





Energy supply with

renewables - Made in Germany

Information on technologies, suppliers, products and services 2014/2015 edition

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Deutsche Energie-Agentur GmbH (dena)

German Energy Agency

Chausseestr. 128a, 10115 Berlin, Germany

Tel: +49(0)30-726165-600 Fax: +49(0)30-726165-699 E-mail: renewables@dena.de

info@dena.de

Internet: www.renewables-made-in-germany.com

www.dena.de

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Technology overview

■ Wind energy	Solar thermal power plants
■ Hydropower	■ Biogas
■ Geothermal energy	■ Solid biomass
Photovoltaics	■ Storage and grid technology
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Preface



Ladies and Gentlemen,

The Federal Republic of Germany is the global market leader in the field of environmental technologies and has a growing base of satisfied customers around the globe. We have recognised the enormous potential in the area of renewable energies, and created appropriate instruments to promote them, at an early stage in the game. For two decades, our companies have been developing and optimising technologies for the production of renewable energies with a high degree of efficiency and outstanding quality – just as you would expect from products "Made in Germany".

Thanks to the pioneering experience and time-tested expertise we have gained both at home and abroad, along with rapid technological development, our manufacturers and project developers are now able to offer technological solutions to meet every need. This is important since every country is facing different challenges due to the current changes in energy supply. Industrialised countries, for instance, which already have their infrastructure in place, primarily require solutions for integrating renewable energies into their system. In many emerging and developing countries, on the other hand, renewable energies can play an important role in expanding their energy supply system.

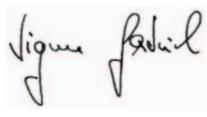
Germany has invested a lot of resources in the research, development and application of technologies for generating energy from renewable sources and would like others to benefit as well. In the context of our "renewables – Made in Germany" initiative (www.renewables-made-in-

germany.com), we help you, our international partners, find the right German company in the renewables industry to meet your needs and help you attain your goals.

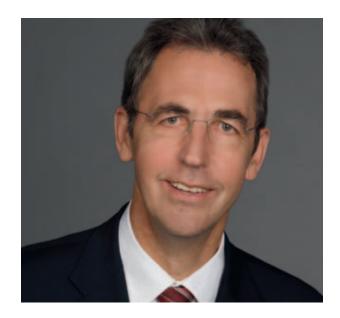
This catalogue provides an overview of our manufacturers and service providers. German companies offer a broad spectrum of long-lasting, sustainable products and solutions. Some of them even have branch offices in your country. By doing business with these companies, you will be creating new jobs at home.

I wish you every success for your project and would be delighted if you decided to work with one of the many companies presented in this catalogue.

Sincerely yours,



Sigmar Gabriel Federal Minister for Economic Affairs and Energy



Ladies and Gentlemen,

How can we ensure a safe, affordable and sustainable energy supply? Which opportunities and advantages do renewable energies have to offer? What role can they play in the supply of energy? These questions and many more are being asked by legislators, businesses and private households the world over. Whether owing to climate protection goals, safety aspects or commercial reasons, the need for electricity, heat, refrigeration and mobility, should – and often can – no longer be covered by fossil fuels alone.

Thanks to technological progress and policies aimed at promoting renewable energy sources, the global expansion of renewables has been advancing for more than two decades. The portion of the world's energy generated from renewable sources, for instance, rose by an average annual 2.0 per cent from 1990 to 2012 – thus growing faster than the worldwide consumption of primary energy (+1.9 per cent). In many of the world's countries, renewable sources of energy are now a mainstay of the energy supply. Their share of the world's primary energy consumption in 2012 was as high as approx. 13 per cent. In Germany, they accounted for 12.3 per cent of final energy consumption in 2013: 25.4 per cent of total gross electricity generation, 9 per cent of total German heat consumption and 5.3 per cent of fuel consumption.

In the context of the German "energy transition", the country is planning its strategies and progressing towards a secure, affordable and sustainable long-term energy supply. Within this framework, renewable sources of energy are constantly being expanded. In the electricity sector, for instance, renewables are to account for a share of 55 to 60 per cent by 2035. This also calls for a respective adjustment of the grid infrastructure and the creation of innovative solutions and technologies to stabilise the energy system.

Legislators, businesses and private households around the world can benefit from the experience Germany has gained in the context of its energy transition. In international comparison, German companies have developed a considerable store of practical experience, setting standards in the generation, distribution, provision and storage of energy from regenerative sources. Germany has developed highly efficient, world-class technologies in all performance categories. Thanks to continuous advancements, German technologies and services stand out for their reliability and deliver optimum customised solutions.

It is my great pleasure to present to you the eleventh edition of the "renewables – made in Germany" supplier catalogue. I hope you will establish a mutually beneficial dialogue with some of the approximately 40 participating companies in the German renewable energy industry.

With best wishes,

S. Lhle

Stephan Kohler, Chief Executive Deutsche Energie-Agentur GmbH (dena) German Energy Agency

Your supply of renewable energies

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

Renewable energy technologies, products and services "Made in Germany" enjoy an outstanding international reputation. They stand for quality, reliability, a long service life, efficiency and safety. The 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 of 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, few invasive intrusions in the natural countryside (environmentally compatible land consumption) and involve a low level 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 a 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.



Aldabra, Seychelles: This hybrid PV plant with a peak capacity of 25.38 kilowatts (kWp) provides an autonomous energy supply for one of the research stations situated in the area.

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 so-called 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 chapter "Technologies" 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

"If renewable energy projects are to be successful, they must be planned and constructed to suit demand with all necessary measures for smooth operation. Whether for the entire spectrum or select phases of a project, Corporate Energies is a competent, experienced group of companies offering individual solutions and products along



the entire value-added chain and providing help with planning and financing, as well as implementation and operation of power plants in Europe and around the world."

Stefan Simon, Director of Industry Development, Corporate Energies GmbH & Co. KG

Partners

Individual consultancy is absolutely necessary to be able to use renewable energies in a way that suits the 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.

To facilitate navigation, you will find in the brief profile of each company a summary of the key technologies on offer, as well as the product/performance categories.

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 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 so-called project financing. To this end, various stakeholders (operating consortium, manufacturer, supplier, etc.) join to form their own company, a so-called special purpose vehicle (SPV). The stakeholders bring a share of their own equity into the SPV; following a due diligence process (review of credit and business), banks then provide debt capital.

The shareholders in a renewable energy project company expect high profits from their investment. With this goal in mind, private equity companies, such as pension and environmental funds, 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.

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



Visitors to the German joint stand at leading trade fairs around the world can talk personally to representatives from German companies and other experts. The photo shows the Moroccan Energy Minister Abdelkader Amara talking to the Consultant of the German pavilion at the "EneR Event – International renewable Energy and Energy Efficiency Trade Fair" (11/2013).



Well-founded knowledge of possible means of funding and subsidy programmes, as well as the statutory framework, is decisive if the foundation for the overall success of a commercial enterprise is to be laid in an early phase.

complicated, expensive preliminary work, only projects whose investment volume is upwards of about $\mathfrak C$ 10 million 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 (so-called 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 on "Advantages of importing German goods and services".

Investment promotion

The federally owned KfW Bank Group plays a pivotal role in providing credit facilities for investments in renewable energy projects in Germany and around the world. In 2012, $\ \in\ 787$ million (66 percent of the total commitments in the energy sector) were granted for renewable energies 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 so-called "on-lending". With this kind of lending, an international organisation extends credit to local banks in the respective eligible countries. The local banks can re-lend this credit 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 European Emissions Trading Scheme. 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.



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

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.

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. That is because this line of business also promotes sustainable global development. Hence 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 credits guarantees of 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 in the area of renewable energies amounts as a rule to eighteen years. Including locally accruing expenses (for



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

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 euro. 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 German companies investing directly abroad a safeguard against political risks. These include participating interests, investment-like loans, capital endowments for branch offices and other proprietary rights. In the case of renewable energy projects, commitments from official or officially 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 or 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

Personal contact

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E-mail: renewables@dena.de Fax: +49(0)30-726165-699 Tel: +49(0)30-726165-600

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 – business, politics 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 12.3 percent of final energy consumption and 23.4 percent of gross electricity production. And the German federal government is continuing 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 prioritising the feed-in of electricity from renewable sources to the grid. By the end of 2012, more than 1.3 million EEG-subsidised installations throughout Germany were feeding in more than 118,000 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 such as additional insulation, or make use of combined heat and power or district heating facilities. The MAP promotes technologies



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.

in the heating market primarily for existing buildings – such as solar thermal systems, wood pellet heating systems and efficient heat pumps. The 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 coming 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 more specifically 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 their roughly 830,000 employees are the basis for the success or failure of a large number of other industries. And the renewable energy industry itself, which now has around 378,000 employees, is also a major economic factor. The so-called Special Equalisation Scheme in the Renewable Energy Sources Act was thus instrumental in creating the policy which enables power-intensive manufacturing companies, as well as operators of railways, to apply for an exemption from the so-called EEG levy.



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

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

TECHNOLOGIES



Bridge over the Rhine River in Emmerich, Germany.



WIND ENERGY



Østerild, Denmark: The energy yield of a wind turbine depends on such things as how much area a rotor covers. The picture shows the world's longest rotor blade, 75 m, being mounted onto the hub of an offshore wind power plant. The 154 m rotor covers an area of 18,600 m 2 – as large as two football pitches. The system can produce 25 GWh of clean electric power per year on offshore sites. This is enough to supply 6,000 households. More than three decades of technical expertise went into the development of the gearless 6 MW system and the 75 m rotor blade.

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 more and more 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 the 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. Wind energy products and services "Made in Germany" 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 per cent of the world's energy demand. The world's entire installed capacity stood at approximately 318 GW at the end of 2013. The largest markets are in China (91.4 GW), USA (61 GW) and Germany (34.2 GW). In Germany, wind energy accounted for 7.9 per cent of the total electricity generation market in 2013.

The following details the three technologies for utilising wind energy:

Onshore wind turbines

Onshore wind farms are often set up alongside or close to the coast these days. 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 continued 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 the 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 per cent.

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 and are largely restricted to the period from April to November. 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.



An installation vessel installing a wind turbine in the London Array wind energy plant.

Small wind turbines

Small wind turbines are particularly suitable for self-sufficient power generation or local electricity production in off-grid areas.

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.

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 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 deep water.



Fitters mounting a nacelle.

German manufacturers of small wind turbines have achieved greater professionalism in production over the past few years. Small turbines from Germany are now the most reliable of their type in a global comparison. Numerous types of turbines from German manufacturers have been positioned in the market, especially in the 1–20 kW range.

Commercial use

The electricity generation costs vary depending on the technology of the wind energy usage:

- Onshore: Wind energy already has the lowest electricity generation costs among what are known as new renewable energy technologies today (with the exception of water power) in the onshore sector and depending on the location. Electricity generation costs are therefore currently in the 4.5 to 10.7 €ct/kWh range and at 2,2000 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 range 11.9 to 19.4 €ct/kWh. 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, the electricity generation are between 15 and 20 €ct/kWh based on 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

Opinion panel

"Experiences from due diligence processes with a total volume of more than 20 GW of wind power onshore and offshore testify to our unique expertise in reviewing and negotiating technical project contracts. Our customers profit from the fact that we can bring the practical experience and current findings from our wind potential evaluation and engineering departments to bear on the project assessments."



Joachim Binotsch, Managing Director, Head of the "Technical Due Diligence" Department, BBB Umwelttechnik GmbH

systems in the future. In addition, further falls in production costs and improved local integration of energy systems should be seen.

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, there is considerable potential for the future here. 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 15 to 17.5 per cent of the world's energy demand 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



 $Repowering\ project\ in\ Schleswig-Holstein,\ Germany.$

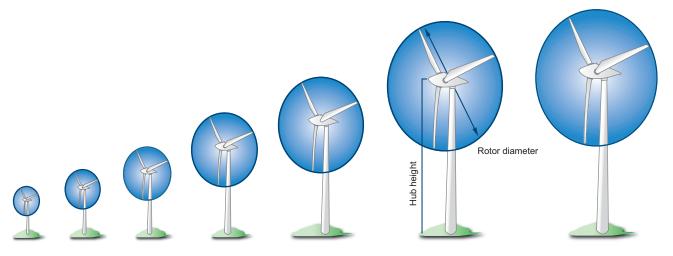
Turkey. It is also apparent that national and multilateral development banks are increasingly steering investment in the wind energy sector towards these emerging economies.

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 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 the 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 as, for example, citizens' wind farms (see information panel). This model is already being used in several countries, for example, in Germany and Denmark.



	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

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

Small wind turbines

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



Small wind turbine manufactured in Germany.

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 through 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.

HYDROPOWER



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 m $^3/\text{sec}$. The plant is run by two horizontal-axis, twin-nozzle Pelton turbines.

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. At around 3,490 TWh, hydropower accounted for 16 per cent of the world's electricity generation in 2011. Given rising demand, the proportion of hydropower in the world's electricity generation is unlikely to increase 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, which still holds great potential in the context of the international transformation 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 short-term fluctuations, caused by wind and solar electricity.

Technologies and applications

Types of power plant

There are various types of hydropower plants:

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.

The so-called 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.

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 the so-called 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 so-called Pelton turbine, a free-stream turbine, is used for high drop heights from 100 m to 1000 m and/or low water volumes.

Opinion panel

"The Ossberger cross-flow turbine has only three moving parts: the rotor and the two guide vanes. The bearing for the guide vanes needs no maintenance and the bearing for the rotor is easily accessible out of the water. This results in very low operating costs!"



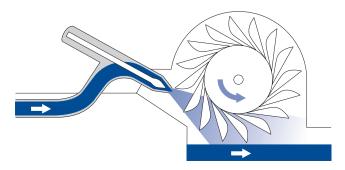
Dipl. Ing. Holger Franke, Sales Manager, Ossberger GmbH+Co

"The simple, robust mechanics of the DIVE turbine enable highly efficient, low-maintenance small hydropower stations to be built and operated. The simple, clear interfaces of the DIVE turbine to the adjoining components of the power plant are of great help in this context, as well as the fact that the entire unit comprising turbine, 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



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.

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.

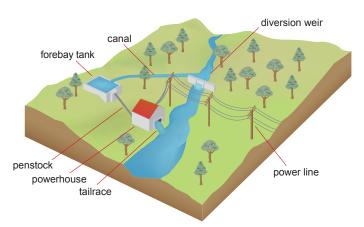
Small hydropower (SHP)

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 the plants are on small rivers and do not have a reservoir but water basins of different size and construction.

There is, however, no international consensus on the definition of small hydropower. The classification of small hydropower systems, which has become generally accepted, is as follows:

Micro: 1 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. The 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 the technology and expertise from Germany – 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 to 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.

Commercial use

Hydropower plants achieve a high efficiency factor. They are able to convert up to 90 per cent of usable hydropower into electricity. Hydropower is very competitive compared with other renewables and conventional power plant technologies thanks to the 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,



The profitability of a hydropower plant is calculated based on investment costs, operating costs and income.

Opinion panel

"Government policies need to promote renewable energy sources in a way that allows hydropower to maximize its contribution to supply reliability."

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



depending on their type, are able to store and provide electricity quickly based on demand, they contribute significantly to grid stability. Hydropower plants reduce the 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 the operating costs, while increasing the productivity of the power plant.

To ensure that the high investment costs are amortised, the site of power plants must be investigated exactly in terms of 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 have 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) particularly provides for the expansion of small hydropower plants in 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 CO₂ 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 per cent 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 and the improvement 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.

There is greater research in technologies and concepts for the use of tidal energies (see also the information panel "Use of 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.

Country	Capacity end 2012 (MW)	Pipeline capacity (MW)
Global	516.7	~3,000.0
South Korea (Tidal)	254.0	2,000.0
France (Tidal)	240.0	0
Canada (Tidal)	20.0	0
UK (Ocean)	1.2	498.0
Russian Fed. (Tidal)	1.7	12.0
USA (Ocean)	0.2	2.5
Spain (Ocean)	0.3	0
China (Tidal)	3.2	50.0
India (Tidal)	0	250.0

Installed and planned tidal and hydropower worldwide (estimate). Source: IHA Hydropower Report 2013.

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 that are surrounded by oceans with high current and/or high tides there is considerable potential for using tides and marine energy for regenerative electricity generation. The comprehensive 3 GW project pipeline worldwide is just at the start of the anticipated market development.

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.



Cherbourg, France: A megawatt tidal current turbine after final assembly. The turbine was developed specifically for use in rough offshore conditions.

GEOTHERMAL ENERGY



Sauerlach, Germany: The Sauerlach Geothermal CHP plant officially started operations in January 2014. The plant uses the roughly 140 °C thermal water both to provide heat for Sauerlach households as well as to generate electricity for around 16,000 households. This cuts annual emissions of CO_2 by around 35,000 tonnes. The figure shows drilling work at the project site.

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 covers the entire range of geothermal technologies: From deep geothermal energy, both hydrothermal and petrothermal, for heating, cooling and electricity generation up 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

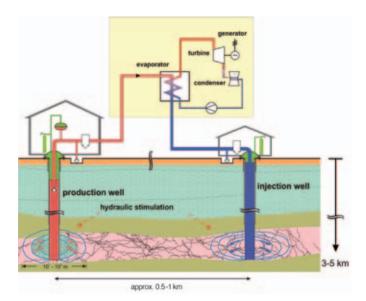
the geothermal gradient and measured in mK per metre. This gradient is caused by the heat flow from the depths to the earth's surface. The temperature of the first metres below the earth's surface is influenced additionally by solar radiation and precipitation.

Depending on the drilling depth, a distinction is made between deep geothermal energy (>400 m) and nearsurface 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 insolated 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

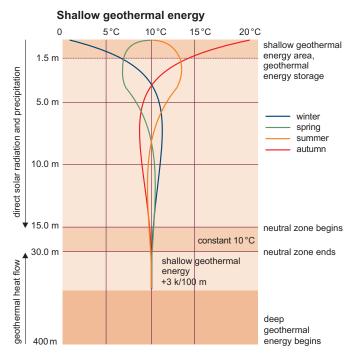
Borehole heat exchangers, geothermal heat collectors or energy piles are commonly used to thermally develop the soil:

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 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.

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 groundcontact 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. The annual costs can as a rule be lowered by approx. 50 per cent 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, 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-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 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 the future energy supply are increasingly looking to geothermal energy. A clear legal and stable policy framework in the field of electricity feed-in are 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" of the Federal Ministry for the Environment and through special exploration insurance policies.

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

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 per cent 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 influence on the economic viability. For example, the use of a heat pump can considerably increase the per centage 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 per cent 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 per cent 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 so-called 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. The KfW programmes cannot be combined with the Market Incentive Programme, however.

Outlook

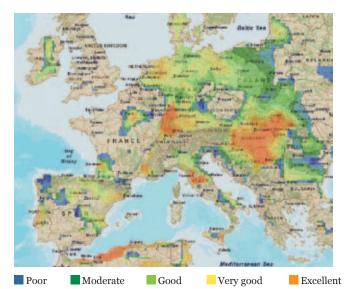
The international market potential of geothermal energy for sustainable and CO₂-free energy generation is huge. According to Bloomberg New Energy Finance, the geothermal electricity production capacity is expected to more

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. Apart from 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, South America along the Andes 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 ground-water 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)
- 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 the items 1 to 4 of the preliminary study and stipulation of planned alternatives
- 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)

- Extended geophysical exploration
 (3D seismic imaging, etc.), if necessary
- 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 des 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
- 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

- 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

PHOTOVOLTAICS



Hanover, Jamaica: The biggest solar power plant in Jamaica was inaugurated in 2014. The private plant with a peak output of 1.6 MW supplies an entire hotel complex with solar power. The project included a total investment from the hotel of nearly € 2.5 million. The full return on equity is expected after four years. In the coming 30 years, savings of € 16 million on energy costs should be achieved. The PV solar system used here was developed especially for the Caribbean: it is lightweight, needs but little maintenance and can withstand category 4 hurricanes.

Photovoltaics

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

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 so-called 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 (up to 22 per cent). 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 up to 16 per cent. 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 83 per cent in 2012.

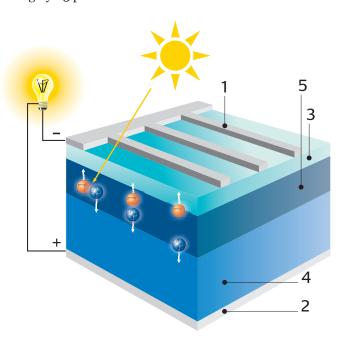


Diagram of a solar cell: 1) negative electrode 2) positive electrode 3) n-silicon 4) p-silicon 5) barrier layer. Source: www.solarpraxis.de/M.Römer.

Opinion panel

"Highly efficient systems, unique quality assurance and innovative services – IBC SOLAR is setting standards in on-grid and off-grid PV solutions all over the world. In the past 32 years, we have established ourselves as a leader in the industry. More than 150,000 installed systems with a total capacity of more than 2.7 GW speak for themselves."



