renewables – Made in Germany

reliable solutions – for the journey ahead

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Introduction

Public services, commercial enterprises and private households around the world are increasingly needing reliable, affordable and environmentally friendly energy to cover their demand for electricity, heat, cooling and mobility. Renewable energies can make a substantial contribution to covering this demand.

Unlike fossil fuels, renewable energies come from partially inexhaustible sources. Various technologies are available around the world to make use of the available natural potential. In conjunction with storage and grid technologies, renewable energies can be stored or transmitted and distributed over long distances from their place of generation to the centres of consumption and thereby used in a manner that best meets demand.

Renewable energy technologies, products and services "Made in Germany" enjoy an outstanding international reputation. They stand for quality, reliability, a long service life, efficiency and safety.

The technologies presented in this brochure provide an insight into the opportunities for use of your regenerative energy supply. The import of German products and services can be promoted through various programmes of the German government and these are presented briefly in the Financing section. In the following text, the individual forms of renewable energy are first introduced, then their possible applications are considered and the role they play in the overall energy system is explained.

Types of renewable energy

Wind power has been used in many regions of the world for centuries and in recent decades has become a mainstay of sustainable energy provision. The majority of the world's turbines are currently installed on land (onshore) and are connected to a public grid. Typically, multiple turbines are connected in a wind farm and feed the electricity generated into the distribution grid. However, single turbines are suitable for decentralised power generation in areas situated at a distance from the public power grid. These types of turbines can feed power into a locality's mini-grid.

Because of the constant wind conditions and higher average wind speeds, the use of turbines in the sea (offshore) has increased dramatically, particularly in Europe and eastern Asia. Yields are up to 40 % higher than on land. By 2030, up to 15 % of Germany's energy needs should be covered by offshore wind power. The Global Wind Energy Council (GWEC) predicts that by 2020, up to 12 % of the world's electricity supply will come from wind power. In countries with a limited surface area, like Germany, there is considerable potential for repowering onshore plants, whereby old, less efficient plants are replaced with new,


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more powerful ones, enabling more output to be achieved with the same number of plants.

In just one hour the sun delivers more energy to the earth than the world uses in an entire year. This **solar energy** can be utilised in many ways. Photovoltaic systems (PV installations) convert sunlight directly into electrical energy. PV installations enable power to be generated and used independently of existing power grids, e.g. through Solar Home Systems (SHS). Photovoltaics can, however, also be used to create stand-alone off-grid systems. Such mini-grids can supply electricity to facilities ranging in size from individual buildings to several small towns. Storage technologies (e.g. batteries) are integrated into mini-grids in order to guarantee electrical power in times of inadequate solar radiation. The use of hybrid systems – a combination of different renewable energies (PV with e.g. wind or hydroelectric power plants) or power generators run on diesel or biofuel – presents a convenient method of supplying power to smaller localities or industrial areas which are not covered by the power grid, such as in the mining industry. PV installations can also be used to guarantee a continuous supply of water for drinking purposes or for irrigation. Furthermore, this technology can be used to disinfect and/or demineralise water. PV systems on roofs or facades can be fully integrated into the architecture of a building. Large systems with an output of several megawatts are usually constructed as free-standing systems in open areas.

The technical exploitation of **solar heat** (solar thermal energy) is a use of energy which has already undergone many decades of testing and development. Solar thermal installations can also be used in areas of low solar radiation. They are suitable for heating tap water and supporting heating systems. A solar energy system makes the user less dependent on fossil fuels and rising energy prices. In many places, small solar energy systems are now standard items in the product range of the heating industry and tradesmen. There is considerable potential in the storage of solar heat in summer for use in winter and for the distribution of hot water via local heating grids. Large solar thermal systems can also be used to support district heating grids. The promising solar thermal application of solar cooling on the other hand is of particular interest in countries with a high demand for air conditioning.

Solar thermal power plants (Concentrated Solar Power – CSP) are especially suitable for the world's sun belt, since this is where the incidence of direct solar radiation needed for the operation of CSP plants is at its highest. The sun belt extends roughly from 40 degrees of latitude in the northern hemisphere to 40 degrees in the southern hemisphere; in other words between southern Spain and South Africa, for example. An increase in the building of solar thermal plants for the purposes of power generation can be seen worldwide. There are currently 2.5 GW of solar thermal power stations in operation and about 1.5 GW under construction. With an output in the region of 5


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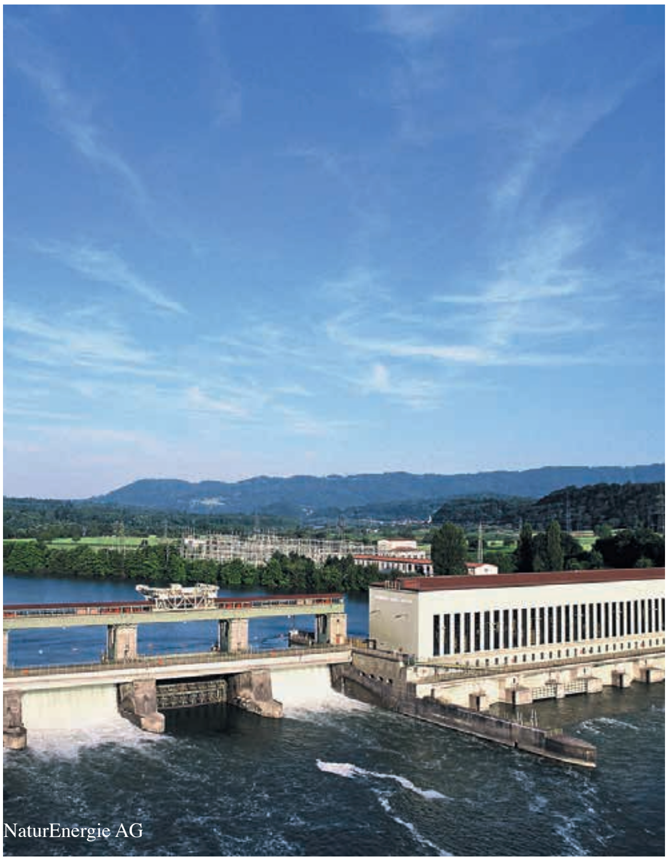
MW, solar thermal power stations are very versatile in terms of application and can be used for supplying individual localities or to supply off-grid centres of consumption. By using storage technologies, the power stations need only cover the base load. According to the International Energy Agency (IEA), the output of all solar thermal power plants installed worldwide will be tripled from 4 to 12 GW by 2020.

Bioenergy is an important and versatile source of renewable energy. Bioenergy in solid, liquid or gaseous form is used to generate electricity/heat and to manufacture biofuels. A major benefit of bioenergy is that it can be stored. Traditionally, solid biomass is exploited by burning wood for heating and cooking In industrial applications, biomass is used to generate electricity and heat. For domestic heating purposes, biomass is increasingly being exploited in the form of wood pellets. They require only slightly more storage space than heating oil. In addition, biomass can be gasified in a thermochemical process. The combustible gas produced is used mainly in efficient CHP plants. These can also be easily installed apart from the power grids and small CHP plants are especially designed for domestic use. Biogas can be extracted from a variety of sources: from organic waste from landfill sites (landfill gas), from municipal wastewater (sewage gas), from organic waste from industry, households and trade and from organic waste materials from agriculture and energy crops. The fermentation residue from biogas production can be used in agriculture as high-grade fertiliser or sold as a by-product to enhance the value creation chain. Of increasing importance is the processing of biogas to natural gas quality. The biomethane obtained in this way can be fed into the existing natural gas grid. In addition, biogas can be used as a transport fuel.

Hydropower is one of the oldest forms of renewable energy known to man and was already in use in pre-industrial times for driving flour mills, sawmills, paper mills and hammer mills. Today, hydropower is used almost exclusively for generating electricity. About 16 % of the world's electricity is currently generated by hydropower. Small hydropower plants in particular are considered to be a sustainable form of exploitation since they are easier to integrate into existing ecosystems than large plants. Estimates indicate that only about a quarter of the economic potential is so far being exploited. There is considerable potential in the modernisation of existing plants. When exploiting hydropower, particular attention must be paid to environmental and water protection (e.g. by constructing fish ladders).



NaturEnergie AG

H. Anger's Söhne Bohr- und Brunnenbaugesellschaft mbH

Geothermal energy is a renewable energy source which is constantly available regardless of seasonal fluctuations in climatic conditions or weather. An attractive option is the use of geothermal energy for generating electricity. Especially in regions which fulfil the geological requirements (e.g. regions of volcanic activity, temperature > 200 °C), geothermal energy forms a sound basis for environmentally friendly and cost-effective energy production and can make a significant contribution to the base load requirement. The principle on which heat is generated by harnessing so-called deep geothermal energy is quite simple: in order to obtain heat from below ground, a liquid is needed to transfer the heat. This transfer medium is already present below ground either in the form of steam or hot water, in which case it is conveyed to the surface, cooled and normally fed back underground, or the liquid must first be pumped deep down and heated and then conveyed back to the surface. The heat obtained can be fed into local and district heating grids or used directly for heating buildings or other heat consumers. With near-surface geothermal energy, the heat stored below the ground up to depths of about 150 m is exploited by means of heat pumps. The heat sources for heat pumps can be the subsurface, a body of water or the ambient air. Near-surface geothermal energy is used above all for the heating and cooling of buildings.

Possible applications

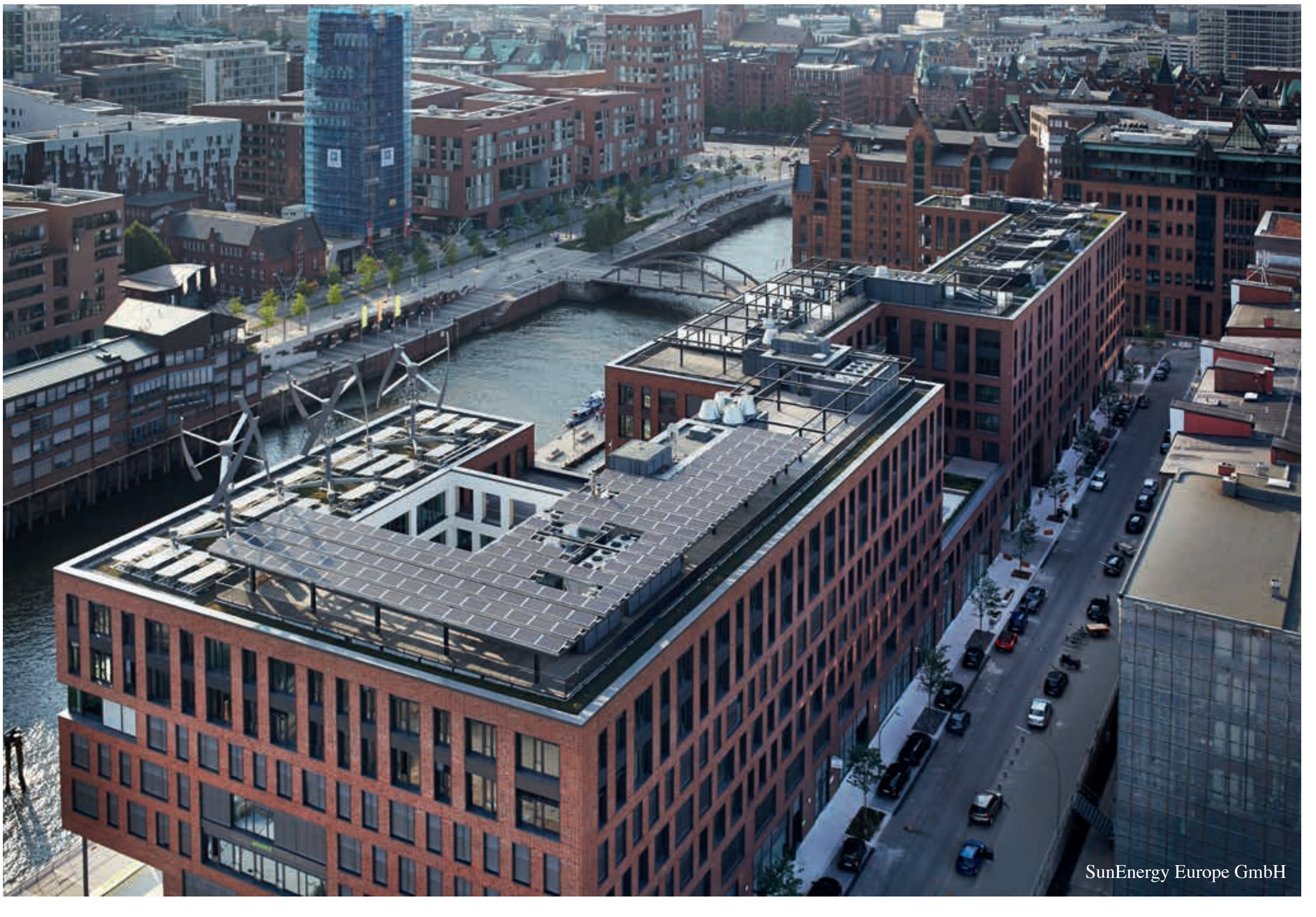
As shown, renewable energies can be used to generate electricity and heat. In addition, there are also applications in the area of mobility. While energy production from wind power and solar energy varies according to the weather, bioenergy, hydropower and geothermal energy remain almost constantly available and can be stored and regulated, though hydropower is heavily dependent on precipitation levels and therefore subject to fluctuations. The interaction of all technologies therefore has the potential to create a permanent and reliable energy supply to meet demand.

Because of the tremendous range of output varying from just a few watts to hundreds of megawatts, renewable energies can also be adapted to any kind of energy supply. When closely networked with modern energy technologies, they can make a considerable contribution to ensuring a reliable energy supply, even in a modern industrial society.

At the moment, not all types of renewable energy are economically viable in all countries. The greatest potential for exploiting solar energy is in the world's so-called sun belt. The technical potential for wind power on the other hand is dependent on the average wind speed. This is generally much lower over the continental land masses than over the oceans. However, virtually all countries have suitable locations for using a variety of renewable energies.

