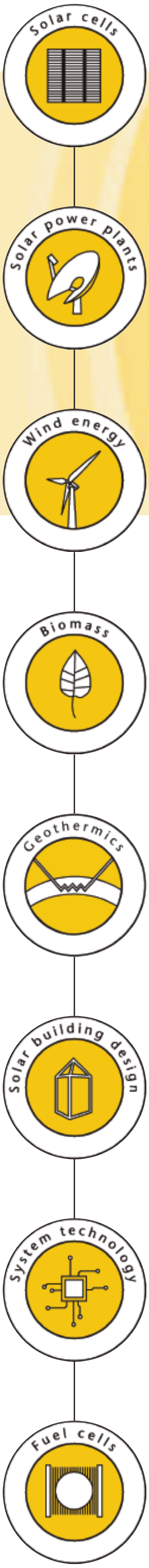
Research Objectives



Joint Research for the Energy of the Future

FVS ForschungsVerbund Sonnenenergie
Renewable Energy Research Association

ForschungsVerbund Sonnenenergie
Renewable Energy Research Association, Germany

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Research Objectives

The Sun – energy for the 21st century

The FVS • ForschungsVerbund Sonnenergie (Renewable Energy Research Association) is working for a sustainable energy supply designed to meet the requirements of modern society. Renewable energy sources provide an essential starting point; after all, the sun, wind, water and geothermal heat are inexhaustible measured on a human scale and can be harvested with efficient, innovative technologies. At the same time, energy efficiency needs to be stepped up so that overall consumption can be reduced.

Sustainable energy supply

The Renewable Energy Research Association's strategic aim is for renewables to become a central pillar of sustainable energy supply, targeting:

- **Ecological viability**

In setting their energy and environmental objectives, the German government and the EU are guided by the international target of an 80% cut in carbon dioxide emissions (based on 1990 levels) in industrialised countries by the middle of the century.
Renewables can make a significant contribution to this end and help to reduce manmade climate change.

- **Reliable resources**

The foreseeable resource depletion of fossil energy sources means that renewables will soon be needed as substitutes for coal, oil and gas. Geostrategic developments are also a compelling reason for the speedy and vigorous expansion of renewables.

- **Social justice**

Renewables are a clean and safe source of energy that is available to everyone and will become increasingly affordable in the future. In developing and emergent countries in particular, the use of renewable energy sources can be combined with the creation of regional jobs and the raising of living standards through local wealth creation and distributed economic structures. Renewables offer a wide range of possibilities for overcoming economic underdevelopment in many parts of the world, as they are freely available, infinite sources of energy.

