dena
German Energy Agency

renewables
Made in Germany

Energy supply with

renewables – Made in Germany

Information on technologies, suppliers, products and services

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Foreword

Germany has been successful in making renewable energies an important pillar of the energy supply. Over the last 10 years the share of renewable energy in the total electricity consumption has risen from 8 percent to approximately 32 percent in the first half of 2015. The German government's goal of expanding the share of renewable energy to between 40 and 45 percent by 2025 has therefore moved within reach.

The energy transition is, however, not just about more renewable energy. It also means using energy efficiently and cross-linking different sectors, such as electricity, heating or even transport. In short, we need to think of energy transition and climate protection in a holistic way, with renewable energy playing a key role in the future.

German companies are international trailblazers in the renewable energy sector. They are noted for their many years of experience and immense capacity for innovation. They offer a broad range of products and services and set new standards, qualities which are valuable and essential. Yet we should strive for more. We would like to share with you the considerable experience which Germany has acquired in the area of renewable energy.

German companies with international expertise are already represented across the entire value chain. Projects and facilities "Made in Germany" support consumers, businesses, agriculture, municipalities and industries across the globe for a sustainable and reliable energy supply by saving energy and costs and reducing dependency on energy imports.

This positive trend should be continued, while always having energy transition, climate protection and sustainable economic development as clear goals. Germany would therefore like to support foreign markets and stakeholders in tapping into renewable energy sources and in stepping up dialogue. dena contributes to this exchange as an agency for an applied energy transition – also beyond Germany's borders.

I am therefore delighted to be able to provide you with the latest edition of the "Renewables – Made in Germany" catalogue, in which over 30 companies from the renewable energy sector present their services and offers. I hope you enjoy reading this issue!

Yours sincerely,

Andreas Kuhlmann, Chief Executive
Deutsche Energie-Agentur GmbH (dena)
German Energy Agency

Technology overview

- Wind energy
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Your supply of renewable energies

Residential estates, commercial enterprises and private households around the world are increasingly in need of 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, both in private households as well as in commercial enterprises, traffic and the public supply of entire residential estates.

Unlike fossil fuels, renewable energies are mostly based on inexhaustible resources. They encompass an energy mix of wind energy, bioenergy, solar energy, hydropower and geothermal energy. Various technologies are on hand to make use of the world's available natural potentials. In combination with storage and grid technology, renewable energies can be stored or transmitted and distributed over long distances from their place of generation to the centres of consumption, and thus utilised optimally with regard to demand.

"Made in Germany" renewable energy technologies, products and services enjoy an outstanding international reputation. They stand for quality, reliability, a long service life, efficiency and safety. The companies presented in this catalogue can help you plan, build and operate your renewable energy supply. The import of German goods and services can be promoted by way of various programmes organised by the German federal government.

Goals	Benefits of renewable energies
Local availability	■ They make use of domestic resources available to varying degrees everywhere in the world.
Sustainable provision of energy	■ By human standards, they are inexhaustible (solar radiation, wind energy, hydropower, geothermal energy) or regenerate (bioenergy).
Safety	■ They entail relatively little danger to produce, operate and dispose of, or they are recyclable.
Price stability	■ They promote independence from the volatile market for fossil fuels; long-term stable energy costs.
Economic efficiency	■ Their commercial utilisation without promotion is already possible depending on the location. ■ In remote areas, they are often the cheapest way to provide energy.
Environmental protection	■ They conserve natural resources by saving fossil raw materials and by leading to few invasive intrusions in the natural countryside (environmentally compatible land consumption) and release only low levels of human-caused emissions into the surrounding air (acidification and eutrophication).
Climate protection	■ They are largely free of emissions, thus supporting international climate protection goals.
Protection of human health	■ They protect human health thanks to their low level of harmful emissions (noise as well as pollutants in air, soil and water).
Local creation of value	■ They create jobs in sustainable-growth industries. ■ They promote the economic development of rural regions by decentralising production and distribution. ■ They support positive economic development through technical innovations.
Independence from the grid	■ They provide for a permanently reliable supply of energy far from the public electricity grid (in combination with energy storage systems).

Using renewable energies supports a large number of requirements. The above table presents examples of these.

dena Renewable Energy Solutions Mongolia Project – a state-of-the-art, stand-alone power system. HEOS Energy GmbH, a Chemnitz-based company, installed two energy containers at the training centre of the Mongolian University of Life Sciences some 140 kilometres from Ulaanbaatar. A 6 kWp photovoltaic system was mounted on top of the containers and a 15 kW small wind turbine was erected close by. A battery system for back-up power is built into the control container.

Possible applications

Renewable energies can be used to generate electricity and heat, as well as in the mobility sector. While wind and sun produce variable amounts of energy in the electricity sector depending on weather conditions, the availability of bioenergy, hydropower and geothermal power is nearly constant or can be stored and controlled. On the whole, this results in an ongoing energy supply that is reliable and tailored to demand.

Owing to their enormous range, from a few watts up to hundreds of megawatts, renewable energies can also be adapted to any kind of energy service. Closely meshed with modern energy technologies, they can make a considerable contribution to a secure energy supply, even in a modern industrial society.

Not every source of renewable energy can be put to commercial use in every country. Certain regions, for instance, have potentials for using solar power at a very low cost. The best potentials for using solar power are found in the world's sun belt (between 20 and 40 degrees of latitude in the northern and southern hemispheres). The technical potential for wind energy is in turn dependent on the average wind velocity. This is generally much lower over continental land masses than over the oceans. Practically every country, however, has attractive locations for a wide variety of renewable energies.

The choice of a suitable technology or combination of technologies depends on conditions at the site as well as the respective requirements placed on the type and scope of energy provision. These include, among others:

Local conditions	User requirements
Natural potentials (for example, solar radiation, wind speed, biomass availability)	Form(s) of energy: electricity, heating/cooling, mobility
Political promotion schemes (for example, public investment grants)	Peak demand
Infrastructure (for example, grid connection)	Capacity/annual capacity
Funding for initial investment (equity or borrowed capital)	Fluctuation of the demand for energy in the course of the day/year

Examples of criteria for choosing suitable renewable energy technologies.

In the "Technologies" chapter you will find detailed information on the available renewable energy technologies, their possible uses and combinations for private households, commercial businesses or public supply of entire residential estates, as well as the required natural and/or political conditions.

Opinion panel

"Renewable energy is both the present and the future. Is there any better business model than that of the renewable energy sector – efficient, environmentally friendly and social? This gives us the incentive to invest in the development of innovative products, such as in our inverters and storage systems for photovoltaic systems. With projects, partners and associations, we continue to forge ahead with development, paving a new path to the success of renewable energy."

Werner Palm, CEO of KOSTAL Solar Electric GmbH

Partners

Individual consultancy is absolutely necessary to be able to use renewable energies in a way that suits demand and is as commercially profitable as possible. When developing and building tailored plants, goals such as reliability, long life cycle and efficiency should be addressed, although a shapely design can also be a desirable factor. Here it is important to work together with experienced partners.

Concrete support in choosing the technologies best suited to your needs and conditions, as well as planning, implementation and commissioning, are offered by the providers presented in the chapter on "Companies". They specialise in a wide variety of user demands, can provide thorough consultancy and come up with offers tailored specifically to your needs.

The company profiles follow the introductory chapters on the technologies and their fields of application. To make it easy to find what you need, the companies in the catalogue are organized according to their stages of value creation. In addition, next to the contact information, every company profile contains a summary of the main fields of application and technology focal points for which our partners offer practical solutions.

Funding your renewable energy plant

Constructing plants to utilise renewable sources of energy entails initial investments for which various forms of funding are available. The choice of 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, for example, be ensured 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 energy certificates". If no public funding is offered at your site, you can use the money saved on buying energy (private consumption) or the revenues from direct marketing of the regenerative energy produced 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 project financing. To this end, various stakeholders (operating consortium, manufacturer, supplier, etc.) join to form their own company, known as a 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, for instance, 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 food chains, for instance, are important stakeholders in this segment. So-called "citizens' parks" are also widespread in Germany, in which private investors get together to carry out a project.

Yield cos are an innovative new way of financing renewable energy projects, and are often used in this sector to protect investors against regulatory changes. Yield cos are public

Visitors to the German joint stand at leading trade fairs around the world can talk personally to representatives from German companies and other experts.

companies that are formed to own operating assets that result in a predictable cashflow, usually through long-term contracts. The cost of capital is lowered by separating volatile activities, such as construction and Research & Development, from stable, less volatile cash flows of operating assets.

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. Owing to the complicated, expensive preliminary work, only projects whose investment volume is upwards of about 10 million euros are worthwhile.

Export financing
Banks affiliated with companies grant purchasers of goods (orderers) several years of credit within the scope of so-called export financing, where the exporter is paid their purchase price from the buyer's credit immediately after 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 (Hermes cover). This covers around 85 percent of the economic and 95 percent of the political risk. You will find more information on Hermes cover in the section entitled "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 euros (64 percent 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 counted among the world's largest financiers for renewable energies in developing countries.

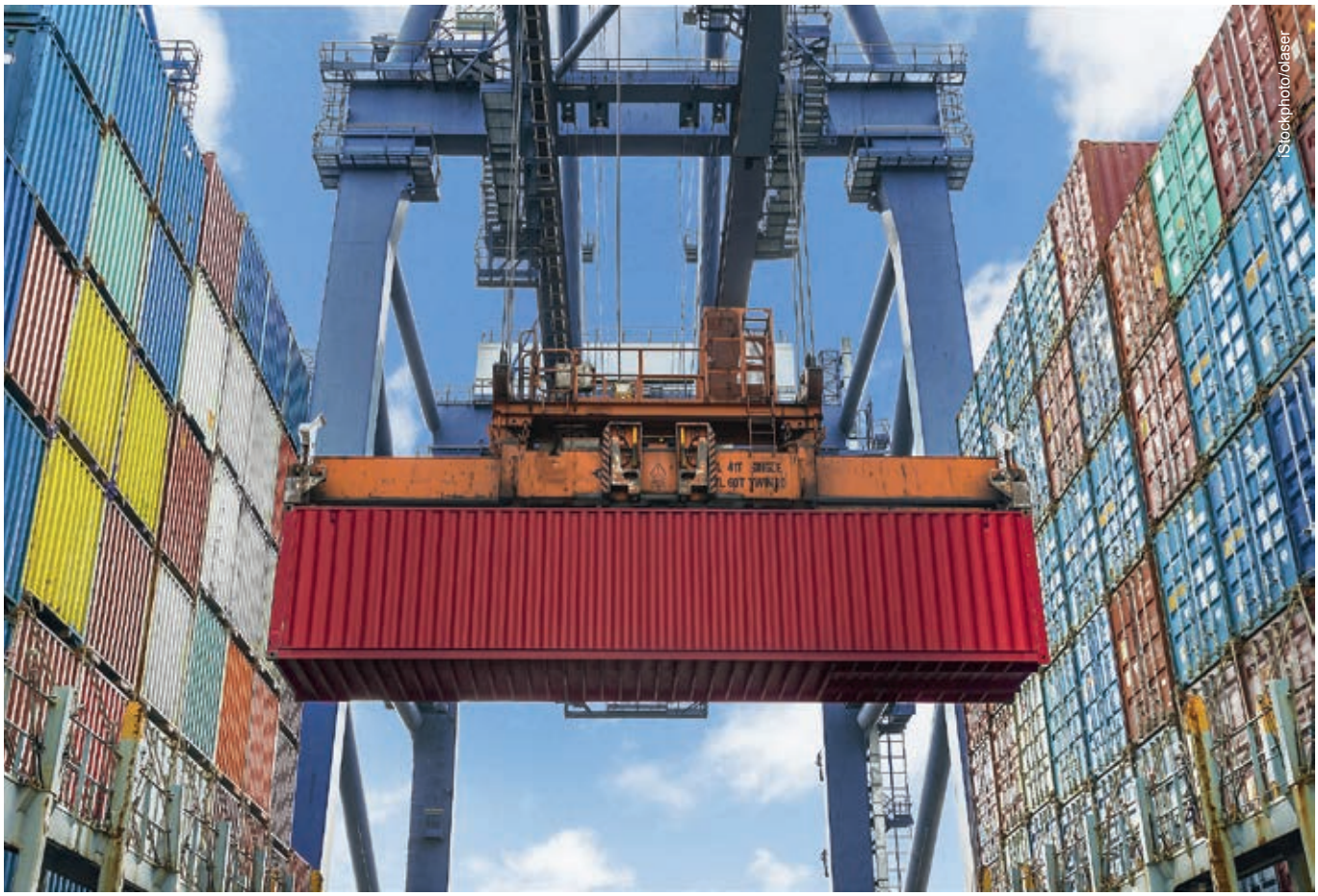
Other major lenders to projects outside the OECD are, for example, the national development agencies, the Global Environment Facility (GEF), the World Bank and the regional development banks. Apart from conventional financial instruments, bilateral and multilateral lenders also provide loans in the form of "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 under certain conditions. Thus the importer can obtain support on terms which are often quite favourable (for example, longer durations).

Flexible mechanisms of the Kyoto Protocol
The flexible mechanisms of the Kyoto Protocol are another way to fund 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 thanks to the technology transfer. In exchange, the German companies obtain emission rights they can use to meet their emission reduction obligations under the EU Emissions Trading System. For this instrument to work as an incentive, however, the trading price for certificates must be at a certain level.

Individual plants / smaller projects

Individual plants or smaller projects are often executed by individual companies. They are funded through a combination of equity and outside capital, or by leasing a plant. The latter puts no burden on an entrepreneur's balance sheet. Income gained from selling the energy produced (for example, electricity or heat) or from the financial savings achieved thanks to the plant's efficiency (lower energy supply costs) can be used to refinance a loan.

Borrowing
Local banks also offer possible loans to private persons and entrepreneurs. The conditions can vary widely. Experience gained by banks in the area of renewable energies is significant with regard to correct risk assessment.



The import of German goods and services can be promoted by way of various programmes organised by the German federal government.

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 the heading "Investment promotion" in the section on "Large-scale projects").

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, since the German government considers exports of renewable energy technologies to be particularly deserving of promotion. This is because this line of business also promotes sustainable global development. For this reason, the German government 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 credit duration for projects

The widespread expansion of renewable energies can be supported by systemic adaptations, such as expanding distribution and transmission networks.

in the area of renewable energies amounts as a rule to eighteen years. Including locally accruing expenses (for example, infrastructure expenses for wind turbines located at remote sites), up to thirty percent of the total contract value can be covered. The share of local costs may not exceed twenty-three percent of the total contract value. Orderers can avoid the risk of being unable to pay the German exporter due to the devaluation of their own currency by choosing the option of paying the German company in their own currency rather than in euros. The German federal government reserves the right to check the stability of the currency requested in each case.

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 a safeguard against political risks for German companies. These measures 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 controlled authorities can also be included in the investment guarantee, such as the construction of infrastructure or a formal guarantee of purchase prices. Guarantees can run for as long as twenty years.

Further information

You can obtain further information at our online portal, in our newsletter or by contacting dena directly.

Online portal
www.renewables-made-in-germany.com

Apart from the information on technical aspects and on companies found in the catalogue, you can also find reference projects of German companies around the world, company news, and an overview of German participation in foreign trade fairs at our online portal, www.renewables-made-in-germany.com. In addition, you can learn valuable facts about networking and business opportunities, such as fact-finding missions to Germany for decision-makers and a bilateral programme of advanced training for executives.

Newsletter

The free English-language newsletter informs subscribers around the world six times a year by e-mail of current developments, interesting projects and applications, the most modern German technologies and services, as well as events in the area of renewable energies.

Subscribe online at: www.renewables-made-in-germany.com/en/service/newsletter

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We would be pleased to help you.

Nationwide expansion of renewable energies: How is Germany dealing with the challenges?

When it comes to the topic of "transitioning from nuclear and fossil fuels to sustainable sources of energy" – especially the region-wide development of renewable energies and their integration into the energy system – businesses, politicians and consumers all over the world are looking to Germany. The intention of the German government's energy policy is to make the country one of the world's most energy-efficient and environmentally sound economies. At the same time, energy prices must be kept competitive, the level of prosperity high and the supply of energy secure. This poses immense challenges for the world's fifth-largest industrial nation. Countries around the world can profit from Germany's experience.

Expansion according to plan: the growth trajectory of renewable energies

Owing to political encouragement early on, renewable energies are now a mainstay of the total commercial energy system in Germany, accounting for 12.4 percent of final energy consumption and 27.8 percent of gross electricity production in 2014. And the German federal government continues to pursue a path of further expansion. In the electricity sector alone, the share of renewable energies is intended to be expanded to 40 – 45 percent by 2025 and 55 – 60 percent by 2035.

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 by prioritising the feed-in of electricity from renewable sources to the grid. By the end of 2014, more than 1.3 million EEG-subsidised installations throughout Germany were feeding in more than 160,000 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 fourteen percent in 2020. The EEWärmeG stipulates that new buildings use renewable energy to provide a certain portion of the buildings' heat, implement certain substitute measures

The goal of the federal government's energy policy is to make Germany one of the most energy-efficient and environmentally compatible economies in the world while keeping energy prices competitive and ensuring a high level of prosperity. The expansion of renewable energies will make a substantial contribution to achieving this goal.

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. Support at the 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). Based on the Biofuel Quota Act, admixtures to fossil fuels have been supported by way of the biofuel quota since 2007.

Today's challenges to energy policy

The enormous expansion of renewable energies, especially photovoltaics and wind power, is today confronting politicians with the challenge of oming up with intelligent solutions to integrate renewable energies – whose production 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 equably distribute the costs of transitioning to renewable sources of energy.

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.

The EEG reform of 2014 is intended to control with greater precision the demanding goals, 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, the fifth-largest industrial nation in the world, remains competitive even for energy-intensive industries. Value added 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 must be taken into consideration, 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. For example, the energy-intensive industries with more than 800,000 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

Energy debate in the Chancellor's Office (1 April 2014).

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 EEG levy.

Long-term perspectives

By transitioning increasingly to renewable energy sources, Germany has struck out upon a path which has gained it international attention. 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 – and do so without incurring any of the risks to humans and the environment posed by nuclear power.

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

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TECHNOLOGIES

Two Siemens SWT-6.0-154 plants, a model actually designed for offshore use, have been built in Wehlens, near Wilhelmshaven. The location offers wind conditions that are similar to the open sea. The two state-of-the-art large-scale plants are equipped with direct drive generators and rotors that measure 154 metres in diameter. The system produces enough energy to supply more than 14,000 households with climate-friendly power.

Wind energy

The use of wind energy to generate electricity is among the most widely developed and most used renewable energy technologies, and is on the increase in a growing number of countries. Because of the economies of scale resulting from falling system costs in production and project development and the high natural potential, wind energy is becoming economically viable in more and more countries.

A distinction is made in the wind energy sector between onshore and offshore and small wind turbines. Onshore wind energy will become increasingly important in terms of system stability in the medium term. But even offshore wind energy will be able to contribute to basic supply given the constant wind speeds and high-capacity utilisation at sea.

German companies are among the leading providers in the wind sector. The range of services offered by Germany covers research, production of all types of components and complete systems, project development, and the maintenance and operational management of wind farms. “Made in Germany” wind energy products and services enjoy an excellent reputation worldwide because of their reliability and their high level of technological development.

Technologies and applications

Wind energy accounts for around 2.5 percent of the world’s energy demand. The world’s entire installed capacity stood at approximately 369.6 GW at the end of 2014. The largest markets are in China (114.6 GW), USA (65.9 GW) and Germany (39.1 GW). In Germany, wind energy accounted for 9.1 percent of the total electricity generation market in 2014.

The following details the three technologies for utilising wind energy:

Onshore wind turbines

To achieve high yields, turbines were developed with high towers and blades with a large sweep. Sites on the top of mountains or elevated positions are particularly suitable for generating wind energy.

Onshore wind energy has seen rapid growth over the past few years. This trend is likely to continue in international markets over the coming years, in particular thanks to the increasing competitiveness of wind energy plants. Further advances in technology have resulted in an ongoing rise in plant efficiency over the past few years. The performance and reliability of the plants have increased significantly, for example.

Two technologies have been developed further for efficiently converting wind energy to electricity:

- Systems with gears
- Gearless systems.

Systems with gears represent the classic drive concept: with variable rotation speed, gears and fast-running generator. Gearless systems are also used as an alternative. In the gearless system, the rotor can be found directly on the rotor shaft.

The advantage of onshore plants compared with offshore wind energy (see below) lies primarily in the currently lower investment costs. In onshore plants, local electricity generation is also carried out closer to the centres of consumption; a situation that requires less investment in terms of grid expansion and operation and minimises transmission losses.

Offshore wind turbines

Offshore wind farms may partly replace conventional power stations in the long term because of greater capacity utilisation as a result of the higher wind speeds at sea. The expected energy yields here exceed any of those on land by up to 100 percent.

Offshore plants have to be sited, cabled, installed, operated and maintained in deep water. The installation of an offshore wind farm is far more technically demanding than that of an onshore wind farm because of the foundations and a complicated grid connection. The construction stages are much more dependent upon the weather. In regular operation exposure to strong wind and waves, together

with the effects of salty air, pose particular challenges for the materials used. As a result, the system costs are significantly higher than those for onshore plants.

Small wind turbines

There is, as yet, no precise definition for a small wind turbine. The most common definitions are outlined briefly here:

- According to IEC standard 61400-2:2006, small wind turbines have a maximum rotor area of 200 m², which equates to a nominal power of a maximum of 50 kW for an electrical voltage of below 1000 V AC or 1500 V 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) and
  - Medium wind turbines (over 30 kW).

The tower is not normally higher than 20 m, and the average capacity of a small wind turbine is between 5 and 10 kW.

Small wind turbines combined with other renewable energy technologies, such as photovoltaics, are especially suited to basic electricity supply in off-grid regions.

Opinion panel

"We have followed wind energy with curiosity and enthusiasm for 25 years. We invest in research and development and take the time to develop and formulate applicable standards, such as for wind reports. In this way, we guarantee quality, combined with state-of-the-art methods and technology, such as our LiDAR wind measurement campaigns. With good initial analysis during the wind measurements, we can reduce measurement errors to a minimum and save time and money during the wind farm planning. That is our concept."

Carmen Bartelmai, Head of Department of Wind Assessment CUBE Engineering GmbH

Offshore wind farm, Thornton Bank.

Competence of the German industry

German manufacturers have considerable expertise in all the given types of application. This includes, for example, the manufacture and setting up of turnkey wind turbines and the production of individual components and modules, such as generators, gears and rotor blades and their individual parts.

Alongside specialised manufacturers of wind energy turbines, many medium-sized companies of classic engineering have developed new business segments in Germany's wind industry. Steel tube towers, concrete footings or castings are required for the construction of wind energy systems just as much as site surveys, certifications and type-approval tests. The entire value creation chain for wind energy is shown from planning and project development right through to the construction and operation of turbines in Germany.

German companies have considerable experience in the setting-up process and in the areas of service/maintenance and work safety in the offshore industry. In contrast with most other countries with significant offshore capacities, what counts here, in particular, is that the German offshore wind farms are erected some distance off the coast and in water up to 45 meters deep.

German manufacturers of small wind turbines have achieved greater professionalism in production over the past few years. Numerous types of turbines from German manufacturers have been positioned in the market, especially in the 1 – 20 kW range.

Commercial use

Electricity generation costs vary depending on the type of wind energy technology used:

- **Onshore:** Wind energy already has the lowest electricity generation costs among what are known as new renewable energy technologies today (with the exception of large-scale hydro power) in the onshore sector, depending on the location. Electricity generation costs are therefore currently in the 5.8 to 13.7 €ct/kWh range and at 2,200 peak-load hours p.a. within the range of conventional hard-coal power plants.

- **Offshore:** In the offshore wind application field the prime costs are still currently significantly higher in the 8.0 to 14.7 €ct/kWh range. Significant potential for cost savings is expected here over the coming years thanks to increasing economies of scale.

- **Small wind turbines:** For small wind turbines, electricity generation lies between 15 and 20 €ct/kWh based on the empirical values of turbine owners. Significant deviations are possible depending on the location. At high electricity prices, the benefits can be achieved through producing your own electricity and therefore reducing the procurement costs for electricity.

Further cost reductions are anticipated over the coming years in all the application fields mentioned.

Outlook

The wind energy business is on its way to becoming a global player. With this development and the increasing number of wind energy plants, service and spare parts management are becoming an ever-growing market.

Even greater utilisation of the plants can be achieved in the area of production through technological development of systems in the future. In addition, further falls in production costs and improved local integration of energy systems are expected.

Opinion panel

"Wind energy is more than a bridging technology; it is a cost-effective, clean and controllable pillar of modern energy matrices that is based on local resources. Combined with the modern grid, the potential can be harnessed significantly and rapidly. It can therefore defuse global disputes about access and ownership of fossil resources.

Our reports are used for development that is optimised and with minimum risk, taking into account financial feasibility and yield optimisation."

Andreas Jansen, CEO, ProfEC Ventus GmbH

There has been a noticeable trend towards ever-larger rotor blades for several decades to increase the plants' yield even at lower wind speeds.

Repowering

With repowering, so-called first generation wind energy plants are replaced by modern turbines. In this way, capacities can be extended even in classic wind markets, such as Germany, without sacrificing any further space.

Even though demand for repowering is currently still low, it holds considerable potential for the future. At the same time, a market has developed for second-hand turbines that are used as individual, stand-alone solutions.

International development

The Global Wind Energy Council (GWEC) estimates that by 2030 around 17 percent of the world's electricity supply could be met by wind energy. Half of the world's total installations are likely to be in aspiring markets, such as Brazil, China, India, Mexico, Morocco, South Africa and Turkey. It is also apparent that national and multilateral development banks are increasingly steering investment in the wind energy sector towards these emerging economies.

Repowering project in Schleswig-Holstein, Germany.

Continued international expansion of wind energy will depend upon the prevailing conditions in energy policy and building legislation over the coming years. The key conditions include the designation of appropriate areas for plants both onshore and at sea, the removal of restrictive height limits, the extension of grid infrastructure and the promotion of energy storage technologies to make high-yield sites even more efficient.

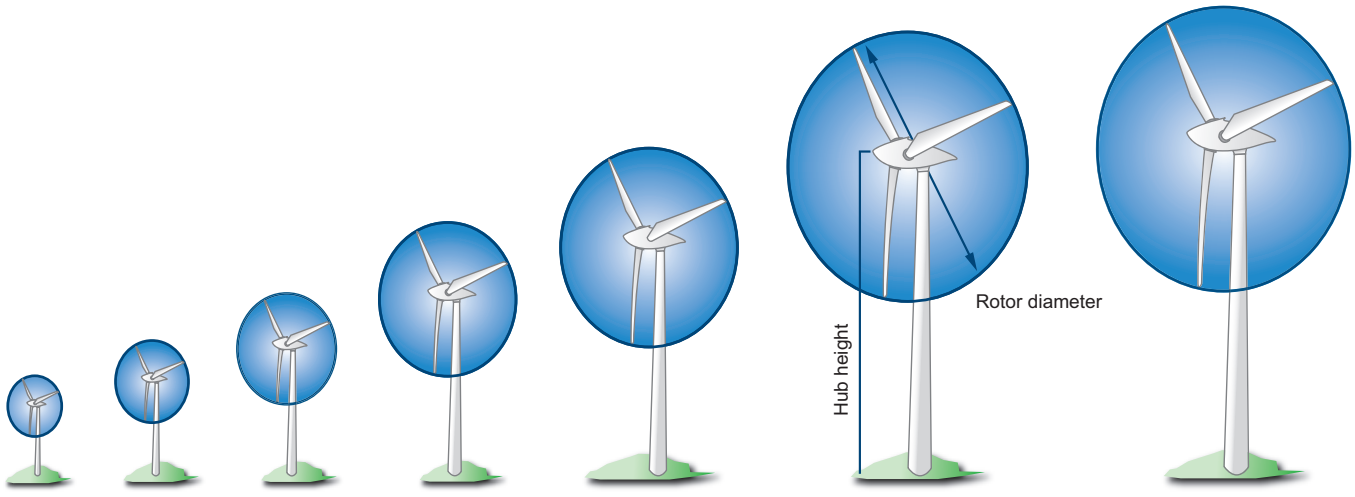
Research and development in wind energy aims, in particular, to reduce its negative environmental impact, such as noise and light emissions.

Onshore

In the case of onshore wind energy, it is also important to improve public acceptance of wind farms. This can be helped by participation models such as citizens' wind farms (see information panel "Wind energy as an addition to hydropower"). This model is already being used in several countries, for example, in Germany and Denmark.

Offshore

Forecasts for the offshore sector are positive and foresee strong growth for 2015 and 2016, particularly in the EU. The reason for this is the planned EU-wide expansion of



	1985	1990	1995	2000	2005	2008	2011	2012	2014
Nominal power (kW)	80	250	600	1,500	3,000	6,000	7,500	7,500	8,000
Rotor diameter (m)	20	30	46	70	90	126	127	154	164
Hub height (m)	40	50	78	100	105	135	149	149	149

Growth of wind energy turbines since 1985. Source: German Wind Energy Association (BWE), dena.

offshore projects that are likely to achieve a newly installed capacity of 2.9 GW in 2015 and 2016. 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. The UK and Belgium show the greatest potential in the offshore area alongside Germany, but the market has also begun to move into the Netherlands and Denmark.

Small wind turbines

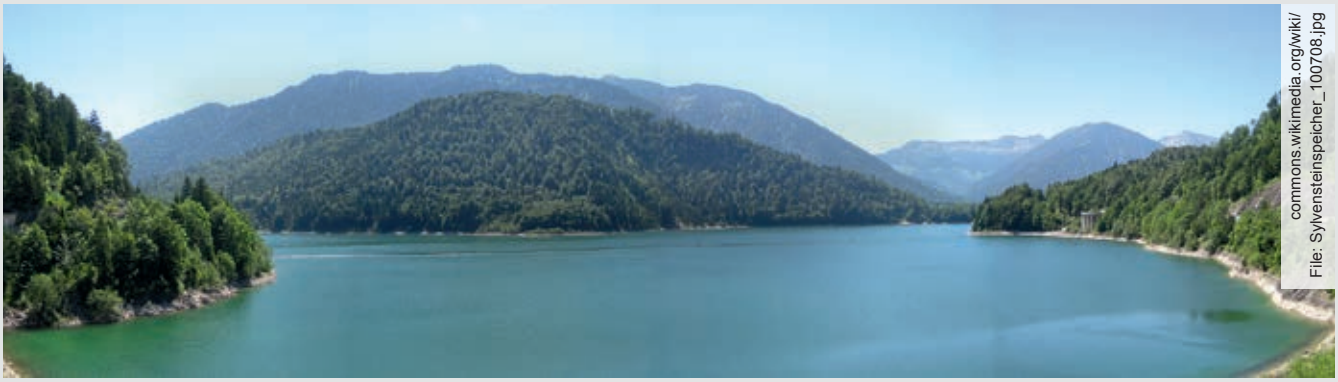
Small wind turbines are becoming increasingly popular for the independent and self-sufficient generation of electricity. Considerable potential is seen here, particularly, in developing and emerging economies with a low electrification rate. For example, small wind turbines can supply electricity as stand-alone systems or be easily integrated into existing island networks or hybrid systems. According to a forecast by the World Wind Energy Association (WWEA), a cumulative installed capacity of approximately 5 GW could be achieved by 2020.

