Electricity from renewable energy

Electricity from solar cells

Electricity from solar thermal plants

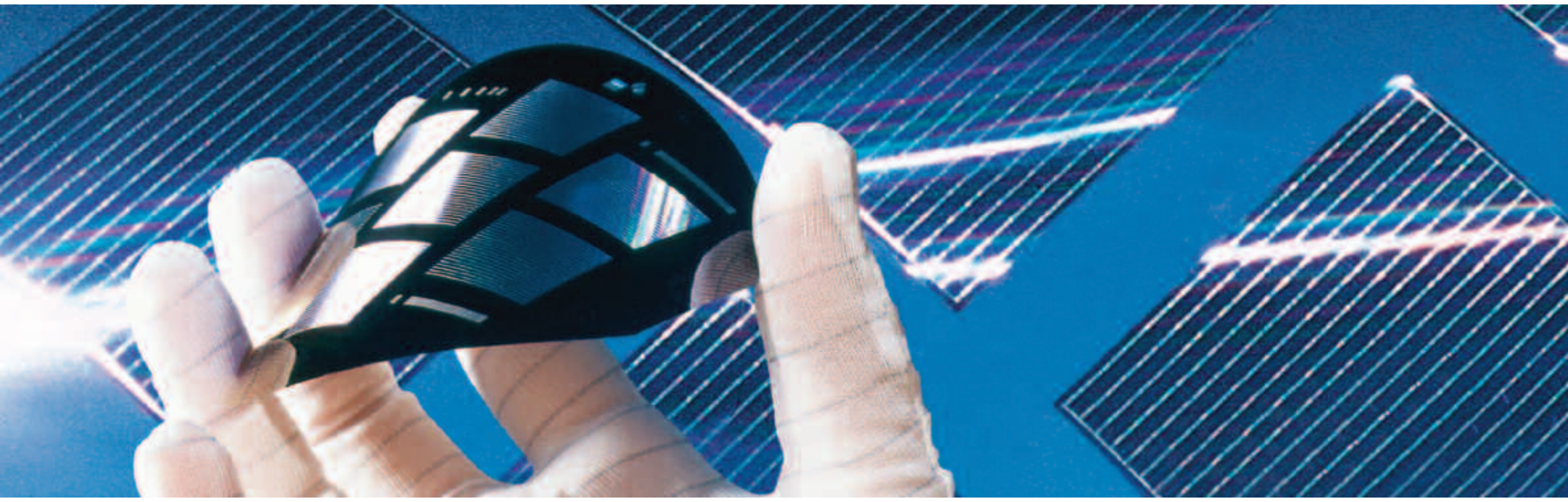
Electricity from wind energy

Electricity from biomass

Electricity from geothermal plants

Electricity from maritime energy sources

Electricity from solar cells



In Central Europe, photovoltaic energy conversion from solar cells has by far the greatest proven technological potential for the production of electricity from renewable energy sources. Yet, its current contribution to the electricity supply is still at levels that are insignificant in terms of the energy industry. Although photovoltaics has had annual global growth rates of over 30% for the past decade or so, it will take several decades before it can make a perceptible contribution to German electricity supplies. In the long run, however, photovoltaics will prove to be one of the most important pillars of a sustainable energy supply system.

Continued committed market development of photovoltaics technology will be essential if it is to become one of the major components of a future energy system. We may assume that photovoltaic electricity, which is still very expensive in comparison with electricity from the grid in industrialised countries, will fall to price levels which, taking into account external costs in the energy system, will make it economically competitive. Solar electric power is already commercially competitive in most standalone applications where it is able to compete with battery-produced electricity or diesel-electric energy transformation, or with the costs of grid expansion respectively. This sector of photovoltaics encompasses a good third of the world market.

The essential condition for a large-scale activation of the potential of photovoltaic electricity production is a further significant cost reduction. This will be supported mainly by research oriented towards the long run, both into the basics of materials and processes and the specific conversion technologies (cells, modules, systems). This can be achieved particularly by increasing efficiency, reducing material usage and developing high-productivity manufacturing technologies.