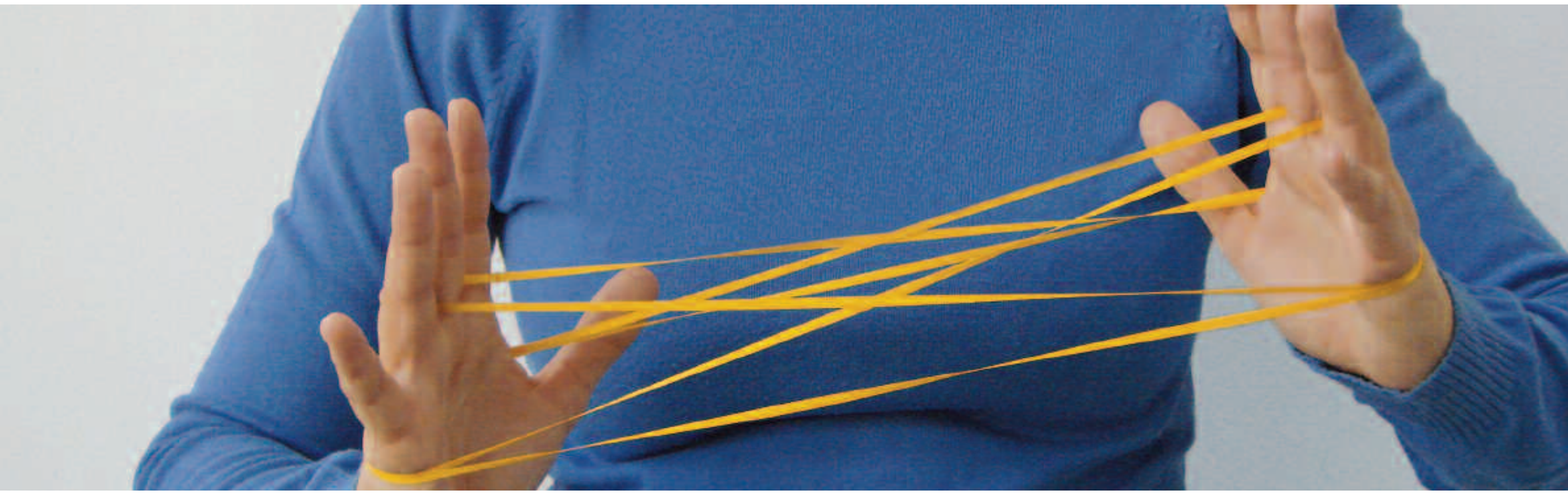
- **Economic effectiveness**

At their full cost-cutting potential, renewables guarantee an economic energy supply at a stable price. Utilisation of renewable sources is increasingly driven by the prospect of positive economic effects. Production of technical components and systems for utilising renewable energy sources will become an essential element of global economic activity.

Priority for renewables

The long-term goal of the German government is to get some 50 percent of its energy supply from renewables by 2050. The European Union recommends that its member states get some 20% of their electricity from renewable sources by 2010. This is to be achieved by introducing strategic economic policy measures and by commitment to market introduction programmes. The basic condition for the accelerated development of renewable energy technologies, however, is still efficient research and technology development. Such a process will extend over decades, mainly driven by the feedback from market application experience to further R&D.

Joint research



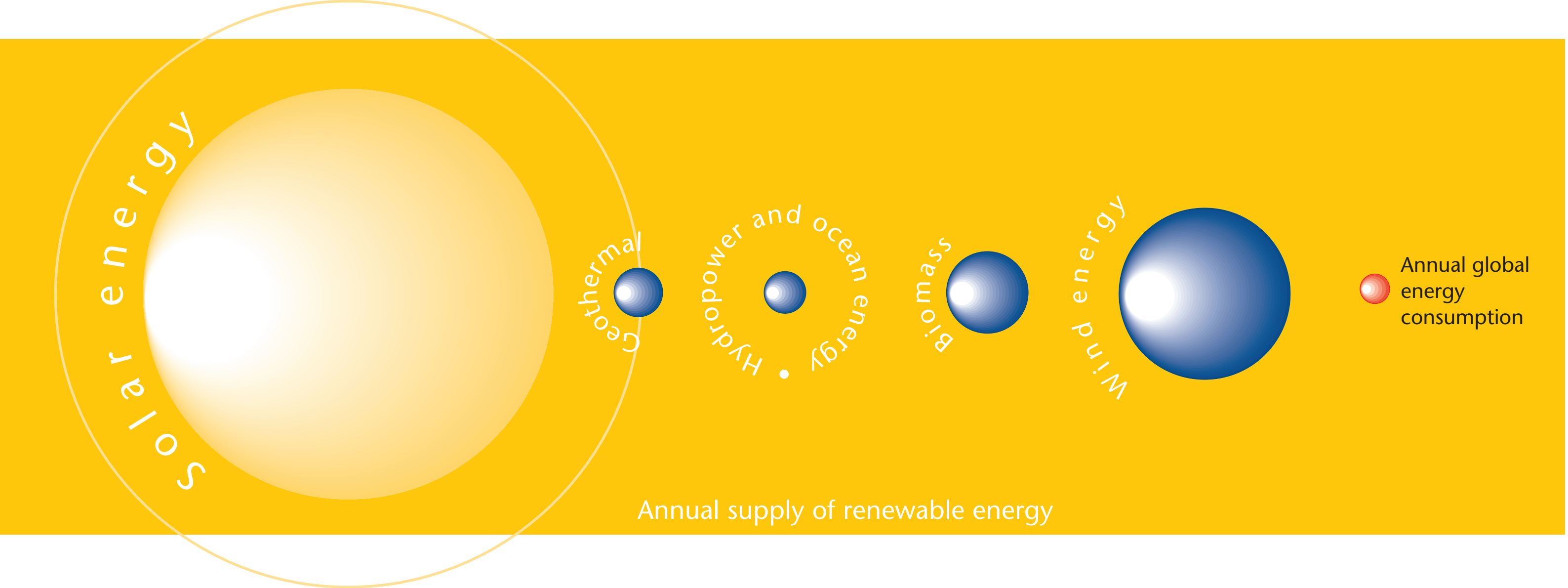
The Renewable Energy Research Association's goal is to develop a sustainable energy supply. Intensive cooperative research and development is required for new technologies to become economically competitive and for various energy sources to be integrated.