Udo Möhrstedt, Chairman of the Board and Founder, IBC SOLAR AG

"As a supplier of planning software with a global clientele, we focus primarily on providing reliable and high quality products. Our clients can trust entirely in the calculations of our products in the areas of photovoltaics, solar thermal power and heat pumps."



Dr. Gerhard Valentin, Managing Director, Valentin Software GmbH

"The Fraunhofer ISE offers its customers research and development services related to the generation, efficiency, distribution and storage of energy. We have a wide range of competences and many years of experience, which we put to use in the best possible manner for the individual requirements of our international customers. Together



we can create an integrated, sustainable energy system based on renewable sources of energy."

Dr. Eicke R. Weber, Director of the Fraunhofer Institute for Solar Energy Systems ISE

Examples of thin-film technologies

Amorphous silicon generally reaches a degree of efficiency of 5–10 per cent, 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 per cent. This relatively new technology has a high potential for development, as the maximum degree of efficiency achieved at present of 14.6 per cent (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.

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 efficiency of 16 per cent is achieved. According to the manufacturer specifications, the CdTe modules outperform crystalline solar cells in low light or high temperatures.

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 convention/traditional PV cells (thin-film and thick-film).

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



With new materials, production techniques and installation technologies, organic photovoltaics (OPV) should 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.

43.6 per cent 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 the small 1 kWp system up to the solar park 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 per cent in 2013. At the end of 2013, 60,000 full-time workers were employed in roughly 5,000 companies in the German PV industry. Of those companies, 200 were involved in the manufacturing sector, producing cells, modules and other components with the highest quality standards.

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 from a wide variety of energy sources.

Opinion panel

"Large coal-fired power plants not only make us dependent on expensive fuels for decades but are also extremely inflexible. Additionally, planning and construction take far too long. It takes many years before this type of power plant actually produces electricity. We do not have this much time. The only way we will be able to provide energy in a reliable, sustainable



and cost-effective way to an increasing global population is by utilizing renewable energy sources and thus make ourselves independent from conventional energy carriers as quickly as possible."

Joseph Mashao, Managing Director, SMA South Africa

"Renewable energies are the present and the future. What business model could be better than the PV industry – economical, environmentally friendly and socially just? These conditions are the incentive for us to invest in our research and development of innovative products, such as our PIKO inverter and PIKO storage systems, and to push



ahead in joint technical projects with our partners and associations to clear the way for the success of renewable sources of energy. Thus we can make a small contribution to the success of the great social task of transitioning to alternative energy."

Werner Palm, Managing Director, KOSTAL Solar Electric GmbH Crystalline modules, thin-film modules and highly efficient inverters 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 kilowatthour are 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 model. With the EEG, which came into force in 2000 and



Solar measurement for site analysis: The solar radiation at the planned site of the solar park must be evaluated in order to get effective, profitable solar projects off the ground.

Fixed feed-in compensation

Electricity exchange

EEG tariff

Management bonus and control energy

Market premium

Market premium

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

which was last amended in 2014, the development of renewable energies has been accelerated due, among other things, to the 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 per cent, 2013 = 25.4 per cent) 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 the 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 500 kilowatts of installed capacity (kWp) or more (100 kWp or more starting in 2016). For the additional effort and expense of direct marketing, 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 m 2 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.



Unterbreizbach, Germany: Built on the ash heap of a coal-fired power plant, this solar park has a total capacity of 2.5 MWp and generates electric power for 750 households.



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 meets 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

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



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.

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, so-called 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.





SOLAR THERMAL ENERGY

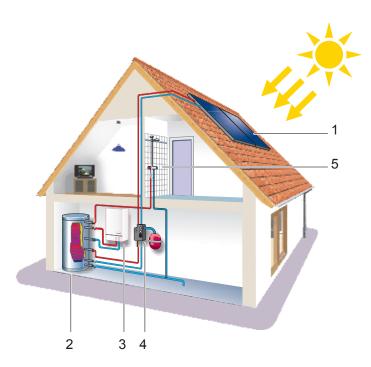


Barcelona, Spain: The ninety flat plate collectors installed on the roof of this hotel were made from environmentally friendly, single-variety materials which can easily be separated and recycled. The collectors used here have an expected life span of 20 years.

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) Solar storage tank 3) Boiler 4) Solar station 5) Hot water consumer (e.g. shower).
Source: www.solarpraxis.de/M.Römer.

Technologies and applications

The application area for solar thermal energy extends from simply heating water to so-called 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 currently still require the most research are solar thermal cooling systems and process heating systems.

System types

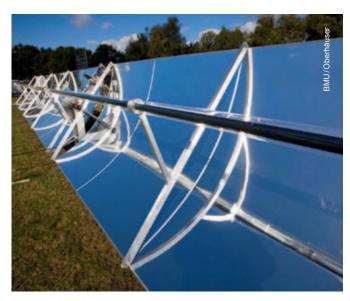
A distinction is made between the following types of systems:

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 per cent 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.



This solar thermal energy system on a rented building in Berlin/Germany supplies the tenants with heating at no additional cost and in an environmentally friendly way using solar thermal energy.



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 per cent of the building, depending on how well the building is insulated and how high the level of heat requirement is. However, there are also special solar houses that cover over 50 per cent and up to 100 per cent 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 per cent 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 both for heating 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

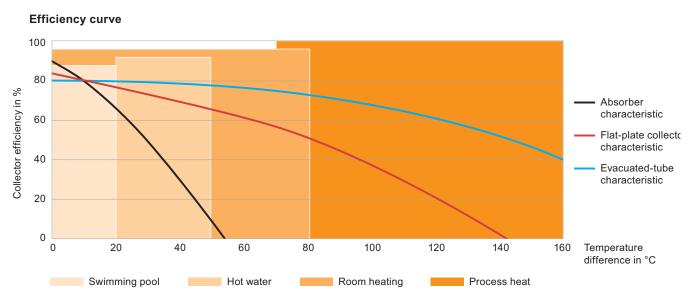
The metal solar absorber is fitted in a casing that reduces the rate of heat loss thanks to thermal insulation and a glass pane. Flat plate collectors generally operate in the temperature range 60-90 °C.

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.

Evacuated tube collectors

Even higher temperatures and degrees of efficiency are achieved with evacuated tube collectors, in which the level of heat loss is significantly reduced thanks to high negative pressure in the glass tubes. A collector is made up of several evacuated tubes. Thanks to the rotatable mounting for the individual tubes, the flat absorber plate in the glass tubes can be turned to the optimum position for sunlight. For this reason, evacuated tube collectors can also be deployed 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.



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

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 also to be available at cooler times of the year. 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. Basic research is one of the areas on which the modern solar research has been concentrating in Germany. New materials and cost reduction has been pushed ahead in collector manufacture. Thanks to increased automation and material savings, the production costs for solar collectors were halved between 1995 and 2010.

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 today 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 is being accelerated.



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 the 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 pane

"The economic efficiency of a solar thermal collector is found mainly in its high yield, long service life and especially its performance reliability – lasting even for decades. Our technology, based on highvacuum tubes, meets all requirements and always performs at the same high level. All essential solar thermal components are located inside



the high vacuum and are thus protected from deterioration for their entire lifetime. Thanks to this and individual customer solutions, many years of practical experience and knowledge gained in a large number of large-scale solar thermal projects, we achieve the best possible economic efficiency and customer satisfaction in every solar thermal project. One hundred per cent 'Made in Germany'."

Günter Schaffron, Managing Director, s-power Entwicklungs- & Vertriebs GmbH

Commercial use

Putting a figure on how cost effective solar thermal systems are is more complex than is the case for 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 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

The turnaround in energy policy will only be realised in many countries, if renewable energies take 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, in apartment blocks and in commercial and public buildings. The 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, in hospitals, homes, hotels and in industry.

Solar-powered cooling systems represent a forward-looking technology, especially in countries where there is a high demand for cooling, in order to 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 the refrigeration machines. However, as the technology for solar cooling is still relatively new, the installation costs are still higher than those for conventional cooling systems. Reasons for the higher costs are 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.



Hot water for the cafeteria of a Brazilian aircraft manufacturer is heated by the power from 180 flat plate collectors. The solar heat supports the washing and cleaning process in the commercial kitchen. The installation reduces the cafeteria's gas consumption by 69 per cent.

Providing process heat for industrial applications

In addition to solar cooling, there is also a major world-wide potential in the provision of solar process heating for industry and in the commercial sector. The system technology required for high temperatures is currently still relatively expensive; by contrast, process heating at temperatures of between $20-100\,^{\circ}\text{C}$ can be provided relatively quickly and can be developed at a comparatively low price. Temperatures of up to $250\,^{\circ}\text{C}$ should be achievable in future.

In Eichstätt in Germany, one of the roughly 100 pilot systems worldwide is supplying 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 $\rm m^2$ and two 60 $\rm m^2$ large solar panels.



Hofmühl brewery in Eichstätt, Germany.

SOLAR THERMAL POWER PLANTS



Murcia, Spain: The 30 MW Puerto Errado solar thermal power plant has been in commercial operation since August 2012. The power plant, with its 28 rows of linear Fresnel collectors, is the world's largest Fresnel solar power plant in operation. It produces 49 GWh of electricity per year, thereby saving 16,000 tonnes of ${\rm CO_2}$ emissions. The energy generated here covers the needs of more than 12,000 households.

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, as well as solar tower power plants, are currently in planning or construction, as are large-scale plants with dish/Stirling and Fresnel technologies. In 2013 approx. 60 solar thermal power plants went on the grid around the world. This corresponds to a capacity of approx. 3,200 MW. Another 40 power plants with a total planned capacity of around 6,000 MW are currently in various stages of construction or actual project development.

As far as research and development of CSP technologies are concerned, German companies are counted among the world's top bracket.

Technologies and applications

The common basic principle of solar thermal power plants is the use of concentrating parabolic dish systems in large-scale solar fields that concentrate the 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 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.

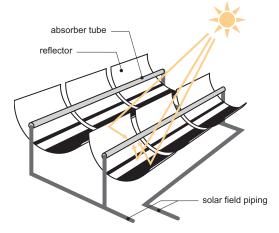
Owing to this principle, solar thermal power plants are characterised by the fact that the heat generated can be stored in a relatively easy and inexpensive way, and can thus be used to generate electricity in the evening and at night. In this way, they can make a decisive contribution to predictable,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

A distinction is made between linear and dish concentrator systems; within these systems there are four different configurations:

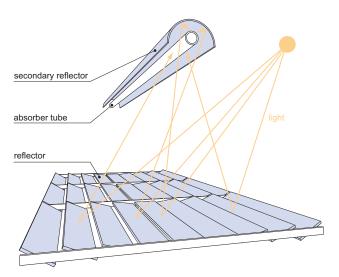
Linear concentrator systems

Parabolic trough plants

The solar field of a parabolic trough plant contains numerous parallel rows of collectors that comprise parabolic curved dishes and concentrate sunlight onto an absorber tube that runs along a focal line, thus producing temperatures of about 400 °C. The heat carrier here is circulating thermal oil which absorbs the generated heat and creates steam at an approximate temperature of 390 °C in a heat exchanger; the steam is then used to drive a steam turbine and a generator to generate electricity as in conventional power plants. 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 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.

heliostats heliostats

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 and vaporising water. 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.

Dish concentrator systems

Solar towers

In solar tower power plants, the solar radiation from hundreds of automatically positioned dishes is concen-



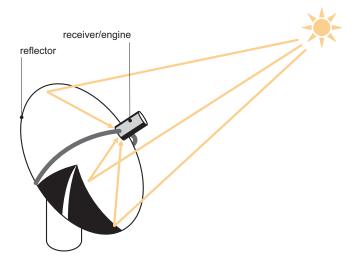
Jülich, Germany: From 2005 to 2010, the Jülich solar tower power plant was built as a solar-thermal operated water-to-steam power plant at a high temperature level. The plant has been used by the project partners for research purposes since 2011.

trated 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 up to about 1,000 °C. This allows for greater efficiency, particularly when using gas turbines, and is therefore likely to lead to lower electricity costs.

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. 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 of 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 into mechanical power or electricity. Efficiencies of over 30 per cent 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.

Flabeg Holding GmbH

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. The 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 have an internationally acknowledged reputation as technology consultants, certification bodies and experts.

German 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 at Jülich in Germany since the end of 2008. 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.

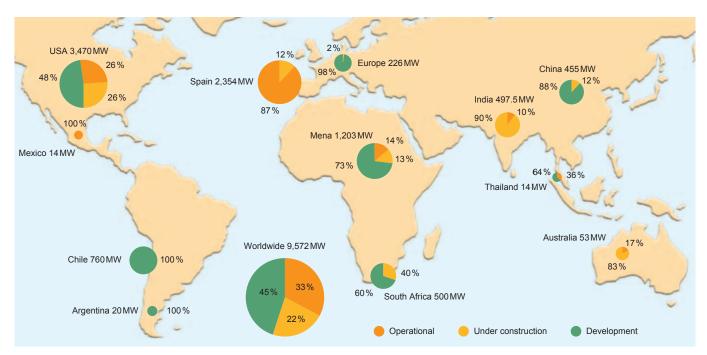
Commercial use

The economic viability of CSP depends very much on local factors. Natural conditions, market conditions, and access to project financing have a major influence 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. Hence they play an important role in a commercially optimised overall energy supply system with a large share of safe and clean renewable energies.

Due to the relatively high electricity production costs, continued marketing of solar thermal power plant technology currently 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.

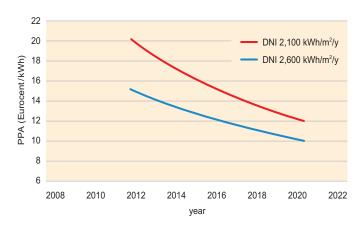


Murcia, Spain: The 30 MW Puerto Errado 2 Fresnel power plant.



Overview of solar thermal power plant projects worldwide (as of the end of 2013). Source: www.solarpaces.org/csp-technology/csp-projects-around-the-world.

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



Costs of solar thermal electricity plants are decreasing rapidly. In some countries they are already almost competitive while in Europe it will happen before 2020. The chart shows the required value of a 25 years Power Purchase Agreement (PPA) for a 150 MW, 4 hours storage, solar thermal electricity plant without any public financial aids and no escalation. The borders of the resulting price band correspond mainly to different Direct Normal Irradiation (DNI) in $kWh/m^2/y$.

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; what is more, 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 the 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 triple by 2018, increasing from the current 3.2 GW to nearly 10 GW, due to the building of solar thermal power plants. This positive global development in the expansion of solar thermal power plants is attributable to projects being extended into many countries and is accompanied by substantial cost reductions in

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

Lowering electricity production costs counts as one of the prime goals of solar thermal power plant operators. High product quality and a decades-long life of the plants 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 many components which have to be structured very precisely to achieve optimum performance and keep running efficiently for decades in a desert climate. The key element is the solar field, whose mirrors have to be shaped and adjusted exactly to reflect the solar radiation in an optimum concentration onto the receiver. Small differences from the optimum 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 precise 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 today be measured quickly and precisely. This development in methods is also important for the introduction of industrial standards in this still relatively young technology. 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 under often adverse operational and environmental conditions.



Linear solar simulator for receiver tests in the QUARZ laboratory in Cologne, Germany.

German research institutes and companies have played a leading role internationally in these areas of work in recent years. 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.

electricity production prices of newly-initiated power 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 2032. Other large-scale projects are currently being implemented in Abu Dhabi, Dubai and Kuwait.

Current developments in Europe are being significantly affected by the ongoing 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 2013, Spain boasted 2,300 MW, the most 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.

BIOGAS

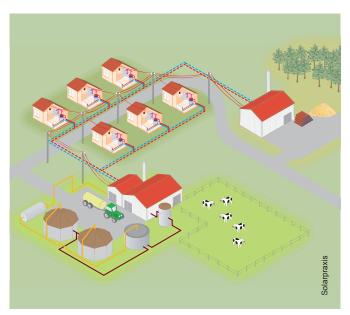


Triesdorf, Germany: Triesdorf is the first European university site to get its heat and electricity entirely from renewable sources of energy. A combination of a biogas system and wood chip heating has been supplying heat to the roughly fifty buildings of the Triesdorf educational facility as well as the Triesdorf dairy association since September 2009. The biogas plant with an electric power output of 290 kW and a net heating capacity of 260 kW supplies the basic heat throughout the entire year. Two wood chip boilers with a total heating capacity of 2,150 kW cover the additional demand during the heating period. A large, 120-cubic-metre buffer water reservoir balances the daily peak demands. In addition, the biogas plant feeds enough electricity into the public grid to supply 700 households.

Biogas

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

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 source of income for agricultural products which cannot otherwise be used or which are commercially uninteresting.

Technologies and applications

The production of biogas

Input

Biogas can be extracted from the following sources:

- Organic waste from landfill sites (landfill gas)
- Municipal wastewater (sewage gas)
- Industrial, domestic or commercial organic waste
- · Agricultural waste materials and energy crops.

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 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.

In general, agricultural biogas plants use liquid manure and energy crops as a fermentation substrate. Using liquid manure for energy in biogas plants largely prevents the climate-damaging methane emissions from open liquid manure tanks. To increase gas yields, more renewable sources such as maize, cereal crops and many other energy crops like sunflowers, Sudan grass, sugar beets, fodder radishes, sweet sorghum etc., are being used. Additionally, commercial plants also process wastewater as well as waste from food production, such as food particles and grease traps.



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.



View of the interior of a fermenter.

Composition of the extracted biogas

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

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

Apart from biogas, a digested sludge is formed, i.e. a mix of water, mineral components and undecomposed organic substances. Closing the nutrient cycle in the cultivation of energy crops, this fermentation residue can be used in agriculture as a high-grade fertiliser.

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 utilised in downstream systems for additional power generation, but also for use in heating, drying or the operation of refrigeration machines.

Feeding biogas into the natural gas grid

Another attractive option is to feed biogas into the natural gas grid. After processing it into natural gas quality — biomethane with a methane content of up to 98 per cent — the biogas can be used in areas with a high demand for heat, and can achieve a high measure of efficiency by simultaneously generating power (CHP). In the demand-driven supply of power, the natural gas grid can play a key role as a long-term storage facility for renewable energy. By feeding in renewable hydrogen (power to gas), the natural gas grid facilitates both the storage of wind power and of biogas processed into biomethane — and hence into natural gas quality. In this way, the natural gas grid can help bridge seasonal fluctuations in electricity supply from solar and wind power plants.

Use in the mobility sector

The decoupling of production and utilisation also makes it possible to use biogas as fuel for natural gas vehicles. Biogas processed into biomethane and used as fuel can make an important contribution to climate protection, enhance supply security and reduce noise emissions. In Germany, the proportion of biomethane in natural gas used as fuel rose from 2 per cent in 2010 to 20 per cent in 2013. More than 80 municipalities in Germany are already relying on ecological, cost-saving natural gas to fuel their buses. Pure biomethane can be found at 180 natural gas filling stations in Germany.



Gas processing plant in Schwandorf, Germany.



Naußlitz, Germany: This biogas plant, which started operation in 2011, can feed 700 Vn (standard cubic metres) of biogas per hour into the public gas grid.

Competence of the German industry

The German biogas industry has taken a pioneering role in the area of generation and utilisation of biogas. Germany is both the market and technology leader and has been able to acquire substantial expertise, particularly in the area of gasification based on organic waste and renewable sources.

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 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 as well as 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 per cent in 2013. Thus German production accounts for more than half of the total European energy extracted from biogas. In 2012, this amounted to 12 mtoe. By the end of 2013, around 7,700 biogas plants with a total installed capacity of around 3.5 GW of electrical power were in operation in Germany alone. They generated around 24,000 GWh of electricity and thereby supplied around 6.8 million households. In May of 2014, 151 biomethane plants were already feeding gas into the German grid.

Commercial use

The economic efficiency of biogas projects largely depends on a low-cost, long-term availability of the substrates. The possibilities for this vary considerably, depending on the location and configuration of the plants. Foresighted planning is indispensable here. The chances for adequately operating a plant increase rapidly if the demand side is considered at an early stage of the project and possible customers for the product on offer (electricity, heat, biomethane) can be identified. If heat sinks with a high yearround demand are developed along with the electricity production, attractive additional income can be generated for the operator of the biogas plant. These can consist, for example, of commercial CHP plants, such as hospitals, swimming pools, greenhouses or OAP homes. Processing the biogas and feeding it into the natural gas grid substantially widens the group of customers to be supplied. In addition, the growing market for biogas as fuel can also be served.