Small wind turbine.

Wind energy as an addition to hydropower

In numerous countries, a significant proportion of electricity is produced in hydroelectric stations. The security of supply is put at risk time and again by dry periods, for example. These shortfalls are still largely countered by conventional backup systems, based on the use of fossil fuels, e.g. generators, or by importing electricity.

Thanks to high natural potential in many regions, wind energy plants offer the possibility of complementing electricity production from hydroelectric power stations or can act as a buffer for shortfalls in the same. For example, wind energy plants can be used for regenerative electricity production in dry periods. Excess wind electricity can be used for the interim storage of water in pumped-storage plants.



Reservoir.

This pumped storage power plant in Häusern, Germany, generates around 120 million kWh of electricity per annum.

Hydropower

Hydropower has been used for generating electricity ever since the end of the nineteenth century, and is now used in 159 countries around the world. Today, it is the most widely used renewable energy source for generating electricity worldwide. With a total installed capacity of 1,055 GW worldwide in 2014, hydropower generation for the year is estimated at 3,900 TWh. Given the rising demand, the proportion of hydropower in the world's electricity generation is unlikely to increase any further in 2020, though it will total approximately 4,500 TWh.

Base load capability, storage capability, grid stabilisation and decentralisation are hydropower's strengths, and it still holds great potential in the context of the international shift from conventional energy supply to the increased use of renewables.

Hydropower will play an even greater role as a base load in an energy mix where more electricity will be generated from renewable energy sources. It can contribute to balancing the fluctuations in generation which arise through the use of weather-dependent solar and wind energy, and therefore enable a stable electricity supply from renewable energy sources. Significant investment therefore continues to be made in pump storage technologies. Pumps with a variable speed, in particular, are required to balance out the increasing number of short-term fluctuations caused by wind and solar electricity.

Technologies and applications

Types of power plant

Run-of-the-river power plants/river power plants
Run-of-the-river/river power plants are the most common type worldwide. They use the flow energy of a river, and are normally used to cover the base load. Their capacity is determined mostly by the gradient and the water level. Some run-of-the-river power plants can also dam water at times of low energy demand in order to use it as a reserve when demand is higher.

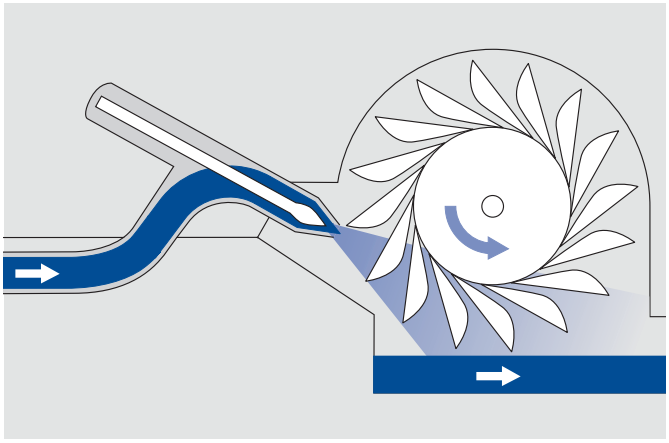
A diversion hydropower plant is a special type of run-of-the-river plant. The water is dammed in a weir and redirected onto the turbines by means of a separate feeder channel. In the case of a standard run-of-the-river power plant, there is only a slight difference in the height between the upper and lower water levels, but a diversion hydropower plant exploits the greater height difference created by the diversion.

Storage power plants
Storage power plants store the water in a natural or artificial lake and feed it via pipelines into a lower-lying power plant. Such plants can operate independently of natural water inflow, and are particularly suited to balancing fluctuations in regional and national electricity generation and consumption. They are used both to cover the electrical base load and for peak load operation.

Pumped storage power plants
A pumped storage power plant uses two reservoirs to store water, with the greatest possible height difference between the upper and lower reservoirs. 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. There, it is once again available for electricity generation at peak load times. Pelton turbines are used to drive the generator.

St. Anton, Austria: The Kartell storage power plant with a capacity of 4,239 kW makes use of water flowing from a drop height of 528 m at a rate of 0.90 m³/sec. The plant is run by two horizontal-axis, twin-nozzle Pelton turbines.

Francis turbine runner on a rotary welding positioner, output 770 MW.



Pelton turbine: The water flows at high speed from one or more nozzles directly onto the blades of the turbine wheel. Source: www.solarpraxis.de / M.Römer.

Types of power plants for exploiting marine energy

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

Turbines

The type of turbine used depends on the rate of flow and head height (pressure) of the water.

Francis turbine

The 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

Hydrodynamic screws work on the principle of the Archimedes' screw. They are primarily used for small drop heights and low capacities.

Kaplan and bulb turbines

Kaplan and bulb turbines are common types of turbine for 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.

Pelton turbine

The Pelton turbine, a free-stream turbine, is used for high drop heights from 100 m to 1,000 m and/or low water volumes.

Cross flow turbines

Cross flow turbines are used for low drop heights and low water volumes. They generally have a small capacity.

Power categories

The power of a hydropower plant is generally dependent upon the water flow rate and the drop height of the system, and on the efficiency of the water turbine, gear mechanism, generator and transformer. A distinction is made between large hydropower plants and small hydropower plants depending on the power category.

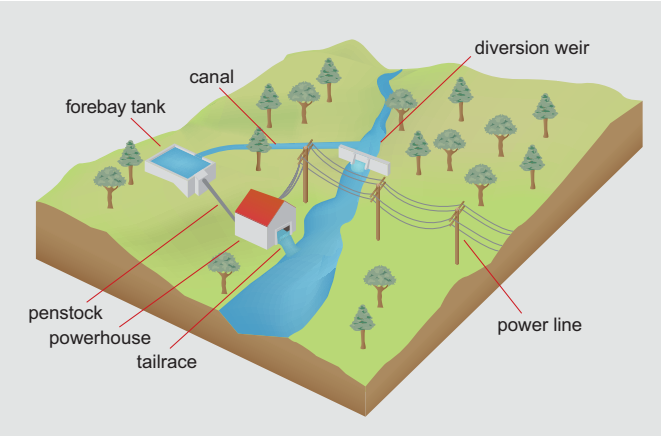
Small hydropower (SHP)

Small hydropower (SHP) is defined as the use of hydraulic energy by local, small hydropower plants that do not generally involve any significant environmental impact. Most of these 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 kW – 100 kW
- Mini: 100 kW – 1,000 kW
- Small: 1,000 kW – 10,000 kW.

Plants with a capacity of up to 1 MW are therefore considered to be small hydropower plants in Germany. In China, small hydropower can refer to capacities of up to 25 MW, in India, up to 15 MW, and in Sweden to plants of up to 1.5 MW. In Europe, a total capacity of up to 10 MW, following the European Small Hydropower Association (ESHA), has become the generally recognised upper limit for small hydropower.



Construction of a typical small hydropower plant. Energy is generated by the fall of the water from the intake basin to the power house, where the generator turbine is located. Many other system layouts are possible. Source: Sunbeam GmbH.

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. Ecological connectivity for fish and other water organisms is guaranteed by means of costly fish ladders.

Small hydropower plants are considered to have less of an impact upon the environment than large power plants. The use, modernisation and reactivation of existing facilities is also carried out alongside building new facilities.

Competence of the German industry

German companies have been developing, installing and operating hydropower plants for more than 100 years. Roughly half of all hydropower plants worldwide are based on German technology and expertise – from project development, to the delivery of components and complete systems right through to business management and maintenance. This longstanding experience is the basis of the excellent quality of German products and services, regardless of whether the capacity is a few kW or several MW.

German firms enable the high-performance and efficient operation of hydropower plants worldwide, with favourable life-cycle costs, in particular thanks to low maintenance requirements. German companies are involved in implementing many international hydropower projects, such as large hydropower projects in eastern Turkey.

A significant proportion of further development in hydropower technology is being provided by German companies. Their current projects include work on innovative turbine concepts and technical solutions for hydropower plants with drop heights of less than 10 m. German companies are also playing an important role in the research and development of turbines and power plants that exploit marine energy, for example, as part of the construction of the first wave power plant with a permanent connection to the national grid in Scotland, and the first commercial wave power plant in Spain, in operation since 2011.

German project development companies have substantial experience in the development and construction of site-adapted fish ladders, which take into account the latest research and technology.

Opinion panel

“Small hydropower plants are extremely well-suited to low-cost power generation in remote areas and therefore contribute significantly to its commercial development. The simplicity of the original OSSBERGER® cross-flow turbines means that absolutely anybody can use the installation and perform the annual maintenance. Thanks to modern remote systems, on-site monitoring is not necessary.”

Dipl. Ing. (FH) Holger Franke, Sales Manager, Ossberger GmbH + Co

“The simple and robust mechanics of the DIVE turbine allow the construction and operation of highly efficient, low-maintenance, small hydropower stations. The straightforward and clear interfaces of the DIVE turbine to the adjoining power plant components are of great help in this context. Generator and electrical equipment is fully assembled and extensively tested in Germany before it is delivered.”

Dipl.-Wi.-Ing. Christian Winkler, Marketing and Product Manager, DIVE Turbinen GmbH & Co. KG

Opinion panel

"Government policies need to promote renewable energy sources in a way that maximises hydropower's contribution to the reliability of the supply."

Dr. Roland Münch, Chairman of the Board, Voith Hydro

Commercial use

Hydropower plants achieve a high efficiency factor. They are able to convert up to 90 percent of usable hydropower into electricity. Hydropower is very competitive compared with other renewables and conventional power plant technologies thanks to low electricity generation costs. The generation costs of large hydropower projects can be as low as 0.02 USD/kWh, while average generation costs are quoted as 0.05 USD/kWh. As the technology is mature, there is limited potential for further cost reductions.

The high reliability in operation and supply and the sustainable reduction in fuel costs offer a cost-effective opportunity to secure basic electricity supplies. As hydropower plants, depending on their type, are able to store and quickly provide electricity based on demand, they contribute significantly to grid stability. Hydropower plants reduce our dependency on and the risks of importing energy and are a basis for economic development in regions without a comprehensive energy supply.

Site-dependent aspects

Hydropower plants are adapted to the natural conditions of their operational site to achieve optimal yields. The financial viability of a plant is calculated based on investment costs, operating costs and income. Operating costs include taxes, possible lease, insurance and maintenance costs. The use of automatic monitoring and maintenance reduces operating costs while increasing the power plant's productivity.

To ensure that the high investment costs are amortised, the site of power plants must be investigated with precision with regard to the conditions offered by the waters on which the power plant is to be erected. The use of hydropower plants is profitable above all in locations with a reliable supply of usable water and good possibilities for connecting to the existing electricity grid. The power plants often have to be switched off during flooding or low water levels. To achieve optimum output, the power plant has to be adapted exactly to the body of water.

Old sites of small hydropower plants are frequently reused to expand hydropower. In most cases, both the control technology and the turbine have to be replaced, significantly increasing the economic viability of the existing power plant.

In regions still lacking an extensive electricity grid, a hydroelectric power plant as the centre of a stand-alone system can support the economic upswing of the entire region.

Incentive schemes

To ensure the continued increase in the use of hydropower plants it is, however, crucial that they receive support from environmental policy. Hydropower plants are subsidised differently in different countries and according to plant size. In Germany, for example, subsidies for electricity from hydropower are regulated by the feed-in tariffs in the German Renewable Energy Sources Act (EEG).

Elsewhere, expansion of hydropower is promoted by means of government invitations to tender: For example, the Peruvian plan for the electrification of rural areas (PNER) provides in particular for the expansion of small hydropower plants over the period from 2011 to 2021.

As well as direct subsidies by means of feed-in tariffs, regional trading in emission rights creates additional incentives for investment in renewable technologies with low CO_2 emissions.

Outlook

Hydropower will continue to play an important role in the worldwide electricity supply in the future. There is still significant potential for expanding hydropower plant capacities in many countries.

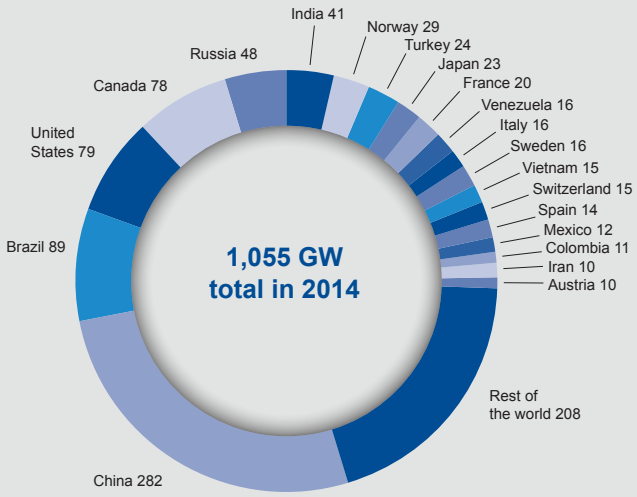
In saturated regions, such as Europe and North America, the focus is on modernising, reactivating or expanding existing plants. Optimising and modernising existing systems also brings larger projects into harmony with the environment, taking account of ecological criteria.

The trend in global development is towards international projects for generating electricity from hydropower. Countries pool their energy resources, 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 on the Madeira river in Brazil.

An exchange programme is also planned between Germany and Norway, including a submarine cable, which will conduct electricity between the two countries. Norway covers around 98 percent of its domestic electricity needs with hydropower, but is also able to exploit its abundance of water to balance out fluctuations in supply from wind and solar power in other countries.

Small-scale hydropower is also being used increasingly for the electrification of remote regions, for example, by means of integration with hybrid systems in conjunction with other renewable energy technologies.

Research into and improvements in the technologies being used are also accelerating an upswing in the progressive development of hydropower capacities. Further regular improvements in the plant design, in the selection of materials or the construction of dams and fish ladders are also making a contribution.



Global total of pure installed hydropower capacity (GW) by country in 2014. Figures do not include pumped storage. Source: 2015 Key Trends in Hydropower.

There is greater research into technologies and concepts for the use of tidal energies (see also the information panel "Use of tidal and marine energy"). According to estimates by the IHA, there is currently an installed capacity of approximately 516 MW in tidal and marine hydropower worldwide. The project pipeline currently accounts for at least 3 GW worldwide.

Use of tidal and marine energy

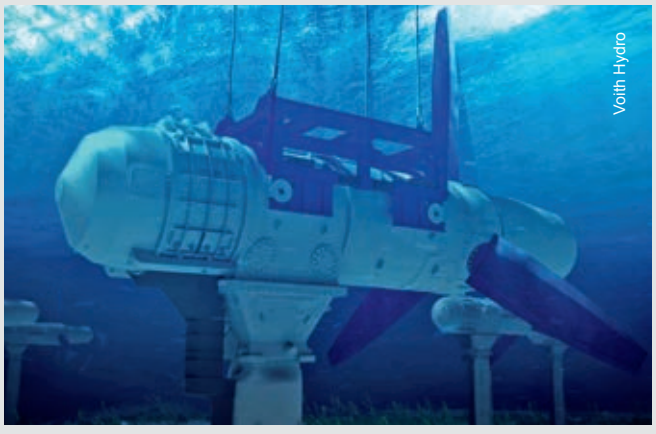
Generating electricity from the natural flow of the oceans is still in its infancy, but may in the future make a substantial contribution to worldwide energy supply.

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 wich 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.

While tidal range power plants are already largely technologically mature, other technologies, such as wave power plants, have yet to achieve the stage of market maturity.

Among the challenges are cost reductions, integration into the electricity grid, tough mechanical demands, corrosion and plant maintenance.



Artist's impression of Voith HyTide 1000-13 1 MW turbine during installation.

Herrenknecht Vertical Terra Invader 350 system in Kirchstockach.

Geothermal energy

Geothermal energy (terrestrial heat) is the heat energy stored beneath the surface of the earth. The heat stored in the earth is available around the clock, does not depend on weather or seasons and is thus suitable for meeting base load requirements. The technologies so far developed offer flexible methods of using this energy for heating, cooling and generating electricity:

- **Near-surface geothermal energy:** Provides heating, cooling or hot water, for example, in multi-family homes.
- **Deep geothermal energy:** Electricity generation in power plants and/or use of heat in heating plants in conjunction with district heating systems.

The potential of geothermal energy can be used practically everywhere. In countries such as Germany, Italy, Indonesia, the Philippines, Mexico, the USA and Iceland, the use of geothermal energy for heating and electricity generation has been part of the energy concept for many years. In 2012, 223 TWh of renewable energy from geothermal sources was extracted worldwide, 2/3 of which was for heating and 1/3 for electricity generation.

The German geothermal energy industry encompasses the entire range of geothermal technologies: from deep geothermal energy, both hydrothermal and petrothermal, for heating, cooling and electricity generation to near-surface geothermal energy which makes use of the heat in the topmost layers of the earth or in the groundwater.

Technologies and applications

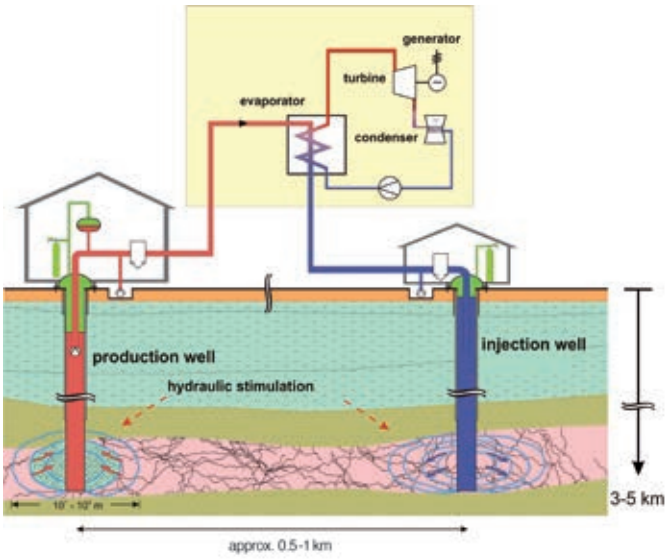
The deeper one drills down into the earth, the warmer it gets. In Germany, the temperature rises an average of three degrees (Kelvin) per 100 metres. The temperature increase per drilled section of a borehole is referred to as the geothermal gradient and measured in mK per metre. This gradient is caused by the heat flow from the depths to the earth's surface. The temperature of the first metres below the earth's surface is influenced additionally by solar radiation and precipitation.

Depending on the drilling depth, a distinction is made between deep geothermal energy (>400 m) and near-surface geothermal energy (<400 m).

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 supplying heat to buildings. One advantage over other renewable energy sources is that deep geothermal energy is not subject to seasonal or diurnal variations, but is constantly available. Geothermal power plants can provide renewable electricity and generating capacities around the clock and independent of seasons, weather or climatic conditions.

Deep geothermal energy assumes the exploitability of heat reservoirs at high temperatures. It is especially popular in regions with high enthalpy deposits. These include countries with volcanoes, such as Iceland, Indonesia, New Zealand or East Africa. Here, temperatures of 100 °C can be found at a depth of only a few metres. Even in low enthalpy regions, geothermal energy can be used through deep boreholes. Depending on the availability of deep water, the water permeability and the system concept, a distinction is made



Principle of petrothermal geothermal energy according to the Organic Rankine Cycle (ORC) method. Source: GFZ German Research Centre for Geosciences.

between hydrothermal and petrothermal geothermal energy, as well as deep borehole heat exchangers:

Hydrothermal geothermal energy
Hydrothermal geothermal energy uses hot water bearing strata at a great depth directly to generate energy. Depending on the flow rate and temperature of the thermal water, hydrothermal geothermal energy can be used for generating heat and/or electricity; for the latter, the water temperature must be above 100 °C. The steam drives a steam turbine and can also be used for other heat consumers such as households or industry. The cooled thermal water is then returned underground through a second borehole, known as the reinjection borehole. The water-bearing bed needs to have the widest possible vertical and lateral spread to ensure long-term use.

Petrothermal geothermal energy
Petrothermal geothermal energy makes use of deep-lying heat reservoirs, which have no water flow, or only a negligible water flow. Reservoirs can be hot, dry layers of rock at a depth of three to six km and with correspondingly high temperatures of more than 150 °C. They are developed by drilling two or more holes. Hydraulic and chemical stimulation processes (enhanced geothermal systems, EGS) create cracks and fissures in the rock. Using an injection borehole, water is pressed into the rock at high pressure where it is heated before rising through the production well. The hot water is used to heat water or agents with a low boiling point to generate steam for a turbine. Heat can also be fed into district heating grids via a heat exchanger.

Deep borehole heat exchangers
Deep borehole heat exchangers refer to a closed system for geothermal energy production comprising a single borehole at depths of more than 400 m down to several thousand metres. The heat thus produced is used directly for heating: From greenhouse heating at low temperatures up to process heat for industrial and commercial applications at high temperatures. Double pipe exchangers are inserted into the borehole. Water circulates through these exchangers in a closed circuit. The heat from the water heated at a depth is then extracted at the surface and delivered to a heat pump circuit.

Near-surface geothermal energy

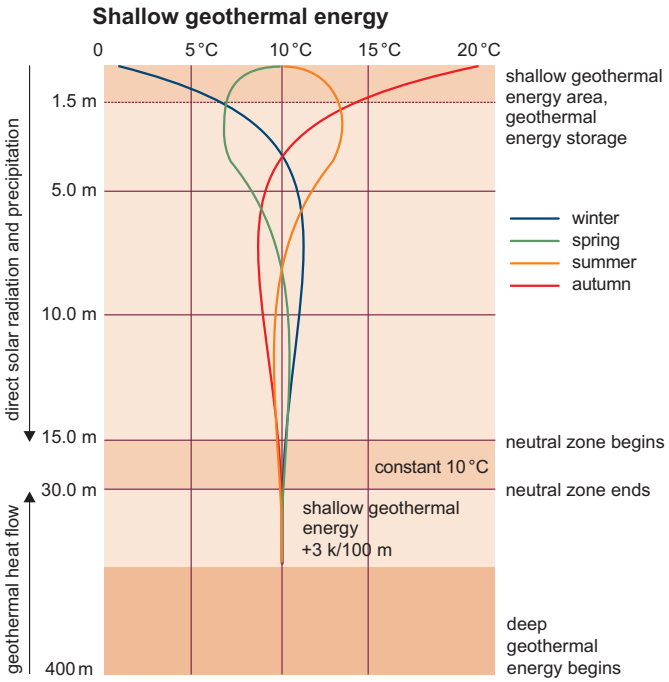
Near-surface geothermal energy makes use of boreholes going down to about 400 m and temperatures of up to 25 °C for heating and cooling buildings, technical plants or infrastructural facilities, as well as for water heating. It can be used in many regions of the world and is particularly suitable for single- or multi-family houses, blocks of flats, public buildings, central administration offices, hospitals, schools and business enterprises, as well as for heating road surfaces for ice prevention and improving road safety.

The heat is drawn from below the ground but near the surface (the upper layers of earth and groundwater). The energy is drawn from insulated heat and the flow of heat from the earth's interior to the earth's surface. Up to a depth of about 20 m, or a maximum of 40 m depending on the geological conditions, the temperature in the upper layers of earth is subject to seasonal fluctuations. Below this depth, the temperature is independent of seasonal temperature changes in the outside air. The annual average temperature differs depending on the location. In Germany, the temperatures at a depth of 10 – 20 m are thus 8 – 12 °C. For each additional 100 m of depth, the temperature increases on average by about 3 °C. At a depth of 400 m, 20 – 25 °C can be achieved. The heat that can be extracted from the ground also depends on the nature of the soil and rock.

Thermal development of the soil
Borehole heat exchangers, geothermal heat collectors or energy piles are commonly used to thermally develop the soil:

Borehole heat exchangers
Borehole heat exchangers are used at depths of 50 – 250 m. Their use is widespread in Central and Northern Europe. They have a low space requirement and make use of a constant temperature level. The exchangers are typically implemented as vertical boreholes in which plastic (HDPE) tubing is installed. Within the tubes, a heat transfer fluid circulates that absorbs heat from the surrounding ground and feeds it to the heat pump. Using this technology, plants of different sizes – from small residential units to complete residential and office complexes – can be supplied with heat or cold.

Geothermal heat collectors
At a depth of 80 – 160 cm, geothermal heat collectors are laid horizontally and their temperature is strongly influenced by prevailing surface weather conditions. An area of about 200 – 250 m² is required for a single-family house.



Natural near-surface temperature distribution in the depths.
Source: www.solarpraxis.de.

The heat transfer medium circulating through the piping loop transports the energy extracted from the ground to the heat pump. Investing in geothermal heat collectors is less expensive than investing in heat exchangers, but less efficient because they operate at less depth.

Energy piles

Energy piles are deep-reaching concrete piles, slurry walls or other structurally necessary concrete components built underground, which are fitted out with plastic pipes. Water is used as the main medium for exploiting the geothermal heat. The cold water is heated by geothermal energy in the concrete piles. An intermediate heat pump uses the warm water to heat the building.

In summer, borehole heat exchangers, geothermal heat collectors and energy piles can be used for moderate cooling.

Groundwater

Groundwater can also be used under certain circumstances as a supply of heat. In Germany, the groundwater temperature is 7 to 14 °C, depending on region, depth and season. At a depth of 20 to 30 m, it is constant at roughly 10 °C. Thus groundwater still supplies enough energy to heat a house, even in extreme winter weather.

Two wells are needed. In the production well, groundwater is conveyed to the surface, where it surrenders a portion of its heat to a heat exchanger. Then the cooled groundwater goes through an inverted well back into the ground to be reheated. Alternative systems work with a single well. Here the groundwater is fed back into a higher layer than it was drawn from.

Using near-surface geothermal energy and the ambient air by means of heat pumps

Heat pumps in combination with energy piles, geothermal heat collectors, borehole heat exchangers or other ground-contact concrete structures enable the use of near-surface geothermal energy. A heat pump relies on electricity – rarely gas – as its driving energy. The efficiency of heat pump systems is a result of the relationship of usable ground temperature and the required flow temperature of the heating system. To help make operations as efficient as possible, an energy assessment should therefore be made before use. An optimally configured heat pump can improve the indoor environment and reduce energy costs for heating and air conditioning in buildings. Geothermal heat pumps increase the temperature prevailing in the ground to the temperatures required in the building. Annual costs can, as a rule, be lowered by approx. 50 percent compared to oil and gas heating systems.

How a heat pump works

Depending on the type of driving energy used, a distinction is made between compression and sorption heat pumps:

Compression heat pumps are the most common type of heat pump. They use the heat generated by the evaporation of a liquid. A refrigerant circulates in a compression heat pump; driven by a compressor, the refrigerant alternately adopts liquid and gaseous states. The basic principle is similar to a refrigerator: heat is extracted from the ground in order to evaporate a refrigerant. This vapour is heated strongly in a compressor and transfers its heat energy to the heating system, cooling and liquefying again in the process.

The sorption heat pump uses thermal drive energy. It can be powered by gas, oil, waste heat and solar heat and is characterised by a high level of efficiency in terms of primary energy use. A distinction is made between two physical/chemical processes, those of absorption and adsorption. Absorption involves a liquid or gas being taken up by another liquid, whereas in adsorption the liquid is retained on the surface of a solid, as a function of pressure and temperature.

Using various sources of energy by means of heat pumps

Heat pumps can use various sources of energy to provide heating or cooling:

- Geothermal heat: brine-to-water heat pumps
- Heat stored in the groundwater: water-to-water heat pumps
- Heat stored in the ambient air: air-to-water heat pumps.

Geothermal heat can be developed using a brine-to-water heat pump. Geothermal heat has nearly the same temperature all year round. A geothermal heat collector at a depth of 1.5 m, laid like a heating coil, draws heat from the earth. The alternative to a collector is to produce heat with a space-saving borehole heat exchanger, which extracts geothermal heat with special heat exchangers which go up to 100 m down into the ground, where the temperature is approx. 10 °C all year round.

The heat stored in the groundwater is always available and does not depend on the season or the outside temperature. A water-to-water heat pump draws the required heat from the groundwater and transfers it to the heating system.

Air-heat pumps use the ambient air as a heat source. However, the ambient air is at its coldest in winter where the demand for heat is high, and this reduces the yield of the heat pump.

Cooling with heat pumps

To enable active cooling, the functional principle of the heat pump is simply reversed. Cooling can be achieved through reversible operation. This means that the refrigeration circuit is internally reversed or achieved by switching over the primary and secondary connections. Like a refrigerator, the heat pump then actively lowers the temperature. This is called “active cooling”.

In passive cooling, the brine liquid or the groundwater takes the heat from the heating circuit by means of a heat exchanger and releases it. In the process, the air in the building cools. This function is also called “natural cooling” because it makes use of the natural ambient temperature for cooling. Here the heat pump is switched off except for the control and the circulating pump.

A brine-to-water heat pump is ideal for heating rooms and providing hot water for single-family homes. The heat pump shown here offers a comfortable year-round heat supply in a range of 5.8 to 17.2 kW in monovalent operation.

Competence of the German industry

The German geothermal industry covers the entire range of geothermal technologies: From near-surface geothermal energy to hydrothermal and petrothermal, deep geothermal energy for generating heat, refrigeration and power.

The low-temperature geothermal energy technologies developed by German engineers have great potential. In particular, technical know-how in plant and process engineering ensures that German specialists are internationally sought-after.

Besides developing and manufacturing technology, the industry covers the entire value-added chain. Feasibility and profitability studies are performed, and practicability concepts created. German companies are successful in all aspects, from project development, planning and construction management, through drilling, facility construction at the power plant, to operating the plant. The German supplier industry rounds off the range of performance, with leading manufacturers of components such as borehole heat exchangers and heat pumps.

With its practical orientation, German research and development aims to minimise the exploration risk in a project and sustainably secure the productivity of the deposits used later on, thus ensuring more efficient and more sustainable power plant operation.

The first geothermal power plant in Germany started operation in Waren an der Müritz in 1984 and is still providing heat for 1,800 households today, three decades later. Since the start of the 21st century, electricity projects using geothermal heat have also been developed in Germany. A large number of successful examples, which have been producing electricity with roughly 248 MW of heat and 31.31 MW of electrical power, underscore the leading role which the development of hydro-geothermal projects occupies in Germany today. A rapid rise in the use of hydro-geothermal energy is expected by 2030.

Commercial use

Deep geothermal energy

The economic viability of deep geothermal projects depends on the local geological characteristics. The decisive factors here are the temperatures and the potential flow rates of the thermal water and drilling the depth necessary for exploitation. The heat grid is also a major factor in heat projects. Given a large coverage area, a mains-locked supply of geothermal energy is a very cheap alternative to an in-house system.