Towards this end, the Renewable Energy Research Association has created a decentralized cooperation structure in Germany that has been expanded into an efficient research network by the following means:

- Distribution of tasks for efficient research
- Facilitated cooperation to produce synergies
- Support for competition to promote creativity
- Cooperation in networks to allow institutions outside of the Association to make productive contributions.

Today, the approximately 1500 members of member institutes constitute the largest network of experts in the field of renewables in Europe. The FVS also works with **industry** on research. The FVS is also a partner of **policy-makers** for the implementation of a sustainable energy supply. Finally, the FVS organizes conferences and workshops for the **public** on research issues into solar and renewables, where it discusses future opportunities and perspectives.

Research and development policy aims of FVS



Potential:
The annual supply of renewable energy is 20,000 times greater than global energy consumption.

Renewables are key technologies

Renewable and solar energy technologies have been declared key technologies with respect to research policy:

- Renewables are used on a large scale.
- In an evolutionary process renewables will change the energy generation, as well as the tasks of energy supply companies, the supply structures, the economic and financial relationship between energy producers and consumers.
- Decentralized energy generation will change the structure and number of stakeholders in the energy sector, and the technologies used everywhere from the construction industry to transport engineering.

Leaders now and in the future

Germany has a leadership role in research and development for renewables and related system technology. Short innovation cycles are a sure sign of rapid transfer of technology into the market and confirm that research and development is efficient and application-oriented. Although many technologies have been successfully deployed and are beginning to find wide application, research and development continue to be necessary in order to mobilise the full potential of these technologies, which are basically still in their early development stages. Experience from other technological fields shows that the linking of science and research to industrial innovations is not a one-way street, but rather an interactive system with many feedback loops.

Taking account of technological diversity in development

Every renewable source of energy with substantial potential for expansion will have to make its contribution relative to regional potential if the German government and the EU are to reach their energy policy goals. The great variety of applications for renewables is an advantage towards this end.

Flexibly connecting excellent basic research with technology development

Excellent applied basic research on the use of renewable energy sources is and will remain a prerequisite for the development of constantly improved conversion technologies and increasingly inexpensive sustainable energy supply systems. Both applied basic research and the development of technologies for market release need to be equally promoted because so many energy conversion paths are promising. At the same time, the path between scientific research and industrial innovation is not a one-way street, but rather an interactive system with many feedback loops in which application problems can become new challenges for basic research. Market dynamics and short innovation cycles require that all activities be conducted flexibly alongside each other.