The choice of suitable technology/technologies depends on the local conditions and on the requirements with regard to the nature and extent of energy provision. These include, among others:

Local conditions	**User requirements**
Natural potentials (e.g. solar radiation, wind speed, availability of biomass)	Form(s) of energy: Electricity, heat/cooling, mobility
Government subsidies (e.g. use of state investment grants to make projects more economically viable)	Peak demand
Infrastructure (e.g. connection to grid)	Output/annual output
Financing of initial investmen (equity or borrowed capital)	Fluctuation in energy demand over the course of a day/year



SunEnergy Europe GmbH

Renewable energies in the energy system

The development of renewable energy generation in the areas of electricity and heat helps to reduce both CO_2 emissions and our dependency on energy generation from imported raw materials. In order to integrate fluctuating amounts of electricity from photovoltaic and wind energy plants, considerable changes are needed along the entire value creation chain for the generation, transmission, distribution, storage and consumption of electricity.

Different applications in which a large number of innovative storage and grid technologies are being used or tried out in Germany are:

- **Modernisation of transport and distribution networks** in order to collect electric power generated by decentralised plants across the country and transport it from the points of generation to the load centres;
- **Grid-compatible and grid-interactive behaviour of decentralised energy plants** in order to ensure stable and secure operation of the grid;
- **Development, use and optimisation of storage systems** to balance fluctuations in residual demand, to make balancing control energy and other system services available, to avoid blackouts and to maintain a safeguarded energy supply, as well as to absorb the occasional significant surpluses from renewable energies and balance longer slack periods in the long term.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In the area of transmission networks, there is a growing need in Europe to significantly increase transmission capacities and connect remote areas to one another. This should open up potentials for renewable energies and storage capacities over a wide area. In addition to expanding the grid with new lines and new line technologies, the workload can be better distributed across the existing transmission capacities in the transmission network by using reactive power management. This can be achieved within the transmission network through modern power electronics technologies such as flexible AC transmission systems (FACTS).

At the **distribution network** level, the use of controllable local network transformer substations, voltage regulators and targeted wide-area control of the supply of reactive power of decentralised energy plants can reduce the need to expand the grid while maintaining a high level of installed generative power (for example, from photovoltaic systems).

As the proportion of renewable energies in the electricity supply increases, the flexibilities provided by storage capacities and load management increase in importance. Important tasks of storage stations include balancing the fluctuations in power generation and demand, the provision of system services to replace conventional power plants that are being used less and less frequently, the assimilation of excess power output from renewable energies and bridging low periods of regenerative power generation. It is possible to distinguish between various storage technologies.

Options for storing electrical energy

With an efficiency of up to 80 %, **pump storage stations** are currently the only economical energy storage option for hourly and daily compensation that is available on an industrial scale and is likely to remain so for the foreseeable future (see also the Hydropower section).

Compressed air storage plants use excess energy, such as energy produced from volatile renewable energy sources, to compress air which is then stored in underground chambers. When electricity is required, it is produced in a gas turbine using the compressed air.

Conventional battery systems have been used to supply energy for decades. As the share of fluctuating renewable energy grows, two new fields of **application for electrochemical storage** have been developed: so-called “home storage devices”, which store self-generated solar power and ensure a supply when it is needed. Large batteries in the multi-megawatt range are gaining in importance. They provide system services such as frequency and voltage maintenance or black start capability within a few milliseconds and thereby ensure grid stability and supply security.

The idea of **power to gas** is to convert renewable electricity into hydrogen or methane. The gas can be transported and stored in the gas infrastructure and then used in the various areas of application (mobility, industry, heating and electricity generation).

Power to gas is thus a cross-system solution for integrating renewable energies into the energy system. Furthermore, power to gas can also be used for electricity storage to help balance fluctuations in electricity generation.

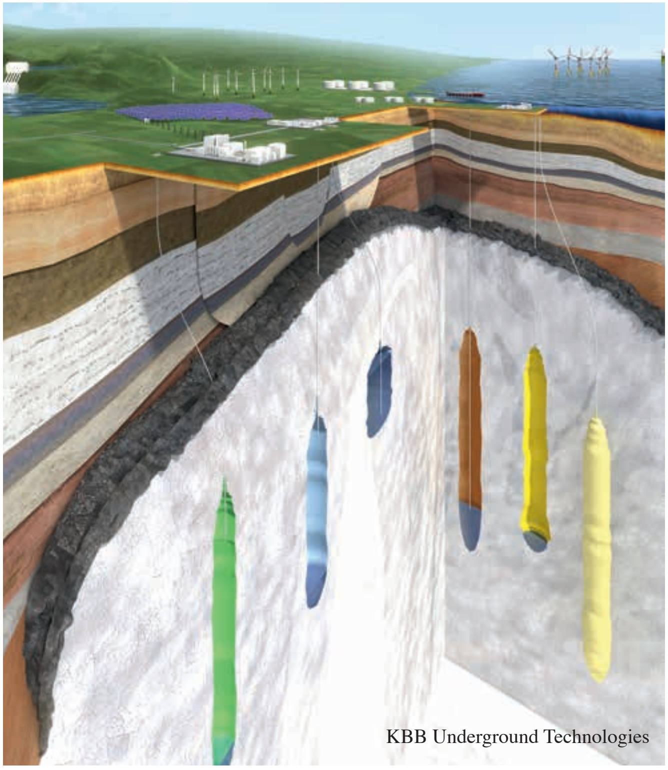
Load management can also be used to balance fluctuations in electricity generation. In the industrial sector, shiftable loads can be harnessed at a comparatively low cost using existing measurement and control solutions together with process and automation technology in order to respond to the supply situation on the electricity market. The same results can be achieved in private households by using smart meters in combination with building automation technology and controllable devices.

In Germany, a wide range of research and pilot projects are currently testing possible ways of utilising modern information and communications technology to intelligently control the electricity grid. In this dynamic environment, German companies are continuing to drive innovation in storage and grid technology and to develop cost-efficient solutions for the supply of energy from renewable sources.

Grid integration via virtual power plants

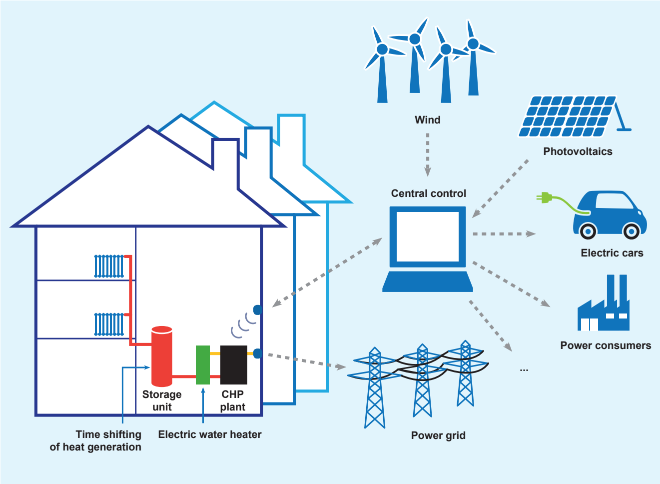
A virtual power plant is a combination of decentralised electricity generators using renewable energy sources – such as biogas, CHP, wind power, solar power and hydropower plants – for the purposes of joint electricity marketing and in order to take over responsibility for the grid, for example in order to provide controllable energy. All controllable plants networked into the virtual power station are accessible from a central control station.

Caverns for gas storage



KBB Underground Technologies

Virtual power plant



Methods of storing heat

Sensitive heat storage systems are a widespread type of storage. These storage systems absorb and release energy through temperature changes in the storage medium. They can be further subdivided into thermal storage systems with solid storage media (e.g. concrete, ground) and liquid storage media (e.g. water).

In the case of **latent thermal storage systems** a phase transformation takes place in the storage medium. For reasons of volume and pressure, transformation between solid and liquid is normally used, whereby transformation between liquid and gaseous is possible in principle. The advantage of this storage technology is the virtually constant temperature level during charging, storage and discharging.

Thermochemical storage systems store thermal energy by exploiting reversible chemical processes. This has the advantage that the storage system has a much higher energy density than is possible with sensitive and latent thermal storage systems, and there is no loss of thermal energy over a long period of time.

Renewable energy technologies – solutions for a sustainable future

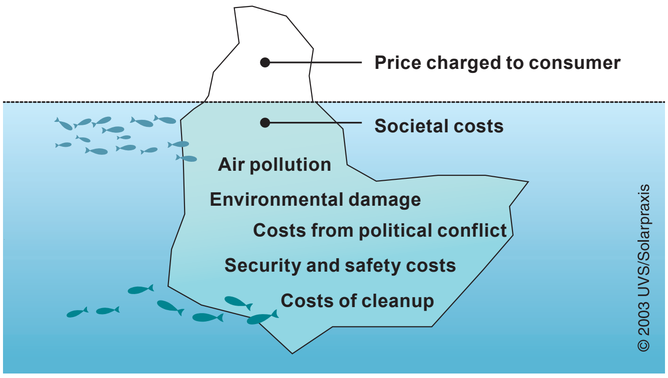
Advantages: beyond the goal of a reliable and efficient energy supply, the use of renewable energies helps to meet a great many demands.

Climate protection	▪ Indigenous resources which are available to varying extents all over the world.
Sustainable energy provision	▪ In human terms inexhaustible (solar radiation, wind energy, hydropower, geothermal energy) or self-regenerating (bioenergy) and storable.
Safety	▪ Relatively safe production, operation and disposal or re-usable within the material cycle by means of recycling.
Price stability	▪ Promoting independence from the volatile markets for fossil fuels, long-term stability of energy costs.
Cost-effectiveness	▪ Cost-effective use without subsidies is already possible depending on the location, provided the initial investments can be compensated for by relatively low subsequent costs (life-cycle analysis). ▪ In remote areas often the most affordable method of providing energy.
Environmental protection	▪ Protecting natural resources by conserving fossil fuels, less invasive interventions into the natural landscape (more environmentally friendly use of land) and reduced anthropogenic emissions into the atmosphere (acidification and eutrophication).
Climate protection	▪ Largely free of emissions, thus supporting international climate protection goals.
Protection of human health	▪ Protect human health thanks to their low level of harmful emissions (noise and pollutants in air, water and soil).
Local value creation	▪ Create jobs in sustainable growth industries. ▪ Promote the economic development of rural regions by decentralising production and distribution. ▪ Support positive economic development through technical innovations.
Independence from the grid	▪ Provide for a permanently reliable supply of energy far from the public electricity grid (in combination with energy storage systems).

Costs of energy provision

The current market prices for fossil fuels and nuclear energy represent only a fraction of the actual costs which society must bear. If the external costs of damage to the environment and political conflicts were to be taken into account, the cost of renewable energies would be competitive or, in many cases, even lower than conventional forms of energy. The use of fossil fuels causes economic damage, especially as a result of climate change and air pollution, which is increasingly becoming an important economic factor with a growing impact on economic decision-making. For example, the cost of CO_2 emissions on the basis of the emission trading system introduced in connection with the Kyoto Protocol is already affecting the flow of investments, such as into the construction of new nuclear power plants. But there are also new risk benchmarks for companies, namely those related to climate change, which are coming into play. In addition, the harmful emissions from burning fossil fuels are the main cause of smog and acid rain. According to a study commissioned by the European Commission, the economic costs and subsequent costs for the population of Germany arising from the use of oil and coal for the generation of electricity is between EUR 0.05 and EUR 0.08 / kWh and EUR 0.03 and EUR 0.06 / kWh respectively. Renewable energies offer the opportunity to meet the global energy demand in an environmentally friendly and sustainable manner.

Social costs of generating energy from fossil fuels



Source: UVS/Solarpraxis 2003

Renewable energy technologies – drivers of energy security

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The challenge: demand is increasing, reserves are dwindling

The worldwide demand for fossil fuels is currently increasing rapidly. This is due in particular to the tremendous economic growth in parts of Asia. Meanwhile, the reserves are decreasing and the remaining resources are restricted to just a few regions. This results in political conflicts and a growing number of military confrontations which entail a high economic risk for all nations and their development, since they are largely dependent on these increasingly expensive raw materials.

A shortage of fossil fuels and nuclear resources

Although it is hotly debated in scientific circles and it is difficult to foresee exactly when world oil production will pass its peak, there is no doubt that this will take place in the near future. According to basic economic principles and in conjunction with increasing demand, especially in emerging countries like China, India and Brazil, oil will become and remain much more expensive. Financial speculations, military conflicts, for example in the Near East, and natural disasters such as those related to climate change, will exacerbate the instability of the price of oil.

Not only will fossil fuels become more scarce but existing reserves will also remain restricted to just a few regions. For example, 74 % of the world's oil and 71 % of all gas reserves are found in the Middle East and in the region around the Caspian Sea.

Increasing dependence on imports

Because of the regional distribution of resources, numerous states are dependent on imported sources of energy. Germany, for example, was over 60 % dependent on imported energy in 2012. For the European Union (EU 28), the figure was 53.4 %. Energy dependence varies considerably from country to country within the EU and worldwide. This goes hand in hand with high capital transfers, high dependence and political and regional uncertainties. The most important suppliers of crude oil and natural gas to the European Union are Russia (37 % of crude oil imports and 38 % of natural gas imports) and Norway (with 10 % and 35 % respectively).

EU 28 dependence on imported energy in 2014

EU Member State	Energy Dependency*
EU-28	53
Malta (EU-Max)	104
Italy	77
Spain	71
Germany	63
Austria	62
France	48
Great Britain	46
Bulgaria	38
Romania	19
Denmark	12
Estonia (EU-Min)	12

*Imports divided by gross consumption. Gross energy consumption in million tonnes oil equivalent (Mtoe). Defined as primary production plus imports, less exports. Source: Europe's Energy Portal

Local value creation of renewable energies

Energies from wind, solar power, the earth and biomass are available all over the world and can make a considerable contribution to energy security and the prevention of conflicts. In addition, renewable energies give 1.6 billion people who do not have access to a modern power supply and the energy-hungry emerging nations the possibility of a sustainable and decentralised energy supply with local value creation – without the need for expensive power grids and dependence on imports. Here, the use of autonomous systems (decentralised systems of power provision) are especially advantageous.

In order to ensure a reliable and affordable energy supply, hybrid systems consisting of different energy sources can be used. For example, energy sources like wind energy, photovoltaics, hydropower and combustion engines work very efficiently in a network.

Renewable energy technologies – in the context of the energy transition in Germany

National expansion of renewable energies: how is Germany facing this challenge?

In the context of the "energy transition" – above all the nationwide expansion of renewable energies and their integration into the energy system – industry stakeholders, politicians and consumers are looking to Germany. Through its energy policy, the German government intends to transform the country into one of the most energy efficient and environmentally friendly economies in the world. At the same time, energy prices are to remain competitive, the standard of living high and the reliability of the power supply is to be guaranteed. This presents the world's fifth largest industrial country with major challenges. Countries around the world can benefit from Germany's experience.