Other factors affecting the economic viability of a deep geothermal power plant are the exploration risk, the reservoir risk, the interface risk and the operating risk.

The exploration risk denotes the danger of finding insufficient quantities or quality of thermal water after one or more drilling operations. The reservoir risk consists of the reinjection borehole not exhibiting sufficient capacity for the cooled thermal water. These risks can be technologically minimised through preliminary explorations and a targeted selection of the drilling site.

During the construction phase of a deep geothermal project, the interfaces between the various people involved in the project have a strong effect on the feasibility and profitability. As a rule, the thermal water used for producing energy has a heavy salt content and a marked corrosive effect during the operating phase. The plant's primary circuit must therefore be designed accordingly and constantly monitored.

The operating risk resulting from operating the plant can be controlled through careful planning and monitoring. In Germany, deep geothermal power plants are usually seen as plants requiring monitoring within the meaning of the Ordinance on Industrial Safety and Health (BetrSichV). This stipulates a comprehensive hazard analysis during planning and before commissioning, as well as repeated inspections when the plant is in operation later. The mechanisms causing corrosion when the plant is in operation are known, however, and can be kept under control by choosing suitable materials.

In view of existing geothermal resources and the fully developed technology available, deep geothermal energy is an especially valuable form of energy production because it is suitable for meeting base load requirements, and is also becoming more and more interesting to investors worldwide. The demonstrated risks can be largely controlled by taking a systematic approach, and competent technical project support provides additional investment security.

Incentive systems

Political discussions on future energy supply are increasingly looking to geothermal energy. A clear legal and stable policy framework in the field of electricity feed-in is a key factor in the success of connecting geothermal power plants to the electricity grid. In the case of power projects, the remuneration tariff as defined in Germany, for example, by the Renewable Energy Sources Act (EEG), plays a major role. Along with the production and lucrative marketing of electricity, selling heat also contributes to the profitability of a project.

The exploration risk, that is, the risk of finding insufficient quantities or temperatures of thermal water after completing drilling operations, can be offset by long-term financing models and insurance solutions or state guarantees. In Germany, for instance, the exploration risk can be reduced through the "Exploration Risk Credit Programme" run by the Federal Ministry for the Environment and through special exploration insurance policies.

Apart from Germany, state development aid programmes which enable geothermal projects to be implemented have been in place for years in Africa, Asia and Latin America.

Near-surface geothermal energy

In near-surface geothermal energy, the flow temperatures of the heating system and the quality of the installation are decisive for bottom-line economic feasibility. Comprehensive planning by a qualified company should precede the building of any geothermal heating system. The use of heat pumps in new and existing buildings began to increase significantly in Central and Northern Europe as early as 2006.

Although air-water heat pumps are cheaper to install, they are 20–30 percent less efficient than ground-coupled heat pumps owing to their greater dependence on weather. Combinations with other renewable energy technologies such as photovoltaics have an additional impact on the economic viability. For example, the use of a heat pump can considerably increase the percentage of internal power consumption from the photovoltaic system, while at the same time ensuring the cost stability of the power supply for the heat pump in the long term.

Incentive systems

The German government plans to have 14 percent of heating in Germany come from renewable energies by 2020. To reach this goal, the use of near-surface geothermal energy, among other things, is being stipulated and promoted. This means that owners of new buildings with usable floor space of more than 50 m² are obligated to cover the energy requirement for heating (and cooling) proportionally from renewable sources of energy. When using geothermal or environmental heating, at least 50 percent of the entire heating requirement must be covered. In order to be approved within the scope of the Renewable Energies Heat Act (EEWärmeG), heat pumps must fulfil particular requirements with regard to efficiency and quality.

What is more, heat pumps in Germany are subsidised by the state through the Market Incentive Programme. The condition for receiving a subsidy is that the heat pumps are installed to meet the need for heating and hot water in existing residential buildings in which there is already a heating system. In order for the subsidy to be approved, heat pumps must fulfil certain performance figures and produce the appropriate certifications.

What is more, the federally owned KfW Bank Group supports the installation of heat pumps in new and existing buildings with low-interest loans. However, the KfW programmes cannot be combined with the Market Incentive Programme.

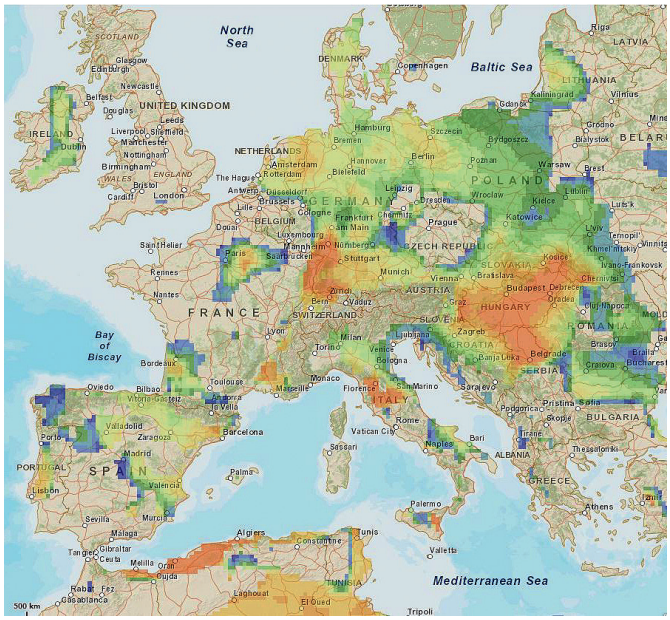
Outlook

The international market potential of geothermal energy for sustainable and CO_2-free energy generation is huge. According to Bloomberg New Energy Finance, the geothermal electricity production capacity is expected to more than double by 2030. In contrast to the comparatively mature markets of solar and wind energy, geothermal energy is still an emerging industry in many places.

In the deep geothermal energy sector, the priority objectives are those of minimising exploration risk and ensuring sustainable deposit productivity in order to reduce the investment risk in the future and thus achieve wider market penetration. Advanced developments with regard to preliminary seismic surveys have already demonstrated their effect.

Near-surface geothermal energy is already well established throughout Central and Northern Europe. In this sector, research is ongoing in new source technologies, drilling methods and the use of seasonal heat and cold storage installations. A reference plant for seasonal energy storage in the ground is located in the Reichstag building, the seat of the German Bundestag in Berlin.

There is considerable potential for geothermal electricity generation along the Ring of Fire around the Pacific Ocean and on the islands in the Mid-Atlantic Ridge, among other areas. Major development perspectives for the electrification of rural areas exist on the African continent in particular. In addition to hot spots such as the Hawaiian Islands, there are also very lucrative sites for heat and electricity generation to be found in Southeast Asia, New Zealand, along the Andes in South America and in parts of the Middle East.



This map shows the current technical potential for geothermal energy in Europe. Source: Boxem, T.A.P., Wees, J.D. van., Pluymaekers, M.P.D., Beekman, F., Batini, F., Bruhn, D., Calcagno, P., Manzella, A., Schellschmidt, T., November 2011, "ThermoGIS World Aquifer Viewer - An Interactive Geothermal Aquifer Resource Assessment Web-tool", EAGE: 1st Sustainable Earth Sciences Conference & Exhibition.

Planning a hydrothermal plant project – what must be done?

Owing to the existence of natural potentials in Europe, water is increasingly being pumped out of deep groundwater pipes to extract its heat and return the cooled water a certain distance away through an injection borehole (doublet). Careful long-term planning is indispensable for this type of hydrothermal plant. The most important steps in the work are presented in abbreviated form below:

I. Preliminary study

1. Objective
2. Clarification of the basic geoscientific conditions / the requirements in terms of mining law
3. Clarification of the use of the energy
   (heat provision with optional generation of power from waste heat),
   clarification of specific aspects of the site
   (heat sinks and possibly existing heat grids)
   clarification of basic economic conditions
   (for example, price of heat, etc.)
4. Preparation of a rough technical concept
   (various development possibilities, necessary drilling, heating systems or power plants)
5. Cost estimate

II. Exploration (Phase 1)

1. Optional: Commissioning a planning office
2. Applying for a mining permit (exploration rights)
3. Geophysical exploration (two-dimensional seismic imaging, etc.), if necessary
4. Identification of the eligible reservoir zones for the development (geologic modelling)

III. Feasibility study (Stage 1)

1. Detailed concept on items 1 to 4 of the preliminary study and stipulation of planned alternatives
2. Determination of expected investment costs (drilling, subsurface facilities, construction of heating or power plant)
3. Provisional drilling planning
4. Start of PR work / civic involvement

IV. Exploration (Phase 2)

5. Extended geophysical exploration
   (3D seismic imaging, etc.), if necessary
6. Final geological modelling and tentative reservoir modelling
   Stipulation of a project site
   (processes related to construction planning regulations, etc.) with the general public involved
7. Detailed planning of the borehole(s) and the drilling area

V. Feasibility study (Stage 2)

5. Calculations of profitability (development and operating costs, expenses and proceeds)
6. Risk analysis (exploration, reservoir, interface and operating risk)
7. Ecological audit, assessment of effects on the environment
8. Project flow chart

VI. Exploration (Phase 3)

8. Call for bids on the first drilling, setting up an operating plan
9. Optional: Planning and call for bids on monitoring measures (groundwater monitoring, vibration monitoring, etc.), construction of the monitoring systems
10. Drilling the first hole, including tests
11. If appropriate, stimulation measures
12. Decision on development potential

VII. Development

1. Call for bids on second drilling, setting up an operating plan
2. Drilling the second hole, including tests
3. If appropriate, stimulation measures
4. Conducting a circulation test as a final basis for data on the plant layout, as well as to stipulate the drilling of the production and injection well
5. Setting up the heating plant or the combined heat and power station (if necessary, in parallel with the previous steps), if necessary, electricity generation system as well
6. Applying to the mining authority for authorisation (rights to the raw materials which have been found)
7. Applying for an extraction operating plan
8. Production

SMA Solar Technology AG

Morbach, Germany, attracts countless visitors from all over the world. Besides photovoltaic systems with a combined output capacity of 1.1 MWp (projected annual yield of approx. 1 million kWh), the area also boasts 14 two-megawatt class wind turbines, one biogas plant and a wood pellet production facility.

Photovoltaics

Solar energy has an enormous potential that can be utilized 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. In recent years, the number of PV installations in the world has grown at a breathtaking pace. Apart from Germany, the markets with the highest installed capacities are also found, for instance, in China, the USA, Italy and Japan. PV technology from Germany is being used all over the world. German PV service providers stand out thanks to their many years of experience and high quality standards. Prices of PV modules have plunged recently. This also caused a noticeable decline in the production costs of PV electricity. Costs in the PV sector are expected to continue to fall in the coming years due to further economies of scale.

Technologies and applications

How a PV cell works

PV cells consist of one or more semiconductor materials and enable solar energy to be directly converted into electrical energy. In order to elicit the photoelectric effect, the semiconductor material must be “doped”. 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. For higher capacities, PV cells are usually interconnected in modules.

Types of technologies

Currently, silicon is the primary material used in the manufacture of PV cells as it is the second most common element on earth and therefore cheap to produce. However, other elements apart from silicon are used in PV, such as copper, gallium or cadmium. We generally differentiate between thick film and thin film technology, both of which will be explained in more detail below:

Thick-film technologies

Monocrystalline silicon cells have the highest degree of efficiency of the various PV technologies (around 20 percent). Their production involves extracting high-purity silicon rods (ingots) from a cast and cutting them into thin slices (wafers), which are then processed into PV cells.

Polycrystalline silicon cells currently have an efficiency of around 16 percent. Unlike monocrystalline silicon, the silicon is cast in blocks. When it hardens, it results in crystal structures of different sizes on whose border defects occur. These defects reduce the degree of efficiency. Traditional silicon cells had a global market share of roughly 90 percent in 2013.

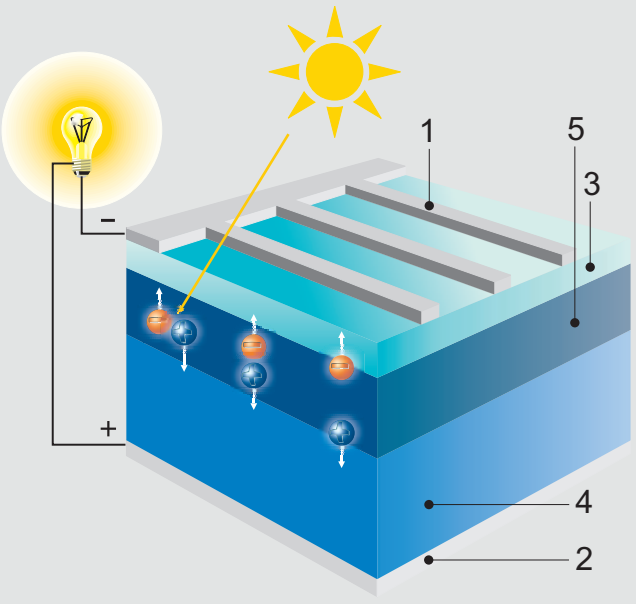


Diagram of a solar cell: **1)** negative electrode **2)** positive electrode **3)** n-silicon **4)** p-silicon **5)** barrier layer.
Source: www.solarpraxis.de / M.Römer.

Royal Cargo, Manila.

Hybrid wind and photovoltaic power plant in Hamburg.

Examples of thin-film technologies

The abbreviation CdTe stands for the combination of tellurium and cadmium, which are combined to produce cadmium telluride (CdTe). The material is cheaper than silicon but also less efficient. As it contains the heavy metal cadmium, the modules are certain to be taken back after de-installation. At present, a maximum degree of cell efficiency of 20 percent is achieved. According to the manufacturer specifications, the CdTe modules outperform crystalline solar cells in low light or high temperatures.

Amorphous silicon generally reaches a degree of efficiency of 5 – 10 percent, which is poor in comparison to the two crystalline silicon technologies. However, important advantages of thin film cells based on amorphous silicon in contrast to crystalline silicon cells include its better performance in areas of diffuse lighting conditions and a production that is cheap thanks to the low amount of material used. It is produced by depositing a layer with a thickness of less than 1 µm on glass or other substrate material.

Another thin-film technology is CIGS. The abbreviation in this case stands for the elements copper, indium, gallium and selenium, with an average degree of efficiency of 13 – 15 percent. This relatively new technology has a high potential for development, as the maximum degree of efficiency achieved at present of 14.6 percent (in relation to the entire module surface) in commercial production coupled with the comparatively low production costs means that the price level of the generated solar power is growing closer to fossil-fuel based electricity generation. On the one hand, the CIGS module has the advantage of a low static load thanks to its light cells, while it also has the ability to absorb direct and indirect sunlight and is therefore suitable for use on flat roofs and in winter.

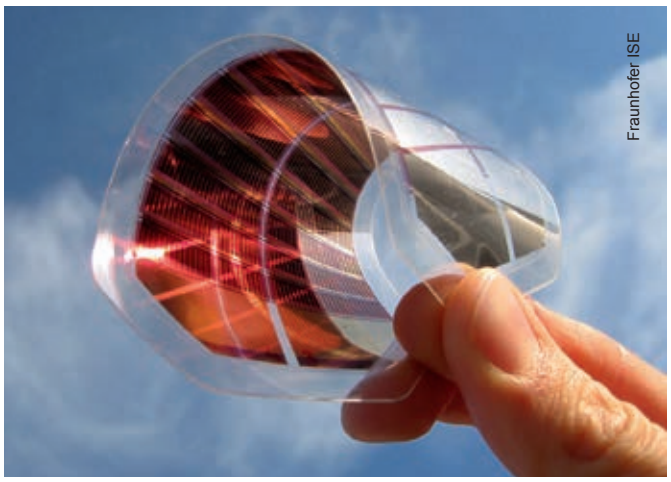
Other types of PV cells

Organic photovoltaic (OPV) cells consist of hydrocarbon compounds which are applied – as with amorphous silicon – to a substrate material. The advantage of these PV cells is that their performance does not drop in the presence of less sunlight and higher temperatures, as with inorganic PV cells. The degree of efficiency of OPV cells, however, is less than that of conventional/traditional PV cells (thin-film and thick-film).

Opinion panel

“We use our measurement systems to calculate the solar radiation at sites where PV farms are planned, as well as environmental factors like pollution and soiling, which affect the performance of the PV modules. The measurement data are used to calculate the expected energy yield at the site or to check the cost-effectiveness of the solar farm. In dry countries, the pollution rating of the PV modules is vital for optimising the performance and should be taken into account in the maintenance plan.”

Vincent Camier, CEO, Ammonit Measurement GmbH



With new materials, production techniques and installation technologies, organic photovoltaics (OPV) are expected to become more efficient and more cost-effective.

Léon, Nicaragua: The PV modules on the roof of this self-sufficient solar house provide electricity for a solar pump system, among other things. Solar-thermal collectors heat the process water.

In concentrator photovoltaics (CPV), systems of mirrors and lenses are used to concentrate a high light intensity on a PV cell. This can achieve degrees of efficiency of up to 43.6 percent at present. However, the system costs are often higher than those of traditional PV installations owing to the need for tracking systems. CPV uses materials similar to those in CIGS cells.

Applications

PV systems can be both grid-connected and off-grid, or supply entire communities with electricity by means of a stand-alone grid system.

Grid-connected PV systems

Grid-connected PV systems consist of several PV modules, an inverter that converts the generated direct current into grid-compliant alternating current, a protective device and a meter. Grid-connected PV systems can be scaled to any size and can cover a large power spectrum, from small 1 kWp systems to solar parks with several hundred MWp.

Off-grid systems

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. Here, too, the advantage is that the PV generator can be scaled to any size, whether it supplies a few watts for electrical devices in the home or several hundred kWp or even MWp for the electrification of mini-grids.

Mini-grids

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; that is, a combination of PV systems and other electricity generation plants, such as wind turbines or diesel generators. However, a system for storing energy is essential to an independent and stable supply of PV electricity.

Competence of the German industry

German companies in the PV industry are represented throughout the world, in the area of production and at all other levels of the value chain, and enjoy an excellent reputation thanks to their many years of experience, exceptional customer service and high quality standards. The export quota of the German PV industry was around 65 percent in 2014. At the end of 2014, more than 45,000 full-time workers were employed.

German companies lead the world in the development and research of new PV technologies. Furthermore, German research organisations are setting quality standards internationally; throughout the world, cutting-edge module factories are equipped with German equipment and machines and are being planned and built by German companies. The German industry also offers sophisticated solutions in the areas of systemic integration of photovoltaics in electricity grids e.g. by providing reliable storage solutions and management systems for efficient energy self-consumption or feed-in.

Opinion panel

"German technology and experience create a solid foundation for solar heating and electricity generation for projects worldwide. However, for implementation to be successful, these factors need to be combined with standardisation and simplification. Locally-sourced materials and skills also need to be adapted to the respective market conditions so that they can be applied there seamlessly and continue to work. For several years, Aschoff Solar has been successfully taking the course of implementing projects in countries in which solar energy is still in its infancy and it relies on internationally experienced and qualified installation teams and close cooperation with industrial customers."

Carsten Aschoff, Founder, Aschoff Solar GmbH

"Whereas the costs of PV systems have steadily dropped in recent years, and the feed-in compensation too, the price of electricity has risen everywhere. Our new PIKO storage system, however, also makes it profitable to invest in your own solar power system in the future, because you recoup the cost over the years in reduced electricity bills."

Markus Vetter, Head of Marketing
KOSTAL Solar Electric GmbH

PV modules, highly efficient inverters as well as energy management and integration technologies are the best advertisements of the German PV industry. The systems for producing silicon, wafers and cells also meet the highest levels of demand and are available worldwide. German manufacturers of software and measuring technologies, module dealers, system integrators, project engineers and project developers, fitters and investors, service providers for operation and maintenance and research organisations all further enhance the PV value chain.

Commercial use

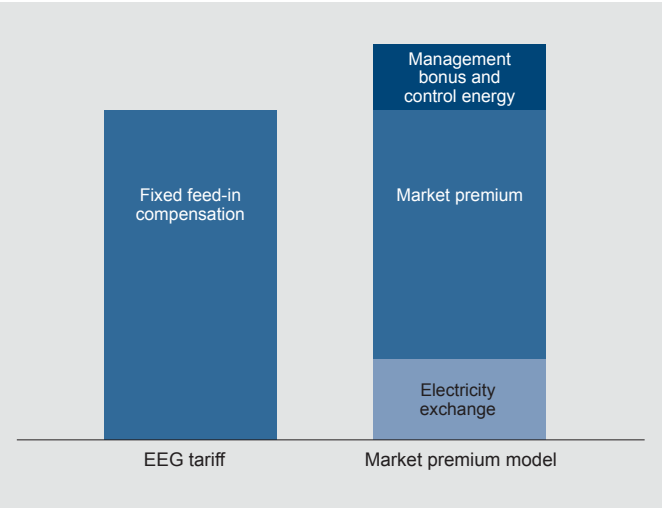
The actual costs of PV systems have fallen significantly in recent years. Consequently, the production costs of PV electricity have been increasingly reduced. In 2013, the price of PV electricity in Germany was between € 0.08 and € 0.13 per kWh, whilst in 2012 it was still between € 0.11 and € 0.17 per kWh. In this context, we speak of "grid parity" or "generation parity". Grid parity is reached when the costs of electricity production reach the same or a lower level than the average price of electricity. Generation parity describes the point in time at which the cost per kilowatt-hour is at the same or a lower level than the average actual cost in the energy mix. This causes private consumption of PV electricity at a higher electricity price to become increasingly attractive for plant operators even without additional support.

Despite this stronger trend towards private consumption, photovoltaics is supported by various support systems in a large number of countries. In recent years, the general regulations for photovoltaics worldwide have changed considerably. More and more countries have introduced different support mechanisms to provide economic incentives for establishing a PV system and to guarantee the participating companies the highest possible level of security of investment. Some of the support mechanisms for PV are provided as examples below:

Minimum price model

The feed-in compensation is a popular model in a large number of countries which are focusing on the installation of grid-connected systems. In this case, the system operator receives a feed-in compensation defined for a specific time period for the electricity produced. For the design of these minimum pricing models, many countries are using the German EEG (Renewable Energy Sources Act) as their

Solar monitoring station for measuring direct, diffuse and global radiation as well as meteorological values.



Market premium in accordance with the EEG.
Source: www.next-kraftwerke.de/wissen/direktvermarktung/marktpraemie (as of 10/2014).

model. With the EEG, which came into force in 2000 and which was last amended in 2014, the development of renewable energies has been accelerated due, among other things, to fixed feed-in compensations. Thanks to the security of investment that it guaranteed (fixed feed-in compensations for 20 years and purchase guarantees), the generation of electricity from renewable energies more than doubled within a few years (share of renewable sources of energy in gross electricity consumption: 2006 = 11.6 percent, 2014 = 27.8 percent) and a new and innovative sector was created. The reform of the EEG in 2014 moved the focus in Germany more strongly towards direct marketing of the regenerative electricity produced and bidding, apart from compensation alone.

Market premium model

The market premium model helps renewable energies to be integrated into the electricity market. Since 2012, the market premium model has also been included as an additional option in the German EEG, introducing suppliers of renewable energies to the market. In accordance with this model, an operator can place electricity on the market directly or via a dealer on the stock exchange. In this case, the market premium compensates for the financial differences between the average electricity price on the stock exchange in one trading month (reference value) and the FIT compensation. The amendment of the Renewable Energy Sources Act in 2014 now makes direct marketing obligatory for operators of new solar installations with 100 kWp of installed capacity or more starting in 2016. For the additional effort and expense of direct marketing, PV plant operators receive a markup (management premium) of 0.4 cents per kilowatt-hour on the market premium.

Quota model

With the quota model, the system operator receives green energy certificates for a certain amount of generated electricity (usually per MWh). These green energy certificates can then be sold on the energy market for a set price. An advantage of this model is that the development of PV can be regulated systematically; that is, the state can control the amount of energy supported through the number of green energy certificates issued. This model is currently in use in Romania and Great Britain, for example.

Praia do Forte, Brazil: A wooden pergola on the beach provides shade for researchers and visitors at the “Projeto Tamar” research station and the modules on its 80 m² of effectively used roof area have a total capacity of 8.6 kWp. The system not only stands up to wind and rain, but also to the salty sea air.

The Port of Hamburg: roof-mounted solar power plant in association with eco-power supplier Hamburg Energie, 125 kWp.

Oak Ridge, Tennessee: A group of German companies set up seven adaptive tracking systems with a total capacity of 50 kWp on the grounds of the 1,200-hectare Oak Ridge Heritage Center. Here the scientific elite from all over the world meet to do research in the fields of energy, metallurgy and environmental technology.

Other models

Additional support options include low-interest credits provided by financial or state institutions, or net metering, in which the electricity generated is consumed by the system operator directly and only the electricity that is not used is fed into the grid. The electricity that is fed in is then charged against the energy consumed from the grid by the system operator.

Outlook

The European Photovoltaic Industry Association (EPIA) expects that the largest growth markets will shift from Europe to other regions of the world. Above all, China and India have massive potential for new PV systems, and on that basis, strong growth has been forecast for their PV markets 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.

While solar roof installations are predominant in Europe, the development of large-scale solar power plants should be expected in the regions lying between the 20 and 40 degree latitude in the northern and southern hemispheres.

Many countries in the world have only an inadequate electricity grid or none at all. In these regions, diesel generators have hitherto been used for electricity generation. In the future, PV-diesel hybrids will provide an environmentally friendly alternative to this situation. Based on estimates from Greenpeace, the global market share of off-grid systems in developing countries in the years ahead is set 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.

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. Thanks to its many different applications, organic photovoltaics (OPV), in particular, is likely to continue to gain importance.

Opinion panel

“Energy is not a problem which needs to be solved, but a source which is available throughout the world. The future lies with renewables. Photovoltaics is now becoming the backbone of the global energy supply: simple, low in price, scalable and accessible.”

Dr. Hartwig Westphalen,
CEO, SunEnergy Europe GmbH

Protecting the PV system from external influences

PV systems are attractive investments and thus attract thieves. Further risks arise from extreme meteorological events. However, system operators can appropriately protect their PV system.

Meteorological events

Meteorological events can interfere with the operation of a PV system. For example, storm or hail can damage PV modules. The insurance industry offers operators of PV systems specially tailored solutions for potential damages. For instance, operator's liability insurance steps in when strong winds snap off PV modules and passers-by or vehicles are damaged. In addition, all-risk coverage is on offer. This covers damages from hailstorms or wind, faulty operation or even acts of negligence.

Theft

To effectively protect a PV system from theft, the following factors must be taken into consideration when the system is installed:

- The "time" factor plays an important part for "PV module thieves". Accordingly, anti-theft protection devices are an important building block when setting up photovoltaic systems, for they cause the perpetrators to "work longer" and thus run a greater risk of being discovered.
- Particular value should be placed on the attachments. PV modules should not be capable of being removed with commercially available tools.
- Driving right up to a system should be prevented if possible by natural obstacles or mechanical barriers. This makes it harder to drive off with a PV system.
- It is advisable to install surveillance technology for the PV system. Special, coordinated surveillance technologies, such as video cameras and burglar alarms are suitable. These measures should be seen as additions to the mechanical and organisational measures and not as replacements.


Fotolia.com / Marina Lohrbach


Fotolia.com / Gekon

Solar thermal plant in a hotel complex in Tunisia.

Solar thermal energy

Solar thermal energy is a tried-and-tested technology that has been used for centuries. It can be used for heating water and rooms, for cooling or dehumidifying ambient air, for process heating and for drying purposes; and crucially, it reduces energy costs for heat production, saving on fossil fuels for heating.

German solar thermal energy companies have many years of extensive experience in the production, planning and construction of solar thermal energy systems and their components. Germany's solar thermal energy industry is among the world leaders.

Solar thermal energy systems for domestic water heating in a detached house: **1)** collector **2)** boiler **3)** solar storage tank **4)** solar station.

Technologies and applications

The application area for solar thermal energy extends from simply heating water to combi-systems, which can also be used for room heating, right through to solar thermal cooling and process heating systems. The first two types are used primarily in residential buildings.

The areas of small-scale and large-scale systems in solar thermal energy are still being developed in very different ways. While the production of small-scale systems has already been standardised, large-scale systems have still only experienced a very low level of standardisation and are usually planned and implemented on an individual basis. The areas that still require the most research are solar thermal cooling systems and process heating systems.

System types

A distinction is made between the following types of systems:

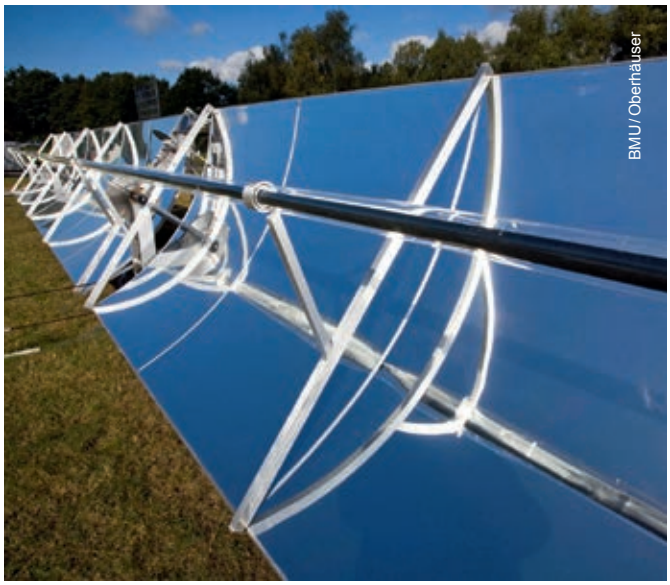
Systems for heating tap water
These systems are typically designed to heat all domestic water throughout the summer period. In the winter months, the hot water is heated mainly by a heat generator (a boiler, usually operated by gas, oil, wood or a heat pump), which is supported by the solar thermal energy system on sunny days. This means that around 60 percent 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.

TPAO (Turkish Petroleum Company) Batman Area Management Heating Central, 2014.

Opinion panel

"Whereas almost 20 years ago we still had to struggle to convince many customers and we would often enough hear the question, "does it really work, though?", today, the majority of the general public understands how solar thermal energy basically works." The overheated car sat in the sun in the supermarket car park, or the hosepipe lying in the garden that soon spurts out hot water are clear examples of the free heating capacity of our daily sun."

A. Appel, Dipl.-Ing. (FH), SOLAR-RIPP®



Pilot system for parabolic trough collectors for solar process heating.

Combi-systems

The solar collector area of combi-systems is larger. They also help to heat the building in spring and autumn. The collector area required in this case also depends on the weather conditions in the country and consumer demand. The solar fraction of the total heating requirement is typically 20 – 30 percent of the building, depending on how well the building is insulated and the heat requirement level. However, there are also special solar houses that cover over 50 percent and up to 100 percent of the total heating requirements with solar heat.