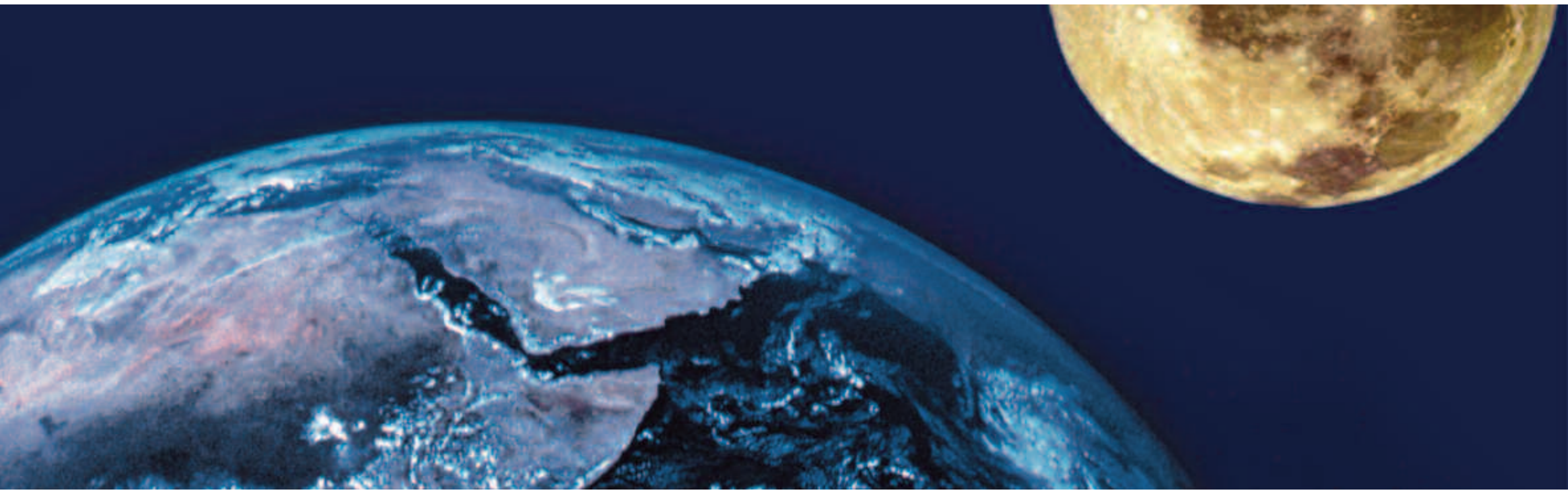
Developing system optimisation

As current energy supply structures in Germany undergo further evolution, consideration of the growing use of renewables becomes necessary. This applies especially to the structure of the electricity grid, which will have to accommodate both greater distributed energy generation and expanded grids, sometimes extending over greater distances. The use of wind energy is a present illustration of this. By 2020, around 60 % of the German power station capacity will have to be replaced, creating the opportunity for far-reaching changes in the type of energy supply.

Replacements that will be necessary within the next twenty years in the fleet of German power stations will therefore provide the leeway required for far-reaching changes in the type of energy supply. Changes in the power station structure brought about by the need to construct new plants must be made part of the equation for optimising the technology used in the whole system. There is a partial shift in electricity supply towards the site of its use, brought about by the considerable expansion of combined heat and power generation and the increase in power generation from renewables. In future, intelligent control systems must coordinate these distributed electricity generation facilities efficiently. It will become increasingly necessary and appropriate to match energy generation to its consumption by using a sophisticated grid-wide demand management system. In the heat supply sector, structural changes in system technology – to much higher degree than has so far been the case – will be necessary to achieve an optimal integration of renewables. This will involve, in particular, local heat supply systems and modern efficiency technologies, such as innovative, decentralized combined heat and power generation technologies and new building energy supply technologies adapted to the use of renewables and to lower energy needs.

Promoting the rational use of energy

To achieve overall optimisation of the energy supply system, greatly improved efficiency in energy utilization is necessary in parallel to the deployment of renewables. An essential precondition for the creation of a sustainable energy supply will be a considerable annual increase in energy productivity to protect the environment and conserve natural resources. Hence specific research and development efforts in efficiency technologies are an additional focus of the FVS research programme.



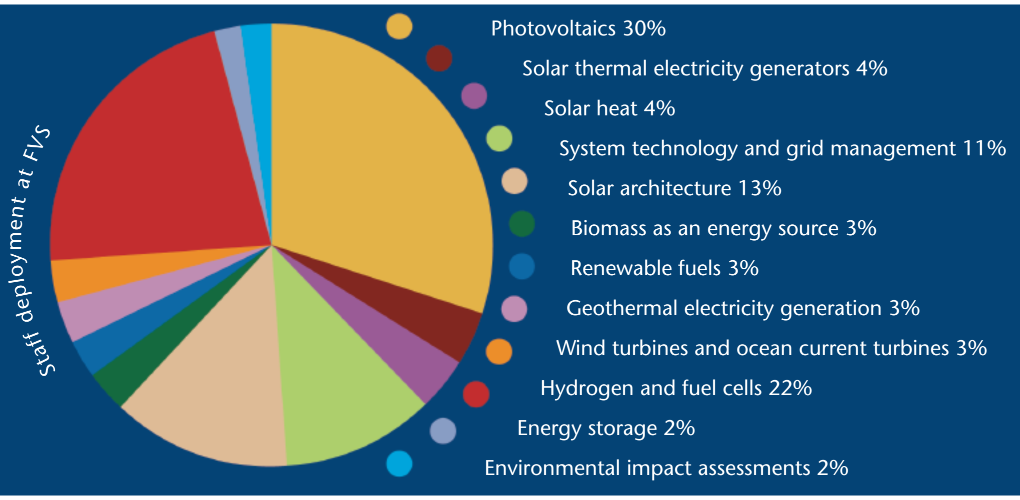
Integrating renewables into society

Integrating renewables into the energy supply means that ecological, sociological and economic issues will have to play their part even in the early stages of research and development. If sustainability is at issue, research will have to address non-technical issues as well. Interdisciplinary and cross-disciplinary research will play a vital role, especially in system analyses and in the evaluation of technologies. Market introduction programmes and targeted subsidy instruments must be accompanied by research into social acceptance, environmental impacts and the integration effects of renewables into our entire economic system.