Deutscher Bundestag/Lichtblick/Achim Melde

Owing to political encouragement early on, renewable energies are now a mainstay of the overall commercial energy system in Germany, accounting for 12.3 % of final energy consumption and 23.4 % of gross electricity production. And the German government is continuing to pursue a path of further expansion. In the electricity sector alone, the share of renewable energies is to be expanded to 40–45 % by 2025 and 55–60 % by 2035.

Expansion according to plan: the growth trajectory of renewable energies up to 2013

The increase in the utilisation of renewable energies in Germany is chiefly a result of the Renewable Energy Sources Act (EEG), which has been in place for the electricity sector since 1 April 2000. The goal of the EEG is to facilitate the market entry of renewable energies through fixed compensation as well as through guaranteed purchase and prioritising the feed-in of electricity from renewable sources to the grid. By the end of 2013, more than 1.5 million EEG-subsidised installations throughout Germany were feeding in more than 150,000 GWh to the German electricity grid.

In the heating sector, as well, the German Renewable Energies Heat Act (EEWärmeG) and the amplified market incentive programme (MAP) are the main starting points for doubling the amount of heat produced from renewable sources of energy to 14 % in 2020. The EEWärmeG stipulates that new buildings use renewable energy to provide a certain portion of the heating, implement certain substitute measures such as additional insulation or make use of combined heat and power or district heating facilities.

The MAP promotes technologies in the heating market primarily for existing buildings – such as solar thermal systems, wood pellet heating systems and efficient heat pumps. The support at federal level is supplemented by a large number of measures in various federal states and municipalities. Biofuels are promoted in Germany within the scope of the Biofuel Quota Act (BiokraftQuG). On the basis of the Biofuel Quota Act, admixtures to fossil fuels have been subsidised by way of the biofuel quota since 2007.

The Energy Line Extension Act 2009 (EnLAG) is intended to accelerate the further expansion of the German transmission network in order to ensure that even those renewable energies that are subject to large fluctuations can be transmitted in the grid from the often decentralised production locations to the centres of high demand for electric power.

Challenges to energy policy as from 2014

The enormous expansion of renewable energies, especially photovoltaics and wind power, is today confronting politicians with the challenge of coming up with intelligent solutions to integrate renewable energies – the production of which is often dependent on the season or weather conditions – into the energy system, to expand infrastructure by upgrading transmission networks and distribution grids, to improve coordination with neighbouring European countries and to spread the cost of transitioning to renewable sources of energy fairly.

The EEG reform of 2014 is intended to control the demanding goals more specifically, while reducing and better distributing the costs of this further expansion. A direct marketing obligation is intended to facilitate the introduction of renewable energies to the market. The federal government's objective is to ensure that Germany's energy-intensive industry remains competitive and does not suffer from rising electricity prices. Value creation and jobs are to be secured – a challenge which the federal government is attempting to master by intensively engaging with industry. When the costs of the transition to renewable sources of energy are apportioned, the concerns of a large number of stakeholders, such as power supply companies, grid operators, the energy supply industry and investors, as well as a large number of energy consumers, including private consumers, must be taken into consideration.

For example, the energy-intensive industries with their roughly 830,000 employees are the basis for the success or failure of a large number of other industries. And the renewable energy industry itself, which now has around 371,000 employees, is also a major economic factor. The "Special Equalisation Scheme" in the Renewable Energy Sources Act was thus instrumental in creating the policy which enables power-intensive manufacturing companies, as well as operators of railways, to apply for an exemption from the so-called EEG levy.

Long-term perspectives

By transitioning increasingly to renewable energy sources, Germany has struck out upon a path which has gained it international recognition. By 2050, Germany intends to have an energy system that is climate friendly, secure and economically efficient. This fundamentally new, sustainable energy system, marked by far lower emissions of CO_2, will make a significant contribution to international climate protection – without incurring any of the risks to humans and the environment posed by nuclear power.

In addition, the federal government is planning to use the new sources of energy to strengthen the German economy in the long term. Thanks to Germany's time-tested use of innovative, efficient technologies, machines and products "Made in Germany", the domestic industry already has a strong competitive position. Successfully transitioning to renewable sources of energy will further strengthen this base.

Solarpromotion GmbH

Funding a renewable energy plant

Constructing plants to utilise renewable sources of energy entails initial investments for which various forms of funding are available. Choosing the right combination of financing depends on a variety of factors, including the type of plant, the size of the plant or project, and the conditions for grants, if any, at the site of the investment. Typically, a combination of financing from borrowed capital, equity and public grants is used.

A foreseeable cash flow from which the debts of the respective project can be serviced can be ensured, for example, by guaranteed public feed-in compensation or the revenues from winning a contract. Financial support can also be obtained by way of investment subsidies through funding institutions or municipalities, tax breaks or marketing so-called green certificates. If no public funding is offered at the site, the money saved on buying energy (private consumption) or the revenues from direct marketing of the regenerative energy produced can be used to refinance the loans.

Large-scale projects

Large-scale projects, such as constructing and operating a wind farm, are often handled within the framework of so-called project financing. To this end, various stakeholders (operating consortiums, manufacturers, suppliers, etc.) join together to form their own company, a so-called special purpose vehicle (SPV). The stakeholders bring a share of their own equity into the SPV; following a due diligence process (review of credit and business), banks then provide debt capital.

The shareholders in a renewable energy project company expect high profits from their investment. With this goal in mind, private equity companies, such as pension and environmental funds, invest in wind and solar farms around the world. Projects of strategic investors are financed in advance largely from the total assets of the respective stakeholders. Energy suppliers, manufacturers of wind turbines and photovoltaic modules, but also grocery chains, for instance, are important stakeholders in this segment. In Germany, so-called “citizens’ parks”, in which private investors get together to carry out a project, are also widespread.

Borrowing

When it comes to financing large-scale projects in the renewable energy sector, extension of credit is directly linked to the specific project and thus to the expected annual profit. Many national and international banking institutions offer services in this area. Because of the complicated and expensive preliminary work involved, only projects with an investment volume more than about €10 million are worth funding.

Export financing

Within the framework of so-called export financing, the supplier’s banks grant purchasers of goods (orderers) several years of credit, whereby the exporter is paid the purchase price from the buyer’s loan immediately upon proper delivery and installation. Normally, the loan is granted on condition that it is covered by the official German export credit insurer Euler Hermes Deutschland AG (so- called Hermes cover). This covers around 85 % of the economic and 95 % of the political risk. You will find more information on Hermes cover in the section on “Advantages of importing German goods and services”.

Investment promotion

The federally-owned KfW Bank Group plays a pivotal role in providing credit facilities for investments in renewable energy projects in Germany and around the world. In 2014, € 3,3 billion (64 % of the total commitments were for climate protection financing) were granted for renewable energies and energy efficiency within the scope of financial cooperation with developing nations. The KfW development bank is among the world’s largest financiers for renewable energies in developing countries.

Other major lenders to projects outside the OECD are, for example, the national development agencies, the Global Environment Facility (GEF), the World Bank and the regional development banks. Apart from conventional financial instruments, bilateral and multilateral lenders also provide loans in the form of so-called “on-lending”. With this kind of lending, an international organisation extends credit to local banks in the respective eligible countries. The local banks can re-lend this credit on certain conditions. This enables the importer to obtain support on terms which are often quite favourable (for example, longer repayment periods).

CDM/JI funding

The flexible mechanisms of the Kyoto Protocol present another way of funding large-scale renewable energy projects. German companies, for instance, fund projects in developing and threshold countries within the scope of the CDM mechanism. The foreign target country receives investments and usually a better starting base as a result of technology transfer. In exchange, the German companies obtain emission rights which they can use to meet their emission reduction obligations under the European Emissions Trading Scheme.

Individual plants/smaller projects

Individual plants or smaller projects are often brought into being by individual companies. They are funded through a combination of equity and outside capital, or by leasing a plant. Income gained from selling the energy produced (for example, electricity or heat) or from the financial savings achieved as a result of the plant's efficiency (lower energy supply costs) can be used to refinance a loan.

Borrowing

Local banks also offer credit facilities to private persons and entrepreneurs. The conditions can vary widely. Experience gained by banks in the area of renewable energies plays an important role in terms of accurate risk assessment.

Investment promotion

Depending on the country or site, investments can be facilitated by public subsidies, such as low-interest loans, investment subsidies or tax breaks. Here too, funds from bilateral and multilateral lenders can come into play through the method of "on-lending" described above (see "Large-scale projects"/"Investment promotion").

Leasing

Leasing is an alternative to buying a plant, and represents a sort of hybrid between purchasing and hiring investment goods. Compared to buying, leasing has the advantage of being off the balance sheet and not affecting an entrepreneur's equity – thus preserving the entrepreneur's liquidity. Leasing offers planning certainty and cost transparency. Revenue can be generated by selling the energy produced.

Advantages of importing German goods and services

Importers of German goods and services from the area of renewable energies obtain direct support in the form of various German government programmes. The government considers exports of renewable energy technologies to be particularly deserving of support because this line of business also promotes sustainable global development. It provides appropriate cover in the form of official export guarantees and investment guarantees. It is also possible to apply for combinations of these.

Export credit guarantees from the German federal government

Risks related to the loss of receivables German companies may incur when exporting goods and services to foreign countries are insured by the state export credit insurance – also called Hermes cover. The repayment period for projects in the area of renewable energies is usually 18 years. Including locally occurring expenses (for example, infrastructure expenses for installing wind turbines at remote sites), up to 30 % of the total contract value can be covered. Orderers can avoid the risk of being unable to pay the German exporter as a result of the devaluation of their own currency by choosing the option of paying the German company in their own currency rather than in euros.

Investment guarantees

Importers of German goods and services also profit from the backing of German companies by the German federal government in the form of investment guarantees. With this instrument, the federal government offers German companies investing directly abroad a safeguard against political risks. These include participating interests, investment-like loans, capital endowments for branch offices and other proprietary rights. In the case of renewable energy projects, commitments from official or officially monitored agencies can also be included in the investment guarantee, such as the creation of infrastructure or a formal guarantee of purchase prices. Guarantees can run for up to 20 years.

Development of wind energy

In many parts of the world, traditional windmills have been used to grind grain or pump water out of the ground. They have been part of the landscape for centuries. Modern wind turbines are power plants, some of which generate electricity at competitive prices. Because it uses the latest technology and is both economical and ecological in use, wind energy is the fastest growing and, in the medium term, the most important source of renewable electricity generation. At the end of 2014, the world's entire installed capacity amounted to approximately 370 GW. The largest markets are in China (114.7 GW), the USA (65.8 GW) and Germany (40.4 GW).


SOWITEC group GmbH

How it works

In the development of modern wind turbines, engineers drew on experience from aircraft construction in order to exploit the upward lift produced by wind. The most widely used technology today is the three-blade horizontal rotor (Danish design). It has proven to be mechanically reliable, visually pleasing and quiet and was developed to deliver optimum power generation at wind speeds of 12 to 16 m/s, but it also operates efficiently at lower speeds. In strong winds, the output is reduced in order to ensure that the amount of electricity fed into the grid remains constant. Using modern control engineering to connect wind farms enables "soft" and gradual transition to be achieved in order to prevent fluctuations in the power grid.

Modern wind farms for grid-connected electricity generation are high-tech installations consisting mainly of 50 to 150 m high towers, the nacelle with the mechanical equipment and the rotor with a horizontal axis and three rotor blades.

The advantages of wind energy

- Wind energy delivers clean and climate-friendly electricity, often at competitive prices.
- Wind farms create jobs and benefit economically disadvantaged regions. Municipalities obtain revenues through taxes and leasing out the use of land.
- Wind turbines cover a wide range of applications from a few kW to several MW.
- Off-grid 10 kW turbines supply agricultural operations and small villages whereas offshore wind farms with an installed output of several hundred megawatts feed electricity into the grid of industrial regions.
- Wind power plants form the ideal basis for an energy mix together with other renewable energy power plants, whether for the public grid, for hybrid power plants or for a mini-grid.

Output of wind power plants

The electricity generating output of wind power plants varies according to the prevailing wind speeds, the height of the installation and the size of the rotor blades. The output increases disproportionately to an increase in wind speed, so that a 10% increase in wind speed can increase the output by one third. In Germany, a 1.5 MW on-shore plant generates an average of 2.5–5 million kWh of electricity per year. The height of the towers enables the rotors to be exposed to more powerful wind speeds and an increase in rotor area also increases the wind power yield and its conversion into electricity. In strong winds, the output is adjusted in order to ensure that a constant level of electricity is fed into the grid. If there is any risk of the grid becoming overloaded or if the wind is so strong that the rotors may be damaged, the plant is switched off.

Wind energy "Made in Germany"

Germany uses its pioneering role and experience to offer modern concepts for applications and solutions which have proven their value on the international stage. German companies are among the leading suppliers in the area of wind power. The range of services extends from research and production of all types of components and complete systems, via project development to the maintenance and operational management of wind farms. Wind energy products and services "Made in Germany" enjoy an excellent reputation internationally because of their reliability and high level of technological development.

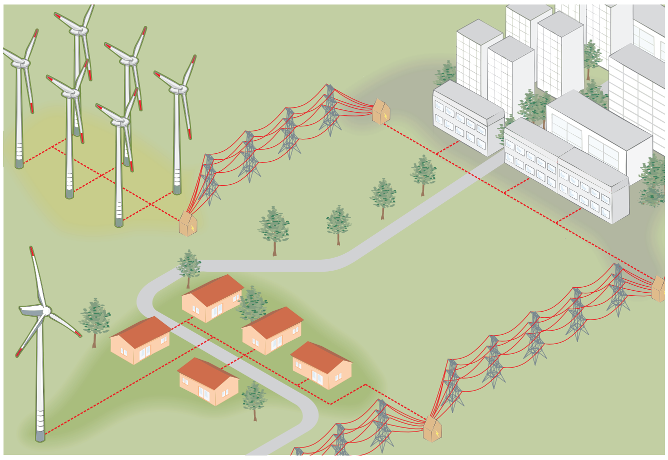
Technologies for using wind energy

Onshore wind energy

Nowadays, onshore wind farms are often set up alongside or close to the coast. To achieve high yields, turbines were developed with high towers and blades with a large sweep. Sites on the tops of mountains or elevated positions are particularly suitable for generating wind energy. There is a wide range of wind power plants for all kinds of applications. Two technologies have been developed for the efficient conversion of wind energy into electricity:

- on the one hand the classic drive type with variable rotation speed, gears and fast-running generator,
- and on the other hand the gearless system.

