24.9%**	**23.1%**

table 14.6: global: primary energy demand

PJ/A	2005	2010	2020	2030	2040	2050
Total	**474,905**	**532,251**	**632,485**	**721,342**	**794,412**	**867,705**
Fossil	**383,120**	**434,042**	**516,377**	**591,380**	**652,760**	**716,620**
Hard coal	103,515	128,188	161,262	190,020	211,515	235,422
Lignite	18,124	18,389	18,422	19,462	20,907	22,113
Natural gas	99,741	111,600	135,291	157,044	170,244	180,559
Crude oil	161,739	175,865	201,402	224,854	250,093	278,527
Nuclear	**30,201**	**30,810**	**33,479**	**34,623**	**36,497**	**38,372**
Renewables	**61,586**	**67,398**	**82,629**	**95,339**	**105,155**	**112,713**
Hydro	10,521	12,103	14,989	17,399	19,585	21,696
Wind	372	985	3,195	4,536	5,561	6,251
Solar	176	409	1,429	2,572	3,749	4,775
Biomass	48,594	51,924	59,375	65,611	69,898	72,350
Geothermal	1,921	1,974	3,621	5,179	6,289	7,510
Ocean Energy	2	2	20	43	72	101
RES share	**12.9%**	**12.6%**	**13.1%**	**13.2%**	**13.2%**	**13.0%**

table 14.5: global: final energy demand

PJ/A	2005	2010	2020	2030	2040	2050
Total (incl. non-energy use)	**328,700**	**366,401**	**433,428**	**495,497**	**558,541**	**625,878**
Total (energy use)	**299,300**	**332,134**	**392,504**	**449,948**	**508,478**	**571,298**
Transport	**83,936**	**93,537**	**114,452**	**134,667**	**157,633**	**183,081**
Oil products	80,145	88,515	106,246	123,913	144,436	168,647
Natural gas	2,077	2,390	3,234	3,961	4,539	5,042
Biofuels	784	1,232	2,836	3,958	5,034	4,949
Electricity	930	1,399	2,123	2,790	3,552	4,333
RES electricity	173	256	426	570	718	852
Hydrogen	0	0	14	45	73	110
RES share Transport	**1.1%**	**1.6%**	**2.9%**	**3.4%**	**3.7%**	**3.2%**
Industry	**91,759**	**105,602**	**125,107**	**142,284**	**158,358**	**174,854**
Electricity	22,251	28,351	37,915	45,845	54,455	63,807
RES electricity	4,312	5,405	7,736	9,397	10,822	12,174
District heat	8,009	8,138	8,878	9,332	9,500	9,730
RES district heat	502	609	890	1,090	1,235	1,531
Coal	17,357	21,058	25,537	28,270	29,981	31,668
Oil products	13,624	15,009	16,305	17,591	18,995	20,178
Gas	23,172	25,100	27,610	31,076	33,955	36,765
Solar	5	10	108	201	312	444
Biomass and waste	7,328	7,914	8,560	9,588	10,600	11,412
Geothermal	12	21	195	381	559	849
RES share Industry	**13.3%**	**13.2%**	**14.0%**	**14.5%**	**14.9%**	**15.1%**
Other Sectors	**123,605**	**132,995**	**152,944**	**172,997**	**192,487**	**213,363**
Electricity	30,885	34,654	45,199	56,685	70,500	86,433
RES electricity	5,239	6,199	9,201	11,796	14,186	16,426
District heat	7,308	7,918	8,651	9,668	10,412	11,165
RES district heat	533	609	935	1,195	1,482	1,887
Coal	4,795	4,819	4,635	4,385	4,210	4,009
Oil products	20,764	22,416	25,564	27,981	28,785	29,021
Gas	24,972	26,882	30,293	33,784	36,566	39,537
Solar	160	334	983	1,746	2,560	3,219
Biomass and waste	34,583	35,779	37,017	37,693	37,982	38,025
Geothermal	137	193	602	1,055	1,473	1,953
RES share Other Sectors	**32.9%**	**32.4%**	**31.9%**	**30.9%**	**30%**	**28.8%**
Total RES	**53,770**	**58,564**	**69,491**	**78,680**	**86,975**	**93,734**
RES share	**16.4%**	**16.0%**	**16.0%**	**15.9%**	**15.6%**	**15.0%**
Non energy use	**29,401**	**34,267**	**40,924**	**45,548**	**50,063**	**54,580**
Oil	22,728	25,753	29,808	32,857	35,830	38,795
Gas	5,498	6,446	8,006	9,286	10,535	11,794
Coal	1,174	2,068	3,110	3,405	3,698	3,992

appendix: global energy [r]evolution scenario

table 14.7: global: electricity generation

TWh/a	2005	2010	2020	2030	2040	2050
Power plants	**16,311**	**19315**	**22,507**	**24,872**	**27,524**	**30,714**
Coal	5,089	6,659	7,587	6,874	5,101	3,285
Lignite	1,532	1,451	726	193	29	0
Gas	2,631	3,474	4,383	4,406	3,575	2,321
Oil	1,047	991	602	303	85	21
Diesel	33	26	13	10	5	3
Nuclear	2,768	2,688	1,647	678	168	0
Biomass	124	211	343	423	531	670
Hydro	2,923	3,334	4,010	4,425	4,918	5,348
Wind	103	362	2,255	4,398	6,271	7,738
PV	2	26	386	1,351	2,663	4,349
Geothermal	56	82	231	488	830	1,048
Solar thermal power plants	1	9	267	1,172	3,010	5,255
Ocean energy	1	3	58	151	338	677
Combined heat & power production	**1,915**	**2,207**	**3,237**	**4,252**	**5,392**	**6402**
Coal	438	514	570	696	863	1,006
Lignite	166	127	70	21	0	0
Gas	1,088	1,230	1,743	1,929	1,884	1,880
Oil	113	109	47	12	0	0
Biomass	109	219	741	1,403	2,221	2,858
Geothermal	1	8	65	191	422	657
CHP by producer						
Main activity producers	1,410	1,493	1,789	2,211	2,660	2,974
Autoproducers	505	714	1,447	2,041	2,731	3,428
Total generation	**18,226**	**21,523**	**25,743**	**29,124**	**32,916**	**37,116**
Fossil	12,138	14,581	15,741	14,444	11,543	8,517
Coal	5,527	7,173	8,157	7,570	5,965	4,291
Gas	1,698	1,578	797	215	29	0
Lignite	3,719	4,704	6,126	6,335	5,459	4,201
Oil	1,160	1,100	649	315	85	21
Diesel	33	26	13	10	5	3
Nuclear	2,768	2,688	1,647	678	168	0
Renewables	**3,321**	**4,254**	**8,355**	**14,002**	**21,205**	**28,599**
Hydro	2,923	3,334	4,010	4,425	4,918	5,348
Wind	103	362	2,255	4,398	6,271	7,738
PV	2	26	386	1,351	2,663	4,349
Biomass	234	430	1,084	1,826	2,752	3,527
Geothermal	58	90	296	679	1,252	1,705
Solar thermal	1	9	267	1,172	3,010	5,255
Ocean energy	1	3	58	151	338	677
Distribution losses	1,596	1,925	2,243	2,428	2,588	2,767
Own consumption electricity	1,597	1,904	2,279	2,457	2,592	2,743
Electricity for hydrogen production	0	0	126	302	570	792
Final energy consumption (electricity)	**15,018**	**17686**	**21,095**	**23,937**	**27,166**	**30,814**
Fluctuating RES (PV, Wind, Ocean)	106	390	2,698	5,900	9,272	12,764
Share of fluctuating RES	0.6%	1.8%	10.5%	20.3%	28.2%	34.4%
RES share	**18.2%**	**19.8%**	**32.5%**	**48.1%**	**64.4%**	**77.1%**
'Efficiency' savings (compared to Ref.)	**0**	**207**	**2,583**	**5,320**	**8,542**	**12,145**

table 14.8: global: heat supply

PJ/A	2005	2010	2020	2030	2040	2050
District heating plants	**5,900**	**6,438**	**8,110**	**9,845**	**11,461**	**11,555**
Fossil fuels	5,305	5,327	4,680	3,441	1,679	325
Biomass	584	910	2,011	2,859	3,426	2,984
Solar collectors	0	113	784	2,045	3,786	5,169
Geothermal	11	88	636	1,499	2,571	3,077
Heat from CHP	**10,136**	**11,079**	**15,284**	**19,204**	**22,865**	**26,069**
Fossil fuels	9,637	9,971	11,115	11,453	10,764	10,257
Biomass	489	1,032	3,560	6,001	8,286	9,920
Geothermal	11	76	608	1,750	3,815	5,892
Direct heating[1)]	**120,217**	**127,879**	**133,364**	**133,334**	**129,717**	**124,082**
Fossil fuels	88,074	92,101	87,374	74,434	56,223	36,580
Biomass	31,978	34,125	36,945	37,421	37,080	34,860
Solar collectors	165	815	5,837	15,185	25,798	36,698
Geothermal	150	838	3,208	6,294	10,617	15,944
Total heat supply[1)]	**136,402**	**145,397**	**156,757**	**162,382**	**164,043**	**161,705**
Fossil fuels	103,015	107,399	103,169	89,327	68,666	47,161
Biomass	33,050	36,067	42,516	46,281	48,791	47,764
Solar collectors	166	928	6,621	17,231	29,584	41,867
Geothermal	171	1002	4,452	9,543	17,002	24,913
RES share (including RES electricity)	**24%**	**26%**	**34%**	**45%**	**58%**	**71%**
'Efficiency' savings (compared to Ref.)	**0**	**2,636**	**8,499**	**19,448**	**31,021**	**46,039**

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

table 14.9: global CO_2 emissions

MILL t/a	2005	2010	2020	2030	2040	2050
Condensation power plants	**8,765**	**10,630**	**10,231**	**7,871**	**5,173**	**2,895**
Coal	4,977	6,561	6,980	5,512	3,683	2,079
Lignite	1,725	1,627	750	201	29	0
Gas	1,273	1,691	2,040	1,916	1,390	792
Oil	743	714	441	226	59	15
Diesel	48	38	20	17	12	9
Combined heat & power production	**1,899**	**1,756**	**1,668**	**1,595**	**1,515**	**1,451**
Coal	621	608	577	583	604	622
Lignite	287	217	106	36	0	0
Gas	826	824	947	967	911	829
Oil	165	106	38	8	0	0
CO_2 emissions electricity & steam generation	**10,664**	**12,386**	**11,899**	**9,466**	**6,688**	**4,346**
Coal	5,598	7,169	7,557	6,095	4,287	2,701
Lignite	2,012	1,844	856	237	29	0
Gas	2,099	2,515	2,987	2,883	2,301	1,622
Oil & diesel	956	858	500	251	71	24
CO_2 emissions by sector	**24,351**	**26,954**	**25,380**	**20,981**	**15,581**	**10,589**
% of 2000 emissions	114%	126%	119%	98%	73%	49%
Industry	4,292	4,553	4,463	3,875	2,993	2,067
Other sectors	3,405	3,526	3,213	2,651	2,004	1,333
Transport	5,800	6,332	5,891	5,272	4,378	3,493
Electricity & steam generation	10,293	11,992	11,382	8,902	6,078	3,675
District heating	561	550	432	281	128	21
Population (Mill.)	6,503	6,894	7,652	8,300	8,803	9,169
CO_2 emissions per capita (t/capita)	**3.7**	**3.9**	**3.3**	**2.5**	**1.8**	**1.15**

table 14.10: global: installed capacity

GW	2005	2010	2020	2030	2040	2050
Power plants	**3,690**	**4,391**	**5,747**	**7,040**	**8,430**	**9,843**
Coal	874	1,160	1,340	1,230	959	651
Lignite	257	240	120	33	6	0
Gas	803	1,025	1,284	1,320	1,155	716
Oil	354	349	235	126	47	14
Diesel	65	51	27	19	11	6
Nuclear	368	352	213	88	22	0
Biomass	21	35	56	65	81	99
Hydro	878	978	1,178	1,300	1,443	1,565
Wind	59	164	893	1,622	2,220	2,733
PV	2	21	269	921	1,799	2,911
Geothermal	9	12	33	71	120	152
Solar thermal power plants	1	5	83	199	468	801
Ocean energy	0	1	17	44	98	194
Combined heat & power production	**565**	**632**	**859**	**1,085**	**1,319**	**1,526**
Coal	141	154	169	217	280	325
Lignite	54	43	21	6	0	0
Gas	281	323	461	544	546	557
Oil	56	51	18	4	0	0
Biomass	32	60	177	275	411	521
Geothermal	0	2	13	38	82	124
CHP by producer						
Main activity producers	439	467	543	653	764	837
Autoproducers	125	165	316	431	554	689
Total generation	**4,254**	**5,023**	**6,606**	**8,124**	**9,749**	**11,369**
Fossil	2,885	3,395	3,674	3,500	3,004	2,269
Coal	1,015	1,314	1,509	1,447	1,239	976
Lignite	311	283	141	39	6	0
Gas	1,084	1,348	1,745	1,865	1,701	1,273
Oil	410	400	253	130	48	14
Diesel	65	51	27	19	11	6
Nuclear	368	352	213	89	22	0
Renewables	**1,001**	**1,276**	**2,719**	**4,536**	**6,723**	**9,100**
Hydro	878	978	1,178	1,300	1,443	1,565
Wind	59	164	893	1,622	2,220	2,733
PV	2	21	269	921	1,799	2,911
Biomass	52	95	233	341	492	620
Geothermal	9	14	46	108	203	276
Solar thermal	1	5	83	199	468	801
Ocean energy	0	1	17	44	98	194
Fluctuating RES (PV, Wind, Ocean)	61	185	1,179	2,588	4,117	5,838
Share of fluctuating RES	1.4%	3.7%	17.8%	31.8%	42.2%	51.4%
RES share	**23.5%**	**25.4%**	**41.2%**	**55.8%**	**69.0%**	**80%**

table 14.11: global: primary energy demand

PJ/A	2005	2010	2020	2030	2040	2050
Total	**474,907**	**524,782**	**540,753**	**525,939**	**503,437**	**480,861**
Fossil	**383,120**	**422,770**	**409,286**	**355,467**	**281,284**	**209,962**
Hard coal	103,515	122,826	125,197	104,040	77,118	51,438
Lignite	18,124	16,613	7,711	2,136	260	0
Natural gas	99,741	115,011	128,798	123,203	100,995	74,596
Crude oil	161,739	168,321	147,580	126,088	102,912	83,927
Nuclear	**30,201**	**29,332**	**17,971**	**7,397**	**1,832**	**0**
Renewables	**61,584**	**72,671**	**113,288**	**163,075**	**220,321**	**270,899**
Hydro	10,521	12,001	14,435	15,930	17,706	19,253
Wind	372	1,301	8,119	15,832	22,576	27,857
Solar	176	1,063	8,978	26,315	50,006	76,441
Biomass	48,594	55,372	71,712	83,207	92,003	94,779
Geothermal	1,921	2,934	10,045	21,247	36,811	50,131
Ocean Energy	2	9	207	544	1,218	2,437
RES share	**12.9%**	**13.8%**	**21%**	**30.9%**	**43.6%**	**56.1%**
'Efficiency' savings (compared to Ref.)	**0**	**7,651**	**91,434**	**195,425**	**291,424**	**387,023**

table 14.12: global: final energy demand

PJ/a	2005	2010	2020	2030	2040	2050
Total (incl. non-energy use)	**328,700**	**361,501**	**383,814**	**392,442**	**393,451**	**390,327**
Total (energy use)	**299,300**	**327,393**	**347,127**	**354,335**	**353,803**	**349,845**
Transport	**83,936**	**92,889**	**92,233**	**89,980**	**85,796**	**83,306**
Oil products	80,145	87,364	80,879	72,286	59,949	47,723
Natural gas	2,077	2,392	2,692	2,500	2,201	1,906
Biofuels	784	1,718	4,996	7,996	10,726	12,757
Electricity	930	1,415	3,365	6,572	11,851	19,644
RES electricity	173	273	1,053	3,105	7,793	15,595
Hydrogen	0	0	301	627	1,069	1,276
RES share Transport	**1.1%**	**2.1%**	**6.9%**	**13.0%**	**22.8%**	**35.6%**
Industry	**91,759**	**102,321**	**112,295**	**114,021**	**113,583**	**110,787**
Electricity	22,251	27,788	33,916	36,583	38,493	39,312
RES electricity	4,312	5,632	10,746	16,972	23,772	29,071
District heat	8,009	8,637	11,668	14,128	16,835	19,380
RES district heat	502	1,099	3,919	6,801	10,798	14,491
Coal	17,357	19,579	20,259	16,959	11,263	4,604
Oil products	13,624	13,905	10,265	6,616	3,565	1,582
Gas	23,172	23,479	24,030	23,501	20,969	17,098
Solar	5	292	1,757	4,533	7,910	11,929
Biomass and waste	7,328	8,279	9,198	9,528	10,475	10,748
Geothermal	12	362	1,202	2,174	4,073	6,133
RES share Industry	**13.3%**	**15.3%**	**23.9%**	**35.1%**	**50.2%**	**65.3%**
Other Sectors	**123,665**	**132,183**	**142,598**	**150,334**	**154,423**	**155,752**
Electricity	30,885	34,467	38,673	43,218	48,036	53,123
RES electricity	5,239	6,596	12,923	21,604	32,036	41,943
District heat	7,308	8,127	10,925	14,090	16,637	17,377
RES district heat	534	958	3,482	7,063	10,873	12,858
Coal	4,795	4,858	3,624	2,825	2,257	1,252
Oil products	20,764	21,403	16,289	11,446	7,029	3,818
Gas	24,972	26,053	28,737	26,093	20,912	14,845
Solar	160	523	4,080	10,653	17,888	24,769
Biomass and waste	34,583	36,352	38,727	38,871	36,704	32,984
Geothermal	137	400	1,545	3,138	4,960	7,584
RES share Other Sectors	**32.9%**	**33.9%**	**42.6%**	**54.1%**	**66.4%**	**77.1%**
Total RES	**53,770**	**62,484**	**93,750**	**132,828**	**178,813**	**221,658**
RES share	**16.4%**	**17.3%**	**24.4%**	**33.8%**	**45.4%**	**56.8%**
Non energy use	**29,401**	**34,108**	**36,688**	**38,107**	**39,648**	**40,482**
Oil	22,728	22,348	24,342	25,390	26,477	27,046
Gas	5,498	9,742	9,936	10,204	10,558	10,796
Coal	1,174	2,018	2,410	2,512	2,612	2,640

appendix: oecd north america reference scenario

table 14.13: oecd north america: electricity generation

TWh/a	2005	2010	2020	2030	2040	2050
Power plants	**4,765**	**5,205**	**6,084**	**6,870**	**7,772**	**8,746**
Coal	1,209	1,362	1,601	2,041	2,659	3,440
Lignite	1,021	1,112	1,250	1,319	1,404	1,494
Gas	666	767	970	1,075	1,155	1,212
Oil	192	188	148	114	90	60
Diesel	12	9	6	4	3	2
Nuclear	914	935	1,001	1,045	1,074	1,098
Biomass	44	55	112	146	168	176
Hydro	664	681	694	698	704	705
Wind	19	62	225	324	388	415
PV	0	4	22	32	40	45
Geothermal	24	29	46	56	64	68
Solar thermal power plants	1	1	9	15	20	25
Ocean energy	0	0	1	2	4	7
Combined heat & power production	**353**	**360**	**396**	**480**	**553**	**632**
Coal	55	57	65	86	113	145
Lignite	2	2	2	0	0	0
Gas	235	233	241	283	313	345
Oil	21	21	18	16	11	4
Biomass	40	47	68	91	110	130
Geothermal	0	1	2	4	5	9
CHP by producer						
Main activity producers	204	208	217	267	299	329
Autoproducers	149	153	180	213	255	303
Total generation	**5,118**	**5,565**	**6,481**	**7,350**	**8,325**	**9,378**
Fossil	3,413	3,751	4,301	4,938	5,749	6,701
Coal	1,264	1,420	1,666	2,127	2,772	3,584
Gas	1,023	1,114	1,252	1,319	1,404	1,494
Lignite	901	1,000	1,211	1,358	1,468	1,557
Oil	212	209	166	130	101	64
Diesel	12	9	6	4	3	2
Nuclear	914	935	1,001	1,045	1,074	1,098
Renewables	**792**	**879**	**1,179**	**1,367**	**1,502**	**1,579**
Hydro	664	681	694	698	704	705
Wind	19	62	225	324	388	415
PV	0	4	22	32	40	45
Biomass	84	102	180	237	278	306
Geothermal	24	30	48	59	69	77
Solar thermal	1	1	9	15	20	25
Ocean energy	0	0	1	2	4	7
Import	64	64	64	64	64	64
Import RES	10	10	13	14	15	16
Export	65	65	65	65	65	65
Distribution losses	348	376	425	468	515	562
Own consumption electricity	367	394	450	502	560	627
Electricity	0	0	5	9	14	23
Final energy consumption (electricity)	**4,403**	**4,795**	**5,600**	**6,372**	**7,236**	**8,166**
Fluctuating RES (PV, Wind, Ocean)	19	66	248	358	432	467
Share of fluctuating RES	0.4%	1.2%	3.8%	4.9%	5.2%	5.0%
RES share	**15.5%**	**15.8%**	**18.2%**	**18.6%**	**18.0%**	**16.8%**

table 14.14: oecd north america: heat supply

PJ/A	2005	2010	2020	2030	2040	2050
District heating plants	**0**	**12**	**44**	**63**	**72**	**74**
Fossil fuels	0	12	43	60	64	59
Biomass	0	0	1	3	6	13
Solar collectors	0	0	0	1	1	1
Geothermal	0	0	0	0	0	0
Heat from CHP	**643**	**687**	**833**	**1,099**	**1,409**	**1,881**
Fossil fuels	488	502	578	770	1,021	1,424
Biomass	155	175	236	295	341	381
Geothermal	0	9	20	34	48	77
Direct heating[1]	**21,080**	**23,254**	**24,247**	**25,810**	**26,695**	**27,559**
Fossil fuels	18,909	20,743	21,244	22,017	22,169	22,317
Biomass	2,081	2,364	2,518	2,877	3,241	3,553
Solar collectors	56	75	201	391	613	824
Geothermal	35	72	284	526	672	866
Total heat supply[1]	**21,723**	**23,953**	**25,124**	**26,973**	**28,177**	**29,515**
Fossil fuels	19,397	21,258	21,864	22,846	23,254	23,800
Biomass	2,235	2,539	2,754	3,175	3,588	3,947
Solar collectors	56	75	202	391	614	825
Geothermal	35	81	304	560	720	943
RES share (including RES electricity)	**10.7%**	**11.3%**	**13.0%**	**15.3%**	**17.5%**	**19.4%**

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

table 14.15: oecd north america: CO_2 emissions

MILL t/a	2005	2010	2020	2030	2040	2050
Condensation power plants	**2,656**	**2,895**	**3,065**	**3,350**	**3,738**	**4,184**
Coal	1,076	1,197	1,379	1,594	1,961	2,399
Lignite	1,133	1,208	1,189	1,261	1,294	1,327
Gas	301	348	391	416	421	416
Oil	137	135	101	76	60	40
Diesel	9	7	5	3	2	2
Combined heat & power production	**163**	**120**	**102**	**123**	**155**	**211**
Coal	51	19	14	23	41	75
Lignite	2	1	1	0	0	0
Gas	101	88	77	90	107	133
Oil	9	12	10	9	7	2
CO_2 emissions electricity & steam generation	**2,820**	**3,015**	**3,167**	**3,472**	**3,893**	**4,395**
Coal	1,127	1,217	1,393	1,617	2,003	2,474
Lignite	1,135	1,209	1,190	1,261	1,294	1,327
Gas	402	436	468	506	528	550
Oil & diesel	155	154	116	89	69	44
CO_2 emissions by sector	**6,433**	**6,851**	**7,297**	**7,838**	**8,410**	**9,135**
% of 1990 emissions	111%	119%	126%	136%	146%	158%
Industry	641	664	564	549	540	563
Other sectors	768	852	959	1,017	1,033	1,028
Transport	2,226	2,343	2,633	2,836	3,000	3,243
Electricity & steam generation	2,797	2,991	3,136	3,430	3,829	4,294
District heating	0	1	5	6	7	6
Population (Mill.)	436	459	500	533	559	577
CO_2 emissions per capita (t/capita)	**14.7**	**14.9**	**14.6**	**14.7**	**15.0**	**15.8**

table 14.16: oecd north america: installed capacity

GW	2005	2010	2020	2030	2040	2050
Power plants	**1,071**	**1,151**	**1,322**	**1,465**	**1,613**	**1,772**
Coal	198	220	257	333	433	560
Lignite	168	180	202	216	230	245
Gas	301	324	361	390	404	416
Oil	58	60	48	36	29	20
Diesel	26	21	13	8	6	4
Nuclear	112	114	121	127	130	133
Biomass	6	8	16	22	25	26
Hydro	187	189	190	190	192	192
Wind	9	28	92	114	128	136
PV	0	2	12	18	22	26
Geothermal	3	4	6	8	9	10
Solar thermal power plants	0	1	3	2	3	4
Ocean energy	0	0	0	1	2	3
Combined heat & power production	**114**	**112**	**113**	**129**	**145**	**164**
Coal	24	26	25	30	40	50
Lignite	1	1	1	0	0	0
Gas	71	67	65	74	80	86
Oil	7	7	6	5	3	2
Biomass	11	12	16	19	21	25
Geothermal	0	0	0	1	1	2
CHP by producer						
Main activity producers	76	77	73	83	92	101
Autoproducers	37	35	40	46	53	63
Total generation	**1,184**	**1,263**	**1,435**	**1,594**	**1,758**	**1,936**
Fossil	855	905	977	1,093	1,225	1,382
Coal	222	246	282	364	473	609
Lignite	169	181	202	216	230	245
Gas	372	390	426	464	484	502
Oil	66	66	54	41	32	21
Diesel	26	21	13	8	6	4
Nuclear	112	114	121	127	130	133
Renewables	**217**	**244**	**337**	**374**	**403**	**422**
Hydro	187	189	190	190	192	192
Wind	9	28	92	114	128	136
PV	0	2	12	18	22	26
Biomass	17	20	32	40	46	51
Geothermal	3	4	7	9	10	11
Solar thermal	0	1	3	2	3	4
Ocean energy	0	0	0	1	2	3
Fluctuating RES (PV, Wind, Ocean)	9	30	105	133	152	164
Share of fluctuating RES	0.8%	2.4%	7.3%	8.3%	8.7%	8.5%
RES share	**18.3%**	**19.3%**	**23.5%**	**23.5%**	**22.9%**	**21.8%**

table 14.17: oecd north america: primary energy demand

PJ/A	2005	2010	2020	2030	2040	2050
Total	**115,888**	**123,563**	**133,975**	**144,339**	**154,364**	**164,342**
Fossil	**98,891**	**105,718**	**112,779**	**120,529**	**128,099**	**137,565**
Hard coal	14,117	15,244	16,385	18,781	22,725	27,669
Lignite	10,226	10,891	10,721	11,360	11,654	11,952
Natural gas	26,259	28,711	30,205	31,489	32,326	33,354
Crude oil	48,290	50,872	55,467	58,899	61,394	64,590
Nuclear	**9,968**	**10,202**	**10,922**	**11,402**	**11,718**	**11,980**
Renewables	**7,029**	**7,643**	**10,274**	**12,407**	**14,546**	**14,797**
Hydro	2,390	2,452	2,498	2,513	2,534	2,538
Wind	70	223	810	1,166	1,397	1,494
Solar	58	93	312	558	827	1,075
Biomass	3,886	4,424	5,826	7,019	8,373	7,970
Geothermal	625	450	824	1,144	1,400	1,695
Ocean Energy	0	1	4	7	14	25
RES share	**6.0%**	**6.1%**	**7.6%**	**8.5%**	**9.4%**	**9.0%**

table 14.18: oecd north america: final energy demand

PJ/A	2005	2010	2020	2030	2040	2050
Total (incl. non-energy use)	**80,224**	**86,280**	**95,014**	**103,187**	**110,769**	**118,571**
Total (energy use)	**72,218**	**77,582**	**85,711**	**93,226**	**100,159**	**107,316**
Transport	**31,310**	**33,115**	**37,769**	**41,182**	**44,375**	**47,469**
Oil products	30,884	32,507	36,515	39,316	41,573	44,924
Natural gas	25	30	56	79	105	134
Biofuels	355	449	816	1,096	1,639	976
Electricity	47	128	367	667	1,017	1,369
RES electricity	12	22	77	145	216	269
Hydrogen	0	0	14	24	41	66
RES share Transport	**1.2%**	**1.4%**	**2.4%**	**3.0%**	**4.2%**	**2.6%**
Industry	**16,067**	**17,442**	**16,455**	**16,597**	**16,837**	**17,494**
Electricity	4,456	5,304	5,813	6,060	6,326	6,770
RES electricity	813	927	1,119	1,136	1,117	1,122
District heat	465	553	582	685	828	1,076
RES district heat	139	162	193	221	248	287
Coal	1,218	1,225	784	610	422	308
Oil products	1,961	1,929	1,735	1,733	1,719	1,729
Gas	6,433	6,849	5,957	5,789	5,639	5,592
Solar	0	1	32	66	112	150
Biomass and waste	1,529	1,577	1,484	1,543	1,654	1,679
Geothermal	4	4	68	111	137	190
RES share Industry	**15.5%**	**15.3%**	**17.6%**	**18.5%**	**19.4%**	**19.6%**
Other Sectors	**24,840**	**27,025**	**31,487**	**35,447**	**38,947**	**42,353**
Electricity	11,348	11,829	13,978	16,209	18,702	21,253
RES electricity	1,567	1,724	2,421	2,935	3,322	3,520
District heat	147	115	265	447	623	849
RES district heat	14	19	58	105	141	179
Coal	120	84	84	64	44	41
Oil products	3,642	3,983	4,547	4,948	4,945	4,561
Gas	8,659	9,757	10,892	11,412	11,703	12,120
Solar	56	75	169	324	501	674
Biomass and waste	837	1,125	1,407	1,759	2,052	2,373
Geothermal	31	56	145	283	376	482
RES share Other Sectors	**10.1%**	**11.1%**	**13.3%**	**15.3%**	**16.4%**	**17.1%**
Total RES	**5,357**	**6,140**	**7,991**	**9,728**	**11,524**	**11,902**
RES share	**7.4%**	**7.9%**	**9.3%**	**10.4%**	**11.5%**	**11.1%**
Non energy use	**8,006**	**8,698**	**9,303**	**9,961**	**10,610**	**11,255**
Oil	7,147	7,775	8,323	8,920	9,509	10,094
Gas	849	912	969	1,030	1,090	1,150
Coal	10	10	10	10	10	10

appendix: oecd north america energy [r]evolution scenario

table 14.19: oecd north america: electricity generation

TWh/a	2005	2010	2020	2030	2040	2050
Power plants	**4,765**	**4,990**	**5,082**	**5,366**	**5,680**	**5,700**
Coal	1,209	1,271	1,090	961	361	19
Lignite	1,021	979	472	86	0	0
Gas	666	831	1,078	975	752	175
Oil	192	168	51	28	5	0
Diesel	12	8	4	2	1	0
Nuclear	914	848	408	53	7	0
Biomass	44	69	80	83	84	85
Hydro	664	690	794	843	878	902
Wind	19	78	697	1,173	1,414	1,534
PV	0	4	137	400	720	1,018
Geothermal	24	40	138	333	586	714
Solar thermal power plants	1	3	115	376	752	1,078
Ocean energy	0	2	19	53	120	175
Combined heat & power production	**353**	**421**	**711**	**868**	**979**	**1,056**
Coal	55	52	21	5	1	0
Lignite	2	1	0	0	0	0
Gas	235	282	482	451	317	247
Oil	21	22	16	0	0	0
Biomass	40	60	178	378	604	733
Geothermal	0	3	14	34	57	75
CHP by producer						
Main activity producers	204	215	277	320	353	386
Autoproducers	149	206	434	548	626	670
Total generation	**5,118**	**5,411**	**5,793**	**6,234**	**6,659**	**6,756**
Fossil	3413	3,615	3,214	2,508	1,437	442
Coal	1264	1,323	1,111	966	361	19
Gas	1023	980	472	86	0	0
Lignite	901	1,113	1,560	1,426	1,069	422
Oil	212	190	67	28	5	0
Diesel	12	8	4	2	1	0
Nuclear	914	848	408	53	7	0
Renewables	**792**	**948**	**2,172**	**3,673**	**5,215**	**6,315**
Hydro	664	690	794	843	878	902
Wind	19	78	697	1,173	1,414	1,534
PV	0	4	137	400	720	1,018
Biomass	84	129	258	461	688	818
Geothermal	24	43	152	367	643	789
Solar thermal	1	3	115	376	752	1,078
Ocean energy	0	2	19	53	120	175
Import	64	64	64	64	64	64
Import RES	10	10	13	14	15	16
Export	65	65	65	65	65	65
Distribution losses	348	365	385	403	411	401
Own consumption electricity	367	383	398	418	438	438
Electricity for hydrogen production	0	0	78	140	207	191
Final energy consumption (electricity)	**4,403**	**4,663**	**4,932**	**5,273**	**5,602**	**5,726**
Fluctuating RES (PV, Wind, Ocean)	19	83	853	1626	2,254	2,727
Share of fluctuating RES	0.4%	1.5%	14.7%	26.1%	33.9%	40.4%
RES share	**15.5%**	**17.5%**	**37.5%**	**58.9%**	**78.3%**	**93.5%**
'Efficiency' savings (compared to Ref.)	**0**	**134**	**668**	**1,100**	**1,644**	**2,461**

table 14.20: oecd north america: heat supply

PJ/A	2005	2010	2020	2030	2040	2050
District heating plants	**0**	**211**	**1,143**	**2,607**	**3,556**	**3,009**
Fossil fuels	0	0	0	0	0	0
Biomass	0	120	538	1,098	1,324	997
Solar collectors	0	46	332	886	1,383	1,305
Geothermal	0	45	273	623	849	707
Heat from CHP	**643**	**848**	**1,791**	**2,634**	**3,377**	**3,624**
Fossil fuels	488	595	1,022	1,060	928	765
Biomass	155	226	644	1,272	1,937	2,182
Geothermal	0	27	125	302	513	677
Direct heating[1)]	**21,080**	**21,315**	**21,168**	**20,145**	**17,938**	**15,031**
Fossil fuels	18,909	18,640	16,918	12,845	8,626	5,940
Biomass	2,081	2,280	2,959	3,330	3,281	2,731
Solar collectors	56	287	827	2,894	4,223	4,379
Geothermal	35	108	464	1,076	1,809	1,981
Total heat supply[1)]	**21,723**	**22,373**	**24,102**	**25,386**	**24,872**	**21,664**
Fossil fuels	19,397	19,235	17,940	13,905	9,553	6,705
Biomass	2,235	2,626	4,141	5,699	6,541	5,910
Solar collectors	56	333	1,159	3,781	5,605	5,684
Geothermal	35	180	862	2,002	3,172	3,365
RES share (including RES electricity)	**11%**	**14%**	**26%**	**45%**	**62%**	**69%**
'Efficiency' savings (compared to Ref.)		**1,580**	**1,022**	**1,586**	**3,305**	**7,850**