Like all renewable energy technologies, photovoltaics offers major benefits from the ecological point of view compared to conventional technologies for electricity generation. Using current state-of-the-art system technology, a photovoltaic installation in central Europe will generate the amount of energy used for its production in about three years. There will be further large reductions in this energy payback time in the near future as new technologies are used.

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Research and development requirements

As it is not yet possible to finally assess the various technological approaches in respect to their long-term development prospects, it is necessary to continue to support the wide range of different photovoltaic technologies:

Basic research

Completely new physics approaches are necessary to reduce costs. Some examples are:

- The development of solar concentrator cells with efficiencies of up to 40 %
- The development of new component structures for solar cells
- Solar cells with highly structured absorbers and nanostructures on the surface
- The development of photon management
- Target-oriented semiconductor diagnostics

Silicon wafer solar cells

Up to now, progress in solar cell technology has been achieved almost exclusively by developing the already sophisticated silicon wafer technology which dominates the market. This technology consists of processing monocrystalline or multicrystalline wafers that are 200-300 µm thick. The potential for further cost cutting is, however, far from being exhausted. Above all, this involves developing new technologies aimed at:

- Using thinner and even ultra-thin silicon wafers
- New kinds of cell structures
- Achieving higher efficiency
- Simplified process technologies
- Lower-cost production of solar silicon (solar-grade Si) and thin silicon wafers

Thin-film solar cells

Thin-film technologies are considered to have a high potential for cutting costs:

- CIS (chalkopyrite) and CdTe thin-film solar cells
- Chrystalline silicon thin-film solar cells
- Amorphous silicon
- Nanocrystalline silicon
- Modified production technologies
- Thin-film solar cells based on dyes and organic semiconductors
- Research into materials and processes for thin-film technologies

Organic solar cells

Organic solar cells based on fluid semi-conducting mixtures can be applied to large flexible substrates by means of screen-printing. Despite their relatively short service lives and relatively low efficiencies, these cells could dominate niches on the market for off grid photovoltaics. The following areas are being researched for the further development of organic solar cells:

- Evaluation of new organic semiconductor systems with improved absorption of these solar spectrum and optimized charge transport properties
- Further development of current cell concepts
- Modified production technologies
- Module wiring
- Encapsulation, especially of flexible solar cells
- Light management

Module technology

Photovoltaic cells must be encapsulated to ensure the long-term, safe operation of these energy converters and allow for integration in construction and technical structures. The research and development issues include:

- The development of methods to greatly expand the service life of modules
- The development of new electrical wiring methods in module technology
- The development of module technologies optimally modified for the aesthetics and mechanics of specific applications, such as flexible modules.

Photovoltaic power plants and systems

In the midterm, photovoltaic power plants and systems will probably be available with an output ranging from several 100 kW to several MW to cover a peak loads (such as for the operation of cooling systems). Greater research and development is required for:

- The development of appropriate solar cells, concentrating optics, and mechanical system technologies

PV system technology

The goal is to develop inexpensive photovoltaics inverters that are highly reliable with long service lives that match those of PV panels. At the same time, the wide variety of system configurations that require customized inverters solutions must be taken into consideration.

To this end, cooperation with system analysis is necessary for the evaluation of PV systems and components in order to improve the reliable operation and design of PV systems.

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Lifecycle analysis and recycling

As production capacities grow for solar cells, recycling issues, technical service lives, and energy payback increasingly play an important role and move more into the focus of research and development projects:

- Reduction of material and energy consumption in manufacture
- Reusability of photovoltaic elements and materials
- Calculations of aging and creation of kinetic models for damage to PV panels

Electricity from solar thermal plants

After early successes in the USA at the end of the 1980s, a new market is now developing for solar thermal power stations in Southern Europe, the USA and in some developing sunbelt countries. Three types of solar thermal power stations have evolved here:

- Parabolic trough systems
- Solar tower systems
- Dish Stirling systems

By 2010, experts expect some 400 MW of newly installed power output in Europe and about 2000 MW worldwide. German industrial firms are taking a leading role in these developments. From about 2030, electricity imports from solar thermal power stations in Southern Europe or North African countries using high voltage direct current transmission into the European electricity grid will be able to make an important contribution to the European electrical landscape. Investor consortia are putting a figure of 12 to 15 cents per kWh on the cost of generating electricity in commercial solar thermal power stations which are in the planning stage at present. Going down the learning curve, full competitiveness with medium or base load electricity could be reached at good locations by 2030, with 15 GW being installed worldwide if research and development is continued.