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

Incentive schemes

The expansion of biogas production in the European Union is being driven particularly by the EU goal of a 20-per cent share of renewable energy in the end energy consumption as well as the provisions of EU directive 2008/98/EC on the processing of waste. Based on these political terms of reference, many countries have introduced incentive schemes for the production of electricity from biogas, such as feed-in compensation for electricity from biogas, green certificates, invitations to bid or subsidies for the use of energy crops.

Feed-in compensation

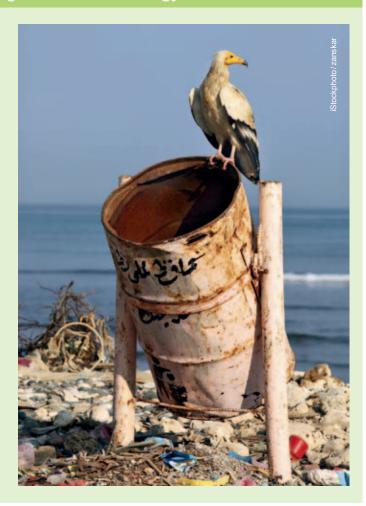
In Germany, for example, the basic conditions created by the Renewable Energy Sources Act (EEG) have proven to be a particularly effective growth engine for the young biogas industry. The EEG ensures that priority is given to electricity from renewable sources when it is fed into the public grid and that the compensation for the electricity fed in will remain unchanged for more than 20 years.

The compensation for electric power generated by biogas in Germany takes its orientation from the materials used as well as the size of the plant. The EEG amendment of 2014 adopted separate regulations for 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 additional plant capacity added each year is capped. Step by step, new plants with an installed capacity of 100 kW or more will be required to sell through direct marketing as part of market premium model.

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 prohibition of 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 – which are often already included in new plants – as well as increasing the energy recovery and thermal output.
- The environmental benefit is even greater if the digested sludge is used (for example, as fertiliser) after fermentation.



Quota regulation

Alternatively, the expansion of electricity generation from biogas can also be regulated by means of quotas. The quota regulation obliges electricity 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 electricity supplier must acquire at a guaranteed minimum price. In Europe, the quota model is currently being used in Belgium, Sweden, Norway, Poland and Rumania. 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.

Outlook

All over the world, biogas can make an important contribution to a secure supply of low-priced energy. Hitherto unused residual biomass materials and waste are certain to offer great potential as input materials. At present, large quantities of suitable raw and residual materials are being disposed of without being put to use. So-called energy crops also offer great potential. The changes in the look of the landscape accompanying an increased cultivation of energy crops could also be controlled by corresponding changes in agricultural laws.

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 the great advantage that adding any amount to natural gas is classified as harmless and thus not subject to limits like conventional biofuels.

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 yet is capable of achieving an electrical efficiency of up to 50 per cent.

Opinion pane

"Sustainability is our concern – not only when it comes to energy supply, but also and especially in the use of technology, in partnerships with our clients and in our dealings with our employees."

Robert Bugar, Founder and Managing Director, agriKomp GmbH



"In the past years, biogas has become a staple of regenerative energy production. Regardless of whether the organic waste is fibrous or weakly structured, solid or liquid, household waste or food leftovers, organic waste or even renewable resources. GICON has mastered the entire spectrum of technology for treating organic waste to



produce biogas. We can draw on the experience we have gained in planning and building more than 60 biogas plants worldwide."

Dipl.-Ing. Sebastian Otto, Supervisor of Bioenergy Dry Fermentation, GICON GmbH

SOLID BIOMASS



Oberlech, Austria: Along with companies in the timber industry, more and more municipalities, contractors and other commercial energy providers are favouring biomass as fuel. A biomass heating plant, whose heart is a wood chip boiler with a capacity of 2.5 MW, supplies the hotels and other commercial businesses in the Austrian tourist region of Lech and Warth with heat. The proportion of fine particles in the exhaust gas is distinctly below the prescribed limits. Heat recovery feeds heat into the district heating system, achieving an efficiency of 98 per cent. A buffer balances fluctuations between the heat supply and demand. An oil-fired boiler can be used in addition to cover peak loads.

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. The proportion of solid biomass (including waste) accounted for around 9.7 per cent of the world's primary energy supply in 2012. Its contribution to global energy supply is equally important compared with other renewable energies. The proportion of solid biomass (including charcoal) in the world's energy supply from renewable energies stood at 68.9 per cent in 2012.

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 a share of some 77.2 per cent, 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, there was an increase in the importance of electricity generation from biomass in Germany. Today, around 11,600 GWh of electricity is produced from waste wood, sawmill waste, standing timber and landscaping materials, which equates to around 1.9 per cent 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 that contribute to a combustion process free from harmful substances at particularly high efficiency factors of over 90 per cent.

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.



Graanul, Latvia: This low-temperature conveyor drier dries chips with an initial moisture level of 50 per cent to a residual content of roughly 10 per cent with the aid of low-calorific heat (drying temperature $60-100\,^{\circ}$ C). Then the chips are processed into pellets. The heat used for the drying process comes from a cogeneration unit.

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, as well as biomass boilers for supplying heat efficiently to several properties and/or industrial processes. Modern wood-burning stoves from German manufacturers particularly 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 developed in Germany that run on biomass 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.

Synthesising generated wood gas into biofuel of the second generation is currently being tested as an alternative at a pilot plant in Karlsruhe.

Commercial use

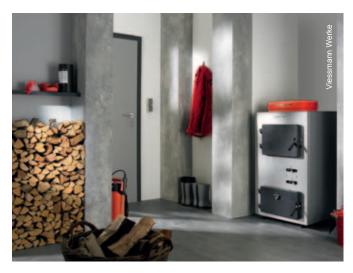
The use of wood as a source of energy continues to be most widespread in heavily wooded and agricultural regions. This is because of the ready availability of wood as a resource, on the one hand, and the lack of cost-effective heating supply concepts, on the other. The increased volumes of waste wood for generating electricity from biomass has also established itself in densely populated areas. The transport and storage of solid biomass across large areas and 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.

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.

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



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

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 in 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 tightening in many regions, efficient combustion technology with low emissions has continued to increase in importance in Europe.

In Europe, the expansion of the use of solid biomass as a source of energy has also been continuously advanced on a political level, as it is an important milestone for achieving Europe's energy policy objectives by 2020. 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 on the one hand that 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 its member countries particularly promote highly efficient levels of conversion, 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 so far been defined. The European Union, however, has been regularly reporting on the effects on food prices, land use rights and the adherence to international labour standards since 2012. To protect the interests of local populations in developing and newly industrialized 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 per cent less than a fossil fuel reference value. In 2017, the reduction of greenhouse gases should rise to 50 per cent and beginning in 2018 even amount to 60 per cent 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 cultivation, 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.

STORAGE AND GRID TECHNOLOGY



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 raw materials. 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 can be increased on existing lines. 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). Thanks to this technology, the lines can even be operated above their nominal outputs in normal conditions, which may reduce the demands placed on new line capacities.

In addition to expanding the grid with new lines and new line technologies, the workload can be better distributed across the existing transmission capacities in the transmission network 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).

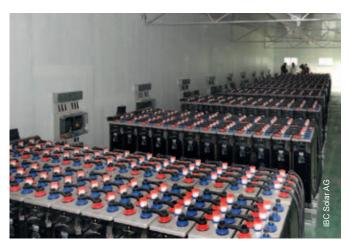
Further development of the grid-compatible/ grid-interactive behaviour of decentralised energy plants

The increase in renewable energies creates a switch 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 secure, 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 destabilise 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



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

support the power at the respective grid levels of the distribution network by supplying controllable reactive power. In the process, inverters can be designed so that they can help 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 become of greater importance. Important tasks related to power storage include balancing the fluctuations in power generation and demand, the provision of system 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 per cent, the pump storage station is currently the only economical energy storage



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.

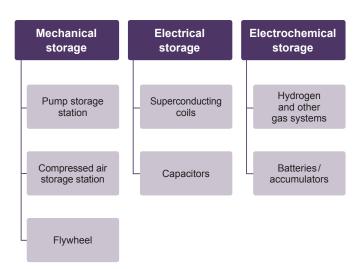
option for hourly and daily compensation that is available on an industrial scale and is likely to remain so for the foreseeable future. There is currently no technology that has such a long service life and has been tested and distributed to a comparable level that is as flexible to utilise and make a substantial contribution to a secure energy 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 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 for the storage of the 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: So-called

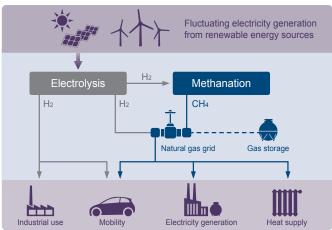


Classification of energy storage technologies: overview of the various options for storing electrical energy. Source: www.powertogas.info/power-to-gas/strom-speichern.html.

"home storage devices" which store self-generated solar power and ensure a supply at need. Large batteries in the multi-megawatt range are gaining in importance. They provide system services such as frequency and voltage maintenance or black start capability with a few milliseconds and thereby ensure grid stability and supply security despite fluctuating feed-in from wind and solar power sources. Especially suited electrochemical storage devices are lead-acid, nickel-cadmium, sodium-sulphur, lithium ion and 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 per cent (nickel-cadmium) and 98 per cent (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 CO₂ 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. What is more, 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 longterm use of electricity which cannot be directly integrated



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

into the electricity grid in 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 increasing 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 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 and controllable devices.

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. 35 GW from photovoltaic systems and approx. 34 GW from wind energy plants in 2013, the share of renewable energies generating electricity in Germany amounted to 27 per cent in 2013. Despite this high degree of integration of renewable energies, it was still possible to operate the power supply grid securely and reliably.

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

Opinion panel

"The challenge is no longer merely to produce electricity or store energy. Our task today is to combine both areas intelligently and use them to conceive and realise for our customers viable solutions which not only increase the energy efficiency but also the economic efficiency. This is the only way we at REFU can uphold our idea of energy for



life at all levels and enter into a sustainable future."

Dr. Armin Keinath, Head of REFU Energy Division, Refu Elektronik GmbH

- 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 system services
 available, to avoid blackouts and to maintain a safeguarded 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 require 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 as well as the operating costs of 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 low-cost 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 per cent for the use of smart metering by 2020. An expansion of the storage systems is part of the energy goals of some US states, such as California, Hawaii or 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 and
- The growing distance between generation and load.

These drivers apply especially to the development of energy supply in Germany. Current forecasts are assuming an expansion of installed power from photovoltaic systems in Germany of approx. 35 GW in 2013 to approx. 60 GW in 2034. The installed capacity of onshore wind power plants is expected to nearly double, to 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 increase demands being placed on the transport capacities of the networks.

At the present time, the possibilities of using modern information and communication technology for an intelligent control of the electricity grid are being tried out in Germany in a wide variety of research and model projects. In this dynamic environment, German companies are continuing to drive innovation 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 the technological development advances, 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

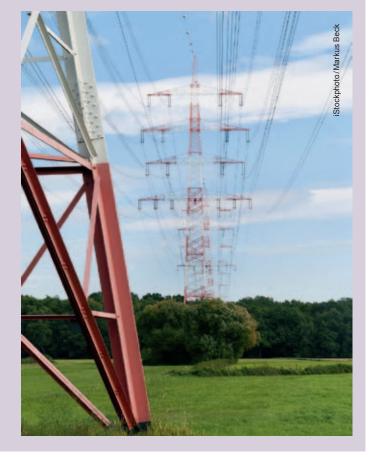
development to accomplish a technological leap towards adiabatic systems and thus a higher efficiency and thereby sufficient profitability. Larger storage capacities could perhaps be achieved through feeding hydrogen or synthetic methane into the natural gas network (power-to-gas concept). Other regions of would can 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 which entails the following advantages:

- Reduction of the costs of electricity generation by coupling the various market areas and dismantling technical trade blockages
- Trans-regional provision of system services
- Balancing effects of load reference and increasing supply security
- 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 for years been a central aspect of energy policy in the European Union and was particularly advanced by the Directives for the Internal Energy Market. Among other things, these entail an opening of the energy markets through decartelisation of vertically integrated utilities and non-discriminatory grid access.



OTHER INDUSTRY SECTORS



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 here are:

- 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.

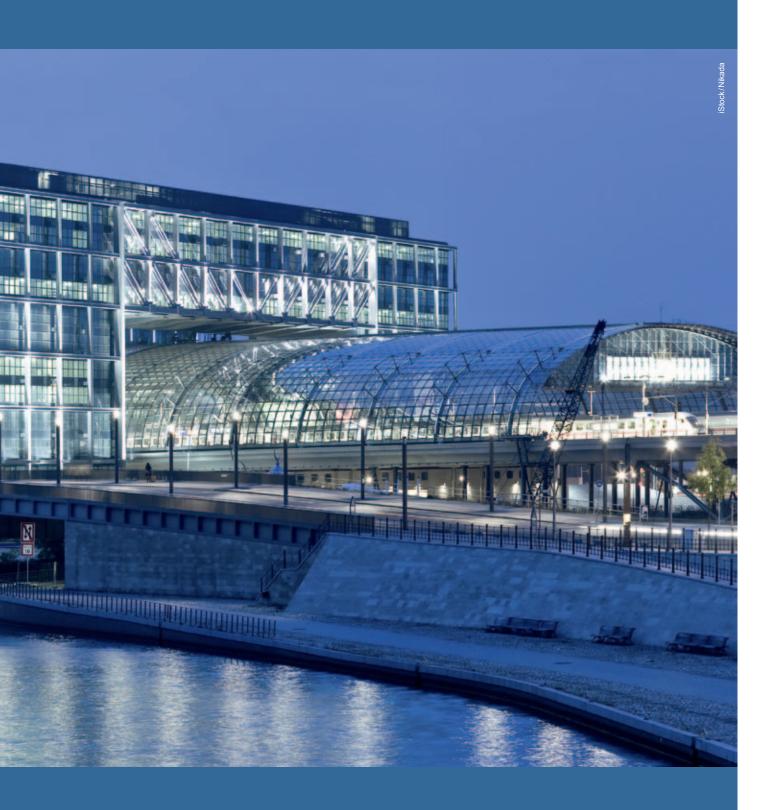


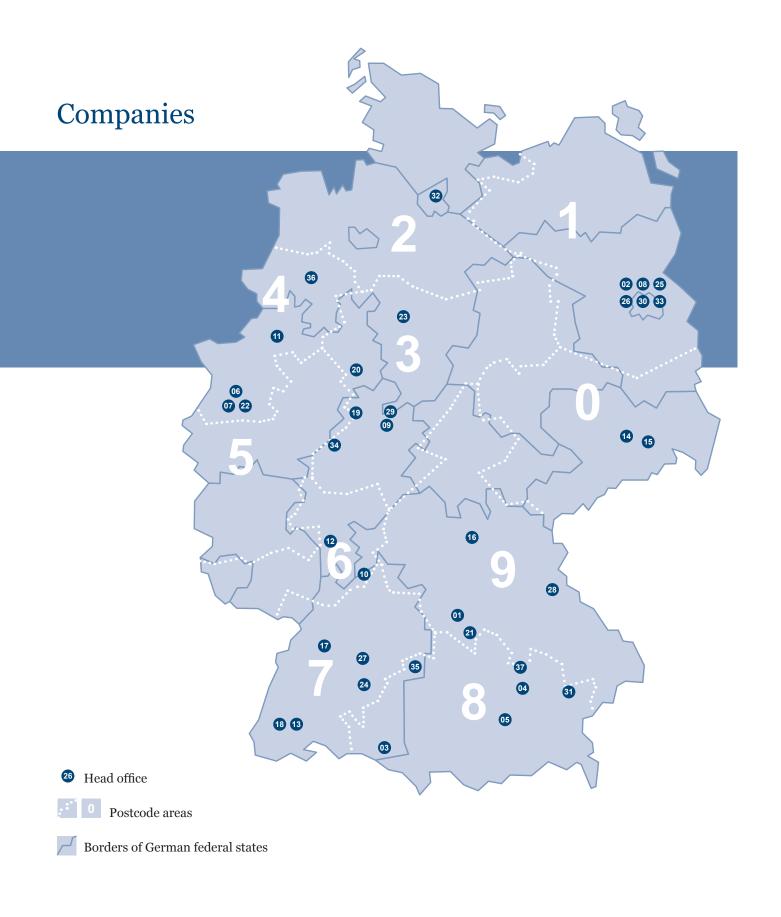
Photovoltaic training on a PV system simulator.

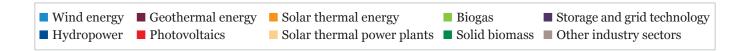
COMPANIES



Central station in Berlin, Germany.







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agriKomp GmbH

address Energiepark 2 \cdot 91732 Merkendorf

contact Thomas Franke

 $\begin{array}{lll} \mbox{telephone} & +49 \, (0) \, 9826 - 65 \, 95 \, 9 \text{-}0 \\ \mbox{fax} & +49 \, (0) \, 9826 - 65 \, 95 \, 9 \text{-}10 \\ \mbox{e-mail} & info@agrikomp.de \\ \mbox{web} & www.agrikomp.com \\ \end{array}$

profile technology full-line supplier | biogas plants

jy 📗

biogas



agriKomp – leading the way nationally and internationally

Everything from a one-stop supplier – this is still of prime importance to agriKomp today. With more than 800 plant projects completed internationally and around 500 employees, this Bavarian biogas plant manufacturer counts amongst the world's leaders in the industry.

Focusing on the fermentation of solid and liquid manure, this complete plant manufacturer covers all areas of efficient biogas technology:

- Consultancy, conception and planning; Plant construction, commissioning, technical and biological service;
- Production of CHP plants; Design and realisation of heat/gas networks; Repowering and extension of existing plants; Its own research and development.

The companies of the agriKomp group cooperate to develop and produce all the essential components of a biogas plant. This guarantees absolute reliability and consistently excellent quality. With its time-tested key components – the flexible gas storage facility (Biolene®), the renewable raw materials mixer (Paddelgigant®) or the robust solid material feeder (Vielfraß®) – this innovative company has set

international standards. Pioneering plant systems, such as "Güllewerk", the first mobile biogas plant, stand for the brilliant engineering performance that comes from research at agriKomp.

agriKomp Group - international

This company has been doing business since the midnineties and is successfully represented by its own branch offices and partners in Germany, Great Britain, Ireland, France, Switzerland, Denmark, Italy, the Czech Republic, Poland and Slovakia. Projects in Canada, Kenya, Russia and Romania round off the group's global activities.



agriKomp biogas plant in Ireland.



Andritz Hydro GmbH

address Escher-Wyss-Weg 1 \cdot 88212 Ravensburg

contact Karin Kowaczek telephone +49(0)751-29511-0 fax +49(0)751-29511-999

e-mail contact-hydro.de@andritz.com

web www.andritz.com

profile full-line supplier | hydroelectric power plants

technology

hydropower



Production of a Francis runner at the Ravensburg plant.

Andritz Hydro supplies electro-mechanical systems and services for hydropower plants worldwide. With approximately 7,500 employees and a sales volume in 2013 valued at approximately € 2 billion, 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 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.



Transport of a turbine housing from the Ravensburg plant.



Ammonit Measurement GmbH

address Wrangelstr. 100 · 10997 Berlin

contact Daniela Treptow

telephone +49(0)30-6003188-0
fax +49(0)30-6003188-10
e-mail info@ammonit.com
web www.ammonit.com

 $\mbox{ profile } \mbox{ dealer, manufacturer} \mid \mbox{ measurement and } \label{eq:continuous}$

control systems, software

technologies

wind energy | photovoltaics | solar thermal

energy



Met mast for wind site assessment.



Ammonit Meteo-40 data logger.

Measuring wind and solar power

Since 1989, Ammonit has been developing and offering first class measurement equipment for wind and solar resource assessment as well as power plant monitoring (SCADA). The product portfolio includes:

- Data loggers
- Meteorological sensors
- LIDAR and SODAR systems
- Monitoring software
- Communication and power supply solutions.

The Meteo-40 data logger series is globally accepted 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's solutions meet the highest quality standards to ensure highest accuracy in the measurement.

Ammonit cooperates with well-known manufacturers, e.g., Thies, to offer complete measurement systems. In more than 100 countries, wind and solar professionals trust in Ammonit's systems. Ammonit and its global partners offer turnkey solutions from proposal to installation and maintenance of the system.

Ammonit offers complete measurement systems for:

- Wind resource assessment
- Wind site assessment in cold climate regions with individually designed power supply solutions
- Wind farm monitoring solutions compatible with most SCADA systems
- Solar resource assessment for PV and CSP/CPV power plants including sun trackers
- Power curve measurement.

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



Meteorological sensors for wind measurement.







Ammonit remote sensing systems (SODAR + LIDAR).



Ammonit solar measurement system.

High quality equipment for wind and solar measurement

Wind measurement systems

Ammonit's systems are designed for wind site assessment as well as for wind farm monitoring (SCADA). According to IEC 61400-12-1 a professional met mast is equipped with the following measurement devices:

- Data logger
- · Anemometer for wind speed measurement
- Wind vane for wind direction determination
- Temperature, humidity and barometric pressure sensor for air density measurement.

