energy technologies

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

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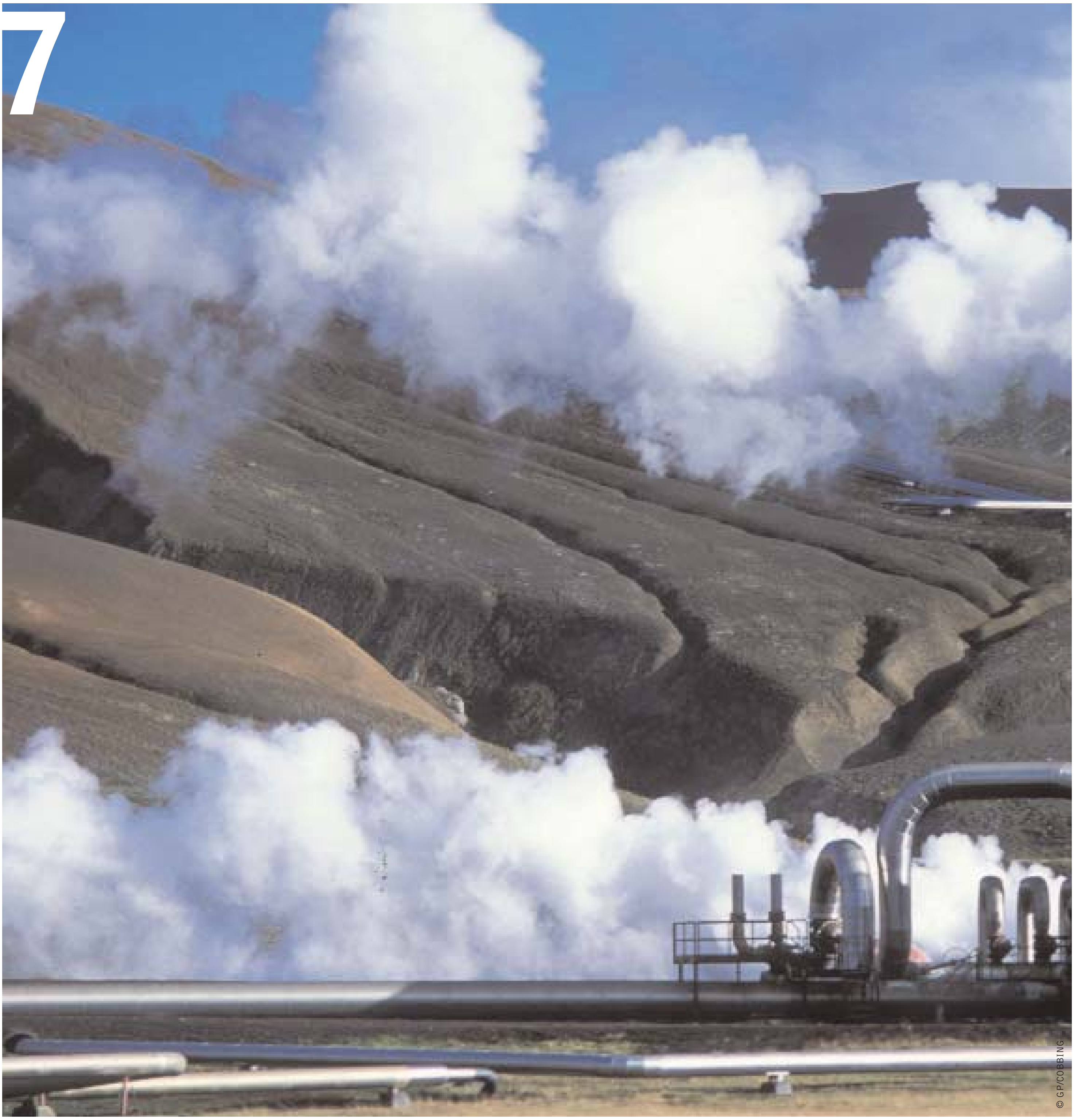


image ENERGY PLANT NEAR REYKJAVIK, ENERGY IS PRODUCED FROM THE GEOTHERMAL ACTIVITY.THE VOLCANIC ROCKS ARE VISIBLE BEHIND THE PLANT. NORTH WEST OF ICELAND.

image GEOTHERMAL POWER STATION PRODUCING ELECTRICITY.