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

table 14.21: oecd north america: CO_2 emissions

MILL t/a	2005	2010	2020	2030	2040	2050
Condensation power plants	**2,656**	**2,691**	**1,869**	**1,243**	**553**	**73**
Coal	1,076	1,132	928	751	266	14
Lignite	1,133	1,064.2	449.1	82.2	0	0
Gas	301	371	454	389	283	60
Oil	137	116.9	34.9	18.7	3.3	0
Diesel	9	7	3.3	1.6	0.8	0
Combined heat & power production	**163**	**132**	**164**	**148**	**121**	**97**
Coal	51	18	6	2	1	0
Lignite	2	1	0	0	0	0
Gas	101	102	150	146	121	97
Oil	9	10	8	0	0	0
CO_2 emissions electricity & steam generation	**2,820**	**2,823**	**2,034**	**1,391**	**675**	**170**
Coal	1,127	1,150	934	753	267	14
Lignite	1,135	1,065	449	82	0	0
Gas	402	474	604	535	404	157
Oil & diesel	155	134	46	21	4	0
CO_2 emissions by sector	**6,433**	**6,452**	**5,131**	**3,808**	**2,272**	**1,058**
% of 1990 emissions	111%	112%	89%	66%	39%	18%
Industry	641	540	410	299	202	156
Other sectors	768	828	790	613	438	316
Transport	2,226	2,293	1,961	1,582	1,037	491
Electricity & steam generation	2,797	2,791	1,969	1,314	595	95
District heating	0	0	0	0	0	0
Population (Mill.)	436	459	500	533	559	577
CO_2 emissions per capita (t/capita)	**14.7**	**14.1**	**10.3**	**7.1**	**4.1**	**1.8**

table 14.22: oecd north america: installed capacity

GW	2005	2010	2020	2030	2040	2050
Power plants	**1,071**	**1,140**	**1,412**	**1,602**	**1,754**	**1,718**
Coal	198	205	175	157	59	3
Lignite	168	158.9	76.1	14.1	0	0
Gas	301	353	435	403	322	57
Oil	58	53	16	9	2	0
Diesel	26	19	10	5	2.5	0
Nuclear	112	103.5	49	6	1	0
Biomass	6	9.8	11.5	12.2	12.3	12.4
Hydro	187	192	217	230	239	246
Wind	9	35.4	284.5	413.5	469.3	504.5
PV	0	2.2	77.2	227.1	409.7	577.5
Geothermal	3	5.5	19.5	48.1	84.8	103.3
Solar thermal power plants	0	2.0	34.1	61.6	117.8	163.9
Ocean energy	0	0.6	5.5	15.3	34.2	50.5
Combined heat & power production	**114**	**125**	**179**	**194**	**199**	**208**
Coal	24	23	8	1	0	0
Lignite	1	1	0	0	0	0
Gas	71	79	123	108	70	52
Oil	7	7	4	0	0	0
Biomass	11	15	41	78	117	141
Geothermal	0	1	3	7	11	15
CHP by producer						
Main activity producers	76	77	84	78	73	75
Autoproducers	37	48	95	116	126	132
Total generation	**1,184**	**1,265**	**1,591**	**1,796**	**1,953**	**1,926**
Fossil	855	899	848	698	456	112
Coal	222	228	184	158	59	3
Lignite	169	160	76	14	0	0
Gas	372	432	558	511	392	109
Oil	66	59	20	9	2	0
Diesel	26	19	10	5	3	0
Nuclear	112	104	49	6	1	0
Renewables	**217**	**263**	**693**	**1,092**	**1,496**	**1,814**
Hydro	187	192	217	230	239	246
Wind	9	35	284	414	469	504
PV	0	2	77	227	410	577
Biomass	17	25	52	90	130	153
Geothermal	3	6	22	55	96	118
Solar thermal	0	2	34	62	118	164
Ocean energy	0	1	5	15	34	51
Fluctuating RES (PV, Wind, Ocean)	9	38	367	656	913	1,133
Share of fluctuating RES	0.8%	3.0%	23.1%	36.5%	46.8%	58.8%
RES share	**18.3%**	**20.8%**	**43.6%**	**60.8%**	**76.6%**	**94.2%**

table 14.23: oecd north america:primary energy demand

PJ/A	2005	2010	2020	2030	2040	2050
Total	**115,888**	**119,660**	**111,063**	**102,974**	**92,416**	**77,697**
Fossil	**98,891**	**101,704**	**86,678**	**68,313**	**45,908**	**26,617**
Hard coal	14,117	14,536	11,395	9,201	3,911	1,175
Lignite	10,226	9,595	4,046	741	0	0
Natural gas	26,259	31,604	34,009	29,172	22,114	13,911
Crude oil	48,290	45,970	37,228	29,200	19,883	11,531
Nuclear	**9,968**	**9,247**	**4,446**	**578**	**76**	**0**
Renewables	**7,029**	**8,709**	**19,939**	**34,082**	**46,432**	**51,079**
Hydro	2,390	2,484	2,858	3,035	3,161	3,247
Wind	70	279	2,509	4,223	5,090	5,522
Solar	58	365	2,073	6,574	10,904	13,230
Biomass	3,886	4,827	9,702	13,758	16,221	15,903
Geothermal	625	747	2,729	6,302	10,623	12,547
Ocean Energy	0	7	68	191	432	630
RES share	**6.0%**	**7.2%**	**17.9%**	**33.0%**	**50.2%**	**65.7%**
'Efficiency' savings (compared to Ref.)		**3,917**	**22,934**	**41,434**	**62,037**	**86,736**

table 14.24: oecd north america: final energy demand

PJ/a	2005	2010	2020	2030	2040	2050
Total (incl. non-energy use)	**80,224**	**83,743**	**82,201**	**79,826**	**73,206**	**62,721**
Total (energy use)	**72,218**	**74,483**	**74,003**	**72,152**	**65,727**	**55,459**
Transport	**31,310**	**32,466**	**30,419**	**27,520**	**22,297**	**16,721**
Oil products	30,884	31,811	27,176	21,887	14,311	6,746
Natural gas	25	31	64	89	100	79
Biofuels	355	499	2,404	3,835	4,688	5,108
Electricity	47	125	585	1,354	2,656	4,271
RES electricity	12	24	253	846	2,107	4,004
Hydrogen	0	0	190	355	542	517
RES share Transport	**1.2%**	**1.6%**	**8.7%**	**17.0%**	**30.5%**	**54.5%**
Industry	**16,067**	**15,337**	**14,332**	**13,719**	**13,106**	**12,356**
Electricity	4,456	4,960	5,120	5,013	4,793	4,192
RES electricity	813	957	1,932	2,931	3,738	3,919
District heat	465	660	1,411	2,032	2,557	2,749
RES district heat	139	279	847	1,516	2,213	2,503
Coal	1,218	750	299	41	6	4
Oil products	1,961	1,537	905	480	199	177
Gas	6,433	5,802	4,684	3,708	2,679	2,041
Solar	0	160	356	738	951	1,122
Biomass and waste	1,529	1,424	1,373	1,404	1,381	1,360
Geothermal	4	44	185	304	540	711
RES share Industry	**15.5%**	**18.7%**	**32.7%**	**50.2%**	**67.3%**	**77.8%**
Other Sectors	**24,840**	**26,680**	**29,252**	**30,913**	**30,324**	**26,383**
Electricity	11,348	11,702	12,051	12,615	12,718	12,151
RES electricity	1,567	1,905	4,438	7,386	9,942	11,330
District heat	147	294	1,412	3,097	4,262	3,769
RES district heat	14	135	991	2,572	3,689	3,259
Coal	120	324	0	22	5	1
Oil products	3,642	3,734	2,529	1,354	800	652
Gas	8,659	9,253	10,541	8,694	6,022	3,964
Solar	56	127	471	2,156	3,271	3,258
Biomass and waste	837	1,194	2,061	2,453	2,396	1,748
Geothermal	31	52	188	522	851	840
RES share Other Sectors	**10.1%**	**12.8%**	**27.9%**	**48.8%**	**66.4%**	**77.5%**
Total RES	**5,357**	**6,801**	**15,579**	**26,909**	**36,208**	**39,375**
RES share	**7.4%**	**9.1%**	**21.1%**	**37.3%**	**55.1%**	**71.0%**
Non energy use	**8,006**	**9,260**	**8,198**	**7,674**	**7,480**	**7,262**
Oil	7,147	4,526	4,016	3,763	3,670	3,565
Gas	849	4,268	3,765	3,516	3,424	3,321
Coal	10	466	417	395	386	376

appendix: latin america reference scenario

table 14.25: latin america: electricity generation

TWh/a	2005	2010	2020	2030	2040	2050
Power plants	**906**	**1,132**	**1,557**	**1,978**	**2,510**	**3,158**
Coal	18	24	36	56	185	423
Lignite	6	9	14	23	35	50
Gas	128	237	435	641	857	1,085
Oil	87	74	60	41	35	35
Diesel	8	7	36	2	2	2
Nuclear	17	27	4	34	32	30
Biomass	19	25	36	48	59	71
Hydro	619	722	915	1,095	1,250	1,390
Wind	0	4	13	22	31	41
PV	0	0	1	2	3	6
Geothermal	2	3	7	12	17	23
Solar thermal power plants	0	0	0	2	3	4
Ocean energy	0	0	0	0	0	0
Combined heat & power production	**0**	**5**	**39**	**73**	**95**	**100**
Coal	0	1	8	13	15	14
Lignite	0	0	0	0	0	0
Gas	0	4	29	55	71	75
Oil	0	0	0	0	0	0
Biomass	0	0	2	5	9	11
Geothermal	0	0	0	0	0	0
CHP by producer						
Main activity producers	0	0	0	0	0	0
Autoproducers	0	5	39	73	95	100
Total generation	**906**	**1,137**	**1,596**	**2,051**	**2,605**	**3,258**
Fossil	248	356	586	831	1,200	1,683
Coal	18	26	44	69	201	437
Lignite	6	9	14	23	35	50
Gas	128	241	464	696	928	1,160
Oil	87	74	60	41	35	35
Diesel	8	7	4	2	2	2
Nuclear	17	27	36	34	32	30
Renewables	**641**	**754**	**974**	**1,186**	**1,373**	**1,545**
Hydro	619	722	915	1,095	1,250	1,390
Wind	0	4	13	22	31	41
PV	0	0	1	2	3	6
Biomass	19	25	38	53	68	82
Geothermal	2	3	7	12	17	23
Solar thermal	0	0	0	2	3	4
Ocean energy	0	0	0	0	0	0
Import	53	66	94	123	159	202
Import RES	9	12	17	22	28	36
Export	51	64	90	118	153	195
Distribution losses	147	184	233	264	266	264
Own consumption electricity	28	42	72	91	139	191
Electricity for hydrogen production	0	0	0	0	0	0
Final energy consumption (electricity)	**734**	**914**	**1,295**	**1,701**	**2,206**	**2,811**
Fluctuating RES (PV, Wind, Ocean)	0	4	14	24	35	47
Share of fluctuating RES	0%	0.4%	0.9%	1.2%	1.3%	1.4%
RES share	**70.8%**	**66.3%**	**61.0%**	**57.8%**	**52.7%**	**47.4%**

table 14.26: latin america: heat supply

PJ/A	2005	2010	2020	2030	2040	2050
District heating plants	**0**	**0**	**2**	**4**	**5**	**5**
Fossil fuels	0	0	2	4	5	5
Biomass	0	0	0	0	0	0
Solar collectors	0	0	0	0	0	0
Geothermal	0	0	0	0	0	0
Heat from CHP	**0**	**28**	**176**	**274**	**308**	**308**
Fossil fuels	0	28	167	255	280	274
Biomass	0	0	9	19	28	34
Geothermal	0	0	0	0	0	0
Direct heating[1)]	**5,911**	**6,513**	**7,765**	**8,961**	**10,217**	**11,556**
Fossil fuels	3,527	4,077	5,200	6,232	7,296	8,412
Biomass	2,381	2,433	2,524	2,633	2,756	2,897
Solar collectors	2	2	2	7	12	16
Geothermal	0	0	39	90	153	231
Total heat supply[1)]	**5,911**	**6,541**	**7,943**	**9,238**	**10,529**	**11,869**
Fossil fuels	3,527	4,105	5,369	6,490	7,581	8,690
Biomass	2,381	2,433	2,533	2,652	2,784	2,931
Solar collectors	2	2	2	7	12	16
Geothermal	0	0	39	90	153	231
RES share (including RES electricity)	**40.3%**	**37.2%**	**32.4%**	**29.7%**	**28.0%**	**26.8%**

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

table 14.27: latin america: CO_2 emissions

MILL t/a	2005	2010	2020	2030	2040	2050
Condensation power plants	**174**	**219**	**292**	**365**	**551**	**810**
Coal	20	25	34	49	149	315
Lignite	9	12	18	26	37	50
Gas	67	116	193	259	339	421
Oil	59	50	42	29	24	23
Diesel	20	15	6	3	2	2
Combined heat & power production	**0**	**3**	**21**	**34**	**39**	**38**
Coal	0	1	6	10	10	9
Lignite	0	0	0	0	0	0
Gas	0	2	14	24	29	29
Oil	0	0	0	0	0	0
CO_2 emissions electricity & steam generation	**174**	**223**	**313**	**398**	**590**	**849**
Coal	20	27	40	58	159	324
Lignite	9	12	18	26	37	50
Gas	67	119	207	283	367	450
Oil & diesel	79	65	48	32	26	25
CO_2 emissions by sector	**827**	**954**	**1,220**	**1,481**	**1,873**	**2,350**
% of 1990 emissions	125%	144%	184%	223%	282%	354%
Industry	189	234	293	346	394	439
Other sectors	120	128	181	224	266	310
Transport	344	372	453	546	662	791
Electricity & steam generation	174	219	292	365	551	810
District heating	0	0	0	0	0	0
Population (Mill.)	450	479	534	580	613	632
CO_2 emissions per capita (t/capita)	**1.8**	**2.0**	**2.3**	**2.6**	**3.1**	**3.7**

table 14.28: latin america: installed capacity

GW	2005	2010	2020	2030	2040	2050
Power plants	**213**	**279**	**403**	**509**	**657**	**846**
Coal	4	5	6	10	37	94
Lignite	0.8	1.2	2.0	3.1	4.9	7.1
Gas	39	78	152	214	295	388
Oil	17	18	20	16	15	16
Diesel	11	10	6	3	3	3
Nuclear	2.4	3.9	5.1	4.9	4.6	4.3
Biomass	3.8	4.6	6.1	7.2	8.2	9.1
Hydro	135	157	199	238	272	302
Wind	0.2	1.8	5.2	9.0	11.9	15.5
PV	0	0	0.7	1.3	2.3	4.1
Geothermal	0.4	0.5	1.0	1.8	2.7	3.5
Solar thermal power plants	0	0	0.1	0.4	0.5	0.5
Ocean energy	0	0	0	0	0	0
Combined heat & power production	**0**	**1**	**9**	**16**	**20**	**21**
Coal	0	0	2	3	4	3
Lignite	0	0	0	0	0	0
Gas	0	1	6	12	14	15
Oil	0	0	0	0	0	0
Biomass	0	0	0	1	2	2
Geothermal	0	0	0	0	0	0
CHP by producer						
Main activity producers	0	0	0	0	0	0
Autoproducers	0	1	9	16	20	21
Total generation	**213**	**280**	**412**	**525**	**677**	**867**
Fossil	72	113	194	261	373	526
Coal	4	5	8	13	41	97
Lignite	1	1	2	3	5	7
Gas	39	79	158	225	310	402
Oil	17	18	20	16	15	16
Diesel	11	10	6	3	3	3
Nuclear	2.4	3.9	5.1	4.9	4.6	4.3
Renewables	**139**	**164**	**212**	**259**	**299**	**337**
Hydro	135	157	199	238	272	302
Wind	0	2	5	9	12	15
PV	0	0	1	1	2	4
Biomass	3.8	4.6	6.5	8.3	10	11.4
Geothermal	0	0	1	2	3	3
Solar thermal	0	0	0	0	1	1
Ocean energy	0	0	0	0	0	0
Fluctuating RES (PV, Wind, Ocean)	0.2	1.8	5.9	10.3	14.2	19.6
Share of fluctuating RES	0.1%	0.7%	1.4%	2.0%	2.1%	2.3%
RES share	**65.1%**	**58.4%**	**51.6%**	**49.3%**	**44.2%**	**38.9%**

table 14.29: latin america: primary energy demand

PJ/A	2005	2010	2020	2030	2040	2050
Total	**21,143**	**24,031**	**30,196**	**36,374**	**43,859**	**52,268**
Fossil	**14,730**	**16,860**	**21,510**	**26,199**	**32,550**	**39,867**
Hard coal	894	1,048	1,245	1,507	2,652	4,478
Lignite	78	110	160	234	332	448
Natural gas	4,246	5,526	8,159	10,601	13,282	15,955
Crude oil	9,511	10,176	11,946	13,857	16,284	18,985
Nuclear	**183**	**295**	**393**	**371**	**349**	**327**
Renewables	**6,230**	**6,876**	**8,294**	**9,803**	**10,961**	**12,074**
Hydro	2,229	2,599	3,294	3,942	4,500	5,004
Wind	1	14	46	79	113	147
Solar	2	2	7	21	36	50
Biomass	3,909	4,158	4,718	5,372	5,777	6,198
Geothermal	89	102	229	389	535	675
Ocean Energy	0	0	0	0	0	0
RES share	**28.7%**	**27.9%**	**26.7%**	**26.2%**	**24.3%**	**22.5%**

table 14.30: latin america: final energy demand

PJ/A	2005	2010	2020	2030	2040	2050
Total (incl. non-energy use)	**16,706**	**18,724**	**23,338**	**28,111**	**33,409**	**39,295**
Total (energy use)	**15,484**	**17,365**	**21,708**	**26,210**	**31,236**	**36,850**
Transport	**5,131**	**5,595**	**6,933**	**8,485**	**10,216**	**12,135**
Oil products	4,598	5,017	6,185	7,499	9,136	10,948
Natural gas	232	192	137	95	65	42
Biofuels	292	377	601	880	1,003	1,127
Electricity	9	9	10	11	13	18
RES electricity	6	6	6	6	7	9
Hydrogen	0	0	0	0	0	0
RES share Transport	**5.8%**	**6.8%**	**8.8%**	**10.4%**	**9.9%**	**9.4%**
Industry	**5,683**	**6,572**	**8,168**	**9,700**	**11,388**	**13,269**
Electricity	1,255	1,555	2,206	2,909	3,788	4,842
RES electricity	888	1,031	1,347	1,682	1,996	2,296
District heat	0	28	176	274	308	308
RES district heat	0	0	0	0	0	0
Coal	333	420	459	500	537	571
Oil products	1,101	1,476	1,745	2,006	2,284	2,584
Gas	1,348	1,455	1,759	2,071	2,397	2,741
Solar	0	0	0	0	0	0
Biomass and waste	1,647	1,639	1,811	1,911	2,023	2,147
Geothermal	0	0	13	30	51	77
RES share Industry	**44.6%**	**40.6%**	**38.8%**	**37.4%**	**35.7%**	**34.1%**
Other Sectors	**4,670**	**5,198**	**6,608**	**8,025**	**9,631**	**11,446**
Electricity	1,377	1,727	2,447	3,203	4,141	5,258
RES electricity	974	1,145	1,493	1,852	2,182	2,493
District heat	0	0	0	0	0	0
RES district heat	0	0	0	0	0	0
Coal	4	0	8	38	62	80
Oil products	1,231	1,331	1,841	2,143	2,451	2,774
Gas	492	512	767	1,074	1,385	1,707
Solar	2	2	2	7	12	16
Biomass and waste	1,563	1,626	1,534	1,538	1,544	1,557
Geothermal	0	0	9	21	36	54
RES share Other Sectors	**54.4%**	**53.4%**	**46.0%**	**42.6%**	**39.2%**	**36.0%**
Total RES	**5,373**	**5,826**	**6,816**	**7,927**	**8,854**	**9,775**
RES share	**32.2%**	**31.1%**	**29.2%**	**28.2%**	**26.5%**	**24.9%**
Non energy use	**1,222**	**1,358**	**1,630**	**1,902**	**2,173**	**2,445**
Oil	825	917	1,100	1,283	1,467	1,650
Gas	392	436	523	610	697	784
Coal	5	6	7	8	9	10

appendix: latin america energy [r]evolution scenario

table 14.31: latin america: electricity generation

TWh/a	2005	2010	2020	2030	2040	2050
Power plants	**906**	**1,107**	**1,213**	**1,387**	**1,751**	**2,280**
Coal	18	20	5	12	6	1
Lignite	6	4	0	0	0	0
Gas	128	200	165	124	100	91
Oil	87	78	20	0	0	2
Diesel	8	7	2	2	0	0
Nuclear	17	18	18	5	0	0
Biomass	19	40	85	110	155	234
Hydro	619	730	770	785	800	822
Wind	0	6	115	215	470	720
PV	0	1	14	80	110	160
Geothermal	2	4	8	15	20	25
Solar thermal power plants	0	0	10	35	80	200
Ocean energy	0	0	2	4	10	25
Combined heat & power production	**0**	**24**	**120**	**192**	**266**	**335**
Coal	0	0	0	0	0	0
Lignite	0	0	0	0	0	0
Gas	0	9	29	44	48	46
Oil	0	0	0	0	0	0
Biomass	0	15	84	135	185	228
Geothermal	0	0	7	12	33	61
CHP by producer						
Main activity producers	0	3	15	35	48	60
Autoproducers	0	21	105	157	218	275
Total generation	**906**	**1,130**	**1,333**	**1,579**	**2,017**	**2,615**
Fossil	248	317	220	182	155	140
Coal	18	20	5	12	6	1
Lignite	6	4	0	0	0	0
Gas	128	209	194	168	148	137
Oil	87	78	20	0	0	2
Diesel	8	7	2	2	0	0
Nuclear	17	18	18	5	0	0
Renewables	**641**	**796**	**1,095**	**1,392**	**1,863**	**2,475**
Hydro	619	730	770	785	800	822
Wind	0	6	115	215	470	720
PV	0	1	14	80	110	160
Biomass	19	55	169	245	340	462
Geothermal	2	4	15	27	53	86
Solar thermal	0	0	10	35	80	200
Ocean energy	0	0	2	4	10	25
Import	53	66	77	89	105	125
Import RES	9	12	14	16	19	22
Export	51	64	74	85	101	121
Distribution losses	147	191.0	212.0	219.0	234.0	253.0
Own consumption electricity	28	27.0	42.0	75.0	122.0	183.0
Electricity for hydrogen production	0	0	0.2	7	18	32
Final energy consumption (electricity)	**734**	**914**	**1,082**	**1,282**	**1,647**	**2,151**
Fluctuating RES (PV, Wind, Ocean)	0	7	131	299	590	905
Share of fluctuating RES	0%	0.6%	9.8%	18.9%	29.2%	34.6%
RES share	**70.8%**	**70.4%**	**82.2%**	**88.1%**	**92.3%**	**94.6%**
'Efficiency' savings (compared to Ref.)		**0**	**213**	**419**	**559**	**659**

table 14.32: latin america: heat supply

PJ/A	2005	2010	2020	2030	2040	2050
District heating plants	**0**	**8**	**151**	**189**	**300**	**421**
Fossil fuels	0	1	17	13	6	0
Biomass	0	5	105	129	189	232
Solar collectors	0	0	14	28	60	105
Geothermal	0	1	15	19	45	84
Heat from CHP	**0**	**133**	**608**	**883**	**1,165**	**1,500**
Fossil fuels	0	50	134	179	177	161
Biomass	0	80	415	603	711	813
Geothermal	0	3	59	101	277	526
Direct heating[1]	**5,911**	**6,409**	**6,794**	**7,213**	**7,424**	**7,543**
Fossil fuels	3,527	3,700	3,172	2,737	2,044	1,459
Biomass	2,381	2,508	2,862	3,140	3,386	3,444
Solar collectors	2	148	490	853	1,291	1,649
Geothermal	0	53	269	482	703	991
Total heat supply[1]	**5,911**	**6,549**	**7,552**	**8,285**	**8,888**	**9,464**
Fossil fuels	3,527	3,752	3,323	2,929	2,227	1,619
Biomass	2,381	2,594	3,383	3,872	4,286	4,489
Solar collectors	2	148	504	882	1,351	1,754
Geothermal	0	56	343	602	1,025	1,602
RES share (including RES electricity)	**40.3%**	**43%**	**56%**	**65%**	**75%**	**83%**
'Efficiency' savings (compared to Ref.)		**-9**	**390**	**953**	**1,641**	**2405**

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

table 14.33: latin america: CO_2 emissions

MILL t/a	2005	2010	2020	2030	2040	2050
Condensation power plants	**174**	**192**	**95**	**63**	**45**	**37**
Coal	20	21	4	10	5	1
Lignite	9	5.4	0	0	0	0
Gas	67	98	73	50	40	35
Oil	59	53.2	13.9	0	0	1.4
Diesel	20	15	3	2.5	0	0
Combined heat & power production	**0**	**5**	**15**	**21**	**22**	**20**
Coal	0	0	0	0	0	0
Lignite	0	0	0	0	0	0
Gas	0	5	15	21	22	20
Oil	0	0	0	0	0	0
CO_2 emissions electricity & steam generation	**174**	**198**	**109**	**83**	**67**	**58**
Coal	20	21	4	10	5	1
Lignite	9	5	0	0	0	0
Gas	67	104	88	71	62	56
Oil & diesel	79	68	17	2	0	1
CO_2 emissions by sector	**827**	**894**	**749**	**655**	**513**	**369**
% of 1990 emissions	125%	135%	113%	99%	77%	56%
Industry	189	208	173	143	105	79
Other sectors	120	117	106	93	65	48
Transport	344	375	371	349	290	197
Electricity & steam generation	174	193	98	70	53	45
District heating	0	0	1	1	0	0
Population (Mill.)	450	479	534	580	613	632
CO_2 emissions per capita (t/capita)	**1.8**	**1.9**	**1.4**	**1.1**	**0.8**	**0.6**

table 14.34: latin america: installed capacity

GW	2005	2010	2020	2030	2040	2050
Power plants	**213**	**271**	**314**	**389**	**507**	**672**
Coal	4	4	1	2	1	0
Lignite	0.8	0.5	0	0	0	0
Gas	39	66	58	41	34	33
Oil	17	19	7	0	0	1
Diesel	10.9	10	2.9	2.9	0	0
Nuclear	2.4	2.5	2.5	0.7	0	0
Biomass	3.8	7.4	14.1	16.6	21.5	30
Hydro	135	159	167	171	174	179
Wind	0.2	2.7	46.9	87.8	178.7	273.8
PV	0	0.5	10	57.1	78.6	114.3
Geothermal	0.4	0.6	1.2	2.3	3.1	3.8
Solar thermal power plants	0	0	3.2	5.8	12.7	30.8
Ocean energy	0	0	0.6	1.1	2.9	7.1
Combined heat & power production	**0**	**6**	**27**	**41**	**55**	**67**
Coal	0	0	0	0	0	0
Lignite	0	0	0	0	0	0
Gas	0	2	7	11	11	11
Oil	0	0	0	0	0	0
Biomass	0	4	19	28	37	45
Geothermal	0	0	1	2	6	12
CHP by producer						
Main activity producers	0	1	4	8	11	13
Autoproducers	0	5	23	33	44	55
Total generation	**213**	**277**	**341**	**430**	**562**	**739**
Fossil	72	101	75	57	47	44
Coal	4	4	1	2	1	0
Lignite	1	1	0	0	0	0
Gas	39	68	64	52	46	43
Oil	17	19	7	0	0	1
Diesel	11	10	3	3	0	0
Nuclear	2.4	2.5	2.5	0.7	0	0
Renewables	**139**	**174**	**264**	**372**	**515**	**695**
Hydro	135	159	167	171	174	179
Wind	0	3	47	88	179	274
PV	0	1	10	57	79	114
Biomass	3.8	11	33	45	59	75
Geothermal	0	1	3	5	9	16
Solar thermal	0	0	3	6	13	31
Ocean energy	0	0	1	1	3	7
Fluctuating RES (PV, Wind, Ocean)	0.2	3.2	57.5	146.0	260.1	395.2
Share of fluctuating RES	0.1%	1.2%	16.9%	34.0%	46.3%	53.5%
RES share	**65.1%**	**62.6%**	**77.4%**	**86.6%**	**91.6%**	**94.0%**

table 14.35: latin america: primary energy demand

PJ/A	2005	2010	2020	2030	2040	2050
Total	**21,143**	**23,716**	**25,201**	**26,947**	**29,367**	**32,484**
Fossil	**14,730**	**16,019**	**13,995**	**12,695**	**10,741**	**8,570**
Hard coal	894	965	707	582	425	355
Lignite	78	48	0	0	0	0
Natural gas	4,246	5,369	5,271	4,932	4,681	3,986
Crude oil	9,511	9,636	8,018	7,181	5,634	4,229
Nuclear	**183**	**191**	**191**	**55**	**0**	**0**
Renewables	**6,230**	**7,506**	**11,014**	**14,198**	**18,626**	**23,915**
Hydro	2,229	2,628	2,772	2,826	2,880	2,959
Wind	1	22	414	774	1,692	2,592
Solar	2	150	590	1,296	2,035	3,050
Biomass	3,909	4,505	6,502	8,049	9,855	11,986
Geothermal	89	201	729	1,239	2,129	3,237
Ocean Energy	0	0	7	14	36	90
RES share	**28.7%**	**30.8%**	**42.4%**	**51.1%**	**61.4%**	**71.1%**
'Efficiency' savings (compared to Ref.)		**302**	**4,944**	**9,349**	**14,366**	**19,582**