Solar thermal energy cooling systems

Solar thermal energy power stations may also be used for cooling buildings (air conditioning) or industrial processes (refrigeration). The cooling process is brought about through evaporation and condensation. A distinction is made between open and closed systems. Solid and liquid sorption materials are used in open systems, while the adsorption refrigeration machine and absorption refrigeration machine are part of closed systems. Closed systems, such as adsorption and absorption refrigeration machines and open cooling and dehumidifying processes, such as sorption-supported air conditioning, are the most widely used systems.

Process heating systems

The energy yields from solar thermal process heating systems can be significantly above those of standard systems in certain cases. The potential for solar thermal energy systems in the area of process heating is enormous: Around 30 percent of 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. Process heating collectors can be divided into non-concentrating collectors with minimal heat loss, semi-concentrating, non-tracking collectors and concentrating, tracking collectors. Depending on the type of collector, the solar thermal energy can be used for heating both water and air that can then be supplied to the processes.

Collector types

Various types of solar collectors can be used:

Unglazed absorbers

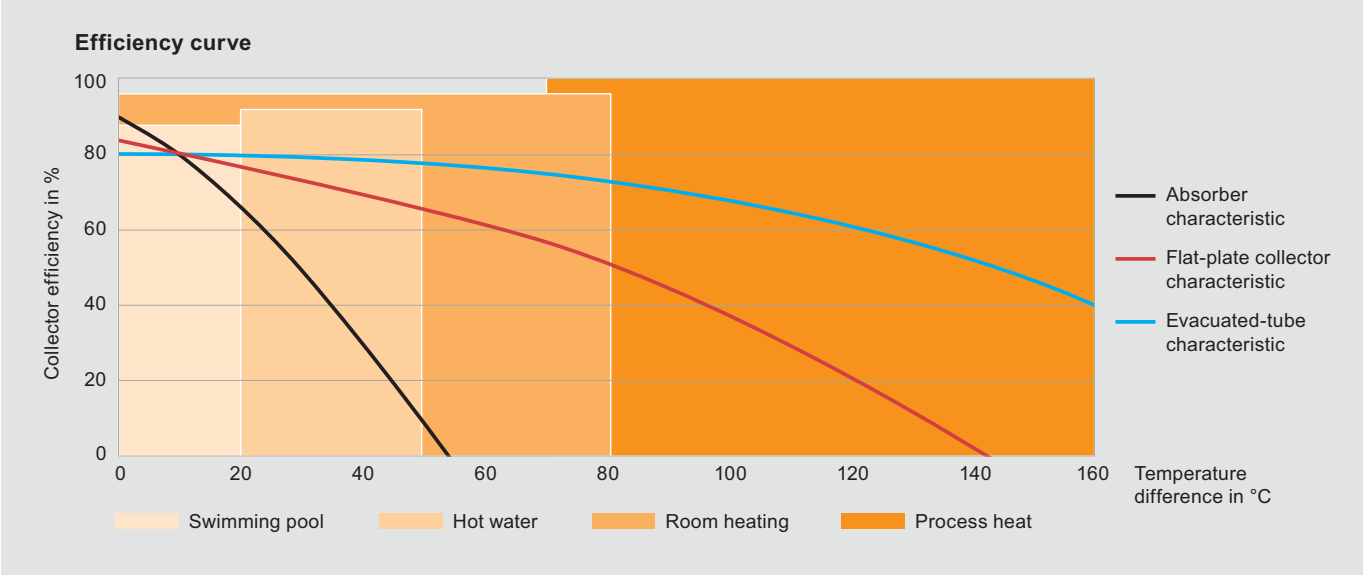
This is the simplest type of solar collector, consisting of a black plastic matting that is often used to heat water in swimming pools in order to reduce their operating costs. They are cheaper than a fossil-fuel boiler and achieve temperatures of 30 – 40 °C.

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 a 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. tap water.



The better insulated the collector, the higher the temperature of the heat it produces. This figure shows the efficiency curves of various types of collectors at 500 W/m² radiation and the resulting fields of application. Source: DLR.

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. The rotatable mounting for the individual tubes enables the flat absorber plate in the glass tubes to be turned to the optimum position for sunlight. For this reason, evacuated tube collectors can also be deployed nearly horizontally on flat roofs. The individual tubes form a closed system that transfers heat through a frost-proof heat cycle to the domestic water supply.

Provision and storage

Local and district heating grids must be developed and connected to sufficiently large storage tanks to be able to make use of solar thermal energy on a larger scale. Whereas a solar collector system requires a storage tank with a capacity of around 350 litres for heating domestic water in single-family dwellings, a storage tank of around 70 litres per collector area square metre is required for combi-systems. 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 available at cooler times of the year as well. For example, the heat can be stored in underground water-bearing seams (aquifers).

Competence of the German industry

Germany's solar thermal energy industry is among the world leaders. One of the areas modern solar research has focused on in Germany is basic research. New materials and cost reduction have been pushed ahead in collector manufacture. Thanks to increased automation and material savings, production costs for solar collectors were halved between 1995 and 2010.

Ontario, Canada: The largest Canadian system to date for solar heating and cooling. German manufacturers produced the evacuated tubes and collectors for the system. The project was awarded the Intersolar AWARD 2012 in the "Solar Projects in North America" category at Intersolar North America in San Francisco. The "Oxford Gardens Solar Project" was chosen by a jury of experts for its innovations and excellence in solar thermal technology, system design and efficiency.

Opinion panel

"In solar thermal energy, as with all energy systems, the criterion for energy efficiency is the consistent performance of the system over decades. The consistency of the heating output unit is crucial. As this (heat absorber + heat conduction unit) is securely and sustainably protected in the full vacuum, a solar thermal plant provides the highest degree of energy efficiency. The full vacuum pipe technology meets these conditions and offers safety and a lasting level of performance. Solar thermal heating and cooling energy currently offer the biggest growth."

CEO Günter Schaffron, s-power Entwicklungs- & Vertriebs GmbH

In addition, German solar thermal energy companies have many years of extensive experience in the production, planning and construction of solar thermal energy systems and their components. Customers profit from this in turn, as solar thermal heating systems now provide an efficient and cheap way to reduce energy costs. Pioneering firms in the field of solar process heating are working in conjunction with machine manufacturers. German researchers are planning the further development of solar thermal energy systems, while the development of solar thermal cooling and process heating systems and the creation of new storage technologies are being accelerated.

Commercial use

Putting a figure on the cost effectiveness of solar thermal systems is a more complex matter than it is for other renewable energy plants. Cost effectiveness is calculated by comparing the system costs, yield and service life of the system with the costs of producing conventional heating and cooling. Yield and service life vary greatly depending on the application area and the technical complexity of the solar thermal energy system. The intensity of solar radiation is always a deciding factor. Applications designed simply for heating water and rooms are generally amortised faster in countries with high prices for conventional forms of energy (primary energy source or electricity) than in countries with a lower price level in this area.

Incentive schemes

A turnaround in energy policy will only be realised in many countries if renewable energies take on a decisive role in the heating market. Various legal targets and subsidies can be used to support this objective.

In Germany, for example, the Renewable Energy Heat Act (EEWärmeG) stipulates that the energy requirements for heating (including water heating) and cooling in new buildings must be covered in part by renewable energies, such as solar thermal energy systems. Furthermore, the state-owned investment bank KfW provides low-interest lending with repayment subsidies for systems with more than 40 m² of gross collector surface area. An additional incentive for installing solar thermal energy systems was created through the German market incentive programme (MAP). The German government grants subsidies for solar thermal systems in single- and two-family houses, apartment blocks and commercial and public buildings. State support is intended to contribute to the promotion of technology that aims to utilise the massive potential of process heat, while also increasing the economic viability of large-scale solar thermal energy systems.

Another type of promotion for solar thermal energy was introduced in Albania in May 2013 with the "RES Law." This states that solar thermal energy systems and components are to be exempt from tax, import duty and VAT.

Outlook

The importance of solar thermal energy has been underestimated for a long time. With rising 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 is becoming increasingly relevant in multiple-family dwellings, hospitals, homes, hotels and industry.

Solar-powered cooling systems represent a forward-looking technology, especially in countries where there is a high demand for cooling, since they reduce electricity consumption and the costs of air conditioning for the long term. The heat captured through solar collectors is used to provide energy for driving refrigeration machines. However, as the technology for solar cooling is still relatively new, installation costs are still higher than those for conventional cooling systems. Reasons for the higher costs include the complexity of the technology and the low degree of industrialisation. Companies and research institutions are

working to further develop this technology to make it more compact and economical, as well as more fit for service where smaller capacities are concerned.

The link between solar thermal energy and other heating technologies is also becoming increasingly important. Thanks to an intelligent energy management system, synergy effects can be created, enabling the heating or cooling of buildings throughout the year, and will therefore play an important role in increasing the proportion of heat generated from renewable energies in the future. Examples of combinations of technology include systems connected to shallow geothermal energy systems or using the ground to store heat or cold.

A collector on a rooftop/gable roof.

Providing process heat for industrial applications

In addition to solar cooling, there is also major worldwide potential in the provision of solar process heating for industry and in the commercial sector. The system technology required for high temperatures is still relatively expensive; by contrast, process heating at temperatures between 20 – 100 °C can be provided relatively quickly and developed at a comparatively low price. Temperatures of up to 250 °C should be achievable in future.

In Eichstätt in Germany, a pilot system, one of roughly 100 worldwide, supplies a brewery with solar thermal water. To increase the economic viability of the brewery, the production processes were adjusted to suit the sun's level of intensity. The system operates with evacuated tube collectors on a collector surface of 900 m² and two 60 m² large solar panels.

Hofmühl brewery in Eichstätt, Germany.

Andasol 50 MW parabolic trough power plant with EuroTrough collectors.

Solar thermal power plants

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, thus allowing electricity to be generated on demand – an important advantage of this technology.

Economic operation of solar thermal power plants relies on a high proportion of direct solar radiation; they are thus typically used in very sunny areas, such as Southern Europe, North Africa, and the southwest of the USA. In the scope of today's dynamic market development, many parabolic trough plants and solar tower power plants are currently in planning or construction, as well as some large-scale plants using Fresnel technology. In 2014 approx. 80 solar thermal power plants were on the grid around the world. This corresponds to a total capacity of approx. 4,400 MW. Another 30 power plants with a total planned capacity of around 5,300 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 considered to belong to the world's top bracket.

Technologies and applications

The common basic principle of solar thermal power plants is the use of concentrating parabolic mirror systems in large-scale solar fields that concentrate solar radiation onto a receiver. All systems must track the sun in order to be able to concentrate the direct radiation. This radiation is first converted in a special absorber system (receiver) into thermal energy at temperatures in the range of about 200 to over 1,000 °C (depending on the system). The thermal energy can then be converted to electric power, as it would be in a conventional power plant, using steam or gas turbines; if needed, it can also be used in other industrial processes, for example, water desalination, cooling or – in the near future – for hydrogen production.

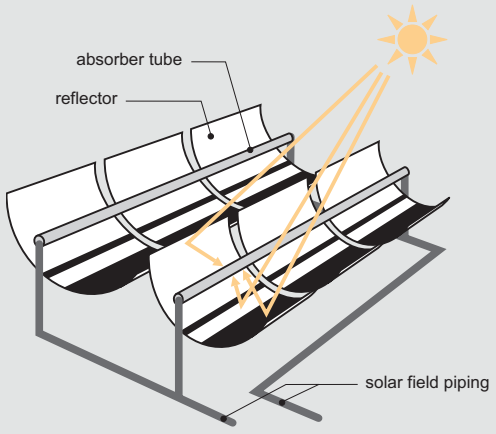
Owing to this principle, solar thermal power plants are characterised by the fact that the heat generated can be stored in a relatively easy and inexpensive way, and can thus be used to generate electricity in the evening and at night. In this way, they can make a decisive contribution to predictable, demand-based electricity generation in a future electricity mix with a high proportion of renewable energy.

A distinction is made between linear and point concentrating systems; within these systems, there are four different configurations:

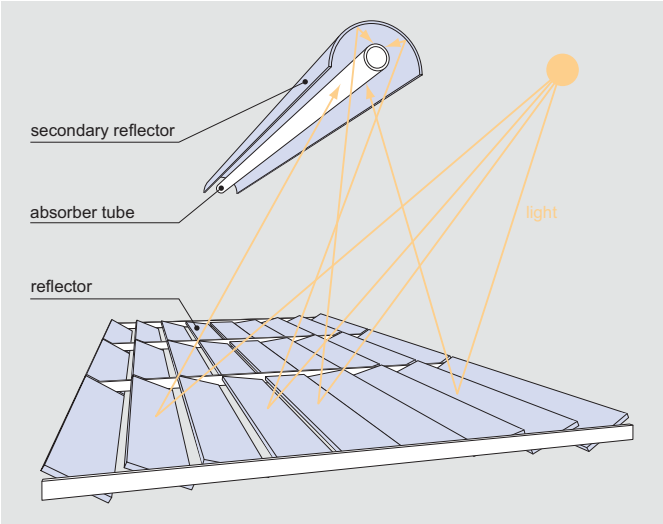
Linear concentrator systems

Parabolic trough plants

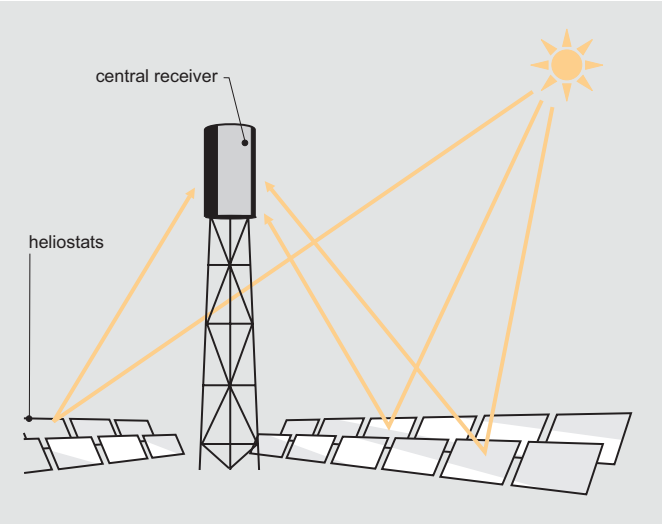
The solar field of a parabolic trough plant contains numerous parallel rows of collectors that comprise parabolic curved mirrors and concentrate sunlight onto an absorber tube that runs in a focal line, thus producing temperatures of about 400 °C. The heat carrier here is circulating thermal oil which absorbs the generated heat and creates steam at an approximate temperature of 390 °C in a heat exchanger; the steam is then used to drive a steam turbine and a generator is used to generate electricity as in conventional power plants. The principal share of solar thermal power generation in Spain is currently supplied by numerous parabolic trough plants each with a capacity of 50 MW, the majority of which have thermal storage for about seven hours of operation without the sun.



Operating principle of a parabolic trough collector.
Source: www.solarpraxis.de / M.Römer.



Operating principle of a Fresnel collector.
Source: www.solarpraxis.de / M.Römer.



Operating principle of a solar tower.
Source: www.solarpraxis.de / M.Römer.

Fresnel collectors

Long, only slightly curved, flat mirrors concentrate the solar radiation onto a fixed absorber tube, thus directly heating water to convert it to steam. In comparison with the parabolic trough, the investment outlay in terms of the reflecting surface is lower due to the simpler basic concept; on the other hand, the comparative annual efficiency is lower. Two Fresnel power plants with a total capacity of 31 MW have been put into operation in the Spanish province of Murcia.

Point concentrating systems

Solar towers

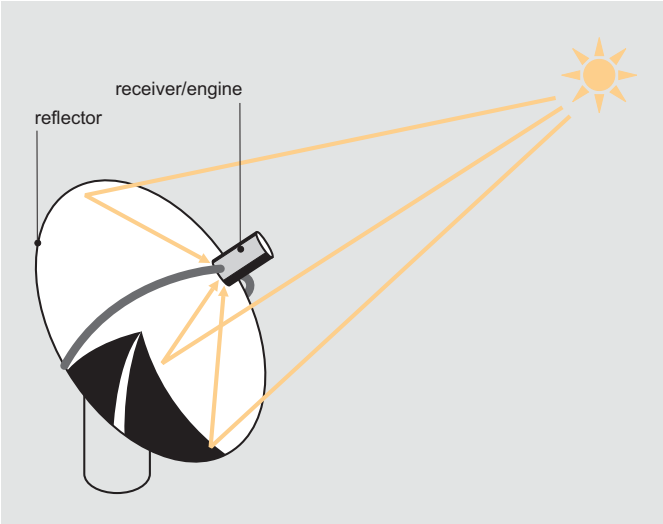
In solar tower power plants, the solar radiation from hundreds of automatically positioned mirrors is concentrated on a central absorber at the top of the receiver. The significantly higher concentration of sunlight than in parabolic trough collectors, for example, also allows for higher temperatures of more than 1,000 °C. This allows for greater efficiency, particularly when using gas turbines, and is therefore likely to lead to lower electricity costs.

Solar power tower in Almería.

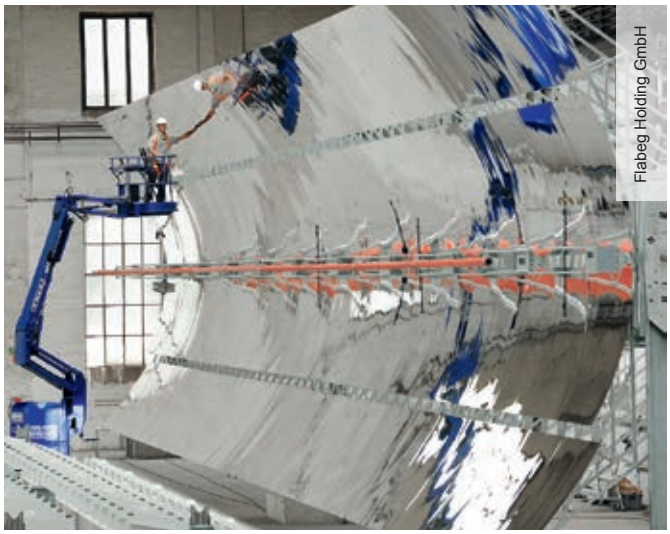
The first commercial solar tower power plant in Europe, the PS10, which has an installed capacity of 10 MW, was commissioned in 2007 in Seville, Spain; it was supplemented in 2009 with the PS20, a twin solar tower power plant of double capacity (20 MW). In mid-2011, the Gemasolar solar tower power plant was connected to the grid in the province of Seville. It has a capacity of 20 MW and uses a thermal molten salt storage system that allows for up to 15 hours of storage at rated power, thus providing electricity from solar energy around the clock during the summer months. In October 2013, a solar tower plant with a capacity of 420 MW went on the grid in the USA, and another with 120 MW is about to be commissioned.

Dish / Stirling systems

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 via mechanical power or electricity. Efficiencies of over 30 percent 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 ten kW to several MW.



Operating principle of a dish/Stirling system.
Source: www.solarpraxis.de / M.Römer.



Cologne, Germany: This new type of parabolic trough collector, "Ultimate Trough", was designed especially for large solar fields with an aperture area of 50,000 to 2,500,000 m². This photo shows the prototype being measured.

Competence of the German industry

Germany is the global leader in research into and development of this technology. As early as 1984 – 1991, German companies supplied the essential components – such as dishes and flexible pipe connections – for parabolic trough plants in California that are still in operation today, and have produced more than 17,000 GWh of electricity since then. Today, German manufacturers supply the core components for solar fields (for example, precision mirrors and solar receivers) and power-station units as well as the necessary measurement and control technology, and thus have a large share of the global market. Besides this, German companies and institutions have an internationally acknowledged reputation as technology consultants, certification bodies and experts.

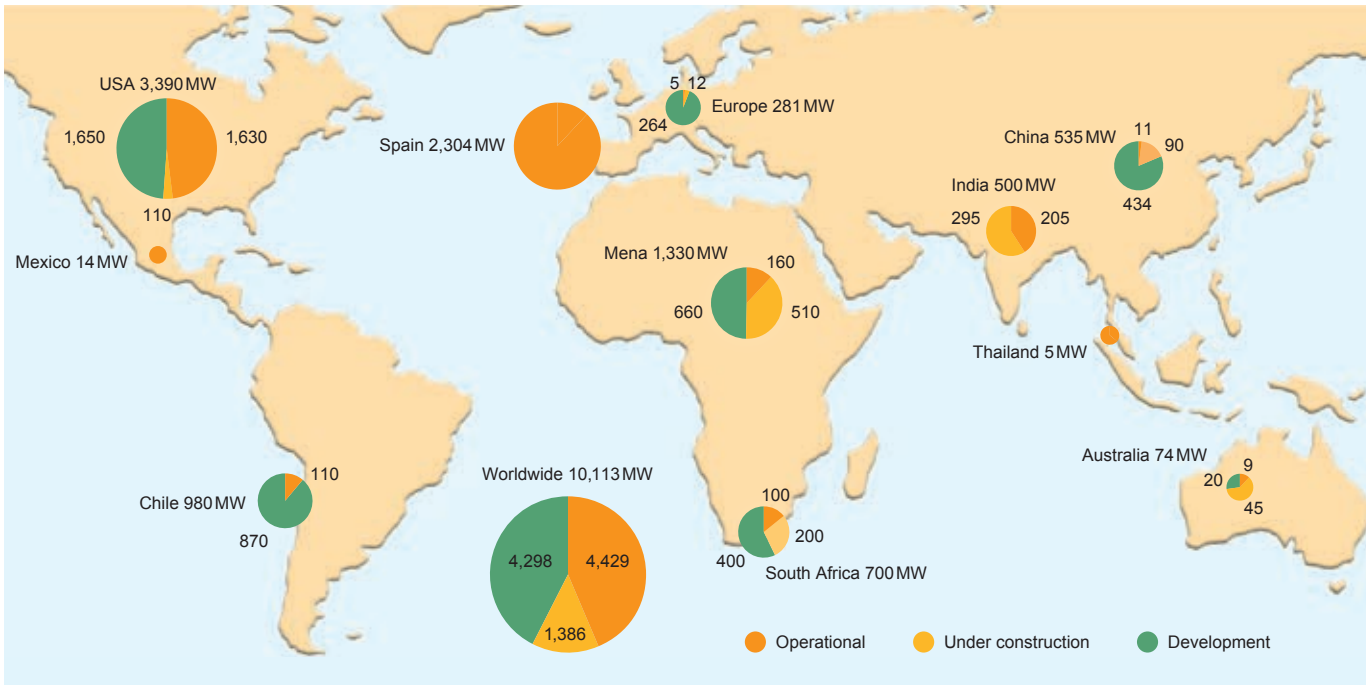
German research institutes and engineering companies are also involved in the construction and operation of various pioneering projects either in terms of project management or through shareholdings. For example, a solar tower power plant with an electrical output of 1.5 MW has been operational in Jülich, Germany since the end of 2008 (pictured above). It is operated as a prototype power plant and research platform in the light of the long-standing experience of German research institutes and companies. Air is used as the heat carrier in a volumetric absorber. It also uses a storage system to compensate for fluctuations in the insolation input. The experience gained from building and operating this prototype power plant will form the basis for further optimisation in future projects.

Commercial use

The economic viability of CSP depends very much on local factors. Natural conditions, market conditions, and access to project financing have a major impact on the success of the technology; for example, the use of solar thermal power plants makes the most economic sense in countries with particularly high solar radiation levels. They can also support the expansion of other renewable energy technologies, since their storage capability enables them to provide electricity on demand and thus offset the fluctuations from PV or wind turbines. They therefore play an important role in a commercially optimised energy supply system with a large share of safe and clean renewable energies.

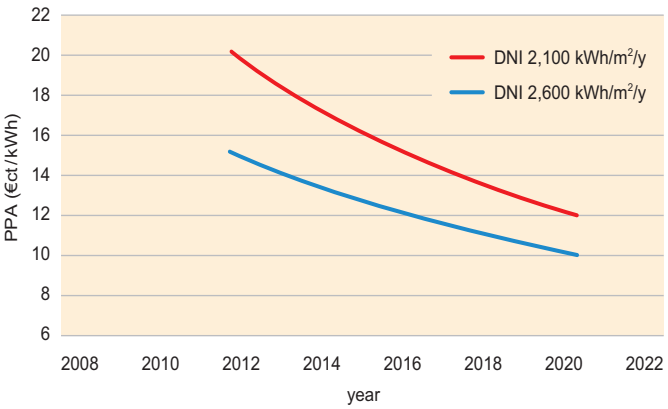
Due to relatively high electricity production costs, continued marketing of solar thermal power plant technology still relies on favourable general economic conditions or support mechanisms such as feed-in compensation, subsidies, or loan guarantees for initial investments, and/or fixed term purchase agreements for specific projects, as well as mandatory renewable energy quotas for utilities, where the long-term reliability of these conditions is essential.

Murcia, Spain: The 30 MW Puerto Errado 2 Fresnel power plant.



Overview of solar thermal power plant projects worldwide (as of the end of 2014). Source: Solarpaces 2015.

Required value of a 25-year Power Purchase Agreement (PPA) for a 150 MW, 4-hour storage, solar thermal electricity plant without any public financial aid and no escalation



Costs of solar thermal electricity plants are decreasing rapidly. In some countries they are already almost competitive while in Europe this will take place before 2020. The chart shows the required value of a 25-year Power Purchase Agreement (PPA) for a 150 MW, 4-hour storage, solar thermal electricity plant without any public financial aid and no escalation. The limits of the resulting price band correspond mainly to different Direct Normal Irradiation (DNI) values in kWh/m²/y.

Source: Estela (2012): The Essential Role of Solar Thermal Electricity.

The exact measures vary from region to region. In Italy, for example, a new support system was introduced at the beginning of 2013 to provide additional incentives for the implementation of CSP projects. The feed-in tariff is now calculated on the basis of the total collector area; moreover, utilities must also generate a fixed proportion of electricity from renewable energy sources. In detail, this means that compensation is graded according to the percentage of solar energy in the total power output. The more electricity from solar energy, the higher the compensation. South Africa also introduced feed-in compensation in 2013 which is considerably higher for peak times in the evening (by a factor of about three). South Africa is thus currently regarded as being one of the most attractive markets in the world for solar thermal power plants.

Outlook

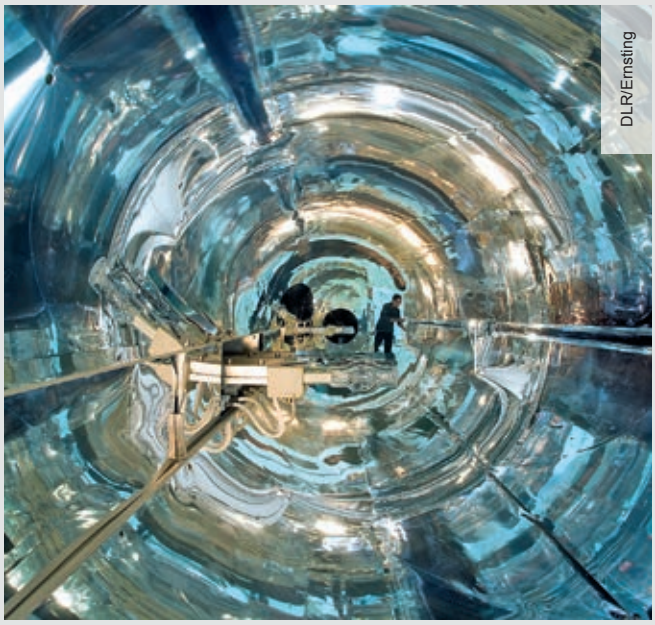
The International Energy Agency (IEA) estimates that the installed capacity will more than double by 2018, increasing from the current 4.4 GW to nearly 10 GW, owing to the building of solar thermal power plants. This positive global development in the expansion of solar thermal power plants is attributable to projects being extended into many countries and is accompanied by substantial cost reductions in electricity production prices of newly initiated power

Top performance for decades: Quality assurance for solar thermal power plants

Lowering electricity production costs is one of the prime goals of solar thermal power plant operators. High product quality and a a plant life that stretches into the decades are therefore becoming ever more important. Quality assurance measuring methods can help plant operators and manufacturers achieve this goal.

Solar thermal power plants consist of several components which have to be produced and assembled very precisely to achieve optimum performance and to continue running efficiently for decades in a desert climate. The key element is the solar field, whose mirrors have to be shaped and adjusted with precision to reflect the solar radiation onto the receiver in an optimum concentration. Small differences from the optimum concentration can quickly lead to serious technical and commercial losses.

In recent years, new methods and measuring instruments have been developed which can be used, for instance, to quickly and precisely control the exact mirror adjustment in the construction phase of the solar field with the aid of optical measuring processes. By the same token, the efficiency of the receivers (for example, the absorber tubes in parabolic trough power plants) in converting solar radiation into high-temperature heat can now be measured quickly and precisely. This development in methods is also important for the introduction of industrial standards in this technology, which is still relatively young. Another current field of work is the development of measuring methods to test the long-term wear resistance of components in solar thermal power plants, which are often under adverse operational and environmental conditions.



At the DLR Institute of Solar Research QUARZ Centre in Cologne, the performance of receivers and mirrors for solar power plants are tested. The ElliRec test bench in the Test and Qualification Centre (QUARZ) simulates sunlight using lamps and tests how well the absorber tubes can convert this light into heat.

In recent years, German research institutes and companies have played a leading role in these areas of work on an international scale. One example is QUARZ, a qualifying centre based in Cologne-Porz, Germany, which was set up with the help of funding provided in part by the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety, and which today offers a wide spectrum of quality assurance measuring methods for many partners and clients from industry and science.

plant projects. Within the next five to ten 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).

One of the most promising future markets, for example, appears to be the Arabian Peninsula. There are plans to build solar thermal power plants with a total capacity of some 25 GW in Saudi Arabia by 2040. Other large-scale projects are currently being implemented in Abu Dhabi, Dubai and Kuwait.

Current developments in Europe have been significantly affected by the economic crisis, which has caused drastic retroactive cutbacks in feed-in tariffs, especially in Spain, an important market for the solar thermal industry. At the end of 2014, Spain boasted 2,300 MW, the highest installed capacity in operation worldwide at present. The largest active market is currently found in the USA. Further expansion is taking place in other regions and countries, and by 2018 nearly 10 GW are likely to be in operation around the world.

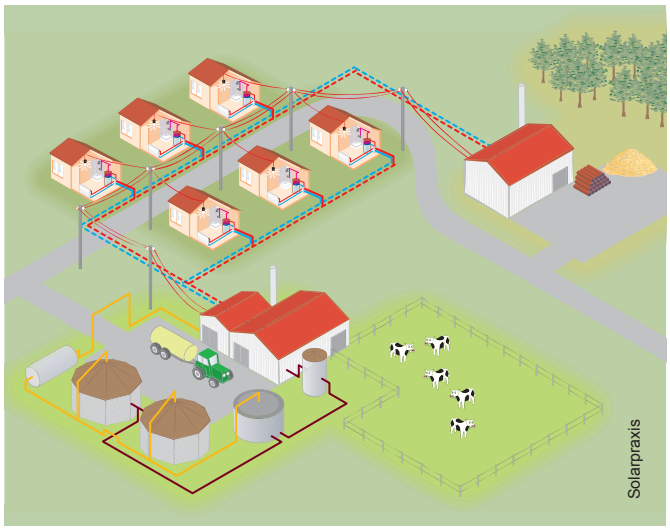
With an annual output of around 15 million standard cubic metres of biomethane, the Könnern biogas park is one of the largest biomethane plants in the world.