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

fossil fuel technologies

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

coal combustion technologies

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

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

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

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

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

gas combustion technologiess

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

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

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

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

carbon storage technologies

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

carbon dioxide storage

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

dangers of ocean storage

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

dangers of underground storage

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

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

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

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

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

carbon storage and climate change targets

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

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

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

conclusion

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

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

image NUCLEAR POWER STATION.

nuclear technologies

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

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

nuclear reactor designs: evolution and safety issues

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

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

generation II: Mainstream reactor designs in commercial operation worldwide.

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

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

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

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

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

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

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

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

renewable energy technologies

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

solar power (photovoltaics)

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

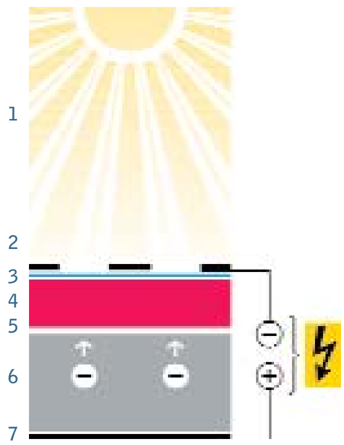
Photovoltaic (PV) technology involves the generation of electricity from light. The secret to this process is the use of a semiconductor material which can be adapted to release electrons, the negatively charged particles that form the basis of electricity. The most common semiconductor material used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

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

types of PV system

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

figure 31: photovoltaics technology



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

concentrating solar power plants(CSP)

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

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

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

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

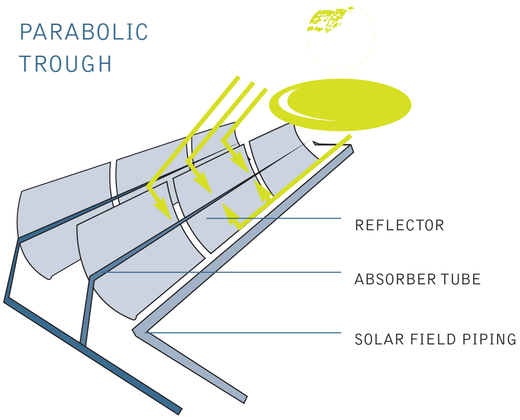
- **central receiver or solar tower** A circular array of heliostats (large individually tracking mirrors) is used to concentrate sunlight on to a central receiver mounted at the top of a tower. A heat-transfer medium absorbs the highly concentrated radiation reflected by the heliostats and converts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

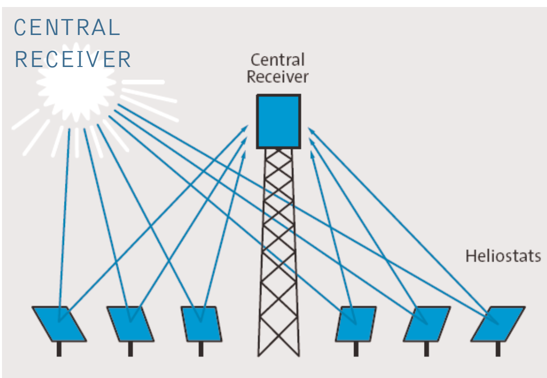
  After an intermediate scaling up to 30 MW capacity, solar tower developers now feel confident that grid-connected tower power plants can be built up to a capacity of 200 MWe solar-only units. Use of heat storage will increase their flexibility. Although solar tower plants are considered to be further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

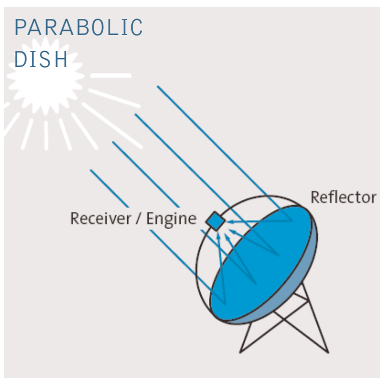
- **parabolic dish** A dish-shaped reflector is used to concentrate sunlight on to a receiver located at its focal point. The concentrated beam radiation is absorbed into the receiver to heat a fluid or gas (air) to approximately 750°C. This is then used to generate electricity in a small piston, Stirling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

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

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







solar thermal collectors

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

solar domestic hot water and space heating

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

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

solar assisted cooling

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

figure 35: flat panel solar technology

wind power

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

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

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

wind turbine design

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

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

The main design drivers for current wind technology are:

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

image ALTERNATIVE ENERGY PRODUCTION WITH WIND GENERATORS AND SOLAR PANELS.