SODAR and LIDAR systems measure wind speed, direction and turbulences at hub height in up to a height of 200 m.



Sodar: AQ510 windfinder.



Lidar: ZephIR 300.

Solar measurement systems

Depending on the application (PV, CPV or CSP), different measurements are necessary. Ammonit's systems measure data for GHI (Global Horizontal Irradiation), DHI (Diffuse Horizontal Irradiation) and DNI (Direct Normal Irradiation). The measurement station can be a met mast or a sun tracker with the following devices:

- Data logger
- · Pyranometer for GHI and DHI measurement
- Pyrheliometer for DNI measurement (installed on sun tracker)
- Reference cell.

Monitoring system

By using the AmmonitOR web platform, measurement data can be checked for integrity and plausibility according to the MEASNET guideline. In doing so, the quality of the valuable measurement data can be kept at a constant high level.

Awite Bioenergie GmbH



address Grünseiboldsdorfer Weg $5 \cdot 85416$ Langenbach

 contact
 Dr. Martin Grepmeier

 telephone
 +49 (0) 8761-72162-0

 fax
 +49 (0) 8761-72162-11

 e-mail
 info@awite.com

web www.awite.com

profile supplier | measurement and control systems

1.

technology

biogas

Gas analysis and automation from a single source

Measurements are indispensable in biotechnological plants. The more exact and constant they are done, the more they prove to be factors which save time and expense. Comprehensive process control and gas analysis are elementary factors in keeping your plant running smoothly and making it a commercial success.

Every biogas plant is an extremely sensitive system which demands reliable process monitoring and an easy-to-operate system control. Automation has become indispensable in meeting this need. AwiControl enables the complete control of your biogas plant at the highest level of operational safety and low staff expenses. Doing without software licensing



AwiFLEX Cool+ XL gas analysis.

fees is as much a matter of course for us as consistently basing implementation on open-source products.

Corporate Energies GmbH & Co. KG



address Düsseldorfer Str. 31A · 10707 Berlin

contact Stefan Simon

telephone +49(0)30-8639028-19
fax +49(0)30-8639028-10
e-mail info@corporate-energies.com
web www.corporate-energies.com

profile

full-line supplier | operations management, funding, construction, planning and engineering services

technologies

vind energy | hydrono

wind energy | hydropower | photovoltaics | biogas

Alliance of renewable energy companies

The Corporate Energies Group offers comprehensive economic and technical expertise along the supply chain of renewable energy projects to provide support in planning and investing, realising and operating power plants in Europe and worldwide.

Corporate Energies services and solutions are comprised of four strategic segments – projects, operations, finance and industry. Whether for the entire scope or selected phases of a project, our solutions and products are configured individually to meet various customer needs and correspond to the specific steps necessary for the successful



Doing business in mature and emerging markets worldwide.

completion and best use of wind, solar, biogas and hydropower plants worldwide.



BBB Umwelttechnik GmbH

address Munscheidstr. 14 \cdot 45886 Gelsenkirchen

contact Markus Rieger

telephone +49(0)209-167255-0 fax +49(0)209-167255-1 e-mail m.rieger@bbb-umwelt.de web www.bbb-umwelt.com profile consultant, appraiser, project engineer | contrac-

ting, measurement and control systems, planning and engineering services, technical project review (due diligence) for wind energy projects

technology

wind energy





The three founders: Gerhard and Joachim Binotsch and Klaus Bergmann.

Engineering Consultant

Since 1996, BBB Umwelttechnik (BBB) has been rendering specialised engineering services in the areas of project development and appraisal. On behalf of its clients, it plans and implements wind energy projects around the world, from the idea up to commissioning. As an accredited company, BBB compiles bankable wind reports (DIN EN ISO/IEC 17025:2005) and performs wind measurements, also using LiDAR technology. In addition, the independent consulting company provides technical project assessments within the scope of due diligence processes.

Wind measurements

BBB offers wind measurements around the world by means of met mast and highly precise laser metrology. In the LiDAR sector, BBB is the leading accredited wind resource specialist in Germany.

Wind reports

BBB is accredited to compile bankable wind yield reports. It has prepared more than 500 independent wind potential studies and analysed more than 25 GW of wind power in the course of project assessments.

Planning/engineering

BBB prepares expert reports on various aspects and renders individual planning services, for example, in the areas of infrastructure and electrical engineering. It competently supports its clients in the procurement process and with construction supervision services. Upon request, BBB also comprehensively develops wind projects on behalf of its client.

Technical due diligence

The extensive experience of BBB in the field of project development enables well-founded technical reviews of project portfolios. Investors receive independent project assessments and a reliable basis for taking decisions.



The energy-self-sufficient LiDAR measuring system of BBB Umwelttechnik.



BayWa r.e. renewable energy GmbH

address Herzog-Heinrich-Str. 9 · 80336 München contact BayWa r.e. renewable energy GmbH

 $\begin{array}{ll} \mbox{telephone} & +49 \, (0) \, 89 \, \hbox{-} \, 38 \, 39 \, 32 \, \hbox{-} \, 0 \\ \mbox{e-mail} & \mbox{info@baywa-re.com} \\ \mbox{web} & \mbox{www.baywa-re.com} \end{array}$

 $\begin{tabular}{ll} \textbf{profile} & full-line supplier, dealer | operations \\ \end{tabular}$

management, funding, construction, planning and engineering services

technologies

wind energy | geothermal energy |

photovoltaics | biogas



Solar farm Great Glemham, United Kingdom.

With more than 800 employees, BayWa r.e. is among the leading international providers in the renewable energy sector. As a wholly-owned subsidiary of BayWa AG head-quartered in Munich, BayWa r.e. functions as a holding company for a number of companies in the business segments of wind energy, solar energy, bio energy and geothermal energy. The many years of experience in the renewable energy sector, coupled with a range of services covering all essential areas, benefits customers and business partners in equal measure. The company's business today focuses on the core markets of Europe and the United States.

A specialist in the development, planning, financing, construction, operational management and maintenance of renewable energy systems, BayWa r.e. is a highly regarded, experienced partner. BayWa r.e. sets itself the goal of reconciling the technical and economic requirements of each new project, ensuring that the systems meet the most stringent requirements and achieve a good long-term yield. Among the core competences of BayWa r.e. are planning, realising and financing megawatt-class plants, operation and marketing the energy they produce. The range also includes specialised services, such as maintenance and repair of rotor blades. BayWa r.e. is one of the largest

system providers of PV plants in Europe, supplying everything needed by a PV plant and using only products of the highest quality.

Project development and turnkey plant construction

BayWa r.e. has developed or realised wind parks, biopower and geothermal power plants with an installed output of more than 1 GW. Its partners include not only municipalities, local developers and energy cooperatives, but also institutional customers. Alongside the development and realisation of its own projects, BayWa r.e. also provides turnkey construction of plants as a service for third parties. Its range of services covers:

- Greenfield development
- · Site analyses and appraisals
- Securing properties
- · Licence planning and detailed design
- Turnkey construction as general contractor
- · Project management
- Preliminary and bridge-over financing
- Project structuring and financing
- Re-powering
- Substrate trade and raw materials management for biogas plants.



Wind farm Campomaggiore, Italy.

Operational management

As owner and service provider for fund companies, banks, international investment companies and citizens' energy cooperatives, BayWa r.e. takes care of the technical and commercial management of wind and solar projects with an installed output of around 700 MW. The range of services includes:

- Multilingual headquarters running three shifts and on call 24/7
- Optimisation of energy availability
- Multi-vendor capable operational management system
- Checks and immediate fault elimination
- Medium and high voltage maintenance work
- Tests and inspections in accordance with BGV A3 (German Trade Association provisions)
- Documentation and reporting throughout the entire life span of the project
- Commercial management
- Representation and assertion of operators' interests.

Maintenance and plant optimisation

As a certified, multi-vendor capable service provider, BayWa r.e. renders a wide range of services for the optimisation and maintenance of wind power plants of all types and power classes:

- · Rotor blade assessment
- Maintenance and repair of rotor blades
- Storage and provision of replacement blade sets
- Design, production and repair of glass fibre reinforced plastic (GRP) components
- Cleaning and sealing rotor blades
- Tower cleaning and corrosion prevention
- Rotor blade optimisation to enhance the performance of the plants (e-ro®)
- Plant demolition
- Disposal and recycling of rotor blades and GRP components
- Heavy haulage and warehouse logistics.

Planning and consultancy

BayWa r.e. offers comprehensive technical consultancy and planning services for renewable energy products, including:

- Due diligence reports
- Project management
- Expert assessments of energy yield and emissions
- · Feasibility studies
- · Licence planning and management
- Detailed engineering and construction supervision.



BayWa r.e. renewable energy GmbH



Biogas plant Pliening, Germany.



As one of the largest system providers of PV plants in Europe, BayWa r.e. supplies everything a PV plant needs. The spectrum of products and services covers:

- Selection of high-quality branded solar modules, inverters and storage solutions
- Proprietary and TÜV-certified mounting system Novotegra
- Comprehensive consulting for plant planning and layout, as well as economic viability calculations
- On-site initial assembly support
- Wide range of services for installers and specialised tradesmen
- Partner programme with sales support measures
- Comprehensive range of seminars on technical and industry issues
- Warehousing and logistics
- Short delivery lead times and on-time delivery directly to the construction site.

Direct marketing and control energy marketing

For producers of electricity from wind, solar, biomass and geothermal power plants, BayWa r.e. offers to market EEG electricity (in accordance with the German Renewable Energy Sources Act) within the framework of the market bonus scheme as well as participation in the control energy market. BayWa r.e. is a competent partner for optimising renewable energy plants and integrating them into the electricity market:

 Marketing and structuring of electricity from renewable energy to the electricity exchanges



Geothermal power plant Dürrnhaar, Germany.

- Trading in electricity by means of a virtual power plant consisting of wind, PV, biogas/biomethane CHP, hydropower and geothermal power plants
- Support and monitoring of the prequalification phase for participation in the control energy market
- Structuring of the tender process of plant capacities with the transmission system operators for the provision of control energy
- Implementation of the control signals of the transmission system operators by way of a virtual power plant for the called pool capacities.

Biomethane trade and sale of green energy

As a leading biomethane trader with a trade volume of more than 1 TWh per year, BayWa r.e. is a major player in the CHP, heat and fuel market. Furthermore, BayWa r.e. provides private, commercial and industrial customers all over Germany with green electricity and gas. Re-distributors and users of domestic and local electricity profit from the competence of BayWa r.e. in the energy business with tailored energy supply concepts. The range of services includes:

- Trade in biomethane to physical meter points as well as to virtual trading points in all German market regions (also separate accounting)
- Serving the CHP, heat and fuel markets
- Change of supplier process, market communication and accounting grid management
- Trade with accounting grid flexibility and administration of biomethane guarantees of origin in the dena biogas register
- Certified green electricity and gas product portfolio with Germany-wide distribution.



Wind farm Gunzenhausen, Germany.

Private consumption solutions

The direct use of renewable wind and solar power is not only the future of the energy supply, but in many cases an economical alternative to procuring electricity from the gird for bulk consumers and private households. The electricity is supplied right where it is needed without any long, expensive transmission networks or high transport losses. For industry, trade and commerce with a high electricity consumption during the day, photovoltaics is particularly the means of choice for achieving a substantial reduction of energy costs.

From feasibility studies to financing up to distribution of unused energy, BayWa r.e offers everything from a single source and is a reliable partner for investors, industry and commerce in all aspects of private electric power supply:

- Concepts for optimising private wind and solar plants
- Leasing models for commercial and industrial customers
- Tailored offers for private customers in cooperation with municipal utility companies
- Development and provision of tailored product and distribution solutions for privately generated green electricity and gas for re-distributors and energy cooperatives
- Concepts for a private supply of electricity from renewable sources in area networks.

Together with the experienced employees of BayWa r.e., many customers and business partners have already found the right solution for their business success. Backed by the respectability of BayWa AG, BayWa r.e. is also a reliable partner for the long term.

Carbotech

VIESMANN Group

address Natorpstr. 27 · 45139 Essen

contact Dr. Alfons Schulte-Schulze Berndt

telephone +49(0)201-50709-300
fax +49(0)201-50709-500
e-mail mail@carbotech.info
web www.carbotech.info

Carbotech GmbH

profile technology manufacturer | gas processing systems

biogas

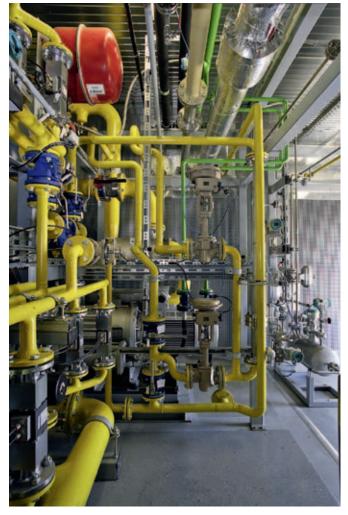


Biogas processing plant in Schwandorf, Germany.

One of the leading companies in gas processing and gas injection

Schmack Carbotech GmbH, a company in the Viessmann Group, is one of the pioneers of biogas purification with more than 40 years of experience in the development, engineering and manufacturing of turnkey gas upgrading plants. The company's technology is based on the pressure swing adsorption (PSA) process and incorporates the experience of more than 60 installed systems in Europe.

Carbotech specialises in biogas, sewage gas and landfill gas upgrading plants for injection of biomethane into the natural gas grid, as well as for fuel production. The expertise acquired from the installation of industrial systems worldwide is put to use in the ongoing further development of the PSA process for efficient, resource-conserving and environmentally friendly upgrading of biogas to biomethane.



A look inside a Carbotech processing plant.

Since 2012, Carbotech has implemented a series of systems with optimised operating costs, which use about 25 per cent less electricity while increasing the methane yield to 99 per cent.

As a result, the Carbotech process stands out owing to its especially low operating costs. The company works closely with investors all the way from initial planning considerations to construction and commissioning, regardless of whether the investor decides on dry or wet fermentation.



DIVE Turbinen GmbH & Co. KG

Am Grundlosen Brunnen 2 · 63916 Amorbach address

Christian Winkler contact +49(0)9373-9749-39 telephone +49(0)9373-9749-49 fax info@dive-turbine.de e-mail www.dive-turbine.de

web

profile

manufacturer, supplier | installation equipment, hydroelectric plants

technology

hydropower



Installing a 900 kW DIVE turbine.

DIVE Turbinen GmbH & Co. KG was founded as a new company by FELLA Maschinenbau GmbH in 2012. It focuses on all activities related to technical solutions for small hydroelectric plants, especially developing and marketing DIVE turbines. Both companies are located in Amorbach, about one hour south of Frankfurt am Main. Together they have the capacities, knowledge and experience to manufacture reliable products for small hydropower.



Turbine housing with DIVE turbine.

The DIVE turbine is a turbine for low drops (2 to 25 m), with a capacity of 50 to 1300 kW per turbine. The entire unit, consisting of turbine and generator, runs entirely under water with a unique sealing system that needs no maintenance and is not subject to wear and tear, at variable speeds and without noise. It must be emphasised that a highly efficient permanent magnet generator is connected to the turbine runner directly, without mechanical transmission. This feature considerably reduces the expense of building the power plant as a whole and minimises the operating risk and costs during operation. At the same time, it ensures high efficiency for the entire plant, from the water to the network. What is more, the DIVE turbine is capable of integration into ecological power plant concepts with little trouble, which enables the requirements with regard to fish protection and ecology to be fulfilled.



CUBE Engineering GmbH

address Breitscheidstr. $6 \cdot 34119$ Kassel

contact Stefan Chun

 $\begin{array}{lll} \text{telephone} & +49\,(0)\,561\,\text{--}\,28\,85\,73\,\text{--}10 \\ \text{fax} & +49\,(0)\,561\,\text{--}\,28\,85\,73\,\text{--}19 \\ \text{e-mail} & \text{info@cube-engineering.com} \\ \text{web} & \text{www.cube-engineering.com} \end{array}$

profile consultant, project developer, project engineer |

combined heat and power systems (CHP), solar heating technology, wind power plant

technology

wind energy



Experts in renewable sources of energy.

The accredited company CUBE Engineering has successfully supported over 4,000 projects worldwide, with a total installed capacity of more than 15,000 MW. In the field of wind consulting, CUBE Engineering is among the top 20 companies internationally delivering certified, bankable results with services based on a QM system (including DIN ISO 17025). Internationally, CUBE Engineering focuses on selected countries and markets in which renewable energy plays a significant role in energy supply and energy security, or will do so in future.

The company supports the principles of the United Nations Global Compact. It cooperates worldwide with a network of project offices.

Its range of services includes:

Wind assessment: Site selection, screening and scoping, wind measurement and measurement campaigns, preliminary assessment, wind assessment, earnings forecasts, wind atlases and wind resource studies, wind farm layout and optimisation, turbulence studies, LiDAR.

Management consulting: Market analyses/country profiles, corporate social responsibility, public-private partnership.

Planning and project management: Due diligence, feasibility studies, permits, invitations for tender and award procedures, construction supervision, road construction.

Environmental assessment: Noise immission forecasts, shadow analyses, ZVI, (3-D) animations and visualisations, analysis of optical intrusion, visual impact analyses.

Network planning: Design, optimisation of grid connections, wind farm extensions.

Decentralised energy systems: Photovoltaics, solar thermal energy, hydropower, CHP, cogeneration, biogas, biomass, stand-alone solutions, smart grids, energy marketing.

The idea of Win(d)Scout was born, appropriately enough, at the beginning of 2011, along with the energy debate in Germany.

The timing could not have been better. At about the same time, the Federal Government took the decision to decommission nuclear power plants and to promote the expansion of energy supply from renewable energy sources. On this firm basis, CUBE Engineering began its development in the field of "Using wind energy in Germany" for terminals manufactured by Apple (iPhone/iPod Touch/iPad). The topic arose naturally from the company's 20-year expertise: The focus must be on wind energy. With Win(d) Scout, users can find out where and how strongly the wind blows in Germany – and now also worldwide, as well as what annual energy yield a plant brings, how much CO_2 emission it avoids, and where the over 15,000 wind energy plants in Germany are sited. Information about wind farms worldwide is also now accessible.

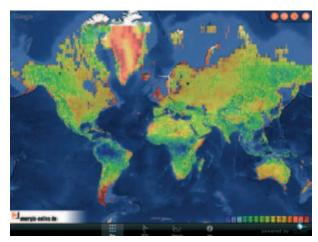
With the Win(d)Scout app, the 'inventor company' CUBE Engineering is pushing forward into a new market segment. It enables renewable energies to be experienced in an upto-the-minute way, and makes the topic of 'wind potential' accessible to a wide range of stakeholders (such as plant manufacturers, operators and interested members of the public). The output the user receives includes energy yields, energy efficiency and CO₂ emissions avoided, for a wind plant in any chosen location in Germany or worldwide.



Win(d)Scout display.



Win(d)Scout Screen wind power plant.



Win(d)Scout Screen wind resource card.



EnviTec Biogas AG

address Boschstr. 2 · 48369 Saerbeck

contact Katrin Selzer

telephone +49(0)2574-8888-0
fax +49(0)2574-8888-800
e-mail k.selzer@envitec-biogas.de
web www.envitec-biogas.com

profile technology full-line supplier | biogas plants

biogas



The Agrivalor waste-to-energy plant has its own hygienisation system with a capacity of 25,000 tonnes/year. More than 65 per cent of the thermal discharge is used to supply a nearby hotel with a casino.

Renewable energy from biogas plants

EnviTec Biogas AG, founded in 2002 and headquartered in Lohne, Lower Saxony, is now active in 20 countries worldwide. EnviTec is among the market leaders in the turnkey biogas plant construction sector and has already installed more than 357 MW and 600 modules around the world, including agricultural biogas plants and waste-to-energy plants. In 2013, EnviTec had sales of € 148.8 million and an EBIT of € 2.4 million. The EnviTec group currently has a total of around 350 employees. EnviTec Biogas has been listed on the Frankfurt Stock Exchange since July 2007.

EnviTec Biogas AG covers the complete value chain for the production of biogas and biomethane. This includes the planning and turnkey construction of biogas plants and biomethane upgrading plants, as well as their commissioning. If required, the company takes on the biological and technical service and, in addition, offers overall plant management as well as production management. In addition, EnviTec also operates its own biogas plants. In 2011, the

scope of its business was extended with EnviTec Energy GmbH & Co. KG and their wholly-owned subsidiary EnviTec Stromkontor GmbH & Co. KG to direct marketing of upgraded biomethane and the marketing of green electricity and balancing energy.



EnviThan is a highly efficient technology for biogas treatment on offer from EnviTec. The membrane technology has decisive advantages compared to other processes: It is more environmentally compatible, considerably more efficient and far more flexible.