Biogas

Biogas occurs when organic material is digested by micro-organisms in the absence of oxygen. Biogas, often called Anaerobic Digestion (AD), is a technology that is widely used the world over for energy generation. The scope of applications range from small home-digester technologies to commercial biogas plants and encompasses a huge range of organic input material.

This chapter focuses on commercial-scale AD plants. Biogas is usually burned in Combined Heat and Power Plants (CHP) to generate electric energy and heat. Other opportunities include direct heating in boilers and the use of biogas as vehicle fuel.

Thanks to their high-quality products and services, as well as their many years of experience, German biogas companies are both market and technology leaders.



Unlike natural gas, biogas can be generated close to the end-consumers. Farmers can also sell biogas to open up a further source of income for agricultural products.

Technologies and applications

The production of biogas

Input

Biogas can be produced from a wide range of organic materials; typical input materials are:

- Agricultural wastes and residues, including manure, dung, leaves of fruits or fruits of low quality
- Industrial residues or organic by-products
- Municipal or household waste and residues
- Energy crops.

Fermentation of the organic substance

The fermenting process of the organic substance in the absence of air involves various anaerobic bacteria. Their composition depends on the organic source materials and the specific conditions of the process (temperature and pH level). The microbiological processes that occur during fermentation are a decisive factor in the productivity of biogas plants.

Agricultural biogas plants can use liquid manure, agricultural residues, organic waste, residues from industrial production (process water, wastewater, process residues) and energy crops as a fermentation substrate. Using liquid manure for energy in biogas plants reduces the climate-damaging methane emissions that result from open liquid manure tanks. To increase gas yields, more renewable sources such as maize, grasses, cereal crops and many other energy crops such as sunflowers, Sudan grass, sugar beets, fodder beets, sweet sorghum etc., are being used. Additionally, industrial plants process wastewater in addition to waste from food production, such as food residues and grease residues.

The production of biomethane from residual materials and waste avoids competition with food production in the use of materials.

Configuration of a gas analysis system.

Very little construction work is required for the mobile Güllewerk biogas plant rated up to 120 kW.

Composition of biogas

The extracted biogas is a mix that consists primarily of the following components:

- 50 to 75 percent methane
- 25 to 45 percent carbon dioxide
- Small amounts of water (2 to 7 percent)
- Trace gases such as hydrogen sulphide, oxygen, nitrogen, ammonia and hydrogen.

In addition to biogas, a highly effective fertiliser (digested sludge, often called digestate) is produced. This digestate is a mix of water, mineral components and decomposed organic substances. In the area of agriculture, fertiliser can be used to help cultivation, for example, when growing fruit, crops or energy crops, to enable a large harvest.

Areas of use

Generation of electricity and heat (CHP)

The stationary use of biogas in combined heat and power plants for generating power and heat 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 rural settlements that are off the grid. The waste heat can be used in heating, drying or the operation of refrigeration machines. It can also be utilised in downstream systems for additional power generation.

Biogas upgrading and feeding of biomethane into the natural gas grid

Biogas can be upgraded to natural gas quality. By separating methane from the other gaseous components (mainly carbon dioxide), nearly any gas quality can be adjusted. The product, called biomethane, can be used at the location or fed into the natural gas grid. The main advantages are that biomethane, like natural gas, can fulfil all utilization options. It can be used as vehicle fuel, transported to the location where the consumer is (especially advantageous for CHP utilization) and stored in the gas grid (to react to seasonal variations of energy consumption and gas supply).

To upgrade biogas, several technologies are available: water scrubbing, amine (or other organic solutions) scrubbing, pressure swing adsorption, membrane separation and other technologies (such as cryogenic separation).

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.

In Germany, there are currently about 160 feed-in plants in operation, with 15 projects planned or under construction. 119 biogas filling stations are in operation and a further 170 filling stations (approximately) offer a blend of biomethane and natural gas.

More than 80 municipalities in Germany already rely on ecological, cost-saving natural gas to fuel their buses.

Use in the mobility sector

To use biogas as vehicle fuel it must (or should) be upgraded to biomethane quality (at least if the motor is designed to use natural gas and not adapted to biogas). Biomethane used as fuel offers:

- Climate-friendly fuel production
- Less agricultural fields needed compared to bioethanol and biodiesel production
- Reduced dependency on fuel imports (enhanced security of supply)
- Emission reduction compared to diesel and petrol motors.

In Germany, the proportion of biomethane in natural gas used as fuel rose from 2 percent in 2010 to 20 percent in 2013. Currently, about 100,000 CNG/CBG vehicles, which are potential biomethane customers, are in operation. More than 80 municipalities in Germany already rely on ecological, cost-saving natural gas to fuel their buses. Pure biomethane can be found at approximately 170 natural gas filling stations in Germany.

Competence of the German industry

Germany has decades of experience with commercial-scale biogas plants. Currently, there are about 8,000 agricultural biogas plants in operation. Germany is the most experienced country in biogas operation in the world, the biggest biogas producer and is home to the largest number of companies offering complete biogas plant solutions, components or biogas know-how. German companies offer best-adapted technology for each location (and the best available biomass) and biogas utilization (including biogas upgrading to national gas quality).

German companies in the biogas industry cover the entire value chain of biogas technology – from planning and financing to the operation and maintenance of biogas plants and the feed-in of biogas into the natural gas grid – and have many years of experience in process biology and its associated laboratory services. Sophisticated products are also available in the fields of combined heat and power plants, storage and tank systems and biogas analysis technology. German companies also play a pioneering role in the growth market of biogas feed-in, and have positioned themselves with efficient technologies in the individual stages of the biomethane value chain.

The export quota of the German biogas industry amounted to around 45 percent in 2013. Thus German production accounts for more than half of the total European energy extracted from biogas. By the end of 2014, around 7,944 biogas plants with a total installed capacity of around 3.7 GW of electrical power were in operation in Germany. They generated around 27,000 GWh of electricity, supplying around 6.8 million households. In May 2014, 151 biomethane plants were already feeding gas into the German grid.

Commercial aspects

Biogas plants offer several potential sources for income. Usually the generated energy (electric power, heat or fuel) is sold or the producer's own energy demand is covered (which leads to lower fossil energy costs for e.g. a factory). In most cases, CHP operation offers the best economic value but, depending on the local circumstances, vehicle fuel could be an attractive option.

Another source of income in cases of waste treatment plants can be a gate fee for waste treatment. The possibility of obtaining CO_2 certificates should be looked into. Usually not sellable but connected with economic value are fertiliser production, odour (smell) reduction or emission reduction (e.g. in case of open lagoon storage).

The costs for biogas plants are the investment costs. Annual costs are typically capital (often 30 – 60 percent of annual costs), operational costs and often costs for the biomass as input material (could be up to 40 percent of the annual costs).

Incentive schemes

A strong driving force behind the expansion of biogas production in the European Union is the EU goal of achieving a 20 percent share of renewable energy in end energy consumption, as well as the provisions of EU Directive 2008/98/EC on the processing of waste. Additional political motives for supporting biogas development include reducing greenhouse gas (GHG) emissions (by reducing methane emissions from the storage of organic material and by the substitution of fossil fuels), reducing dependency on fossil fuel imports, creating jobs, especially in rural areas, supporting the development of a new market (to stimulate sales and taxes) and developing rural electrification.

Based on these political targets, many countries have introduced incentive schemes for the production of electricity from biogas, such as feed-in tariffs for electricity from biogas, green certificates, invitations to bid or subsidies.

Feed-in compensation

In Germany, for example, the basic conditions created by the Renewable Energy Sources Act (EEG) have proven to be a particularly effective growth engine for the young biogas industry. The EEG ensures that priority is given to electricity from renewable sources when it is fed into the public grid and that the feed-in tariff for the electricity is guaranteed for 20 years. In this feed-in tariff model, security for the investors is a crucial success factor. The EEG is not a subsidy because no government money is spent; the feed-in tariff is financed by all consumers of electricity.

Opinion panel

"With over 800 biogas plants constructed worldwide, each of our projects has the advantage of our experience. The same high standards of quality apply to our international projects as to our national construction projects. We also aim for this in our after-sales service. Comprehensive services in the Service, Repowering and Expansion sectors lay the foundations for the safe and efficient operations of our plants, well beyond the planned service life."

Gernot Buchta, Head of Marketing and Product Management, agriKomp GmbH

The feed-in tariff is defined by the biomass used and the size of the plant. The EEG amendment of 2014 adopted separate regulations for the fermentation of biological waste and small agricultural liquid manure plants (power class 75 kW). In order to make electricity generation more flexible, remote-controlled plants receive a bonus for each kilowatt of installed capacity. The amount of new built plant capacity each year is capped. Step by step, new plants with an installed capacity of 100 kW or more will be required to sell electricity through direct marketing as part of the market premium model. The premium model is intended to motivate generators to operate their systems in a market-oriented manner. This means that the plant operators are to increase feeding-in of green power at times when demand, and, as a result, prices on the exchange, are particularly high.

Quota regulation

Alternatively, the expansion of renewable energy generation from biogas can also be stimulated by means of quotas (e.g. for electricity, heat, biofuels). The quota regulation obliges energy suppliers to provide proof that they have supplied a fixed share of renewable energies to their end customers. This is proved by green certificates, which the energy supplier must acquire. In Europe, the quota model is currently being used in Belgium, Sweden, Norway, Poland and Romania for electricity. Sweden and Norway have been doing a joint trade in certificates since early 2012 – the first common market of this kind for renewable energies in Europe. A quota for vehicle fuels is in force in some European countries.

Outlook

All over the world, biogas can make an important contribution to achieving a secure supply of low-priced energy and lead to environmental benefits. Unused residual biomass materials and waste have great potential as input materials. At present, large quantities of suitable raw and residual materials are disposed of instead of being used. Energy crops also have interesting potential. The focused cultivation of certain plants for energy extraction (e.g. energy plants such as maize, grass, rye) can change entire landscapes. For this reason, there is a need for legal frameworks that steer this activity in the direction of sustainable development.

The possibility of processing biogas into natural-gas-quality biomethane is opening up new perspectives in the use of biogas in centralised and decentralised stationary plants for generating electricity and heat, as well as in the mobility

sector. In this latter case, biomethane has a considerable advantage in that adding any amount to natural gas is classified as harmless and is thus not subject to limits, unlike conventional biofuels. In this way, the natural gas grid can help bridge seasonal fluctuations in electricity supply from solar and wind power plants.

In order to achieve higher electricity yields than a CHP plant, German companies are also using biogas in fuel cells, which can turn the chemical energy of processed biogas directly into electricity. The technology is not yet widespread, but has the advantage of producing very little noise while being capable of achieving an electrical efficiency of up to 50 percent.

Environmental advantages of fermenting biogenic waste for energy extraction

Waste-to-energy describes the process of turning waste into energy, usually by incineration. However, fermentation of biogenic waste, for instance, can also produce valuable energy in the form of biogas. Using waste for energy extraction offers several environmental advantages for market players:

- Otherwise untapped residual materials are put to sensible use.
- Environmental regulations (for example, the ban on ocean dumping) can be complied with.
- An upstream fermentation stage can enhance the utilisation of the input materials in an ecologically efficient manner with existing composting plants in the form of a cascade system.
- The fermentation process can considerably improve the environmental balance of certain plants by establishing technical solutions for reducing emissions (e.g. odour and noise) – which are often already included in new plants – as well as increasing energy recovery and thermal output.
- The environmental benefit is even greater with the digested sludge used (for example, as fertiliser) after fermentation.

Environmental impact of biogas production

Biogas operation affects the environment in several ways. One of the main political motives for supporting biogas is GHG emission reduction. If organic materials (e.g. manure, organic effluents of industrial processes) are stored, methane emissions usually occur (methane is about 25 times more GHG-effective than carbon dioxide). By processing the material in a biogas plant, these emissions are avoided. The energy produced can substitute fossil energy, meaning that additional GHG emissions are reduced. The output of the plant (called digestate) can be used as fertiliser. As a result, synthetic fertilisers can be substituted (GHG reduction) and higher crop yields can be achieved. In low input farming systems, the fertilising effect of biogas can lead to higher crop yield and result in new opportunities for crop production. In several cases, new crop rotation options lead to higher biodiversity.

There are other environmental aspects: odour (smell) emissions are reduced; seeds are deactivated (less work on the fields needed); pathogen microorganisms are reduced. In some countries, the main motive for biogas is that local homes get a pure burning fuel (to avoid smoke from burning wood). If biomass is processed in a biogas plant instead of leaving it on the fields (e.g. in the case of clover grass in organic farms without animals,) the washing out of nitrate and air emissions of nitrous oxide are reduced.

Of course, biogas could also have possible negative environmental effects. If waste is treated, the material should be sanitised to avoid growing pathogen bacteria. The heavy metal content of the digestate should be controlled. If energy crops are used, the concurrency of food and fodder production should be considered. A number of additional security standards (explosion protection, emission control, and other) should be observed.


iStockphoto / zanskar

The Viessmann Vitoflex 300 is a highly efficient wood-burning system that can be operated with a flat moving grate, step grate, direct firing system or special-purpose furnace according to customer requirements.

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. Biomass for cooking and heating is the most important energy source in many parts of the globe. Total primary energy demand from biomass in 2014 was approximately 16,250 TWh. Its contribution to global energy supply is equally significant compared with other renewable energies. In 2014, solid biomass accounted for 80 percent of the world's heat supply from renewable energies and 75 percent of its electricity supply.

Solid biomass includes all dry and dried single items or bulk goods made from plants and parts of plants. For example, they may be stored in the form of wood pellets or wood chips, making continuous heat and electricity generation possible based on requirements.

In Germany, solid biomass has traditionally been used to provide room heating and hot water, and with 83.7 TWh in 2014, makes up the greatest proportion of the heat supply from renewable energy sources. When the Renewable Energy Sources Act (EEG) first came into force in 2000, electricity generation from biomass gained importance in Germany. In 2014, around 48.8 TWh of electricity was produced from biomass, which equates to around 9 percent of Germany's electricity supply.

Technologies and applications

When you burn solid biomass in modern heating systems, the energy locked into the biomass is used very efficiently. The predominant source of energy is wood in the form of firewood, wood chips and pellets. Ovens and boilers fed manually, partly or fully automatically with electronically adjusted firing systems have been developed and contribute to a combustion process free from harmful substances, with particularly high efficiency factors of over 90 percent.

Solid biomass is also used to generate electricity in combined heat and power (CHP) plants. Any waste heat that arises during electricity generation is used, and supplied, for example, as heat in local and district heat grids or made available to industrial processes in the form of steam or heat. It can also be used to produce cooling, if required, for industrial purposes, for cold storage or for air conditioning in buildings.

Solid biomass is also suitable for gasification as well as burning. Fixed beds, fluidised beds and entrained gasifiers can be used depending on the characteristics of the combustion materials and the capacity of the plant. The resulting wood gas can then be used in combustion engines or gas turbines to produce electricity with high electricity efficiency. Total efficiency can be enhanced significantly through the use of waste heat using CHP.

Stela low-temperature belt drier for drying wood chips.

Competence of the German industry

Thanks to continuous further development of German engineering, the technology for the utilisation of solid biomass is characterised by high reliability and is ideal for customers' tailored solutions. To this end, German companies supply highly efficient and world-leading technologies

in all performance categories. For example, modern stoves are offered for heating single rooms or for preparing hot water, combustion plants for supplying heat to single or multiple family dwellings, and biomass boilers for supplying heat efficiently to several properties and/or industrial processes. Modern wood-burning stoves from German manufacturers in particular boast efficient combustion technology and low emissions. Intelligent and user-friendly control and management technologies are among the strengths of German providers, particularly in the area of small-scale firing systems, for example, networking with smartphones and developing convenient automatic feeding systems. As a result, relatively high efficiency levels are achieved and emissions are significantly reduced.

Highly efficient combined heat and power plants that run on biomass and were developed in Germany lead the world in this technology. German developers and providers offer the latest plant in above 10 kW performance range. In the last few years, German companies have helped to develop wood gasification to market maturity and now have the greatest experience in this highly efficient technology for generating electricity from solid biomass, with an estimated 500 plants in operation worldwide.

Commercial use

The use of wood as a source of energy continues to be most widespread in heavily wooded and agricultural regions. This is because of the ready availability of wood as a resource, on the one hand, and the lack of cost-effective heating supply concepts on the other. The increased volumes of waste wood for generating electricity from biomass has also established itself in densely populated areas. The transport and storage of solid biomass across large areas and in different periods has become economically feasible as wood can be dried and compressed in the form of pellets. There are very minor regional price differences in Germany, if any.

The interest in biomass heating has increased greatly in many regions thanks to rising oil, gas and electricity prices. The use of wood as an energy resource for the provision of heating and hot water is a cost-effective alternative to fossil-fuel applications.

Wood pellet boilers may be used to generate heat in single or multiple-family dwellings and in business premises. It is also possible to combine them with solar panels for hot water production or for additional heating.

Incentive systems

Investment subsidies and cheap loans have proved effective in promoting new biomass heating systems in Germany despite the higher procurement costs of the technology for storing and supplying the fuel and the boiler. Setting a minimum proportion for supplying energy from renewable energies in the building sector may also prove to be an effective regulatory measure for promoting the use of renewable energy. In Germany, for example, such a minimum share has been set at national level since 2009 in the Renewable Energy Heat Act (EEWärmeG). The enormous growth in the market for local energy generation from solid biomass in Germany has been made possible by the Renewable Energy Sources Act (EEG), which guarantees statutory payments for supplying electricity generated from renewable energy sources in the long term.

With the tightening of CO_2 certificate trading in the EU, the co-incineration of solid biomass in combined heat power stations can present an economic option to avoid the purchase of CO_2 certificates. However, if you look at the certificate prices from 2014 – less than 8 €/tCO_2 – co-incineration is generally not that interesting financially. In several European states, such as Belgium, Holland and the UK, co-incineration of biomass is promoted and accounts for a significant proportion of the electricity generated from renewables.

Given the rising prices for fossil fuels, wood continues to represent a very good alternative.

Outlook

Rising energy prices have led to an increasing number of private individuals, municipalities and companies considering the use of biomass as an energy source. The rapid growth of the global biomass trade has made it possible for many European regions to further expand the use of 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 tightered in many regions, efficient combustion technology with low emissions has continued to gain 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. The political measures are supported by several European funding programmes for researching efficient and sustainable biomass technologies and concepts.

Research is also being carried out, in particular, on other processes for the separate use of the individual elements of biomass. For example lignin, a component of wood, can be removed using the Lignoboost process.

Sustainability criteria for the provision and use of biomass

The increased use of solid biomass for energy generation is also increasing the importance of introducing and adhering to sustainability criteria. Since February 25, 2010, the European Union has had recommendations for sustainability criteria concerning the use of solid or gaseous biomass for electricity generation, heating and refrigeration. The recommendations and directives of the European Commission [Directive 2009/28/EC; COM(2010)11] contain the following sustainability aspects:

- Protection of ecosystems with great biological diversity and high carbon stocks
- Efficiency in energy conversion
- Social aspects
- Reduction of greenhouse gases.

The protection of ecosystems means, that on the one hand, biomass may not come from areas which evince a high level of biological diversity, were designated as nature conservation areas or are old-growth forests. On the other hand, deforestation and excessive removal of forestry residues as well as tree stumps should be prevented with regard to woody biomass. There are voluntary certification systems for checking sustainability in forestry.

When biomass is used to produce electricity and heat, the efficiency can potentially be increased (efficiency in energy conversion). That is why the European Commission recommends that the Member States promote highly efficient levels of conversion in particular such as combined heat and power, when producing electricity and heat from biomass.

With regard to the social aspects of using biomass to generate energy, no binding criteria have yet been defined. The European Union, however, has regularly reported on the effects on food prices, land-use rights and adherence to international labour standards since 2012. To protect the interests of local populations in developing and newly industrialised countries, the European Union suggests corrections if appropriate.

Reducing greenhouse gases is of prime importance when woody biomass is used to produce electricity and heat. The report COM(2010)11, taking its orientation from the sustainability criteria in the Renewable Energy Directive of 2009 (EU Directive 2009/28/EC), suggests both a method for calculating greenhouse gas emissions as well as criteria for reducing greenhouse gases. According to the report, the greenhouse gas emitted in the use of biomass for producing energy should be at least 35 percent less than a fossil fuel reference value. In 2017, the reduction of greenhouse gases should rise to 50 percent and from 2018 even amount to 60 percent for new systems. Unlike conventional sources of energy, the method of calculating greenhouse gas emissions suggested by the EU prescribes an entire life cycle analysis for using biomass to generate energy. This means that all greenhouse gas emissions from cultivating, harvesting and producing the biomass, the subsequent processing of woody biomass into a source of energy (for example, wood shavings into pellets) are taken into consideration, as well as emissions arising from the transport and distribution of woody biomass/energy sources.

In order to enable high proportions of renewable energy to be successfully integrated into the power supply system, various areas of the conventional energy system must be rebuilt and the generation, storage and distribution of electricity, as well as the demand side, must be coordinated.

Storage and grid technology

The development of renewable energy generation in the field of electricity helps to reduce both CO_2 emissions and our dependency on energy generation from imported natural resources. For the integration of high levels of fluctuating feed-in from photovoltaics and wind energy plants, substantial changes to the value-added chain in the areas of energy generation, transmission, distribution, storage and consumption of electric power are required.

Compared to other countries, German companies have a great deal of practical experience and innovative products.

Technologies and applications

A large number of storage and grid technologies can be used for the optimised integration of renewable energies. A selection of essential technologies is presented in the following:

Improved efficiency of transport networks and grids

In the area of transmission networks in Europe, the goal is to significantly increase transmission capacities and connect wide-ranging areas to one another. This should open up potential for both renewable energies and storage capacities over wide areas.

In addition to classic 380 kV three-phase overhead power lines, alternative transmission technologies for boosting the grid are available. For example, high-voltage direct current (HVDC) transmission is primarily suited to the transmission of high levels of power over long distances as well as to the connection of off-shore wind parks. Using high-temperature conductors, the transmission capacity on existing lines can be increased. Overhead line temperature monitoring enables much higher load capacities for the operation of conductors by monitoring the temperature of overhead lines in the relevant weather conditions (low temperatures and wind). As a result of this technology, the lines can even be operated above their nominal outputs in normal conditions, which may reduce the demand for further expansion of the grid.

In addition to expanding the grid with new power lines and new grid technologies the workload can be better distributed across the existing transmission capacities in the transmission network using reactive power management. This can be achieved through modern power electronics technologies such as flexible AC transmission systems (FACTS).

At the distribution network level, 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 for expanding the grid while maintaining a high level of installed generative power (from photovoltaic systems, for example).

Further development of the grid-compatible / grid-interactive behaviour of decentralised energy plants

The increase in renewable energies creates a shift from electricity supply at the highest voltage level being generated mostly by generators to a system that is increasingly fed through decentralised plants by means of inverters at the level of the distribution networks. These plants can and must contribute to the security of supply and stable grid operation. The following are some of the technological solutions relevant to this goal:

Fault-Ride-Through capability keeps decentralised energy plants from being immediately disconnected from the grid in the event of a grid fault (and thus possibly further destabilising the grid), but rather remain available for a certain time even in the event of a fault to support the system.

Harmonics impair the quality of the power in the grid and can thus disrupt the operation of sensitive consumers. Installing filters at the grid connection point of the decentralised energy plants can reduce harmonics and thus improve the quality of the power supply.

A voltage regulator is necessary, particularly if decentralised energy plants are connected to grids which have already reached the limit of their capacity. Thus it represents a complement to expanding the grid. The voltage at the connection point can be influenced by a reactive power supply. This requires inverters which can help support the

Battery banks of a 1.5 MWp PV diesel hybrid project in Senporna, Malaysia. Battery storage: 6.8 MWh.

Geesthacht, Germany: The Geesthacht pump storage station on the Elbe River has been covering the electricity demand at times of peak load and as an emergency reserve in the event of blackouts since 1958. Renewable electric power from a 500 kW wind power plant and a 60 kW photovoltaic system pump the river water up a slope into an artificial reservoir.

power at the respective grid levels of the distribution network by supplying controllable reactive power. In the process, inverters can be designed so they can help to support the network even when no active power is being supplied (for example, photovoltaic plants at night).

If a large portion of power is no longer generated by conventional power plants but by decentralised energy plants connected to the grid by inverters, then rapid changes in frequency must also be attenuated (which otherwise would be attenuated by the inertia of the rotating masses in the generators of a conventional power plant complex). To do so, it is possible to use the power electronic system of the inverter for grid feeding in a decentralised energy plant to imitate the slowing function of an electromechanical synchronous generator.

Use of electricity storage and load management

As the share of renewable energies in the electricity supply increases, the flexibilities provided by storage capacities and load management take on greater importance. Important tasks related to power storage include balancing the fluctuations in power generation and demand, the provision of ancillary services to replace conventional power plants that are less frequently used, the assimilation of excess power output from renewable energies and bridging low periods of regenerative power generation. Various storage technologies can be distinguished (see the illustration “Classification of energy storage technologies”).

Pump storage stations

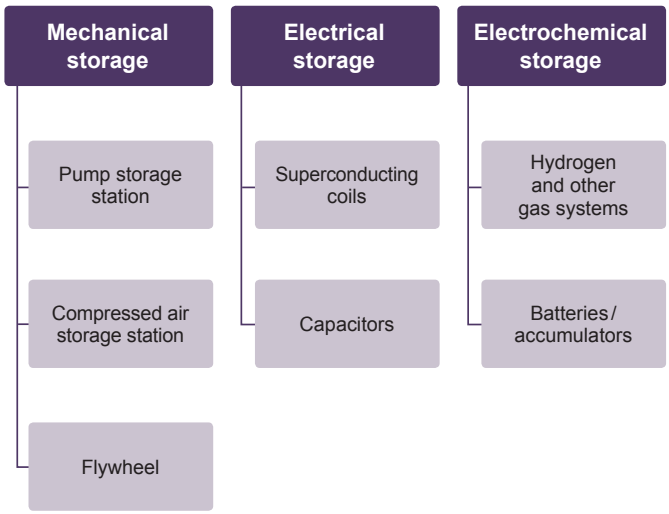
With an efficiency of up to 80 percent, the pump storage station is currently the only economical energy storage option for hourly and daily compensation that is available on an industrial scale and is likely to remain so for the foreseeable future. There is currently no technology that has such a long service life and has been tested and distributed to a comparable level that is as flexible to utilise and is able to make a substantial contribution to the security of supply. Volatile electricity generation can provide assured power in combination with pump storage stations and thus help reduce CO_2, since the need for conventional power station reserves is sinking.

Compressed air and liquid air storage

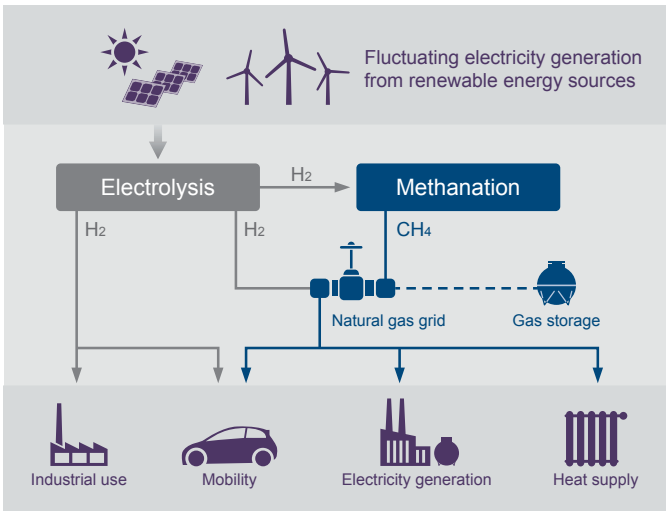
Compressed air storage plants use excess energy, such as energy produced from volatile renewable energy sources, to compress air, which is then stored in underground chambers. When electricity is required, it is produced in a gas turbine using the compressed air. An alternative to the underground storage of compressed air is to liquefy the air. Cryogenic liquefied air can be stored in tanks above ground with high density at ambient pressure. To reconvert it to electricity, the air is pressurised with a pump, vaporised and depressurised in a gas turbine.

Electrochemical storage

Batteries are especially well suited to the storage of electrical energy. These batteries consist of galvanic elements that generate voltage through a combination of two different electrodes and an electrolyte in an electrochemical process. 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: home



Classification of energy storage technologies: overview of the various options for storing electrical energy. Source: www.powertogas.info/power-to-gas/spartenuebergreifende-systemloesung/rolle-von-stromspeichern/.



Power to gas value-added chain. Source: dena (2013).

storage devices which store self-generated solar power and ensure a supply at need. Large batteries in the multi-megawatt range are becoming increasingly important. They provide ancillary services such as frequency and voltage maintenance or black-start capability within a few milliseconds and thereby ensure grid stability and security of supply despite fluctuating feed-in from wind and solar power sources. Especially suited electrochemical storage devices are lead-acid, nickel-cadmium, sodium-sulphur, lithium ion or vanadium redox flow accumulators. However, there are substantial differences with regard to energy density, efficiency, operating life and cost of the system. The accumulators mentioned above achieve efficiencies between 57 percent (nickel-cadmium) and 98 percent (lithium-ion).

Power to gas

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 by the various areas of application. At need, it is converted back into electricity. By the same token, the hydrogen can be used directly, for instance, in the mobility sector. Power to gas is thus a cross-system solution for integrating renewable energies into the energy system. Power to gas can help lower CO_2 emissions in various consumer sectors by using the gas renewably generated by the power-to-gas method to replace the fossil fuels used as energy carriers in mobility, industry, heat supply and electricity generation. Power to gas can also be used for electricity storage to help balance the increasing fluctuations from wind and solar energy in electricity generation or to enable the long-term use of electricity which cannot be directly integrated into the electricity grid at times of especially high renewable generation. In comparison to other storage technologies, the power-to-gas system solution offers a considerably higher storage capacity and can, moreover, also be used for seasonal energy storage.

Load management

With the growing share of renewable energies comes the need to utilise flexibilities in relation to demand in order to balance fluctuations in the generation of energy. In the industrial sector, shiftable loads can be harnessed at a comparatively low cost by using existing measurement and control solutions together with process and automation technology in order to respond to the situation with regard to supply on the electricity market. The same results can be achieved in private households by using smart meters in combination with building automation technology, controllable devices and time-of-use tariffs.

Competence of the German industry

Compared to other countries, German companies have a high level of practical experience and necessary innovations in the area of storage and grid technology. With an installed capacity of approx. 38 GW from photovoltaic systems and approx. 40 GW from wind energy plants in 2014, the share of renewable energies generating electricity in Germany amounted to 27 percent in 2014. Despite this high degree of integration of renewable energies, it was still possible to operate the power supply grid securely and reliably.