table 14.36: latin america: final energy demand

PJ/A	2005	2010	2020	2030	2040	2050
Total (incl. non-energy use)	**16,706**	**18,657**	**20,384**	**21,833**	**23,336**	**25,049**
Total (energy use)	**15,484**	**17,288**	**18,894**	**20,242**	**21,637**	**23,229**
Transport	**5,131**	**5,595**	**5,718**	**5,842**	**5,965**	**6,089**
Oil products	4,598	5,001	4,952	4,640	3,824	2,552
Natural gas	232	253	258	257	250	231
Biofuels	292	326	459	747	1,205	1,865
Electricity	9	14	49	180	638	1,355
RES electricity	6	10	40	158	589	1,282
Hydrogen	0	0	0	17	48	85
RES share Transport	**5.8%**	**6.0%**	**8.7%**	**15.8%**	**30.8%**	**53.0%**
Industry	**5,683**	**6,547**	**7,288**	**7,722**	**7,978**	**8,136**
Electricity	1,255	1,555	1,983	2,329	2,685	3,015
RES electricity	888	1,094	1,629	2,053	2,479	2,854
District heat	0	131	517	592	815	1,116
RES district heat	0	71	403	462	682	1,010
Coal	333	366	318	130	29	6
Oil products	1,101	1,126	667	482	116	64
Gas	1,348	1,534	1,570	1,607	1,598	1,248
Solar	0	19	220	374	400	409
Biomass and waste	1,647	1,781	1,912	2,049	2,139	2,041
Geothermal	0	35	99	159	196	237
RES share Industry	**44.6%**	**45.8%**	**58.5%**	**66.0%**	**73.9%**	**80.5%**
Other Sectors	**4,670**	**5,146**	**5,888**	**6,679**	**7,694**	**9,005**
Electricity	1,377	1,724	1,863	2,106	2,606	3,374
RES electricity	974	1,213	1,531	1,856	2,407	3,193
District heat	0	8	230	464	626	772
RES district heat	0	5	179	362	524	698
Coal	4	35	0	0	0	0
Oil products	1,231	1,145	883	706	367	247
Gas	492	507	610	570	518	385
Solar	2	128	270	479	890	1,240
Biomass and waste	1,563	1,581	1,890	2,083	2,280	2,426
Geothermal	0	18	142	271	407	562
RES share Other Sectors	**54.4%**	**57.2%**	**68.1%**	**75.6%**	**84.6%**	**90.2%**
Total RES	**5,373**	**6,280**	**8,776**	**11,068**	**14,241**	**17,897**
RES share	**32.2%**	**36.3%**	**46.4%**	**54.7%**	**65.8%**	**77.0%**
Non energy use	**1,222**	**1,369**	**1,490**	**1,591**	**1,699**	**1,820**
Oil	825	924	1,006	1,074	1,147	1,228
Gas	392	439	478	510	545	584
Coal	5	6	6	7	7	8

appendix: oecd europe reference scenario

table 14.37: oecd europe: electricity generation

TWh/a	2005	2010	2020	2030	2040	2050
Power plants	**2,853**	**3,037**	**3,529**	**3,973**	**4,358**	**4,742**
Coal	456	513	597	851	1,112	1,433
Lignite	274	239	205	192	189	185
Gas	463	535	742	1,003	1,135	1,210
Oil	82	76	49	9	4	1
Diesel	4	2	1	0	0	0
Nuclear	981	945	796	574	475	430
Biomass	29	35	52	57	60	62
Hydro	486	535	607	648	650	650
Wind	71	142	432	556	625	645
PV	2	5	22	37	47	54
Geothermal	6	7	13	16	19	22
Solar thermal power plants	0	2	9	21	28	31
Ocean energy	1	1	4	9	14	18
Combined heat & power production	**628**	**705**	**759**	**832**	**860**	**877**
Coal	145	184	135	157	170	163
Lignite	81	65	59	60	59	58
Gas	295	324	364	391	398	410
Oil	48	47	47	47	46	20
Biomass	58	85	153	175	184	224
Geothermal	1	1	1	2	2	2
CHP by producer						
Main activity producers	443	498	534	604	625	641
Autoproducers	185	207	225	228	235	236
Total generation	**3,481**	**3,742**	**4,288**	**4,805**	**5,218**	**5,618**
Fossil	1,848	1,985	2,198	2,710	3,114	3,480
Coal	601	697	731	1,008	1,282	1,597
Lignite	355	304	264	252	248	243
Gas	757	859	1,106	1,394	1,533	1,620
Oil	131	123	96	56	50	21
Diesel	4	2	1	0	0	0
Nuclear	981	945	796	574	475	430
Renewables	**653**	**812**	**1,293**	**1,521**	**1,629**	**1,708**
Hydro	486	535	607	648	650	650
Wind	71	142	432	556	625	645
PV	2	5	22	37	47	54
Biomass	87	120	205	232	244	286
Geothermal	7	8	14	18	21	24
Solar thermal	0	2	9	21	28	31
Ocean energy	1	1	4	9	14	18
Import	348	376	445	486	521	553
Import RES	65	82	131	154	166	172
Export	330	357	422	462	494	524
Distribution losses	244	255	283	294	293	297
Own consumption electricity	298	302	342	362	367	366
Electricity for hydrogen production	0	0	0	0	0	0
Final energy consumption (electricity)	**2,957**	**3,204**	**3,685**	**4,174**	**4,585**	**4,983**
Fluctuating RES (PV, Wind, Ocean)	73	148	458	602	686	717
Share of fluctuating RES	2.1%	3.9%	10.7%	12.5%	13.1%	12.8%
RES share	**18.7%**	**21.7%**	**30.2%**	**31.6%**	**31.2%**	**30.4%**

table 14.38: oecd europe: heat supply

PJ/A	2005	2010	2020	2030	2040	2050
District heating plants	**2,179**	**1,952**	**1,398**	**1,273**	**1,171**	**1,310**
Fossil fuels	1,662	1,532	1,094	995	914	1,021
Biomass	506	410	294	267	246	275
Solar collectors	0	0	0	0	1	1
Geothermal	10	10	10	10	11	12
Heat from CHP	**2,250**	**2,428**	**2,815**	**3,162**	**3,296**	**3,217**
Fossil fuels	1,981	2,040	2138	2,524	2,782	2,631
Biomass	258	382	664	624	499	571
Geothermal	10	7	12	14	15	15
Direct heating[1)]	**20,314**	**20,605**	**19,827**	**21,295**	**22,328**	**23,219**
Fossil fuels	18,456	18,341	17,264	18,140	18,593	18,873
Biomass	1,723	2,059	2,030	2,239	2,401	2,700
Solar collectors	44	109	292	545	825	972
Geothermal	90	96	241	370	508	674
Total heat supply[1)]	**24,743**	**24,985**	**24,039**	**25,730**	**26,794**	**27,746**
Fossil fuels	22,100	21,913	20,496	21,659	22,289	22,526
Biomass	2,488	2,850	2,988	3,131	3,146	3,546
Solar collectors	45	109	292	546	826	973
Geothermal	111	113	263	394	533	702
RES share (including RES electricity)	**10.7%**	**12.3%**	**14.7%**	**15.8%**	**16.8%**	**18.8%**

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

table 14.39: oecd europe: CO_2 emissions

MILL t/a	2005	2010	2020	2030	2040	2050
Condensation power plants	**925**	**1,028**	**1,159**	**1,306**	**1,388**	**1,452**
Coal	391	471	552	695	798	906
Lignite	282	267	237	204	183	164
Gas	187	235	335	402	403	381
Oil	62	53	33	6	3	1
Diesel	3.4	2.1	0.8	0.3	0.1	0
Combined heat & power production	**495**	**417**	**323**	**369**	**444**	**426**
Coal	156	162	92	121	152	150
Lignite	98	59	41	41	66	63
Gas	146	150	155	180	200	202
Oil	96	46	35	28	27	11
CO_2 emissions electricity & steam generation	**1,421**	**1,445**	**1,482**	**1,676**	**1,832**	**1,878**
Coal	547	633	644	815	950	1,055
Lignite	380	325	278	244	249	228
Gas	332	386	490	582	603	583
Oil & diesel	162	101	69	34	29	12
CO_2 emissions by sector	**4,062**	**4,085**	**4,004**	**4,283**	**4,477**	**4,553**
% of 1990 emissions	99%	100%	98%	104%	109%	111%
Industry	716	661	591	604	597	545
Other sectors	807	786	749	771	786	812
Transport	1,129	1,169	1,190	1,239	1,273	1,298
Electricity & steam generation	1,260	1,329	1,374	1,579	1,740	1,808
District heating	149	141	100	89	81	90
Population (Mill.)	536	547	561	568	568	563
CO_2 emissions per capita (t/capita)	**7.6**	**7.5**	**7.1**	**7.5**	**7.9**	**8.1**

table 14.40: oecd europe: installed capacity

GW	2005	2010	2020	2030	2040	2050
Power plants	**666**	**709**	**876**	**953**	**1,035**	**1,109**
Coal	90	102	118	169	220	284
Lignite	54.3	47.4	40.6	38.1	37.5	36.7
Gas	110	123	160	204	218	220
Oil	43	45	41	8	4	1
Diesel	3.7	2.3	0.9	0.3	0.1	0.1
Nuclear	131	126	106.1	76.5	63.3	61.4
Biomass	4.7	6	7.8	8.2	8.3	8.3
Hydro	184	187	212	227	227	227
Wind	42.1	64	162.9	178.2	200.3	206.7
PV	1.5	4.8	19.1	32.2	40.9	47.0
Geothermal	0.9	1.0	1.9	2.3	2.7	3.1
Solar thermal power plants	0	0.7	3.0	6.5	8.0	7.8
Ocean energy	0.3	0.2	1.8	3.3	4.5	5.1
Combined heat & power production	**159**	**173**	**182**	**185**	**186**	**185**
Coal	33	41	30	35	38	36
Lignite	18	14	13	13	13	13
Gas	68	73	81	85	86	88
Oil	22	18	16	16	14	6
Biomass	17	25	42	35	35	42
Geothermal	0	0	0	0	0	0
CHP by producer						
Main activity producers	112	124	132	136	138	138
Autoproducers	47	48	50	49	48	47
Total generation	**825**	**882**	**1,058**	**1,138**	**1,221**	**1,294**
Fossil	443	467	501	569	631	685
Coal	123	143	149	204	259	320
Lignite	72	62	54	51	51	49
Gas	179	196	241	289	303	308
Oil	65	64	57	24	18	7
Diesel	4	2	1	0	0	0
Nuclear	130.5	125.8	106.1	76.5	63.3	61.4
Renewables	**251**	**289**	**451**	**493**	**527**	**548**
Hydro	184	187	212	227	227	227
Wind	42	64	163	178	200	207
PV	2	5	19	32	41	47
Biomass	22	30.9	49.3	43.3	43.1	50.5
Geothermal	1	1	2	3	3	3
Solar thermal	0	1	3	6	8	8
Ocean energy	0	0	2	3	5	5
Fluctuating RES (PV, Wind, Ocean)	44	69.0	183.8	213.7	245.7	258.8
Share of fluctuating RES	5.3%	7.8%	17.4%	18.8%	20.1%	20%
RES share	**30.4%**	**32.8%**	**42.6%**	**43.3%**	**43.2%**	**42.3%**

table 14.41: oecd europe: primary energy demand

PJ/A	2005	2010	2020	2030	2040	2050
Total	**81,482**	**82,762**	**83,795**	**86,896**	**88,953**	**90,284**
Fossil	**64,215**	**64,685**	**64,214**	**68,318**	**70,819**	**71,698**
Hard coal	10,612	10,715	9,902	11,490	12,635	13,548
Lignite	3,419	2,932	2,508	2,202	2,242	2,050
Natural gas	19,773	21,030	22,873	25,962	27,354	27,965
Crude oil	30,411	30,008	28,930	28,664	28,587	28,134
Nuclear	**10,699**	**10,311**	**8,685**	**6,263**	**5,183**	**4,692**
Renewables	**6,568**	**7,766**	**10,896**	**12,315**	**12,952**	**13,894**
Hydro	1,749	1,926	2,185	2,333	2,340	2,340
Wind	255	511	1,555	2,002	2,250	2,322
Solar	50	134	403	754	1,096	1,279
Biomass	4,152	4,968	6,284	6,584	6,443	6,917
Geothermal	360	227	468	642	823	1,036
Ocean Energy	2	2	14	32	50	65
RES share	**8.1%**	**9.4%**	**13.0%**	**14.2%**	**14.6%**	**15.4%**

table 14.42: oecd europe: final energy demand

PJ/A	2005	2010	2020	2030	2040	2050
Total (incl. non-energy use)	**58,601**	**60,530**	**62,544**	**67,171**	**70,374**	**73,196**
Total (energy use)	**53,773**	**55,624**	**57,172**	**61,520**	**64,495**	**67,114**
Transport	**16,080**	**16,860**	**17,983**	**19,014**	**19,689**	**20,269**
Oil products	15,650	16,125	16,114	16,481	16,745	16,967
Natural gas	20	121	510	914	1,187	1,353
Biofuels	132	295	940	1,091	1,091	1,083
Electricity	278	319	419	528	665	867
RES electricity	52	69	126	167	208	263
Hydrogen	0	0	0	0	0	0
RES share Transport	**1.1%**	**2.2%**	**5.9%**	**6.6%**	**6.6%**	**6.6%**
Industry	**15,380**	**15,893**	**15,550**	**16,572**	**16,940**	**17,113**
Electricity	4,382	4,699	5,173	5,597	5,903	6,171
RES electricity	822	1,020	1,560	1,771	1,843	1,876
District heat	1,877	1,825	1,868	2,012	1,994	2,010
RES district heat	294	316	389	382	330	425
Coal	1,355	1,077	778	852	768	551
Oil products	2,250	2,218	1,944	1,857	1,787	1,568
Gas	4,778	5,059	4,854	5,262	5,466	5,571
Solar	5	7	5	6	6	17
Biomass and waste	730	1,006	917	968	978	1,138
Geothermal	2	3	10	19	38	86
RES share Industry	**12.0%**	**14.8%**	**18.5%**	**19.0%**	**18.9%**	**20.7%**
Other Sectors	**22,313**	**22,872**	**23,639**	**25,934**	**27,866**	**29,732**
Electricity	5,986	6,515	7,673	8,902	9,937	10,901
RES electricity	1,122	1,414	2,315	2,817	3,102	3,313
District heat	2,287	2,299	2,089	2,172	2,227	2,272
RES district heat	452	454	540	489	405	413
Coal	559	216	138	56	10	18
Oil products	4,393	4,433	4,051	3,990	3,822	3,666
Gas	7,520	7,657	7,635	8,262	8,824	9,484
Solar	39	102	286	540	819	955
Biomass and waste	1,442	1,549	1,517	1,630	1,718	1,796
Geothermal	88	100	250	381	510	640
RES share Other Sectors	**14.1%**	**15.8%**	**20.8%**	**22.6%**	**23.5%**	**23.9%**
Total RES	**5,181**	**6,334**	**8,856**	**10,261**	**11,047**	**12,006**
RES share	**8.8%**	**10.5%**	**14.2%**	**15.3%**	**15.7%**	**16.4%**
Non energy use	**4,828**	**4,906**	**5,373**	**5,651**	**5,879**	**6,082**
Oil	4,208	4,276	4,683	4,925	5,124	5,302
Gas	574	584	639	672	699	724
Coal	46	46	51	53	55	57

appendix: oecd europe energy [r]evolution scenario

table 14.43: oecd europe: electricity generation

TWh/a	2005	2010	2020	2030	2040	2050
Power plants	**2,853**	**2,960**	**2,767**	**2,539**	**2,358**	**2,439**
Coal	456	444	302	104	34	10
Lignite	274	230	101	33	15	0
Gas	463	537	630	565	233	125
Oil	82	70	34	12	0	0
Diesel	4	2	1	0	0	0
Nuclear	981	925	420	155	22	0
Biomass	29	40	45	57	70	80
Hydro	486	498	513	517	520	520
Wind	71	194	570	793	964	1040
PV	2	11	110	215	330	410
Geothermal	6	6	11	20	45	75
Solar thermal power plants	0	2	26	54	93	125
Ocean energy	1	1	3	13	32	54
Combined heat & power production	**628**	**712**	**832**	**852**	**855**	**813**
Coal	145	168	113	42	3	0
Lignite	81	49	26	5	0	0
Gas	295	340	460	475	414	328
Oil	48	46	16	8	0	0
Biomass	58	106	209	298	378	407
Geothermal	1	3	9	25	60	77
CHP by producer						
Main activity producers	443	487	516	503	475	408
Autoproducers	185	225	316	349	380	405
Total generation	**3,481**	**3,672**	**3,599**	**3,391**	**3,213**	**3,252**
Fossil	1,848	1,886	1,683	1,244	699	463
Coal	601	612	415	146	37	10
Lignite	355	279	127	38	15	0
Gas	757	877	1090	1040	647	453
Oil	131	116	50	20	0	0
Diesel	4	2	1	0	0	0
Nuclear	981	925	420	155	22	0
Renewables	**653**	**861**	**1,496**	**1,991**	**2,492**	**2,789**
Hydro	486	498	513	517	520	520
Wind	71	194	570	793	964	1040
PV	2	11	110	215	330	410
Biomass	87	146	254	355	448	487
Geothermal	7	9	20	45	105	152
Solar thermal	0	2	26	54	93	125
Ocean energy	1	1	3	13	32	54
Import	348	376	445	486	660	910
Import RES	65	82	138	292	649	906
Export	330	357	384	255	120	78
Distribution losses	244	251.0	241.0	220	206.0	210
Own consumption electricity	298	296.0	291.0	272.0	257.0	258.0
Electricity for hydrogen production	0	0	38	64	96	96
Final energy consumption (electricity)	**2,957**	**3,144**	**3,089**	**3,066**	**3,194**	**3,520**
Fluctuating RES (PV, Wind, Ocean)	73	206	683	1,021	1,326	1,504
Share of fluctuating RES	2.1%	5.6%	19.0%	30.1%	41.3%	46.3%
RES share	**18.7%**	**23.4%**	**41.6%**	**58.7%**	**77.6%**	**85.8%**
'Efficiency' savings (compared to Ref.)		**60**	**596**	**1,108**	**1,391**	**1,463**

table 14.44: oecd europe: heat supply

PJ/A	2005	2010	2020	2030	2040	2050
District heating plants	**2,179**	**2,191**	**1,994**	**2,046**	**2,454**	**3,088**
Fossil fuels	1,662	1,601	1,167	798	294	0
Biomass	506	526	578	552	614	710
Solar collectors	0	44	140	471	1,129	1,822
Geothermal	10	20	110	225	417	556
Heat from CHP	**2,250**	**2,494**	**3,145**	**3,383**	**3,267**	**2,994**
Fossil fuels	1,981	1,993	2,189	2,075	1,630	1,192
Biomass	258	471	880	1,084	1,094	1,106
Geothermal	10	30	77	223	543	696
Direct heating[1]	**20,314**	**19,669**	**16,745**	**15,140**	**14,679**	**14,312**
Fossil fuels	18,456	16,652	12,583	9,427	7,793	6,701
Biomass	1,723	2,564	2,946	2,534	2,133	1,750
Solar collectors	44	117	550	2,213	3,309	4,102
Geothermal	90	337	666	966	1,444	1,758
Total heat supply[1]	**24,743**	**24,353**	**21,884**	**20,569**	**20,400**	**20,394**
Fossil fuels	22,100	20,246	15,939	12,300	9,717	7,893
Biomass	2,488	3,561	4,404	4,171	3,841	3,567
Solar collectors	45	160	689	2,684	4,438	5,924
Geothermal	111	386	852	1,415	2,404	3,010
RES share (including RES electricity)	**10.7%**	**17%**	**27%**	**40%**	**52%**	**61%**
'Efficiency' savings (compared to Ref.)		**632**	**2,155**	**5,161**	**6,394**	**7,352**

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

table 14.45: oecd europe: CO_2 emissions

MILL t/a	2005	2010	2020	2030	2040	2050
Condensation power plants	**925**	**952**	**705**	**355**	**122**	**45**
Coal	391	408	280	85	24	6
Lignite	282	256.7	117.0	35.0	14.6	0
Gas	187	236	285	226	83	39
Oil	62	48.5	23.0	7.9	0	0
Diesel	3.4	2.1	0.8	0.3	0.1	0
Combined heat & power production	**495**	**391**	**302**	**258**	**203**	**151**
Coal	156	147	75	32	3	0
Lignite	98	44	18	3	0	0
Gas	146	158	198	217	200	151
Oil	96	42	11	5	0	0
CO_2 emissions electricity & steam generation	**1,421**	**1,343**	**1,007**	**612**	**325**	**196**
Coal	547	555	355	118	27	6
Lignite	380	301	135	38	15	0
Gas	332	394	482	444	283	190
Oil & diesel	162	92	35	13	0	0
CO_2 emissions by sector	**4,062**	**3,837**	**2,895**	**1,990**	**1,289**	**884**
% of 1990 emissions	99%	94%	71%	49%	31%	22%
Industry	716	563	419	311	254	223
Other sectors	807	757	574	429	339	280
Transport	1,129	1,142	903	675	432	258
Electricity & steam generation	1,260	1,230	900	516	246	122
District heating	149	145	99	59	19	0
Population (Mill.)	536	547	561	568	568	563
CO_2 emissions per capita (t/capita)	**7.6**	**7.0**	**5.2**	**3.5**	**2.3**	**1.6**

table 14.46: oecd europe: installed capacity

GW	2005	2010	2020	2030	2040	2050
Power plants	**666**	**705**	**810**	**828**	**888**	**964**
Coal	90	88	60	21	7	2
Lignite	54.3	45.6	20	6.5	3.0	0
Gas	110	124	136	115	45	23
Oil	43	42	28	11	0	0
Diesel	3.7	2.3	0.9	0.3	0.1	0.1
Nuclear	130.5	123.2	56.0	20.7	2.9	0
Biomass	4.7	6.3	6.8	8.2	9.7	10.7
Hydro	184	174	179	181	182	182
Wind	42.1	87.5	214.9	254.2	309.0	333.3
PV	1.5	10.5	95.7	187.0	287.0	356.5
Geothermal	0.9	0.9	1.6	2.9	6.4	10.7
Solar thermal power plants	0	0.7	8.7	16.6	26.6	31.3
Ocean energy	0.3	0.3	1.5	4.8	10.3	15.4
Combined heat & power production	**159**	**178**	**195**	**183**	**173**	**162**
Coal	33	38	25	9	1	0
Lignite	18	11	6	1	0	0
Gas	68	77	102	103	88	69
Oil	22	21	7	3	0	0
Biomass	17	31	54	61	73	78
Geothermal	0	1	2	5	12	15
CHP by producer						
Main activity producers	112	126	126	109	97	81
Autoproducers	47	52	70	74	77	81
Total generation	**825**	**883**	**1,005**	**1,011**	**1,062**	**1,126**
Fossil	443	447	385	270	143	93
Coal	123	126	85	30	7	2
Lignite	72	56	26	8	3	0
Gas	179	200	238	218	133	91
Oil	65	63	35	14	0	0
Diesel	4	2	1	0	0	0
Nuclear	130.5	123.2	56.0	20.7	2.9	0
Renewables	**251**	**312**	**564**	**720**	**915**	**1,033**
Hydro	184	174	179	181	182	182
Wind	42	87	215	254	309	333
PV	2	10	96	187	287	357
Biomass	22.0	37	61	69	82	88
Geothermal	1	2	3	8	18	26
Solar thermal	0	1	9	17	27	31
Ocean energy	0	0	1	5	10	15
Fluctuating RES (PV, Wind, Ocean)	43.9	98.2	312.1	446.0	606.3	705.3
Share of fluctuating RES	5.3%	11.1%	31.1%	44.1%	57.1%	62.6%
RES share	**30.4%**	**35.4%**	**56.1%**	**71.2%**	**86.2%**	**91.7%**

table 14.47: oecd europe: primary energy demand

PJ/A	2005	2010	2020	2030	2040	2050
Total	**81,482**	**81,432**	**69,143**	**58,892**	**52,202**	**48,918**
Fossil	**64,215**	**61,498**	**49,681**	**37,644**	**27,196**	**21,000**
Hard coal	10,612	9,219	5,987	2,745	1,443	1,145
Lignite	3,419	2,711	1,216	346	131	0
Natural gas	19,773	19,904	19,733	17,380	13,168	10,494
Crude oil	30,411	29,664	22,746	17,173	12,454	9,361
Nuclear	**10,699**	**10,093**	**4,583**	**1,691**	**240**	**0**
Renewables	**6,568**	**9,842**	**14,879**	**19,557**	**24,767**	**27,917**
Hydro	1,749	1,793	1,847	1,861	1,872	1,872
Wind	255	698	2,052	2,855	3,470	3,744
Solar	50	207	1,179	3,652	5,961	7,850
Biomass	4,152	6,611	8,652	9,012	9,259	8,986
Geothermal	360	530	1,137	2,130	4,090	5,271
Ocean Energy	2	2	12	47	115	194
RES share	**8.1%**	**12.0%**	**21.2%**	**33.3%**	**49.5%**	**59.6%**
'Efficiency' savings (compared to Ref.)		**1,289**	**14,094**	**26,776**	**35,096**	**38,617**

table 14.48: oecd europe: final energy demand

PJ/A	2005	2010	2020	2030	2040	2050
Total (incl. non-energy use)	**58,601**	**59,687**	**54,206**	**49,553**	**46,630**	**45,314**
Total (energy use)	**53,773**	**54,781**	**48,833**	**43,902**	**40,751**	**39,231**
Transport	**16,080**	**16,860**	**14,377**	**11,770**	**9,779**	**8,693**
Oil products	15,650	15,747	12,217	9,136	5,882	3,529
Natural gas	20	120	400	283	126	52
Biofuels	132	669	1,201	1,409	1,755	1,810
Electricity	278	324	465	780	1,763	3,043
RES electricity	52	76	193	458	1,367	2,610
Hydrogen	0	0	95	162	252	259
RES share Transport	**1.1%**	**4.4%**	**10%**	**16.7%**	**33.9%**	**53.4%**
Industry	**15,380**	**15,374**	**13,636**	**12,430**	**12,038**	**11,908**
Electricity	4,382	4,641	4,463	4,140	3,913	3,879
RES electricity	822	1,088	1,855	2,431	3,035	3,327
District heat	1,877	2,124	2,234	2,410	2,490	2,607
RES district heat	294	506	803	1,190	1,748	2,263
Coal	1,355	255	113	8	39	77
Oil products	2,250	2,431	1,475	694	270	0
Gas	4,778	4,450	3,498	2,968	2,758	2,596
Solar	5	45	221	721	983	1,175
Biomass and waste	730	1,242	1,338	1,069	885	709
Geothermal	2	185	294	422	700	865
RES share Industry	**12.0%**	**19.9%**	**33.1%**	**46.9%**	**61.1%**	**70%**
Other Sectors	**22,313**	**22,547**	**20,821**	**19,702**	**18,934**	**18,630**
Electricity	5,986	6,354	6,191	6,117	5,821	5,748
RES electricity	1,122	1,490	2,573	3,593	4,515	4,930
District heat	2,287	2,355	2,701	2,814	3,027	3,271
RES district heat	452	561	971	1,390	2,125	2,839
Coal	559	415	76	61	19	16
Oil products	4,393	4,364	3,067	1,789	965	448
Gas	7,520	6,919	5,949	5,113	4,691	4,338
Solar	39	72	329	1,493	2,326	2,927
Biomass and waste	1,442	1,939	2,195	1,871	1,510	1,193
Geothermal	88	130	312	444	576	688
RES share Other Sectors	**14.1%**	**18.6%**	**30.6%**	**44.6%**	**58.4%**	**67.5%**
Total RES	**5,181**	**8,003**	**12,325**	**16,584**	**21,720**	**25,559**
RES share	**8.8%**	**13.4%**	**22.7%**	**33.5%**	**46.6%**	**56.4%**
Non energy use	**4,828**	**4,906**	**5,373**	**5,651**	**5,879**	**6,082**
Oil	4,208	4,276	4,683	4,925	5,124	5,302
Gas	574	584	639	672	699	724
Coal	46	46	51	53	55	57

appendix: africa reference scenario

table 14.49: africa: electricity generation

TWh/a	2005	2010	2020	2030	2040	2050
Power plants	**564**	**681**	**986**	**1327**	**1739**	**2264**
Coal	252	280	316	374	531	849
Lignite	0	0	0	0	0	0
Gas	149	220	413	596	758	871
Oil	58	52	41	36	31	28
Diesel	1	1	1	2	2	2
Nuclear	11	11	15	15	15	15
Biomass	1	4	23	41	49	57
Hydro	91	107	159	232	305	379
Wind	1	3	9	16	23	31
PV	0	0	1	2	3	6
Geothermal	1	2	5	9	13	17
Solar thermal power plants	1	2	4	6	8	8
Ocean energy	0	0	0	0	0	0
Combined heat & power production	**0**	**2**	**15**	**35**	**55**	**75**
Coal	0	1	8	23	38	56
Lignite	0	0	0	0	0	0
Gas	0	0	2	4	6	8
Oil	0	1	3	4	3	0
Biomass	0	0	2	5	8	11
Geothermal	0	0	0	0	0	0
CHP by producer						
Main activity producers	0	0	0	0	0	0
Autoproducers	0	2	15	35	55	75
Total generation	**564**	**683**	**1,001**	**1,362**	**1,794**	**2,339**
Fossil	459	554	785	1,036	1,369	1,814
Coal	252	281	325	396	570	905
Lignite	0	0	0	0	0	0
Gas	149	220	414	599	764	878
Oil	58	53	44	39	34	28
Diesel	1	1	1	2	2	2
Nuclear	11	11	15	15	15	15
Renewables	**94**	**118**	**202**	**311**	**410**	**510**
Hydro	91	107	159	232	305	379
Wind	1	3	9	16	23	31
PV	0	0	1	2	3	6
Biomass	1	5	25	46	57	69
Geothermal	1	2	5	9	13	17
Solar thermal	1	2	4	6	8	8
Ocean energy	0	0	0	0	0	0
Import	31	37	54	75	101	135
Import RES	6	7	10	14	18	24
Export	31	28	54	75	100	134
Distribution losses	63	100	135	154	163	166
Own consumption electricity	44	51	78	114	159	210
Electricity for hydrogen production	0	0	0	0	0	0
Final energy consumption (electricity)	**457**	**541**	**788**	**1,095**	**1,473**	**1,964**
Fluctuating RES (PV, Wind, Ocean)	1	3	10	18	27	37
Share of fluctuating RES	0.1%	0.5%	0.9%	1.3%	1.5%	1.6%
RES share	**16.6%**	**17.2%**	**20.2%**	**22.8%**	**22.9%**	**21.8%**

table 14.50: africa: heat supply

PJ/A	2005	2010	2020	2030	2040	2050
District heating plants	**0**	**0**	**0**	**0**	**0**	**0**
Fossil fuels	0	0	0	0	0	0
Biomass	0	0	0	0	0	0
Solar collectors	0	0	0	0	0	0
Geothermal	0	0	0	0	0	0
Heat from CHP	**0**	**11**	**68**	**131**	**178**	**231**
Fossil fuels	0	10	58	112	152	196
Biomass	0	1	9	20	27	35
Geothermal	0	0	0	0	0	0
Direct heating[1)]	**9,769**	**10,484**	**11,455**	**12,436**	**13,412**	**14,222**
Fossil fuels	2,474	2,778	3,147	3,413	3,656	3,843
Biomass	7,296	7,693	8,240	8,913	9,601	10,181
Solar collectors	0	0	11	25	40	57
Geothermal	0	13	57	85	113	141
Total heat supply[1)]	**9,769**	**10,495**	**11,523**	**12,568**	**13,590**	**14,453**
Fossil fuels	2,474	2,788	3,205	3,525	3,808	4,039
Biomass	7,296	7,695	8,249	8,933	9,628	10,215
Solar collectors	0	0	11	25	40	57
Geothermal	0	13	57	85	113	141
RES share (including RES electricity)	**74.7%**	**73.4%**	**72.2%**	**72.0%**	**72.0%**	**72.1%**