Research and development requirements

One particularly important approach to cost reduction is to increase the exit temperature of the concentrating solar systems in order to achieve better efficiency in the downstream power station. This would enable the same electrical energy to be generated from smaller collector surface. All three solar thermal power station types would also benefit from:

- Automation of plant operation
- Development of cost-effective thermal energy storage
- Reducing the weight of collectors and concentrators

Parabolic trough technology

- Further development of direct solar steam (DISS) technology
- Selective solar absorber layers for high temperatures of around 500°C
- Development of new optical concentrator concepts, e.g. Fresnel reflector systems

Solar tower technology

- Technological development for coupling solar heat to gas turbines to tap the high temperature potential
- Development of cost-effective mirrors and highly reflective mirrors

Dish Stirling technology

- Development of solar/fossil and solar/biomass hybrid system configurations

Solar power plants

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Electricity from wind energy

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There is huge potential for short to mid-term expansion of wind energy use. The German government's aim by 2025/2030 is to cover 15% of total electricity requirements in Germany from offshore wind installations and a further 10% from onshore wind farms.

Research and development requirements

Developing offshore wind energy use currently poses the greatest challenge. The associated research and development activities touch on almost all areas of wind energy utilisation. An increase in R&D activities will also be necessary for the further expansion of wind energy utilisation on land, especially with respect to its prospective application in developing and industrializing countries. New challenges arise when new climates and topographical conditions (highly structured terrain) are entered into. One of the main goals of research and development is further cost reductions through fundamental innovations:

- Further development of system technology: new materials, elasticity and noise reduction, innovative control methods, generators and output electronics, new facility concepts
- Investigations of wind climatology and ambient conditions: wind potential, plant siting in complex terrain, forecasting energy yields, design wind characteristics, wind and wave characteristics for offshore applications
- Optimisation of system integration and plant management: control and management of wind farms, early fault recognition and plant maintenance according to the condition, information and communications systems, grid interaction effects, wind power forecasts
- Monitoring of technological development as well as basic surveys of technical, economic, ecological and legal aspects, and prospects for national and international use of wind energy

Electricity from biomass

Biomass can make an important contribution to the solar energy revolution in the next few decades. The energy potential for Germany is at least 10 % of present-day energy consumption. Solar energy obtained in the form of biomass is convertible into all forms of energy. It can be stored, and it is already being used as a substitute for fossil resources.

There is still a considerable need for research and development in the areas of biomass electricity generation, as well as a large untapped application potential. Used as distributed electricity generation plants in integrated grids, biomass facilities are suitable as background reserve systems that can compensate for the fluctuating capacity available from photovoltaic and wind generators.

Research and development requirements

- Processes for the production of carbon-derived fuels from biomass (in fuel cells, micro turbines, and block heat and power plants)
- Integrated decentralized/communal energy concepts for the large-scale use of biomass (logistics)
- Optimal coproduction of food stock and energy
- Optimization of biogas systems: Measurement systems and sensors for optimal plant management, customized control technology, standardization and modularization of system components
- Interface technologies for various thermodynamic energy converters such as conventional combined heat and power (CHP) plants, micro gas turbines, Stirling engines and fuel cells
- Integration of modern biomass systems into electricity supply structures – also into decentralized energy supplies in developing countries – as well as development of "micro gas networks" fed by biogas