Taking global perspectives into account

The global character of environmental problems and the global contribution potential of renewables to their solution necessitate an international approach. For applications in southern climates and eastern Europe, research and technological developments are increasingly playing a more important role. Here it will be necessary to include the very wide range of user requirements into the promotional concepts, such as providing energy supply to neglected rural areas, meeting energy requirements of urban centers and providing drinking water. The use of renewables will have to be closely linked to energy conservation.

Research and development fields



Overview of the research issues at FVS and the staff capacities currently devoted to them.

Energy supply is the provision of useful energy as electricity, heat, and solid or liquid fuels. The various types of solar energy, geothermal heat, and ocean energy are available as primary energy sources for a sustainable energy supply.

Solar energy can be converted into useful secondary energy with technologies used today.

- Photovoltaics
- Solar heat
- Solar thermal electricity generation
- Wind turbines
- Hydropower
- Biomass
- Solar chemical processes

Geothermal heat is converted into

- Electricity
- Heat

Ocean energy is converted into electricity by means of

- tidal power plants
- ocean current turbines
- wave energy

These energy technologies complement each other in terms of quality and time distribution in a mixture of thermal and electric energy sources: in the midterm, in an optimized combination with conventional energy technologies; in the long term, largely on their own.

The issues covered by FVS include all solar and renewable energy, including a large variety of individual scientific issues.