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

table 14.51: africa: CO_2 emissions

MILL t/a	2005	2010	2020	2030	2040	2050
Condensation power plants	**355**	**404**	**495**	**585**	**748**	**997**
Coal	230	255	280	314	419	632
Lignite	0	0	0	0	0	0
Gas	81	109	181	240	300	338
Oil	39	35	29	26	23	22
Diesel	5	5	5	5	6	6
Combined heat & power production	**0**	**1**	**10**	**20**	**30**	**40**
Coal	0	1	7	17	26	37
Lignite	0	0	0	0	0	0
Gas	0	0	1	2	2	3
Oil	0	1	2	2	1	0
CO_2 emissions electricity & steam generation	**355**	**406**	**505**	**606**	**777**	**1,037**
Coal	230	256	287	331	445	668
Lignite	0	0	0	0	0	0
Gas	81	110	182	242	302	341
Oil & diesel	44	41	36	33	30	28
CO_2 emissions by sector	**780**	**890**	**1,104**	**1,330**	**1,646**	**2,064**
% of 1990 emissions	109%	124%	154%	185%	229%	287%
Industry	112	129	153	171	185	197
Other sectors	113	125	142	157	171	185
Transport	200	231	314	418	542	685
Electricity & steam generation	355	404	495	585	748	997
District heating	0	0	0	0	0	0
Population (Mill.)	922	1031	1270	1517	1764	1997
CO_2 emissions per capita (t/capita)	**0.8**	**0.9**	**0.9**	**0.9**	**0.9**	**1.0**

table 14.52: africa: installed capacity

GW	2005	2010	2020	2030	2040	2050
Power plants	**120**	**147**	**214**	**290**	**375**	**480**
Coal	40	47	55	65	93	149
Lignite	0	0	0	0	0	0
Gas	37	50	90	135	172	198
Oil	19	20	20	18	16	15
Diesel	1.3	1.4	1.9	2.3	2.7	3.3
Nuclear	1.6	1.6	2.2	2.2	2.2	2.2
Biomass	0.1	0.6	3.1	5.5	6.6	7.8
Hydro	21	24	36	53	70	87
Wind	0.4	1.4	3.6	6.5	8.9	11.7
PV	0	0.2	0.4	0.8	1.6	3.2
Geothermal	0.1	0.2	0.7	1.2	1.7	2.3
Solar thermal power plants	0.2	0.8	1.3	1.0	1.1	1.1
Ocean energy	0	0	0	0	0	0
Combined heat & power production	**0**	**0**	**4**	**8**	**13**	**18**
Coal	0	0	2	6	10	14
Lignite	0	0	0	0	0	0
Gas	0	0	0	1	1	2
Oil	0	0	1	1	1	0
Biomass	0	0	0	1	2	2
Geothermal	0	0	0	0	0	0
CHP by producer						
Main activity producers	0	0	0	0	0	0
Autoproducers	0	0	4	8	13	18
Total generation	**120**	**148**	**218**	**299**	**388**	**497**
Fossil	97	119	170	227	295	381
Coal	40	47	57	71	102	163
Lignite	0	0	0	0	0	0
Gas	37	50	90	136	173	199
Oil	19	20	21	19	17	15
Diesel	1	1	2	2	3	3
Nuclear	1.6	1.6	2.2	2.2	2.2	2.2
Renewables	**21**	**28**	**46**	**69**	**91**	**115**
Hydro	21	24	36	53	70	87
Wind	0	1	4	7	9	12
PV	0	0	0	1	2	3
Biomass	0.1	0.6	3.5	6.6	8.3	10
Geothermal	0	0	1	1	2	2
Solar thermal	0	1	1	1	1	1
Ocean energy	0	0	0	0	0	0
Fluctuating RES (PV, Wind, Ocean)	0.4	1.6	4.0	7.3	10.5	14.8
Share of fluctuating RES	0.3%	1.1%	1.8%	2.5%	2.7%	3.0%
RES share	**17.9%**	**18.6%**	**21.0%**	**23.2%**	**23.5%**	**23.1%**

table 14.53: africa: primary energy demand

PJ/A	2005	2010	2020	2030	2040	2050
Total	**25,243**	**28,040**	**33,712**	**39,767**	**46,177**	**53,286**
Fossil	**12,687**	**14,566**	**18,409**	**22,354**	**27,275**	**33,088**
Hard coal	4,198	4,586	5,014	5,514	6,780	9,207
Lignite	0	0	0	0	0	0
Natural gas	3,024	3,857	5,752	7,419	9,073	10,184
Crude oil	5,465	6,123	7,643	9,422	11,422	13,697
Nuclear	**123**	**123**	**164**	**164**	**164**	**164**
Renewables	**12,433**	**13,351**	**15,139**	**17,249**	**18,738**	**20,034**
Hydro	327	383	571	835	1,099	1,363
Wind	3	11	31	58	84	111
Solar	2	8	28	54	81	110
Biomass	12,069	12,917	14,394	16,116	17,214	18,118
Geothermal	32	32	115	186	260	333
Ocean Energy	0	0	0	0	0	0
RES share	**49.3%**	**47.5%**	**44.9%**	**43.3%**	**40.5%**	**37.5%**

table 14.54: africa: final energy demand

PJ/a	2005	2010	2020	2030	2040	2050
Total (incl. non-energy use)	**18,647**	**20,662**	**24,486**	**28,848**	**33,368**	**38,329**
Total (energy use)	**18,073**	**20,000**	**23,699**	**27,921**	**32,296**	**37,096**
Transport	**2,812**	**3,254**	**4,442**	**5,918**	**7,705**	**9,757**
Oil products	2,722	3,149	4,289	5,719	7,440	9,415
Natural gas	65	76	92	104	116	128
Biofuels	0	1	27	57	93	146
Electricity	24	28	34	38	57	68
RES electricity	4	5	7	9	13	15
Hydrogen	0	0	0	0	0	0
RES share Transport	**0.1%**	**0.2%**	**0.8%**	**1.1%**	**1.4%**	**1.6%**
Industry	**3,345**	**3,720**	**4,370**	**4,909**	**5,433**	**5,910**
Electricity	750	824	1,097	1,375	1,677	1,998
RES electricity	124	142	221	314	384	435
District heat	0	11	68	131	178	231
RES district heat	0	0	0	0	0	0
Coal	408	478	540	539	541	539
Oil products	556	619	676	697	704	700
Gas	587	657	761	862	945	981
Solar	0	0	3	6	9	12
Biomass and waste	1,043	1,131	1,225	1,299	1,378	1,449
Geothermal	0	0	0	0	0	0
RES share Industry	**34.9%**	**34.2%**	**33.2%**	**33.0%**	**32.6%**	**32.1%**
Other Sectors	**11,916**	**13,026**	**14,887**	**17,094**	**19,157**	**21,429**
Electricity	872	1,096	1,708	2,528	3,569	5,004
RES electricity	145	189	344	577	816	1,091
District heat	0	0	0	0	0	0
RES district heat	0	0	0	0	0	0
Coal	209	239	258	274	293	309
Oil products	1,107	1,213	1,371	1,486	1,595	1,700
Gas	195	225	278	358	438	518
Solar	0	0	9	19	31	45
Biomass and waste	9,532	10,240	11,207	12,343	13,117	13,712
Geothermal	0	13	57	85	113	141
RES share Other Sectors	**81.2%**	**80.2%**	**78.0%**	**76.2%**	**73.5%**	**69.9%**
Total RES	**10,849**	**11,720**	**13,099**	**14,709**	**15,955**	**17,047**
RES share	**58.2%**	**56.7%**	**53.5%**	**51.0%**	**47.8%**	**44.5%**
Non energy use	**575**	**662**	**787**	**927**	**1,073**	**1,233**
Oil	311	342	406	478	554	637
Gas	204	255	303	357	413	475
Coal	59	65	77	91	105	121

appendix: africa energy [r]evolution scenario

table 14.55: africa: electricity generation

TWh/a	2005	2010	2020	2030	2040	2050
Power plants	**564**	**682**	**880**	**1,050**	**1,496**	**1,907**
Coal	252	280	315	316	287	184
Lignite	0	0	0	0	0	0
Gas	149	220	293	286	281	242
Oil	58	52	40	20	10	5
Diesel	1	1	1	2	2	2
Nuclear	11	11	8	0	0	0
Biomass	1	4	17	16	18	21
Hydro	91	107	130	150	170	195
Wind	1	3	25	51	82	133
PV	0	1	15	110	210	350
Geothermal	1	2	4	4	7	11
Solar thermal power plants	1	2	30	90	420	750
Ocean energy	0	0	2	6	10	15
Combined heat & power production	**0**	**2**	**34**	**95**	**142**	**169**
Coal	0	1	16	44	62	70
Lignite	0	0	0	0	0	0
Gas	0	0	10	27	42	51
Oil	0	1	0	0	0	0
Biomass	0	0	5	14	22	27
Geothermal	0	0	3	10	16	21
CHP by producer						
Main activity producers	0	0	4	10	17	19
Autoproducers	0	2	30	85	125	150
Total generation	**564**	**684**	**914**	**1,146**	**1,639**	**2,076**
Fossil	459	554	675	694	684	553
Coal	252	281	331	360	349	253
Lignite	0	0	0	0	0	0
Gas	149	220	303	313	323	292
Oil	58	53	40	20	10	5
Diesel	1	1	1	2	2	2
Nuclear	11	11	8	0	0	0
Renewables	**94**	**118**	**231**	**451**	**955**	**1,523**
Hydro	91	107	130	150	170	195
Wind	1	3	25	51	82	133
PV	0	1	15	110	210	350
Biomass	1	5	22	30	40	48
Geothermal	1	2	7	15	23	32
Solar thermal	1	2	30	90	420	750
Ocean energy	0	0	2	6	10	15
Import	31	37	48	59	73	90
Import RES	6	9	19	29	44	70
Export	31	28	67	123	390	562
Distribution losses	63	100.2	113.8	123.7	132.7	140.8
Own consumption electricity	44	51.0	75.8	89.6	104.3	119.9
Electricity for hydrogen production	0	0	0	0	0	0
Final energy consumption (electricity)	**457**	**542**	**706**	**868**	**1,085**	**1,343**
Fluctuating RES (PV, Wind, Ocean)	1	4	42	167	302	498
Share of fluctuating RES	0.1%	0.6%	4.6%	14.6%	18.4%	24.0%
RES share	**16.6%**	**17.3%**	**25.3%**	**39.4%**	**58.3%**	**73.4%**
'Efficiency' savings (compared to Ref.)	**0**	**0**	**83**	**227**	**389**	**620**

table 14.56: africa: heat supply

PJ/A	2005	2010	2020	2030	2040	2050
District heating plants	**0**	**0**	**0**	**0**	**0**	**0**
Fossil fuels	0	0	0	0	0	0
Biomass	0	0	0	0	0	0
Solar collectors	0	0	0	0	0	0
Geothermal	0	0	0	0	0	0
Heat from CHP	**0**	**11**	**170**	**418**	**574**	**665**
Fossil fuels	0	10	121	275	358	393
Biomass	0	1	22	51	69	83
Geothermal	0	0	27	92	146	189
Direct heating[1]	**9,769**	**10,484**	**11,097**	**11,771**	**12,565**	**13,238**
Fossil fuels	2,474	2,778	2,838	2,833	2,790	2,701
Biomass	7,296	7,693	7,779	7,842	7,778	7,576
Solar collectors	0	0	425	984	1,850	2,784
Geothermal	0	13	56	111	148	177
Total heat supply[1]	**9,769**	**10,495**	**11,266**	**12,189**	**13,139**	**13,902**
Fossil fuels	2,474	2,788	2,958	3,108	3,148	3,094
Biomass	7,296	7,695	7,801	7,894	7,847	7,658
Solar collectors	0	0	425	984	1,850	2,784
Geothermal	0	13	83	203	294	366
RES share (including RES electricity)	**74.7%**	**73%**	**74%**	**74%**	**76%**	**78%**
'Efficiency' savings (compared to Ref.)		**0**	**256**	**378**	**451**	**551**

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

table 14.57: africa: CO_2 emissions

MILL t/a	2005	2010	2020	2030	2040	2050
Condensation power plants	**355**	**405**	**440**	**401**	**350**	**240**
Coal	230	255	279	266	226	137
Lignite	0	0	0	0	0	0
Gas	81	109	129	115	111	94
Oil	39	35.4	27.8	14.2	7.5	3.9
Diesel	5	5	5	5	6	6
Combined heat & power production	**0**	**1**	**19**	**45**	**62**	**68**
Coal	0	1	13	32	43	46
Lignite	0	0	0	0	0	0
Gas	0	0	5	12	19	22
Oil	0	1	0	0	0	0
CO_2 emissions electricity & steam generation	**355**	**406**	**459**	**446**	**412**	**309**
Coal	230	256	292	298	269	183
Lignite	0	0	0	0	0	0
Gas	81	110	134	128	130	116
Oil & diesel	44	41	33	20	13	10
CO_2 emissions by sector	**780**	**890**	**977**	**991**	**980**	**895**
% of 1990 emissions	109%	124%	136%	138%	137%	125%
Industry	112	129	132	134	130	121
Other sectors	113	125	136	152	161	166
Transport	200	231	266	299	330	358
Electricity & steam generation	355	405	443	406	360	251
District heating	0	0	0	0	0	0
Population (Mill.)	922	1031	1270	1517	1764	1997
CO_2 emissions per capita (t/capita)	**0.8**	**0.9**	**0.8**	**0.7**	**0.6**	**0.4**

table 14.58: africa: installed capacity

GW	2005	2010	2020	2030	2040	2050
Power plants	**120**	**148**	**201**	**261**	**360**	**472**
Coal	40	47	55	55	50	32
Lignite	0	0	0	0	0	0
Gas	37	50	64	65	64	55
Oil	19	20	19	10	5	3
Diesel	1.3	1.4	1.9	2.3	2.7	3.3
Nuclear	1.6	1.6	1.2	0	0	0
Biomass	0.1	0.6	2.3	2.2	2.5	2.8
Hydro	21	24	30	34	39	45
Wind	0.4	1.4	10.1	20.7	31.2	50.6
PV	0	0.5	7.6	55.0	105.0	175.0
Geothermal	0.1	0.2	0.5	0.6	0.9	1.5
Solar thermal power plants	0.2	1.0	9.7	14.3	57.5	100
Ocean energy	0	0	0.6	1.7	2.9	4.3
Combined heat & power production	**0**	**0**	**8**	**23**	**33**	**39**
Coal	0	0	4	11	16	18
Lignite	0	0	0	0	0	0
Gas	0	0	2	6	10	12
Oil	0	0	0	0	0	0
Biomass	0	0	1	3	4	5
Geothermal	0	0	1	2	3	4
CHP by producer						
Main activity producers	0	0	1	3	6	6
Autoproducers	0	0	7	19	28	33
Total generation	**120**	**148**	**210**	**283**	**394**	**511**
Fossil	97	119	146	150	147	123
Coal	40	47	59	66	66	50
Lignite	0	0	0	0	0	0
Gas	37	50	66	71	74	67
Oil	19	20	19	10	5	3
Diesel	1	1	2	2	3	3
Nuclear	1.6	1.6	1.2	0	0	0
Renewables	**21**	**28**	**62**	**134**	**246**	**388**
Hydro	21	24	30	34	39	45
Wind	0	1	10	21	31	51
PV	0	0	8	55	105	175
Biomass	0.1	1	3	5	7	8
Geothermal	0	0	1	3	4	6
Solar thermal	0	1	10	14	58	100
Ocean energy	0	0	1	2	3	4
Fluctuating RES (PV, Wind, Ocean)	0.4	1.8	18.3	77.4	139.0	229.9
Share of fluctuating RES	0.3%	1.2%	8.7%	27.3%	35.3%	45.0%
RES share	**17.9%**	**18.8%**	**29.7%**	**47.2%**	**62.6%**	**76.0%**

table 14.59: africa: primary energy demand

PJ/A	2005	2010	2020	2030	2040	2050
Total	**25,243**	**28,045**	**31,170**	**33,485**	**36,405**	**38,347**
Fossil	**12,687**	**14,568**	**16,238**	**16,713**	**16,902**	**16,055**
Hard coal	4,198	4,588	4,996	5,027	**4,688**	**3,749**
Lignite	0	0	0	0	**0**	**0**
Natural gas	3,024	3,859	4,934	5,201	**5,528**	**5,384**
Crude oil	5,465	6,121	6,308	6,484	**6,685**	**6,923**
Nuclear	**123**	**123**	**87**	**0**	**0**	**0**
Renewables	**12,433**	**13,354**	**14,845**	**16,772**	**19,504**	**22,292**
Hydro	327	383	468	540	612	702
Wind	3	11	89	183	295	479
Solar	2	10	587	1,704	4,118	6,744
Biomass	12,069	12,917	13,488	13,830	13,710	13,382
Geothermal	32	32	205	494	733	930
Ocean Energy	0	0	7	22	36	54
RES share	**49.3%**	**47.6%**	**47.6%**	**49.9%**	**52.4%**	**56.4%**
'Efficiency' savings (compared to Ref.)		**15**	**2,646**	**6,584**	**11,057**	**16,743**

table 14.60: africa: final energy demand

PJ/A	2005	2010	2020	2030	2040	2050
Total (incl. non-energy use)	**18,647**	**20,665**	**22,924**	**25,262**	**27,359**	**29,336**
Total (energy use)	**18,073**	**20,003**	**22,174**	**24,412**	**26,409**	**28,286**
Transport	**2,812**	**3,254**	**3,759**	**4,265**	**4,770**	**5,276**
Oil products	2,722	3,149	3,626	4,093	4,518	4,914
Natural gas	65	76	81	78	74	66
Biofuels	0	1	13	38	76	130
Electricity	24	28	40	56	103	164
RES electricity	4	5	10	22	60	121
Hydrogen	0	0	0	0	0	0
RES share Transport	**0.1%**	**0.2%**	**0.6%**	**1.4%**	**2.9%**	**4.8%**
Industry	**3,345**	**3,720**	**3,933**	**4,016**	**4,111**	**4,071**
Electricity	750	824	995	1,115	1,229	1,337
RES electricity	124	143	251	439	716	981
District heat	0	11	170	418	573	664
RES district heat	0	0	15	32	34	36
Coal	408	478	446	377	323	271
Oil products	556	619	485	322	187	82
Gas	587	658	673	631	616	565
Solar	0	0	57	126	199	254
Biomass and waste	1,043	1,131	1,084	966	894	790
Geothermal	0	0	23	63	90	109
RES share Industry	**34.9%**	**34.2%**	**36.4%**	**40.4%**	**47.0%**	**53.3%**
Other Sectors	**11,916**	**13,029**	**14,482**	**16,132**	**17,527**	**18,939**
Electricity	872	1,099	1,505	1,956	2,573	3,334
RES electricity	145	190	380	770	1,499	2,446
District heat	0	0	0	0	0	0
RES district heat	0	0	0	0	0	0
Coal	209	239	282	305	327	353
Oil products	1,107	1,212	1,025	961	900	825
Gas	195	226	603	926	1,126	1,284
Solar	0	0	367	859	1,650	2,531
Biomass and waste	9,532	10,240	10,667	11,077	10,893	10,544
Geothermal	0	13	33	49	59	68
RES share Other Sectors	**81.2%**	**80.2%**	**79.0%**	**79.1%**	**80.5%**	**82.3%**
Total RES	**10,849**	**11,723**	**12,900**	**14,439**	**16,170**	**18,010**
RES share	**58.2%**	**56.7%**	**56.3%**	**57.2%**	**59.1%**	**61.4%**
Non energy use	**575**	**662**	**750**	**850**	**950**	**1,050**
Oil	311	342	387	439	491	542
Gas	204	255	289	327	366	405
Coal	59	65	74	84	93	103

appendix: middle east reference scenario

table 14.61: middle east: electricity generation

TWh/a	2005	2010	2020	2030	2040	2050
Power plants	**640**	**788**	**1,147**	**1,507**	**1,925**	**2,402**
Coal	35	42	63	80	179	364
Lignite	0	0	0	0	1	1
Gas	343	448	723	1,026	1,277	1,451
Oil	238	265	301	321	372	473
Diesel	2	3	3	3	3	3
Nuclear	0	0	7	7	7	7
Biomass	0	2	4	9	11	14
Hydro	21	28	38	45	52	58
Wind	0	2	5	10	15	19
PV	0	0	0	0	0	1
Geothermal	0	0	0	0	0	0
Solar thermal power plants	0	0	2	6	9	12
Ocean energy	0	0	0	0	0	0
Combined heat & power production	**0**	**1**	**7**	**15**	**25**	**30**
Coal	0	0	0	1	2	2
Lignite	0	0	0	0	0	0
Gas	0	0	3	8	13	15
Oil	0	1	3	5	8	9
Biomass	0	0	1	2	3	4
Geothermal	0	0	0	0	0	0
CHP by producer						
Main activity producers	0	0	0	0	0	0
Autoproducers	0	1	7	15	25	30
Total generation	**640**	**789**	**1,154**	**1,522**	**1,950**	**2,432**
Fossil	619	758	1,096	1,444	1,853	2,317
Coal	35	42	63	81	181	366
Lignite	0	0	0	0	1	1
Gas	343	448	726	1,033	1,290	1,466
Oil	238	265	304	327	379	482
Diesel	2	3	3	3	3	3
Nuclear	0	0	7	7	7	7
Renewables	**21**	**32**	**51**	**71**	**90**	**108**
Hydro	21	28	38	45	52	58
Wind	0	2	5	10	15	19
PV	0	0	0	0	0	1
Biomass	0	2	5	10	14	18
Geothermal	0	0	0	0	0	0
Solar thermal	0	0	2	6	9	12
Ocean energy	0	0	0	0	0	0
Import	5	6	9	11	15	18
Import RES	1	1	2	3	5	7
Export	4	6	8	11	14	18
Distribution losses	82	90	120	141	156	180
Own consumption electricity	57	76	113	150	193	239
Electricity for hydrogen consumption	0	0	0	0	0	0
Final energy consumption (electricity)	**501**	**624**	**922**	**1,231**	**1,601**	**2,015**
Fluctuating RES (PV, Wind, Ocean)	0	2	6	10	15	**20**
Share of fluctuating RES	0%	0.2%	0.5%	0.7%	0.8%	**0.8%**
RES share	**3.3%**	**4.0%**	**4.4%**	**4.7%**	**4.6%**	**4.5%**

table 14.62: middle east: heat supply

PJ/A	2005	2010	2020	2030	2040	2050
District heating plants	**0**	**0**	**0**	**1**	**1**	**1**
Fossil fuels	0	0	0	1	1	1
Biomass	0	0	0	0	0	0
Solar collectors	0	0	0	0	0	0
Geothermal	0	0	0	0	0	0
Heat from CHP	**0**	**7**	**42**	**78**	**115**	**125**
Fossil fuels	0	7	38	69	98	103
Biomass	0	0	4	9	17	22
Geothermal	0	0	0	0	0	0
Direct heating[1]	**4,643**	**5,514**	**7,542**	**9,209**	**10,974**	**12,814**
Fossil fuels	4,575	5,442	7,434	9,028	10,700	12,387
Biomass	35	40	46	53	60	67
Solar collectors	33	32	42	63	83	104
Geothermal	0	0	20	65	131	256
Total heat supply[1]	**4,643**	**5,521**	**7,584**	**9,288**	**11,091**	**12,940**
Fossil fuels	4,575	5,449	7,473	9,098	10,800	12,491
Biomass	35	40	49	62	77	89
Solar collectors	33	32	42	63	83	104
Geothermal	0	0	20	65	131	256
RES share (including RES electricity)	**1.5%**	**1.3%**	**1.5%**	**2.0%**	**2.6%**	**3.5%**

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

table 14.63: middle east: CO_2 emissions

MILL t/a	2005	2010	2020	2030	2040	2050
Condensation power plants	**481**	**568**	**761**	**933**	**1,122**	**1,361**
Coal	30	34	50	63	137	271
Lignite	0	0	0	0	1	1
Gas	231	289	433	574	660	697
Oil	214	238	271	289	319	387
Diesel	6	7	7	7	7	7
Combined heat & power production	**0**	**1**	**5**	**8**	**13**	**13**
Coal	0	0	0	1	2	1
Lignite	0	0	0	0	0	0
Gas	0	0	2	4	6	7
Oil	0	1	2	4	5	5
CO_2 emissions electricity & steam generation	**481**	**569**	**766**	**942**	**1,135**	**1,375**
Coal	30	35	51	64	138	272
Lignite	0	0	0	0	1	1
Gas	231	289	435	578	666	703
Oil & diesel	220	245	280	299	330	399
CO_2 emissions by sector	**1,173**	**1,390**	**1,833**	**2,180**	**2,533**	**2,929**
% of 1990 emissions	162%	191%	253%	300%	349%	403%
Industry	192	246	351	434	521	606
Other sectors	179	200	259	308	357	404
Transport	321	376	462	503	533	558
Electricity & steam generation	481	568	761	933	1,122	1,361
District heating	0	0	0	0	0	0
Population (Mill.)	188	207	249	286	319	347
CO_2 emissions per capita (t/capita)	**6.2**	**6.7**	**7.4**	**7.6**	**7.9**	**8.4**

table 14.64: middle east: installed capacity

GW	2005	2010	2020	2030	2040	2050
Power plants	**200**	**249**	**364**	**484**	**744**	**1,284**
Coal	6	7	10	13	32	73
Lignite	0	0	0	0.1	0.1	0.1
Gas	98	129	212	305	505	854
Oil	79	92	113	132	169	315
Diesel	6	6	6	6	6	6
Nuclear	0	0	1.0	1.0	1.0	1.0
Biomass	0	0.2	0.7	1.4	1.8	2.3
Hydro	10	13	18	20	22	23
Wind	0	0.7	2.2	4.1	5.6	7.3
PV	0	0.1	0.2	0.2	0.2	0.3
Geothermal	0	0	0	0	0	0
Solar thermal power plants	0	0.1	0.8	0.9	1.3	1.9
Ocean energy	0	0	0	0	0	0
Combined heat & power production	**0**	**0**	**2**	**3**	**5**	**6**
Coal	0	0	0	0	0	0
Lignite	0	0	0	0	0	0
Gas	0	0	1	2	3	3
Oil	0	0	1	1	2	2
Biomass	0	0	0	0	1	1
Geothermal	0	0	0	0	0	0
CHP by producer						
Main activity producers	0	0	0	0	0	0
Autoproducers	0	0	2	3	5	6
Total generation	**200**	**249**	**365**	**488**	**749**	**1290**
Fossil	190	234	343	460	717	1,253
Coal	6	7	10	13	33	73
Lignite	0	0	0	0	0	0
Gas	98	129	212	307	507	857
Oil	79	92	114	133	170	317
Diesel	6	6	6	6	6	6
Nuclear	0	0	1.0	1.0	1.0	1.0
Renewables	**10**	**15**	**21**	**27**	**31**	**36**
Hydro	10	13	18	20	22	23
Wind	0	1	2	4	6	7
PV	0	0	0	0	0	0
Biomass	0	0.2	0.8	1.7	2.4	3.1
Geothermal	0	0	0	0	0	0
Solar thermal	0	0	1	1	1	2
Ocean energy	0	0	0	0	0	0
Fluctuating RES (PV, Wind, Ocean)	0	0.8	2.3	4.2	5.8	7.6
Share of fluctuating RES	0%	0.3%	0.6%	0.9%	0.8%	0.6%
RES share	**5.2%**	**5.9%**	**5.9%**	**5.4%**	**4.2%**	**2.8%**

table 14.65: middle east: primary energy demand

PJ/A	2005	2010	2020	2030	2040	2050
Total	**21,416**	**25,563**	**34,370**	**41,518**	**48,193**	**54,982**
Fossil	**21,262**	**25,341**	**33,917**	**40,874**	**47,383**	**53,974**
Hard coal	370	420	601	755	1,574	3,030
Lignite	2	2	3	4	5	7
Natural gas	9,075	11,016	16,150	20,914	24,613	27,323
Crude oil	11,815	13,902	17,163	19,202	21,191	23,614
Nuclear	**0**	**0**	**81**	**79**	**78**	**76**
Renewables	**154**	**222**	**372**	**565**	**732**	**931**
Hydro	76	101	138	162	186	210
Wind	0	5	19	36	53	69
Solar	33	33	52	85	116	149
Biomass	44	82	152	245	303	357
Geothermal	0	0	11	37	74	145
Ocean Energy	0	0	0	0	0	0
RES share	**0.7%**	**0.9%**	**1.1%**	**1.4%**	**1.6%**	**1.7%**

table 14.66: middle east: final energy demand

PJ/A	2005	2010	2020	2030	2040	2050
Total (incl. non-energy use)	**13,932**	**16,667**	**22,255**	**26,679**	**31,226**	**35,905**
Total (energy use)	**12,011**	**14,329**	**19,171**	**22,985**	**26,905**	**30,944**
Transport	**4,460**	**5,226**	**6,426**	**7,001**	**7,414**	**7,769**
Oil products	4,449	5,213	6,407	6,977	7,381	7,725
Natural gas	11	13	17	20	22	25
Biofuels	0	0	0	2	3	7
Electricity	0	0	1	3	7	12
RES electricity	0	0	0	0	0	1
Hydrogen	0	0	0	0	0	0
RES share Transport	**0%**	**0%**	**0%**	**0%**	**0.1%**	**0.1%**
Industry	**3,324**	**4,294**	**6,218**	**7,790**	**9,475**	**11,242**
Electricity	363	477	730	976	1,272	1,617
RES electricity	12	19	32	46	59	72
District heat	0	7	42	78	115	125
RES district heat	0	0	0	0	0	0
Coal	20	17	23	38	53	70
Oil products	1,395	1,667	2,181	2,611	3,017	3,392
Gas	1,539	2,115	3,227	4,056	4,961	5,926
Solar	0	0	0	0	0	0
Biomass and waste	8	10	14	17	20	23
Geothermal	0	0	3	16	37	88
RES share Industry	**0.6%**	**0.7%**	**0.8%**	**1.0%**	**1.2%**	**1.6%**
Other Sectors	**4,226**	**4,809**	**6,527**	**8,193**	**10,016**	**11,933**
Electricity	1,442	1,767	2,589	3,454	4,486	5,623
RES electricity	48	71	115	161	206	250
District heat	0	0	0	0	0	0
RES district heat	0	0	0	0	0	0
Coal	1	0	1	2	5	5
Oil products	1,426	1,821	2,349	2,692	3,023	3,343
Gas	1,288	1,147	1,494	1,913	2,330	2,746
Solar	33	32	42	63	83	104
Biomass and waste	36	41	43	48	52	56
Geothermal	0	0	9	21	37	56
RES share Other Sectors	**2.8%**	**3.0%**	**3.2%**	**3.6%**	**3.8%**	**3.9%**
Total RES	**138**	**172**	**258**	**373**	**498**	**658**
RES share	**1.0%**	**1.0%**	**1.2%**	**1.4%**	**1.6%**	**1.8%**
Non energy use	**1,922**	**2,338**	**3,084**	**3,694**	**4,321**	**4,961**
Oil	1,126	1,370	1,807	2,165	2,532	2,908
Gas	795	968	1,277	1,529	1,788	2,054
Coal	0	0	0	0	0	0

appendix: middle east energy [r]evolution scenario

table 14.67: middle east: electricity generation

TWh/a	2005	2010	2020	2030	2040	2050
Power plants	**640**	**780**	**912**	**1,192**	**1,508**	**2,101**
Coal	35	38	26	16	7	0
Lignite	0	0	0	0	0	0
Gas	343	470	532	500	290	90
Oil	238	240	200	100	10	2
Diesel	2	3	3	3	2	1
Nuclear	0	0	5	5	5	0
Biomass	0	2	3	3	3	3
Hydro	21	24	40	45	48	50
Wind	0	2	62	150	190	230
PV	0	1	6	55	230	420
Geothermal	0	0	5	14	20	40
Solar thermal power plants	0	2	30	300	700	1260
Ocean energy	0	0	1	2	3	5
Combined heat & power production	**0**	**1**	**21**	**33**	**55**	**70**
Coal	0	0	0	0	0	0
Lignite	0	0	0	0	0	0
Gas	0	0	3	3	3	2
Oil	0	0	0	0	0	0
Biomass	0	0	10	16	27	36
Geothermal	0	0	7	13	25	32
CHP by producer						
Main activity producers	0	0	0	0	0	0
Autoproducers	0	1	21	33	55	70
Total generation	**640**	**781**	**933**	**1,225**	**1,563**	**2,171**
Fossil	619	751	764	622	312	96
Coal	35	38	26	16	7	0
Lignite	0	0	0	0	0	0
Gas	343	470	535	503	293	92
Oil	238	240	200	100	10	2
Diesel	2	3	3	3	2	1
Nuclear	0	0	5	5	5	0
Renewables	**21**	**31**	**164**	**598**	**1,246**	**2,076**
Hydro	21	24	40	45	48	50
Wind	0	2	62	150	190	230
PV	0	1	6	55	230	420
Biomass	0	2	13	19	30	39
Geothermal	0	0	12	27	45	72
Solar thermal	0	2	30	300	700	1,260
Ocean energy	0	0	1	2	3	5
Import	5	6	7	8	10	12
Import RES	1	1	3	4	8	11
Export	4	6	15	135	179	310
Distribution losses	82	86.0	89.0	91.0	93	104.0
Own consumption electricity	57	73.0	84.0	97.0	115	138.0
Electricity for hydrogen production	0	0	3	7	8	9
Final energy consumption (electricity)	**501**	**622**	**749**	**904**	**1,178**	**1,622**
Fluctuating RES (PV, Wind, Ocean)	0	3	69	207	423	655
Share of fluctuating RES	0%	0.3%	7.4%	16.9%	27.1%	30.2%
RES share	**3.3%**	**3.9%**	**17.6%**	**48.8%**	**79.7%**	**95.6%**
'Efficiency' savings (compared to Ref.)		**1**	**174**	**328**	**423**	**392**

table 14.68: middle east: heat supply

PJ/A	2005	2010	2020	2030	2040	2050
District heating plants	**0**	**10**	**101**	**178**	**400**	**616**
Fossil fuels	0	0	0	0	0	0
Biomass	0	0	0	0	0	0
Solar collectors	0	9	91	161	360	555
Geothermal	0	1	10	18	40	62
Heat from CHP	**0**	**8**	**155**	**236**	**388**	**479**
Fossil fuels	0	2	19	17	12	8
Biomass	0	4	70	100	153	187
Geothermal	0	2	66	119	223	284
Direct heating[1)]	**4,643**	**5,504**	**7,052**	**7,935**	**8,558**	**9,197**
Fossil fuels	4,575	5,315	6,164	5,883	4,490	1,775
Biomass	35	54	95	155	226	317
Solar collectors	33	91	577	1,437	3,098	5,878
Geothermal	0	45	217	461	744	1,227
Total heat supply[1)]	**4,643**	**5,522**	**7,308**	**8,349**	**9,346**	**10,292**
Fossil fuels	4,575	5,317	6,182	5,900	4,502	1,784
Biomass	35	57	165	255	379	505
Solar collectors	33	100	668	1,597	3,458	6,432
Geothermal	0	48	293	597	1,007	1,572
RES share (including RES electricity)	**1.5%**	**4%**	**15%**	**29%**	**52%**	**83%**
'Efficiency' savings (compared to Ref.)		**0**	**276**	**939**	**1,744**	**2,648**