Opinion panel

"An intelligent energy management system - micro-smart grid - provides integrated networking and management of electricity generation, storage, e-mobility and other local electrical loads and is the basis for linking autonomous domestically-generated electricity with the power grid. We at asola consider ourselves consultants and service providers; designing, configuring and installing micro-smart grids according to customer specifications."

Erich Klosterkamp, CEO, asola Technologies GmbH

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

- Increasing the efficiency 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 for ensuring a stable and secure grid operation
- Development, use and optimisation of storage systems to balance fluctuations in residual demand, to make balancing control energy and other ancillary services available, to avoid blackouts and to maintain a safe-guarded energy supply, as well as to absorb the occasional significant surpluses caused by renewable energies and balance longer slack periods in the long term.

Commercial use

An essential condition for enabling the use of grid technology is the creation of binding grid connection regulations and standards. The goal is to create a secure foundation for investment decisions. This offers the basis for considering when it is necessary to expand the grid in order to enable enhanced integration of renewable energies and when grid expansion can be complemented or even rendered unnecessary by the use of intelligent equipment. Intelligent equipment requires the installation and operation of control and regulation technology, which increases the complexity of operation. Thus in order to find an economically viable solution, both the investment and the operating costs for all possible options must be assessed.

In addition, it will be necessary to ensure that the most efficient technology is also the most competitive through changes in market design. This is the only way to successfully avoid damage to the economy and continue to ensure a affordable supply of energy.

Outlook

The worldwide demand for storage and grid technology is rising. For instance, the European Union has set itself the goal of achieving a Europe-wide market penetration of 80 percent for the use of smart metering by 2020. An expansion of storage systems is part of the energy goals of some US states, such as California, Hawaii and Montana. China is planning, among other things, to increase its solar capacity threefold to 70 GW installed power by 2017.

Storage and grid technologies are absolutely necessary for a regenerative energy supply with a constant level of supply security. Essential drivers for the use of these technologies are:

- An increasingly volatile electricity feed-in by way of inverters
- The shift of generation to the distribution network level
- The growing distance between generation and load.

These drivers are especially applicable to the development of energy supply in Germany. Current forecasts are assuming an expansion of installed power from photovoltaic systems in Germany of approx. 38 GW in 2014 to approx. 60 GW in 2034. The installed capacity of onshore wind power plants is expected to reach approx. 72 GW in the same period. This means an increase in the volatility of feed-in as well as a further shift of generation to the level of distribution networks. The growing distance between the place and the different times of generation and the place of consumption is leading to increased demands being placed on the transport capacities of the power grid.

At the present time, the possibilities of using modern information and communication technology for an intelligent control of the electricity grid are being tested in Germany in a wide variety of research and model projects. In this

dynamic environment, German companies are continuing to promote innovations in storage and grid technology and to develop cost-efficient solutions for a supply of energy from renewable sources.

Initial commercial projects show that battery storage devices can be used to quickly provide control energy for short periods of time. As technological developments occur, compressed and liquefied air storage could complement pump storage plants with a similar range of tasks in the electricity supply system in the medium term. This would require efforts in the area of research and development to accomplish a technological leap towards adiabatic systems and thus a higher efficiency and thereby sufficient profitability. Larger storage capacities could perhaps be achieved through feeding hydrogen or synthetic methane into the natural gas network (power-to-gas concept). Other regions could also profit from the experience thus far gained in these fields in Germany.

Advantages of cooperation beyond regional borders

By expanding power transmission capacities beyond regional borders, a wide-ranging domestic market for electricity can be created, entailing the following advantages:

- Reduction of electricity generation costs by coupling the various market areas and dismantling technical trade blockages
- Trans-regional provision of ancillary services
- Balancing effects of load reference and increasing security of supply
- Balancing effects of feeding photovoltaic and wind energy into the grid between various geographical regions
- Connection of productive regions for renewable energies
- Development of storage capacities over a wide area.

For these reasons, the implementation of a unified internal energy market in Europe has been a central aspect of energy policy in the European Union for years, and was particularly advanced by the Directives for the Internal Energy Market. Among other things, these involve further opening the energy markets through the decartelisation of vertically integrated utilities and non-discriminatory grid access.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istockphoto.com/alexsl

Other industry sectors

Irrespective of the technology, a large number of German market players provide other products and services that supplement the value chain in the various renewable energy sectors.

Project developers check the technological and economical feasibility of concepts and provide support in obtaining project partners and drafting authorisation documents. They coordinate and control the planning and construction of plants. Other service providers have specialised in analysis and optimisation methods. They identify efficiency potentials during the production, construction and operation of the plant and in the electricity supply processes.

Equally, certain manufacturers of process-related components cater for a range of technologies in the area of renewable energies. For example, plate heat exchangers are used in solar power technology, in the area of near-surface geothermal energy, and in combined heat and power plants (CHP). German companies offer frequency converters to efficiently design drive solutions that are characterised by high energy efficiency and reliability, coupled with long service life and high efficiency levels. Frequency converters are able to bring about significant savings potential combined with energy technology and energy storage turnkey solutions. These system solutions can be found in the on- and off-grid area, although they also offer the possibility of switching between on- and off-grid mode.

German companies offer comprehensive solutions in terms of environmental compatibility and safety. Examples of this include:

- The certification of biofuels
- The validation, verification and certification of climate protection projects in accordance with the Kyoto Protocol, e.g. “Joint Implementation” (JI) or “Clean Development Mechanism” (CDM)
- The validation, verification and certification of company and state projects and programmes in the area of verified emission reductions (VER)
- The certification of electricity generation from renewable energies
- The testing of plant sites and construction statics
- The monitoring of power station operations.

German investors finance projects, facilitate shareholdings or offer public placements via investment funds. In the area of “Carbon Investments” they handle the approval process for CDM and JI projects up to the sale of CDM emissions certificates, which are known as “Certified Emission Reductions”, or CER, on the stock market.

Educational institutions offer training and further education in the areas of energy technology based on renewable energies, efficiency and financing for projects, including the planning and construction of off-grid plants. A diverse range of seminars are on offer for a wide target group: from technicians and engineers to investors, solicitors, developers and decision makers.

Opinion panel

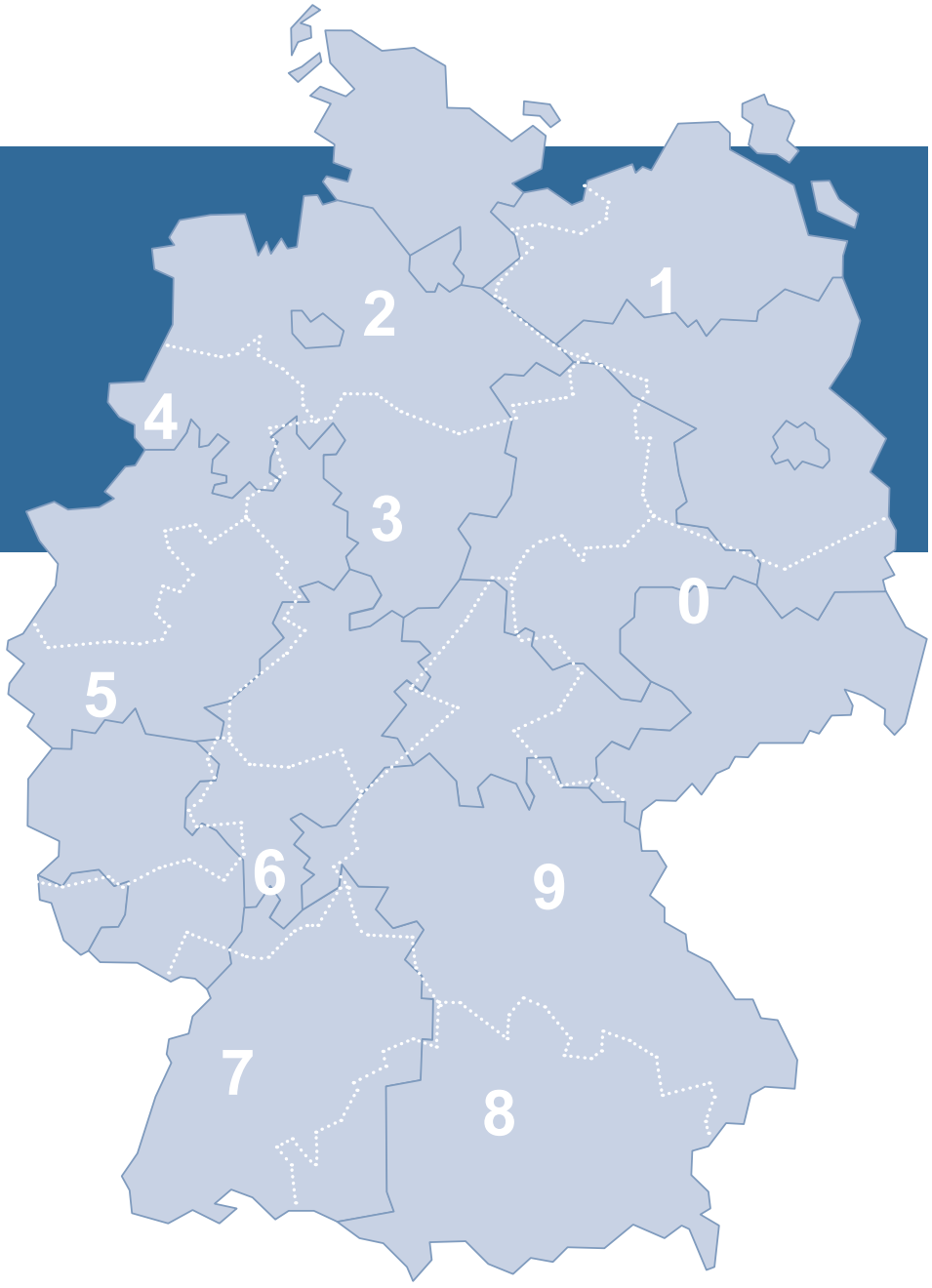
“Knowledge is one of the key factors for the future growth of energy markets using a clean and safe energy supply. The challenge is for key actors from politics, project development, administration, engineering companies, finance and network operators to identify the technology-specific expertise needed at the right time so that market development can be continuous. Through our educational services, we provide the necessary expertise for the growth of renewable energy and energy efficiency.”

Berthold Breid, CEO, Renewables Academy AG (RENAC)

Dabarti CGI/Shutterstock.com

COMPANIES

Companies



- Wind energy
- Hydropower
- Geothermal energy
- Photovoltaics
- Solar thermal energy
- Solar thermal power plants
- Biogas
- Solid biomass
- Storage and grid technology
- Other industry sectors

no.	company	technologies	postcode area	full-line supplier	manufacturer	operator	research and development	educational provider	consultant	appraiser	dealer	project developer	project engineer	supplier	other	page
Plant engineering																
01	Aschoff Solar GmbH		9	■												82
02	LAMBION Energy Solutions GmbH		3		■											97
Full-line supplier																
03	aap GmbH/Nature Technology Systems (nts)		1	■												78
04	agriKomp GmbH		9	■												79
05	Ammonit Measurement GmbH		1	■												81
06	Andritz Hydro GmbH		8	■												84
07	asola Technologies GmbH		9	■												85
08	BayWa r.e. renewable energy GmbH		8	■												88
09	EnviTec Biogas AG		4	■												95
10	Schmack Biogas GmbH		9	■												105
11	Viessmann Photovoltaik GmbH		3	■							■	■				111
12	Viessmann Wärmepumpen GmbH		3	■												112
13	Viessmann Werke GmbH & Co. KG		3	■												113
14	Voith Hydro Holding GmbH		8	■												114
15	WELTEC BIOPOWER GmbH		4	■												115
Manufacturer																
16	AkoTec Produktionsgesellschaft mbH		1		■								■			80
17	Awite Bioenergie GmbH		8		■											86
18	Carbotech GmbH		4		■											92
19	DIVE Turbinen GmbH & Co. KG		6	■	■											94
20	KOSTAL Solar Electric GmbH		7		■						■					96
21	LIPP GmbH		7		■											98
22	Nolting Holzfeuerungstechnik GmbH		3		■											99
23	Ossberger GmbH + Co		9		■							■				100
24	Parker Hannifin Manufacturing Germany GmbH & Co. KG, Hiross Zander Filtration Division		4		■											101
25	SOLAR-RIPP®		5		■											108
26	s-power Entwicklungs- und Vertriebs GmbH		4	■	■											109
27	Stela Laxhuber GmbH		8		■											110
Services																
28	CUBE Engineering GmbH		3						■	■						93
29	ProfEC Ventus GmbH		2						■	■						102
30	Renewables Academy AG (RENAC)		1					■								103
31	sbp sonne gmbh		7						■			■				104
32	Solar Promotion GmbH		7												■	106

aap GmbH / Nature Technology Systems (nts)

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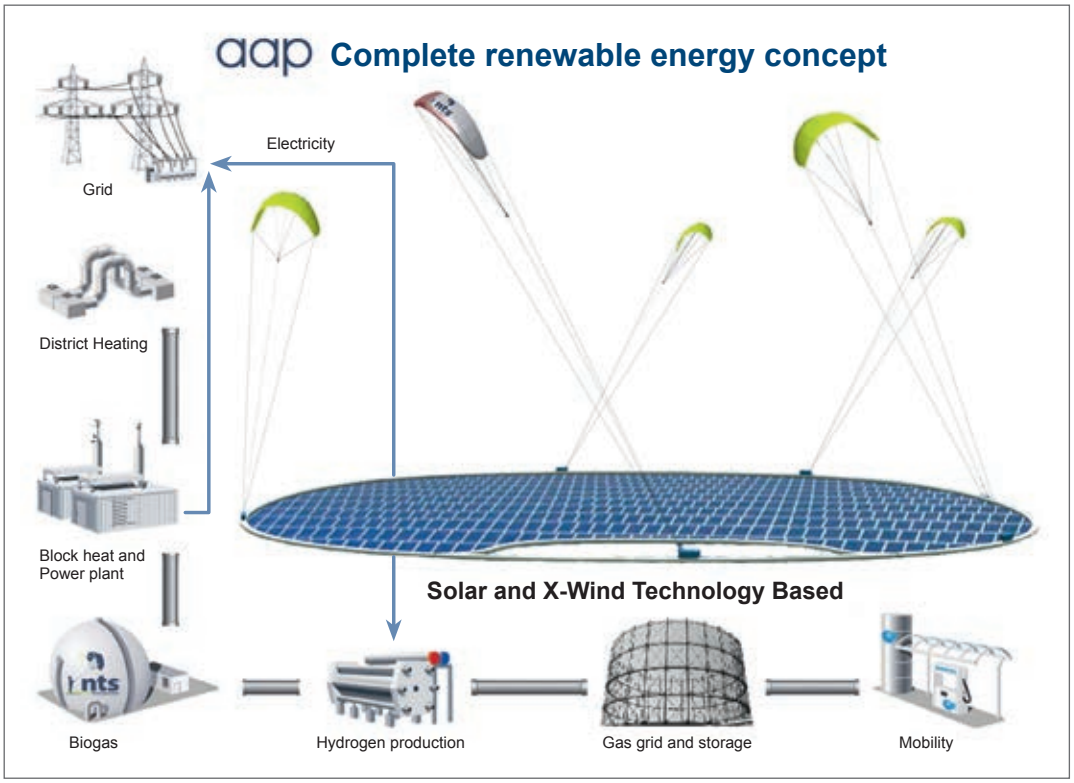
value chain full-line supplier

technology ■ wind energy
application electricity | all electricity users
profile full-line supplier | installation equipment, further education, wind turbines



NTS Nature Technology Systems X-Wind Technology

aap to full-range supplier of X-wind systems for electricity generation

For the first time, it is possible to generate electric power to compete with fossil fuels. A wind power plant is built by combining automatically controlled kites with electric locomotives. Wind speed and frequency increases disproportionately to altitude (increases by a power of three). aap builds X-wind systems designed to exploit these powerful and stable winds at heights of up to 500 m. These systems deliver three times greater availability than conventional wind turbines. Longer periods of calm are bridged (<4 percent of the year). Here, the patented use of NTS X-wind technology comes into its own. We can run with a kite like a child and in this way keep the kite in the air even when there is not enough wind.

aap X-wind technology (pronounced: cross wind technology)

X-wind power plants, also referred to as high altitude wind energy systems are a new CO_2-free source of energy which generates electricity more cost-effectively than fossil fuels.

The other benefits

- Investment, operating and maintenance costs are lower than with conventional energy generation system
- Base load capability is largely guaranteed
- Very good controllability (0 to 50 percent nominal output in less than 60 seconds)
- Quiet
- Low decommissioning costs
- Recyclable components which have been approved for decades
- Tourist attraction
- Almost invisible in the landscape.

agriKomp GmbH

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value chain full-line supplier

technology ■ biogas
application electricity, heat | agriculture
profile full-line supplier | plant components, biogas plants, combined heat and power systems (CHP)

Custom plant in Millbrook (Canada) for manure, grass and waste materials.

As biogas technology is used: flexibly

agriKomp GmbH has been one of the few full-range suppliers of agriculturally designed biogas plants for over 15 years. It focuses on the fermentation of liquid manure, solid dung and renewable raw materials. agriKomp covers the entire value chain from planning and design, constructing the facilities, producing the combined heat and power (CHP) plants, through maintenance, technical and biological services to repowering and expanding its own and external plants. An extensive service network in Germany and abroad encompasses the full range of services for biogas plants.

agriKomp has now set up about 800 biogas plants worldwide and today is among the leading companies in the sector.

agriKomp now draws on the experience and competence of 400 employees active worldwide in enhancing plants and components that have been developed in the network. This guarantees the customer consistently high quality, long service life and low-maintenance plants. As a full-range supplier, agriKomp builds biogas plants from 75 kW to 2.5 MW and larger. The portfolio of agriKomp includes combined heat and power plants (CHP), heating networks and gas treatment from biogas to biomethane. Today the company actively works with its own subsidiaries and partners in the United Kingdom, Ireland, France, Switzerland, Denmark, Italy, the Czech Republic, Poland and Slovakia. Its activities worldwide also include projects in Canada, China, Kenya, Romania and Bulgaria.

Custom plant in Ascea (Italy) for cattle dung.

AkoTec Produktionsgesellschaft mbH

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value chain	manufacturer

technologies	solar thermal energy, solar thermal power plants
application	heat | from industry to the end user
profile	manufacturer, project engineer | plant components, planning and engineering services, solar heating technology

Solar heating & cooling, Prenzlau (Neue Mitte), Germany.

Your producer of full evacuated tube collectors made in Germany

AkoTec is a manufacturer of high-performance full evacuated tube collectors. The tube collectors are manufactured entirely in Germany. They offer one of the best possible performance, integrated overheating protection in the collector and have passed Class 4 hail resistance tests.

The collectors are used for single-family houses and blocks of flats, as well as for production facilities. An entire village could even be supplied with heating by introducing the collectors as autonomous heating facilities.

The assembly is particularly straightforward because the system is put together using plug-in connections. In addition, the tubes can be rotated 360 degrees and can therefore be optimised to point towards the sun.

The vacuum pipe collectors can be installed on a roof or facade, be free-standing or placed on balcony railings. They can also be placed on terrace canopies. In all cases, the plants have consistently been generating high yields for 25 years and have made a considerable contribution to reducing heating costs.

By deciding on AkoTec full vacuum pipe collectors, you are not only opting for high-quality German products, but also for a comprehensive range of services. Whether you are a private property developer, architect or gas fitter, we can offer you our experienced advice. From the free first meeting to the planning and handing over of the facilities, everything is received from one source. This guarantees quicker decision-making and better communication. We are also happy to help you to realise your energy design.

Industrial facade, Kekava, Latvia.

Ammonit Measurement GmbH

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value chain full-line supplier

technologies wind energy, photovoltaics, solar thermal power plants
application electricity | industry
profile full-line supplier | measurement and control systems, software

Measurement stations for wind and solar energy assessment.

Accurate measurement of wind and solar energy

Since 1989, Ammonit has been developing and producing meteorological measurement systems for resource assessment as well as wind farm and solar power plant monitoring. Our product range includes:

- Data loggers
- Meteorological sensors
- LiDAR and SoDAR devices
- Web platform for system monitoring
- Communication and power supply systems.

The Meteo 40 data logger is highly respected worldwide by professionals in the wind and solar industry. Via the web platform AmmonitOR, measurement systems can be monitored to check data for integrity and plausibility according to the MEASNET guideline. Ammonit measurement systems meet international quality standards and are well-known on the market for their accuracy.

Ammonit cooperates with well-known manufacturers of measurement equipment such as Thies and is therefore able to offer all-in-one systems. Our systems are used by wind and solar professionals in over 100 countries. Thanks to our global partner network we are also available for our customers locally.

Ammonit provides measurement systems for:

- Wind resource assessment – and also for cold climate zones with ultrasonic sensors and special heating systems
- Resource assessment for photovoltaic (PV), concentrated solar power (CSP) and concentrated photovoltaic (CPV) power plants
- Wind farm and solar power plant monitoring (compatible with the common SCADA systems)
- Power curve measurement
- Measurement of environmental factors, e.g. pollution.

Ammonit designs its measurement systems with regard to regional and climatic requirements – always offering top quality equipment to ensure accurate IEC-compliant measurements.

Aschoff Solar GmbH

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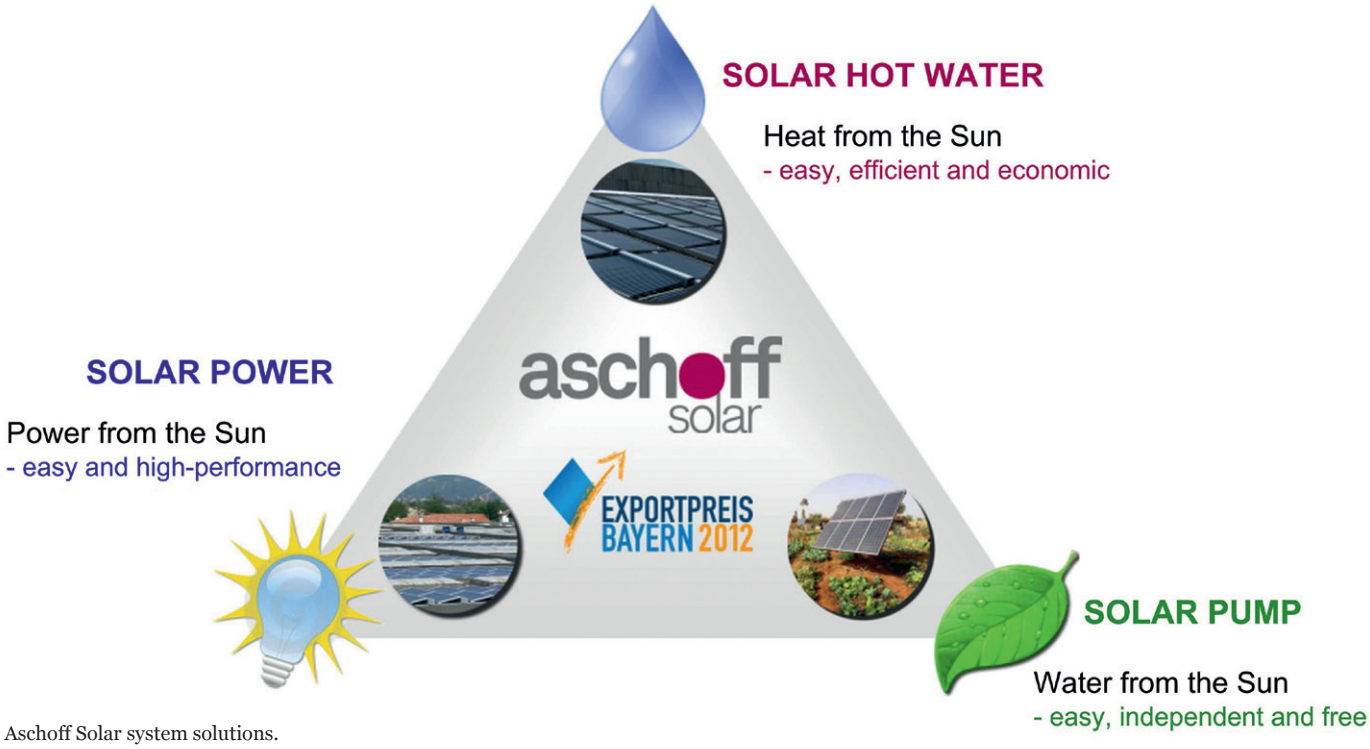
value chain plant engineering

technologies photovoltaics, solar thermal energy
application electricity, heat | industry
profile full-line supplier | installation, planning and engineering services, pv installations



Aschoff Solar system solutions.

Solar power is simple, efficient and economically viable

Aschoff Solar GmbH

Aschoff Solar offers complete solar system solutions for industrial customers on the international market. The activities are focused regionally in Asia and Africa aiming for electricity-intensive and heat-intensive industries as a priority. Besides the classic solar applications of power generation and heat supplies, solutions are planned and established for solar pump stations with an output of > 30 kW. Aschoff Solar designs, delivers and installs the systems through German installation teams, with the support of local partners. In 2012, Aschoff Solar GmbH received the export award in the service category by the Bavarian Minister of Economic Affairs.

Large scale solar thermal systems for industrial applications

Based on the standardised systems and collector areas, with modular design, Aschoff Solar carries out large-scale solar thermal plants as turnkey solutions in warm-water-intensive industries, such as tanneries and jeans factories of up to several thousand square metres. The drive and heat transfer units may optionally be integrated into industrial control cabinets or sea freight containers to be used as hot water tanks. The units are manufactured in Germany on a project by project basis, tested and delivered ready for connection to the project and integrated there. Since 2014 projects in specific markets and applications have been implemented in cooperataion with Bosch Thermotechnik GmbH (Thermal Technology), Germany.

Aschoff Solar thermal systems.

Aschoff Solar power systems.

Aschoff Solar pump systems.

Solar power systems for industrial customers

Solar power systems, often designed as self-consumption plants, are an additional focus of the activities of Aschoff Solar. Also based on a high degree of standardisation and modular development, grid-connected systems for self-consumption are designed and implemented in the production plants. On the basis of the high quality of German supporting structures and connection technologies, great importance will be attached to installation by German specialists, with support from local partners, to ensure German-standard quality for customers. Substations and connection units are manufactured exclusively in Germany, and tested, delivered and integrated as turnkey projects.

Solar pump systems

Aschoff Solar offers all-in-one solutions for the water supply in applications without access to the public grid in desert regions as pure solar or hybrid solutions. With a modular design and based on standardised module units, the systems offer the opportunity for autonomous irrigation or water supply, installed by German specialists with support by local partners. In 2015, guidelines were drawn up on the development of solar pump systems, based on a demonstration project in the deserts of Egypt, in collaboration with GIZ and the Fraunhofer Institut, Germany. These are available now at www.raseed-giz.com.

Andritz Hydro GmbH

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value chain full-line supplier

technology ■ hydropower
application electricity | industry
profile full-line supplier | plant components, planning and engineering services, hydroelectric power plants

Manufacturing of a Francis turbine runner at the Ravensburg plant.

Andritz Hydro supplies electromechanical equipment and services for hydroelectric power plants. With approximately 8,300 employees and a sales volume in 2014 valued at around 2 billion euros, the company is one of the largest suppliers for the hydraulic power generation market. Andritz Hydro GmbH Ravensburg has been manufacturing components for hydroelectric power plants up to a weight of 200 tonnes for over 150 years, making it one the most important manufacturing locations for hydraulic core components in western Europe.

We offer design and construction of large Kaplan, bulb, Francis and Pelton turbines, pump turbines for storage power plants and shut-off valves with a capacity of up to 800 MW. From 1 to 30 MW, all turbine types are available as compact versions. Our comprehensive range of services extends from professional project planning, precision engineering services and the manufacture of high-quality turbines to control technology, monitoring and related training courses. Our services include repairs and rehabilitations. We have outstanding expertise in the field of automation.

Andritz Hydro GmbH Ravensburg office building.

asola Technologies GmbH

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web	www.asola-tech.de
value chain	full-line supplier
technologies	photovoltaics, storage and grid technology
application	electricity, mobility | end users, industry, trade, agriculture, local government
profile	full-line supplier | installation, planning and engineering services, pv installations

asola VITRUM® facade system.

Architecture and sustainable power generation

asola Technologies GmbH is a specialised developer and manufacturer of customised products and unique engineering services for building integrated photovoltaics (BIPV).

asola is backed by a network of certified specialist partners in the DACH region (Germany, Austria and Switzerland) as well as throughout the world in Italy, the Middle East (Saudi Arabia and the UAE), China, the USA and South America (Columbia), which ensures fast and reliable customer service.

asola offers a wide range of facade applications, overhead glazing and railing systems as well as products for e-mobility, such as battery systems and charging stations. However, the portfolio is not restricted just to products only. asola also supplies complete solutions from consultation, planning and project management to customised module design, matching and perfectly fitting accessories, fastening systems, installation, commissioning and maintenance.

asola's customers benefit from the company's many years of experience, extensive product range and its guiding principle of combining renewable energy with individual aesthetic design.

Head office of asola Technologies, Erfurt.

Awite Bioenergie GmbH

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value chain manufacturer

technology ■ biogas
application electricity, mobility, heat | end consumer
profile manufacturer | measurement and control systems

Tailor made solutions for satisfied customers.

Gas analysis, automation and desulphurisation from a single supplier

Awite is specialised in gas analysis systems, automation and measuring technology in the area of biogas plants. Since 2001, Awite has been manufacturing according to individual customer requirements and to the highest standards of quality at its own facility in Langenbach. In addition to the development, manufacturing, installation and startup of our systems, we are also your partner for service and maintenance. Awite offers gas analysis systems for biogas plants, for monitoring the feeding in of biogas into the natural gas grid, controlling fuel cell applications, for raw biogas distribution and also for handling other control tasks.

The range of products and services also includes the automation and visualisation of biogas plants, wastewater treatment plants and lab-scale plants with the company's own software developed specially in house.

Gas analysis – the right system for every process

AwiECO and AwiFLEX – our gas analysis systems – use extensive process controls to ensure smooth workflows and above all the economic use of energy in your plants. Constantly.

The more accurate and continuous the measurements, the more they prove to be time and cost-saving factors.

Automation – full support

Our AwiCONTROL automation solution gives you complete control of your system, including peripheral equipment. When developing our own automation solution in house, we also had a view to maximum operational reliability.

For us, it goes without saying that we do not charge license fees. In addition, we are committed to developing products on an open-source basis. This enables us to protect our customers from hidden costs. Of course, AwiCONTROL – like all our other products – enables you to control your systems from a distance. Using a smart phone or tablet. At any time.

Desulphurisation – never too much O_2 in the system

The AwiDESULF microbiological desulphurisation system with fuzzy logic gives you full control over hydrogen sulphide. Sounds complicated? It's actually rather simple: simply switch on. The gas analysis system measures the oxygen content and the hydrogen sulphide concentration and uses this data to regulate the air supply.