Areas of application



Advantages of onshore wind energy

- Investment costs are lower than for offshore plants, which need to be positioned, cabled, installed, operated and maintained at sea, in some cases a long way from land.
- In addition, decentralised electricity generation is carried out closer to centres of consumption, which requires less investment for grid expansion and operation.

Grid-connected wind power plants

Wind power plants are either grouped together in so-called wind farms or set up as single units. Single units normally feed their electricity directly into the available grid. When setting up wind farms, the main outlay is the high cost of connecting to the power grid (cables to the overland grid, control units and transformer substations).

Single units / off-grid

Single unit plants are mainly used in areas which are situated far from the power grid or where the cost of connection is prohibitive.

Repowering

With repowering, so-called first generation wind energy plants are replaced by modern turbines. This enables capacities to be expanded even in classic wind markets such as Germany without sacrificing any further space. Even though demand for repowering currently remains low in new wind markets, there is considerable potential for the future here, too. At the same time a market has developed for second-hand turbines, which are used in individual stand-alone solutions.

Small wind turbines

There is, as yet, no precise definition of a small wind turbine. The most common definitions are:

- According to IEC standard 61400-2:2006, small wind turbines are those with a maximum rotor area of 200 m^2, corresponding to a nominal power of about 50 kW at a voltage of below 1,000 volts AC or 1,500 volts DC.
- Germany's Wind Energy Association (BWE) distinguishes between three types of small wind turbines:
  Micro wind turbines (up to 5 kW nominal output),
  Mini wind turbines (from 5 kW to 30 kW),
  Medium wind turbines (from 30 to 100 kW).
- The tower is not normally higher than 20 m, and the average capacity lies between 5 and 10 kW.

Advantages of small wind turbines in off-grid regions

In addition to supplying electricity for own use, small wind turbines can also conserve the diesel fuel which would otherwise be used in generators. Combined with other renewable energy technologies such as photovoltaics, these turbines are especially suited to basic electricity supply in off-grid regions.

Small wind turbines are increasingly becoming an alternative for independent and self-sufficient electricity generation. Great potential for this is seen particularly in developing and newly industrialising countries with a low electrification rate. Small wind turbines can supply electricity as stand-alone systems or can easily be integrated into existing island networks or hybrid systems.

Offshore: Gigantic dimensions

- The hub height of a 5 MW offshore wind turbine is currently about 90 metres above sea level,
- the rotor diameter is approximately 125 m, the rotor blades cover an area about the size of one and a half football pitches,
- the nacelle is as large as a detached house and weighs up to 400 tonnes, an offshore wind turbine with a total weight of up to 1,000 tonnes weighs as much as 250 elephants.

Advantages of offshore wind energy

- Offshore wind farms create new opportunities for more jobs, especially for specialised services such as those that focus on the existing requirements at sea. This can benefit economically disadvantaged coastal regions.
- Wind farms with several hundred megawatts of installed capacity deliver constant electricity and can replace large-scale power plants and provide system services such as frequency stabilisation.
- Low competition for the use of the area of water, since there is little competition and little potential for alternative applications.

Outlook

The Global Wind Energy Council (GWEC) estimates that by 2020 about 12 % (2030 15–17.5 %) of worldwide energy demand could be met by wind energy. Half of total installations worldwide are likely to be in aspiring markets such as Brazil, China, India, Mexico, Morocco, South Africa or Turkey. It is also apparent that national and multilateral banks are increasingly channelling investments in the wind energy sector into these newly-industrialising countries.

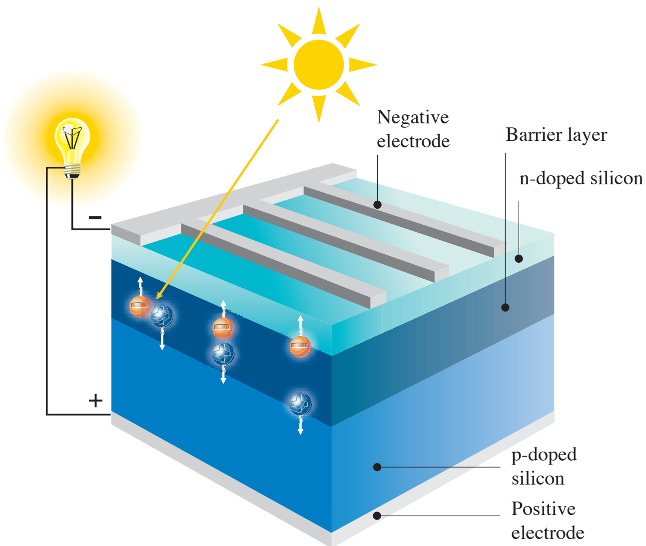
Onshore: Especially in the case of onshore wind energy it is also important to improve public acceptance of wind farms. This can be aided by participation models such as citizens' wind farms. These are already in use in some countries, for example Germany and Denmark.

Offshore: Forecasts for the offshore sector are positive, and predict strong growth for 2015, especially in the EU. The reason for this is the EU-wide planned expansion of offshore projects that are likely to achieve a newly installed capacity of 1.9 GW in 2014 and 12 GW in 2015. Numerous footings have already been set up off the German coast and are awaiting further expansion as part of the wind farms currently under construction. Alongside Germany, the UK and Belgium show the greatest potential for growth within Europe in the offshore area, but the market has also begun to move in the Netherlands and Denmark. France has set itself an expansion target of 6 GW.

Small wind turbines: Small wind turbines are increasingly becoming an alternative for independent and self-sufficient electricity generation. Great potential for this is seen particularly in developing and newly industrialising countries with a low electrification rate. Small wind turbines can supply electricity as stand-alone systems or can easily be integrated into existing island networks or hybrid systems. According to a forecast by the World Wind Energy Association (WWEA), the accumulated installed capacity could reach about 5 GW by 2020.

Solar energy: Photovoltaics

Solar energy has an enormous amount of potential that can be utilised by various forms of technology. One example of these technologies is photovoltaics (PV). Thanks to the global availability of solar energy, PV offers an attractive solution for generating both grid-connected and off-grid electricity.

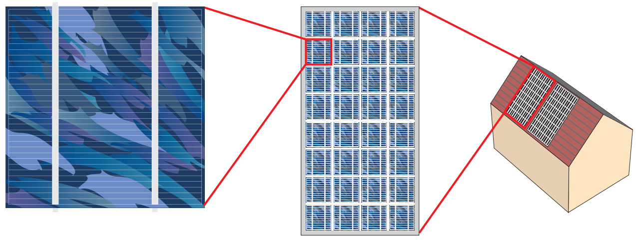


How it works

- PV cells consist of one or more semiconductor materials and enable solar energy to be converted directly into electrical energy.
- Chemical elements are added to produce two layers, a p-conductive layer with a positive charge carrier surplus and an n-conductive layer with a negative charge carrier surplus. Due to this imbalance, an inner electrical field forms on the barrier layer, which produces a charge separation on incidence of light. The charge carriers released in this process can be conducted through contact with metal and used as direct current (DC) by an electrical device or fed into the network as alternating current (AC) via an interconnected inverter.
- To provide higher capacities, PV cells are interconnected in modules.
- Elements other than silicon, such as copper, gallium or cadmium, are also used in PV. We generally differentiate between thick film technology (monocrystalline and polycrystalline silicon cells) and thin film technology (for example amorphous silicon).

Advantages of photovoltaic electricity generation

- Quiet, emission-free electricity generation
- A wide range of applications from very small applications such as for operating solar-powered pocket calculators to electricity generation for domestic use and large-scale installations with an output of several megawatts.
- No moving parts – the installations have a long service life.
- Very environmentally friendly – using and disposing of silicon entails no danger to the environment.
- Currently, silicon is the primary material used in the manufacture of PV cells and since it is the second most common element on earth, it is inexpensive to obtain.



Solar cell – Solar module – Solar generator

Photovoltaic systems

Depending on the application, the modules are installed as complete systems fully configured and wired with inverters, charge regulators, batteries and other devices. Photovoltaic systems can be designed as autonomous systems or as grid-connected installations. In autonomous systems, the energy yield corresponds to the energy requirements. If necessary, the energy is stored in rechargeable batteries or supplemented by means of an additional source of energy (hybrid system). In grid-connected systems, the public power grid serves as an energy storage medium.

Current conversion

- Inverters convert the generated direct current into alternating current, which can then be fed into the grid.
- This conversion is generally carried out by means of an inverter which also ensures that the operating mode is the best for the prevailing solar radiation and acts as a monitoring and protection device.
- In addition, the inverter has a special part to play in integrating electricity from renewable energies into the grid. This means that inverters are closely integrated into the intelligent power grid in order to optimise the generation of electricity and the load within the grid.

Worldwide installed capacity 2014

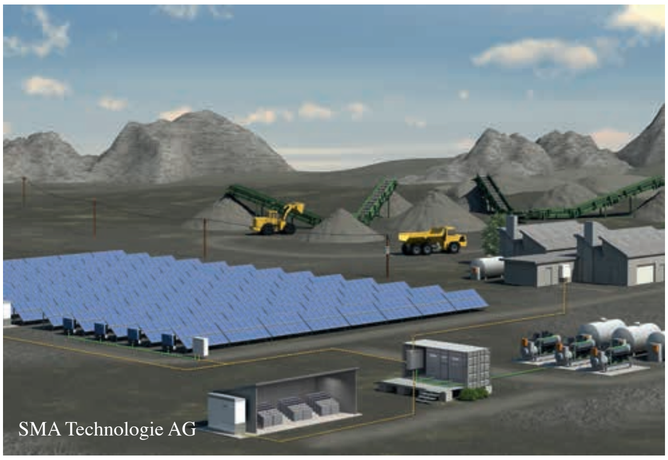
In recent years, there has been a rapid upsurge in the expansion of PV installations worldwide. With new installations totalling roughly 42 GW, the total installed output worldwide was over 170 GW at the end of 2014.

Areas of application

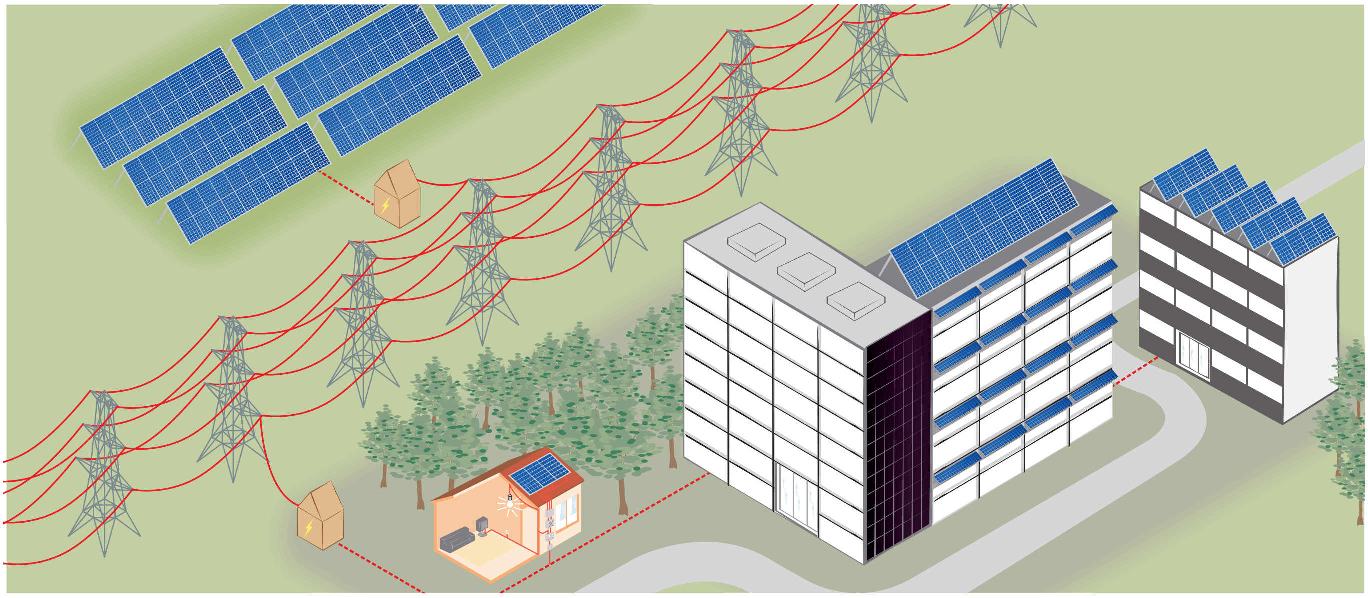
PV systems can be both grid-connected and off-grid, or can supply entire communities with electricity by acting together with other technologies in hybrid systems by means of a stand-alone grid system. Off-grid systems are especially suited to electricity supply in off-grid areas or in regions in which there is a low level of security for electricity supply. Another advantage here is that the PV generator can be scaled to any size: from a single watt for supplying electrical devices in the home to several hundred kW_p or even MW_p.

(1) Domestic applications – the typical system consists of a rooftop installation. New areas of application are found in the integration of PV systems into the building itself, e.g. by incorporating PV into the roof, facade or windows. For example, to meet the annual requirement of a four-person family in Germany, an average household needs a PV system with a peak output of 3.5 to 4 kW. Depending on the PV technology used, this corresponds to a solar panel surface area of about 35 to 40 m^2 or more. Intelligent systems technology can be used to optimise one's own energy consumption. By **connecting to the grid,** the excess electricity can be supplied directly to the grid operator. Compared with an off-grid installation, the costs of the system are lower, since it is not normally necessary to store energy, which also improves the system's efficiency. Furthermore, electricity generation using PV together with storage solutions can also be carried out **off-grid.** Mobile charging stations or lighting systems are further applications for the private consumer.

(2) Trade and industry – In the main, the same rooftop installations are used as in private households and these enable the roofs of factory buildings and commercial complexes to be used to generate electricity by means of PV systems in order to supply production facilities and commercial sites. This can be carried out **off-grid** or be **grid-connected.** Here, hybrid systems present a special case. These combine PV systems with other renewable energy technologies and/or with diesel generators. This enables diesel costs to be reduced and the consumption structure to be diversified.


SMA Technologie AG

(3) Grid-connected large systems – As a rule, large systems are designed as free-standing systems in the open or as large rooftop installations. Systems of this type can be used to electrify municipalities and regions and to supply stand-alone power systems (mini-grids) with electricity. In the case **of mini-grids,** several PV systems feed into a stand-alone power system, allowing them to supply several houses or even whole towns with electricity. Hybrid systems are generally used in this case. In order to optimise the generation of electricity, the modules can be made to track the sun.