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

table 14.69: middle east: CO_2 emissions

MILL t/a	2005	2010	2020	2030	2040	2050
Condensation power plants	**481**	**557**	**526**	**389**	**169**	**48**
Coal	30	31	21	13	6	0
Lignite	0	0.2	0.2	0.2	0	0
Gas	231	303	319	280	150	43
Oil	214	216.0	180	90	8.6	1.6
Diesel	6	7	7	7	5	3
Combined heat & power production	**0**	**0**	**2**	**2**	**1**	**1**
Coal	0	0	0	0	0	0
Lignite	0	0	0	0	0	0
Gas	0	0	2	2	1	1
Oil	0	0	0	0	0	0
CO_2 emissions electricity & steam generation	**481**	**557**	**528**	**391**	**171**	**49**
Coal	30	31	21	13	6	**0**
Lignite	0	0	0	0	0	**0**
Gas	231	303	320	282	151	**44**
Oil & diesel	220	223	186	96	14	**4**
CO_2 emissions by sector	**1,173**	**1,358**	**1,352**	**1,148**	**781**	**393**
% of 1990 emissions	162%	187%	186%	158%	108%	54%
Industry	192	236	265	241	196	99
Other sectors	179	190	210	203	151	55
Transport	321	375	352	314	265	191
Electricity & steam generation	481	557	526	389	169	48
District heating	0	0	0	0	0	0
Population (Mill.)	188	207	249	286	319	347
CO_2 emissions per capita (t/capita)	**6.2**	**6.5**	**5.4**	**4.0**	**2.4**	**1.1**

table 14.70: middle east: installed capacity

GW	2005	2010	2020	2030	2040	2050
Power plants	**200**	**245**	**300**	**362**	**451**	**600**
Coal	6	6	4	3	1	0
Lignite	0	0	0	0	0	0
Gas	98	135	156	149	115	53
Oil	79	83	75	41	5	1
Diesel	6	6	6	6	5	3
Nuclear	0	0	0.7	0.7	0.7	0
Biomass	0	0.3	0.4	0.5	0.5	0.5
Hydro	10	12	18	20	20	20
Wind	0	0.9	25.3	61.2	72.2	87.5
PV	0	0.3	3.1	30.6	127.8	233.3
Geothermal	0	0	0.8	2.2	3.1	6.2
Solar thermal power plants	0	0.8	9.7	47.6	100	193.8
Ocean energy	0	0	0.3	0.4	0.9	1.4
Combined heat & power production	**0**	**0**	**4**	**7**	**11**	**14**
Coal	0	0	0	0	0	0
Lignite	0	0	0	0	0	0
Gas	0	0	1	1	1	0
Oil	0	0	0	0	0	0
Biomass	0	0	2	4	6	7
Geothermal	0	0	1	3	5	6
CHP by producer						
Main activity producers	0	0	0	0	0	0
Autoproducers	0	0	4	7	11	14
Total generation	**200**	**245**	**305**	**369**	**462**	**613**
Fossil	190	231	**242**	200	126	57
Coal	6	6	4	3	1	0
Lignite	0	0	0	0	0	0
Gas	98	135	156	150	115	53
Oil	79	83	75	41	5	1
Diesel	6	6	6	6	5	3
Nuclear	0	0	0.7	0.7	0.7	0
Renewables	**10**	**14**	**62**	**168**	**335**	**556**
Hydro	10	12	18	20	20	20
Wind	0	1	25	61	72	87
PV	0	0	3	31	128	233
Biomass	0	0	3	4	6	8
Geothermal	0	0	2	5	8	12
Solar thermal	0	1	10	48	100	194
Ocean energy	0	0	0	0	1	1
Fluctuating RES (PV, Wind, Ocean)	0	1.2	28.7	92.2	200.9	322.2
Share of fluctuating RES	0%	0.5%	9.4%	25.0%	43.5%	52.5%
RES share	**5.2%**	**5.7%**	**20.2%**	**45.7%**	**72.6%**	**90.7%**

table 14.71: middle east: primary energy demand

PJ/A	2005	2010	2020	2030	2040	2050
Total	**21,416**	**25,504**	**28,403**	**28,967**	**27,662**	**27,590**
Fossil	**21,262**	**25,132**	**26,202**	**23,441**	**17,090**	**10,089**
Hard coal	370	377	255	168	91	34
Lignite	2	2	2	2	0	0
Natural gas	9,075	11,707	14,279	14,007	9,861	4,742
Crude oil	11,815	13,046	11,665	9,264	7,137	5,312
Nuclear	**0**	**0**	**58**	**57**	**56**	**0**
Renewables	**154**	**372**	**2,143**	**5,469**	**10,517**	**17,501**
Hydro	76	86	144	162	173	180
Wind	0	7	223	540	684	828
Solar	33	108	796	2,875	6,806	12,480
Biomass	44	118	366	632	876	1,037
Geothermal	0	53	610	1,254	1,967	2,958
Ocean Energy	0	0	4	5	11	18
RES share	**0.7%**	**1.5%**	**7.6%**	**18.7%**	**37.4%**	**62.3%**
'Efficiency' savings (compared to Ref.)		**60**	**6,041**	**13,429**	**21,347**	**28,521**

table 14.72: middle east: final energy demand

PJ/A	2005	2010	2020	2030	2040	2050
Total (incl. non-energy use)	**13,932**	**16,604**	**19,073**	**20,401**	**21,644**	**22,719**
Total (energy use)	**12,011**	14,266	16,437	17,575	18,648	19,564
Transport	**4,460**	5,226	5,004	4,686	4,332	3,990
Oil products	4,449	5,182	4,842	4,305	3,611	2,576
Natural gas	11	27	51	72	88	100
Biofuels	0	1	43	132	180	180
Electricity	0	16	60	160	431	1,109
RES electricity	0	1	10	78	344	1,060
Hydrogen	0	0	8	17	21	25
RES share Transport	**0%**	**0%**	**1.1%**	**4.7%**	**12.5%**	**31.7%**
Industry	**3,324**	**4,266**	**5,604**	**6,198**	**6,637**	**6,751**
Electricity	363	466	671	815	972	1,143
RES electricity	12	18	118	398	775	1,093
District heat	0	17	235	368	599	819
RES district heat	0	17	235	368	599	819
Coal	20	11	0	0	0	0
Oil products	1,395	1,506	1,070	740	591	368
Gas	1,539	2,187	3,262	3,294	2,686	1,266
Solar	0	32	201	663	1,312	2,426
Biomass and waste	8	20	50	108	168	228
Geothermal	0	28	115	210	308	500
RES share Industry	**0.6%**	**2.7%**	**12.8%**	**28.2%**	**47.7%**	**75.0%**
Other Sectors	**4,226**	**4,774**	**5,829**	**6,690**	**7,680**	**8,823**
Electricity	1,442	1,759	1,964	2,279	2,838	3,587
RES electricity	48	69	345	1,112	2,262	3,430
District heat	0	0	16	37	170	247
RES district heat	0	0	16	37	170	247
Coal	1	0	0	0	0	0
Oil products	1,426	1,496	1,267	933	753	306
Gas	1,288	1,395	2,060	2,388	1,705	595
Solar	33	59	376	774	1,786	3,451
Biomass and waste	36	48	68	81	102	145
Geothermal	0	17	79	200	325	491
RES share Other Sectors	**2.8%**	**4.0%**	**15.2%**	**32.9%**	**60.5%**	**88.0%**
Total RES	**138**	**310**	**1,657**	**4,169**	**8,350**	**14,094**
RES share	**1.0%**	**2.2%**	**10.1%**	**23.7%**	**44.8%**	**72.0%**
Non energy use	**1,922**	**2,338**	**2,636**	**2,826**	**2,996**	**3,155**
Oil	1,126	1,370	1,545	1,656	1,756	1,849
Gas	795	968	1,091	1,170	1,240	1,306
Coal	0	0	0	0	0	0

appendix: transition economies reference scenario

table 14.73: transition economies: electricity generation

TWh/a	2005	2010	2020	2030	2040	2050
Power plants	**821**	**1,002**	**1,322**	**1,544**	**1,796**	**2,055**
Coal	61	137	158	154	235	319
Lignite	72	77	120	170	246	311
Gas	88	135	272	330	328	342
Oil	14	19	17	11	10	9
Diesel	0	1	3	5	5	5
Nuclear	281	297	341	399	437	475
Biomass	0	2	5	15	21	25
Hydro	304	326	379	414	449	483
Wind	0	6	19	34	49	63
PV	0	0	0	0	0	0
Geothermal	0	3	7	11	15	19
Solar thermal power plants	0	0	0	1	2	2
Ocean energy	0	0	0	0	0	0
Combined heat & power production	**777**	**787**	**801**	**854**	**866**	**879**
Coal	137	160	145	139	123	107
Lignite	71	64	65	69	70	71
Gas	520	526	562	616	644	672
Oil	38	26	16	13	7	0
Biomass	10	10	14	17	22	30
Geothermal	0	0	0	0	0	0
CHP by producer						
Main activity producers	724	732	740	790	800	810
Autoproducers	53	55	61	64	66	69
Total generation	**1,598**	**1,789**	**2,123**	**2,397**	**2,662**	**2,934**
Fossil	1,002	1,146	1,358	1,507	1,668	1,836
Coal	198	298	303	293	358	426
Lignite	144	141	185	239	316	382
Gas	608	662	834	946	972	1,013
Oil	52	45	33	24	17	9
Diesel	0	1	3	5	5	5
Nuclear	281	297	341	399	437	475
Renewables	**314**	**346**	**425**	**491**	**557**	**623**
Hydro	304	326	379	414	449	483
Wind	0	6	19	34	49	63
PV	0	0	0	0	0	0
Biomass	10	12	19	31	43	55
Geothermal	0	3	7	11	15	19
Solar thermal	0	0	0	1	2	2
Ocean energy	0	0	0	0	0	0
Import	87	89	94	93	87	78
Import RES	9	9	9	9	9	8
Export	126	116	134	139	157	176
Distribution losses	195	221	267	309	348	388
Own consumption electricity	262	279	303	308	315	321
Electricity for hydrogen production	0	0	0	8	12	15
Final energy consumption (electricity)	**1,101**	**1,261**	**1,513**	**1,726**	**1,917**	**2,112**
Fluctuating RES (PV, Wind, Ocean)	0	6	19	34	49	**64**
Share of fluctuating RES	0%	0.3%	0.9%	1.4%	1.8%	**2.2%**
RES share	**19.7%**	**19.3%**	**20%**	**20.5%**	**20.9%**	**21.2%**

table 14.74: transition economies: heat supply

PJ/A	2005	2010	2020	2030	2040	2050
District heating plants	**2,196**	**2,431**	**2,917**	**3,347**	**4,004**	**4,589**
Fossil fuels	2,136	2,283	2,558	2,731	2,983	3,185
Biomass	60	146	350	602	1,001	1,377
Solar collectors	0	0	0	0	0	0
Geothermal	1	2	9	13	20	28
Heat from CHP	**6,222**	**6,010**	**5,653**	**5,609**	**5,172**	**4,809**
Fossil fuels	6,149	5,939	5,564	5,507	5,039	4,637
Biomass	73	71	89	102	132	173
Geothermal	0	0	0	0	0	0
Direct heating[1]	**9,933**	**10,204**	**11,341**	**12,544**	**13,499**	**14,436**
Fossil fuels	9,484	9,783	10,787	11,819	12,569	13,308
Biomass	441	404	444	494	567	623
Solar collectors	2	2	4	5	8	10
Geothermal	6	14	106	226	355	495
Total heat supply[1]	**18,351**	**18,645**	**19,911**	**21,499**	**22,675**	**23,834**
Fossil fuels	17,769	18,005	18,909	20,057	20,592	21,129
Biomass	573	621	883	1,198	1,700	2,173
Solar collectors	2	2	4	5	8	10
Geothermal	6	17	115	240	375	522
RES share (including RES electricity)	**3.2%**	**3.4%**	**5.0%**	**6.7%**	**9.2%**	**11.3%**

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

table 14.75: transition economies: CO_2 emissions

MILL t/a	2005	2010	2020	2030	2040	2050
Condensation power plants	**199**	**299**	**434**	**508**	**628**	**741**
Coal	54	119	132	124	182	238
Lignite	88	93	142	199	285	355
Gas	47	71	140	166	145	132
Oil	11	14	13	8	7	7
Diesel	0.2	2.6	7.1	10.8	9.8	9
Combined heat & power production	**1,057**	**996**	**864**	**798**	**721**	**655**
Coal	263	285	229	197	157	123
Lignite	179	157	145	143	134	125
Gas	568	522	471	443	423	407
Oil	48	33	19	15	8	0
CO_2 emissions electricity & steam generation	**1,256**	**1,296**	**1,299**	**1,307**	**1,349**	**1,396**
Coal	316	404	361	321	338	361
Lignite	267	249	288	342	419	481
Gas	614	593	611	609	567	539
Oil & diesel	59	50	39	34	25	16
CO_2 emissions by sector	**2,375**	**2,479**	**2,616**	**2,734**	**2,868**	**3,003**
% of 1990 emissions	53%	56%	59%	61%	64%	67%
Industry	331	329	348	385	409	435
Other sectors	387	415	457	481	495	507
Transport	278	300	359	398	433	469
Electricity & steam generation	1,214	1,258	1,262	1,272	1,318	1,367
District heating	165	176	191	198	214	225
Population (Mill.)	341	339	332	321	309	294
CO_2 emissions per capita (t/capita)	**7.0**	**7.3**	**7.9**	**8.5**	**9.3**	**10.2**

table 14.76: transition economies: installed capacity

GW	2005	2010	2020	2030	2040	2050
Power plants	**167**	**201**	**263**	**302**	**367**	**449**
Coal	9	21	24	23	39	58
Lignite	11.1	11.8	18.0	25.0	36.2	45.8
Gas	12	19	40	50	66	98
Oil	6	9	10	7	6	6
Diesel	0.1	1	3	5	5	5
Nuclear	39.6	41.8	48.0	56.2	61.5	66.9
Biomass	0	0.2	0.6	1.8	2.6	3.2
Hydro	89	96	112	122	132	142
Wind	0.1	2.3	7.0	11.4	16.2	20.9
PV	0	0	0	0.1	0.2	0.3
Geothermal	0.1	0.3	1.0	1.5	2.0	2.6
Solar thermal power plants	0	0	0.1	0.2	0.3	0.4
Ocean energy	0	0	0	0	0	0
Combined heat & power production	**244**	**252**	**252**	**293**	**304**	**308**
Coal	53	60	45	40	35	30
Lignite	28	25	20	20	20	20
Gas	135	148	175	225	243	253
Oil	25	16	8	5	3	0
Biomass	3	3	4	3	4	6
Geothermal	0	0	0	0	0	0
CHP by producer						
Main activity producers	231	240	239	280	291	294
Autoproducers	13	13	14	14	13	14
Total generation	**411**	**454**	**515**	**595**	**671**	**757**
Fossil	279	310	343	399	452	515
Coal	62	81	68	63	74	88
Lignite	39	36	38	45	56	66
Gas	147	167	215	275	308	350
Oil	31	25	18	12	9	6
Diesel	0	1	3	5	5	5
Nuclear	39.6	41.8	48.0	56.2	61.5	66.9
Renewables	**93**	**102**	**124**	**140**	**158**	**175**
Hydro	89	96	112	122	132	142
Wind	0	2	7	11	16	21
PV	0	0	0	0	0	0
Biomass	3.2	3.3	4.2	5.2	6.8	8.8
Geothermal	0	0	1	1	2	3
Solar thermal	0	0	0	0	0	0
Ocean energy	0	0	0	0	0	0
Fluctuating RES (PV, Wind, Ocean)	0.1	2.3	7.0	11.5	16.4	21.3
Share of fluctuating RES	0%	0.5%	1.4%	1.9%	2.4%	2.8%
RES share	**22.5%**	**22.4%**	**24.1%**	**23.5%**	**23.5%**	**23.1%**

table 14.77: transition economies: primary energy demand

PJ/A	2005	2010	2020	2030	2040	2050
Total	**46,254**	**48,352**	**52,961**	**57,020**	**60,434**	**63,933**
Fossil	**41,242**	**42,918**	**46,267**	**48,922**	**50,908**	**53,038**
Hard coal	6,408	7,598	7,085	6,620	6,802	6,988
Lignite	2,401	2,248	2,593	3,082	3,771	4,332
Natural gas	23,234	23,374	25,842	27,693	28,290	29,089
Crude oil	9,199	9,699	10,747	11,528	12,046	12,628
Nuclear	**3,070**	**3,235**	**3,721**	**4,354**	**4,768**	**5,183**
Renewables	**1,942**	**2,198**	**2,974**	**3,744**	**4,758**	**5,712**
Hydro	1,093	1,172	1,365	1,490	1,615	1,740
Wind	1	22	69	122	175	228
Solar	2	2	5	9	14	18
Biomass	825	903	1,228	1,625	2,271	2,864
Geothermal	21	100	306	497	682	863
Ocean Energy	0	0	0	0	0	0
RES share	**4.1%**	**4.5%**	**5.5%**	**6.5%**	**7.8%**	**8.9%**

table 14.78: transition economies: final energy demand

PJ/a	2005	2010	2020	2030	2040	2050
Total (incl. non-energy use)	**30,924**	**32,551**	**36,251**	**39,683**	**42,447**	**45,232**
Total (energy use)	**28,620**	**30,042**	**33,386**	**36,547**	**39,095**	**41,661**
Transport	**5,853**	**6,531**	**7,716**	**8,491**	**9,118**	**9,747**
Oil products	3,848	4,149	4,952	5,490	5,959	6,448
Natural gas	1,636	1,835	2,174	2,400	2,588	2,780
Biofuels	0	0	1	3	6	12
Electricity	368	547	589	578	534	466
RES electricity	72	106	118	118	112	99
Hydrogen	0	0	0	21	31	41
RES share Transport	**1.2%**	**1.6%**	**1.5%**	**1.5%**	**1.4%**	**1.2%**
Industry	**10,277**	**10,104**	**10,857**	**12,028**	**13,011**	**14,015**
Electricity	1,901	2,109	2,593	3,020	3,427	3,857
RES electricity	374	408	518	619	717	819
District heat	3,826	3,475	3,283	3,329	3,320	3,319
RES district heat	54	86	168	265	418	560
Coal	712	713	533	523	454	399
Oil products	802	1,020	1,107	1,219	1,307	1,393
Gas	2,957	2,702	3,229	3,790	4,278	4,755
Solar	0	0	0	0	0	0
Biomass and waste	79	83	85	88	129	151
Geothermal	0	2	26	59	97	140
RES share Industry	**4.9%**	**5.7%**	**7.3%**	**8.6%**	**10.5%**	**11.9%**
Other Sectors	**12,491**	**13,407**	**14,812**	**16,028**	**16,965**	**17,899**
Electricity	1,696	1,882	2,266	2,616	2,941	3,278
RES electricity	334	364	453	536	616	696
District heat	4,199	4,563	4,864	5,185	5,405	5,618
RES district heat	59	113	249	412	680	948
Coal	399	539	650	599	526	448
Oil products	1,454	1,462	1,525	1,581	1,604	1,628
Gas	4,276	4,540	5,016	5,460	5,795	6,120
Solar	2	2	4	5	8	10
Biomass and waste	458	410	437	473	516	558
Geothermal	6	9	51	109	171	239
RES share Other Sectors	**6.9%**	**6.7%**	**8.1%**	**9.6%**	**11.7%**	**13.7%**
Total RES	**1,438**	**1,584**	**2,111**	**2,690**	**3,476**	**4,239**
RES share	**5.0%**	**5.3%**	**6.3%**	**7.4%**	**8.9%**	**10.2%**
Non energy use	**2,304**	**2,508**	**2,865**	**3,136**	**3,352**	**3,571**
Oil	802	873	998	1,092	1,167	1,243
Gas	1,392	1,516	1,731	1,895	2,026	2,158
Coal	109	119	136	149	159	170

appendix: transition economies energy [r]evolution scenario

table 14.79: transition economies: electricity generation

TWh/a	2005	2010	2020	2030	2040	2050
Power plants	**821**	**992**	**1,112**	**1,132**	**1,164**	**1,260**
Coal	61	58	47	37	8	4
Lignite	72	68	40	25	0	0
Gas	88	220	320	265	115	15
Oil	14	14	6	3	0	0
Diesel	0	0	0	0	0	0
Nuclear	281	305	290	150	30	0
Biomass	0	5	10	10	10	10
Hydro	304	320	350	360	370	375
Wind	0	1	28	210	490	710
PV	0	0	2	40	95	95
Geothermal	0	1	3	4	5	6
Solar thermal power plants	0	0	1	8	15	15
Ocean energy	0	0	15	20	25	30
Combined heat & power production	**777**	**796**	**810**	**816**	**819**	**823**
Coal	137	132	85	23	0	0
Lignite	71	67	38	15	0	0
Gas	520	538	532	496	419	385
Oil	38	33	9	1	0	0
Biomass	10	26	138	241	322	360
Geothermal	0	1	9	39	78	79
CHP by producer						
Main activity producers	724	739	750	750	750	750
Autoproducers	53	57	60	66	69	73
Total generation	**1,598**	**1,788**	**1,923**	**1,948**	**1,983**	**2,083**
Fossil	1,002	1,129	1,077	865	543	403
Coal	198	190	132	60	9	4
Lignite	144	135	78	40	0	0
Gas	608	758	852	761	534	400
Oil	52	47	15	4	0	0
Diesel	0	0	0	0	0	0
Nuclear	281	305	290	150	30	0
Renewables	**314**	**354**	**556**	**933**	**1,410**	**1,679**
Hydro	304	320	350	360	370	375
Wind	0	1	28	210	490	710
PV	0	0	2	40	95	95
Biomass	10	31	148	251	332	370
Geothermal	0	2	12	43	83	85
Solar thermal	0	0	1	8	15	15
Ocean energy	0	0	15	20	25	30
Import	87	97	101	101	99	95
Import RES	9	17	25	40	59	76
Export	126	140	147	157	182	197
Distribution losses	195	216.0	228.0	230	228.0	229.0
Own consumption electricity	262	273.0	259.0	229.0	207.0	189.0
Electricity for hydrogen production	0	0	0	1	6	13
Final energy consumption (electricity)	**1,101**	**1,256**	**1,390**	**1,431**	**1,459**	**1,550**
Fluctuating RES (PV, Wind, Ocean)	0	1	45	270	610	835
Share of fluctuating RES	0%	0.1%	2.3%	13.9%	30.8%	40.1%
RES share	**19.7%**	**19.8%**	**28.9%**	**47.9%**	**71.1%**	**80.6%**
'Efficiency' savings (compared to Ref.)		**5**	**124**	**295**	**458**	**562**

table 14.80: transition economies: heat supply

PJ/A	2005	2010	2020	2030	2040	2050
District heating plants	**2,196**	**2,240**	**2,659**	**3,100**	**3,181**	**3,151**
Fossil fuels	2,136	2,005	1,861	1,643	891	315
Biomass	60	202	532	775	954	788
Solar collectors	0	11	80	217	414	788
Geothermal	1	22	186	465	922	1,260
Heat from CHP	**6,222**	**6,080**	**5,697**	**5,439**	**5,210**	**4,981**
Fossil fuels	6,149	5,890	4,660	3,446	2,392	1,990
Biomass	73	184	958	1,637	2,118	2,283
Geothermal	0	5	78	355	700	708
Direct heating[1]	**9,933**	**9,967**	**10,464**	**10,749**	**10,302**	**9,712**
Fossil fuels	9,484	9,129	7,593	6,005	4,331	2,208
Biomass	441	550	1,467	2,111	2,506	2,585
Solar collectors	2	45	702	1,167	1,563	2,262
Geothermal	6	243	702	1,467	1,902	2,657
Total heat supply[1]	**18,351**	**18,287**	**18,820**	**19,288**	**18,693**	**17,844**
Fossil fuels	17,769	17,024	14,114	11,094	7,614	4,513
Biomass	573	936	2,957	4,523	5,578	5,656
Solar collectors	2	56	782	1,384	1,976	3,050
Geothermal	6	271	966	2,287	3,525	4,625
RES share (including RES electricity)	**3.2%**	**7%**	**25%**	**42%**	**59%**	**75%**
'Efficiency' savings (compared to Ref.)		**358**	**1,091**	**2,212**	**3,982**	**5,990**

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

table 14.81: transition economies: CO_2 emissions

MILL t/a	2005	2010	2020	2030	2040	2050
Condensation power plants	**199**	**258**	**256**	**195**	**58**	**9**
Coal	54	50	39	29	7	3
Lignite	88	81.8	47.5	29.3	0	0
Gas	47	116	165	134	51	6
Oil	11	10.5	4.5	2.3	0	0
Diesel	10	0.3	0.2	0.2	0.2	0.2
Combined heat & power production	**1,057**	**973**	**676**	**420**	**273**	**232**
Coal	263	235	136	33	0	0
Lignite	179	163	84	31	0	0
Gas	568	531	444	355	273	232
Oil	48	43	12	0	0	0
CO_2 emissions electricity & steam generation	**1,256**	**1,231**	**933**	**614**	**331**	**240**
Coal	316	286	175	62	7	3
Lignite	267	245	132	60	0	0
Gas	614	647	609	489	324	238
Oil & diesel	59	54	17	3	0	0
CO_2 emissions by sector	**2,375**	**2,321**	**1,830**	**1,334**	**850**	**539**
% of 1990 emissions	53%	52%	41%	30%	19%	12%
Industry	331	289	226	174	139	101
Other sectors	387	380	315	244	175	81
Transport	278	305	259	220	170	115
Electricity & steam generation	1,214	1,196	903	588	309	222
District heating	165	151	126	109	57	20
Population (Mill.)	341	339	332	321	309	294
CO_2 emissions per capita (t/capita)	**7.0**	**6.9**	**5.5**	**4.2**	**2.8**	**1.8**

table 14.82: transition economies: installed capacity

GW	2005	2010	2020	2030	2040	2050
Power plants	**167**	**196**	**228**	**304**	**416**	**473**
Coal	9	9	7	5	1	1
Lignite	11.1	10.4	6.0	3.7	0	0
Gas	12	32	49	42	20	3
Oil	6	6	3	2	0	0
Diesel	0.1	0.1	0.1	0.1	0.1	0.1
Nuclear	39.6	43.0	40.8	21.1	4.2	0
Biomass	0	0.6	1.3	1.3	1.3	1.3
Hydro	89	94	103	106	109	110
Wind	0.1	0.4	10.2	72.4	169.0	244.8
PV	0	0.1	1.9	42.1	100	100
Geothermal	0.1	0.1	0.4	0.5	0.7	0.8
Solar thermal power plants	0	0	0.3	1.8	2.9	2.9
Ocean energy	0	0	4.3	5.7	7.1	8.6
Combined heat & power production	**244**	**256**	**250**	**247**	**232**	**226**
Coal	53	50	26	7	0	0
Lignite	28	26	12	4	0	0
Gas	135	151	166	180	156	143
Oil	25	21	5	0	0	0
Biomass	3	8	39	48	60	67
Geothermal	0	0	2	8	16	16
CHP by producer						
Main activity producers	231	243	236	233	218	211
Autoproducers	13	13	13	14	14	14
Total generation	**411**	**452**	**477**	**551**	**647**	**698**
Fossil	279	305	275	244	178	147
Coal	62	58	34	12	1	1
Lignite	39	36	18	8	0	0
Gas	147	183	215	222	176	147
Oil	31	28	9	2	0	0
Diesel	0	0	0	0	0	0
Nuclear	39.6	43.0	40.8	21.1	4.2	0
Renewables	**93**	**104**	**162**	**285**	**466**	**551**
Hydro	89	94	103	106	109	110
Wind	0	0	10	72	169	245
PV	0	0	2	42	100	100
Biomass	3.2	9	40	49	61	68
Geothermal	0	0	2	8	16	17
Solar thermal	0	0	0	2	3	3
Ocean energy	0	0	4	6	7	9
Fluctuating RES (PV, Wind, Ocean)	0.1	0.5	16.4	120.2	276.1	353.4
Share of fluctuating RES	0%	0.1%	3.4%	21.8%	42.6%	50.6%
RES share	**22.5%**	**23.0%**	**33.9%**	**51.8%**	**71.9%**	**78.9%**

table 14.83: transition economies: primary energy demand

PJ/A	2005	2010	2020	2030	2040	2050
Total	**46,254**	**47,787**	**46,635**	**43,510**	**39,315**	**35,764**
Fossil	**41,242**	**41,436**	**35,100**	**27,871**	**19,608**	**13,625**
Hard coal	6,408	5,658	4,073	2,535	2,010	1,896
Lignite	2,401	2,207	1,189	544	0	0
Natural gas	23,234	24,285	23,229	19,691	13,704	8,790
Crude oil	9,199	9,286	6,610	5,102	3,894	2,939
Nuclear	**3,070**	**3,328**	**3,164**	**1,637**	**327**	**0**
Renewables	**1,942**	**3,023**	**8,370**	**14,002**	**19,380**	**22,139**
Hydro	1,093	1,152	1,260	1,296	1,332	1,350
Wind	1	4	101	756	1,764	2,556
Solar	2	57	792	1,556	2,372	3,446
Biomass	825	1,525	4,999	7,330	9,027	9,030
Geothermal	21	286	1,164	2,991	4,794	5,649
Ocean Energy	0	0	54	72	90	108
RES share	**4.1%**	**6.3%**	**18.0%**	**32.1%**	**49.1%**	**61.9%**
'Efficiency' savings (compared to Ref.)		**744**	**6,387**	**13,504**	**20,949**	**27,859**

table 14.84: transition economies: final energy demand

PJ/a	2005	2010	2020	2030	2040	2050
Total (incl. non-energy use)	**30,924**	**32,019**	**32,246**	**31,970**	**30,523**	**28,651**
Total (energy use)	**28,620**	**29,511**	**29,693**	**29,460**	**28,128**	**26,399**
Transport	**5,853**	**6,531**	**6,025**	**5,464**	**4,863**	**4,237**
Oil products	3,848	4,223	3,583	3,036	2,339	1,577
Natural gas	1,636	1,761	1,623	1,456	1,268	1,069
Biofuels	0	7	94	247	400	366
Electricity	368	540	725	722	842	1,190
RES electricity	72	107	210	346	599	959
Hydrogen	0	0	0	3	15	35
RES share Transport	**1.2%**	**1.7%**	**5.0%**	**10.9%**	**20.7%**	**31.9%**
Industry	**10,277**	**9,700**	**9,732**	**9,350**	**8,678**	**7,756**
Electricity	1,901	2,080	2,289	2,309	2,220	2,060
RES electricity	374	412	662	1,106	1,578	1,661
District heat	3,826	3,420	3,267	3,125	2,862	2,545
RES district heat	54	169	718	1,276	1,768	1,847
Coal	712	585	504	320	401	336
Oil products	802	686	276	37	34	30
Gas	2,957	2,681	2,336	2,091	1,413	903
Solar	0	34	134	256	350	461
Biomass and waste	79	151	791	1,019	1,194	1,164
Geothermal	0	62	134	192	204	256
RES share Industry	**4.9%**	**8.5%**	**25.1%**	**41.2%**	**58.7%**	**69.5%**
Other Sectors	**12,491**	**13,280**	**13,936**	**14,645**	**14,587**	**14,405**
Electricity	1,696	1,902	1,989	2,121	2,191	2,329
RES electricity	334	376	575	1,016	1,558	1,878
District heat	4,199	4,495	4,675	5,000	5,121	5,191
RES district heat	59	222	1,028	2,041	3,162	3,768
Coal	399	160	142	0	0	0
Oil products	1,454	1,334	620	369	226	223
Gas	4,276	4,712	4,541	3,833	2,809	1,137
Solar	2	11	568	910	1,213	1,801
Biomass and waste	458	520	936	1,379	1,654	1,773
Geothermal	6	147	465	1,033	1,375	1,951
RES share Other Sectors	**6.9%**	**9.6%**	**25.6%**	**43.6%**	**61.4%**	**77.5%**
Total RES	**1,438**	**2,218**	**6,314**	**10,824**	**15,064**	**17,915**
RES share	**5.0%**	**7.5%**	**21.3%**	**36.7%**	**53.6%**	**67.9%**
Non energy use	**2,304**	**2,508**	**2,553**	**2,510**	**2,395**	**2,252**
Oil	802	873	889	874	834	784
Gas	1,392	1,516	1,543	1,517	1,447	1,361
Coal	109	119	121	119	114	107

appendix: india reference scenario

table 14.85: india: electricity generation

TWh/a	2005	2010	2020	2030	2040	2050
Power plants	**699**	**988**	**1,762**	**2,690**	**4,066**	**5,850**
Coal	464	667	1,160	1,808	2,936	4,478
Lignite	16	23	42	66	107	164
Gas	62	85	186	292	348	384
Oil	31	33	34	31	28	26
Diesel	0	0	0	0	0	0
Nuclear	17	24	83	128	173	219
Biomass	2	4	14	29	44	60
Hydro	100	127	189	258	327	397
Wind	6	25	52	69	86	104
PV	0	0	3	8	13	18
Geothermal	0	0	0	1	2	2
Solar thermal power plants	0	0	0	0	0	0
Ocean energy	0	0	0	0	0	0
Combined heat & power production	**0**	**9**	**45**	**84**	**123**	**162**
Coal	0	9	45	84	123	162
Lignite	0	0	0	0	0	0
Gas	0	0	0	0	0	0
Oil	0	0	0	0	0	0
Biomass	0	0	0	0	0	0
Geothermal	0	0	0	0	0	0
CHP by producer						
Main activity producers	0	0	0	0	0	0
Autoproducers	0	9	45	84	123	162
Total generation	**699**	**997**	**1,807**	**2,774**	**4,188**	**6,012**
Fossil	574	817	1,467	2,281	3,542	5,213
Coal	464	676	1,205	1,892	3,059	4,639
Lignite	16	23	42	66	107	164
Gas	62	85	186	292	348	384
Oil	31	33	34	31	28	26
Diesel	0	0	0	0	0	0
Nuclear	17	24	83	128	173	219
Renewables	**108**	**156**	**257**	**365**	**473**	**581**
Hydro	100	127	189	258	327	397
Wind	6	25	52	69	86	104
PV	0	0	3	8	13	18
Biomass	2	4	14	29	44	60
Geothermal	0	0	0	1	2	2
Solar thermal	0	0	0	0	0	0
Ocean energy	0	0	0	0	0	0
Import	2	3	5	8	12	18
Import RES	0.3	0.4	0.7	1	2	3
Export	0.1	0.1	0.2	0.3	0.5	0.7
Distribution losses	175	243	392	551	710	870
Own consumption electricity	48	67	108	151	195	239
Electricity for hydrogen production	0	0	0	0	0	0
Final energy consumption (electricity)	**478**	**690**	**1,312**	**2,079**	**3,295**	**4,921**
Fluctuating RES (PV, Wind, Ocean)	6	25	55	77	99	122
Share of fluctuating RES	0.9%	2.5%	3.0%	2.8%	2.4%	2.0%
RES share	**15.5%**	**15.6%**	**14.2%**	**13.2%**	**11.3%**	**9.7%**

table 14.86: india: heat supply

PJ/A	2005	2010	2020	2030	2040	2050
District heating plants	**0**	**0**	**0**	**0**	**0**	**0**
Fossil fuels	0	0	0	0	0	0
Biomass	0	0	0	0	0	0
Solar collectors	0	0	0	0	0	0
Geothermal	0	0	0	0	0	0
Heat from CHP	**0**	**48**	**204**	**315**	**398**	**497**
Fossil fuels	0	48	204	315	398	497
Biomass	0	0	0	0	0	0
Geothermal	0	0	0	0	0	0
Direct heating[1]	**8,082**	**8,980**	**11,071**	**13,309**	**15,687**	**18,077**
Fossil fuels	2,958	3,645	5,382	7,294	9,301	11,356
Biomass	5,125	5,335	5,665	5,951	6,278	6,563
Solar collectors	0	0	11	27	47	72
Geothermal	0	0	13	37	61	85
Total heat supply[1]	**8,082**	**9,028**	**11,275**	**13,625**	**16,085**	**18,574**
Fossil fuels	2,958	3,693	5,587	7,610	9,700	11,853
Biomass	5,125	5,335	5,665	5,951	6,278	6,563
Solar collectors	0	0	11	27	47	72
Geothermal	0	0	13	37	61	85
RES share (including RES electricity)	**63.4%**	**59.1%**	**50.5%**	**44.1%**	**39.7%**	**36.2%**