Your benefits? Easy to use, low costs, highly reliable process and low substrate losses.

Awite partners worldwide.

Service – you can rely on us

The assembly, startup and maintenance of our process analysis systems is carried out by our trained staff on site at your plant. We monitor the service intervals for you and on request can offer you full-service maintenance contracts. By planning trips and specifying dates, we can keep costs transparent for you.

Maintenance comprises a full check of your systems, including calibration with certified gases. To ensure perfect operation, on-site service is essential and frees up your time for other important tasks.

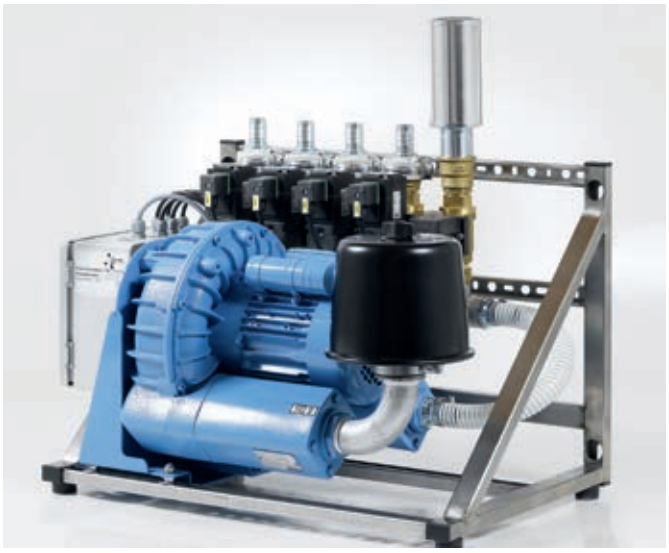
Emergencies are not restricted to weekdays. So neither are we. Whenever you need a fault in your gas analysis system fixing quickly, just call us. At any time.

AwiFLEX gas analysis system with integrated AwiCool gas cooler.

Awite international

Awite operates internationally. With Awite Bioenergia Srl in Bolzano and partners worldwide in Argentina, Bulgaria, Canada, Chile, Great Britain, Lithuania, Mexico, Netherlands, Poland, Spain, Thailand and Turkey, we can provide our high standard of quality and excellent service in these countries and others.

Our passion for this industry means that we are always looking ahead. For optimum processes, today and tomorrow.



AwiDESULF 500 microbiological desulphurisation system.

BayWa r.e. renewable energy GmbH

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e-mail info@baywa-re.com
web www.baywa-re.com
value chain full-line supplier

technologies wind energy, geothermal energy, photovoltaics, biogas, storage and grid technology
application electricity | commerce
profile full-line supplier | plant components, operations management, planning and engineering services

Solar farm Great Glemham, United Kingdom.

With some 860 employees worldwide, BayWa r.e. is one of the leading suppliers of the renewable energy sector. BayWa r.e., completely owned by BayWa AG and headquartered in Munich, acts as a holding company for a range of companies in the business segments of solar power, wind power, bioenergy and geothermal power. Their many years of experience in the renewable energy sector, coupled with a range of services covering all the main sectors, benefit customers and business partners alike. Their current focus is on the core markets of Europe and USA.

A specialist in development, planning, financing, constructing, running and maintaining renewable energy plants and on the renewable energies market, BayWa r.e. is a robust and experienced partner. In each new project, BayWa r.e. strives to harmonise technical and economic requirements and ensures that the plants meet the highest standards and consistently achieve good yields. Services like the maintenance and repair of rotor blades are also within its scope. As one of the largest providers of PV systems in Europe, BayWa r.e can also deliver everything needed for a PV installation. Only high-quality products are used.

Project development and turnkey assembly

BayWa r.e. has developed and set up wind, solar, bioenergy and geothermal facilities with an installed capacity of over 1.8 GW. The partners of BayWa r.e. include municipalities, local developers, energy cooperatives and institutional customers. In addition to developing and carrying out its own projects, BayWa r.e. is also in charge of the turnkey installation of facilities for third parties. Its services include:

- Greenfield projects
- Site analysis and assessment
- Securing land
- Planning of approval and implementation
- Raw material acquisition for biogas plants
- Turnkey assembly as a general contractor
- Project management
- Preliminary and interim financing
- Project structuring and financing
- Repowering.

Wind farm Campomaggiore, Italy.

Operational management

As an owner and service provider for fund companies, banks, international investment companies and citizens' energy cooperatives, BayWa r.e. performs the technical and commercial management of wind, solar and bioenergy projects with a total installed output of roughly 1,500 MW. The range of services includes:

- Multilingual control centre in three-shift operation and on-call 24 hours a day
- Optimisation of the energy availability
- Manufacturer-independent management system
- Checks and immediate triggering of fault clearance
- Regular visual inspections with the internally developed service app
- Maintenance in the medium and high-voltage range
- BGV A3 tests
- Systems operations for biogas plants
- Raw material management for biogas plants
- Documentation and reporting on the entire project process
- Commercial management, including contract and stakeholder management, regular accounting, budget and liquidity management and insurance management
- Representation and implementation of the operators' interests.

Maintenance and plant optimization

As a manufacturer-independent and certified service provider, BayWa r.e. offers comprehensive service solutions for the optimisation and maintenance of wind turbines of all types and rated classes:

- Rotor blade assessment
- Maintenance and repair of rotor blades in the wind farm
- Repairs/retrofits supported on site
- Storage and provision of exchange sheet records
- Construction, production and repair of GFK components
- Cleaning and sealing of rotor blades
- Tower cleaning and corrosion protection
- Rotor blade optimisation to improve plant performance
- Plant decommissioning and marketing
- Disposal and recycling of rotor blades and GFK building components
- Heavy transport and warehouse logistics.

BayWa r.e. renewable energy GmbH

Biogas plant Pliening, Germany.

Geothermal power plant Dürrnhaar, Germany.

Planning and consultation

BayWa r.e. offers comprehensive technical consultation and planning services for renewable energy projects. Its services include:

- Due diligence checks
- Project management
- Yield and immission reports
- LIDAR wind measurements
- Feasibility studies
- Approval planning and management
- Implementation planning and construction supervision.

PV trading

As one of the largest providers of PV systems in Europe, BayWa r.e. delivers everything necessary for a PV installation. The range of services includes:

- Selection of high-quality solar modules, inverters and storage solutions from reputable manufacturers
- Novotegra and Creotecc assembly systems developed internally and TÜV certified
- Comprehensive advice in plant planning and design and feasibility studies
- First-time assembly support on the building site
- A variety of services for fitters and engineers
- Fitter partner programme with sales support
- Broad range of seminars on specialist and industry-specific topics
- Storage with high availability and logistics
- Short delivery times and punctual delivery directly to the building site
- Sales cooperation with public utilities, prefabricated housing constructors and other sales partners for end customers.

Direct marketing and marketing of control energy

For producers of wind, solar, biomass and geothermal power, BayWa r.e. offers the marketing of electricity under the German Renewable Energy Act (EEG), in accordance with the market premium model and the control energy market. BayWa r.e. is a qualified partner for connecting renewable energy plants to the electricity market and for their optimisation in accordance with the energy industry:

- Marketing and structuring of renewable energy power on the electricity trading exchanges
- Electricity trading via virtual power plants from wind power, photovoltaic, biogas/biomethane/combined heat and power (CHP) plants, hydropower and geothermal plants
- Support and monitoring of the prequalification phase for participation on the control energy market
- Structuring of the tendering process for plant capacity among the transmission network operations for the control energy supply
- Application of the control signals of the transmission network operators via a virtual power plant for the requested pool capacities.

Biomethane trading and sale of green energy

As a leading biomethane trader with a trading volume of over 1.4 TWh per year, BayWa r.e. is a key supplier of the CHP, heating and fuel markets. BayWa r.e. also provides private, commercial and industrial end customers throughout Germany with eco-power and eco-gas. Redistributors, domestically generated electricity and local electricity users benefit from the expertise of BayWa r.e. in the energy sector through tailor-made electricity supply concepts. Its services include:

Wind farm Gunzenhausen, Germany.

- Trade in biomethane to physical metering points and virtual trading points in all German market areas (also separate accounting)
- Operations on the markets for CHP, heating and fuel
- Process for changing suppliers, market communication and maintenance of a balancing group
- Trading with balancing group flexibility and management of biomethane proof of origin in the dena biogas register
- Certified eco-electricity and eco-gas product portfolio with sales across Germany.

Solutions for self-consumption

The direct usage of the renewable energy sources of wind and solar power is not only the future of energy supplies, but also in many cases for bulk consumers and private households a cost-saving alternative to purchasing electricity from the network. Electricity is supplied directly to where the energy is needed, without long, expensive transmission networks being required or high transport losses sustained. In industry, commerce and business, where there is high electricity consumption during the day, photovoltaic is the main choice for achieving a significant reduction in energy costs.

BayWa r.e offers everything from the one source, from its feasibility analysis and financing right through to the sale of unused energy, and is a reliable partner for investors, industry and commerce for all aspects of the supply of domestically generated electricity.

- Ideas for optimising the self-consumption of wind and solar plants
- Rental and leasing model for commercial and industrial customers
- Customised offers for private customers in cooperation with public utilities
- Development and provision of customised product and sales solutions for domestically generated eco-electricity and eco-gas for redistributors and energy cooperatives
- Ideas for self-consumption with renewable energy electricity in area networks.

Together with the experienced employees at BayWa r.e., many customers and business partners have already found the best solution for commercial success. With the backing of BayWa AG, BayWa r.e. is also a reliable long-term partner.

Carbotech

VIESMANN Group

Carbotech GmbH

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e-mail mail@carbotech.info
web www.carbotech.info
value chain manufacturer

technology ■ biogas
application mobility, heat | industry
profile manufacturer | gas purification systems

Sofielund biogas upgrading plant, 2,000 Nm³/h.

Pioneer in gas purification

Schmack Carbotech, a company in the Viessmann Group, is a market leader in the area of biogas purification and has more than 30 years' experience in the development, engineering and manufacturing of turnkey gas upgrading plants. The purification technology developed in-house is based on the principle of pressure swing adsorption (PSA).

Experience gained from building more than 70 plants throughout Europe, together with a continuous development process, guarantee a highly efficient process with very low operating costs.

Reliable and efficient technology

Schmack Carbotech specialises in biogas and landfill gas upgrading for gas grid injection or use as CNG vehicle fuel. In addition, Carbotech offers turnkey solutions in the area of industrial gas purification and gas upgrading processes for nitrogen, hydrogen and synthetic gases. The pressure swing adsorption process developed by Carbotech is reliable and highly efficient.

View inside a gas upgrading plant.

CUBE Engineering GmbH

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web www.cube-engineering.com
value chain services

technologies wind energy, photovoltaics, biogas
application electricity, heat | interdisciplinary
profile consultant, appraiser | energy management, combined heat and power systems (CHP), planning and engineering services

Experts for renewable energies.

THINKING OUTSIDE THE BOX

The CUBE spectrum offers comprehensive consultancy services in the sectors of WIND, SOLAR and SMART POWER. The integration of fluctuating energy sources into the existing grid and its interaction make use of the synergy effects of these technologies. CUBE is interdisciplinary and provides all services from one source always with a close eye on market occurrences and the technological pulse of the time. The company, accredited according to DIN EN ISO / IEC Norm 17025:2005, has successfully supported over 4,800 projects worldwide, with a total installed capacity of over 16,300 MW.

Management Consulting
Country profiles, greenfield development, due diligence.

Planning & Project Management
Tender support, site identification, tech. project management, approval planning, construction supervision, feasibility study.

Wind Assessment
Wind reports, wind potential map, site identification, LiDAR , yield report, wind measurement campaign, CFD modeling, preliminary assessment.

Solar Assessment
Yield predictions, radiation maps, measurement campaigns, loss analyses.

Environmental Assessment
Noise allotment, shadow analyses, visualisation & animation, visibility study, preservation order study, icefall study, environmental impact assessment.

Electrical Networks
Electrical loss analysis, cable dimensioning, grid connection conditions.

Smart Energy
Integral dynamic energy analysis, energy self supply, biogas/CHP plants, energy efficiency and management, cogeneration.

DIVE Turbinen GmbH & Co. KG

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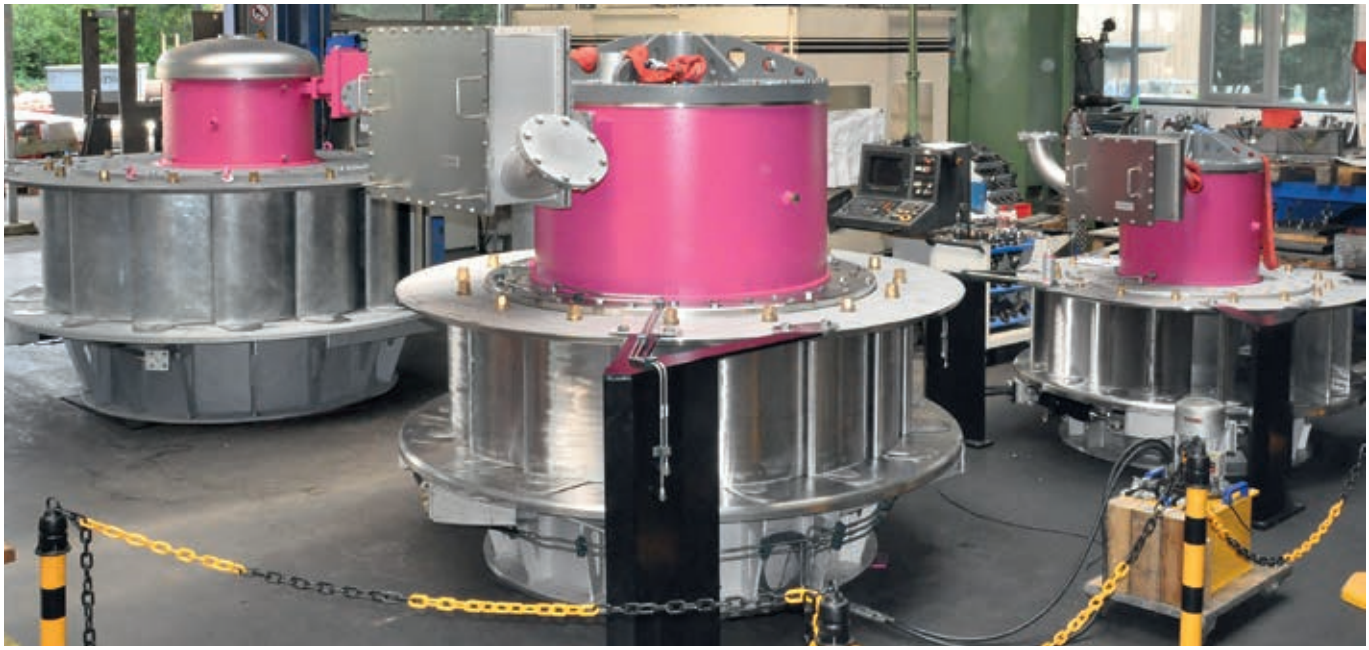
value chain manufacturer

technology ■ hydropower
application electricity | energy producer
profile full-line supplier | hydroelectric power plants



Pre-assembled DIVE-Turbines ready for delivery at the factory in Amorbach.

DIVE Turbinen GmbH & Co. KG concentrates on technical solutions for small hydropower plants, especially on the development and marketing of the DIVE-Turbine. All key components are developed and manufactured in the facility in Amorbach, about one hour south of Frankfurt am Main. A large number of DIVE-Turbines are already in operation around the world. Furthermore, DIVE Turbinen GmbH & Co. KG can provide support for the financing and authorisation procedure. This includes customized planning and development of hydropower plants, with documentation on fluid hydraulics and ecological aspects.

The DIVE-Turbine is designed for low head (2 to 25 m), with an electrical output from 50 to 2,000 kW per unit. The compact unit, consisting of a turbine and generator, is operated entirely submerged, with minimal noise and at variable speeds. The unit has a unique wear and tear free sealing system, which it is absolutely maintenance free. The high-efficiency permanent magnet generator is connected with the turbine runner directly and without a mechanical transmission (gearbox). Due to the compact design of the unit and its technical advantages, the costs and risks for constructing the civil works of the entire power plant are reduced to an absolute minimum. At the same time, it ensures high efficiency for the entire power plant – from water to wire and maximum availability of the equipment. With the DIVE-Turbine it is possible to realize a fish friendly hydro power plant, due to the fix blade runner design without gaps and the speed variable operation.

Installation of a turbine generator unit with 900 kW.

EnviTec Biogas AG

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value chain full-line supplier

technology ■ biogas
application electricity, heat | agriculture, local government and industry
profile full-line supplier | installation equipment, biogas plants, planning and engineering services

The EnviThan gas upgrading plant in Oxfordshire (GB) produces 370 Sm³ biomethane per hour.

Renewable energy from biogas plants and biogas upgrading plants

EnviTec Biogas AG, founded in 2002 and headquartered in Lohne, Lower Saxony, is active in 16 countries worldwide. EnviTec is one of the leading companies in the segment of turnkey biogas plant construction and has already installed worldwide over 370 MW and 600 modules, including agricultural biogas plants and waste-to-energy plants. In 2014, EnviTec achieved a turnover of 163.4 million euros and an EBIT of 6.3 million euros. The EnviTec group currently has a total of 350 employees. Since July 2007, EnviTec Biogas has been listed on the Frankfurt Stock Exchange.

EnviTec Biogas covers the complete value chain for the production of biogas and biomethane. This includes the planning and turnkey construction of biogas plants and biomethane plants, as well as their commissioning. If required, the company takes on the biological and technical service and offers overall plant management as well as production management. In addition, EnviTec operates its own biogas plants. In 2011, with EnviTec Energy GmbH & Co. KG and its subsidiary EnviTec Stromkontor GmbH & Co. KG, it extended the scope of its business to direct marketing of upgraded biomethane and the marketing of green electricity and balancing energy.

250 kW waste-to-energy biogas plant in Kishiwada/Osaka, Japan.

KOSTAL Solar Electric GmbH

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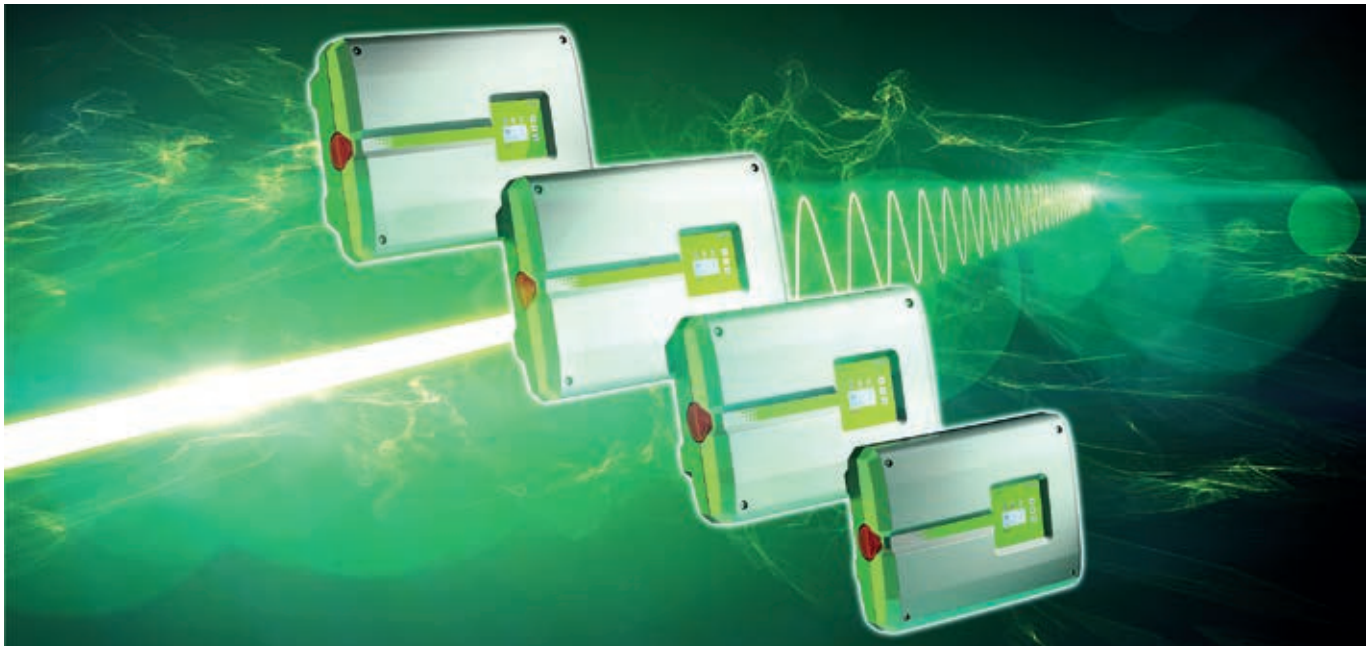
value chain manufacturer

technologies photovoltaics, storage and grid technology
application electricity | commerce
profile dealer, manufacturer | solar home systems, storage technologies, inverter



PIKO generation: more flexible, more communicative, more practical.

Smart connections for the energy of the future

KOSTAL Solar Electric was founded under the umbrella of KOSTAL Industrie Elektrik in 2006 and is part of the KOSTAL group, an automotive supplier with operations worldwide. With its headquarters in Freiburg and subsidiaries in various international markets, KOSTAL Solar Electric sells PIKO inverters for the international market.

The philosophy of "smart connections", with the competitive advantages of the KOSTAL family, partnership, quality-offensive thinking and future-oriented programmes, is reflected both in contact with partners and customers and in the broad product portfolio. This includes the PIKO BA System storage systems and single-phase and three-phase inverters with power ratings of between 3 and 20 kW.

The innovative storage solutions of KOSTAL have numerous features for optimising the usage and cost of energy. They control whether electricity is used in the building, stored or fed into the public network. In addition to the system with lead gel batteries, there is the PIKO BA System Li with lithium iron phosphate batteries, which won an ees AWARD in 2015. It stands out for the three-step safety design. A modular assembly system offers solutions for almost any customer requirement.

With the new generation of PIKO inverters, KOSTAL is taking a further stride into the future. The enhanced product benefits of flexibility, communication and practicality, as well as the varied design, provides a solution for almost every PV plant.

PIKO BA System Li storage system – ees AWARD winner 2015.

LAMBION Energy Solutions GmbH

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value chain plant engineering

technology ■ solid biomass
application electricity, heat | trade, industry, local government
profile manufacturer | heating systems, power plants, combined heat and power systems (CHP)

Biomass thermal power plant by LAMBION Energy Solutions GmbH.

Solid fuel energy

For over 90 years, LAMBION Energy Solutions GmbH has been planning and building individual biomass power plants in the capacity range 1 to 50 MWth which use solid fuels and biogenic waste.

LAMBION uses natural resources in a sustainable and consistent way and sets standards in development and construction by harnessing the latest solid fuel combustion technologies.

Over 3,400 biomass power plants installed worldwide give the company a vast wealth of experience in the economical and environmentally responsible use of almost 100 types of solid fuel.

Biomass power plants and heating plants in the 1 to 50 MWth range

LAMBION biomass plants are energy producers tailored to individual requirements. The special LAMBION furnace design takes account of the chemical and physical properties of biogenic waste products from apple cores to sugar cane. The special feature of this design is that biofuels with different properties, whether dry or moist, coarse or fine, can be incinerated and transformed into energy simultaneously.

We design, develop and manufacture efficient power plants from 1 to 50 MWth for almost 100 different types of solid biomass. Ideally, complete with all peripherals required.

LAMBION is committed to long service life and sustainability in plant operation; LAMBION biomass plants are economical in their own energy consumption, easy to operate, require little maintenance and, with their robust technology made in Germany, achieve a lifespan which often exceeds 30 years.

UNIQUE.WORLDWIDE

LIPP GmbH

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value chain	manufacturer

technology	■ biogas
application	electricity, heat | agriculture, local government
profile	manufacturer | installation equipment, biogas plants, tank construction

600 kW agricultural biogas plant in Tannhausen.

Tanks and system solutions for biogas plants – flexible and efficient

LIPP GmbH is a family business that operates worldwide. The basis of their success is the unique LIPP Double-Fold System, in which steel bands are formed and permanently joined in an automated process. The patented VERINOX stainless steel composite material manufactured in house guarantees the highest quality and long service life of the biogas digester at a low cost.

LIPP offers two types of digesters

1. LIPP KomBio Reactor, with integrated gas accumulator up to 2,500 m³
2. LIPP universal digester with stainless steel diaphragm roof or foil roof for 5,000 m³ and over.

Summary of benefits offered by LIPP

- Fast and automated on-site production
- Very little installation space required
- Consistently high quality worldwide
- Flexibility in terms of diameter, height and cover
- Long service life
- Low investment costs.

This means that LIPP is always the right choice, both as a specialist in digesters and tanks and as a partner for the planning and design of small and large plants. With the unique LIPP Double Seam System, LIPP GmbH manufacturers biogas digesters, post-digesters, hydrolysis/mixing tanks and final storage tanks as well as a wide range of other storage tanks for liquids, gases and bulk materials.

In addition to its tank solutions, LIPP GmbH offers its customers and partners mainly planning services and know-how in the design of biogas plants. The company's decades of experience in the biogas sector and in tank construction form a sound basis for this and represent a considerable advantage.

KomBio digester and universal post-digester.

Nolting Holzfeuerungstechnik GmbH

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value chain manufacturer

technology ■ solid biomass
application heat | industry
profile manufacturer | heating systems

Site example: automatic feed grate firing with fine particulate air filter.

Combustion plants for biomass and pellets

Nolting Holzfeuerungstechnik GmbH has offered high-quality non-polluting biomass combustion plants for more than 65 years, in the capacity range from 50 to 3,000 kW. Our high-quality products are manufactured and supervised, from development to manufacture, by 55 employees at the company's own plant in Detmold. From fuel analysis and profitability forecasting to acceptance and maintenance, we support you with expertise, decades of experience and our own factory customer service.

Almost 40 percent of our production goes to export, and we supply a wide range of sectors including woodworking, wood processing, municipal buildings, crafts and industry, agriculture and horticulture.

The product range covers manually-loaded log-burning boilers, automatic underfeed and feed grate firing, fine particulate air filters, container solutions, special combustion systems, silo discharges and conveyor technology, plus all accessories and additional components. The experienced staff support you during the planning phase to create a suitable solution for the best possible overall design. Customised manufacturing makes it possible to design furnaces and their equipment according to individual requirements. Nolting can respond to problematic conditions, such as difficult fuels or small available boiler rooms, and find individual solutions.

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value chain manufacturer

technology ■ hydropower
application electricity | different
profile manufacturer, project developer | measurement and control systems, hydroelectric power plants, trash rack cleaning systems

Pre-assembled 3.4 MW plant for Turkey in front of one of the Ossberger production halls.

Hydropower experts for more than 100 years

Ossberger GmbH + Co from Weissenburg in Bavaria owes its extensive experience in the three areas of **small hydropower plants** (cross flow turbines, trash rack cleaning and automation), **parts cleaning** ("Coli-Cleaner") and **plastics machinery** ("Pressblower") to its more than 100 years of company history.

The development of the **OSSBERGER free jet turbine** by the firm's founder Fritz Ossberger in 1922 laid the foundations for the company's successful performance. More than 10,000 **original OSSBERGER® cross-flow turbines** have been produced and installed in approximately 100 countries, with outputs of between a few kilowatts up to currently 3.5 MW.

Ossberger Hydro is represented in about 50 countries worldwide.

Original OSSBERGER® cross-flow turbines from standardised individual components are configured on economic grounds for tailor-made systems in specific projects. With only three moving parts, they follow the Ossberger principle of simplicity and adapt themselves extremely well to a fluctuating water supply. This makes them ideal, in particular, as individual machines in run-of-river power plants. They operate from practically zero load to full opening, and have already proven their worth thousands of times in the toughest conditions.

The Ossberger hydro range also offers automation solutions and stationary and mobile trash rack cleaning systems that are essential for increasing the profitability of both smaller and larger hydroelectric power plants.

Exploded drawing of the original OSSBERGER® cross-flow turbine.

Parker Hannifin Manufacturing Germany GmbH & Co. KG Hiross Zander Filtration Division

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value chain manufacturer

technology
biogas
application electricity | industry
profile manufacturer | plant components, installation equipment, refrigeration technology

Regenerative, zero-loss adsorption system for drying biomethane.

Biogas dehumidification system with cooler, demister and water chiller.

Parker PpTek regenerative siloxane removal system.

Parker are globally recognised as the world leader in biogas purification, building on more than 40 years of experience in the field of compressed air and gas treatment to offer the industry's most comprehensive range of biogas treatment solutions.

Typical applications include filtration, dehumidification, desulphurisation and the removal of siloxanes and V.O.C's from biogas, sewage gas and landfill gas with all products backed by the support of Parker's global sales company network.

The Parker BioEnergy range includes the following products:

- Fully-automatic, regenerative PpTek siloxane removal systems (for siloxane and VOC removal) with media life guaranteed for 5 years
- Dry scrubber H2S removal systems (with more than 10 times the efficiency of activated carbon based systems)
- Packaged biogas dehumidification systems (skid-mounted, including all interconnecting pipework)
- High-efficiency filters for raw biogas & biomethane (particulate and coalescing types)
- Water chillers (with special treatment for biogas plant installation)
- Shell & tube heat exchangers (gas coolers and re-heaters)
- Water separators (cyclonic & demister type)
- High-efficiency regenerative adsorption dryers (for biogas and biomethane, PSA and TSA types)
- Oil vapour adsorbers (for removal of hydrocarbons)
- Bacteria & micro-organism removal filters.

Aftercooler Hypercool BioEnergy.

Hyperfilter BioEnergy FFB has been specifically designed to provide maximum protection for downstream equipment and pipework and to reduce maintenance costs and plant downtime.

ProfEC Ventus GmbH

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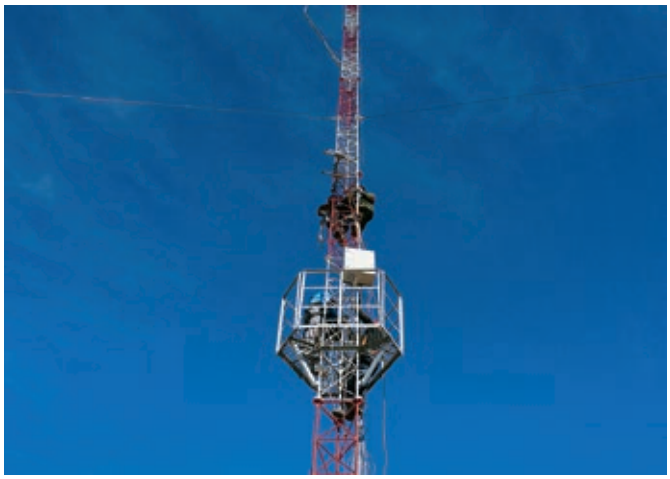
value chain services

technologies wind energy | storage and grid technology
application electricity | industry
profile consultant, appraiser | planning and engineering services, wind turbines, accredited MEASNET/IEC calibration of anemometers & wind vanes, wind measurements & yield assessments

Power curve measurements and power performance verifications.