Electricity from renewable energy

Electricity from solar cells

Electricity from solar thermal plants

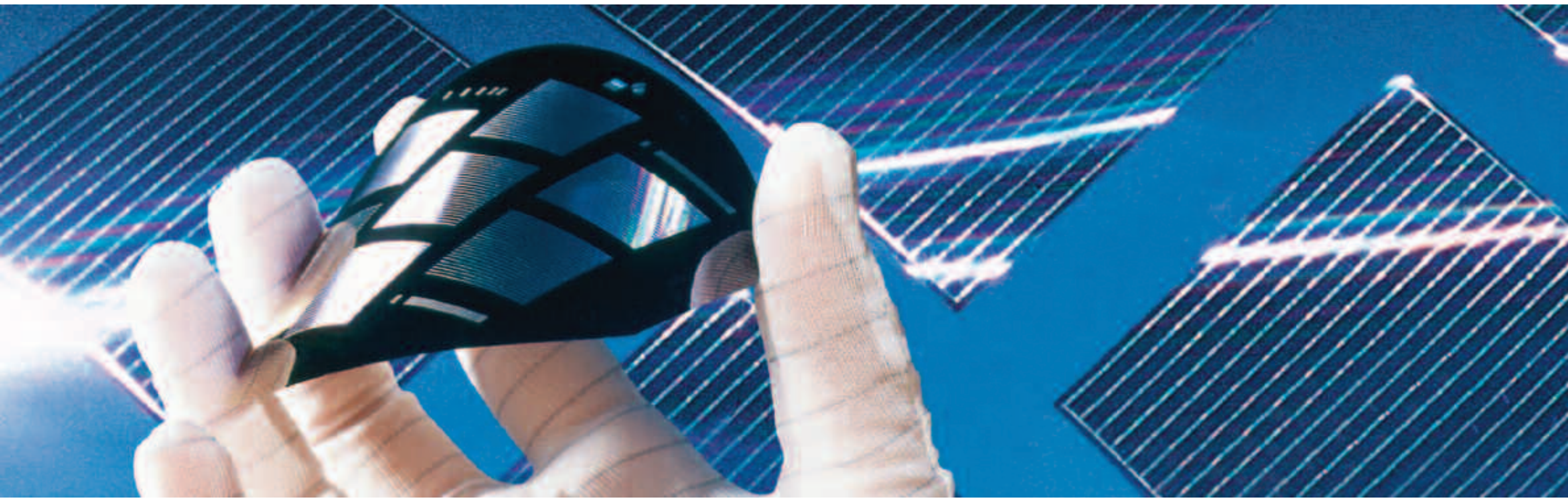
Electricity from wind energy

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

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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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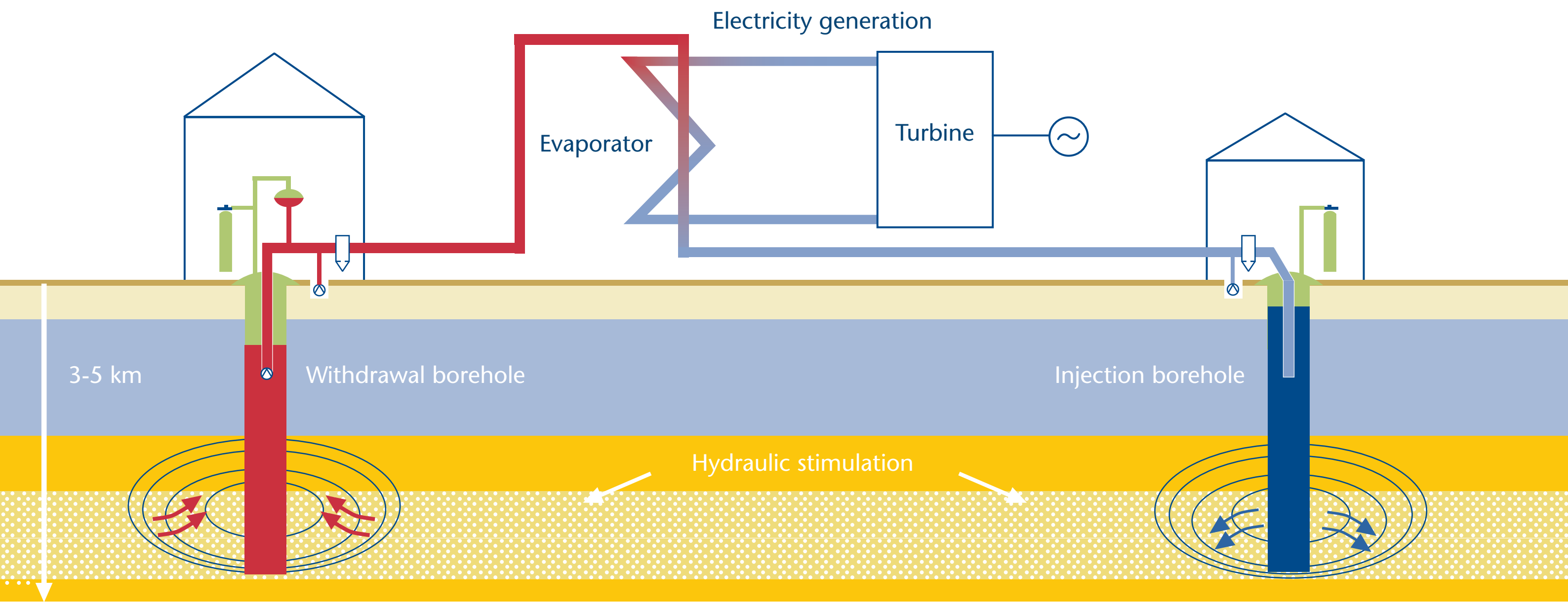
Electricity from geothermal heat



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

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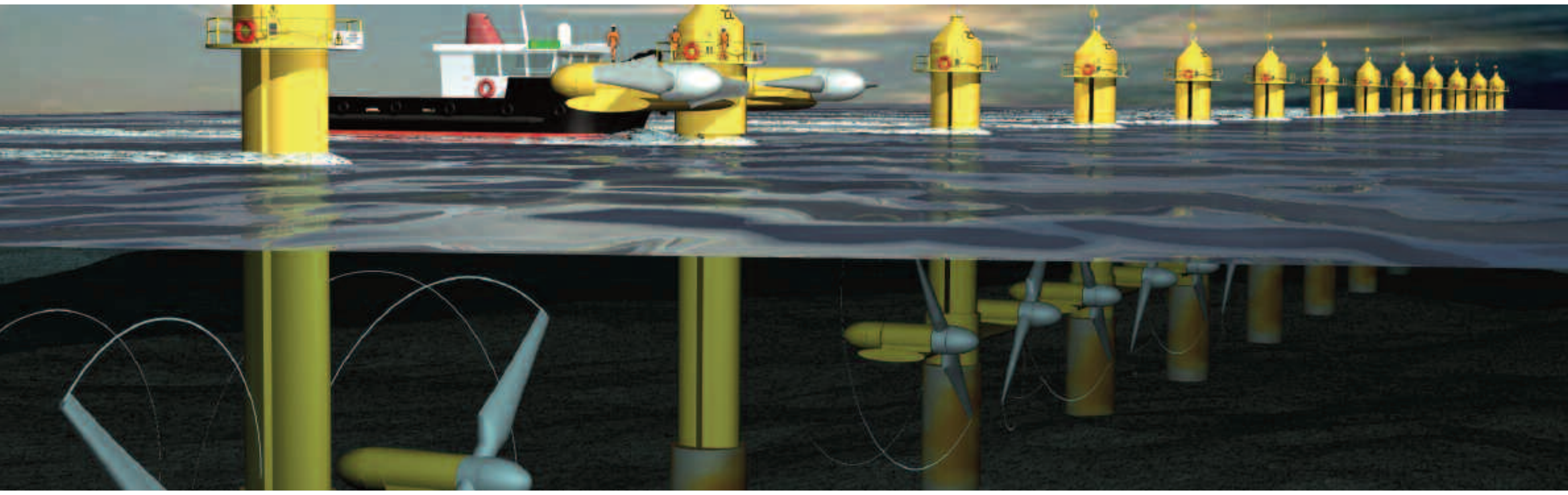
Electricity from maritime energy sources