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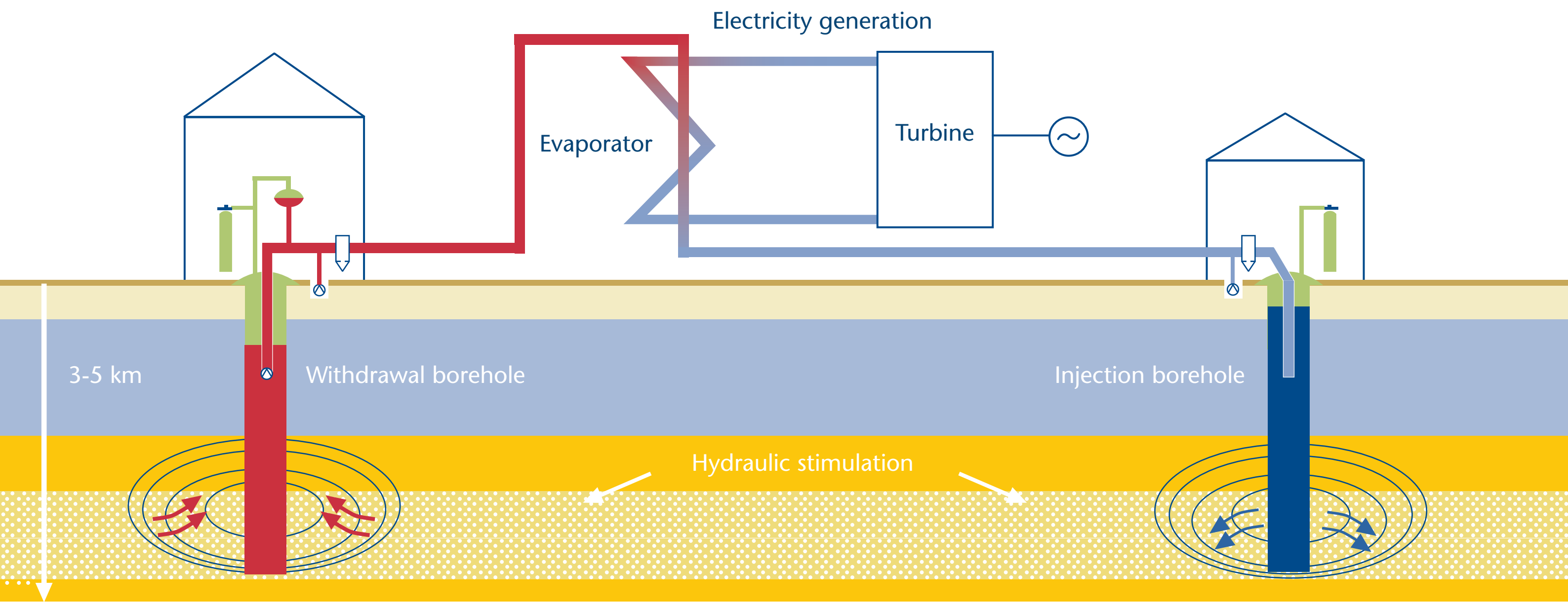
Electricity from geothermal heat



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Geothermal units run 24 hours a day regardless of the weather and the season to provide renewable energy around the clock. Geothermal is thus indispensable for a sustainable future supply of energy because it can cover the base load for electricity.

While Germany has great geothermal resources, they have hardly been tapped. Geothermal technologies therefore have great expansion and innovative potential. If we manage to tap this potential through research and development, geothermal will make up a significant part of renewals by 2010.