- aerodynamic performance
- visual impact
- offshore expansion

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

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

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

biomass energy

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

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

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

figure 36: wind turbine technology

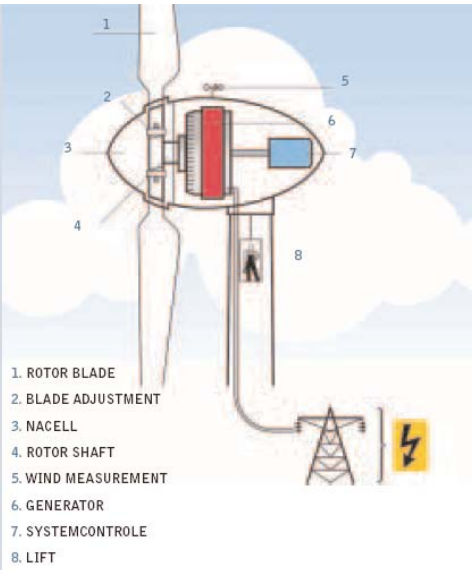
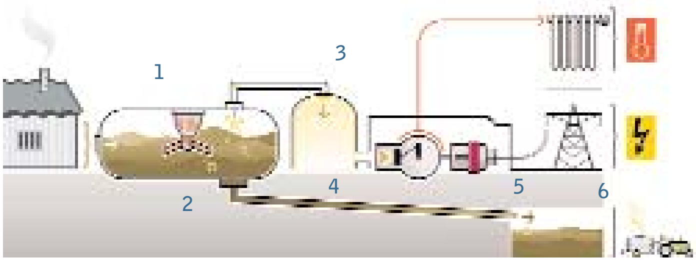


figure 37: biomass technology



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

biomass technology

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

thermal systems

- **direct combustion** Direct combustion is the most common way of converting biomass to energy, for heat as well as electricity. Worldwide it accounts for over 90% of biomass generation. Technologies can be distinguished as either fixed bed, fluidised bed or entrained flow combustion. In fixed bed combustion, such as a grate furnace, primary air passes through a fixed bed, in which drying, gasification and charcoal combustion takes place. The combustible gases produced are burned after the addition of secondary air, usually in a zone separated from the fuel bed. In fluidised bed combustion, the primary combustion air is injected from the bottom of the furnace with such high velocity that the material inside the furnace becomes a seething mass of particles and bubbles. Entrained flow combustion is suitable for fuels available as small particles, such as sawdust or fine shavings, which are pneumatically injected into the furnace.
- **gasification** Biomass fuels are increasingly being used with advanced conversion technologies, such as gasification systems, which offer superior efficiencies compared with conventional power generation. Gasification is a thermochemical process in which biomass is heated with little or no oxygen present to produce a low energy gas. The gas can then be used to fuel a gas turbine or a combustion engine to generate electricity. Gasification can also decrease emission levels compared to power production with direct combustion and a steam cycle.
- **pyrolysis** Pyrolysis is a process whereby biomass is exposed to high temperatures in the absence of air, causing the biomass to decompose. The products of pyrolysis always include gas ('biogas'), liquid ('bio-oil') and solid ('char'), with the relative proportions of each depending on the fuel characteristics, the method of pyrolysis and the reaction parameters, such as temperature and pressure. Lower temperatures produce more solid and liquid products and higher temperatures more biogas.

biological systems

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

- **anaerobic digestion** Anaerobic digestion means the breakdown of organic waste by bacteria in an oxygen-free environment. This produces a biogas typically made up of 65% methane and 35% carbon dioxide. Purified biogas can then be used both for heating or electricity generation.
- **fermentation** Fermentation is the process by which plants of high sugar and starch content are broken down with the help of micro-organisms to produce ethanol and methanol. The end product is a combustible fuel that can be used in vehicles.