Accredited installation services and bankable documentation for measurement mast up to 155 m.

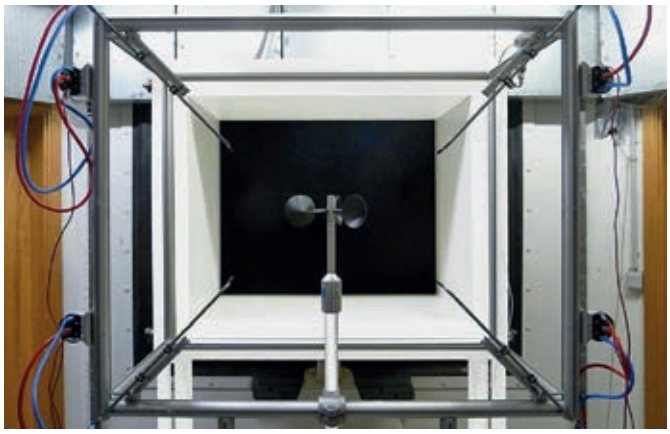
Closer, committed, competitive

ProfEC Ventus is a DAkkS-ilac accredited expert and consulting firm, specialising in wind measurements (with masts of up to 155 m and LIDAR), measurement and verification of power curves, site assessments, turbulence assessments, long-term energy yield and loss assessments (FGW TR6 Rev. 9), wind maps (CFD, mesoscale and microscale), anemometer and wind vane calibrations compliant with MEASNET and IEC, etc.

Our premise is to increase planning certainty, to identify and minimise risks and to define residual uncertainties and possible losses. We offer a range of services to assess information and to use it as reliable support of essential project-specific investment and planning decisions. Our procedures and processes are in line with internationally recognized industry standards and represent best practices based on latest findings. Our accreditations as testing and as calibration laboratory, in accordance with ISO 17025, proves that banks and investors worldwide can trust the high standards of our work.

Through our top-quality services, we manage requests across the globe and can meet the expectations of project developers, governments and public bodies, banks/investors and wind turbine manufacturers. Our expertise has been applied in over 30 countries, including in leading wind energy industries and markets as well as in emerging or difficult markets like Papua New Guinea, North Korea or Honduras. We see wind projects through right from the initial idea and optimal site selection to the calibration of measurement systems, resource assessments, power performance measurements, through to wind plant farm optimisation, performance enhancement and problem analyses of existing wind farms.

We provide bankable, accredited services and are happy to offer advice worldwide on the role of owners or lenders/banks engineer, as well as independent expert or consultant.



Wind vane and anemometer calibrations in accordance with MEASNET and IEC standards.

Renewables Academy AG (RENAC)

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value chain services

technologies wind energy, hydropower, photovoltaics, solar thermal energy, biogas, solid biomass, storage and grid technology
application electricity, heat | individuals, companies, institutions, organisations, educational establishments, etc.
profile educational provider | further education

PV training in the RENAC training centre in Berlin.

Renewables Academy AG (RENAC), headquartered in Berlin, is one of the leading international providers of education and further training, as well as of a number of educational services concerning renewable energy and energy efficiency.

Specialising in the sector of sustainable energy generation, RENAC can impart knowledge on a broad range of technologies, including photovoltaics, solar thermics, solar thermal power plants, wind energy, bioenergy, small hydropower plants, hybrid systems, electricity grids and energy efficiency.

Since it was founded in 2008, RENAC has trained over 5,800 participants from 145 countries worldwide.

RENAC offers customised training sessions with topics across the entire value chains: from the establishment of political frameworks on engineering, installation and maintenance, to the economic efficiency and financing of power engineering plants.

In addition to the training sessions, RENAC helps other institutions and companies to set up and run their own training sessions on renewable energy, whether for short seminars, professional training or academia.

Its services include the assessment of training needs, the development of curricula and training material, the qualification of training staff in train-the-trainer seminars and the establishment of turnkey training centres and consultancy services on the topic of market development.

sbp sonne gmbh

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value chain services

technologies
solar thermal energy, solar thermal power plants
application electricity | industry
profile consultant, project developer | solar thermal power plants

Andasol 50 MW parabolic trough power plant with EuroTrough collectors (aerial photo).

For over 30 years schlaich bergermann partner – sbp sonne has been developing components and systems for solar thermal power plants. Today we are a leading international engineering firm in this sector, designing parabolic trough collectors, heliostats and towers for central receiver power stations, dish systems, concentrating photovoltaic systems (CPV) and photovoltaic systems (PV).

In collaboration with our partners, we have successfully designed and implemented large projects worldwide. In 2010, the EuroTrough received the SolarPACES Technology Innovation Award, and today many parabolic trough power plants around the world use the EuroTrough collector that was developed under our leadership. The UltimateTrough® followed the design of the EuroTrough and won the SolarPACES 2013 Technology Innovation Award; in 2015, it received a commendation from the Ulrich Finsterwalder Ingenieurbaupreis, a prestigious German engineering award.

Our latest development in solar technology is the Stellio Heliostat. Stellio created new benchmarks for the industry because it provides the highest quality at the lowest cost compared to any existing heliostat worldwide. Our experience in the field allows us to operate in a range of areas, from offering turnkey solutions to licensing our technologies.

- sbp sonne designs and develops technologies and acts as license provider for collectors and solar fields of parabolic troughs (EuroTrough, UltimateTrough®) and dish systems (EuroDish and SBPS 25 kW).
- As part of the Stellio Consortium, we offer a turnkey solution for heliostat fields, including the complete solar field design and warranties.
- sbp sonne offers the complete design and planning (except CPU) of dish systems (Air Receivers, CPV, Stirling, Solar Furnace).

We cover all stages of the design and engineering development process: from the initial idea and feasibility studies through planning and construction of the first prototypes to drafting construction plans for approval and managing production, construction and commissioning during the subsequent building of the power plant. This includes all optical calculations, structural planning, drive and control technology.

Parabolic trough test loop, UltimateTrough®, California, USA.

Schmack Biogas GmbH

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value chain full-line supplier

technology
biogas
application electricity, mobility, heat | industry
profile full-line supplier | plant components, operations management, biogas plants

Biogas plant Stausebach, Germany.

Comprehensive supplier of highly efficient and economic biogas plants

Schmack Biogas GmbH, Schwandorf, is one of Germany's leading providers of biogas plants. Since 1995, the company has been setting standards for highly efficient and economic biogas plants. The portfolio includes plant systems in the output range of 50 kW for compact plants up to 20 MW gas feed-in plants. More than 450 plants in 18 countries have been installed worldwide. Since January 2010, Schmack Biogas is part of the Viessmann Group.

Innovative technologies and processes

The range of products and services covers the entire biogas value chain: from project development and engineering to feedstock and operations management. Besides technical support, the focus is on comprehensive micro-biological services. An in-house R & D laboratory is used to identify and realize efficiency potentials in the area of process biology.

Specialist in wet and dry fermentation

With system solutions for wet and dry fermentation, Schmack Biogas covers the entire range of fermentation technologies. By using high-quality components manufactured in-house, particularly in the areas of agitator and feeding technology, Schmack offers process and energy optimised system solutions. Schmack Biogas is also active in international markets. With subsidiaries in Italy, the USA and the UK, Schmack has a broad international presence.

Components made in-house.

inter solar
connecting solar business | EUROPE

Solar Promotion GmbH

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value chain services

technologies ■ ■ ■
photovoltaics, solar thermal energy, storage and grid technology
application electricity, mobility, heat | manufacturer, subcontractor, wholesaler, service provider and partner of the solar energy industry
profile other | trade fairs, events

The world's leading exhibition for the solar industry

With events spanning four continents, Intersolar is the world's leading exhibition for the solar industry and its partners. It unites people and companies from around the world with the aim of increasing the share of solar power in our energy supply. We have more than 20 years of experience in opening up markets, providing specialist knowledge and creating links: Connecting Solar Business!

Intersolar Europe

Intersolar Europe, the world's leading exhibition for the solar industry and its partners, takes place annually at Messe München and focuses on the areas of photovoltaics, PV production technologies, energy storage systems and renewable heating. Since its founding, it has become the most important industry platform for manufacturers, suppliers, distributors, service providers and partners of the solar industry. Intersolar Europe 2016 takes place at Messe München from June 22 to June 24.

In 2016, the ees Europe, Europe's largest exhibition for batteries and energy storage systems, takes place again in conjunction with Intersolar Europe. Covering the entire value chain of innovative battery and energy storage technologies, both events form the leading industry platform for storage systems presented in combination with photovoltaics solutions. In 2015, more than 1,000 international exhibitors and over 38,000 trade visitors attended Intersolar Europe and ees Europe.

The accompanying Intersolar Europe Conference and ees Europe Conference consolidates the topics of the exhibition. In 2015, more than 1,500 attendees gained information about current industry topics and the background.

A busy exhibition booth at Intersolar Europe 2015.

A visitor to Intersolar Europe 2015 inspects a solar module.

Meet manufacturers, suppliers, distributors, service providers and partners of the solar energy industry.

The international platform for the solar energy industry – visitors from 165 countries and exhibitors from 42 countries.

SOLAR-RIPP®

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value chain manufacturer

technology ■ solar thermal energy
application heat | swimming pool operator
profile manufacturer | solar heating technology

493 m² SOLAR-RIPP ® on a flat roof in Gran Canaria.

Swimming pool solar heating

Based 20 km south of Bonn, the Rhineland-Palatinate company is focused on the development, manufacture and sale of swimming pool solar technology under the name of SOLAR-RIPP®. In addition to a number of standard absorber sizes, the company specialises in solutions tailored to the customer's structural conditions (flat roof, pitched roof, wall, fence, pergola, floor, etc.). With over 20 years of experience and exports already handled in 40 countries, SOLAR-RIPP® is one of the pioneers and leading companies in this sector.

The primary goal of this solar heating technique is to transport very large amounts of heat to swimming pool water at target temperatures of +30 °C. Product solutions are available for solar heating for small, private pools, up to large communal and hotel pools. For this, the aim is to achieve extremely high efficiency grades of over 80 percent through solar thermal energy. A number of technical challenges need to be overcome, including material resistance against salt, chlorine and UV rays, while at the same time supporting an extremely long plant service life. With this kind of solar technology, the solar flows directly to the swimming pool water warming it up, without additional heat exchangers through the hydraulic piping. A ribbed surface increases the total heat exchanger surface by the power of 3.2. The amortisation period for this inexpensive variant of solar thermal energy may be between only 3 and 5 years.

SOLAR-RIPP ® Solar absorber for swimming pool solar heating.

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application heat | industry
profile full-line supplier | planning and engineering services, solar heating technology, accessories

Industry solutions/installation examples with full vacuum tubes.

Industry solutions with full evacuated tube collectors

s-power is a globally successful company specialized in solar thermal energy. The founder, CEO Günter Schaffron, is the inspiration and initiator behind the NARVA solar thermal energy full vacuum tubes and the collector design.

100 percent made in Germany

Wherever quality and efficiency are being discussed, s-power already sets the standard worldwide thanks to its high-end quality in product and technical expertise.

Individual industry solutions

Deutsche Telekom AG, the Fraunhofer Institute, luxury hotels, the food industry, car paint industry and countless examples from industry and business all highlight our expertise. Whether process heat/process cooling, hot water, heating, pool heating or solar air conditioning, s-power offers individual sector solutions for industry, business and private housing. Consulting, planning, preparation, support: all-in-one.

Full vacuum instead of “partial” vacuum

Unlike the competition, the vacuum tube stands out because the high-performance absorber unit is completely inside the full or high vacuum. It is therefore guaranteed to be protected from corrosion, condensation and material change throughout its service life. This is made possible thanks to many innovative product characteristics, especially the globally patented unique glass metal connection.

Hail resistance class HW4

In the most stringent test, the s-power full evacuated tube collector currently receives the highest attainable hail resistance class for tube collectors, HW4.

Process heat, process cooling, warm water, solar air conditioning, heating and pool, with solar thermal energy installations generate savings in all areas of 30-70 percent of energy costs. Images of installation options.

stela drying technology

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technologies biogas, solid biomass
application heat | industry
profile manufacturer | installation equipment

Stela BT 1/6200-42 low temperature dryer in Italy.

Drying technology

STELA Laxhuber GmbH was founded in 1922 and specialises in the manufacture of dryers for the agricultural and industrial sectors. 150 trained staff are employed at the company's head office and production facility in Massing, Germany. The product range covers a wide variety of sectors from the chipboard industry, wood pellet production, agriculture and foods industry, fuel drying, energy and waste disposal. To date, more than 3,900 dryers have been successfully put into operation.

The topic of energy efficiency and energy saving is becoming increasingly important and Stela is therefore exploiting the innovative principle of circulating air drying. Here, the exhaust air streams from the rear area of the dryer are fed back to the front zones and heated up again. The hot air is fed through the product pile, becomes saturated and cools down in the process. The saturation level depends to a very large extent on the amount of moisture in the product being dried. Especially when drying to low levels of final moisture, the air in the rear area of the dryer can not be fully absorbed. This system delivers a considerable energy saving of up to 30 percent.

The moist product layer through which the air circulates acts as an additional filter. This enables dust content values of less than 10 mg/m³ to be achieved. The proven Stela multi-vent system further optimises the power consumption of the circulating air system. The system is the subject of a patent application.

BTU 2/6200-45 – 10/4 low-temperature belt dryer.

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application electricity | end users, trade, local government
profile full-line supplier, dealer, project developer | pv modules, inverter, accessories

Solar park in Bromskirchen, Germany.

Efficient systems for power generation from solar energy

Power and heat are continuing to converge – the trend towards combining power and heat as well as the increasing share of fluctuating energy sources are leading to a decentralisation of power generation. The use of solar energy for the generation of electricity is a pillar of the decentralised power supply.

In the context of its comprehensive product range, Viessmann has been selling photovoltaic products and systems for more than ten years now. To strengthen participation in this market segment, Viessmann Photovoltaik GmbH was founded in 2011.

The right solution for any requirement

With its Vitovolt 200 and 300 modules, matching inverters and battery storage systems, as well as a complete range of mounting accessories, Viessmann offers the right photovoltaic system for every requirement – for detached and semi-detached houses as well as for larger projects such as bioenergy villages or solar parks. The high quality standards applied in the selection of components guarantee reliable and efficient operation throughout the useful life of the system.

Apart from consulting and maintenance services, the company also supplies solutions for thermal and electrical storage, as well as system solutions for intelligent off-energy use, for example with reversible heat pumps and ventilation units for heating, cooling and ventilation using off-grid photovoltaic electricity.

Detached house with Vitovolt photovoltaic system from Viessmann.

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technology ■ geothermal energy
application heat | residential buildings, trade, industry
profile full-line supplier | full-range supplier

Cascade with four Vitocal 300 heat pumps from Viessmann.

Efficient heating and cooling with air and ground source heat

Viessmann Wärmepumpen GmbH is a production company within the Viessmann Group. The company develops and produces heat pumps from 1.7 to 118 kW, for the utilisation of heat from the ground, groundwater or ambient air. The output capacity range up to 2 MW is covered by Viessmann (Schweiz) AG, based in Worb, Switzerland.

The comprehensive Viessmann range includes heat pumps for new buildings and the modernisation of residential buildings, commercial use and hybrid systems, which combine heat pumps and condensing appliance technology. The portfolio is completed with domestic hotwater heatpumps, ventilation systems and components for cooling and refrigeration.

Wide range of products

With a very extensive product range, Viessmann supplies heat pumps for domestic hot water and living areas, compact appliances with integrated storage water heaters, hybrid appliances with integrated gas-fired and oil-fired condensing boilers and standardised high-capacity heat pumps up to approx. 300 kW.

Depending on the version, the heat pumps can also be used for waste-heat recovery, as well as for the cooling of buildings. As an alternative to deephole heat exchanger drilling, Viessmann's ice storage system offers an innovative energy source for heat pumps.

Vitocaldens 222-F hybrid heater from Viessmann.

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profile full-line supplier | full-range supplier

Solar thermal system for commercial use.

Full-range supplier of heating, industrial and cooling systems

The Viessmann Group is one of the leading international manufacturers of heating, cooling and climate control technology. Founded in 1917, the family business maintains a staff of 11,500 employees and generates a group turnover of 2.2 billion euros.

With 22 production divisions in 11 countries, subsidiaries and representations in 74 countries and 120 sales offices around the world, Viessmann is an internationally orientated company. 56 percent of sales are generated abroad.

The comprehensive Viessmann range includes individual solutions with efficient systems and outputs of 1.5 to 120,000 kilowatts for all applications and all sources of energy. In the area of solar thermal energy, the company has over 30 years' experience in the development and manufacture of highly efficient solar thermal systems with flat-plate and vacuum tube collectors.

Vitosol 300-F flat-plate collector.

Solar energy systems for residential buildings, trade, industry

Viessmann solar energy systems are suitable for new buildings and for modernising residential buildings, for applications in trade and industry and for use in local and district heating networks. Depending on the particular application, up to 60 percent of the hot water requirement and up to one third of the heating requirement can be covered.

The portfolio includes flat-plate and vacuum tube solar collectors, storage water heaters, buffer storage, solar power control systems and accessories. Because all components are carefully coordinated, this results in efficient and reliable solutions.

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application electricity | industry
profile full-line supplier | measurement and control systems, planning and engineering services, hydroelectric power plants

The dam of the pump storage power plant Limberg I in Austria.

Voith is a global technology group. With energy, oil & gas, paper, raw materials and transport & automotive, the broad portfolio with its plants, products and services serves five essential markets in all regions of the world. Voith's operating business is bundled in four Group Divisions: Voith Hydro, Voith Industrial Services, Voith Paper and Voith Turbo.

As a division of the group, Voith Hydro is among the global leaders in the hydropower sector, with approximately 5,200 employees and turnover of 1.3 billion euros in business year 2013 – 14.

As a full-line supplier of equipment for hydropower plants, Voith Hydro is one of the leading industrial partners for power plant operators all over the world. This includes the fields of electricity generation from hydropower as well as energy storage systems.

Voith Hydro's range of products and services covers the entire life cycle and all components of large and small hydropower plants: From generators, turbines and pumps to automation systems, that is, measuring and control technologies, up to service including modernisation of existing plants.

Moreover, Voith Hydro offers research and development, consulting, technical planning, manufacturing, assembly or commissioning operations.

Generator and magnetic core housing; Wehr hydropower plant.

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technology	biogas
application	electricity, heat | agriculture, local government and industry
profile	full-line supplier | plant components, installation equipment, biogas plants

WELTEC builds waste-to-energy biogas plants around the globe.

WELTEC BIOPOWER GmbH is one of the leading global companies in the construction of biogas plants from stainless steel. The company has planned, developed and constructed biogas plants since 2001. WELTEC currently employs around 80 employees and has set up over 300 power plants in 25 countries. The global sales and service network is spread over six continents. Customers include companies from the waste and food industries, agriculture and the wastewater industry.

The strengths of WELTEC are individual, sophisticated solutions up to a plant size of 10 megawatts. A core component of the success is the high proportion of internally developed components. Its advantage is also that it uses stainless steel material. The precious metal allows substrates to be used in various ways, fast assembly with low effort and a consistently high standard of quality regardless of the site.

Since commissioning the biogas plant, WELTEC has offered skilled support from the mechanical and biological service team. The cost-effectiveness of the plants is substantially guaranteed through 24/7 availability and its own laboratory. Since 2008, ISO 9001 and 14001 certificates have guaranteed their quality and environmental management.

With the subsidiary Nordmethan, a further area of business is to run biomethane plants and supply heating through energy contracting.

WELTEC offers solutions for gas treatment to biomethane.

iStock.com/Fabian Wenzel

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application field: electricity p. 78

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Wind energy · Geothermal energy · Solar thermal energy · Biogas · Storage and grid technology
Hydropower · Photovoltaics · Solar thermal power plants · Solid biomass · Other industry sectors

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application field: electricity, heat p. 82

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Wind energy · Hydropower · Geothermal energy · Photovoltaics · Solar thermal energy · Solar thermal power plants · Biogas · Solid biomass · Storage and grid technology · Other industry sectors

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Wind energy · Hydropower · Geothermal energy · Photovoltaics · Solar thermal energy · Solar thermal power plants · Biogas · Solid biomass · Storage and grid technology · Other industry sectors

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homepage: www.wind-energie.de

Verband Deutscher Maschinen- und
Anlagenbau e. V. (VDMA)
(German Engineering Federation)
address: Lyoner Str. 18, 60528 Frankfurt/Main, Germany
telephone: +49 (0) 69 - 66 03-0
fax: +49 (0) 69 - 66 03-1511
homepage: www.vdma.org

Hydropower

Bundesverband Deutscher
Wasserkraftwerke e. V. (BDW)
(German Hydropower Association)
address: Invalidenstr. 91, 10115 Berlin, Germany
telephone: +49 (0) 30 - 27 58 25 05
fax: +49 (0) 30 - 27 87 94 32
homepage: www.wasserkraft-deutschland.de

Verband Deutscher Maschinen- und
Anlagenbau e. V. (VDMA)
(German Engineering Federation)
address: Lyoner Str. 18, 60528 Frankfurt/Main, Germany
telephone: +49 (0) 69 - 66 03-0
fax: +49 (0) 69 - 66 03-1511
homepage: www.vdma.org

Geothermal energy

Bundesverband Geothermie e. V.
(German Geothermal Association)
address: Albrechtstr. 22, 10117 Berlin, Germany
telephone: +49 (0) 30 - 20 09 54 95-0
fax: +49 (0) 30 - 20 09 54 95-9
homepage: www.geothermie.de

Solar energy

Bundesverband der Deutschen Heizungsindustrie e. V.
(BDH)
(Federation of German heating Industry)
address: Frankfurter Str. 720 – 726,
51145 Köln (Porz-Eil), Germany
telephone: +49 (0) 2203 - 935 93-0
fax: +49 (0) 2203 - 935 93-22
homepage: www.bdh-koeln.de

BSW – Bundesverband Solarwirtschaft e. V.
(German Solar Association)
address: Quartier 207, Französische Str. 23,
10117 Berlin, Germany
telephone: +49 (0) 30 - 29777 88-0
fax: +49 (0) 30 - 29777 88-99
homepage: www.solarwirtschaft.de

Centrales Agrar-Rohstoff Marketing- und Energie-Netzwerk e. V. (C.A.R.M.E.N.)
(Central Marketing and Development Network)
address: Schulgasse 18, 94315 Straubing, Germany
telephone: +49 (0) 9421 - 96 03-00
fax: +49 (0) 9421 - 96 03-33
homepage: www.carmen-ev.de

Deutsches Zentrum für Luft- und Raumfahrt e. V. (DLR)
(German Aerospace Center)
address: Linder Höhe, 51147 Köln, Germany
telephone: +49 (0) 2203 - 601-0
fax: +49 (0) 2203 - 673 10
homepage: www.dlr.de

Deutscher Energieholz- und Pellet-Verband e. V. (DEPV)
(German Energy Pellet Association)
address: Neustädtische Kirchstr. 8, 10117 Berlin, Germany
telephone: +49 (0) 30 - 688 15 99-66
fax: +49 (0) 30 - 688 15 99-77
homepage: www.depv.de

Bioenergy

Bundesverband BioEnergie e. V. (BBE)
(German Bioenergy Association)
address: Godesberger Allee 142 –148, 53175 Bonn,
Germany
telephone: +49 (0) 228 - 810 02-22
fax: +49 (0) 228 - 810 02-58
homepage: www.bioenergie.de

Bundesverband der deutschen Bioethanolwirtschaft e. V. (BDBe)
(German Bioethanol Association)
address: Reinhardtstr. 16, 10117 Berlin, Germany
telephone: +49 (0) 30 - 301 29 53-0
fax: +49 (0) 30 - 301 29 53-10
homepage: www.bdbe.de

Fachagentur Nachwachsende Rohstoffe e. V. (FNR)
(Agency for Renewable Resources)
address: Hofplatz 1, 18276 Gülzow-Prüzen, Germany
telephone: +49 (0) 3843 - 69 30-0
fax: +49 (0) 3843 - 69 30-102
homepage: www.fnr.de

Fachverband Biogas e. V. (FvB)
(German Biogas Association)
address: Angerbrunnenstr. 12, 85356 Freising, Germany
telephone: +49 (0) 8161 - 98 46-60
fax: +49 (0) 8161 - 98 46-70
homepage: www.biogas.org

Fördergesellschaft für nachhaltige Biogas- und Bioenergienutzung (FnBB) e. V.
(German Biogas and Bioenergy Society)
address: Am Feuersee 8, 74592 Kirchberg / Jagst, Germany
telephone: +49 (0) 7954 - 92 19 69
fax: +49 (0) 7954 - 926-204
homepage: www.fnbb.org

IBBK Fachgruppe Biogas GmbH
(International Biogas & Bioenergy Center of Competence, IBBK)
address: Am Feuersee 6, 74592 Kirchberg / Jagst, Germany
telephone: +49 (0) 7954 - 926-203
fax: +49 (0) 7954 - 926-204
homepage: www.ibbk.fachgruppe-biogas.de

Union zur Förderung von Oel- und Proteinpflanzen e. V. (UFOP)
(Union for the Promotion of Oil and Protein Plants)
address: Claire-Waldoff-Str. 7, 10117 Berlin, Germany
telephone: +49 (0) 30 - 319 04-202
fax: +49 (0) 30 - 319 04-485
homepage: www.ufop.de

Verband der Deutschen Biokraftstoffindustrie e. V. (VDB)
(German Biofuels Industry Association)
address: Am Weidendamm 1A, 10117 Berlin, Germany
telephone: +49 (0) 30 - 72 62 59-11
fax: +49 (0) 30 - 72 62 59-19
homepage: www.biokraftstoffverband.de

Storage and grid technology

Bundesverband Energiespeicher e. V. (BVES)
(German Energy Storage Association)
address: Oranienburger Str. 15, 10178 Berlin, Germany
telephone: +49 (0)30 - 546 10 – 630
fax: +49 (0)30 - 300 145-500
homepage: www.bves.de

Other institutions and partners

AUMA – Ausstellungs- und Messe-Ausschuss der Deutschen Wirtschaft e. V.
(Association of the German Trade Fair Industry)
address: Littenstr. 9, 10179 Berlin, Germany
telephone: +49 (0) 30 - 240 00-0
fax: +49 (0) 30 - 240 00-330
homepage: www.auma.de

B2B Renewable Energies – Multilingual online business platform for renewable energies
homepage: www.renewablesb2b.com

Deutsche Auslandshandelskammern
(German Chambers of Commerce)

Directory of German Chambers of Commerce abroad:
homepage: www.ahk.de/en

Deutscher Industrie- und Handelskammertag (DIHK)
(The German Chambers of Industry and Commerce)
address: Breite Str. 29, 10178 Berlin, Germany
telephone: +49 (0) 30 - 20 30 80
fax: +49 (0) 30 - 203 08 10 00
homepage: www.dihk.de

Germany Trade and Invest – Gesellschaft für Außenwirtschaft und Standortmarketing mbH
(The economic development agency of the Federal Republic of Germany)
address: Friedrichstr. 60, 10117 Berlin, Germany
telephone: +49 (0) 30 - 20 00 99-0
fax: +49 (0) 30 - 20 00 99-812
homepage: www.gtai.com

iXPOS – The German Business Portal
homepage: www.ixpos.de

German authorities and ministries

Auswärtiges Amt (AA)
(Federal Foreign Office)
address: Werderscher Markt 1, 10117 Berlin, Germany
telephone: +49 (0) 3018 - 17-2000
fax: +49 (0) 3018 - 17-3402
homepage: www.auswaertiges-amt.de

Bundesministerium für Ernährung und Landwirtschaft (BMEL)
(Federal Ministry of Food and Agriculture)
address: Wilhelmstr. 54, 10117 Berlin, Germany
telephone: +49 (0) 30 - 185 29-0
fax: +49 (0) 30 - 185 29-42 62
homepage: www.bmel.de

Bundesministerium für Umwelt, Naturschutz, Bau und Reaktorsicherheit (BMUB)
(Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety)
address: Stresemannstr. 128 – 130, 10117 Berlin, Germany
telephone: +49 (0) 30 - 183 05-0
fax: +49 (0) 30 - 183 05-2044
homepage: www.bmub.bund.de

Bundesministerium für Wirtschaft und Energie (BMWi)
(Federal Ministry for Economic Affairs and Energy)
address: Scharnhorststr. 34 – 37, 10115 Berlin, Germany
telephone: +49 (0) 30 - 186 15-0
fax: +49 (0) 30 - 186 15-7010
homepage: www.bmwi.de

Bundesministerium für wirtschaftliche Zusammenarbeit und Entwicklung (BMZ)
(Federal Ministry for Economic Cooperation and Development)
address: Stresemannstr. 94, 10963 Berlin, Germany
telephone: +49 (0) 30 - 185 35-0
fax: +49 (0) 30 - 185 35-250
homepage: www.bmz.de

Umweltbundesamt (UBA)
(Federal Environment Agency)
address: Wörlitzer Platz 1, 06844 Dessau-Roßlau, Germany
telephone: +49 (0) 340 - 21 03-0
fax: +49 (0) 340 - 21 03-2285
homepage: www.umweltbundesamt.de

Cooperation partners

Bundesverband der Deutschen Heizungsindustrie e. V. (BDH)
(Federation of German heating Industry)
homepage: www.bdh-koeln.de

Information on: Geothermal, Photovoltaics, Solar thermal, Solid biomass

Bundesverband BioEnergie e. V. (BBE)
(German Bioenergy Association)
homepage: www.bioenergie.de

Information on: Solid biomass

Bundesverband Deutscher Wasserkraftwerke e. V. (BDW)
(German Hydropower Association)
homepage: www.wasserkraft-deutschland.de

Information on: Hydropower

Bundesverband Energiespeicher e. V.
(German Energy Storage Association)
homepage: www.bves.de

Information on: Storage and grid technology

Bundesverband Geothermie e. V.
(German Geothermal Association)
homepage: www.geothermie.de

Information on: Geothermal energy

Bundesverband Solarwirtschaft (BSW-Solar)
(German Solar Association)
homepage: www.solarwirtschaft.de

Information on: Photovoltaics, Solar thermal energy

Bundesverband WindEnergie e. V. (BWE)
(German Wind Energy Association)
homepage: www.wind-energie.de

Information on: Wind energy

Deutscher Energieholz- und Pellet-Verband e. V. (DEPV)
(German Wood Energy and Wood Pellet Association)
homepage: www.depv.de

Information on: Solid biomass

Deutsches Zentrum für Luft- und Raumfahrt e. V. (DLR)
(German Aerospace Center)
homepage: www.dlr.de

Information on: Solar thermal power plants

Fachverband Biogas e. V.
(German Biogas Association)
homepage: www.biogas.org

Information on: Biogas