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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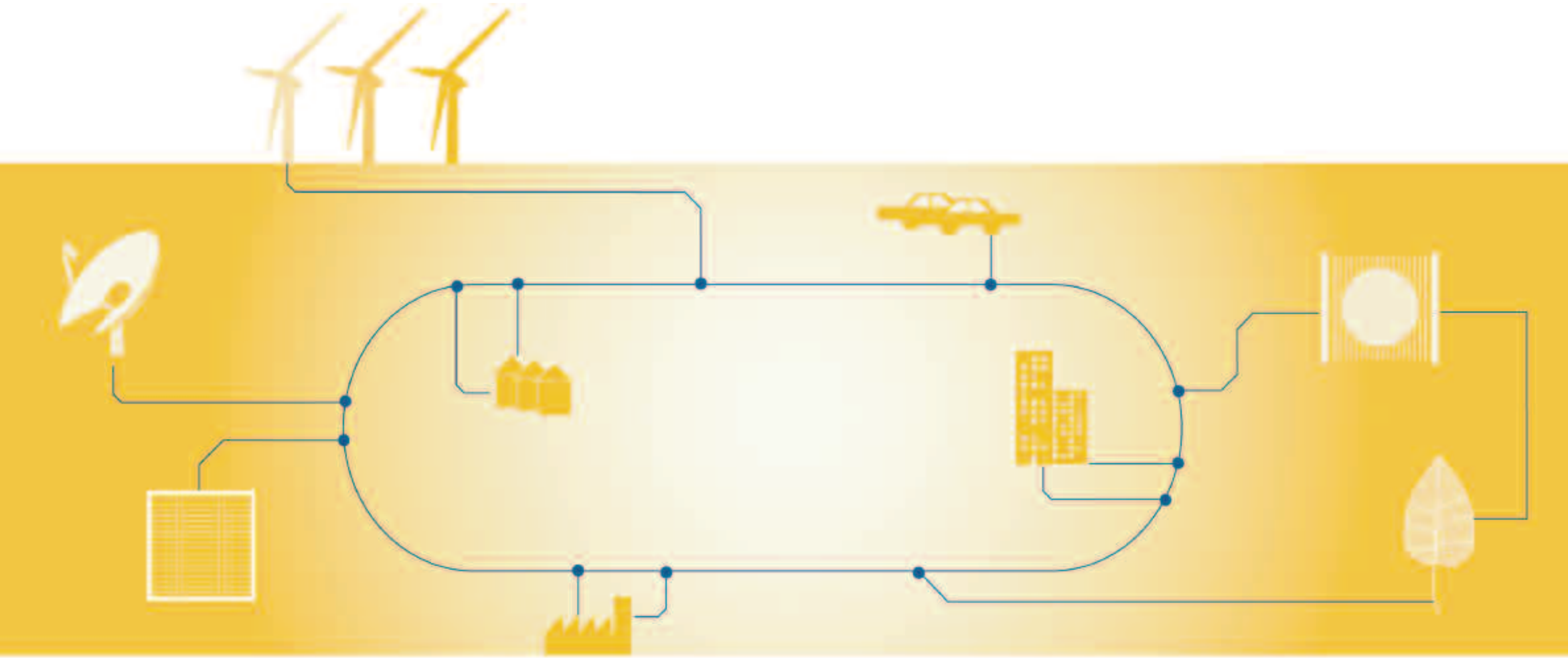
Electrical system technology, grid management and distributed power stations



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The liberalisation of the energy market and the European target of increasing the share of renewables in electricity production to 22% by 2010 demand considerable restructuring within the European integrated grid system. The evolution of the electricity supply from large, centralised power stations to a system consisting both of centralised and distributed electricity suppliers also places new demands on equipment technology and electrical engineering.