Future trends





Bosch Solar Energy AG

Development of new technologies

German companies are world leaders in the research and development of new PV technologies. A prerequisite for positive market development in the future is a further reduction in costs, for example, by increasing the degree of efficiency and reducing the amount of material used, as well as increased use in other areas of application. The following PV technologies are therefore set to increase in importance in the future:

Concentrator photovoltaic systems (CPV)

Mirror and lens systems are used to concentrate a high level of light intensity on the PV cell. As a result, degrees of efficiency of up to 43.6 % can currently be achieved. This technology has high potential for reducing production costs and therefore represents a cheap source of electricity supply for the future.

Organic photovoltaics (OPV)

Organic PV cells consist of hydrocarbon compounds which are applied, as with amorphous silicon, to a substrate material. The advantage of such PV cells over inorganic PV cells is that their performance does not drop in the presence of less sunlight and higher temperatures. This gives a higher solar electricity yield and in addition the colourfulness and flexibility of the material opens up opportunities for more applications.

Integration into the grid

The ongoing expansion of PV systems places the spotlight on integration into the grid. In rural areas in particular, large quantities of solar electricity are being generated and fed into the power grid. On the other hand, rural regions have a comparatively low demand for electricity. The expansion of PV systems goes hand in hand with the expansion and development of the power grid and the potential to store PV electricity. The German PV industry is developing modern inverters which can increase the capacity of power grids and thereby help to keep down the costs of expanding the grid.

Manufacturers' responsibility and recycling

PV modules contain materials such as glass, aluminium and numerous semiconductor products which can be used in new installations or alternatively re-used. As modules are taken off the grid over the coming 10 to 15 years in accordance with their expected service life, companies in particular bear the responsibility for offering sustainable solutions for their disposal. Industrial recycling processes already exist for thin-film and crystalline modules. In 2007, companies from the European photovoltaics industry developed the recycling system known as "PV CYCLE".

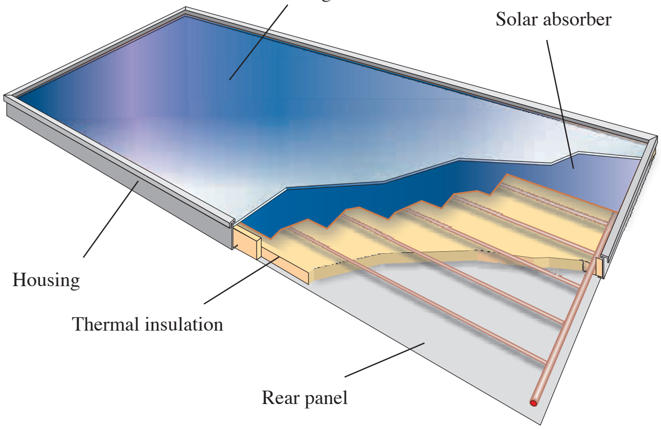
Outlook

The European Photovoltaic Industry Association (EPIA) expects that the largest growth markets will shift from Europe to other regions in the world. Above all, China and India have massive potential for new PV systems, and on that basis, strong growth has been forecasted there for the PV market in the years ahead. Further development for PV systems is also expected in South East Asia, Latin America and in the MENA (Middle East and North Africa) region.

In many countries of the world, there is either no electricity grid or only an inadequate one. In the regions in question, diesel generators have so far been used for electricity generation. In the future, PV-diesel hybrids will provide an environmentally friendly alternative to this. According to estimates by Greenpeace, the global market share of off-grid systems in developing countries in the years ahead is said to increase considerably, ensuring the off-grid supply of electricity to around 2 billion people by 2030. The first commercial PV diesel hybrid system was put into operation in South Africa at the end of 2012.

Solar thermal technologies

The use of solar energy to generate heat is a tried-and-tested technology and has been used for decades. Solar thermal energy can be used to heat non-potable water, for room heating and also for cooling.



Operating p rinciple and different types of solar collectors

Unglazed absorbers. This is the most simple type of solar collector, consisting of a black plastic matting that is often used to heat water in swimming pools in order to reduce their operating costs. They are cheaper than a fossil-fuel boiler and achieve temperatures of 30 – 40 °C.

Almost 90 % of the solar collectors in Germany are **flat plate collectors.** The metal solar absorber is fitted in a casing that reduces the rate of heat loss thanks to thermal insulation and a glass pane. Flat plate collectors generally operate in the temperature range of 60 – 90 °C.

Air heater solar collectors. This is a special kind of flat plate collector. Air is heated and normally used to heat buildings immediately, without having to be stored in the interim. The heated air can also be used to dry agricultural products. The use of air-water heat exchangers allows you to heat water (e.g. for heating tap water).

Evacuated tube collectors. Even higher temperatures and degrees of efficiency are achieved with evacuated tube collectors, in which the level of heat loss is significantly reduced thanks to high negative pressure in the glass tubes. A collector is made up of several evacuated tubes. Thanks to the rotatable mounting for the individual tubes, the flat absorber plate in the glass tubes can be turned to the optimum position for sunlight. For this reason, evacuated tube collectors can also be deployed almost horizontally on flat roofs. The individual tubes form a closed system that transfers the heat through a frost-proof heat cycle to the water to be heated.

Advantages

- Reduced consumption of fossil fuels, considerable savings in heating bills and more plannable heating costs
- Less dependence on imported energy
- Helps to reduce CO_2 emissions
- Tried-and-tested technology

Solar thermal systems

Pump-driven circulation system

- The thermal energy obtained is fed to the energy storage system by means of a heat transfer medium.
- The heat transfer medium is circulated by means of a pump. This means that the energy storage system can be located in the basement, which makes it easier to integrate the solar thermal energy system and the conventional heating system.
- The control unit monitors and regulates the system, so that there is always sufficient heat energy available.


KBB Solar Colectors

Thermal syphon system (convection)

These systems are ideally installed in frost-free areas and their design is undemanding and works without using electrical energy for pumps and regulators.

Heated liquids have a lower density than cold liquids and gravity therefore causes the heat transfer medium to circulate between the collector and the storage tank located above it.

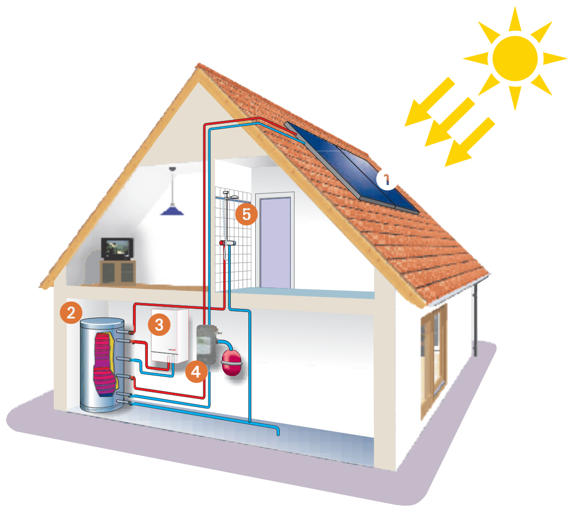
Outlook

The importance of solar heating technology has long been underestimated. With increasing energy prices and the development of innovative solar heating systems, increased development is to be expected in the future. The use of solar thermal energy in apartment blocks, hospitals, hostels, hotels and in industry is becoming more and more important.

Areas of application for solar heating

Heating water for detached houses

This is the most common application for solar thermal energy worldwide. In Europe, these systems are designed to provide 100 % of the warm water required in summer and 50–70 % in winter. They consist of a large collector with a surface area of 3 to 6 m² and a boiler with a capacity of 200 to 400 litres for storing the heated water needed by a family of four.



Solar thermal energy systems for domestic water heating in a detached house:
1) Collector
2) Solar storage tank
3) Boiler
4) Solar station with integrated solar controller
5) Hot water consumer (e.g. shower)

Systems for heating tap water

Systems for heating tap water are typically designed to heat all domestic water throughout the summer period. In the winter months, the hot water is heated mainly by a heat generator (a boiler, usually operated with gas, oil, wood or a heat pump), which is supported by the solar thermal energy system on sunny days. This means that around 60 % of the annual heating requirements for heating water are provided by the solar thermal energy system. The collector area required to do so depends on the weather conditions in the country in question.

Combi-systems

The solar collector area of combi-systems is larger. These systems also help to heat the building in spring and autumn. Here, too, the collector area required depends on the weather conditions in the country concerned and on consumer demand.

The solar component of the total heating requirement of the building is typically 20–30 % depending on how well the building is insulated and how much heat is required. However, there are also special solar houses that cover over 50 % and up to 100 % of the total heating requirement by means of solar thermal energy.

Provision and storage

In order to be able to use solar thermal energy on a larger scale, local and/or district heating grids must be set up and connected to sufficiently large storage tanks. Huge tank volumes are necessary if the solar heat is to be used via a district heat grid so as to enable entire residential districts to be supplied with heating and for the heat stored in the summer to be also available at cooler times of the year. For example, the heat can be stored in underground water-bearing seams (aquifers).

Providing process heat for industrial applications

There is enormous potential for solar thermal systems in the area of process heating: some 30 % of the industrial heating demand is within a temperature range below 100 °C. Solar thermal energy can be supplied either at a supply level (industrial hot water or steam network) or at process level.
The systems technology required for high temperatures is still relatively expensive; by contrast, process heating at temperatures of between 20–100 °C can be provided relatively quickly and can be developed at comparatively low cost. In future, it should be possible to achieve temperatures of up to 250 °C.

Project example

In Eichstaett in Germany, one of the roughly 100 pilot systems worldwide is supplying a brewery with water heated by solar thermal energy. In order to increase the economic viability of the brewery's processes, the production processes were adjusted to suit the sun's level of intensity. The system operates with evacuated tube collectors on a collector surface area of 900 m² and two 60 m³ solar panels.

Outlook

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Areas of application for solar cooling systems


Wagner & Co Solartechnik GmbH

Solar air conditioning

Solar thermal energy can make a significant contribution to air conditioning systems. The energy obtained through a collector is used to operate an air-conditioning system. The advantage of this technology is that the need for cooling is greatest when the sun is at its most intense, whereby neither heat nor cold need to be stored over a long period. In addition to the immediate saving in fossil fuels, this also enables the peak period power loads to be reduced in summer. The increasing desire for a higher standard of living, taken together with the trend toward buildings with large glass facades, will probably also increase the demand for environmentally friendly air conditioning systems. These systems present a reliable alternative, especially in warmer countries in which the power grids reach their limits as a result of the power requirement of electrically operated cooling systems at peak times.

Systems used for solar thermal energy cooling:

In **closed systems,** an absorption cooling process is initiated using solar energy. Here the enclosed liquid makes no contact with the outside air. In **open systems** on the other hand, the water used as a coolant is in direct contact with the outside air which is to be cooled. Open systems normally use a combination of sorptive dehumidification and evaporation cooling which is used in ventilation systems for processing the air. Sorption-supported air conditioning is a well developed technology. In the so-called dry coolant method, the water vapour from the incoming air is removed by means of a desiccant such as a silica gel which is applied to a porous rotating cylinder and which absorbs the moisture. As it rotates, a part of the cylinder is continuously heated by an air stream heated by solar energy so that the humidity is transferred to the ambient air. In open systems both the humidified exhaust air and the incoming air serve as coolants. The incoming air is blown directly into the room by means of a heat recovery process. In the area of the first rotor, the incoming air is heated slightly as it dries. When it flows past the second rotor, it cools back down to the ambient temperature. The air is then cooled to the required level by evaporating the water in the incoming air.

Outlook

Particularly in countries with high cooling requirements, solar-powered cooling systems represent a future technology that provides a long-term option for reducing energy consumption and air-conditioning costs. In this case, the heat captured by the solar collectors is used to provide the operating power for refrigerating machines.
However, as the technology for solar cooling is still relatively new, the installation costs are still higher than those for conventional cooling systems. The reasons for the higher costs are the complexity of the technology and the low degree of industrialisation. Companies and research institutions are working on developing this technology further to make it more compact and more economical, as well as more fit for service where smaller capacities are involved.


Schüco AG


Wagner & Co Solartechnik GmbH


KBB Kollektorbau GmbH

Solar thermal power plants

Technology overview

Power plants based on concentrated solar power (CSP) use the sun's energy to generate electricity on an industrial scale. Solar radiation is optically concentrated, thus generating very high temperatures for the power plant process. This high-temperature heat can be stored, allowing electricity to be generated on demand – an important advantage of this technology.
Cost-effective operation of solar thermal power plants relies on a high incidence of direct solar radiation; they are therefore typically used in very sunny areas, such as southern Europe, North Africa or in the south-west of the USA. In the scope of today's market development, many parabolic trough plants, and increasingly central receiver solar power plants, are currently in planning or under construction, as are large-scale plants based on Fresnel technologies. In 2013 approximately 60 solar thermal power plants went on the grid around the world. This corresponds to a capacity of approximately 3,200 MW. Another 40 power plants with a total planned capacity of around 6,000 MW are currently in various stages of construction or actual project development. As far as research and development of CSP technologies are concerned, German companies are among the world leaders.

Novatec Solar GmbH

Parabolic trough plants contain numerous parallel rows of collectors that comprise parabolic curved dishes and concentrate sunlight onto an absorber tube that runs along a focal line, thus producing temperatures of about 400 °C. The heat carrier here is circulating thermal oil which absorbs the generated heat and creates steam at a temperature of approximately 390 °C in a heat exchanger. The steam is then used to drive a steam turbine and a generator to generate electricity as in conventional power plants.
In Fresnel collectors long, only slightly curved, flat mirrors concentrate the solar radiation onto a fixed absorber tube, where water is directly heated and vaporised. The resultant steam can be used to generate electricity or used directly in industrial processes for cooling or desalination. The basic concept of these collectors is simpler than that of the parabolic trough, so that the annual efficiency is somewhat lower, but the capital investment for the reflective surface is also lower.

FLABEG Holding GmbH

In **solar tower power plants,** the solar radiation from hundreds of automatically positioned dishes is concentrated onto a central absorber and heat exchanger. At up to 1,000 °C, the temperatures reached are considerably higher than with parabolic trough collectors. This allows for greater efficiency, particularly when using gas turbines, and is therefore likely to lead to lower electricity costs.
In **dish/Stirling systems,** a paraboloid dish concentrates the solar radiation onto the heat receiver of a downstream Stirling engine, which then converts the thermal energy directly into mechanical power or electricity. Efficiencies of over 30 % are achieved. There are prototype systems at the Plataforma Solar, for example, in Almeria, Spain. These plants are particularly suitable as stand-alone systems. They also offer the possibility of interconnecting several individual systems to create a solar farm, thus meeting an electricity demand from 10 kW to several MW.