FRANK GmbH

address Starkenburgstr. 1 \cdot 64546 Mörfelden-Walldorf

 contact
 Michael Große-Bley

 telephone
 +49 (0) 6105 - 40 85-0

 fax
 +49 (0) 6105 - 40 85-260

 e-mail
 info@frank-gmbh.de

 web
 www.frank-gmbh.de

profile

dealer, manufacturer | biogas plants, measurement and control systems, accessories, geothermal probes

technology

geothermal energy



For over 45 years the FRANK group, located in Mörfelden-Walldorf near Frankfurt am Main, has been one of the leading suppliers in the plastic pipe market. This long-standing owner-managed company offers its customers a broad range of products, outstanding quality and advanced technical know-how. As well as complete systems for industry, gas and water supply, the sewer sector, and systems for near-surface geothermal energy, FRANK also offers special innovative solutions for out-of-the-ordinary uses. The sophisticated systems can be used for major projects in the commercial sector as well as for single family houses.

The exploitation of geothermal heat is an ideal alternative to generating energy from sun, wind, hydropower and biomass. This source of energy is inexhaustible, since it is continuously replenished, like a battery, from the earth's interior and by solar radiation. And it is permanently available.

FRANK offers complete system solutions: From pre-assembled borehole heat exchangers made of PE100-RC, brine circuit manifolds and distribution ducts including all accessories, up to heat pump connections.

Even where drilling depth is restricted, the new FRANK VTP provides a solution. The secure setting of the pipe

spacing and the lack of a need for a sand layer enable simple installation.

The PKS-Thermpipe sewer pipe allows for the simultaneous extraction of heat from wastewater and the ground. With the new LIMNION® LIMA-1 and a heat pump, energy from lakes, rivers and coastal waters can be used for heating and cooling.



LIMNION LIMA 1.



Fraunhofer Institute for Solar Energy Systems ISE

address Heidenhofstr. 2 · 79110 Freiburg

contact Karin Schneider

telephone +49 (0) 761 - 4588 - 5150 e-mail info@ise.fraunhofer.de web www.ise.fraunhofer.de $\label{eq:profile} \textbf{profile} \qquad \textbf{research and development} \mid \textbf{PV modules, solar}$

thermal power plants, storage technologies,

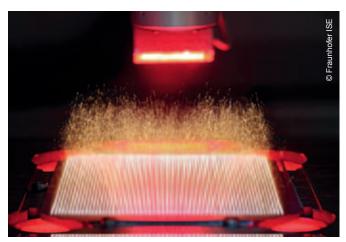
inverter

technologies

photovoltaics | solar thermal energy | storage and grid technology | other industry sectors







Laser drilling process on a back-contacted solar cell.

Research for the energy transition

The Fraunhofer Institute for Solar Energy Systems ISE champions a sustainable, economical, safe, secure and socially just system of energy supply. It creates the technical conditions necessary for an efficient, environmentally compatible supply of energy. Core research at Fraunhofer ISE focuses on topics within the fields of energy efficiency, energy conversion, energy distribution and energy storage.

Going beyond basic research, the institute is engaged in the development of production technology and prototypes, as well as the construction of demonstration systems. Fraunhofer ISE plans, advises, tests and provides knowhow and technical facilities for a range of services. The institute also renders calibration, measuring, testing and inspection services.

Fraunhofer ISE has been certified in accordance with DIN EN ISO 9001:2008 since March, 2001.

Areas of business

Fraunhofer ISE conducts applied research and development of new technologies, processes and solutions in twelve areas of business closely related to industry:

- Energy efficient buildings
- · Silicon photovoltaics
- III-V and concentrator photovoltaics
- Dye, organic and novel solar cells
- Photovoltaic modules and power plants
- Hydrogen and fuel cell technology
- Solar thermal technology
- System integration and grids electricity, heat, gas
- Energy efficient power electronics
- Zero-emission mobility
- Storage technologies
- Energy system analysis.



FLATCON® concentrator module with an efficiency of 36.7 per cent.

Concentrator module made of highly efficient multi-junction solar cells

New world record in concentrator photovoltaics: Solar module with an efficiency of 36.7 per cent

The Fraunhofer Institute for Solar Energy Systems ISE has been working for many years on the technology of highly concentrated photovoltaics. Here sunlight is bundled with a Fresnel lens in order to direct it to a very small but highly efficient solar cell. The FLATCON® technology developed at Fraunhofer ISE has already been transferred to industry. Today, Soitec Solar is using this technology as a basis to produce large quantities of modules for concentrator power plants in sunny areas of the world with a high level of direct sunlight (for example, the USA or South Africa).

In 2014 a new world record of 36.7 per cent was achieved for FLATCON® modules at Fraunhofer ISE. This is the highest efficiency for a photovoltaic module so far. A major factor in achieving this result was the use of a new generation of wafer-bonded quadruple junction solar cells developed together with Soitec. Furthermore, the optics were adapted to the new solar cell structure. The module uses 52 Fresnel lenses of 16 cm² each in order to concentrate the sunlight with a factor 230 onto cells roughly seven mm² in size.

Concentrator photovoltaic systems generate solar electricity at a cost of less than € 0.08 per kilowatt-hour. Decisive for this technology is the efficiency of the cells and the concentrating optics. In the record-setting module, the newly developed quadruple junction solar cell was combined with Fresnel lenses, manufactured industrially by ORAFOL Fresnel Optics according to a new design from Fraunhofer ISE.

GFC

address Grenzstr. 5 · 01640 Coswig

contact Peter Heise

telephone +49(0)3523-94-60 fax +49(0)3523-74-142 e-mail info@gfc-drives.com web www.gfc-drives.com

GFC AntriebsSysteme

profile technology

manufacturer | solar thermal power plants

solar thermal power plants



The headquarter of GFC AntriebsSysteme GmbH in Germany.

Your drive system for solar thermal power plants worldwide!

The name GFC stands for the highest levels of precision, reliability and engineering skill. We offer long-term solutions and drive system components in top-quality materials for machines and power plants of almost all dimensions.

From printing machines and container cranes to construction machines, escalators and elevators, GFC products guarantee reliable drive systems operation in a wide range of industrial sectors. In order to achieve this product diversity and to meet variations in demand, GFC expertly controls every step of the manufacturing process in-house. Certification in accordance with DIN ISO 9001 and product certification through DNV and ABS are important quality parameters, and GFC's manufacturing standard.

Solar power plants demand a robust drive system with high accuracy, efficiency and long-term, maintenance-free operation together with a high level of reliability. These requirements can only be met by drive components especially designed for outdoor use.

Our worm drives are especially designed for tracking azimuth and elevation, they can perform slow movements with high transmission ratios and almost zero backlash.



CSP power tower.



A presentation of slewing gearboxes in various sizes which are predestined for use in the solar thermal energy sector.

Our CSP drives operate over 25 years maintenance free and with life-long lubrication. GFC can provide these systems in various applications.

All this makes CSP power tower plants highly efficient and gives them a head start compared to other systems.

Challenge us to provide solutions for you!

GICON[®]

GICON – Grossmann Ingenieur Consult GmbH

address Tiergartenstr. 48 · 01219 Dresden

contact Dr. Hagen Hilse

telephone +49(0)351-47878-738 fax +49(0)351-47878-78 e-mail j.schellmann@gicon.de web www.gicon-engineering.com profile full-line supplier | biogas plants, energy

management, planning and engineering

services

technologies

biogas | other industry sectors



The illustration shows a biogas plant using two-stage dry-wet fermentation (GICON® Process) in Richmond, BC, Canada.

Consultancy - Planning - Project Management - Realisation - Expert Reports

The independent GICON group consists of several independent engineering and consulting firms and also boasts specialised laboratory and pilot plant facilities for its own innovative technology developments, in addition to its own plant engineering and construction division. The GICON Group, which employs more than 300 experts is head-quartered in Dresden. Branch offices throughout Germany as well as a large number of international offices ensure proximity to customers and high-quality service.

One focus of the group's competence is in the area of biogas technology for recycling organic waste. GICON offers the entire spectrum of services, from procedural conception to complete engineering up to turnkey plant construction as general contractor.

GICON has comprehensive knowledge of recycling a wide spectrum of organic waste. Choosing the best biogas

technology, in conjunction with coordinated pre- and posttreatment of the feedstock, will help ensure the success of a project.

For instance, the two-stage GICON® Process for high-solids anaerobic digestion is specially designed for waste which contains large amounts of impurities and offers many advantages with regard to flexibility, energy efficiency and robustness.

GICON can also draw on comprehensive competences in implementing wet fermentation systems in the construction and operation of biogas plants for less structured substrates (food waste, sludges, etc.).

Furthermore, the company is one of the leading providers of planning for biogas grid injection systems, including recompression plants for high-pressure transmission grids.



Intersolar Europe 2015

address Kiehnlestr. 16 · 75172 Pforzheim

contact Solar Promotion GmbH, Horst Dufner

telephone +49(0)7231-58598-0

 $\begin{array}{ll} \text{fax} & +49 \, (\text{O}) \, 7231 \text{-} 58 \, 598 \text{-} 28 \\ \text{e-mail} & \text{info@intersolar.de} \\ \text{web} & \text{www.intersolar.de} \\ \end{array}$

profile other | trade fairs/events

technologies

photovoltaics | solar thermal energy

The world's leading trade show for the solar industry and its partners

With events spanning four continents, Intersolar is the world's leading exhibition series 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.

Intersolar Europe

Intersolar Europe takes place annually at the Messe München exhibition center in Munich, Germany. The exhibition focuses on the areas of photovoltaics, PV production technologies, energy storage and renewable heating technologies. Since being founded, Intersolar has become the most important and most international industry platform for manufacturers, suppliers, distributors, service providers and partners of the solar industry. With more than 20 years of experience, Intersolar has the unique ability to bring together members of the solar industry from across the world's most influential markets: 'Connecting Solar Business'.

Since 2014, the exhibition electrical energy storage (ees), the international trade fair for batteries, energy storage systems and innovative production, takes place in conjunction with Intersolar Europe. Covering the entire value chain of innovative battery and energy storage technologies, the ees and Intersolar Europe together form the leading industry platform for storage systems presented in combination with photovoltaics solutions. In 2014, 1,129 international exhibitors and 42,380 trade visitors attended Intersolar Europe and electrical energy storage (ees).

The accompanying Intersolar Europe Conference consolidates the exhibition topics. In 2014, around 190 speakers and 1,100 participants from all around the world attended the conference and its side events and discussed the latest market developments, technological trends and practical expertise.

For more information about the Intersolar events please visit www.intersolarglobal.com. Intersolar Europe 2015 takes place at Messe München from June 10 to June 12.



A well-frequented stand at the Intersolar Europe 2014.



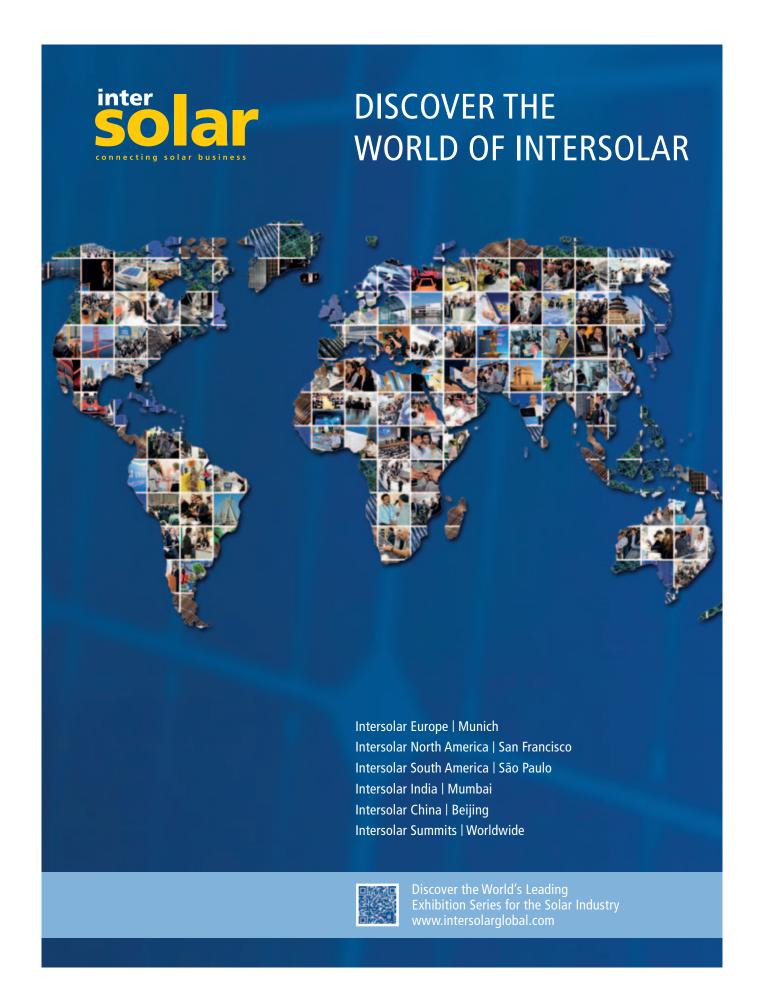
Exhibitors at the Intersolar Europe 2014 present batteries and energy storage systems.



A visitor to the Intersolar Europe 2014 inspects a solar module.



The proud winners of the Intersolar AWARD and electrical energy storage (ees) AWARD 2014.



IBC SOLAR AG



address Am Hochgericht 10 · 96231 Bad Staffelstein

contact IBC SOLAR

 $\begin{array}{ll} \textbf{telephone} & +49\,(0)\,9573\,\text{-}\,92\,2475\text{-}0 \\ \textbf{e-mail} & info@ibc\text{-}solar.de \\ \textbf{web} & www.ibc\text{-}solar.com \\ \end{array}$

profile

dealer, project developer, project engineer | plant components, operations management,

hybrid systems, power stations

technologies

photovoltaics | storage and grid technology

Smart Systems for Solar Power

IBC SOLAR is one of the world's leading specialist for photovoltaic systems, providing complete solutions for generating electricity from sunlight. Long-term planning, organic growth and financial stability have made this family-owned company a reliable partner for national and international projects. IBC SOLAR has already implemented 2.5 GW in more than 150,000 individual systems around the world. The scope of these plants ranges from PV power plants feeding electricity into the public grid up to PV systems for private consumption and off-grid installations. IBC SOLAR sells its PV components and systems through specialised local partners. As a project developer, this systems integrator plans, realises and markets large-scale solar projects



IBC SOLAR AG's main office in Bad Staffelstein.

worldwide. IBC SOLAR's maintenance and monitoring ensures the optimum performance of the PV park.

SunEnergy Europe GmbH



address Fuhlentwiete 10 · 20355 Hamburg

contact Eike Dehning

 $\begin{array}{lll} \mbox{telephone} & +49 \, (0) \, 40 \, \hbox{-} \, 52 \, 0143 \hbox{-} \, 287 \\ \mbox{fax} & +49 \, (0) \, 40 \, \hbox{-} \, 52 \, 0143 \hbox{-} \, 200 \\ \mbox{e-mail} & \mbox{eike.dehning@sunenergy.eu} \end{array}$

web www.sunenergy.eu

profile

consultant, certified expert, project manager | operations management, hybrid systems, planning and engineering services, PV installations

technologies

photovoltaics | storage and grid technology |

other industry sectors

Benefit from new energy – worldwide!

PV expertise from planning to maintenance

PV has been our business since 2001. From our German head office, we develop energy solutions for customers around the world: Solar power plants, hybrid solutions, stand-alone systems and storage, as well as integrated supply concepts for heating and cooling. We also offer our PV expertise in the form of individual consultancy and

planning services for all phases of a PV project. In the area of O&M, we are experienced partners to contact if you want to optimise your plant and safeguard earnings. Our TÜV-certified experts support investors, plant operators, banks and insurance companies in solving quality problems, warranty cases and damage claims. We believe that electricity is the future of the entire global energy supply. PV is going to become the backbone of the energy supply: low in price, easy to install, scalable and sustainable.



Module inspection on site.



Aerial view of an 8.3 MWp solar park.



PV installation on commercial building in Hamburg's "Hafencity".

KOSTAL

KOSTAL Solar Electric GmbH

address Hanferstr. $6 \cdot 79108$ Freiburg i. Br.

contact Sales team

telephone +49 (0) 761 - 477 44-100 fax +49 (0) 761 - 477 44-111 e-mail sales-solar@kostal.com

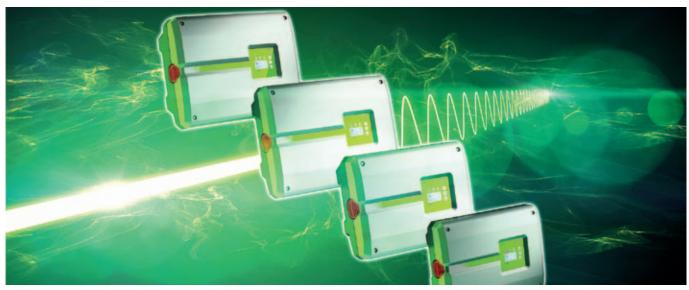
web www.kostal-solar-electric.com

profile manufacturer | plant components, storage

technologies, inverter

technology

photovoltaics



New PIKO generation: Even more flexible, communicative and practical.

Smart connections for the energy of the future

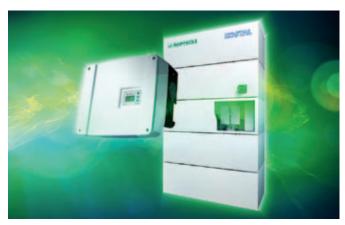
KOSTAL Solar Electric was founded under the umbrella of KOSTAL Industrial Electronics in 2006 and is part of the KOSTAL Group. Headquartered in Fribourg and with various subsidiaries in Europe, KOSTAL Solar Electric is responsible for the international sales and service of the PIKO inverter.

The company philosophy, "Smart connections.", along with the competitive advantages of the KOSTAL family, partnership, quality-offensive thinking and future programmes, is reflected both in contact with partners and customers as well as in the extensive product portfolio. This includes the PIKO BA System storage solution as well as single-phase and three-phase inverters in power classes from 3 to 20 kW.

The storage solution from KOSTAL has many features to promote the beneficial, cost-optimised use of energy. The PIKO BA System controls whether the energy is used directly in the house, stored or fed into the public grid. The lead-gel storage technology with certified safety concept currently used for this fulfils the highest demands. Starting in

mid-2015 a lithium iron phosphate battery will also be available with multistage electronic overcharge protection.

The new generation of PIKO inverters shows that KOSTAL is taking another step into the future. The products have been improved to make them even more flexible, communicative and practical, and the wide range of features offers a solution for nearly every PV plant. The dynamic self-consumption control lowers electricity costs, and due to the Smart Home-compatibility an integration into intelligent domestic systems is possible.



PIKO BA System Pb – Use energy smartly.



Lambion Energy Solutions GmbH

address Auf der Walme $1 \cdot 34454$ Bad Arolsen

contact Ralf Baues

telephone +49(0)5691-807-0fax +49(0)5691-807-138e-mail office@lambion.de

web www.lambion.de

profile manufacturer, project developer, project

engineer | plant components, installation equipment, heating systems, combined heat

and power systems (CHP)

technology

solid biomass



Biomass thermal power plant by LAMBION Energy Solutions GmbH.

For more than 90 years, LAMBION Energy Solutions GmbH has devoted itself enthusiastically and with the greatest care to generating energy from solid biomass and biogenic waste products.

LAMBION plans and builds individual power and heating plants based on bio-waste technology in the power class 1 to 50 MWth.

The company has a huge wealth of experience of the economic and environmental handling of nearly 100 different types of biomass, gained from completing over 3,400 biomass plants around the world.

Biomass power and heating plants from 1 to 50 MWth

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 combusted and transformed into energy simultaneously. We design, develop and manufacture efficient plants from 1 to 50 MWth for almost 100 different types of solid biomass. Best of all with all peripherals.

LAMBION is committed to long-term perspective 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.



Biomass heating plant by LAMBION Energy Solutions GmbH.



Nolting Holzfeuerungstechnik GmbH

address Aquafinstr. $15 \cdot 32760$ Detmold contact Joachim Eggers, Sascha Bartsch

 $\begin{array}{lll} \text{telephone} & +49\,(0)\,5231\,\text{-}\,95\,55\,\text{-}0 \\ \text{fax} & +49\,(0)\,5231\,\text{-}\,95\,55\,\text{-}55 \\ \text{e-mail} & \text{info@nolting-online.de} \\ \text{web} & \text{www.nolting-online.de} \\ \end{array}$

profile manufacturer, project developer | heating

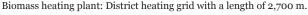
systems, measurement and control systems,

accessories

technology

solid biomass







Local heating supply with wood chips.



Our Japanese licensees at a training session.