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

table 14.87: india: CO_2 emissions

MILL t/a	2005	2010	2020	2030	2040	2050
Condensation power plants	**666**	**870**	**1,350**	**1,938**	**2,591**	**3,410**
Coal	585	772	1,194	1,729	2,340	3,123
Lignite	25	32	47	63	99	145
Gas	30	40	85	125	133	125
Oil	26	26	24	20	19	17
Diesel	0	0	0	0	0	0
Combined heat & power production	**0**	**8**	**37**	**61**	**77**	**87**
Coal	0	8	37	61	77	87
Lignite	0	0	0	0	0	0
Gas	0	0	0	0	0	0
Oil	0	0	0	0	0	0
CO_2 emissions electricity & steam generation	**666**	**879**	**1,387**	**1,999**	**2,668**	**3,498**
Coal	585	781	1,231	1,790	2,418	3,210
Lignite	25	32	47	63	99	145
Gas	30	40	85	125	133	125
Oil & diesel	26	26	24	20	19	17
CO_2 emissions by sector	**1,074**	**1,400**	**2,216**	**3,207**	**4,361**	**5,776**
% of 1990 emissions	187%	244%	386%	558%	759%	1,005%
Industry	181	255	431	625	831	1,040
Other sectors	119	126	153	175	185	186
Transport	108	149	283	469	754	1,139
Electricity & steam generation	666	870	1,350	1,938	2,591	3,410
District heating	0	0	0	0	0	0
Population (Mill.)	1,134	1,220	1,379	1,506	1,597	1,658
CO_2 emissions per capita (t/capita)	**1.0**	**1.2**	**1.7**	**2.3**	**2.9**	**3.6**

table 14.88: india: installed capacity

GW	2005	2010	2020	2030	2040	2050
Power plants	**147**	**204**	**340**	**509**	**749**	**1042**
Coal	77	111	178	270	438	668
Lignite	2.2	3.2	5.9	9.5	16.0	25.2
Gas	16	21	45	79	94	104
Oil	10	11	12	11	19	21
Diesel	0	0	0	0	0	0
Nuclear	3.0	4.2	11.0	17.0	23.0	29.0
Biomass	0.4	0.7	2.1	4.0	5.9	8.0
Hydro	34	43	62	85	108	130
Wind	4.0	11.2	21.1	28.2	35.2	42.3
PV	0	0.1	2.1	5.7	9.4	12.9
Geothermal	0	0	0	0.2	0.3	0.4
Solar thermal power plants	0	0	0	0	0	0
Ocean energy	0	0	0	0	0	0
Combined heat & power production	**0**	**2**	**11**	**21**	**30**	**40**
Coal	0	2	11	21	30	40
Lignite	0	0	0	0	0	0
Gas	0	0	0	0	0	0
Oil	0	0	0	0	0	0
Biomass	0	0	0	0	0	0
Geothermal	0	0	0	0	0	0
CHP by producer						
Main activity producers	0	0	0	0	0	0
Autoproducers	0	2	11	21	30	40
Total generation	**147**	**206**	**351**	**530**	**779**	**1082**
Fossil	105	148	253	390	598	859
Coal	77	113	190	291	469	709
Lignite	2	3	6	10	16	25
Gas	16	21	45	79	94	104
Oil	10	11	12	11	19	21
Diesel	0	0	0	0	0	0
Nuclear	3.0	4.2	11.0	17.0	23.0	29.0
Renewables	**38**	**55**	**88**	**123**	**158**	**194**
Hydro	34	43	62	85	108	130
Wind	4	11	21	28	35	42
PV	0	0	2	6	9	13
Biomass	0.4	0.7	2.1	4.0	5.9	8.0
Geothermal	0	0	0	0	0	0
Solar thermal	0	0	0	0	0	0
Ocean energy	0	0	0	0	0	0
Fluctuating RES (PV, Wind, Ocean)	4.0	11.3	23.2	33.9	44.6	55.3
Share of fluctuating RES	2.7%	5.5%	6.6%	6.4%	5.7%	5.1%
RES share	**26.2%**	**26.5%**	**25.0%**	**23.2%**	**20.3%**	**17.9%**

table 14.89: india: primary energy demand

PJ/A	2005	2010	2020	2030	2040	2050
Total	**22,344**	**27,344**	**40,161**	**54,676**	**70,433**	**89,090**
Fossil	**15,150**	**19,660**	**30,909**	**43,784**	**58,442**	**76,067**
Hard coal	8,449	11,290	17,780	25,521	33,956	44,241
Lignite	221	284	426	569	890	1,310
Natural gas	1,208	1,542	2,715	3,900	4,421	4,693
Crude oil	5,272	6,545	9,987	13,794	19,175	25,824
Nuclear	**189**	**262**	**902**	**1,396**	**1,891**	**2,386**
Renewables	**7,005**	**7,422**	**8,350**	**9,496**	**10,101**	**10,637**
Hydro	360	457	679	929	1,178	1,428
Wind	22	88	186	248	311	373
Solar	0	1	22	55	94	137
Biomass	6,623	6,876	7,443	8,202	8,416	8,560
Geothermal	0	0	20	61	101	138
Ocean Energy	0	0	0	0	0	0
RES share	**31.3%**	**27.1%**	**20.8%**	**17.4%**	**14.3%**	**11.9%**

table 14.90: india: final energy demand

PJ/A	2005	2010	2020	2030	2040	2050
Total (incl. non-energy use)	**14,908**	**17,621**	**25,031**	**33,977**	**45,796**	**60,427**
Total (energy use)	**13,569**	**16,010**	**22,728**	**30,837**	**41,819**	**55,612**
Transport	**1,549**	**2,156**	**4,103**	**6,783**	**10,833**	**16,281**
Oil products	1,480	2,040	3,866	6,418	10,338	15,644
Natural gas	28	40	77	125	172	219
Biofuels	4	21	56	84	111	142
Electricity	38	55	104	156	212	275
RES electricity	6	9	15	21	24	27
Hydrogen	0	0	0	0	0	0
RES share Transport	**0.7%**	**1.4%**	**1.7%**	**1.5%**	**1.2%**	**1.0%**
Industry	**4,145**	**5,431**	**8,387**	**11,690**	**15,923**	**20,829**
Electricity	756	1,193	2,247	3,476	5,372	7,831
RES electricity	117	186	320	457	606	756
District heat	0	48	204	315	398	497
RES district heat	0	0	0	0	0	0
Coal	1,093	1,617	2,869	4,450	6,117	7,887
Oil products	798	985	1,328	1,585	2,025	2,417
Gas	355	396	492	560	604	682
Solar	0	0	5	13	25	42
Biomass and waste	1,143	1,192	1,241	1,289	1,377	1,465
Geothermal	0	0	1	2	4	8
RES share Industry	**30.4%**	**25.4%**	**18.7%**	**15.1%**	**12.6%**	**10.9%**
Other Sectors	**7,875**	**8,423**	**10,238**	**12,364**	**15,063**	**18,502**
Electricity	927	1,235	2,373	3,852	6,276	9,609
RES electricity	143	193	338	507	708	928
District heat	0	0	0	0	0	0
RES district heat	0	0	0	0	0	0
Coal	345	295	252	222	244	232
Oil products	1,143	1,275	1,636	1,879	1,938	1,917
Gas	32	53	125	244	308	383
Solar	0	0	6	14	22	30
Biomass and waste	5,427	5,565	5,835	6,120	6,219	6,256
Geothermal	0	0	11	33	55	75
RES share Other Sectors	**70.7%**	**68.4%**	**60.5%**	**54.0%**	**46.5%**	**39.4%**
Total RES	**6,840**	**7,166**	**7,828**	**8,540**	**9,152**	**9,729**
RES share	**50.4%**	**44.8%**	**34.4%**	**27.7%**	**21.9%**	**17.5%**
Non energy use	**1,339**	**1,611**	**2,303**	**3,140**	**3,977**	**4,815**
Oil	1,028	1,174	1,614	2,201	2,788	3,375
Gas	311	437	688	939	1,189	1,439
Coal	0	0	0	0	0	0

appendix: india energy [r]evolution scenario

table 14.91: india: electricity generation

TWh/a	2005	2010	2020	2030	2040	2050
Power plants	**699**	**989**	**1,601**	**2,253**	**2,985**	**3,765**
Coal	464	667	931	1,042	1,061	1,044
Lignite	16	23	13	8	4	0
Gas	62	85	188	424	538	546
Oil	31	33	12	3	0	0
Diesel	0	0	0	0	0	0
Nuclear	17	24	53	43	24	0
Biomass	2	4	15	20	25	30
Hydro	100	127	189	258	392	474
Wind	6	25	170	310	416	520
PV	0	0	13	71	190	480
Geothermal	0	0	4	8	16	16
Solar thermal power plants	0	0	10	60	304	630
Ocean energy	0	0	4	7	14	25
Combined heat & power production	**0**	**9**	**60**	**150**	**370**	**670**
Coal	0	9	21	31	59	87
Lignite	0	0	0	0	0	0
Gas	0	0	10	22	52	114
Oil	0	0	0	0	0	0
Biomass	0	0	24	75	185	335
Geothermal	0	0	5	23	74	134
CHP by producer						
Main activity producers	0	0	0	0	0	0
Autoproducers	0	9	60	150	370	670
Total generation	**699**	**997**	**1,661**	**2,403**	**3,355**	**4,435**
Fossil	574	817	1,174	1,529	1,714	1,791
Coal	464	676	952	1,072	1,120	1,131
Lignite	16	23	13	8	4	0
Gas	62	85	198	446	590	660
Oil	31	33	12	3	0	0
Diesel	0	0	0	0	0	0
Nuclear	17	24	53	43	24	0
Renewables	**108**	**156**	**434**	**831**	**1,617**	**2,644**
Hydro	100	127	189	258	392	474
Wind	6	25	170	310	416	520
PV	0	0	13	71	190	480
Biomass	2	4	39	95	210	365
Geothermal	0	0	9	30	90	150
Solar thermal	0	0	10	60	304	630
Ocean energy	0	0	4	7	14	25
Import	2	3	4	6	9	11
Import RES	0.3	0.4	1	3	5	8
Export	0.1	0.1	0.2	0.2	0.3	0.4
Distribution losses	175	243.0	354.0	455.0	557.0	659.0
Own consumption electricity	48	67.0	97.0	125.0	153.0	181.0
Electricity for hydrogen production	0	0	0	0.6	39	93
Final energy consumption (electricity)	**478**	**690**	**1,214**	**1,829**	**2,614**	**3,514**
Fluctuating RES (PV, Wind, Ocean)	6	25	187	388	620	1,025
Share of fluctuating RES	0.9%	2.5%	11.3%	16.1%	18.5%	23.1%
RES share	**15.5%**	**15.6%**	**26.1%**	**34.6%**	**48.2%**	**59.6%**
'Efficiency' savings (compared to Ref.)		**0**	**98**	**250**	**680**	**1,407**

table 14.92: india: heat supply

PJ/A	2005	2010	2020	2030	2040	2050
District heating plants	**0**	**0**	**28**	**86**	**234**	**482**
Fossil fuels	0	0	0	0	0	0
Biomass	0	0	20	43	59	58
Solar collectors	0	0	7	38	145	313
Geothermal	0	0	1	5	30	111
Heat from CHP	**0**	**48**	**292**	**681**	**1,626**	**2,855**
Fossil fuels	0	48	140	197	360	618
Biomass	0	0	108	281	600	1,031
Geothermal	0	0	43	203	666	1,206
Direct heating[1)]	**8,082**	**8,980**	**10,542**	**11,891**	**12,341**	**12,103**
Fossil fuels	2,958	3,645	4,577	5,037	4,718	3,888
Biomass	5,125	5,335	5,283	4,837	4,418	3,672
Solar collectors	0	0	591	1,691	2,556	3,401
Geothermal	0	0	92	325	649	1,142
Total heat supply[1)]	**8,082**	**9,028**	**10,862**	**12,658**	**14,201**	**15,440**
Fossil fuels	2,958	3,693	4,717	5,234	5,078	4,507
Biomass	5,125	5,335	5,411	5,161	5,076	4,761
Solar collectors	0	0	598	1,729	2,702	3,714
Geothermal	0	0	136	533	1,345	2,459
RES share (including RES electricity)	**63.4%**	**59%**	**57%**	**59%**	**64%**	**71%**
'Efficiency' savings (compared to Ref.)		**0**	**413**	**967**	**1,884**	**3,134**

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

table 14.93: india: CO_2 emissions

MILL t/a	2005	2010	2020	2030	2040	2050
Condensation power plants	**666**	**870**	**1,002**	**1,022**	**970**	**820**
Coal	585	773	894	830	772	648
Lignite	25	31.6	14.5	7.6	3.7	0
Gas	30	40	85	182	194	172
Oil	26	25.9	8.6	2.0	0	0
Diesel	0	0	0	0	0	0
Combined heat & power production	**0**	**8**	**22**	**32**	**57**	**84**
Coal	0	8	17	22	37	47
Lignite	0	0	0	0	0	0
Gas	0	0	5	10	20	37
Oil	0	0	0	0	0	0
CO_2 emissions electricity & steam generation	**666**	**879**	**1,024**	**1,054**	**1,027**	**904**
Coal	585	781	911	853	809	695
Lignite	25	32	15	8	4	0
Gas	30	40	90	191	213	209
Oil & diesel	26	26	9	2	0	0
CO_2 emissions by sector	**1,074**	**1,400**	**1,706**	**1,824**	**1,816**	**1,662**
% of 1990 emissions	187%	244%	297%	317%	316%	289%
Industry	181	255	338	368	357	321
Other sectors	119	126	122	117	105	79
Transport	108	149	245	318	385	443
Electricity & steam generation	666	870	1,002	1,022	970	820
District heating	0	0	0	0	0	0
Population (Mill.)	1134	1220	1379	1506	1597	1658
CO_2 emissions per capita (t/capita)	**1.0**	**1.2**	**1.3**	**1.3**	**1.2**	**1.0**

table 14.94: india: installed capacity

GW	2005	2010	2020	2030	2040	2050
Power plants	**147**	**204**	**351**	**572**	**827**	**1,157**
Coal	77	111	143	171	185	188
Lignite	2.2	3.2	1.8	1.2	0.6	0
Gas	16	21	46	115	146	148
Oil	10	11	4	1	0	0
Diesel	0	0	0	0	0	0
Nuclear	3.0	4.2	7.0	5.7	3.2	0
Biomass	0.4	0.7	2.3	2.8	3.3	4.0
Hydro	34	43	62	85	129	156
Wind	4.0	11.2	69.2	126.5	169.8	212.2
PV	0	0.2	9.5	51.0	135.7	342.9
Geothermal	0	0	0.6	1.2	2.5	2.5
Solar thermal power plants	0	0	3.3	10	48.3	96.9
Ocean energy	0	0	1.2	1.9	4.1	7.1
Combined heat & power production	**0**	**2**	**14**	**33**	**77**	**138**
Coal	0	2	5	8	15	22
Lignite	0	0	0	0	0	0
Gas	0	0	2	5	10	23
Oil	0	0	0	0	0	0
Biomass	0	0	5	16	37	66
Geothermal	0	0	1	5	15	27
CHP by producer						
Main activity producers	0	0	0	0	0	0
Autoproducers	0	2	14	33	77	138
Total generation	**147**	**207**	**364**	**605**	**904**	**1,295**
Fossil	105	148	202	300	356	380
Coal	77	113	148	179	199	210
Lignite	2	3	2	1	1	0
Gas	16	21	48	119	156	170
Oil	10	11	4	1	0	0
Diesel	0	0	0	0	0	0
Nuclear	3.0	4.2	7.0	5.7	3.2	0
Renewables	**38**	**55**	**155**	**299**	**545**	**915**
Hydro	34	43	62	85	129	156
Wind	4	11	69	127	170	212
PV	0	0	10	51	136	343
Biomass	0.4	1	8	19	41	70
Geothermal	0	0	2	6	17	29
Solar thermal	0	0	3	10	48	97
Ocean energy	0	0	1	2	4	7
Fluctuating RES (PV, Wind, Ocean)	4.0	11.4	79.9	179.4	309.6	562.2
Share of fluctuating RES	2.7%	5.5%	21.9%	29.7%	34.2%	43.4%
RES share	**26.2%**	**26.5%**	**42.5%**	**49.4%**	**60.3%**	**70.6%**

table 14.95: india: primary energy demand

PJ/A	2005	2010	2020	2030	2040	2050
Total	**22,344**	**27,345**	**35,210**	**41,644**	**47,617**	**52,120**
Fossil	**15,150**	**19,661**	**24,940**	**28,080**	**28,833**	**27,333**
Hard coal	8,449	11,292	13,410	12,897	12,108	10,478
Lignite	221	284	131	69	33	0
Natural gas	1,208	1,543	3,596	6,449	7,166	7,116
Crude oil	5,272	6,540	7,802	8,665	9,526	9,738
Nuclear	**189**	**262**	**576**	**467**	**260**	**0**
Renewables	**7,005**	**7,423**	**9,694**	**13,097**	**18,524**	**24,787**
Hydro	360	457	679	929	1,413	1,706
Wind	22	88	610	1,116	1,498	1,872
Solar	0	1	682	2,202	4,480	7,710
Biomass	6,623	6,876	7,340	7,584	7,729	7,839
Geothermal	0	0	368	1,242	3,353	5,570
Ocean Energy	0	0	15	24	52	90
RES share	**31.3%**	**27.1%**	**27.5%**	**31.4%**	**38.9%**	**47.6%**
'Efficiency' savings (compared to Ref.)		**0**	**4,960**	**13,058**	**22,872**	**37,071**

table 14.96: india: final energy demand

PJ/A	2005	2010	2020	2030	2040	2050
Total (incl. non-energy use)	**14,908**	**17,618**	**23,154**	**28,674**	**34,264**	**39,563**
Total (energy use)	**13,569**	**16,009**	**21,188**	**26,174**	**31,247**	**36,263**
Transport	1,549	2,156	3,786	5,417	7,047	8,677
Oil products	1,480	2,040	3,342	4,331	5,259	6,056
Natural gas	28	40	71	98	109	112
Biofuels	4	21	112	250	363	510
Electricity	38	55	262	737	1,288	1,928
RES electricity	6	9	68	255	621	1,150
Hydrogen	0	0	0	0	28	69
RES share Transport	**0.7%**	**1.4%**	**4.8%**	**9.3%**	**14.2%**	**19.6%**
Industry	**4,145**	**5,431**	**7,582**	**9,531**	**11,525**	**13,421**
Electricity	756	1,193	2,003	2,793	3,790	4,903
RES electricity	117	186	523	966	1,827	2,923
District heat	0	48	313	732	1,789	3,116
RES district heat	0	0	313	732	1,789	3,116
Coal	1,093	1,617	1,920	1,870	1,586	1,228
Oil products	798	985	1,012	874	641	297
Gas	355	396	1,089	1,723	1,862	1,789
Solar	0	0	217	569	842	1,044
Biomass and waste	1,143	1,192	971	759	586	430
Geothermal	0	0	57	211	427	613
RES share Industry	**30.4%**	**25.4%**	**27.4%**	**34.0%**	**47.5%**	**60.6%**
Other Sectors	**7,875**	**8,422**	**9,819**	**11,227**	**12,676**	**14,165**
Electricity	927	1,235	2,106	3,055	4,434	6,059
RES electricity	143	193	550	1,056	2,137	3,612
District heat	0	0	6	34	71	221
RES district heat	0	0	6	34	71	221
Coal	345	295	271	259	218	182
Oil products	1,143	1,273	972	782	634	296
Gas	32	54	428	611	663	719
Solar	0	0	374	1,122	1,714	2,357
Biomass and waste	5,427	5,565	5,629	5,270	4,764	3,890
Geothermal	0	0	33	94	176	442
RES share Other Sectors	**70.7%**	**68.4%**	**67.1%**	**67.5%**	**69.9%**	**74.3%**
Total RES	**6,840**	**7,166**	**8,854**	**11,318**	**15,331**	**20,349**
RES share	**50.4%**	**44.8%**	**41.8%**	**43.2%**	**49.1%**	**56.1%**
Non energy use	**1,339**	**1,609**	**1,966**	**2,500**	**3,017**	**3,300**
Oil	1,028	1,172	1,433	1,800	2,167	2,350
Gas	311	437	533	700	850	950
Coal	0	0	0	0	0	0

appendix: developing asia reference scenario

table 14.97: developing asia: electricity generation

TWh/a	2005	2010	2020	2030	2040	2050
Power plants	**897**	**1,200**	**1,728**	**2,180**	**2,641**	**3,181**
Coal	229	361	544	749	967	1255
Lignite	19	24	41	57	72	88
Gas	342	454	630	758	886	1020
Oil	122	136	137	111	86	61
Diesel	42	43	70	72	74	76
Nuclear	0	0	0	0	0	0
Biomass	6	13	32	55	77	101
Hydro	120	143	219	284	349	415
Wind	0	5	21	44	67	91
PV	0	1	4	7	10	14
Geothermal	17	22	32	42	52	62
Solar thermal power plants	0	0	0	0	0	0
Ocean energy	0	0	0	0	0	0
Combined heat & power production	**3**	**10**	**30**	**54**	**84**	**102**
Coal	0	2	5	8	14	17
Lignite	3	4	5	6	7	7
Gas	0	3	14	28	42	50
Oil	0	0	1	3	4	5
Biomass	0	1	4	10	17	23
Geothermal	0	0	0	0	0	0
CHP by producer						
Main activity producers	3	4	6	8	10	12
Autoproducers	0	6	24	46	74	90
Total generation	**901**	**1,210**	**1,758**	**2,234**	**2,725**	**3,283**
Fossil	716	983	1,377	1,720	2,078	2,503
Coal	229	363	549	758	981	1,272
Lignite	23	28	46	62	79	95
Gas	342	456	644	786	928	1070
Oil	122	136	138	114	90	66
Diesel	0	0	0	0	0	0
Nuclear	42	43	70	72	74	76
Renewables	**143**	**184**	**311**	**442**	**573**	**705**
Hydro	120	143	219	284	349	415
Wind	0	5	21	44	67	91
PV	0	1	4	7	10	14
Biomass	6	14	36	65	94	124
Geothermal	17	22	32	42	52	62
Solar thermal	0	0	0	0	0	0
Ocean energy	0	0	0	0	0	0
Import	6	7	11	14	17	21
Import RES	1	1	2	2	2	2
Export	3	4	6	8	10	12
Distribution losses	86	106	143	181	215	246
Own consumption electricity	51	74	113	145	181	220
Electricity for hydrogen production	0	0	0	0	0	0
Final energy consumption (electricity)	**766**	**1,033**	**1,507**	**1,914**	**2,337**	**2,826**
Fluctuating RES (PV, Wind, Ocean)	0	6	24	51	78	104
Share of fluctuating RES	0%	0.5%	1.4%	2.3%	2.8%	3.2%
RES share	**15.8%**	**15.2%**	**17.7%**	**19.8%**	**21.0%**	**21.5%**

table 14.98: developing asia: heat supply

PJ/A	2005	2010	2020	2030	2040	2050
District heating plants	**0**	**1**	**13**	**10**	**9**	**13**
Fossil fuels	0	1	13	10	9	13
Biomass	0	0	0	0	0	0
Solar collectors	0	0	0	0	0	0
Geothermal	0	0	0	0	0	0
Heat from CHP	**37**	**83**	**142**	**216**	**286**	**326**
Fossil fuels	37	75	119	173	223	248
Biomass	0	7	22	43	62	78
Geothermal	0	0	0	0	0	0
Direct heating[1)]	**10,087**	**10,614**	**12,053**	**13,724**	**15,608**	**17,556**
Fossil fuels	4,745	5,332	6,546	7,833	8,850	9,870
Biomass	5,342	5,276	5,453	5,803	6,634	7,518
Solar collectors	0	6	25	42	63	88
Geothermal	0	0	29	46	61	79
Total heat supply[1)]	**10,123**	**10,697**	**12,208**	**13,950**	**15,903**	**17,895**
Fossil fuels	4,781	5,407	6,679	8,016	9,083	10,130
Biomass	5,342	5,283	5,475	5,846	6,696	7,597
Solar collectors	0	6	25	42	63	88
Geothermal	0	0	29	46	61	79
RES share (including RES electricity)	**52.8%**	**49.4%**	**45.3%**	**42.5%**	**42.9%**	**43.4%**