Outlook

The International Energy Agency (IEA) estimates that the installed capacity will be tripled by 2018, increasing from the current 3.2 GW to just under 10 GW, due to the building of solar thermal power plants. This positive global development in the expansion of solar thermal power plants is attributable to projects being extended into many countries and is accompanied by substantial cost reductions in electricity production in newly initiated power plant projects. Within the next 5 to 10 years, solar thermal plants in favourable locations are likely to be capable of competing with electricity from medium load power plants, depending on the development of the total costs of fossil fuels (purchasing and CO_2 avoidance costs).

Bioenergy – mobility, heat and electricity generation



Solid	Gaseous	Liquid
▪ Wood residues	▪ Biogas	▪ Vegetable oil
▪ Stem product residues	▪ Sewage gas	▪ Biodiesel
▪ Energy crops (wood and stem products)	▪ Landfill gas	▪ Bioethanol
	▪ Synthetic biogas	▪ Synthetic biofuels

Plants use photosynthesis to form biomass and thereby store energy. Biomass can be used to produce fuel, heat and energy. Biomass includes wood, organic waste, manure and other plant and animal substances.

Market overview

The use of solid biomass is of tremendous importance in the supply of energy worldwide; developing countries in particular predominantly use bioenergy for heating and cooking. In 2010, bioenergy was the most widespread form of renewable energy in the world, accounting for 9.5 % of the world's primary energy consumption.

Classification of bioenergy

Bioenergy can be extracted from a variety of sources. These differ in their availability, their combustion properties and their possible uses. Biomass can be used to produce solid, liquid and gaseous fuels.

Solid biomass

- Solid biomass includes all dry or dried single items or bulk goods made from plants or parts of plants. It can be stored, for example, in the form of wood pellets or wood chips. This makes demand-based continuous heat and electricity generation possible.
- In 2012, the proportion of solid biomass (including waste) accounted for around 9.7 % of the world's primary energy supply.
- The proportion of solid biomass (including charcoal) in the world's energy supply from renewable energies amounted to 68.9 % in 2012.

Biogas

- Biogas, produced by the fermentation of biomass, is utilised worldwide to supply energy in various ways: by burning it in combined heat and power plants for power generation using waste heat (combined heat and power, CHP), as biomethane fed into the natural gas grid after appropriate processing of the biogas, as fuel for natural-gas vehicles, or directly for cooking.
- Half of all recovered energy in Europe comes from biogas produced in Germany.
- Around 56.7 % of the plants in Europe produced biogas from agricultural waste, with landfills at 31.3 %, and wastewater treatment plants at 12 % of total biogas production in the EU.

Liquid biofuels

- Biofuels are obtained from solid biomass and are comparable in quality to conventional fuels.
- The two main biofuels are biodiesel and bioethanol, which account for 80 % and 20 % respectively of the biofuel market.

Advantages of bioenergy

- Bioenergy is virtually CO_2 neutral. It only gives off the amount of carbon dioxide which the plants previously absorbed when they were growing. In terms of CO_2, it is irrelevant whether wood decays in the forest or is used to produce energy.
- In addition Biomass is storable and flexible in use.
- Biomass is able to balance fluctuations in solar and wind energy by virtue of its flexibility and constant availability.
- Biomass is available in almost all countries.
- The use of biomass helps to reduce problems of waste disposal, whilst at the same time providing valuable energy.
- Agricultural regions benefit from the creation and safeguarding of jobs
in agriculture and forestry, as well as throughout the entire production process.
- The planting of energy crops opens up new business opportunities for farmers.
- The use of bioenergy decentralises energy production and creates a material and energy cycle.

Solid biomass: technologies and applications

Heat | Elektricity

Generating heat and electricity from solid biomass

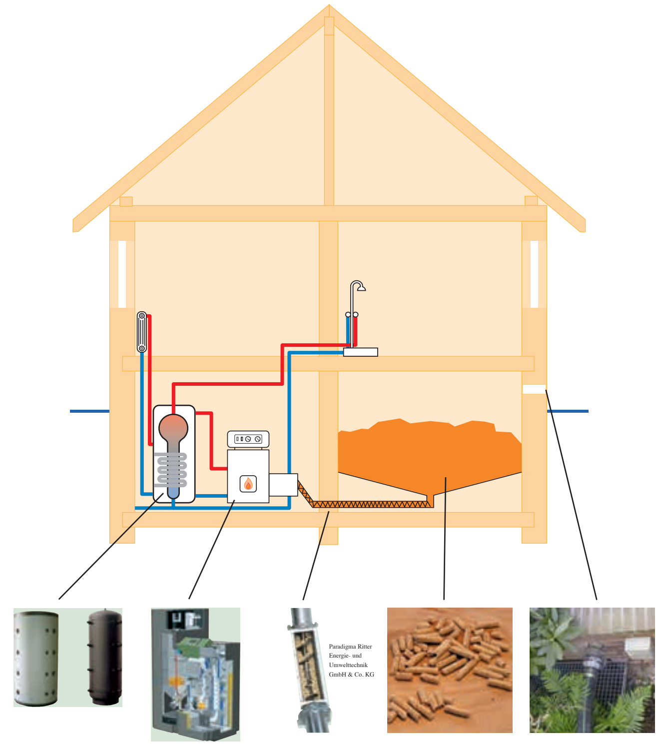
Using energy from solid biomass has the longest tradition worldwide and continues to be the most commonly used of all renewable energy technologies. Because solid biomass is continuously available, it can be used not only to produce heat, but also for example in electricity generation to compensate for fluctuations in energy fed in from wind and solar power. Solid biomass includes all dry or dried single items or bulk goods made from plants or parts of plants.

Technologies and applications

When **solid biomass is fired in modern heating systems,** the energy locked into the biomass is exploited very efficiently. The predominant source of energy is wood in the form of firewood, wood chips and pellets. Ovens and boilers fed manually, partly automatically or fully automatically with electronically regulated firing systems have been developed that contribute to a combustion process free from harmful substances at particularly high efficiency factors of up to more than 90 %.

Solid biomass is also used to **generate electricity in combined heat and power (CHP) plants.** The waste heat produced by this electricity generation is then, for instance, utilised in local and district heating grids or made available to industrial processes as vapour or heat. It can also be used to produce cooling for industrial purposes, for refrigerated warehouses or for cooling buildings.

Solid biomass is **suitable for gasification** as well as for burning. Depending on the characteristics of the combustion material and the capacity of the plant, fixed beds, fluidised beds or entrained gasifiers can be used. Resulting wood gas is then used to produce electricity in combustion engine systems or gas turbines with high electrical efficiency. Total efficiency can be enhanced significantly through the use of waste heat using CHP.



Storage tanks | Wood pellet boiler | Automatic pellet transport | Pellets | Delivery of wood pellets

Outlook

Rising energy prices have led an increasing number of private individuals, municipalities and companies to consider the use of biomass as an energy source for heating and electricity. The rapid growth in the global biomass trade has made it possible for many European regions to further expand the use of solid biomass as a source of energy in the future. As the prices for wood as an energy source have risen in the past, and as the requirements for emissions have been tightening in many regions, efficient combustion technology with low emissions has continued to increase in importance in Europe.

In Europe, the expansion of the use of solid biomass as a source of energy has also been continuously advanced on a political level, as it is an important milestone for achieving Europe’s energy policy objectives by 2020.

Electricity and heat from biogas

Biogas, produced by the fermentation of biomass, is utilised worldwide to supply energy in various ways: by burning it in combined heat and power plants for power generation using waste heat (combined heat and power, CHP), as biomethane fed into the natural gas grid after appropriate processing of the biogas, as fuel for natural-gas vehicles, or directly for cooking.

The production of biogas

- Biogas can be extracted from the following sources:
- Organic waste from landfill sites (landfill gas),
- Municipal wastewater (sewage gas),
- Industrial, domestic or commercial organic waste,
- Agricultural waste materials and energy crops.

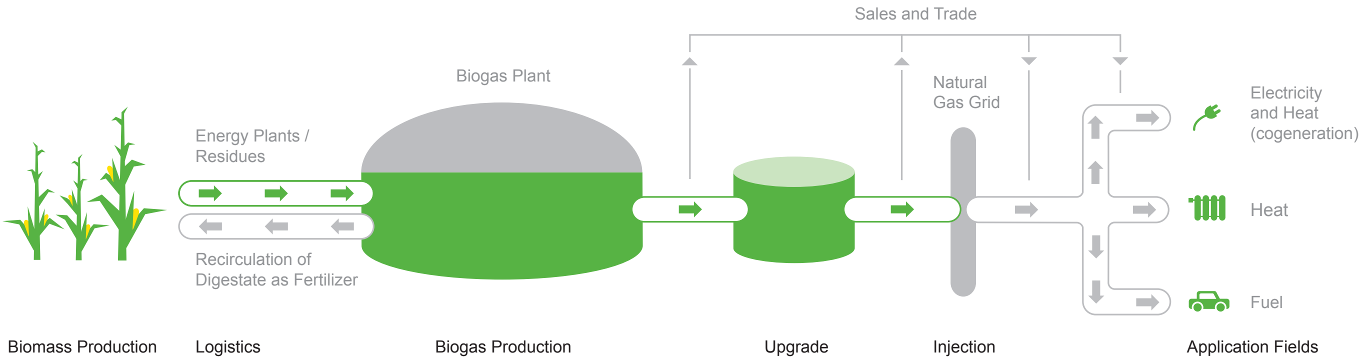
The process of **fermenting** the organic substance in the absence of air involves various anaerobic bacteria, the composition of which depends on the organic source materials and the specific processing conditions such as temperature and pH value. The microbiological processes that occur during fermentation are a decisive factor in the productivity of biogas plants.
In general, agricultural biogas plants use liquid manure and energy crops as a fermentation substrate. Using liquid manure for energy in biogas plants largely prevents the climate-damaging methane emissions from open liquid manure tanks. To increase gas yields, more renewable sources such as maize, cereal crops and many other energy crops like sunflowers, Sudan grass, sugar beets, fodder radishes, sweet sorghum, etc. are being used. In addition, commercial plants also process wastewater and waste from food production, such as food particles and grease traps. Apart from biogas, a digested sludge is formed, i.e. a mix of water, mineral components and undecomposed organic substances. This fermentation residue can be used in agriculture as a high-grade fertiliser, thus closing the nutrient cycle in the cultivation of energy crops.

Generation of electricity and heat (CHP)

The stationary use of biogas in combined heat and power plants for generating power and heat (CHP) achieves a very high degree of efficiency. The electricity produced can be fed into the public grid or used as an independent power supply for industrial and commercial areas, or it can be used to provide power to off-grid rural settlements. The waste heat can be utilised in downstream systems for additional power generation, but also for use in heating, drying or the operation of refrigeration machines.

Feeding biogas into the natural gas grid

Another attractive option is to feed biogas into the natural gas grid. After refining it to natural gas quality – biomethane with a methane content of up to 98 % – the biogas can be used in areas with a high demand for heat, and achieves a high measure of efficiency when electricity is generated at the same time (CHP). In the demand-driven supply of power, the natural gas grid can play a key role as a long-term storage facility for renewable energy, and thereby help to bridge seasonal fluctuations in the supply of electricity from solar and wind power plants.



Use of hydropower

Hydropower – current facts

Today, it is the most widely used renewable energy source for generating electricity worldwide. At around 1.31 TW capacity are installed at the end of 2014, hydropower accounted for approximately 16 % of the world's electricity generation in 2011. Given rising demand, the proportion of hydropower in the world's electricity generation is unlikely to increase much further in 2020, though it will reach approximately 4,500 TWh in absolute terms.

Advantages of hydropower

- storable and flexible in use,
- base load capability and grid stabilisation: able to balance fluctuations in solar and wind energy by virtue of its flexibility and constant availability,
- reduces the amount of imported energy,
- can promote regions which are not yet developed and connected to the grid,
- can provide decentralised energy.

Technologies and applications

There are currently three main technologies used to generate electricity from hydropower:

Run-of-the-river power plant / river power plants

- are the most common type worldwide,
- use the flow energy of a river and are normally used to cover the basic load,
- capacity is determined mostly by the gradient and the water level,
- can also store water at times of low energy demand in order to use it as a reserve when demand is higher.

Storage power plants

- store the water in a natural or artificial lake and feed it via pipelines into a lower-lying power plant,
- operate independently of natural water inflow,
- are particularly suited to balancing fluctuations in regional and national electricity generation and consumption.

Pumped storage power plants

- Pumped storage power plants use two reservoirs to store water, with the greatest possible height difference between the two (upper and lower reservoirs); in the upper reservoir, water is available for generating electricity during peak periods.
- During off-peak periods (e.g. at night or when there is a large amount of solar or wind energy in the grid), water is pumped from the lower to the upper reservoir.
- Pelton turbines are used to drive the generator.

Turbines for hydropower

The type of turbine used depends on the rate of flow and the drop height (pressure) of the water.
Francis turbine is one of the oldest types of conventional turbine, used primarily in small hydropower plants. It is suitable for low drop heights and medium flow rates.
Hydrodynamic screws work on the principle of Archimedes' screw. They are primarily used for low drop heights and low capacities.
Kaplan and bulb turbines are common types of turbine for large run-of-the-river power plants with small drop heights of 6 to 15 m and high volume flows. They are suitable for fluctuating water volumes.
The so-called **Pelton turbine,** a free-stream turbine, is used for high drop heights of 100 to 1,000 m and/or low water volumes. Cross flow turbines are used for low drop heights and low water volumes. They generally have a small capacity.

Environmental requirements

The construction of hydropower plants does entail intervention into the landscape. Statutory regulations affecting water, nature and landscape protection therefore have to be taken into account when planning a hydropower plant. The ecological connectivity for fish and other water organisms is guaranteed by means of costly fish ladders. Small hydropower plants are considered to be less burdensome for the environment than large plants. As well as the construction of new plants, there is a particular focus of activity on the replacement, modernisation and reactivation of existing plants.