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

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

reference

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

geothermal energy

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

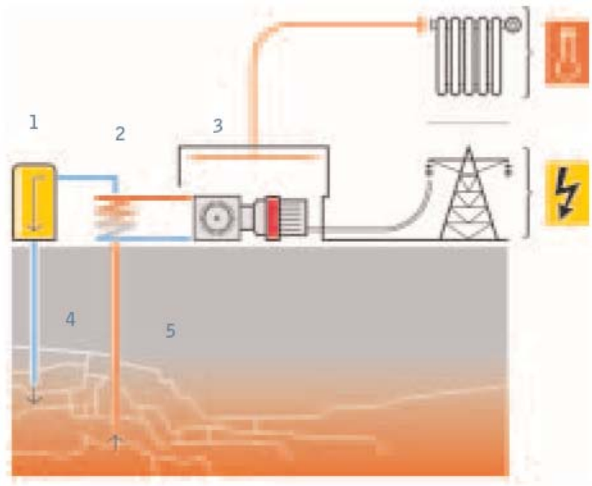
Geothermal power plants use the earth's natural heat to vapourise water or an organic medium. The steam created powers a turbine which produces electricity. In New Zealand and Iceland, this technique has been used extensively for decades. In Germany, where it is necessary to drill many kilometres down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

hydro power

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

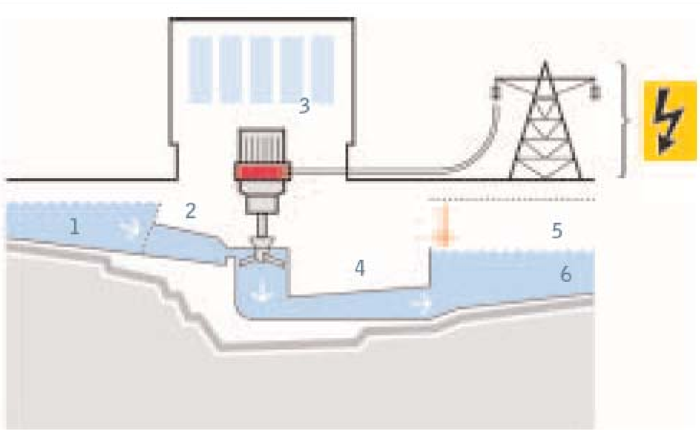
The main requirement for hydro power is to create an artificial head so that water, diverted through an intake channel or pipe into a turbine, discharges back into the river downstream. Small hydro power is mainly 'run-of-the-river' and does not collect significant amounts of stored water, requiring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

figure 38: geothermal technology



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

figure 39: hydro technology



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

ocean energy

tidal power

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

wave and tidal stream power

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

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

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

energy efficiency

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

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

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

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

electricity

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

heating

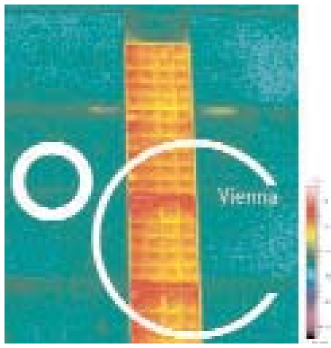
Insulation and thermal design can dramatically reduce heat loss and help stop climate change. Energy demand for heating in existing buildings can be reduced on average by 30-50%. In new buildings it can be reduced by 90-95% using widely available and competitive technology and design.

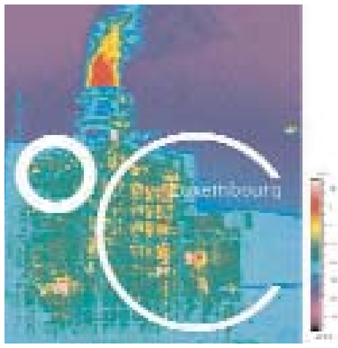
Heat losses can be easily detected with thermographic photos (see example below). A thermographic camera shows details the eye cannot detect. Parts of the building that have a higher surface temperature than the rest appear in yellow and red. This means that in these areas heat is leaking through gaps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

table 13: examples of electricity saving potential

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

source ECOFYS 2006, GLOBAL ENERGY DEMAND SCENARIOS





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

energy efficiency in the energy [r]evolution Scenario

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

table 14: energy efficiency measures

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

industry

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

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

transport

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

households/services

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

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

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