Combustion plants for biomass and pellets

Nolting has offered high-quality non-polluting biomass combustion plants for more than 60 years, in the capacity range from 50 to 3,000 kW. These are produced 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, lengthy experience and our own factory customer service. Almost 40 per cent of our production goes to export, and we supply a wide range of sectors including woodworking, wood processing, municipal buildings, crafts, industry, agriculture and horticulture.

Heating that is simple, low in cost and CO₂ neutral

The product range covers manually-loaded log-burning boilers, automatic underfeed and forward feed grate furnaces, container solutions, special combustion systems, silo discharges and conveyor technology, plus all accessories and additional components.

Our experienced staff will support you with the planning in order to compile the right solution for the best possible overall concept for you. 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.

web



Ossberger GmbH + Co

address Otto-Rieder-Str. 7 · 91781 Weißenburg in Bayern

 $\begin{array}{ll} \mbox{contact} & \mbox{Holger Franke} \\ \mbox{telephone} & +49\,(0)\,9141\,\text{-}\,977\text{-}0 \\ \mbox{e-mail} & \mbox{info@ossberger.de} \end{array}$

www.ossberger.de

profile

manufacturer, project developer | plant components, measurement and control systems,

hydroelectric plants

technology

hydropower



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

...we make your electricity flow even with small streams!

Ossberger GmbH + Co in Weissenburg in Bavaria owes its extensive experience in the three areas of **small hydro-power 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 foundation for decades of successful work by the company. 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 and currently 3.5 MW.

Ossberger Hydro is present in about 50 countries around the world.

Original OSSBERGER® cross-flow turbines consist of standardised individual components, configured with an

eye to the commercial aspects of specific projects to complete tailor-made systems according to requirements.

With only three moving parts, they follow the Ossberger principle of simplicity and can adapt themselves extremely well to a fluctuating water supply; for this reason, they are ideal as individual machines in a hydro-electric power plant. They operate smoothly from practically zero load to full opening, and have already proved themselves a thousand times in the toughest conditions.

Stationary and mobile trash rack cleaning systems, which are indispensable for increasing the profitability of both small and large hydroelectric power plants, complete the range of hydro products on offer from Ossberger.



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



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

address Im Teelbruch 118 \cdot 45219 Essen

contact Steven Scott

 $\begin{array}{ll} \mbox{telephone} & +44(0)\,191\,\hbox{-}\,402\,\hbox{-}9688 \\ \mbox{e-mail} & steven.scott@parker.com \\ \mbox{www.parker.com/hzd} \\ \end{array}$

profile

manufacturer | biogas treatment products

technology

biogas



Regenerative, zero-loss adsorption system for drying Biomethane.

Building on more than 40 years of experience in the field of compressed air and gas treatment, Parker offers the industry's most comprehensive range of biogas treatment products. Typical applications include filtration, dehumidification, separation, cooling and drying of biogas, sewage gas and landfill gases with all products backed by the support of Parker's global sales company network.

The Parker product range includes the following highly efficient system components:

- High-efficiency filters for 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 (cyclone & demister type)
- Condensate drains (zero gas loss)
- Packaged biogas dehumidification systems (skid-mounted, including all interconnecting pipework)
- High-efficiency regenerative adsorption dryers (for biogas and biomethane, PSA and TSA types)



Biogas dehumidification system with cooler, demister and water chiller.

- Oil vapour adsorbers (for removal of hydrocarbons)
- Regenerative siloxane removal systems (for siloxane and VOC removal)
- Bacteria & microorganism removal filters
- · O2 Generators.



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.

address



PSE Engineering GmbH

Ahrensburger Str. 1 · 30659 Hannover

contact Bernd Schmidt

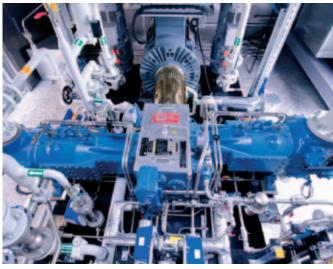
 $\begin{array}{lll} \mbox{telephone} & +49\,(0)\,511\,\hbox{--}\,26\,14\,20\,\hbox{--}\,98 \\ \mbox{fax} & +49\,(0)\,511\,\hbox{--}\,26\,14\,20\,\hbox{--}\,11 \\ \mbox{e-mail} & \mbox{bernd.schmidt@pse-eng.de} \\ \end{array}$

web www.pse-eng.de

profile technology

manufacturer | gas compressor systems

biogas



Top-class biogas compression from PSE Engineering.

PSE Compression Systems is your competent partner for the economically optimal use of biogas. Thanks to efficient, high-quality ARIEL compressors, the high level of reliability and outstanding price-performance ratio of our concepts for biogas units cannot fail to convince.

PSE Engineering GmbH is a medium-sized company with a number of subdivisions.

Compression systems

Engineering, manufacturing, installation and commissioning of compressor plants nationally and internationally.

- Underground storage technology
- Water-treatment technology
- Oil and gas
- Industrial technology.

Biogas compressor plants

We offer gas compression plants in the capacity range from 500 to 5,000 $\rm Nm^3/hr,$ in the pressure range from 1 bar suction pressure to 100 bar discharge pressure. We will



Natural gas storage and compressor system.

provide you with a customised unit – from engineering up to manufacturing, installation and commissioning. You can also select your unit design from a range of already completed plants.

Natural gas compression plants

If you require a two-, four- or six-throw natural gas compressor, please contact us. We will offer you compression systems in the capacity range from 100 kW to 7,500 kW from the large product range of ARIEL compressors.

Process gas compressors

If you are looking for a reciprocating compressor you can use as a process gas compressor or a special gas compressor in the refinery sector or in special gas manufacturing, we can offer you the right product.

Service and maintenance

It is our pleasure to offer you after-sales service, maintenance and repair. PSE is proud of its highly-trained team of mechanics, technicians and engineers, and is an official distributor of ARIEL-OEM spare parts.



Renergiepartner Group

address Volmerstr. $9 \cdot 12489$ Berlin

contact Ines Schuldt

telephone +49(0)30-678904-25
fax +49(0)30-678904-26
e-mail schuldt@deig-energie.de
web www.deig-energie.de

 $\begin{tabular}{ll} \textbf{profile} & \textbf{operator, project developer, other} \ | \end{tabular}$

operations management, planning and engineering services, storage technologies

technologies

wind energy | geothermal energy | biogas |

storage technology

Network for renewable energy conversion, storage, sustainable resource protection

The SMEs in the network cooperate in bidding, planning and operating consortiums as well as in project-specific and technological partnerships.

Building on extensive experience in the realisation of renewable energy projects, they are increasingly developing applications, complementary technologies and integrative solutions incorporating a wide range of technologies, such as storage technologies for electricity, heating and refrigeration, technologies for water treatment, desalination and renaturalisation, as well as raw materials exploration, mining and treatment processes.

The Renergiepartner Group functions as general contractor covering the entire performance spectrum of project development for wind, solar, biomass and gas, as well as geothermal energy project solutions, starting with prefeasibility studies up to turnkey completion of the projects. These services can be obtained as a complete package or as individual services. The roughly 140 employees, with their rich store of more than two decades of experience and the high qualification of young, highly motivated



Hundertwasser, adaptation based on 808 End of the Waters. © 2014 Namida AG, Glarus, Switzerland.

experts in the network partners' SMEs vouch for the holistic implementation of the services offered by the Renergiepartner Group.

Members of the network	Focus of business activities	Homepage
CarboCycle Ingenieurbüro	Fermentation plants, among others gas injection	www.carbocycle.de
DEIG Energietechnik-Insumma GmbH	Solar energy conversion, storage	www.deig-energie.de
€-Co-Partner GbR	Test and operation of wind power plants, and due diligence	
GABEG-Solar Solutions GbR	Wind energy and photovoltaic applications	www.gabeg.net
G.E.O.S. Ingenieurgesellschaft mbH	Geothermal energy and environmental technologies	www.geosfreiberg.de
Karl-Steiger GmbH	Environmental and CO ₂ capture projects	www.karlsteiger.de
SEP Sustainable Energy Projects GmbH	Compliance tests and due diligence for wind energy projects	www.sep-energie.de

 $Table \ showing \ the \ members \ of \ the \ networks, their \ main \ business \ segments \ and \ websites.$



REFU Elektronik GmbH | REFUenergy

address Marktstr. 185 \cdot 72793 Pfullingen

contact Dr. Armin Keinath telephone +49(0)157-35764003 e-mail info@refu-energy.de web www.refu-energy.de $\label{eq:profile} \textbf{profile} \qquad \text{full-line supplier} \mid \textbf{plant components},$

installation equipment, energy management, combined heat and power systems (CHP)

technologies

storage and grid technology | other industry sectors



The REFU Elektronik building with the REFUstation+ container solution on the grounds.

REFUenergy - energy for life

Life needs energy – REFUenergy has set itself the task of making this energy available. In the form in which it is needed. Always and everywhere. And in a way that is economically efficient and ecologically aware.

The innovative smart grid solutions from the experienced REFU Elektronik GmbH, part of the internationally active PRETTL group, are setting new standards in the areas of electric power supply, electricity storage and converter technology. At its site in Pfullingen near Stuttgart (Germany), REFUenergy develops and coordinates customer-specific solutions at the highest level of technology.

REFUenergy, the especially reliable partner for your energy needs

From software development to setting up independent container solutions up to providing connections for e-mobility concepts, REFUenergy is the interface between electricity suppliers and consumers, makes renewable energy accessible and maximises its success thanks to an effective link with time-tested technologies for energy

production. Thus innovative concepts are developed to integrate CHP plants into container solutions, for instance, and thus combine the advantages of both products in one solution. Off-grid, peak shave, load shift and mains stabilisation are only a few of the competences realised in large as well as small REFU solutions. And their data can be viewed by way of touchscreen displays and smartphone applications.

REFUenergy connects sources to energy



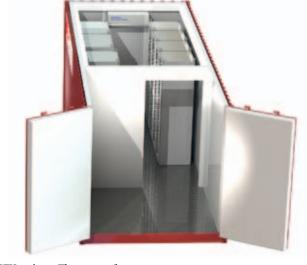
REFUstation+ - for more security and independence.

REFUenergy – solutions for your energy needs

Battery systems for full integration

REFUstation

The REFUrack and REFUeye REFUenergy solutions are combined in mobile 20-foot containers. At the same time, these containers offer an integration area for renewable sources of energy. All values of the individual components in the container, such as battery elements and inverters, are controlled, recorded, processed and shown on the touch display by means of modern technology. This also makes them an ideal leasing solution. Moreover, the free area provides protected space for components for the desalination of seawater, for instance. The REFUstation+ is a special highlight equipped with CHP or a diesel generator for more security and self-sufficiency.



 $REFU station-The\ centre\ of\ your\ energy.$

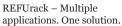
REFUrack

Batteries, inverters and control unit combined in cabinet sizes make up the REFUrack and its combination solution when energy is important. This redundant system offers security and a capacity that can be enhanced by inserting additional battery elements. With an efficiency of 95 per cent, they supply power for high-performance applications, regardless of whether you need an emergency power supply or, for instance, want to increase private consumption from photovoltaics.



With its especially efficient and lightweight lithium ion battery units, bidirectional inverter and easy-to-understand monitoring display, the REFUbox lets you feed in, store and consume energy for specific purposes, and add additional sources of energy. For instance, you can easily switch from on-grid to off-grid mode. The compact size is ideal for mounting on or in buildings – also on rural mud huts.







REFUbox – The container in a mini-format.

	REFUstation	REFUrack	REFUbox
Grid-connected operation	Yes	Yes	Yes
Independent operation (off-grid)	Yes	Yes	Yes
Power range	3 KW	18-150 KW	44-300 KW
PV system can be connected	Yes	Yes	Yes
Generator can be connected	Yes	Yes	Yes
Reliable Li-ion batteries	Yes	Yes	Yes



The REFUeye - Everything in view even when mobile.



Renewables Academy AG (RENAC)

address Schönhauser Allee $10-11\cdot 10119$ Berlin

contact Manolita Wiehl

 $\begin{array}{ll} \text{telephone} & +49\,(0)\,30\,\text{-}\,52\,68\,95\text{-}\,871 \\ \text{fax} & +49\,(0)\,30\,\text{-}\,52\,68\,95\text{-}\,899 \end{array}$

e-mail wiehl@renac.de web www.renac.de profile educational provider, consultant, other | further education, trade fairs/events

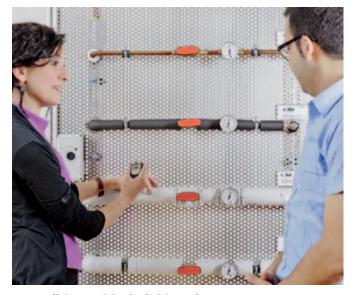
technologies

wind energy | photovoltaics | solar thermal energy | solar thermal power plants | biogas |

other industry sectors



Practice-oriented training on solar technologies.



Energy efficiency training for decision makers.

Energy through Education!

RENAC is an internationally operating provider of training and capacity building services for renewable energy and energy efficiency. Since our founding in 2008, participants from more than 130 nations worldwide have benefited from our expertise in solar, wind power, bioenergy, hydropower, hybrid systems, electricity grids and energy efficiency.

Our training programs cover topics and skills along the whole value chains, such as financing, management, engineering, assessing, implementing, designing and maintaining of grid-connected and off-grid energy systems.

Our services are tailored to our customers' needs and are directly catered to the specific country and organisational framework. Our goal is to equip our participants for the challenges of real projects through an intense and absorbing training experience. Therefore we use a variety of training techniques and methodologies. Our lecturers are practically experienced experts.

Training Courses

In our well equipped training center in Berlin or with our mobile training center at any place worldwide: Open training, tailor-made training, online training.

Capacity Building Services

Capacity needs assessment, development of curricula and training material, turn-key training centers, train-the-trainer, quality assurance.

Masters' Degrees

MBA Renewables, GPE New Energy, ERE International – Energy and Resource Efficiency.

Market Development & Consulting

Advisory services, delegation programs.



schlaich bergermann und partner

schlaich bergermann und partner, sbp sonne gmbh

address

Schwabstr. 43 · 70197 Stuttgart

contact Sarah Arbe

telephone e-mail web Sarah Arbes

+49(0)711-64871-910 solarinfo@sbp.de www.sbp.de profile

consultant, research and development | power plants, measurement and control systems, planning and engineering services,

solar thermal power plants

technology

solar thermal energy | solar thermal power plants



Ultimate Trough $^{\scriptscriptstyle\mathsf{TM}}$ parabolic trough collector, California, USA.



 $500~\mathrm{m}^2$ Fresnel systems in Mongolia.

Consulting engineers for renewable energy

For more than 30 years, schlaich bergermann und partner have been developing the most varied components and systems for solar thermal power plants.

Today, we are a leading international engineering firm, known as experts for parabolic trough collectors, heliostats and towers for central receiver solar power plants, dish/Stirling systems as well as concentrating photovoltaic systems.

In collaboration with our partners, we successfully plan and implement large solar projects. The majority of parabolic trough plants use the EuroTrough collector, which we had a leading role in developing. Our next generation component is the UltimateTrough® collector. For both of these, we were awarded the SolarPACES Technology Innovation Award. In addition, we have been developing and designing heliostats for more than 20 years, and we have planned and implemented dish/Stirling systems in Saudi Arabia, Germany, Spain, Italy, France and India.

Our scope of work

- Solar field design of parabolic trough and solar tower power plants.
- Development and design of dish/Stirling systems and concentrating photovoltaic (CPV) systems (except for the Stirling engine/PV module).

From the idea to feasibility studies, to planning and construction of the first prototypes, continuing with the elaboration of approvable construction drawings, and the management of component manufacturing, construction and commissioning in the subsequent building of a power plant, we cover all the planning and engineering stages. This also includes all optical calculations, structural design, drive and control technology.



VIESMANN Group

address Bayernwerk $8 \cdot 92421$ Schwandorf

contact Michael Groth
telephone +49 (0) 9431-751-0
fax +49 (0) 9431-751-204
e-mail info@schmack-biogas.com
web www.schmack-biogas.com

Schmack Biogas GmbH

profile technology

full-line supplier | biogas plants

biogas



The integration of various biogas technologies enables all raw materials to be put to optimal use.

Full-service provider of highly efficient and economic biogas plant systems

Schmack Biogas GmbH is one of the leading German providers of biogas plants. Since 1995, the company, which is based in Schwandorf (Bavaria), has been setting standards for highly efficient and economic biogas plants. The wide range of products includes plant systems in the output range of 50 kW in compact plants, up to a 20 MW feed-in-plant. Worldwide, more than 400 plants have been commissioned. Since January 2010, Schmack Biogas has been part of the Viessmann Group.

Innovative technologies and processes

The range of services includes the entire biogas value chain: From project development and engineering to feedstock and operations management. Schmack Biogas is one of the few full-service providers in the industry. Besides technical support, the focus is on comprehensive microbiological services. The company's exceptional in-house research and development laboratory is used to identify and exploit potential efficiencies in the area of process biology. Schmack has won numerous awards for its innovative technologies and processes.



Gate system with substrate barrier in the mixing building.

Specialist for wet and dry fermentation

With systems for wet and dry fermentation, Schmack Biogas covers the entire field of technologies for the fermentation of solid and pumpable waste. In wet fermentation, energy crops and organic waste materials from agriculture and the food industry are used as a pumpable substrate. Schmack's biogas plants are distinguished by their high levels of flexibility and reliability. By using high-quality components manufactured in-house, particularly in the key areas of agitator and feeding technology, Schmack is able to offer process- and energy-optimized systems.

BIOFerm technology for non-pumpable raw materials

Schmack Biogas also offers the BIOFerm technology of dry fermentation for non-pumpable raw materials. This method is used to convert biogenic waste materials (e.g. municipal biowaste, waste from agriculture and landscape management) into energy. The requirements for the input material are extremely low and it is not necessary to pretreat the biomass.

Internationally present

Schmack is also active in international markets. With Schmack Biogas Srl in Bolzano as well as BIOFerm Energy Systems in Madison, Wisconsin, Schmack Biogas has its own subsidiaries in Italy and the USA. In addition, Schmack Biogas has a presence in Great Britain through Schmack Biogas UK Ltd.



Complete microbiological service.



Interior view of a COCCUS fermenter with Remex paddle agitators.



SMA Solar Technology AG

profile

manufacturer | energy management,

hybrid systems, inverter, system solutions

for storage integration

technologies

photovoltaics | storage and grid technology

address Sonnenallee $1 \cdot 34266$ Niestetal contact Ulrich Trabler +49 (0) 561 - 9522 - 0 e-mail info@SMA.de web www.sma.de



Europe's biggest thin-film solar plant, Templin (Brandenburg), Germany.

Become more independent in the use of energy: Employing cost-efficient solar power means to achieve a reliable power supply, high return on investment, lower energy and operating costs, reduced carbon emissions, and less dependence on fossil-fueled power generation.

SMA Solar Technology AG offers system solutions for grid-connected photovoltaic plants from the module level to the multi-megawatt range, PV diesel hybrid systems, off-grid power systems, and solutions for the integration of storage devices. The product range includes a compatible inverter for every type of module on the market and for all plant sizes. The product portfolio is supplemented by comprehensive services and operational management of utility-scale PV plants.

The SMA group is the global market leader for solar inverters and offers innovative key technologies for future power supply structures and energy management. Headquartered in Germany, SMA is represented in 21 countries and employs more than 5,000 people worldwide. Customers profit from more than 30 years of experience in solar inverter technology,

as well as from SMAs global expertise in planning and commissioning photovoltaic power plants of all sizes and off-grid hybrid power systems.



SMA Fuel Save Solution for a mine in Thabazimbi, South Africa.



SOLARC Innovative Solarprodukte GmbH

address Glogauer Str. 21 · 10999 Berlin

contact Dieter Werner

telephone +49(0)30-3198554-10 fax +49(0)30-3198554-99 e-mail werner@solarc.de web www.solarc.de profile

dealer, manufacturer, project developer | measurement and control systems, pv modules, solar home systems

technology

photovoltaics

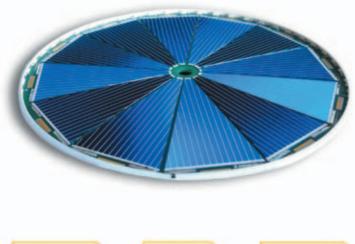
Top-class solar technology!

SOLARC is your industrial partner for the development and manufacturing of innovative solar power systems, customised solar modules, solar charge controllers, DC/DC converters, as well as motor and lighting controls systems.

We are the right address for those companies seeking for an experienced and a reliable partner to develop and manufacture customised components for a solar power-supply for their product or even a complete new solar-powered solution, right from the prototype to series run.