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

table 14.99: developing asia: CO_2 emissions

MILL t/a	2005	2010	2020	2030	2040	2050
Condensation power plants	**475**	**621**	**805**	**986**	**1,137**	**1,325**
Coal	233	321	424	569	703	875
Lignite	21	26	42	55	67	78
Gas	166	209	262	289	311	332
Oil	55	66	76	73	56	40
Diesel	0	0	0	0	0	0
Combined heat & power production	**8**	**13**	**18**	**26**	**35**	**39**
Coal	0	2	4	6	9	11
Lignite	8	8	6	6	6	6
Gas	0	2	7	12	17	20
Oil	0	0	1	2	2	3
CO_2 emissions electricity & steam generation	**483**	**634**	**823**	**1,012**	**1,172**	**1,364**
Coal	233	323	429	575	713	886
Lignite	30	34	48	61	73	84
Gas	166	211	269	301	328	351
Oil & diesel	55	66	77	75	59	43
CO_2 emissions by sector	**1,303**	**1,577**	**2,007**	**2,441**	**2,830**	**3,265**
% of 1990 emissions	268%	325%	414%	503%	583%	673%
Industry	330	369	447	523	591	659
Other sectors	133	149	173	197	204	211
Transport	357	429	575	727	889	1060
Electricity & steam generation	483	630	811	994	1,146	1,333
District heating	0	0	2	1	1	1
Population (Mill.)	975	1050	1195	1324	1428	1504
CO_2 emissions per capita (t/capita)	**1.3**	**1.5**	**1.7**	**1.8**	**2.0**	**2.2**

table 14.100: developing asia: installed capacity

GW	2005	2010	2020	2030	2040	2050
Power plants	**228**	**301**	**444**	**574**	**642**	**716**
Coal	39	68	114	156	179	209
Lignite	2.6	3.2	5.6	7.9	10.1	12.5
Gas	89	122	181	234	252	268
Oil	41	42	41	36	33	30
Diesel	0	0	0	0	0	0
Nuclear	5.0	5.0	8.3	9.0	9.3	9.5
Biomass	2.0	3.0	5.4	8.1	11.2	14.4
Hydro	46	51	73	94	107	118
Wind	0	2.1	8.4	18.0	25.6	34.5
PV	0	0.7	2.6	5.0	7.4	9.8
Geothermal	3.0	3.6	4.7	6.0	7.4	8.9
Solar thermal power plants	0	0	0	0	0	0
Ocean energy	0	0	0	0	0	0
Combined heat & power production	**2**	**3**	**8**	**13**	**19**	**23**
Coal	0	0	1	2	4	5
Lignite	2	2	2	2	2	2
Gas	0	1	3	6	9	10
Oil	0	0	0	1	1	1
Biomass	0	0	1	2	3	5
Geothermal	0	0	0	0	0	0
CHP by producer						
Main activity producers	2	2	3	3	3	4
Autoproducers	0	1	5	10	15	19
Total generation	**230**	**304**	**452**	**586**	**661**	**739**
Fossil	174	239	349	444	489	539
Coal	39	69	115	158	183	214
Lignite	5	5	8	10	12	15
Gas	89	123	184	240	260	279
Oil	41	42	41	36	34	31
Diesel	0	0	0	0	0	0
Nuclear	5.0	5.0	8.3	9.0	9.3	9.5
Renewables	**51**	**61**	**95**	**133**	**162**	**191**
Hydro	46	51	73	94	107	118
Wind	0	2	8	18	26	34
PV	0	1	3	5	7	10
Biomass	2.0	3.2	6.3	10.2	14.6	18.9
Geothermal	3	4	5	6	7	9
Solar thermal	0	0	0	0	0	0
Ocean energy	0	0	0	0	0	0
Fluctuating RES (PV, Wind, Ocean)	0	2.8	11.1	23.0	32.9	44.3
Share of fluctuating RES	0%	0.9%	2.5%	3.9%	5.0%	6.0%
RES share	**22.2%**	**19.9%**	**21.0%**	**22.7%**	**24.5%**	**25.8%**

table 14.101: developing asia:primary energy demand

PJ/A	2005	2010	2020	2030	2040	2050
Total	**31,095**	**36,308**	**45,797**	**54,638**	**60,887**	**67,414**
Fossil	**22,484**	**27,061**	**34,439**	**41,405**	**46,373**	**51,661**
Hard coal	4,718	6,054	7,611	9,320	10,967	13,023
Lignite	268	309	432	553	659	754
Natural gas	6,047	7,558	10,086	12,358	12,786	12,956
Crude oil	11,450	13,140	16,311	19,174	21,961	24,928
Nuclear	**463**	**469**	**764**	**786**	**807**	**829**
Renewables	**8,148**	**8,779**	**10,594**	**12,448**	**13,707**	**14,925**
Hydro	432	515	787	1,022	1,257	1,493
Wind	0	16	75	158	242	327
Solar	0	10	39	67	100	138
Biomass	7,122	7,446	8,512	9,642	10,549	11,400
Geothermal	594	792	1,181	1,558	1,559	1,567
Ocean Energy	0	0	0	0	0	0
RES share	**26.2%**	**24.2%**	**23.1%**	**22.8%**	**22.5%**	**22.1%**

table 14.102: developing asia: final energy demand

PJ/a	2005	2010	2020	2030	2040	2050
Total (incl. non-energy use)	**22,554**	**25,977**	**32,560**	**38,661**	**44,589**	**50,892**
Total (energy use)	**20,553**	**23,450**	**29,280**	**34,923**	**40,394**	**46,239**
Transport	**4,964**	**5,988**	**8,131**	**10,367**	**12,753**	**15,270**
Oil products	4,914	5,908	7,924	10,015	12,255	14,621
Natural gas	42	50	70	87	104	121
Biofuels	0	22	126	251	373	500
Electricity	7	8	12	15	21	28
RES electricity	1	1	2	3	4	6
Hydrogen	0	0	0	0	0	0
RES share Transport	**0%**	**0.4%**	**1.6%**	**2.5%**	**3.0%**	**3.3%**
Industry	**6,285**	**7,334**	**9,222**	**10,898**	**12,389**	**13,945**
Electricity	1,210	1,652	2,340	2,823	3,254	3,739
RES electricity	192	251	414	559	684	803
District heat	12	66	125	185	246	285
RES district heat	0	0	2	4	5	7
Coal	1,881	2,021	2,249	2,415	2,547	2,694
Oil products	1,334	1,452	1,698	1,941	2,188	2,486
Gas	988	1,227	1,791	2,435	2,960	3,477
Solar	0	0	5	13	23	35
Biomass and waste	860	915	1,006	1,071	1,145	1,190
Geothermal	0	0	7	16	26	39
RES share Industry	**16.7%**	**15.9%**	**15.5%**	**15.2%**	**15.2%**	**14.9%**
Other Sectors	**9,305**	**10,128**	**11,927**	**13,658**	**15,253**	**17,025**
Electricity	1,541	2,058	3,072	4,053	5,137	6,409
RES electricity	244	313	543	802	1,081	1,376
District heat	25	15	26	36	42	46
RES district heat	0	0	0	1	1	1
Coal	139	241	273	313	353	397
Oil products	1,351	1,389	1,586	1,809	1,806	1,802
Gas	348	398	492	551	607	646
Solar	0	6	20	29	40	54
Biomass and waste	5,901	6,022	6,435	6,836	7,232	7,631
Geothermal	0	0	23	30	35	40
RES share Other Sectors	**66.0%**	**62.6%**	**58.9%**	**56.4%**	**55.0%**	**53.5%**
Total RES	**7,199**	**7,531**	**8,583**	**9,614**	**10,649**	**11,680**
RES share	**35.0%**	**32.1%**	**29.3%**	**27.5%**	**26.4%**	**25.3%**
Non energy use	**2,001**	**2,526**	**3,280**	**3,738**	**4,195**	**4,652**
Oil	1,412	1,783	2,315	2,638	2,961	3,284
Gas	578	730	948	1,080	1,212	1,344
Coal	10	13	17	19	22	24

appendix: developing asia energy [r]evolution scenario

table 14.103: developing asia:electricity generation

TWh/a	2005	2010	2020	2030	2040	2050
Power plants	**897**	**1,199**	**1,489**	**1,698**	**1,903**	**2,106**
Coal	229	360	387	288	201	105
Lignite	19	24	15	8	3	0
Gas	342	454	518	526	531	531
Oil	122	136	108	69	30	10
Diesel	0	0	0	0	0	0
Nuclear	42	43	60	40	12	0
Biomass	6	13	23	24	26	29
Hydro	120	143	210	240	263	286
Wind	0	5	99	310	450	530
PV	0	1	18	95	195	325
Geothermal	17	22	39	60	91	114
Solar thermal power plants	0	0	9	30	90	160
Ocean energy	0	0	3	8	12	16
Combined heat & power production	**3**	**10**	**71**	**147**	**209**	**250**
Coal	0	2	19	45	53	69
Lignite	3	4	3	1	0	0
Gas	0	3	27	44	54	54
Oil	0	0	2	1	0	0
Biomass	0	1	13	35	67	81
Geothermal	0	0	6	21	34	47
CHP by producer						
Main activity producers	3	4	6	9	12	15
Autoproducers	0	6	65	138	197	235
Total generation	**901**	**1,209**	**1,560**	**1,845**	**2,112**	**2,356**
Fossil	716	982	1080	982	872	769
Coal	229	362	407	333	254	174
Lignite	23	28	18	9	3	0
Gas	342	456	545	570	585	585
Oil	122	136	110	70	30	10
Diesel	0	0	0	0	0	0
Nuclear	42	43	60	40	12	0
Renewables	**143**	**184**	**420**	**823**	**1,228**	**1,587**
Hydro	120	143	210	240	263	286
Wind	0	5	99	310	450	530
PV	0	1	18	95	195	325
Biomass	6	14	36	59	93	110
Geothermal	17	22	45	81	125	160
Solar thermal	0	0	9	30	90	160
Ocean energy	0	0	3	8	12	16
Import	6	7	10	11	12	13
Import RES	1	2	4	6	7	9
Export	3	4	6	6	7	8
Distribution losses	86	106.0	119.0	142.0	167.0	197.0
Own consumption electricity	51	74.0	102.0	116.0	127.0	135.0
Electricity for hydrogen production	0	0	0	2	24	64
Final energy consumption (electricity)	**766**	**1,032**	**1,343**	**1,590**	**1,799**	**1,965**
Fluctuating RES (PV, Wind, Ocean)	0	6	120	413	657	871
Share of fluctuating RES	0%	0.5%	7.7%	22.4%	31.1%	37.0%
RES share	**15.8%**	**15.2%**	**26.9%**	**44.6%**	**58.1%**	**67.4%**
'Efficiency' savings (compared to Ref.)		**1**	**164**	**324**	**537**	**862**

table 14.104: developing asia: heat supply

PJ/A	2005	2010	2020	2030	2040	2050
District heating plants	**0**	**1**	**35**	**38**	**46**	**61**
Fossil fuels	0	1	2	2	1	0
Biomass	0	0	16	18	22	29
Solar collectors	0	0	8	8	11	16
Geothermal	0	0	8	10	12	16
Heat from CHP	**37**	**83**	**381**	**723**	**925**	**1,065**
Fossil fuels	37	75	233	347	353	379
Biomass	0	7	69	149	234	267
Geothermal	0	0	79	227	338	419
Direct heating[1)]	**10,087**	**10,614**	**11,378**	**12,232**	**13,154**	**13,865**
Fossil fuels	4,745	5,332	5,476	5309	4,931	4,111
Biomass	5,342	5,276	5,065	4973	5,081	5,183
Solar collectors	0	6	632	1528	2,265	3,265
Geothermal	0	0	205	421	876	1,306
Total heat supply[1)]	**10,123**	**10,697**	**11,794**	**12,993**	**14,125**	**14,990**
Fossil fuels	4,781	5,408	5,711	5,658	5,285	4,490
Biomass	5,342	5,283	5,150	5,141	5,338	5,479
Solar collectors	0	6	640	1,536	2,276	3,281
Geothermal	0	0	293	658	1,226	1,742
RES share (including RES electricity)	**52.8%**	**49%**	**52%**	**56%**	**63%**	**70%**
'Efficiency' savings (compared to Ref.)		**0**	**414**	**957**	**1,778**	**2,904**

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

table 14.105: developing asia: CO_2 emissions

MILL t/a	2005	2010	2020	2030	2040	2050
Condensation power plants	**475**	**620**	**594**	**472**	**355**	**253**
Coal	233	320	302	219	146	73
Lignite	21	25.8	15.3	7.8	2.8	0
Gas	166	209	216	200	186	173
Oil	55	65.6	60.3	45.2	19.8	6.6
Diesel	0	0	0	0	0	0
Combined heat & power production	**8**	**13**	**34**	**54**	**58**	**66**
Coal	0	2	16	33	36	45
Lignite	8	8	3	1	0	0
Gas	0	2	13	20	22	21
Oil	0	0	1	1	0	0
CO_2 emissions electricity & steam generation	**483**	**633**	**628**	**526**	**413**	**318**
Coal	233	323	318	251	182	118
Lignite	30	34	19	9	3	0
Gas	166	211	229	220	208	194
Oil & diesel	55	66	62	46	20	7
CO_2 emissions by sector	**1,303**	**1,576**	**1,596**	**1,482**	**1,329**	**1,148**
% of 1990 emissions	268%	325%	329%	305%	274%	236%
Industry	330	369	390	383	357	302
Other sectors	133	149	145	139	120	95
Transport	357	429	462	484	495	496
Electricity & steam generation	483	629	598	475	357	255
District heating	0	0	0	0	0	0
Population (Mill.)	975	1050	1195	1324	1428	1504
CO_2 emissions per capita (t/capita)	**1.3**	**1.5**	**1.3**	**1.1**	**0.9**	**0.8**

table 14.106: developing asia: installed capacity

GW	2005	2010	2020	2030	2040	2050
Power plants	**228**	**301**	**409**	**544**	**656**	**762**
Coal	39	68	81	60	42	23
Lignite	2.6	3.5	2.6	1.8	0.9	0
Gas	89	122	149	162	166	166
Oil	41	42	32	22	20	8
Diesel	0	0	0	0	0	0
Nuclear	5.0	5.0	7.1	5.0	1.5	0
Biomass	2.0	3.0	3.9	3.6	3.8	4.1
Hydro	46	51	70	79	81	82
Wind	0	2.1	40.4	126.5	171.1	201.5
PV	0	0.7	12.9	67.9	139.3	232.1
Geothermal	3.0	3.6	5.6	8.6	13.0	16.2
Solar thermal power plants	0	0	2.9	5.0	14.3	24.6
Ocean energy	0	0	0.9	2.3	3.4	4.6
Combined heat & power production	**2**	**3**	**17**	**33**	**45**	**54**
Coal	0	0	5	11	13	17
Lignite	2	2	1	0	0	0
Gas	0	1	6	10	11	11
Oil	0	0	0	0	0	0
Biomass	0	0	3	7	13	16
Geothermal	0	0	1	4	7	9
CHP by producer						
Main activity producers	2	2	2	2	3	4
Autoproducers	0	1	15	31	42	50
Total generation	**230**	**304**	**426**	**577**	**700**	**816**
Fossil	174	239	278	267	253	226
Coal	39	69	86	71	55	41
Lignite	5	5	4	2	1	0
Gas	89	123	155	172	177	177
Oil	41	42	33	22	20	8
Diesel	0	0	0	0	0	0
Nuclear	5.0	5.0	7.1	5.0	1.5	0
Renewables	**51**	**61**	**141**	**305**	**446**	**590**
Hydro	46	51	70	79	81	82
Wind	0	2	40	127	171	202
PV	0	1	13	68	139	232
Biomass	2.0	3	7	11	17	20
Geothermal	3	4	7	13	20	26
Solar thermal	0	0	3	5	14	25
Ocean energy	0	0	1	2	3	5
Fluctuating RES (PV, Wind, Ocean)	0	2.8	54.1	196.7	313.8	438.2
Share of fluctuating RES	0%	0.9%	12.7%	34.1%	44.8%	53.7%
RES share	**22.2%**	**19.9%**	**33.1%**	**52.8%**	**63.6%**	**72.3%**

table 14.107: developing asia:primary energy demand

PJ/A	2005	2010	2020	2030	2040	2050
Total	**31,095**	**36,299**	**40,538**	**43,393**	**43,884**	**43,838**
Fossil	**22,484**	**27,051**	**28,258**	**27,548**	**25,217**	**22,449**
Hard coal	4,718	6,044	6,123	5,116	4,223	3,043
Lignite	268	309	169	83	25	0
Natural gas	6,047	7,561	8,959	9,662	8,951	8,109
Crude oil	11,450	13,137	13,007	12,688	12,018	11,297
Nuclear	**463**	**469**	**655**	**436**	**131**	**0**
Renewables	**8,148**	**8,779**	**11,625**	**15,408**	**18,535**	**21,389**
Hydro	432	515	756	864	947	1,030
Wind	0	16	356	1,116	1,620	1,908
Solar	0	10	737	1,986	3,302	5,027
Biomass	7,122	7,446	7,861	7,995	7,983	7,977
Geothermal	594	792	1,903	3,418	4,640	5,390
Ocean Energy	0	0	11	29	43	58
RES share	**26.2%**	**24.2%**	**28.7%**	**35.5%**	**42.2%**	**48.8%**
'Efficiency' savings (compared to Ref.)		**14**	**5,276**	**11,270**	**17,048**	**23,642**

table 14.108: developing asia:final energy demand

PJ/a	2005	2010	2020	2030	2040	2050
Total (incl. non-energy use)	**22,554**	**25,974**	**29,357**	**32,051**	**34,130**	**35,726**
Total (energy use)	**20,553**	**23,448**	**26,357**	**28,651**	**30,330**	**31,625**
Transport	**4,964**	**5,988**	**6,637**	**7,189**	**7,740**	**8,292**
Oil products	4,914	5,908	6,366	6,667	6,815	6,812
Natural gas	42	50	59	66	73	79
Biofuels	0	22	88	132	297	576
Electricity	7	8	123	323	539	778
RES electricity	1	1	33	144	313	524
Hydrogen	0	0	0	1	17	48
RES share Transport	**0%**	**0.4%**	**1.8%**	**3.8%**	**8.0%**	**13.6%**
Industry	**6,285**	**7,334**	**8,292**	**8,898**	**9,203**	**9,300**
Electricity	1,210	1,652	2,058	2,264	2,384	2,450
RES electricity	192	251	554	1,010	1,386	1,650
District heat	12	66	351	667	858	989
RES district heat	0	0	225	501	685	835
Coal	1,881	2,021	1,993	1,807	1,717	1,268
Oil products	1,334	1,452	1,208	927	565	299
Gas	988	1,228	1,535	1,711	1,813	1,806
Solar	0	0	168	404	648	1,077
Biomass and waste	860	915	834	813	743	705
Geothermal	0	0	145	305	477	704
RES share Industry	**16.7%**	**15.9%**	**23.2%**	**34.1%**	**42.8%**	**53.5%**
Other Sectors	**9,305**	**10,126**	**11,428**	**12,565**	**13,387**	**14,033**
Electricity	1,541	2,055	2,653	3,143	3,617	4,013
RES electricity	244	313	714	1,402	2,103	2,703
District heat	25	15	58	81	99	119
RES district heat	0	0	37	61	79	101
Coal	139	241	241	210	160	123
Oil products	1,351	1,387	1,126	980	729	384
Gas	348	399	678	805	868	941
Solar	0	6	464	1,124	1,618	2,188
Biomass and waste	5,901	6,022	6,149	6,108	5,919	5,686
Geothermal	0	0	60	114	377	579
RES share Other Sectors	**66.0%**	**62.6%**	**65.0%**	**70.1%**	**75.4%**	**80.2%**
Total RES	**7,199**	**7,532**	**9,472**	**12,118**	**14,653**	**17,361**
RES share	**35.0%**	**32.1%**	**35.9%**	**42.3%**	**48.3%**	**54.9%**
Non energy use	**2,001**	**2,526**	**3,000**	**3,400**	**3,800**	**4,101**
Oil	1,412	1,783	2,117	2,398	2,679	2,871
Gas	578	730	868	985	1,102	1,210
Coal	10	13	15	17	19	20

appendix: china reference scenario

table 14.109: china: electricity generation

TWh/a	2005	2010	2020	2030	2040	2050
Power plants	**2,438**	**3,786**	**6,059**	**7,980**	**9,928**	**11,786**
Coal	1,884	3,030	4,825	6,327	7,934	9,463
Lignite	0	0	0	0	0	0
Gas	38	47	98	148	138	133
Oil	61	58	49	42	32	23
Diesel	0	0	0	0	0	0
Nuclear	53	70	167	256	345	433
Biomass	3	7	24	52	65	61
Hydro	397	557	813	1,005	1197	1,389
Wind	2	16	77	133	189	245
PV	0	0	5	15	25	34
Geothermal	0	1	1	2	4	5
Solar thermal power plants	0	0	0	0	0	0
Ocean energy	0	0	0	0	0	0
Combined heat & power production	**101**	**171**	**328**	**492**	**657**	**822**
Coal	97	149	225	260	297	343
Lignite	0	0	0	0	0	0
Gas	3	15	72	165	239	287
Oil	0	2	6	8	11	14
Biomass	0	5	24	58	107	173
Geothermal	0	0	2	3	4	4
CHP by producer						
Main activity producers	13	18	56	117	179	241
Autoproducers	88	153	272	375	478	581
Total generation	**2,539**	**3,957**	**6,388**	**8,472**	**10,585**	**12,607**
Fossil	2,084	3,300	5,274	6,948	8,650	10,263
Coal	1,982	3,179	5,050	6,586	8,231	9,806
Lignite	0	0	0	0	0	0
Gas	41	62	170	313	376	420
Oil	61	60	55	49	43	37
Diesel	0	0	0	0	0	0
Nuclear	53	70	167	256	345	433
Renewables	**402**	**587**	**946**	**1,268**	**1,590**	**1,911**
Hydro	397	557	813	1,005	1,197	1,389
Wind	2	16	77	133	189	245
PV	0	0	5	15	25	34
Biomass	3	12	48	110	172	234
Geothermal	0	1	3	5	7	9
Solar thermal	0	0	0	0	0	0
Ocean energy	0	0	0	0	0	0
Import	16	25	40	53	78	105
Import RES	0	0	0	0	0	0
Export	16	24	39	52	60	74
Distribution losses	173	293	439	530	521	476
Own consumption electricity	330	535	866	1,132	1,346	1,497
Electricity for hydrogen production	0	0	0	0	0	0
Final energy consumption (electricity)	**2,035**	**3,129**	**5,083**	**6,812**	**8,735**	**10,665**
Fluctuating RES (PV, Wind, Ocean)	2	16	82	148	214	279
Share of fluctuating RES	0.1%	0.4%	1.3%	1.7%	2.0%	2.2%
RES share	**15.8%**	**14.8%**	**14.8%**	**15.0%**	**15.0%**	**15.2%**

table 14.110: china: heat supply

PJ/A	2005	2010	2020	2030	2040	2050
District heating plants	**1,480**	**1,679**	**1,900**	**1,812**	**1,608**	**1,290**
Fossil fuels	1,471	1,649	1,799	1,631	1,431	1,135
Biomass	9	30	101	181	177	155
Solar collectors	0	0	0	0	0	0
Geothermal	0	0	0	0	0	0
Heat from CHP	**809**	**1,179**	**1,733**	**2,034**	**2,310**	**2,663**
Fossil fuels	809	1,137	1,574	1,744	1,886	2,048
Biomass	0	38	144	268	393	576
Geothermal	0	4	15	22	31	39
Direct heating[1]	**23,229**	**27,433**	**33,434**	**36,105**	**36,949**	**37,225**
Fossil fuels	15,971	19,903	25,551	28,856	30,336	31,478
Biomass	7,258	7,446	7,481	6,543	5,609	4,462
Solar collectors	0	83	381	656	927	1,183
Geothermal	0	0	21	49	76	103
Total heat supply[1]	**25,518**	**30,290**	**37,067**	**39,952**	**40,867**	**41,178**
Fossil fuels	18,251	22,689	28,924	32,231	33,653	34,661
Biomass	7,267	7,515	7,727	6,993	6,179	5,193
Solar collectors	0	83	381	656	927	1,183
Geothermal	0	4	35	72	108	142
RES share (including RES electricity)	**28.5%**	**25.1%**	**22.0%**	**19.3%**	**17.7%**	**15.8%**

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

table 14.111: china: CO_2 emissions

MILL t/a	2005	2010	2020	2030	2040	2050
Condensation power plants	**2,030**	**3,205**	**4,973**	**6,317**	**6,647**	**6,657**
Coal	1,962	3,139	4,896	6,230	6,575	6,600
Lignite	0	0	0	0	0	0
Gas	20	23	44	60	50	42
Oil	48	43	33	27	21	15
Diesel	0	0	0	0	0	0
Combined heat & power production	**149**	**205**	**275**	**284**	**308**	**335**
Coal	146	192	227	201	203	219
Lignite	0	0	0	0	0	0
Gas	3	12	44	79	100	109
Oil	0	1	4	4	6	7
CO_2 emissions electricity & steam generation	**2,179**	**3,410**	**5,248**	**6,601**	**6,955**	**6,993**
Coal	2,108	3,330	5,123	6,431	6,778	6,819
Lignite	0	0	0	0	0	0
Gas	23	35	88	139	150	151
Oil & diesel	48	45	37	32	27	23
CO_2 emissions by sector	**4,429**	**6,246**	**8,995**	**10,969**	**11,919**	**12,572**
% of 1990 emissions	198%	279%	401%	489%	532%	561%
Industry	1,295	1,664	2,124	2,251	2,308	2,355
Other sectors	481	577	696	790	829	857
Transport	360	529	913	1340	1891	2495
Electricity & steam generation	2,049	3,228	5,026	6,392	6,731	6,746
District heating	244	248	235	197	160	118
Population (Mill.)	1321	1359	1430	1467	1458	1418
CO_2 emissions per capita (t/capita)	**3.4**	**4.6**	**6.3**	**7.5**	**8.2**	**8.9**

table 14.112: china: installed capacity

GW	2005	2010	2020	2030	2040	2050
Power plants	**483**	**759**	**1,245**	**1,652**	**2,043**	**2,421**
Coal	336	549	892	1,185	1,486	1,772
Lignite	0	0	0	0	0	0
Gas	9	14	36	51	48	46
Oil	12	13	12	9	7	5
Diesel	0	0	0	0	0	0
Nuclear	7.0	8.9	20.4	31.0	41.7	52.5
Biomass	0.6	1.9	5.8	10.2	12.7	11.8
Hydro	117	166	243	300	357	415
Wind	1.0	7.4	31.4	54.3	71.9	93.2
PV	0.1	0.2	3.9	10.7	17.6	24.6
Geothermal	0	0.1	0.2	0.4	0.6	0.8
Solar thermal power plants	0	0	0	0	0	0
Ocean energy	0	0	0	0	0	0
Combined heat & power production	**32**	**46**	**87**	**131**	**172**	**212**
Coal	31	40	62	71	83	98
Lignite	0	0	0	0	0	0
Gas	1	5	20	50	72	86
Oil	0	0	1	2	2	3
Biomass	0	1	4	8	15	25
Geothermal	0	0	0	0	1	1
CHP by producer						
Main activity producers	10	9	24	47	70	91
Autoproducers	22	37	63	84	102	122
Total generation	**516**	**805**	**1,332**	**1,784**	**2,215**	**2,633**
Fossil	390	620	1,023	1,368	1,697	2,010
Coal	367	589	954	1,256	1,569	1,870
Lignite	0	0	0	0	0	0
Gas	11	18	56	101	119	132
Oil	12	13	13	11	9	8
Diesel	0	0	0	0	0	0
Nuclear	7.0	8.9	20.4	31.0	41.7	52.5
Renewables	**119**	**176**	**289**	**384**	**476**	**571**
Hydro	117	166	243	300	357	415
Wind	1	7	31	54	72	93
PV	0	0	4	11	18	25
Biomass	0.6	2.8	9.6	18.6	28.2	36.9
Geothermal	0	0	1	1	1	2
Solar thermal	0	0	0	0	0	0
Ocean energy	0	0	0	0	0	0
Fluctuating RES (PV, Wind, Ocean)	1.1	7.6	35.3	65.0	89.5	117.7
Share of fluctuating RES	0.2%	0.9%	2.7%	3.6%	4.0%	4.5%
RES share	**23.0%**	**21.9%**	**21.7%**	**21.6%**	**21.5%**	**21.7%**

table 14.113: china: primary energy demand

PJ/A	2005	2010	2020	2030	2040	2050
Total	**73,007**	**96,340**	**133,181**	**159,872**	**174,347**	**185,017**
Fossil	**61,628**	**83,943**	**117,931**	**142,596**	**155,289**	**164,523**
Hard coal	45,951	62,553	85,716	100,422	103,678	103,595
Lignite	0	0	0	0	0	0
Natural gas	1,805	3,175	5,871	8,341	9,600	10,519
Crude oil	13,872	18,215	26,344	33,834	42,010	50,409
Nuclear	**579**	**764**	**1,825**	**2,793**	**3,761**	**4,728**
Renewables	**10,800**	**11,633**	**13,424**	**14,482**	**15,297**	**15,767**
Hydro	1,429	2,005	2,927	3,618	4,309	5,000
Wind	8	58	277	479	680	882
Solar	0	84	400	710	1,016	1,307
Biomass	9,362	9,452	9,709	9,482	9,020	8,232
Geothermal	0	34	111	193	272	345
Ocean Energy	0	0	0	0	0	0
RES share	**14.8%**	**12.1%**	**10.1%**	**9.0%**	**8.7%**	**8.5%**

table 14.114: china: final energy demand

PJ/A	2005	2010	2020	2030	2040	2050
Total (incl. non-energy use)	**47,534**	**61,392**	**83,846**	**99,656**	**115,907**	**132,236**
Total (energy use)	**43,677**	**55,361**	**75,163**	**90,021**	**105,318**	**120,694**
Transport	**5,062**	**7,557**	**13,119**	**19,259**	**27,118**	**35,741**
Oil products	4,986	7,318	12,630	18,547	26,189	34,586
Natural gas	3	7	12	15	17	19
Biofuels	0	55	168	335	489	676
Electricity	73	177	309	362	422	459
RES electricity	12	26	46	54	63	70
Hydrogen	0	0	0	0	0	1
RES share Transport	**0.2%**	**1.1%**	**1.6%**	**2.0%**	**2.0%**	**2.1%**
Industry	**20,405**	**27,453**	**37,956**	**43,857**	**48,480**	**52,300**
Electricity	4,880	7,934	12,826	16,538	20,226	23,635
RES electricity	772	1,177	1,900	2,475	3,038	3,583
District heat	1,667	1,976	2,303	2,126	1,946	1,741
RES district heat	9	36	127	206	220	238
Coal	9,674	12,811	16,714	17,723	17,962	18,193
Oil products	1,627	1,871	2,271	2,492	2,603	2,558
Gas	2,557	2,825	3,466	4,020	4,335	4,539
Solar	0	0	20	44	69	94
Biomass and waste	0	37	356	914	1,339	1,540
Geothermal	0	0	0	0	0	0
RES share Industry	**3.8%**	**4.6%**	**6.3%**	**8.3%**	**9.6%**	**10.4%**
Other Sectors	**18,210**	**20,350**	**24,089**	**26,904**	**29,720**	**32,653**
Electricity	2,373	3,154	5,165	7,622	10,796	14,302
RES electricity	376	468	765	1,141	1,621	2,168
District heat	596	852	1,292	1,680	1,934	2,178
RES district heat	3	16	71	163	218	297
Coal	2,723	2,931	2,822	2,688	2,546	2,374
Oil products	2,585	3,220	4,321	5,142	5,390	5,562
Gas	627	1,000	1,707	2,450	2,958	3,425
Solar	0	83	361	612	858	1,089
Biomass and waste	9,305	9,110	8,400	6,662	5,164	3,624
Geothermal	0	0	19	47	73	99
RES share Other Sectors	**53.2%**	**47.5%**	**39.9%**	**32.1%**	**26.7%**	**22.3%**
Total RES	**10,477**	**11,006**	**12,233**	**12,653**	**13,153**	**13,478**
RES share	**24.0%**	**19.9%**	**16.3%**	**14.1%**	**12.5%**	**11.2%**
Non energy use	**3,858**	**6,032**	**8,683**	**9,636**	**10,589**	**11,542**
Oil	2,626	3,729	5,057	5,506	5,956	6,405
Gas	315	513	832	1,074	1,317	1,559
Coal	917	1,790	2,794	3,055	3,317	3,578

appendix: china energy [r]evolution scenario

table 14.115: china: electricity generation

TWh/a	2005	2010	2020	2030	2040	2050
Power plants	**2,438**	**3,774**	**5,499**	**6,283**	**6,749**	**7,271**
Coal	1,884	3,002	3,946	3,599	2,813	1,801
Lignite	0	0	0	0	0	0
Gas	38	44	96	131	155	221
Oil	61	56	45	25	10	0
Diesel	0	0	0	0	0	0
Nuclear	53	70	103	63	23	0
Biomass	3	7	29	58	93	127
Hydro	397	557	850	1,050	1,290	1,530
Wind	2	38	370	930	1,330	1,510
PV	0	1	22	190	420	810
Geothermal	0	1	5	12	19	23
Solar thermal power plants	0	0	28	200	520	990
Ocean energy	0	0	5	25	75	260
Combined heat & power production	**101**	**173**	**484**	**975**	**1,529**	**1,990**
Coal	97	148	291	507	685	781
Lignite	0	0	0	0	0	0
Gas	3	18	124	289	465	599
Oil	0	0	0	0	0	0
Biomass	0	7	66	172	347	503
Geothermal	0	1	3	8	33	107
CHP by producer						
Main activity producers	13	20	184	535	934	1,223
Autoproducers	88	153	300	440	595	767
Total generation	**2,539**	**3,948**	**5,983**	**7,258**	**8,278**	**9,261**
Fossil	2,084	3,267	4,503	4,550	4,128	3,401
Coal	1,982	3,150	4,238	4,105	3,498	2,581
Lignite	0	0	0	0	0	0
Gas	41	62	220	420	620	820
Oil	61	56	45	25	10	0
Diesel	0	0	0	0	0	0
Nuclear	53	70	103	63	23	0
Renewables	**402**	**611**	**1,378**	**2,645**	**4,127**	**5,860**
Hydro	397	557	850	1,050	1,290	1,530
Wind	2	38	370	930	1,330	1,510
PV	0	1	22	190	420	810
Biomass	3	14	95	230	440	630
Geothermal	0	1	8	20	52	130
Solar thermal	0	0	28	200	520	990
Ocean energy	0	0	5	25	75	260
Import	16	24	36	43	55	64
Import RES	0	2	9	17	29	45
Export	16	24	35	42	43	45
Distribution losses	173	278.0	407.0	452.0	472.0	492.0
Own consumption electricity	330	540	808.0	917.0	958.0	998.0
Electricity for hydrogen production	0	0	4.6	75	162	285
Final energy consumption (electricity)	**2,035**	**3,130**	**4,764**	**5,816**	**6,698**	**7,505**
Fluctuating RES (PV, Wind, Ocean)	2	39	397	1145	1825	2,580
Share of fluctuating RES	0.1%	1.0%	6.6%	15.8%	22.0%	27.9%
RES share	**15.8%**	**15.5%**	**23.0%**	**36.4%**	**49.9%**	**63.3%**
'Efficiency' savings (compared to Ref.)		**0**	**319**	**996**	**2,036**	**3,161**

table 14.116: china: heat supply

PJ/A	2005	2010	2020	2030	2040	2050
District heating plants	**1,480**	**1,663**	**1,775**	**1,268**	**964**	**508**
Fossil fuels	1,471	1,633	1,571	934	484	10
Biomass	9	30	107	95	101	66
Solar collectors	0	0	80	127	154	178
Geothermal	0	0	18	111	225	254
Heat from CHP	**809**	**1,197**	**2,650**	**4,321**	**5,714**	**7,063**
Fossil fuels	809	1,140	2,268	3,543	4,287	4,556
Biomass	0	52	358	709	1,134	1,545
Geothermal	0	4	24	70	293	962
Direct heating[1]	**23,229**	**27,428**	**30,780**	**29,325**	**26,428**	**23,264**
Fossil fuels	15,971	19,901	22,111	19,738	13,406	6,155
Biomass	7,258	7,444	7,722	7,411	6,933	6,108
Solar collectors	0	83	768	1,758	4,435	7,044
Geothermal	0	0	178	418	1,654	3,956
Total heat supply[1]	**25,518**	**30,287**	**35,205**	**34,913**	**33,106**	**30,835**
Fossil fuels	18,251	22,675	25,950	24,216	18,177	10,720
Biomass	7,267	7,526	8,186	8,215	8,168	7,720
Solar collectors	0	83	848	1,884	4,589	7,222
Geothermal	0	4	221	599	2,172	5,172
RES share (including RES electricity)	**28.5%**	**25%**	**26%**	**31%**	**45%**	**65%**
'Efficiency' savings (compared to Ref.)		**3**	**1,862**	**5,038**	**7,762**	**10,344**