Electricity from small hydropower plants and marine energy

Small hydropower

Small hydropower is defined as the use of hydraulic energy by local, small hydropower plants that do not generally involve any significant environmental impact. Most of the plants are on small rivers and do not have a reservoir but water basins of different size and construction. There is, however, no international consensus on the definition of small hydropower. The classification of small hydropower systems which has become generally accepted is as follows:

- Micro: 1–100 kW
- Mini: 100–1,000 kW
- Small: 1,000–10,000 kW

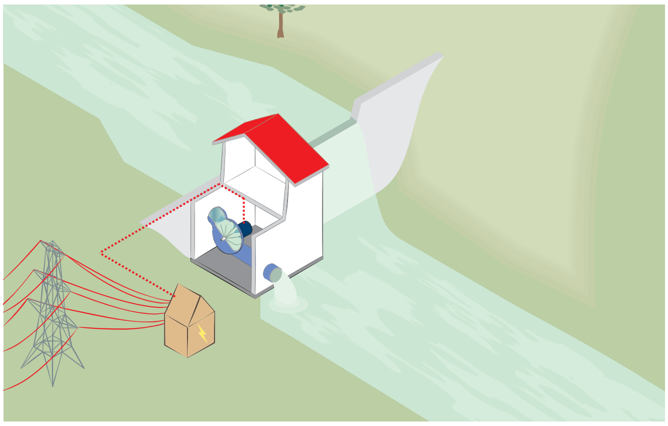
Turbines for small hydropower plants

The Francis turbine is mainly used in this area and has a helical housing. It is used for low drop heights and medium flow rates. In this type of turbine, only the distributor is adjustable. The water flows from a radial direction onto the runner and exits along the axis of rotation.

Other turbines for small hydropower plants:

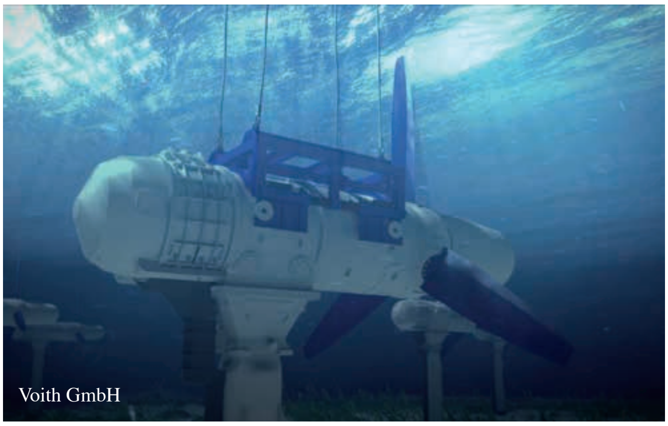
- Cross flow turbines are used for low drop heights and low water flow rates.
- Pelton turbines are suitable for high drop heights and low flow rates.
- Screw turbines are suitable for low drop heights and low capacities.

Micro run-of-river power plants



Types of power plant for using marine energy

The kinetic energy of waves, tidal range and tidal flow can be used to generate electricity. One advantage of using marine energy is the consistent energy supply and the ensuing balancing effect on the renewable energy mix. Whilst tidal range power plants are already technically mature, other technologies such as so-called wave power plants are still at the development stage.



Voith GmbH

Use of tidal and marine energy

Generating electricity from the natural flow of the oceans is still in its infancy, but may in future make a substantial contribution to the worldwide energy supply. One benefit is the base load capability of the generated electricity, as the tides of the oceans are easy to predict. In countries such as Canada, the USA, Russia, Australia or Great Britain that are surrounded by oceans with high current and/or high tides, there is considerable potential for using tides and marine energy for regenerative electricity generation. The comprehensive 3 GW project pipeline worldwide is just at the start of the anticipated market development. Among the challenges are cost reduction, integration into the electricity grid, tough mechanical demands, corrosion and plant maintenance.

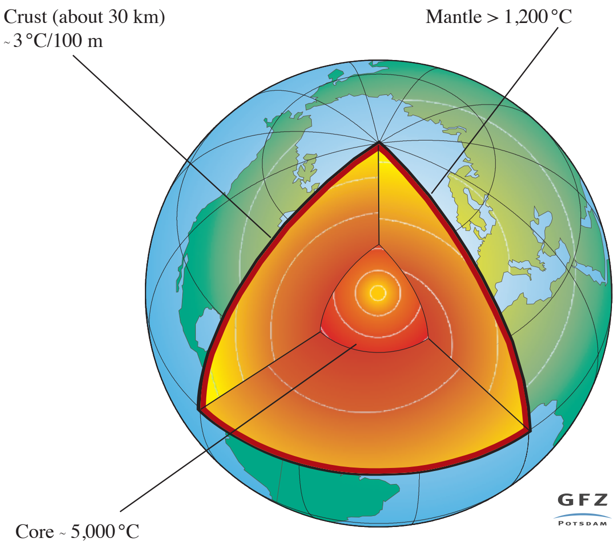
Outlook

In the worldwide electricity supply, hydropower will continue to play an important role in the future. In many countries of the world, there is still significant potential for expanding power plant capacities. In saturated regions such as Europe and North America, the focus is on modernising, reactivating or expanding existing systems. Optimising and modernising existing systems whilst taking ecological criteria into account also brings larger projects into harmony with the environment. There is a worldwide tendency towards international projects for electricity generation by means of hydropower. Countries are combining their energy resources, as for example in Central America's Electrical Interconnection System (SIEPAC) or Africa's power pools. Even remote areas are able to use electricity from hydropower thanks to new and very long transmission lines. The longest transmission line on earth is currently taking shape in the Madeira river region in Brazil.

Deep geothermal energy

Geothermal energy is available around the clock and does not depend on seasons, weather or climatic conditions. Geothermal energy is already used in many countries around the world for generating electricity or feeding directly into heating grids. Especially in regions which fulfil the geological requirements (for example regions of volcanic activity, temperature > 200 °C), geothermal energy forms a sound basis for environmentally friendly and cost-effective energy production.

The geothermal energy available in the earth's crust originates mainly from the residual heat from the time of the earth's formation and processes of radioactive decay. In addition, the topmost layers (up to 2 m deep) partly store energy from the sun's radiation.



GFZ (Deutsches GeoForschungsZentrum)

Deep geothermal energy

Deep geothermal energy is used both to generate electricity in power plants and for heat in large heat grids for industrial production or for heating buildings.

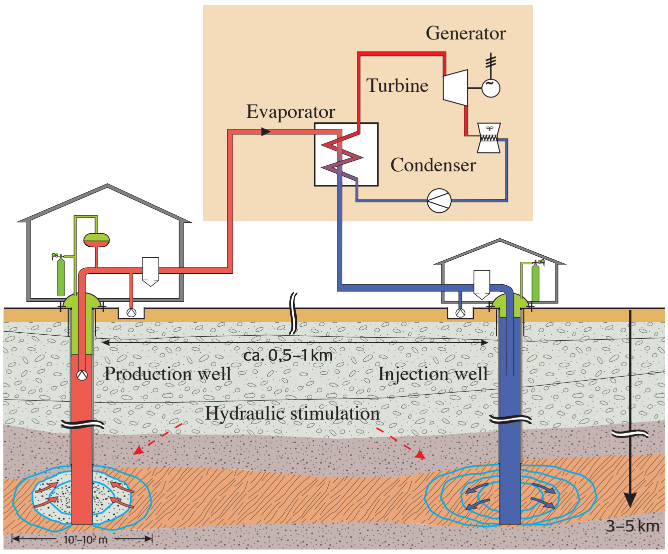
In deep geothermal energy, a distinction is made between hydrothermal geothermal energy, HDR systems and deep borehole heat exchangers. Hydrothermal geothermal energy makes direct use of hot water bearing strata found at great depths.

Depending on the temperature, hydrothermal geothermal energy can be used for generating heat or electricity.

In countries such as Germany, Italy, Indonesia, Mexico and the USA, the use of geothermal energy has been part of the energy concept for many years. In Germany, the focus of technical development is on the efficient use of available high temperatures and also on technologies for using available low temperatures in the range of about 120–200 °C.

The so-called **HDR process** (Hot Dry Rock) uses geothermal energy present in deep rock strata (between 3,000 and 7,000 m) in which no or insufficient natural water is present. Here, deep boreholes are used to circulate water through a system of cracks and fissures in the rock created by a controlled process. The hot water is conveyed to the surface through an extraction borehole and used as steam to drive a turbine for electricity generation or fed into the heat grid. German companies also offer various solutions for using lower temperature levels. The Kalina Cycle and the Organic Rankine Cycle (ORC) are suitable for using lower temperature levels of 120–200 °C for generating electricity. The downstream use of such systems can considerably increase the yields of high enthalpy deposits.

The principle of ORC geothermal electricity generation



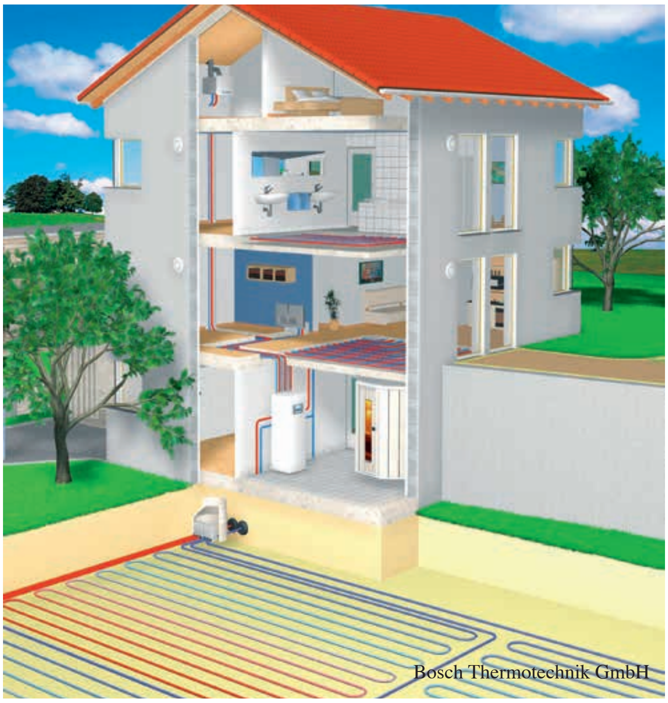
GFZ (Deutsches GeoForschungsZentrum)

Near-surface geothermal energy for heating and cooling buildings

Near-surface geothermal energy is suitable for both heating and cooling buildings. Here energy is used which is obtained from the upper layers of the earth up to a maximum depth of 400 m. Various systems such as geothermal heat collectors, borehole heat exchangers, energy piles or other ground-contact concrete structures enable the average temperatures of 7 to 12 °C present in the first 100 to 150 m of the earth's surface to be used. When used for heating, heat pumps are used to bring these low temperature levels to the temperatures required in the building. This involves extracting heat from the ground in a cyclic process. However, the constant temperatures prevailing underground can also be used directly without a heat pump in order to cool the building. If the underground source does not provide adequate cooling, a heat pump can be used in reverse to provide the remainder of the cooling capacity required.

Geothermal heat collectors are laid horizontally at a depth of 80 to 160 cm and are affected by the weather conditions prevailing on the surface. In order to extract the heat stored in the ground, a heat transfer medium is circulated through the collectors. Heat pumps can also be operated using ambient air. The advantage of air is that it is permanently available everywhere and is cheaper. However, the disadvantage is that the ambient air is colder.

Heat pump with geothermal collectors is at its coldest when the demand for heat is at its highest, namely in winter, which reduces the yield of the heat pump. The so-called temperature lift of heat pumps for borehole heat exchangers can be kept relatively constant during the year whereas the amount of input energy required is low. The energy absorbed comes mainly from the environment, the average temperature of which is determined by the annual amount of solar radiation.


Bosch Thermotechnik GmbH

Heat pump system with geothermal heat collectors

Borehole heat exchangers are in widespread use in central and northern Europe. In order to use near-surface geothermal energy, they are sunk to depths of 50 to 400 m. They have a low space requirement and make use of a constant temperature level. They consist of plastic tubes which are installed in closed cycles and connected to the cooling and heating system of the building. A heat transfer fluid circulates inside the tubes and absorbs heat from the surrounding ground and feeds it to the heat pump.

Energy piles are deep-reaching concrete piles, slurry walls or other structurally necessary concrete components built underground which are fitted with plastic pipes which in turn carry water as a medium for exploiting the geothermal heat or the coldness of the earth. The cold water is heated by geothermal energy in the concrete piles. An intermediate heat pump uses the hot water to heat the building. In summer, this system can be used as described above to provide moderate cooling.

Outlook

At present, political discussions on the future energy supply are increasingly looking to geothermal energy. Against the background of rising costs for fossil fuels, the certainty of the long-term availability of geothermal energy and the flexibility of its possible applications for heating, cooling and electricity generation, more and more systems are being installed worldwide. In the area of heating, an annual increase of installed capacity of 20 to 30 % is expected.


Bosch Thermotechnik GmbH

Off-grid use of renewable energies

Access to energy is a fundamental basis for economic and social development. Energy is a prerequisite for companies to manufacture and jobs to be created. It is required to grow food, to prepare meals, to heat homes and schools, to operate hospitals and to provide clean tap water. Energy also makes global communication and mobility possible.

Regions affected by energy poverty

In 2013 nearly one fifth of the world's population – over 1.3 billion people – had no access to electricity. In fact, nearly two fifths of people on the planet – around 2.7 billion people – do not even have clean cooking facilities. Energy poverty mainly affects sub-Saharan Africa and the developing countries in Asia; 84 % of those affected live in rural areas with no connection to the public electricity grid. For the households affected, this has a direct impact on everyday life: for example, these households cannot – or can only sporadically – operate electric lights and TVs, charge mobile phones or reliably keep medicines cool.

Areas of application

Electricity from renewable energies can be used to provide a source of energy which is independent of the power grid and fossil fuel imports. Solar power, wind energy, hydropower and bioenergy alone or in combination (hybrid systems) enable electricity to be used off-grid, for example for lighting, radio, television, refrigerators, telephones, data transmission, schools, hospitals, water pumps and stand-alone systems for villages and entire rural regions.

Choice of technology

The use of renewable energies in off-grid regions is cost-effective in many cases, whereby the systems can also be integrated into an existing or new power grid. The selection of technologies to use depends on the current and future demand for energy, the available resources and of course on the costs of installation and operation.