SOLARC focuses on four major technology areas:

- Customised solar modules (crystalline, thin film, outdoor and indoor)
- Solar charge controllers and DC/DC converters as well as motor and lighting control units, especially designed for low-power solar off-grid systems
- Solar irradiance monitoring devices and systems (MacSolar product family)
- Complete new product development of new solarpowered products, e.g. solar chargers, solar-powered GPS tracking solutions or OEM irradiation sensors.









Customised solar modules, DC/DC converters, solar irradiance monitoring devices, new product development.



Various solar modules on offer.

web



STELA Laxhuber GmbH

address Öttingerstr. 2 · 84323 Massing

 contact
 Thomas Laxhuber

 telephone
 +49 (0) 8724 - 899-0

 fax
 +49 (0) 8724 - 899-80

 e-mail
 sales@stela.de

www.stela.de

 $\begin{tabular}{ll} \textbf{profile} & manufacturer \mid plant components, \\ \end{tabular}$

installation equipment

technologies

biogas | solid biomass| other industry sectors



One of the biggest STELA low-temperature dryers, the BT 1/6200-61,5 in Chile, for drying eucalyptus bark, with a length of 61.5 m.

Drying Technology

STELA Laxhuber GmbH is an internationally focusing company specialising in the manufacture of drying systems, with 140 qualified employees working at the company and production headquarters in Massing, Germany. All its expertise lies in the development of ultramodern drying systems for agriculture and industry. More than 3,800 STELA drying systems have been supplied and put into operation around the world until now. Thanks to professionalism and ongoing further development, STELA has established itself as one of the market leaders in low-temperature drying. In the area of fuel drying alone, 5.5 million tonnes of water evaporation per year have been vaporised by STELA drying systems since 2002, all using so-called "waste heat" – energy which would otherwise go into the atmosphere unused.

The product range of STELA drying systems covers a wide variety of sectors, from the chipboard industry, wood pellet production, agriculture and the food industry, fuel pre-drying up to power engineering and disposal technology. For each of its products, STELA develops a technical drying solution tailored to the customer. Competent collaboration

between distribution, engineering and service ensures the best possible support from sale up to commissioning. A large number of references at home and abroad, especially in the international industry, have been convinced by STELA drying systems.



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



Valentin Software GmbH

address Stralauer Platz 34 · 10243 Berlin

contact Denise Dawes

 telephone
 +49 (0) 30 - 58 84 39 - 0

 fax
 +49 (0) 30 - 58 84 39 - 11

 e-mail
 info@valentin-software.com

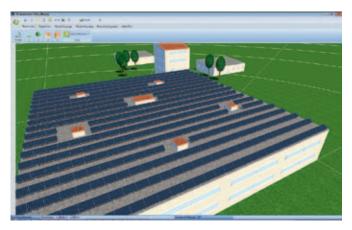
 web
 www.valentin-software.com

 $\textbf{profile} \qquad \quad manufacturer \mid software$

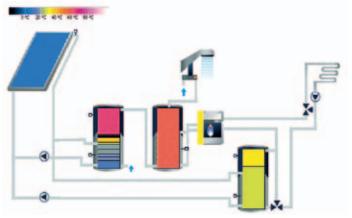
technologies

geothermal energy | photovoltaics |

solar thermal energy



PV*SOL premium - mounted system in 3D.



T*SOL – dynamic annual simulation, time intervals of 1 – 6 minutes.

Quality and reliability with professional planning software worldwide

Valentin Software has been developing smart software solutions for planning, designing, dynamic simulation and yield forecasts for energy supply for over 25 years. Our simulation programs – PV*SOL, T*SOL and GeoT*SOL – support planners, engineers, consultants, installers, specialised tradesmen and investors in designing and professionally planning photovoltaic, solar thermal and heat pump systems. Our software is used in more than 100 countries around the world.

PV*SOL and PV*SOL premium

Our PV programs simulate grid-connected PV plants with self-consumption and storage in battery systems. In addition to the features offered by PV*SOL, PV*SOL premium also includes 3D visualization and a detailed shading analysis.

T*SOL

With T*SOL you can optimally design solar thermal plants, dimension collector arrays and storage tanks and calculate the economic efficiency.

GeoT*SOL

Our user-friendly tool for planning heat pump systems. GeoT*SOL supports the following sources of heat: Ground, outdoor air, groundwater. There are five plant types to choose from.

Test versions of our software programs are available on our website. We support our customers with free webinars and video tutorials. Our software maintenance includes both program as well as database updates. The program price covers one year of software maintenance starting on the date of purchase. The software comes in several languages.



GeoT*SOL - heat pump system with solar thermal support.



climate of innovation

Viessmann

address Viessmannstr. 1 · 35107 Allendorf (Eder)

contact Jörg Schmidt

telephone +49(0)6452-70-1569 e-mail SmdJ@viessmann.com web www.viessmann.com profile full-range provider | heating systems,

combined heat and power systems (CHP), pv installations, solar heating technology

technologies

all technologies



As a full-range provider, Viessmann offers system solutions for equipment upgrades and new constructions, for detached homes, apartment buildings, commercial and industrial properties and local heating networks.

The Viessmann Group

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 approximately 11,400 employees and generates € 2.1 billion in annual group turnover.

With 27 production divisions in 11 countries, subsidiaries and representations in 74 countries and 120 sales offices around the world, Viessmann is an internationally orientated company. 55 per cent of sales are generated abroad.

Sustainability in practice

As a family-run company, Viessmann sets great store by responsible conduct with a long-term vision. Sustainability is already firmly embedded into the company's guiding principles. For Viessmann, the practice of sustainability means reconciling cost efficiency, ecology and social responsibility throughout the entire company to enable us to meet our current needs without compromising the ability of future generations to meet theirs.

As an environmental pioneer and technology leader in the heating industry, Viessmann has been supplying minimal emission, energy-efficient heating systems for oil and gas for decades as well as solar thermal systems, wood combustion systems and heat pumps. Many Viessmann developments are regarded as milestones in heating technology.

Viessmann's comprehensive range of products

Viessmann's comprehensive range of products offers individual solutions with efficient systems and services ranging from 1.5 to 120,000 kW for all application areas and all fuel sources. Viessmann's product portfolio includes wall-mounted condensing units from 1.9 to 150 kW, freestanding condensing boilers from 1.9 to 6,000 kW and combined heat and power (CHP) stations from 1.0 to 530 kWel and 5.3 to 660 kWth. The CHP systems are designed to operate with natural or bio-natural gas and are available in combination with a bio-natural gas supply agreement.



View of a production line for wall-mounted gas boilers at the company's head quarters in Allendorf (Eder), Federal Republic of Germany.

The range of regenerative energy systems includes solar thermal systems with flat-plate and vacuum tube collectors for DHW heating, heating system backup and solar power building cooling, special boilers and combustion units from 4 kW to 50 MW for logs, wood chips and pellets, heat pumps from 1.7 to 2,000 kW that use heat from the ground, groundwater or ambient air and photovoltaic systems.

For local heating networks and bio-energy villages Viessmann also offers everything from a single source – from initial feasibility studies and detail engineering to the delivery of all necessary components like biogas systems, heaters, CHP modules, geothermal piping and residential transfer stations to construction and commissioning.

The Viessmann Group covers the cooling and refrigeration technology sector with a comprehensive range of temperature-controlled rooms, refrigeration solutions for the food retail industry, powerful refrigeration cells and units as well as accessories and services.

Full-range service

As a full-range supplier, Viessmann includes an extensive range of service offers.

For example, the Viessmann Academy provides a comprehensive training and professional development program to heating contractors, designers, architects, housing associations, flue gas inspectors, technical education establishments and its own staff. By doing this, the company is seeking to meet the increasing training requirements of its trade partners due to structural changes in the heating market towards efficient technologies and regenerative energy systems as well as the associated increase in the range of technologies available. Worldwide 92,000 industry specialists take part in the Viessmann Academy's training sessions every year.

The Viessmann service package also includes support from the Technical Service Department, a software range meeting the customers' demands, support through advertising and sales promotion as well as a user-friendly information and ordering system available around-the-clock online.

VOITH

Voith Hydro Holding GmbH & Co. KG

address Alexanderstr. 11 \cdot 89522 Heidenheim

contact Ute Boehringer-Mai telephone +49(0)7321-37-0

e-mail info.voithhydro@voith.com

web www.voith.com

 $\begin{tabular}{ll} \textbf{profile} & full-line supplier | hydroelectric plants \\ \end{tabular}$

technology

hydropower



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

Voith is a global provider of leading-edge technology and industrial services. Voith offers a broad portfolio of systems, products and services that serve the five markets of energy, oil & gas, paper, raw materials and transport & automotive all over 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 5,300 employees and turnover of € 1.3 billion in business year 2012−13.

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.



WELTEC BIOPOWER GmbH

address Zum Langenberg 2 \cdot 49377 Vechta

contact Hajo Schierhold

telephone +49(0)4441-99978-0 fax +49(0)4441-99978-8 e-mail info@weltec-biopower.de web www.weltec-biopower.de profile full-line supplier | plant components,

biogas plants, contracting, planning and

engineering services

technology

biogas



WELTEC BIOPOWER is a specialist in waste-to-energy systems.

Biogas technology made of stainless steel

WELTEC BIOPOWER was founded in 2001 and has now set up more than 300 plants in 25 countries around the globe. This makes the company one of the world's leading suppliers of biogas plants.

WELTEC BIOPOWER builds its digesters from stainless steel due to the fact that the hydrogen sulphide and ammonia contained in the biogas will corrode unprotected parts. This guarantees that the plant will have a long life cycle. The vertical integration also guarantees a constant high standard that is independent of location.

WELTEC BIOPOWER plants are built in a modular fashion: Only tried and tested system components are used, and the majority of technologies along the entire value chain are developed in-house: Control technology, hygienisation systems and solutions for the processing of fermentation residue all come from within the company.

The strength of this medium-sized company lies in individual solutions – from compact plants to computer-controlled high

capacity plants at the megawatt level and waste processing systems to biogas parks with gas processing technology.

With comprehensive service support, WELTEC BIOPOWER ensures the technical and economic stability of biogas plants. The CHP service guarantees stable performance, the biological management takes care of constant monitoring of the relevant parameters, and targeted repowering keeps the biogas plant always up to date. The operators can choose among service packages that differ in type and scope.



The WELTEC product range includes solutions for gas processing.



Wolf GmbH

address Industriestr. 1 · 84048 Mainburg

 $\begin{array}{lll} \textbf{contact} & Josef \, K\"{o}glmeier \\ \textbf{telephone} & +49\,(0)\,8751\,\text{-}\,74\,\text{-}\,0 \\ \textbf{fax} & +49\,(0)\,8751\,\text{-}\,74\,\text{-}\,1600 \\ \textbf{e-mail} & info@wolf-heiztechnik.de \\ \textbf{web} & www.wolf-heiztechnik.de \\ \end{array}$

profile manufacturer | heating systems,

combined heat and power systems (CHP),

solar heating technology

technology

solar thermal energy

Wolf GmbH in Mainburg, Bavaria, is one of the leading providers of air conditioning and heating technology. Opera houses, airports and office buildings are equipped with air conditioning and ventilation systems from Wolf. For example, Wolf air conditioning equipment is installed in the Allianz Arena in Munich, the Kremlin in Moscow, German government buildings in Berlin, as well as the hotel in the new fairgrounds in Abu Dhabi. Heating and air-conditioning by Wolf are there to serve human beings and their environment. For the human being is our benchmark. Wolf produces exclusively in Mainburg, Bavaria, is committed to Germany as a business location, and is betting on "The future – Made in Germany".

As a complete system provider, Wolf presents its products in the areas of heating, climate, ventilation and solar technology, as well as combined heating plants, under the motto: Energy savings and climate protection are standard.

- 2013: € 337 million total revenues
- Wholly-owned subsidiary of Centrotec Sustainable AG, Brilon
- 15 sales offices and 2 distribution warehouses in Germany
- 6 foreign subsidiaries in Spain, France, the Netherlands, Italy, Poland and Russia
- 60 sales partners in 45 other countries
- Around 30 % export share
- Around 1,460 employees at the Mainburg site and in the sales and service network throughout Germany
- Around 350 additional employees worldwide.



Corporate headquarters in Mainburg, Bavaria, Germany.



The only production site is in Mainburg, Bavaria.



contact

Initiative: "renewables – Made in Germany"

address Chausseestr. 128 a \cdot 10115 Berlin

Your "renewables – Made in Germany" team

telephone +49(0)30-726165-600fax +49(0)30-726165-699e-mail renewables@dena.de

web www.renewables-made-in-germany.com

profile information provider technologies

all technologies



The "renewables – Made in Germany" exhibition stand of the German Federal Ministry for Economic Affairs and Energy (BMWi) offers the opportunity to learn more about renewable energy technologies and meet with German renewable energy companies at leading trade fairs all over the world.

Since 2002 the German government has been closely involved in supporting the global dissemination and transfer of technologies for renewable energies, under the banner "renewables – Made in Germany". The responsible authority, the Federal Ministry for Economic Affairs and Energy (BMWi), is thus making an active contribution to the global fight against climate change while promoting the worldwide acceptance and use of renewable energies. By showcasing Germany's technical expertise in the field of renewable energy and by organising business trips to and from Germany, the initiative facilitates business contacts between German companies and those from abroad.

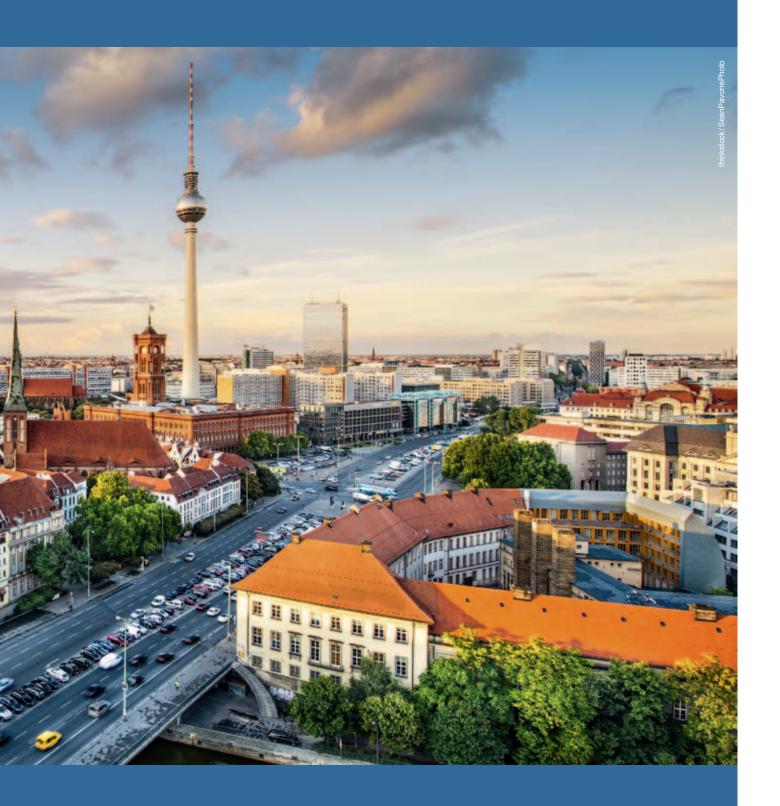
Coordinated and financed by the BMWi, the initiative is implemented in cooperation with partner organizations such as the Deutsche Energie-Agentur GmbH (dena) — the German Energy Agency, the Association of German Chambers of Industry and Commerce (DIHK), the Federal Office for Economic Affairs and Export Control (BAFA), the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH as well as relevant industry associations and other partners.

We would be pleased to help you.

DIRECTORY



Cityscape of Berlin, Germany.



Company directory

Awite Bioenergie GmbH agenpa Carl Philipp Dr. Martin Grepmeier Brunnenstr. 192, 10119 Berlin, Germany Grünseiboldsdorfer Weg 5, 85416 Langenbach, Germany telephone: +49(0)30-288833-08 telephone: +49(0)8761-72162-0 info@agenpa.com fax: +49(0)8761-72162-11 www.agenpa.com info@awite.com www.awite.com p. 84 agriKomp GmbH Thomas Franke BayWa r.e. renewable energy GmbH Herzog-Heinrich-Str. 9 Energiepark 2, 91732 Merkendorf, Germany telephone: +49(0)9826-65959-0 80336 München, Germany fax: +49(0)9826-65959-10 telephone: +49(0)89-383932-0 info@agrikomp.de info@baywa-re.com www.agrikomp.com p. 80 www.baywa-re.com p. 86 **Alpha New Technology Services GmbH BBB Umwelttechnik GmbH** Stefan Simon Markus Rieger Düsseldorfer Str. 31A, 10707 Berlin, Germany Munscheidstr. 14, 45886 Gelsenkirchen, Germany telephone: +49(0)30-8639028-22 telephone: +49(0)209-167255-0 fax: +49 (0)30-8639028-10 fax: +49(0)209-167255-1 stefan.simon@alpha-nts.com m.rieger@bbb-umwelt.de www.alpha-nts.com www.bbb-umwelt.com **Ammonit Measurement GmbH** Christa Vogel Daniela Treptow Albert-Einstein-Str. 5, 92637 Weiden, Germany Wrangelstr. 100, 10997 Berlin, Germany telephone: +49(0)961-391728-0 telephone: +49(0)30-6003188-0 fax: +49(0)961-391728-299 fax: +49(0)30-6003188-10 c.vogel@bbb.umwelt.de info@ammonit.com www.bbb-umwelt.com p. 85 p. 82 www.ammonit.com **BerlinWind GmbH Andritz Hydro GmbH** Anke Grunwald Karin Kowaczek Bundesallee 67, 12161 Berlin, Germany telephone: +49(0)30-688333-740 Escher-Wyss-Weg 1, 88212 Ravensburg, Germany telephone: +49(0)751-29511-0 fax: +49(0)30-688333-769 fax: +49(0)751-29511-999 info@berlinwind.com contact-hydro.de@andritz.com www.berlinwind.com www.andritz.com p. 81 Carbotech GmbH Dr. Alfons Schulte-Schulze Berndt Natorpstr. 27, 45139 Essen, Germany telephone: +49(0)201-50709-300 fax: +49(0)201-50709-500 mail@carbotech.info www.carbotech.info p. 90

Biogas

■ Solar thermal power plants ■ Solid biomass ■ Other industry sectors

■ Storage and grid technology

■ Wind energy ■ Geothermal energy ■ Solar thermal energy

■ Hydropower ■ Photovoltaics

CEPP Capital AG

Daniel Bussin

Kurfürstendamm 72, 10709 Berlin, Germany telephone: +49(0)30-8639028-254 fax: +49(0)30-8639028-10 daniel.bussin@cepp-capital.de

www.cepp-capital.de

CEPP Invest GmbH

Michael Klein Kurfürstendamm 72, 10709 Berlin, Germany telephone: +49(0)30-8639028-258 fax: +49(0)30-8639028-10 michael.klein@cepp-invest.de www.cepp-invest.de

Corporate Energies GmbH & Co. KG

Stefan Simon

Düsseldorfer Str. 31 A, 10707 Berlin, Germany telephone: +49(0)30-8639028-19 fax: +49(0)30-8639028-10

info@corporate-energies.com www.corporate-energies.com

w.corporate-energies.com p. 84

CUBE Engineering GmbH

Breitscheidstr. 6, 34119 Kassel, Germany

telephone: +49(0)561-288573-10 fax: +49(0)561-288573-19 info@cube-engineering.com

www.cube-engineering.com p. 92

D.I.E. - Erneuerbare Energien

Ingo Ewald

Stefan Chun

Zuckerberg 16, 55276 Oppenheim, Germany telephone: +49(0)6133-57808-20

fax: +49(0)6133-57808-29

info@die-ee.de www.die-ee.de

DIVE Turbinen GmbH & Co. KG

Christian Winkler

Am Grundlosen Brunnen 2, 63916 Amorbach, Germany

telephone: +49(0)9373-9749-39

fax: +49(0)9373-9749-49 info@dive-turbine.de

www.dive-turbine.de

e:craft:systems GmbH

Alexander Pohle

Bergstr. 12, 4626 Nöbdenitz OT Lohma, Germany

telephone: +49(0)34496-6099-8 fax: +49(0)34496-6099-9 info@ecraft-systems.de www.ecraft-systems.de