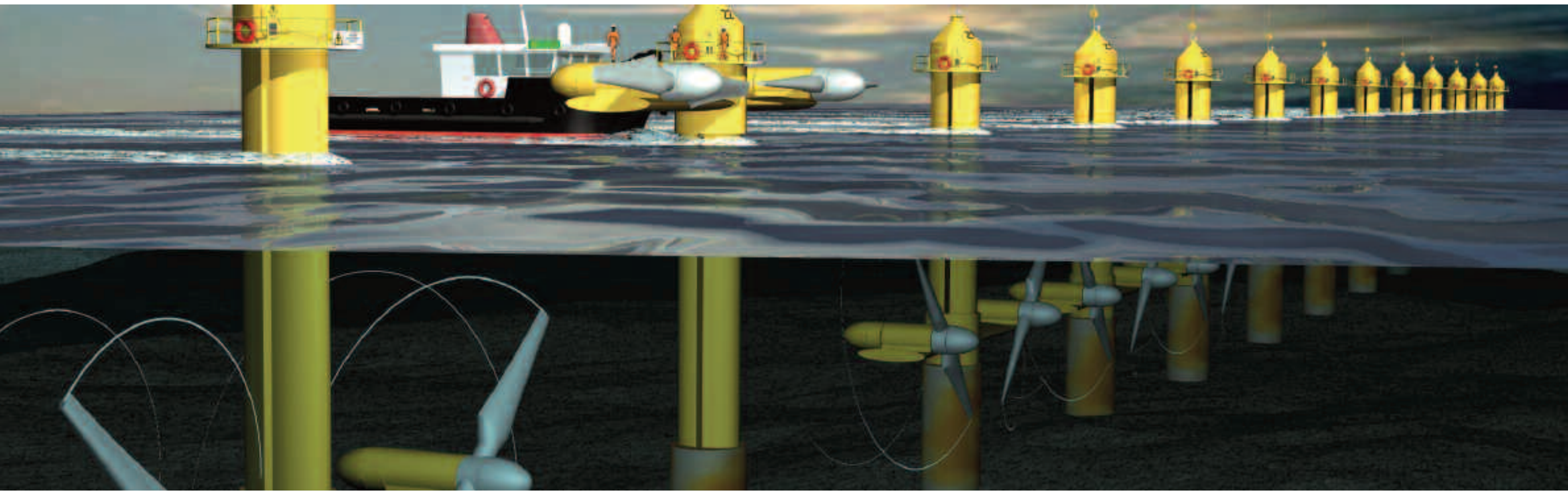
Drilling down some 3-4 km to where temperatures are high enough for electricity generation is an expensive affair. Research and development can incrementally lower current financial risks. After all, for geothermal to be a common application, such drilling has to become less expensive, the effectiveness of underground fissures more reliable, and projects more economic overall. Geothermal technology projects must be able to reliably implement planning regardless of the location. To this end, hydraulic experiments and drilling measurements are currently being conducted under process conditions at the 4.3 km deep research borehole at Gross Schönebeck.

Germany's geological substrate is typical of Central Europe. Technological developments that are successful year therefore represent export items that can be used in numerous similar locations.

Research and development requirements

- Development of new exploration methods, e.g. geophysical methods of improving the accuracy of required deep drillings
- Development of stimulation methods to increase the economic yield of geothermal boreholes
- Greater efficiency of energy conversion of low-temperature heat for electricity and cooling
- Better integration of geothermal in (current) energy systems
- Mapping of technical feasibility of multiple systems in areas with normal geothermal conditions (medium depths between 3000 and 4000 m)
- Ensuring sufficient, long-term thermal water circulation and optimal conversion technologies above ground

Electricity from maritime energy sources



Maritime energy sources are primarily tidal and wave energy systems. In addition, there are ways of exploiting temperature differences and the different salt concentrations of freshwater and seawater.
The German coast has relatively little potential for maritime energy sources. The technology for the utilisation of these energy sources nonetheless has considerable long-term significance for Germany in view of the possibilities of energy imports in the form of electricity and synthetic fuels and the export opportunities for German plant technology.

The ebb and flow of the **tides** allows conventional water turbines to generate electricity. At present, an installed generating capacity of 260 MW exists worldwide.

Wave energy is based on the interaction between the surface of the sea and the wind. Currently around 2 MW are installed in demonstration plants in offshore locations. The potential for wave energy in Europe is estimated at over 200 TWh/a, 1 % of which is on German coasts.

Sea currents in coastal areas are caused primarily by the tide. Where the topological conditions are right, the water flow speed can be fast enough for commercial energy use. The global technical potential is estimated at around 1500 TWh/a, almost 10 % of which is in Europe. Since 2003, the first test systems with an output of 100 to 300 kW have been an operation in Italy, Great Britain, and Norway with the participation of German researchers and industry. Furthermore, megawatt systems are also being developed.

Generally speaking, technologies for maritime energy sources are still in their infancy. The aim is to make the economically efficient utilisation of these potentials a reality. To achieve this, large installed capacities are necessary in all offshore technologies.

Research activities in this field are taking place in close cooperation with countries whose coastal and sea areas have a high potential for maritime energy, such as Great Britain.

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