Areas of application	Power supply	Heating/cooling
Domestic households	Mobile phones, lighting, computers, sewing machines, radios, TVs	Hot water, room heating, cooking, building A/C
Agriculture	Water pumps, flour mills, sea water desalination	Drying of agricultural products
Commerce and services	Machines, computers, scientific measuring stations	Process heat, building A/C
Public and social facilities	Lighting, refrigerators, medical devices	Building A/C
Infrastructure	Phone and land mobile networks, mini grids, street lighting and road sign illumination, maritime on-board electrical systems	Vegetable fuels
Industry	Electrification and standby systems in urban and rural areas, for unstable power grids	Industrial process heat

Energiebau Solarstromsysteme GmbH

Steca Elektronik GmbH

Phaesun GmbH

Fraunhofer ISE

Phocos AG

Technologies for energy and water supply

Photovoltaics

Photovoltaic systems generate electricity directly from sunlight and can be used almost anywhere in the world. The systems are available in various size classes from small mobile PV lamps and water pumps via stand-alone systems for small households to large-scale installations for companies, hospitals and industry. Larger stand-alone systems enable buildings, residential estates or villages to be supplied with electricity. In most off-grid stand-alone systems, the electricity is stored in batteries and can be drawn on as required. In the case of larger systems, generators are used to supply the base load and batteries can be used, for example, to relieve diesel generators and to reduce their fuel consumption.

Phocos AG

Wind energy

Small to medium-sized wind turbines (with a rotor diameter of up to 20 m and an output of approximately 100 kW) offer a variety of possible applications in off-grid regions. The electricity generating output varies according to the prevailing wind conditions. Ideally, the wind speeds are measured over the course of a year in order to provide reliable forecasts for the future yield and the selection of the best plant configuration.

Hydropower

New, small pico and micro hydropower plants provide electricity from flowing bodies of water. Depending on the technology used, higher or lower gradients or flow rates are required. Pico systems generally have an output of 5 kW and are often used to charge batteries. The electricity generated by pico and micro systems is generally used directly and can in many cases provide electricity more economically than wind energy and photovoltaic systems.

GIZ/Michael Netzhammer

Solar thermal energy

Solar thermal power plants use the sun's thermal energy to generate heat. Hot water can be provided for hotels, hospitals or for industrial processes. Solar thermal collectors absorb the heat and store it in insulated tanks so that hot water is also available on demand at a later time. For solar thermal power plants, a variety of technologies are available, such as unglazed plastic absorbers, flat plate collectors and evacuated tube collectors. Parabolic dish systems are also used as solar boilers. Solar thermal energy can cover 60 to 80 % of a family's heating requirement. Solar thermal energy power plants can also feed electricity into existing stand-alone systems.

Bioenergy

Bioenergy can be extracted from a variety of sources. These differ in their availability, their combustion properties and their possible uses. Bioenergy can be derived from solid, liquid and gaseous fuels. Biogas from fermentation can be extracted from a variety of sources: from organic waste from landfill sites (landfill gas), from municipal wastewater (sewage gas), from organic waste from industry, households and trade and from organic waste materials from agriculture and energy crops.
Biogas is used, for example, in combined heat and power plants (CHP) to generate electricity and heat with high degrees of efficiency. The electricity produced can be fed into the public grid or used for off-grid applications.

Advantages of renewable energies for off-grid solutions:

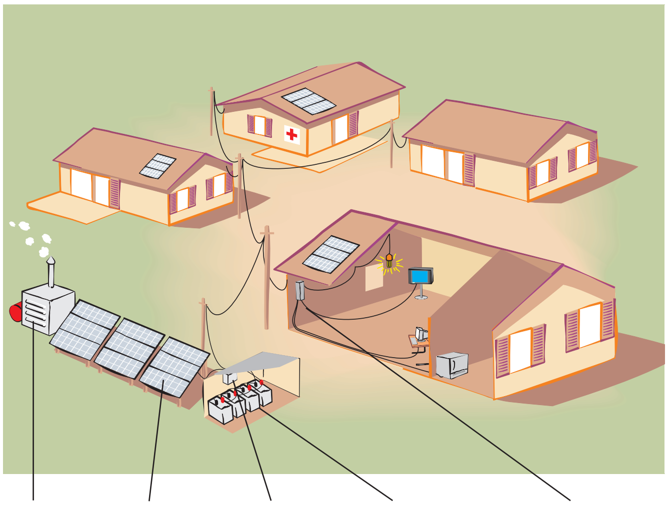
- Advanced technology
- Uncomplicated installation
- Easy to operate
- Minimum maintenance
- Easy to integrate mobile payment systems
- Unlimited scalability
- Can supplement existing systems
- Conserves resources

Areas of application

Hybrid systems for supplying electricity to industry are similar to the systems designed for rural areas and are autonomous off-grid systems. Hybrid systems are autonomous electrical systems which integrate more than one source of energy. They are used to supply off-grid power consumers, can meet higher energy demands and provide electricity reliably. The connection of all electricity generators and consumers in DC operation enables a system to be designed or expanded flexibly and in a modular way using standard components. Common configurations consist of photovoltaics with diesel generators (PV/diesel) or wind power with diesel generators (wind/diesel). Optionally, conventional diesel can be replaced by biodiesel. It is also possible to integrate a hydroelectric power plant into the system. If the energy requirement is high enough, larger hybrid systems, in particular with a conventional diesel generator, are economically attractive: they can be operated at lower costs than plants run entirely on diesel. What are known as "energy containers" or "power containers" are mobile variants of hybrid systems. With these, a wind turbine, solar module, battery and diesel generator are fitted in or on a conventional freight container. The hybrid system is therefore quickly ready for use at changing locations.

Water supply in rural areas. PV-assisted systems can provide both tap water for human consumption and water for irrigation and for livestock. Solar power systems are also suitable for disinfecting and desalinating water. Solar powered water pumps can drive rotary or membrane pumps directly. Hybrid systems can generate electricity continuously in order to pump groundwater to the surface or into tanks, as necessary.

Hybrid systems for generating electricity in rural areas can be a sustainable source of electricity. Here, complementary renewable energy technologies such as wind power, hydropower and combustion engines are combined with PV systems. Combinations of battery systems are also available so that energy generated during daytime can be used at night.



Within the scope of heat generation, renewable energies can offer solutions, e.g. through solar thermal energy plants, to provide hot water for households, hotels and hospitals. Solar thermal energy can also be used for domestic heating and for providing heat for industrial processes. In the area of food processing, biogas can be used for cooking.

Stand-alone systems for households supply electricity for lighting, radio, television, refrigerators, mobile phones, ventilators, computers and other domestic appliances. Stand-alone systems were developed to supply households in rural areas with off-grid electricity. Such a system consists of a solar module or for example a small wind turbine, a rechargeable battery and a charge regulator so that devices which run on direct current can be supplied with electricity. The output and storage capacity of stand-alone systems are adapted to individual requirements. The advantages are: easy installation, advanced technology, simple operation, little maintenance, plug-and-play systems for reliable installation and the option to use integrated prepayment systems.

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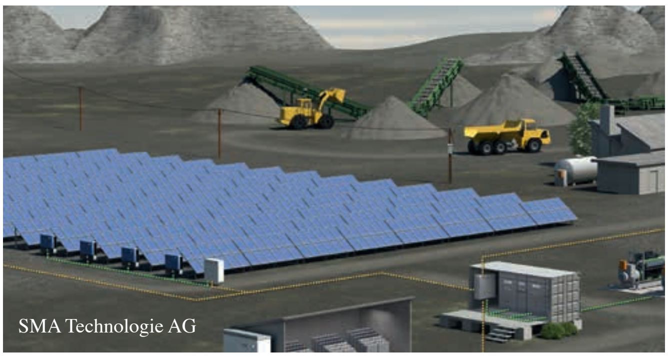


SMA Technologie AG

Domestic power supply supported by renewable energies

The increased use of renewable energies and alternative concepts of energy production is of great significance in houses since, after all, this is where a large part of the energy generated by any given country for electricity and heating is consumed. In the area of renewable energies and efficient domestic engineering, German products and services are world leaders. Fully automatic pellet heating systems, solar thermal energy plants for generating heat or for air conditioning, heat pumps which use near-surface geothermal energy for heating and photovoltaic modules for generating electricity from sunlight can all be combined intelligently within a house in order to greatly reduce the annual energy consumption for heating, ventilation and air conditioning.

Advantages

- Smaller ecological footprint through efficient and climate-friendly use of energy sources in the house
- Reduction in CO_2 emissions
- Potentially lower operating costs for electricity and heat
- Increasingly lower dependence on power grid and lower energy costs

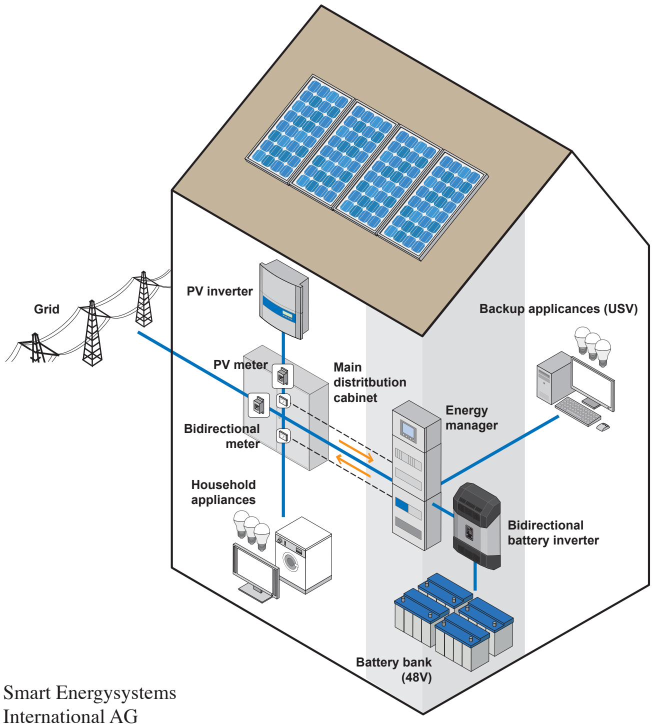
Electricity generation using photovoltaic systems

Photovoltaic systems (PV) are now one of the most environmentally friendly and efficient energy supply systems for many buildings. German PV research and industry companies are working on the further development of cell structures and production processes in order to optimise application and reduce costs still further. In many countries, the cost of generating electricity from solar energy is comparable with the consumer price for conventional electricity ("grid parity").

Areas of application and further uses

- As technology develops, it will be able to use flexible, super-thin PV modules on windows, large building facades, roofs or mobile phone chargers – so-called organic solar cells based on the technology of organic LED (OLED).
- Building-integrated PV systems offer the option of a visually more pleasing and less conspicuous integration into a house and can offer additional functions such as solar protection or insulation.

At the moment, a large proportion of the PV electricity generated in private households is fed into the grid. However, if the PV system is equipped with an intelligent energy management system and storage tank, the domestically produced electricity can be used more effectively for the household's own consumption.



Smart Energysystems International AG

Electricity generation using small wind turbines

Small wind turbines can also be used to generate electricity. For example, on commercial or agricultural buildings and also on or near multiple family dwellings and detached houses.

Generating electricity and heat using combined heat and power plants (CHP)

Electricity and heat can be generated simultaneously by using CHP plants. In this type of plant, an engine is used to drive a generator to produce electricity and the resultant exhaust heat is used for room heating and to provide hot water. If the combined electricity and heat production takes place in a compact, decentral plant and not in a large-scale CHP plant, then this is referred to as an apartment block-type thermal power station (BTTP). Micro BTTP plants are suitable for use within a building. They cover the lowest output segment of all CHP systems (0.8–10 kW_{el}). They are also sometimes known as "thermal power stations". They are used to supply small, single buildings, i.e. they are suitable above all for use in multiple-family dwellings, detached houses and for small commercial properties. The output of these systems is such that they can cover the average base load of electricity and heat for a single-family dwelling.

Heating and cooling in a renewable energy house

Regardless of whether you own a house or a flat or are renting, you are faced with the financial costs and burdens of heating and cooling. From 1995 to 2012, the prices for heating in Germany rose on average by 161 %. The use of heating and cooling from renewable energies:

- Reduces the financial burden and protects the climate.
- Avoids burning fossil fuels and therefore reduces the emission of greenhouse gases, in particular carbon dioxide (CO_2).
- Offers greater independence from rising heating prices.

Solar thermal energy for heating and cooling

The solar collectors of a solar thermal energy system absorb solar radiation and convert it into heat. Solar thermal energy is usually used to heat water for showering and washing or to support room heating systems. Amongst the innovations in the field of solar energy are solar energy systems which produce both heating and cooling from sunlight. Modern cooling systems convert heat from sunlight directly into air cooling. The advantage of solar cooling systems is that much less electricity is consumed than with conventional air-conditioning systems. This is of particular interest in southern countries because here up to 80 % of the electricity needed is fed into the building's air cooling system in the hot summer months. This technology is based on parabolic collectors which are used to bundle the light. The system works on the same principle as a refrigerator. The heat collected in the collector is used as energy to generate cool air. One advantage is that the demand for cool air rises whenever the sun shines and the temperatures are high.

Geothermal energy for heating and cooling

Heat pumps can be used above ground or the ambient air can be used as a source of heat for the heating system. A heat pump extracts heat at a low temperature level from an external heat source such as the ground, groundwater or the ambient air and transfers it to the heating system. In summer, heat pumps can also be operated on the opposite principle to provide cooling.

Combinations of solar thermal energy and heat pumps

An intelligent energy management system can be used to create synergy effects to heat or cool a building all year round and can significantly help to increase the share of heat generation from renewable energy in future. Examples of technology combinations include combining this with near-surface geothermal energy or using the earth to store heat or cold.

Biomass for heating

Heat can also be obtained from wood pellets, wood chips, firewood or biogas. The use of wood pellets has gained in importance over recent years. Wood pellets (pressed wood chips) are ideal for heating and therefore present an alternative to fossil fuels. Depending on the fuel and the intended purpose, there are a variety of stoves which can use wood for heating. There are three different systems of wood pellet heaters in common use and these differ mainly in their efficiency:

- Stand-alone pellet stoves (of between 2 and 10 kW)
- Large pellet-fired central heating systems (heat output up to 70 kW)
- Combi boilers which can be fired with both wood pellets and logs.

Solid biomass is also used to generate electricity in combined heat and power (CHP) plants. Here, the heat given off as a by-product of electricity generation is used, for example, for heating purposes.

Outlook

In view of the increasing requirements placed on the electricity and heating supply of houses, the use of automation and control technology is on the increase. Measuring and control engineering and building services IT are converging into complex information and communications systems. The use of storage capacities (heat and cold) of buildings, the optimisation of the building shell (insulation and protection against heat and/or cold), the incorporation of additional storage systems (heat, cold, electricity, including electrical mobility) and the use of combined processes (combined heat and power) will become increasingly important.