Energy Competence Centre GmbH

Nicolas Barnier

Kurfürstendamm 72, 10709 Berlin, Germany

telephone: +49(0)30-86390281-6 fax: +49(0)30-86390281-0

nicolas.barnier@ecc-renewables.com

www.ecc-renewables.com

EnviTec Biogas AG

Katrin Selzer

Boschstr. 2, 48369 Saerbeck, Germany telephone: +49(0)2574-8888-0 fax: +49(0)2574-8888-800

k.selzer@envitec-biogas.de www.envitec-biogas.com

EuroSkyPark GmbH

Bianca Gisin Heinrich-Barth-Str. 30, 66115 Saarbrücken, Germany

telephone: +49(0)681-976172-0 bianca.gisin@euroskypark.com

www.euroskypark.com

Fichtner GmbH & Co. KG

Claudia Zipfel

Sarweystr. 3, 70191 Stuttgart, Germany telephone: +49(0)711-8995-238 Claudia.Zipfel@fichtner.de

www.fichtner.de

FRANK GmbH

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Michael Große-Bley

Starkenburgstr. 1, 64546 Mörfelden-Walldorf, Germany

telephone: +49(0)6105-4085-0 fax: +49(0)6105-4085-260 info@frank-gmbh.de

www.frank-gmbh.de p. 95

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Fraunhofer Institute for **Solar Energy Systems ISE**

Karin Schneider

Heidenhofstr. 2, 79110 Freiburg, Germany telephone: +49(0)761-4588-5150

info@ise.fraunhofer.de www.ise.fraunhofer.de

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GEO-NET Umweltconsulting GmbH

Thorsten Frey

Große Pfahlstr. 5a, 30161 Hannover, Germany

telephone: +49(0)511-3887-200 fax: +49(0)511-3887-201

info@geo-net.de www.geo-net.de

GFC AntriebsSysteme

Peter Heise

Grenzstr. 5, 01640 Coswig, Germany telephone: +49(0)3523-94-60 fax: +49(0)3523-74-142 info@gfc-drives.com www.gfc-drives.com

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GICON - Grossmann Ingenieur Consult GmbH

Dr. Hagen Hilse

Tiergartenstr. 48, 01219 Dresden, Germany

telephone: +49(0)351-47878-738

fax: +49(0)351-47878-78 j.schellmann@gicon.de www.gicon-engineering.com

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Green Energy World GmbH

Denis Kühn

Kurfürstendamm 72, 10709 Berlin, Germany

telephone: +49(0)30-443196-50

■ Hydropower ■ Photovoltaics

fax: +49(0)30-443196-51

info@g-e-w.net www.g-e-w.net

Heinz-Dieter Jäckel GmbH

Heinz-Dieter Jäckel

Postfach 42 40 33, 12082 Berlin, Germany

telephone: +49(0)30-767665-41 fax: +49(0)3221-11752-47 jaeckel-engineering-berlin@arcor.de

www.reegas.de

IBC SOLAR AG

Am Hochgericht 10, 96231 Bad Staffelstein, Germany

telephone: +49(0)9573-922475-0

info@ibc-solar.de www.ibc-solar.com

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ingfeld GmbH

Aleksandra Sparacino

Monumentenstr. 33-34, 10829 Berlin, Germany

telephone: +49(0)30-983307-92

info@ingfeld.com www.ingfeld.com

Intersolar Europe 2015

Solar Promotion GmbH

Horst Dufner

Kiehnlestr. 16, 75172 Pforzheim, Germany

telephone: +49(0)7231-58598-0 fax: +49(0)7231-58598-28

info@intersolar.de www.intersolar.de

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KBB Kollektorbau

Anja Schmidt

Bruno-Bürgel-Weg 142 – 144, 12439 Berlin, Germany

telephone: +49(0)30-6781789-12 fax: +49(0)30-6781789-55 a.schmidt@kbb-solar.com

www.kbb-solar.com

KOSTAL Solar Electric GmbH

Sales-Team

Hanferstr. 6, 79108 Freiburg im Breisgau, Germany

telephone: +49(0)761-47744-100 fax: +49(0)761-47744-111

sales-solar@kostal.com www.kostal-solar-electric.com

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■ Wind energy ■ Geothermal energy ■ Solar thermal energy

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■ Solar thermal power plants ■ Solid biomass ■ Other industry sectors

Lahmeyer International GmbH

Bernhard Menzel

Friedberger Str. 173, 61118 Bad Vilbel, Germany

telephone: +49(0)6101-55-0 fax: +49(0)6101-55-2222 info@de.lahmeyer.com www.lahmeyer.de

Lambion Energy Solutions GmbH

Ralf Baues

Auf der Walme 1, 34454 Bad Arolsen, Germany

telephone: +49(0)5691-807-0 fax: +49(0)5691-807-138 office@lambion.de www.lambion.de

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Nolting Holzfeuerungstechnik GmbH

Joachim Eggers, Sascha Bartsch

Aquafinstr. 15, 32760 Detmold, Germany

telephone: +49(0)5231-9555-0 fax: +49(0)5231-9555-55 info@nolting-online.de www.nolting-online.de

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OneShore Energy GmbH

Philipp Neff

Metzer Str. 13, 10405 Berlin, Germany telephone: +49(0)30-208981-720

info@oneshore.com www.oneshore.com

Ossberger GmbH + Co

Holger Franke

Otto-Rieder-Str. 7, 91781 Weißenburg in Bayern, Germany telephone: +49(0)9141-977-0

info@ossberger.de

www.ossberger.de p. 106

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

Steven Scott

Im Teelbruch 118, 45219 Essen, Germany

telephone: +44(0)191-402-9688

steven.scott@parker.com

www.parker.com/hzd p. 107

Planungsbüro SolarForm

Christian Ladwig

Sackmannstr. 1, 30453 Hannover, Germany

telephone: +49(0)511-210575-8 fax: +49(0)511-210575-3

info@solarform.de www.solarform.de

protarget AG

Martin Scheuerer

Zeissstr. 5, 50859 Köln, Germany telephone: +49(0)2234-9491-562 info@protarget-ag.com

www.protarget-ag.com

PSE Engineering GmbH

Bernd Schmidt

Ahrensburger Str. 1, 30659 Hannover, Germany

telephone: +49(0)511-261420-98 fax: +49(0)511-261420-11

bernd.schmidt@pse-eng.de

www.pse-eng.de p. 108

PV-Projects Agency – Projects for Sustainable Development – Global Marketing of PV

Matthias Raab

Fontanestr. 32, 12049 Berlin, Germany telephone: +49(0)162-8002010

raab@pv-pa.com www.pv-pa.com

REFU Elektronik GmbH | REFUenergy

Dr. Armin Keinath

Marktstr. 185, 72793 Pfullingen, Germany

telephone: +49(0)157-35764003

info@refu-energy.de www.refu-energy.de

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Renergiepartner Group

Ines Schuldt

Volmerstr. 9, 12489 Berlin, Germany telephone: +49(0)30-678904-25 fax: +49(0)30-678904-26 schuldt@deig-energie.de www.deig-energie.de

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Renewables Academy AG (RENAC)

Manolita Wiehl Dieter Werner Schönhauser Allee 10 – 11, 10119 Berlin, Germany Glogauer Str. 21, 10999 Berlin, Germany telephone: +49(0)30-3198554-10 telephone: +49(0)30-526895-871 fax: +49(0)30-526895-899 fax: +49(0)30-3198554-99 wiehl@renac.de werner@solarc.de www.renac.de www.solarc.de p. 112 p. 117 **RuSiTec GmbH STELA Laxhuber GmbH** Dr. Michael Strecker Thomas Laxhuber Riedemannstr. 3, 27572 Bremerhaven, Germany Öttingerstr. 2, 84323 Massing, Germany telephone: +49(0)471-984064-00 telephone: +49(0)8724-899-0 info@rusitec-biogas.de fax: +49(0)8724-899-80 www.rusitec-biogas.de sales@stela.de www.stela.de p. 118 schlaich bergermann und partner, sbp sonne gmbh s-power Entwicklungs- & Vertriebs GmbH Sarah Arbes Nina Maass Industriestr. 24–27, 49716 Meppen, Germany Schwabstr. 43, 70197 Stuttgart, Germany telephone: +49(0)711-648719-10 telephone: +49(0)5931-88388-15 solarinfo@sbp.de fax: +49(0)5931-88388-99 www.sbp.de info@s-power.de p. 113 www.s-power.de Schmack Biogas GmbH Michael Groth SunEnergy Europe GmbH Bayernwerk 8, 92421 Schwandorf, Germany Eike Dehning telephone: +49(0)9431-751-0 Fuhlentwiete 10, 20355 Hamburg, Germany fax: +49(0)9431-751-204 telephone: +49(0)40-520143-287 info@schmack-biogas.com fax: +49(0)40-520143-200 www.schmack-biogas.com p. 114 eike.dehning@sunenergy.eu www.sunenergy.eu p. 102 **SMA Solar Technology AG** Tembra GmbH - Wind Turbine Development Ulrich Trabler Jochen Manz Sonnenallee 1, 34266 Niestetal, Germany telephone: +49(0)561-9522-0 Warschauer Str. 38, 10243 Berlin, Germany info@SMA.de telephone: +49(0)30-2000339-20 www.sma.de fax: +49(0)30-2000339-99 p. 116 im@tembra.com www.tembra.com

Biogas

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■ Storage and grid technology

SOLARC Innovative Solarprodukte GmbH

■ Wind energy ■ Geothermal energy ■ Solar thermal energy

■ Hydropower ■ Photovoltaics

Torres & Cie.

Consulting International

Jose Luis Alberto Torres-Jaime

An den Mühlen 25, 48151 Münster, Germany

telephone: +49(0)251-141073-2 contact@torres-consulting.de www.torres-consulting.de

Valentin Software GmbH

Denise Dawes

Stralauer Platz 34, 10243 Berlin, Germany

telephone: +49(0)30-588439-0

fax: +49(0)30-588439-11 info@valentin-software.com

www.valentin-software.com

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Vertrieb von innovativen Energiesparsystemen

Jens Meinhold

Teichweg 7, 01723 Kesselsdorf, Germany

telephone: +49(0)173-1909134 fax: +49(0)35204-6046-2 info@auto-mit-wasserstoff.de www.auto-mit-wasserstoff.de

Viessmann

Jörg Schmidt

Viessmannstr. 1, 35107 Allendorf (Eder), Germany

telephone: +49(0)6452-70-1569

SmdJ@viessmann.com

www.viessmann.com

Voith Hydro Holding GmbH & Co. KG

Ute Boehringer-Mai

Alexanderstr. 11, 89522 Heidenheim, Germany

telephone: +49(0)7321-37-0 info.voithhydro@voith.com

www.voith.com p. 122

WELTEC BIOPOWER GmbH

Hajo Schierhold

Zum Langenberg 2, 49377 Vechta, Germany

telephone: +49(0)4441-99978-0

fax: +49(0)4441-99978-8

info@weltec-biopower.de www.weltec-biopower.de

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Wolf GmbH

Josef Köglmeier

Industriestr. 1, 84048 Mainburg, Germany

telephone: +49(0)8751-74-0 fax: +49(0)8751-74-1600 info@wolf-heiztechnik.de www.wolf-heiztechnik.de

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WSB Neue Energien Holding GmbH

Katja Popp

Schweizer Str. 3a, 01069 Dresden, Germany

telephone: +49(0)351-2118-30

k.popp@wsb.de www.wsb.de



Institutions and associations

Renewable energy

Bundesverband Erneuerbare Energie e.V. (BEE), (German Renewable Energy Federation, BEE)

Invalidenstraße 91, 10115 Berlin, Germany telephone: +49(0)30-2758170-0 fax: +49(0)30-2758170-20

www.bee-ev.de

Fördergesellschaft Erneuerbare Energien e. V. (FEE) (Association for the Promotion of Renewable Energy, FEE)

Invalidenstr. 91, 10115 Berlin, Germany telephone: +49(0)30-84710697-0 fax: +49(0)30-84710697-9 www.fee-ev.de

Wind energy

Bundesverband WindEnergie e.V. (BWE) (German Wind Energy Association)

Neustädtische Kirchstr. 6, 10117 Berlin, Germany telephone: +49(0)30-212341-210 fax: +49(0)30-212341-410 www.wind-energie.de

Verband Deutscher Maschinen- und Anlagenbau e.V. (VDMA) (German Engineering Federation)

Lyoner Str. 18, 60528 Frankfurt/Main, Germany telephone: +49(0)69-6603-0 fax: +49(0)69-6603-1511 www.vdma.org

Hydropower

Bundesverband Deutscher Wasserkraftwerke e.V. (BDW) (German Hydropower Association)

Invalidenstraße 91, 10115 Berlin, Germany telephone: +49(0)30-27582505 fax: +49(0)30-27879432 www.wasserkraft-deutschland.de

Verband Deutscher Maschinen- und Anlagenbau e.V. (VDMA) (German Engineering Federation)

Lyoner Str. 18, 60528 Frankfurt/Main, Germany telephone: +49(0)69-6603-0 fax: +49(0)69-6603-1511 www.vdma.org

Geothermal energy

GtV – Bundesverband Geothermie e.V. (German Geothermal Association)

Albrechtstr. 22, 10117 Berlin, Germany telephone: +49(0)30-20095495-0 fax: +49(0)30-20095495-9 www.geothermie.de

Solar energy

Bundesindustrieverband Deutschland Haus-, Energieund Umwelttechnik e. V. (BDH)

(Federal Industrial Association of Germany House, Energy and Environmental Technology)

Frankfurter Str. 720 – 726, 51145 Cologne (Porz-Eil), Germany

telephone: +49(0)2203-93593-0 fax: +49(0)2203-93593-22 www.bdh-koeln.de

BSW – Bundesverband Solarwirtschaft e.V. (German Solar Industry Association)

Quartier 207, Friedrichstr. 78, 10117 Berlin, Germany telephone: +49(0)30-2977788-0 fax: +49(0)30-2977788-99 www.solarwirtschaft.de

Deutsches Zentrum für Luft- und Raumfahrt e. V. (DLR) (German Aerospace Center)

Linder Höhe, 51147 Cologne, Germany telephone: + 49(0)2203-601-0 fax: +49(0)2203-67310 www.dlr.de

Bioenergy

Bundesverband BioEnergie e.V. (BBE) (German Bioenergy Association)

Godesberger Allee 142 –148, 53175 Bonn, Germany telephone: +49(0)228 -81002-22 fax: +49(0)228 -81002-58 www.bioenergie.de

Bundesverband der deutschen Bioethanolwirtschaft e.V. (BDBe) (German Bioethanol Association)

Reinhardtstr. 16, 10117 Berlin, Germany telephone: +49(0)30-3012953-0 fax: +49(0)30-3012953-10 www.bdbe.de

Centrales Agrar-Rohstoff Marketing- und Energie-Netzwerk e. V. (C.A.R.M.E.N.) (Central Marketing and Development Network)

Schulgasse 18, 94315 Straubing, Germany telephone: +49(0)9421-9603-00 fax: +49(0)9421-9603-33 www.carmen-ev.de

Deutscher Energieholz- und Pellet-Verband e. V. (DEPV) (German Energy Pellet Association)

Neustädtische Kirchstr. 8, 10117 Berlin, Germany telephone: +49(0)30-6881599-66 fax: +49(0)30-6881599-77 www.depv.de

Fachagentur Nachwachsende Rohstoffe e.V. (FNR) (Agency for Renewable Resources)

Hofplatz 1, 18276 Gülzow-Prüzen, Germany telephone: +49(0)3843-6930-0 fax: +49(0)3843-6930-102 www.fnr.de

Fachverband Biogas e.V. (FvB) (German Biogas Association)

Angerbrunnenstr. 12, 85356 Freising, Germany telephone: +49(0)8161-9846-60 fax: +49(0)8161-9846-70 www.biogas.org

Fördergesellschaft für nachhaltige Biogas- und Bioenergienutzung (FnBB) e. V. (German Biogas and Bioenergy Society)

Am Feuersee 8, 74592 Kirchberg / Jagst, Germany telephone: +49(0)7954-921969 fax: +49(0)7954-926-204 www.fnbb.org

IBBK Fachgruppe Biogas GmbH (International Biogas & Bioenergy Center of Competence, IBBK)

Am Feuersee 6, 74592 Kirchberg / Jagst, Germany telephone: +49(0)7954-926-203 fax: +49(0)7954-926-204 www.ibbk.fachgruppe-biogas.de

Union zur Förderung von Oel- und Proteinpflanzen e. V. (UFOP) (Union for the Promotion of Oil and Protein Plants)

Claire-Waldoff-Str. 7, 10117 Berlin, Germany telephone: +49(0)30-31904-202

fax: +49(0)30-31904-485

www.ufop.de

Verband der Deutschen Biokraftstoffindustrie e. V. (VDB) (German Biofuels Industry Association)

Am Weidendamm 1A, 10117 Berlin, Germany telephone: +49(0)30-726259-11 fax: +49(0)30-726259-19 www.biokraftstoffverband.de

Storage and grid technology

Bundesverband Energiespeicher e.V. (BVES) (German Energy Storage Association)

Pariser Platz 4a, 10117 Berlin, Germany telephone: +49 (0)30-300145-711 fax: +49 (0)30-300145-500 www.bves.de

Other institutions and partners

AUMA – Ausstellungs- und Messe-Ausschuss der Deutschen Wirtschaft e.V. (Association of the German Trade Fair Industry)

Littenstr. 9, 10179 Berlin, Germany telephone: +49(0)30-24000-0 fax: +49(0)30-24000-330 www.auma.de

B2B Renewable Energies – Multilingual online business platform for renewable energies

www.renewablesb2b.com

Deutsche Auslandshandelskammern (German Chambers of Commerce)

Directory of German Chambers of Commerce abroad:

www.ahk.de/en

Deutscher Industrie- und Handelskammertag (DIHK) (The German Chambers of Industry and Commerce)

Breite Str. 29, 10178 Berlin, Germany telephone: +49(0)30-203080 fax: +49(0)30-203081000 www.dihk.de

Germany Trade and Invest – Gesellschaft für Außenwirtschaft und Standortmarketing mbH (The economic development agency of the Federal Republic of Germany)

Friedrichstr. 60, 10117 Berlin, Germany telephone: +49(0)30-200099-0 fax: +49(0)30-200099-812 www.gtai.com

iXPOS – The German Business Portal

www.ixpos.de

German authorities and ministries

Auswärtiges Amt (AA) (Federal Foreign Office)

Werderscher Markt 1, 10117 Berlin, Germany telephone: +49(0)3018-17-2000 fax: +49(0)3018-17-3402 www.auswaertiges-amt.de

Bundesministerium für Ernährung und Landwirtschaft (BMEL)

(Federal Ministry of Food and Agriculture)

Wilhelmstr. 54, 10117 Berlin, Germany telephone: +49(0)30-18529-0 fax: +49(0)30-18529-4262 www.bmel.de

Bundesministerium für Umwelt, Naturschutz, Bau und Reaktorsicherheit (BMUB) (Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety)

Stresemannstr. 128 – 130, 10117 Berlin, Germany telephone: +49(0)30-18305-0 fax: +49(0)30-18305-2044 www.bmub.bund.de

Bundesministerium für Wirtschaft und Energie (BMWi) (Federal Ministry for Economic Affairs and Energy)

Scharnhorststr. 34 – 37, 10115 Berlin, Germany telephone: +49(0)30-18615-0 fax: +49(0)30-18615-7010 www.bmwi.de

Bundesministerium für wirtschaftliche Zusammenarbeit und Entwicklung (BMZ) (Federal Ministry for Economic Cooperation and Development)

Stresemannstr. 94, 10963 Berlin, Germany telephone: +49(0)30-18535-0 fax: +49(0)30-18535-2595 www.bmz.de

Umweltbundesamt (UBA) (Federal Environment Agency)

Wörlitzer Platz 1, 06844 Dessau-Roßlau, Germany telephone: +49(0)340-2103-0 fax: +49(0)340-2103-2285 www.uba.de

Cooperation partners

Bundesindustrieverband Deutschland Haus-, Energie- und Umwelttechnik e. V. (BDH) (Federal Industrial Association of Germany House, Energy and Environmental Technology) www.bdh-koeln.de

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

Bundesverband BioEnergie e. V. (BBE) (German Bioenergy Association)

www.bioenergie.de

Information on: Solid biomass

Bundesverband Deutscher Wasserkraftwerke e.V. (BDW) (German Hydropower Association)

www.wasserkraft-deutschland.de

Information on: Hydropower

Bundesverband Energiespeicher e.V. (German Energy Storage Association)

www.bves.de

Information on: Storage and grid technology

Bundesverband Geothermie e. V. (German Geothermal Association)

www.geothermie.de

Information on: Geothermal energy











Bundesverband Solarwirtschaft (BSW-Solar) (German Solar Industry Association)

www.solarwirtschaft.de

Information on: Photovoltaics, Solar thermal energy





Bundesverband WindEnergie e.V. (BWE) (German Wind Energy Association)

www.wind-energie.de

Information on: Wind energy

Deutscher Energieholz- und Pellet-Verband e. V. (DEPV) (German Wood Energy and Wood Pellet Association)

www.depv.de

Information on: Solid biomass

DEPV Deutscher Energieholzund Pellet-Verhand e.V.

Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR) (German Aerospace Center)

www.dlr.de

Information on: Solar thermal power plants



Fachverband Biogas e.V. (German Biogas Association)

www.biogas.org

Information on: Biogas