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

table 14.117: china: CO_2 emissions

MILL t/a	2005	2010	2020	2030	2040	2050
Condensation power plants	**2,030**	**3,173**	**3,805**	**2,938**	**2,041**	**1,186**
Coal	1,962	3,109	3,732	2,869	1,978	1,116
Lignite	0	0	0	0	0	0
Gas	20	22	43	53	57	70
Oil	48	41.6	30.4	16.	6.6	0
Diesel	0	0	0	05	0	0
Combined heat & power production	**149**	**205**	**390**	**575**	**683**	**707**
Coal	146	191	311	429	485	484
Lignite	0	0	0	0	0	0
Gas	3	14	80	146	198	223
Oil	0	0	0	0	0	0
CO_2 emissions electricity & steam generation	**2,179**	**3,378**	**4,196**	**3,513**	**2,725**	**1,893**
Coal	2,108	3,300	4,043	3,297	2,463	1,600
Lignite	0	0	0	0	0	0
Gas	23	36	122	199	255	293
Oil & diesel	48	42	30	16	7	0
CO_2 emissions by sector	**4,429**	**6,211**	**7,287**	**6,249**	**4,779**	**3,209**
% of 1990 emissions	198%	277%	325%	279%	213%	143%
Industry	1,295	1,662	1,847	1,612	1,111	557
Other sectors	481	576	597	511	364	197
Transport	360	529	657	710	761	831
Electricity & steam generation	2,049	3,198	3,988	3,308	2,493	1,622
District heating	244	245	199	108	51	1
Population (Mill.)	1321	1359	1430	1467	1458	1418
CO_2 emissions per capita (t/capita)	**3.4**	**4.6**	**5.1**	**4.3**	**3.3**	**2.3**

table 14.118: china: installed capacity

GW	2005	2010	2020	2030	2040	2050
Power plants	**483**	**763**	**1,227**	**1,614**	**1,925**	**2,311**
Coal	336	544	729	673	552	375
Lignite	0	0	0	0	0	0
Gas	9	13	35	46	52	74
Oil	12	12	11	6	2	0
Diesel	0	0	0	0	0	0
Nuclear	7.0	8.9	12.5	7.6	2.8	0
Biomass	0.6	1.8	7.2	11.4	18.2	24.8
Hydro	117	166	254	313	385	457
Wind	1.0	17.4	151.0	379.6	505.7	574.1
PV	0.1	0.4	15.8	135.7	300	578.6
Geothermal	0	0.1	0.8	2.0	3.2	3.8
Solar thermal power plants	0	0	9.0	33.3	82.5	150
Ocean energy	0	0	1.4	7.1	21.4	74.3
Combined heat & power production	**32**	**47**	**146**	**301**	**462**	**579**
Coal	31	40	95	170	235	268
Lignite	0	0	0	0	0	0
Gas	1	5	41	105	173	224
Oil	0	0	0	0	0	0
Biomass	0	1	10	25	49	72
Geothermal	0	0	1	1	5	16
CHP by producer						
Main activity producers	10	10	80	209	342	426
Autoproducers	22	37	66	92	120	153
Total generation	**516**	**810**	**1,373**	**1,915**	**2,386**	**2,890**
Fossil	390	614	910	999	1,013	940
Coal	367	584	824	843	787	643
Lignite	0	0	0	0	0	0
Gas	11	18	76	150	224	298
Oil	12	12	11	6	2	0
Diesel	0	0	0	0	0	0
Nuclear	7.0	8.9	12.5	7.6	2.8	0
Renewables	**119**	**186**	**450**	**909**	**1,370**	**1,950**
Hydro	117	166	254	313	385	457
Wind	1	17	151	380	506	574
PV	0	0	16	136	300	579
Biomass	0.6	3	17	36	68	96
Geothermal	0	0	1	3	8	20
Solar thermal	0	0	9	33	83	150
Ocean energy	0	0	1	7	21	74
Fluctuating RES (PV, Wind, Ocean)	1.1	17.7	168.3	522.4	827.1	1227.0
Share of fluctuating RES	0.2%	2.2%	12.3%	27.3%	34.7%	42.5%
RES share	**23.0%**	**23.0%**	**32.8%**	**47.5%**	**57.4%**	**67.5%**

table 14.119: china: primary energy demand

PJ/A	2005	2010	2020	2030	2040	2050
Total	**73,007**	**95,449**	**114,434**	**110,505**	**104,438**	**99,152**
Fossil	**61,628**	**82,949**	**96,979**	**86,621**	**70,482**	**52,997**
Hard coal	45,951	61,703	69,859	58,181	42,866	26,160
Lignite	0	0	0	0	0	0
Natural gas	1,805	3,124	6,442	8,148	8,811	8,886
Crude oil	13,872	18,122	20,678	20,292	18,805	17,950
Nuclear	**579**	**764**	**1,124**	**687**	**251**	**0**
Renewables	**10,800**	**11,736**	**16,331**	**23,197**	**33,706**	**46,155**
Hydro	1,429	2,005	3,060	3,780	4,644	5,508
Wind	8	137	1,332	3,348	4,788	5,436
Solar	0	85	1,026	3,288	7,973	13,702
Biomass	9,362	9,476	10,455	11,617	13,006	13,920
Geothermal	0	33	440	1,074	3,025	6,652
Ocean Energy	0	0	18	90	270	936
RES share	**14.8%**	**12.3%**	**14.3%**	**21.0%**	**32.3%**	**46.6%**
'Efficiency' savings (compared to Ref.)		**910**	**18,787**	**49,433**	**70,071**	**86,179**

table 14.120: china: final energy demand

PJ/a	2005	2010	2020	2030	2040	2050
Total (incl. non-energy use)	**47,534**	**60,787**	**75,135**	**79,170**	**80,712**	**81,620**
Total (energy use)	**43,677**	**55,359**	**67,869**	**71,370**	**72,412**	**73,120**
Transport	**5,062**	**7,557**	**9,992**	**12,054**	**13,970**	**17,296**
Oil products	4,986	7,318	9,077	9,805	10,502	11,465
Natural gas	3	7	13	16	20	20
Biofuels	0	55	146	484	763	1,208
Electricity	73	177	753	1,695	2,566	4,389
RES electricity	12	27	173	618	1,279	2,777
Hydrogen	0	0	3	55	120	214
RES share Transport	**0.2%**	**1.1%**	**3.2%**	**9.3%**	**15.0%**	**23.8%**
Industry	**20,405**	**27,453**	**34,646**	**35,245**	**34,024**	**31,365**
Electricity	4,880	7,934	11,678	13,220	14,102	14,139
RES electricity	772	1,227	2,689	4,818	7,030	8,946
District heat	1,667	1,976	2,770	3,325	3,791	4,260
RES district heat	9	36	245	506	956	1,663
Coal	9,674	12,811	14,229	12,082	7,052	1,414
Oil products	1,627	1,870	1,927	1,352	756	189
Gas	2,557	2,826	3,503	3,848	3,729	3,270
Solar	0	0	144	535	1,991	3,664
Biomass and waste	0	37	292	654	1,592	2,414
Geothermal	0	0	103	230	1,012	2,015
RES share Industry	**3.8%**	**4.7%**	**10%**	**19.1%**	**37.0%**	**59.6%**
Other Sectors	**18,210**	**20,349**	**23,231**	**24,071**	**24,419**	**24,458**
Electricity	2,373	3,156	4,733	6,216	7,868	9,231
RES electricity	376	488	1,090	2,265	3,922	5,841
District heat	596	855	1,615	2,215	2,833	3,257
RES district heat	3	16	143	337	715	1,271
Coal	2,723	2,930	2,597	1,959	1,522	573
Oil products	2,585	3,215	3,166	2,721	1,355	365
Gas	627	1,003	1,687	1,671	1,418	1,333
Solar	0	83	624	1,222	2,443	3,380
Biomass and waste	9,305	9,106	8,741	7,903	6,443	4,663
Geothermal	0	0	68	164	537	1,656
RES share Other Sectors	**53.2%**	**47.6%**	**45.9%**	**49.4%**	**57.6%**	**68.7%**
Total RES	**10,477**	**11,075**	**14,459**	**19,755**	**28,743**	**39,635**
RES share	**24.0%**	**20%**	**21.3%**	**27.7%**	**39.7%**	**54.2%**
Non energy use	**3,858**	**5,428**	**7,266**	**7,800**	**8,300**	**8,500**
Oil	2,626	3,688	4,918	5,259	5,575	5,687
Gas	315	454	639	720	802	858
Coal	917	1,286	1,709	1,821	1,923	1,955

appendix: oecd pacific reference scenario

table 14.121: oecd pacific: electricity generation

TWh/a	2005	2010	2020	2030	2040	2050
Power plants	**1,726**	**1,854**	**2,145**	**2,332**	**2,499**	**2,665**
Coal	482	539	659	713	766	868
Lignite	123	135	140	137	135	133
Gas	351	377	456	508	552	583
Oil	162	149	107	70	37	17
Diesel	6	5	3	2	1	1
Nuclear	452	472	552	643	713	734
Biomass	21	21	23	23	23	24
Hydro	121	137	151	154	157	161
Wind	3	10	35	52	71	83
PV	0	2	10	17	25	35
Geothermal	6	7	8	9	10	11
Solar thermal power plants	0	0	1	3	7	13
Ocean energy	0	0	1	1	2	3
Combined heat & power production	**54**	**57**	**65**	**71**	**75**	**79**
Coal	3	4	5	6	7	6
Lignite	8	6	3	2	0	0
Gas	36	38	45	49	53	57
Oil	6	6	7	8	8	8
Biomass	2	2	4	5	6	7
Geothermal	0	0	1	1	2	2
CHP by producer						
Main activity producers	23	24	26	27	28	29
Autoproducers	31	33	39	44	47	50
Total generation	**1,780**	**1,911**	**2,210**	**2,402**	**2,574**	**2,744**
Fossil	1,175	1,259	1,425	1,494	1,558	1,672
Coal	484	543	664	719	772	874
Lignite	131	141	143	139	135	133
Gas	387	415	501	557	605	640
Oil	167	155	114	78	45	25
Diesel	6	5	3	2	1	1
Nuclear	452	472	552	643	713	734
Renewables	**153**	**180**	**233**	**265**	**303**	**338**
Hydro	121	137	151	154	157	161
Wind	3	10	35	52	71	83
PV	0	2	10	17	25	35
Biomass	23	24	26	28	29	30
Geothermal	6	7	9	10	12	13
Solar thermal	0	0	1	3	7	13
Ocean energy	0	0	1	1	2	3
Import	0	0	0	0	0	0
Import RES	0	0	0	0	0	0
Export	0	0	0	0	0	0
Distribution losses	84	90	104	109	114	119
Own consumption electricity	111	121	135	141	147	149
Electricity for hydrogen production	0	0	0	0	0	0
Final energy consumption (electricity)	**1,585**	**1,700**	**1,972**	**2,152**	**2,313**	**2,476**
Fluctuating RES (PV, Wind, Ocean)	3	12	46	70	98	121
Share of fluctuating RES	0.2%	0.6%	2.1%	2.9%	3.8%	4.4%
RES share	**8.6%**	**9.4%**	**10.5%**	**11.0%**	**11.8%**	**12.3%**

table 14.122: oecd pacific: heat supply

PJ/A	2005	2010	2020	2030	2040	2050
District heating plants	**45**	**46**	**49**	**51**	**52**	**52**
Fossil fuels	36	36	35	34	32	29
Biomass	9	10	13	16	18	21
Solar collectors	0	0	0	0	1	1
Geothermal	0	0	0	1	1	2
Heat from CHP	**175**	**179**	**297**	**294**	**298**	**292**
Fossil fuels	172	172	281	272	267	251
Biomass	3	5	11	14	17	21
Geothermal	0	2	5	8	14	20
Direct heating[1]	**7,318**	**7,651**	**8,237**	**8,663**	**9,003**	**9,397**
Fossil fuels	6,975	7,253	7,493	7,634	7,707	7,735
Biomass	297	336	505	631	756	895
Solar collectors	28	35	121	185	254	338
Geothermal	18	27	118	213	286	428
Total heat supply[1]	**7,539**	**7,877**	**8,583**	**9,008**	**9,353**	**9,740**
Fossil fuels	7,183	7,461	7,809	7,940	8,006	8,015
Biomass	309	351	528	661	791	937
Solar collectors	28	35	121	186	254	339
Geothermal	18	30	124	221	301	450
RES share (including RES electricity)	**4.7%**	**5.3%**	**9.0%**	**11.9%**	**14.4%**	**17.7%**

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

table 14.123: oecd pacific: CO_2 emissions

MILL t/a	2005	2010	2020	2030	2040	2050
Condensation power plants	**804**	**933**	**1,083**	**1,075**	**1,000**	**963**
Coal	396	478	613	628	600	605
Lignite	167	179	175	162	150	140
Gas	144	170	221	238	225	206
Oil	92	103	72	46	24	11
Diesel	4	3	2	1	1	0.4
Combined heat & power production	**26**	**27**	**39**	**39**	**38**	**35**
Coal	5	6	7	6	6	5
Lignite	0	0	0	0	0	0
Gas	9	9	23	25	26	26
Oil	13	11	10	8	6	5
CO_2 emissions electricity & steam generation	**831**	**960**	**1,122**	**1,114**	**1,038**	**998**
Coal	401	484	620	634	606	610
Lignite	168	179	175	162	150	140
Gas	153	179	244	263	251	232
Oil & diesel	109	118	84	55	31	16
CO_2 emissions by sector	**1,895**	**2,060**	**2,248**	**2,253**	**2,176**	**2,127**
% of 1990 emissions	123%	134%	146%	146%	141%	138%
Industry	303	312	316	312	307	300
Other sectors	296	287	296	303	304	302
Transport	478	513	536	544	544	544
Electricity & steam generation	814	944	1,097	1,091	1,017	979
District heating	4	4	4	4	3	3
Population (Mill.)	200	202	202	197	188	178
CO_2 emissions per capita (t/capita)	**9.5**	**10.2**	**11.1**	**11.4**	**11.5**	**11.9**

table 14.124: oecd pacific: installed capacity

GW	2005	2010	2020	2030	2040	2050
Power plants	**394**	**414**	**470**	**523**	**591**	**680**
Coal	72	81	103	119	146	193
Lignite	18.3	20.3	21.9	22.8	25.7	29.6
Gas	92	100	127	153	183	216
Oil	68	63	49	39	26	15
Diesel	16	13	7	5	3	1
Nuclear	66.7	63.8	68.9	80.5	89.2	91.9
Biomass	2.9	3.2	3.7	3.8	3.8	3.9
Hydro	55	63	70	71	72	74
Wind	2.1	4.5	11.9	16.1	22.0	25.7
PV	0	1.4	7.1	12.1	17.9	25.0
Geothermal	1.0	1.0	1.1	1.2	1.3	1.5
Solar thermal power plants	0	0	0.4	0.5	1.1	2.0
Ocean energy	0	0	0.1	0.3	0.6	0.9
Combined heat & power production	**14**	**14**	**14**	**16**	**17**	**18**
Coal	1	1	2	2	2	2
Lignite	4	3	2	0	0	0
Gas	7	7	8	10	12	13
Oil	2	2	2	2	2	2
Biomass	0	0	1	1	1	1
Geothermal	0	0	0	0	0	0
CHP by producer						
Main activity producers	8	8	7	7	8	8
Autoproducers	6	6	7	8	9	10
Total generation	**408**	**428**	**485**	**538**	**608**	**697**
Fossil	280	290	321	352	398	471
Coal	73	82	105	121	148	195
Lignite	23	24	23	23	26	30
Gas	99	107	135	163	195	228
Oil	70	64	51	41	27	17
Diesel	16	13	7	5	3	1
Nuclear	66.7	63.8	68.9	80.5	89.2	91.9
Renewables	**62**	**74**	**95**	**106**	**120**	**134**
Hydro	55	63	70	71	72	74
Wind	2	5	12	16	22	26
PV	0	1	7	12	18	25
Biomass	3.3	3.7	4.4	4.6	4.8	4.9
Geothermal	1	1	1	1	2	2
Solar thermal	0	0	0	1	1	2
Ocean energy	0	0	0	0	1	1
Fluctuating RES (PV, Wind, Ocean)	2.1	6.0	19.2	28.5	40.4	51.6
Share of fluctuating RES	0.5%	1.4%	4.0%	5.3%	6.7%	7.4%
RES share	**15.2%**	**17.3%**	**19.6%**	**19.6%**	**19.7%**	**19.2%**

table 14.125: oecd pacific: primary energy demand

PJ/A	2005	2010	2020	2030	2040	2050
Total	**37,035**	**39,946**	**44,322**	**46,211**	**46,712**	**47,024**
Fossil	**30,831**	**33,289**	**36,002**	**36,397**	**35,622**	**35,140**
Hard coal	7,798	8,681	9,923	10,091	9,746	9,642
Lignite	1,509	1,612	1,579	1,459	1,355	1,260
Natural gas	5,070	5,811	7,637	8,366	8,497	8,521
Crude oil	16,454	17,185	16,864	16,481	16,023	15,718
Nuclear	**4,927**	**5,150**	**6,023**	**7,015**	**7,778**	**8,007**
Renewables	**1,277**	**1,507**	**2,297**	**2,799**	**3,312**	**3,877**
Hydro	436	493	544	554	565	580
Wind	12	36	126	187	256	299
Solar	28	42	162	258	369	512
Biomass	601	699	1,109	1,324	1,532	1,733
Geothermal	200	237	355	472	583	743
Ocean Energy	0	0	2	4	7	11
RES share	**3.4%**	**3.8%**	**5.2%**	**6.1%**	**7.1%**	**8.2%**

table 14.126: oecd pacific: final energy demand

PJ/A	2005	2010	2020	2030	2040	2050
Total (incl. non-energy use)	**24,669**	**25,997**	**28,103**	**29,523**	**30,655**	**31,795**
Total (energy use)	**21,322**	**22,370**	**24,486**	**25,759**	**26,762**	**27,772**
Transport	**6,716**	**7,256**	**7,831**	**8,166**	**8,412**	**8,644**
Oil products	6,613	7,091	7,363	7,452	7,419	7,371
Natural gas	15	26	88	122	164	220
Biofuels	1	12	101	159	225	281
Electricity	87	127	279	432	603	772
RES electricity	7	12	29	48	71	95
Hydrogen	0	0	0	0	1	1
RES share Transport	**0.1%**	**0.3%**	**1.7%**	**2.5%**	**3.5%**	**4.4%**
Industry	**6,847**	**7,359**	**7,925**	**8,242**	**8,482**	**8,737**
Electricity	2,297	2,604	2,890	3,070	3,210	3,345
RES electricity	198	245	304	338	377	412
District heat	163	149	226	196	166	139
RES district heat	7	9	11	13	14	15
Coal	662	680	589	621	579	456
Oil products	1,800	1,772	1,619	1,452	1,361	1,351
Gas	1,629	1,814	2,074	2,231	2,371	2,502
Solar	0	3	38	53	68	94
Biomass and waste	289	326	421	490	557	630
Geothermal	6	12	67	129	169	221
RES share Industry	**7.3%**	**8.1%**	**10.6%**	**12.4%**	**14.0%**	**15.7%**
Other Sectors	**7,760**	**7,755**	**8,730**	**9,351**	**9,869**	**10,391**
Electricity	3,322	3,388	3,928	4,245	4,515	4,796
RES electricity	286	319	414	468	531	591
District heat	54	73	116	146	180	201
RES district heat	5	8	18	25	36	48
Coal	297	272	149	130	127	105
Oil products	2,432	2,290	2,337	2,309	2,211	2,069
Gas	1,536	1,593	1,887	2,059	2,217	2,389
Solar	28	32	83	132	185	244
Biomass and waste	80	91	202	285	367	462
Geothermal	13	15	29	45	67	125
RES share Other Sectors	**5.3%**	**6.0%**	**8.5%**	**10.2%**	**12.0%**	**14.2%**
Total RES	**919**	**1,083**	**1,716**	**2,185**	**2,668**	**3,219**
RES share	**3.7%**	**4.2%**	**6.1%**	**7.4%**	**8.7%**	**10.1%**
Non energy use	**3,347**	**3,627**	**3,617**	**3,765**	**3,893**	**4,023**
Oil	3,242	3,514	3,504	3,647	3,771	3,897
Gas	88	96	95	99	103	106
Coal	16	18	18	18	19	20

appendix: oecd pacific energy [r]evolution scenario

table 14.127: oecd pacific: electricity generation

TWh/a	2005	2010	2020	2030	2040	2050
Power plants	**1,726**	**1,842**	**1,951**	**1,972**	**1,930**	**1,885**
Coal	482	521	538	500	323	118
Lignite	123	122	85	33	7	0
Gas	351	413	563	610	580	285
Oil	162	145	86	44	20	2
Diesel	6	5	2	1	0	0
Nuclear	452	445	283	164	45	0
Biomass	21	28	36	41	46	51
Hydro	121	138	164	177	187	194
Wind	3	11	120	256	465	811
PV	0	7	49	95	163	281
Geothermal	6	7	14	18	21	24
Solar thermal power plants	0	1	8	19	36	47
Ocean energy	0	0	3	14	37	72
Combined heat & power production	**54**	**60**	**94**	**124**	**167**	**226**
Coal	3	3	2	0	0	0
Lignite	8	7	4	0	0	0
Gas	36	41	68	77	69	54
Oil	6	6	4	1	0	0
Biomass	2	3	13	39	85	147
Geothermal	0	1	3	6	13	25
CHP by producer						
Main activity producers	23	25	37	49	71	113
Autoproducers	31	35	57	75	96	113
Total generation	**1,780**	**1,902**	**2,045**	**2,096**	**2,097**	**2,111**
Fossil	1,175	1,261	1,351	1,266	999	459
Coal	484	523	540	500	323	118
Lignite	131	129	89	33	7	0
Gas	387	454	631	687	649	339
Oil	167	151	90	45	20	2
Diesel	6	5	2	1	0	0
Nuclear	452	445	283	164	45	0
Renewables	**153**	**196**	**411**	**665**	**1,053**	**1,652**
Hydro	121	138	164	177	187	194
Wind	3	11	120	256	465	811
PV	0	7	49	95	163	281
Biomass	23	31	49	80	131	198
Geothermal	6	8	17	24	34	49
Solar thermal	0	1	8	19	36	47
Ocean energy	0	0	3	14	37	72
Import	0	0	0	0	0	0
Import RES	0	0	0	0	0	0
Export	0	0	0	0	0	0
Distribution losses	84	88.8	94.2	91.9	87.0	81.0
Own consumption electricity	111	120.1	122.5	118.8	111.0	103.0
Electricity for hydrogen production	0	0	2	6	10	9
Final energy consumption (electricity)	**1,585**	**1,693**	**1,826**	**1,879**	**1,889**	**1,918**
Fluctuating RES (PV, Wind, Ocean)	3	18	172	365	665	1,164
Share of fluctuating RES	0.2%	1.0%	8.4%	17.4%	31.7%	55.1%
RES share	**8.6%**	**10.3%**	**20.1%**	**31.8%**	**50.2%**	**78.3%**
'Efficiency' savings (compared to Ref.)		**7**	**145**	**273**	**424**	**558**

table 14.128: oecd pacific: heat supply

PJ/A	2005	2010	2020	2030	2040	2050
District heating plants	**45**	**115**	**224**	**331**	**326**	**218**
Fossil fuels	36	85	62	50	3	0
Biomass	9	28	114	149	163	105
Solar collectors	0	2	34	109	130	87
Geothermal	0	0	14	23	29	26
Heat from CHP	**175**	**178**	**396**	**487**	**619**	**843**
Fossil fuels	172	167	328	314	267	195
Biomass	3	6	38	115	237	422
Geothermal	0	5	30	58	115	226
Direct heating[1]	**7,318**	**7,510**	**7,344**	**6,932**	**6,328**	**5,817**
Fossil fuels	6,975	7,009	5,943	4,619	3,093	1,642
Biomass	297	421	766	1,087	1,339	1,494
Solar collectors	28	40	275	660	1,208	1,934
Geothermal	18	40	360	566	688	748
Total heat supply[1]	**7,539**	**7,803**	**7,963**	**7,751**	**7,273**	**6,878**
Fossil fuels	7,183	7,262	6,333	4,983	3,363	1,837
Biomass	309	455	918	1,351	1,738	2,020
Solar collectors	28	42	309	769	1,339	2,021
Geothermal	18	44	404	647	833	1,000
RES share (including RES electricity)	**4.7%**	**7%**	**20%**	**36%**	**54%**	**73%**
'Efficiency' savings (compared to Ref.)		**73**	**619**	**1,258**	**2,080**	**2,862**

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

table 14.129: oecd pacific: CO_2 emissions

MILL t/a	2005	2010	2020	2030	2040	2050
Condensation power plants	**804**	**912**	**939**	**795**	**510**	**184**
Coal	396	462	501	440	253	82
Lignite	167	161.6	106.3	39.0	7.8	0
Gas	144	186	272	286	236	101
Oil	92	100.4	58.1	29.0	13.2	1.3
Diesel	4	3	1	0.7	0	0
Combined heat & power production	**26**	**26**	**43**	**40**	**34**	**25**
Coal	5	5	3	0	0	0
Lignite	0	0	0	0	0	0
Gas	9	11	35	39	34	25
Oil	13	10	5	1	0	0
CO_2 emissions electricity & steam generation	**831**	**938**	**982**	**835**	**544**	**209**
Coal	401	466	503	440	253	82
Lignite	168	162	106	39	8	0
Gas	153	196	307	325	270	126
Oil & diesel	109	114	65	31	14	1
CO_2 emissions by sector	**1,895**	**2,016**	**1,858**	**1,499**	**970**	**433**
% of 1990 emissions	123%	131%	120%	97%	63%	28%
Industry	303	301	264	211	144	108
Other sectors	296	278	218	150	86	16
Transport	478	505	415	321	214	113
Electricity & steam generation	814	923	955	813	526	196
District heating	4	9	7	4	1	0
Population (Mill.)	200	202	202	197	188	178
CO_2 emissions per capita (t/capita)	**9.5**	**10**	**9.2**	**7.6**	**5.1**	**2.4**

table 14.130: oecd pacific: installed capacity

GW	2005	2010	2020	2030	2040	2050
Power plants	**394**	**418**	**497**	**564**	**648**	**714**
Coal	72	78	84	83	61	26
Lignite	18.3	18.3	13.3	5.5	1.3	0
Gas	92	109	157	183	192	106
Oil	68	61	39	24	14	2
Diesel	16	12	5	3	0.1	0
Nuclear	66.7	60.1	35.3	20.5	5.6	0
Biomass	2.9	4.2	5.9	6.7	7.5	8.4
Hydro	55	64	76	81	86	89
Wind	2.1	5.0	40.8	79.3	144.0	251.1
PV	0	5.3	35.1	67.9	116.4	200.7
Geothermal	1.0	1.0	1.9	2.4	2.8	3.2
Solar thermal power plants	0	0.2	2.6	3.2	5.7	7.2
Ocean energy	0	0	0.9	4.0	10.6	20.6
Combined heat & power production	**14**	**14**	**19**	**24**	**32**	**41**
Coal	1	1	0	0	0	0
Lignite	4	4	2	0	0	0
Gas	7	8	13	16	15	12
Oil	2	1	1	0	0	0
Biomass	0	1	2	7	14	25
Geothermal	0	0	1	1	2	4
CHP by producer						
Main activity producers	8	8	9	11	15	22
Autoproducers	6	6	10	13	17	19
Total generation	**408**	**432**	**515**	**588**	**679**	**754**
Fossil	280	292	314	316	285	146
Coal	73	79	84	83	61	26
Lignite	23	22	15	6	1	0
Gas	99	117	169	200	208	118
Oil	70	62	40	25	14	2
Diesel	16	12	5	3	0	0
Nuclear	66.7	60.1	35.3	20.5	5.6	0
Renewables	**62**	**80**	**166**	**252**	**389**	**609**
Hydro	55	64	76	81	86	89
Wind	2	5	41	79	144	251
PV	0	5	35	68	116	201
Biomass	3.3	5	8	13	22	33
Geothermal	1	1	2	3	5	7
Solar thermal	0	0	3	3	6	7
Ocean energy	0	0	1	4	11	21
Fluctuating RES (PV, Wind, Ocean)	2.1	10.3	76.8	151.1	271.0	472.4
Share of fluctuating RES	0.5%	2.4%	14.9%	25.7%	39.9%	62.6%
RES share	**15.2%**	**18.5%**	**32.2%**	**42.9%**	**57.3%**	**80.7%**

table 14.131: oecd pacific: primary energy demand

PJ/A	2005	2010	2020	2030	2040	2050
Total	**37,035**	**39,545**	**38,955**	**35,622**	**30,131**	**24,952**
Fossil	**30,831**	**32,753**	**31,213**	**26,540**	**19,309**	**11,227**
Hard coal	7,798	8,443	8,391	7,590	5,353	3,402
Lignite	1,509	1,457	959	351	70	0
Natural gas	5,070	6,055	8,346	8,561	7,011	3,177
Crude oil	16,454	16,798	13,518	10,038	6,875	4,647
Nuclear	**4,927**	**4,855**	**3,088**	**1,789**	**491**	**0**
Renewables	**1,277**	**1,936**	**4,654**	**7,293**	**10,331**	**13,725**
Hydro	436	497	590	637	673	698
Wind	12	40	432	922	1,674	2,920
Solar	28	70	514	1,180	2,055	3,202
Biomass	601	1,070	2,347	3,400	4,339	4,720
Geothermal	200	260	760	1,104	1,457	1,927
Ocean Energy	0	0	11	50	133	259
RES share	**3.4%**	**4.9%**	**11.9%**	**20.5%**	**34.3%**	**55.0%**
'Efficiency' savings (compared to Ref.)		**401**	**5,367**	**10,588**	**16,582**	**22,072**

table 14.132: oecd pacific: final energy demand

PJ/a	2005	2010	2020	2030	2040	2050
Total (incl. non-energy use)	**24,669**	**25,746**	**25,134**	**23,702**	**21,645**	**19,629**
Total (energy use)	**21,322**	**22,243**	**21,678**	**20,397**	**18,513**	**16,669**
Transport	**6,716**	**7,256**	**6,515**	**5,774**	**5,033**	**4,035**
Oil products	6,613	6,984	5,699	4,386	2,888	1,496
Natural gas	15	26	72	84	95	96
Biofuels	1	116	437	721	999	1,004
Electricity	87	129	302	567	1,025	1,416
RES electricity	7	13	61	180	515	1,108
Hydrogen	0	0	5	16	26	24
RES share Transport	**0.1%**	**1.8%**	**7.7%**	**15.7%**	**30.3%**	**52.8%**
Industry	**6,847**	**7,159**	**7,251**	**6,913**	**6,284**	**5,723**
Electricity	2,297	2,484	2,655	2,585	2,404	2,193
RES electricity	198	255	533	821	1,207	1,716
District heat	163	183	400	460	502	514
RES district heat	7	20	115	218	325	398
Coal	662	685	437	324	110	0
Oil products	1,800	1,694	1,241	710	207	75
Gas	1,629	1,717	1,880	1,921	1,815	1,615
Solar	0	2	38	147	232	297
Biomass and waste	289	385	553	687	894	906
Geothermal	6	8	47	80	119	123
RES share Industry	**7.3%**	**9.4%**	**17.7%**	**28.3%**	**44.2%**	**60.1%**
Other Sectors	**7,760**	**7,828**	**7,912**	**7,710**	**7,196**	**6,911**
Electricity	3,322	3,482	3,617	3,612	3,371	3,296
RES electricity	286	358	727	1,147	1,692	2,579
District heat	54	104	212	348	428	530
RES district heat	5	19	111	229	338	453
Coal	297	219	16	8	6	4
Oil products	2,432	2,243	1,635	851	299	72
Gas	1,536	1,584	1,639	1,483	1,093	150
Solar	28	37	236	513	976	1,637
Biomass and waste	80	137	391	646	744	916
Geothermal	13	24	166	249	278	307
RES share Other Sectors	**5.3%**	**7.3%**	**20.6%**	**36.1%**	**56.0%**	**85.3%**
Total RES	**919**	**1,376**	**3,415**	**5,644**	**8,332**	**11,463**
RES share	**3.7%**	**5.3%**	**13.6%**	**23.8%**	**38.5%**	**58.4%**
Non energy use	**3,347**	**3,503**	**3,456**	**3,305**	**3,132**	**2,960**
Oil	3,242	3,394	3,348	3,202	3,034	2,868
Gas	88	92	91	87	83	78
Coal	16	17	17	16	15	14

GREENPEACE

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

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EREC

european renewable energy council - [EREC]

Created on 13 April 2000, the European Renewable Energy Council (EREC) is the umbrella organisation of the European renewable energy industry, trade and research associations active in the sectors of bioenergy, geothermal, ocean, small hydropower, solar electricity, solar thermal and wind energy. EREC represents thus 40 billion € turnover and provides jobs to around 350,000 people!

EREC is composed of the following non-profit associations and federations: AEBIOM (European Biomass Association); eBIO (European Bioethanol Fuel Association); EGEC (European Geothermal Energy Council); EPIA (European Photovoltaic Industry Association); ESHA (European Small Hydropower Association); ESTIF (European Solar Thermal Industry Federation); EUBIA (European Biomass Industry Association); EWEA (European Wind Energy Association); EUREC Agency (European Association of Renewable Energy Research Centers); EREF (European Renewable Energies Federation); EU-OEA (European Ocean Energy Association); ESTELA (European Solar Thermal Electricity Association) and Associate Member: EBB (European Biodiesel Board)

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