The greater the proportion of distributed "micro power stations", the more deeply they must be integrated into the grid control system. The management units and the communications concepts which need to be developed for this will be essential in realising the concept of "distributed electricity generation".

Autonomous electricity supplies based on photovoltaics, wind power, solar thermal electricity generation, hydropower or hybrid systems are key to the development of regions with underdeveloped infrastructure throughout the world, as well as to supplying off-grid systems in Europe. They represent a large global export market, which is especially attractive for the diversification of German companies.

In order to open up these markets using reliable and cost-effective systems, new technologies will be needed for control technology for stand-alone grids, optimised energy management for the operation of complex systems and optimised system management at the planning stage.

Research and development requirements

The aim of future R&D efforts must be to organise the changing supply structures in such a way as to enable network stability and supply reliability. In addition to a proper energy mix, high-performance communications structures, online procedures and forecasts for greater capacity planning, and bidirectional energy management and trading systems will be crucial for the dialogue between energy generators, distributors, and consumers. The development of modern information and communications technologies is indispensable for improved energy management methods.

Furthermore, the following are among the most important goals of applied research and development:

- Integration of fluctuating renewables and distributed electricity generation into integrated grids (energy and communications interfaces, output forecasting and control)
- Development of grid management systems and grid control processes as well as overall models for technological, economic and ecological optimisation (for all technologies and grid levels, including the low voltage level)
- Research in the area of controlling electricity consumption by private and industrial users as the basis for comprehensive grid management.
- Development of intelligent, communication-capable and multifunctional power converters to provide energy and capacity, emergency power supply and network quality improvement for all technologies in distributed electricity generation and storage.
- Research in the field of power electronics as key technology in energy system technology (new components/technologies, digitalisation/automation, thermal optimisation)
- In the medium-term, electricity storage facilities will be required for large volumes of energy.
- Technologies in the fields of compressed-air storage, flywheels, supercaps and superconductive coils will be extremely important for the provision of high capacities.
- Development of modelling and simulating tools for the design of energy supply systems.

For autonomous electricity supplies, developments in control engineering, energy management for flexibly expandable systems and management control centres to optimise the maintenance of many individual installations distributed over a wide area are just as important as opening up new appropriate applications and energy conversion technologies. At the same time, electrification in rural areas particularly requires an even better understanding of socio-economic and socio-technological relationships. This knowledge must be taken into account when developing new concepts and products for rural electrification in order first to allow the construction of small-cell electricity supplies in the region of a few hundred watts, which can then be connected to local and regional power supply structures as the grid is expanded.

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Heating and cooling with renewable energy

The energy devoted to heating purposes makes up 57 % of Germany's overall final energy consumption.

Some 40 % of final energy consumption in Germany is used to heat buildings. In the mid- to long-term goal is to have solar heating (active and passive) cover nearly all heating demand (space heating and hot water) in new buildings and a large part of demand in existing buildings. Another field of application that is becoming more important is the provision of process heat at high temperatures.

Heat from solar thermal collectors

Heat generation from biomass

Cooling with solar heat

Heating and cooling with geothermal energy

Heat storage

Heat from solar thermal collectors

Solar heat can be collected in various ways as a source of energy:

- Solar thermal collectors can heat up service water and drinking water, be used for space heating, and high-temperature process heat
- Passive solar energy can be used in architecture

Research and development requirements

- R&D into more efficient and more cost-effective large collector fields in the low temperature range, especially for the heating of buildings
- Development of improved long-term storage as an important component in a more intensive collector utilisation strategy
- Material research for alternative, ecologically friendly absorbers with good heat conductivity, anti-corrosive properties, and temperature resistance
- Development of new heat carrier media modified for absorbers
- Development of highly efficient collectors, including concentrating systems for industrial and commercial process heat (also in conjunction with combined heat and power) as well as desalination of sea water
- Development of model-based networked control systems and remote monitoring processes
- Development of switchable absorption surfaces on building envelopes
- Development and implementation of parameters for the logging of the solar energy yields of various systems

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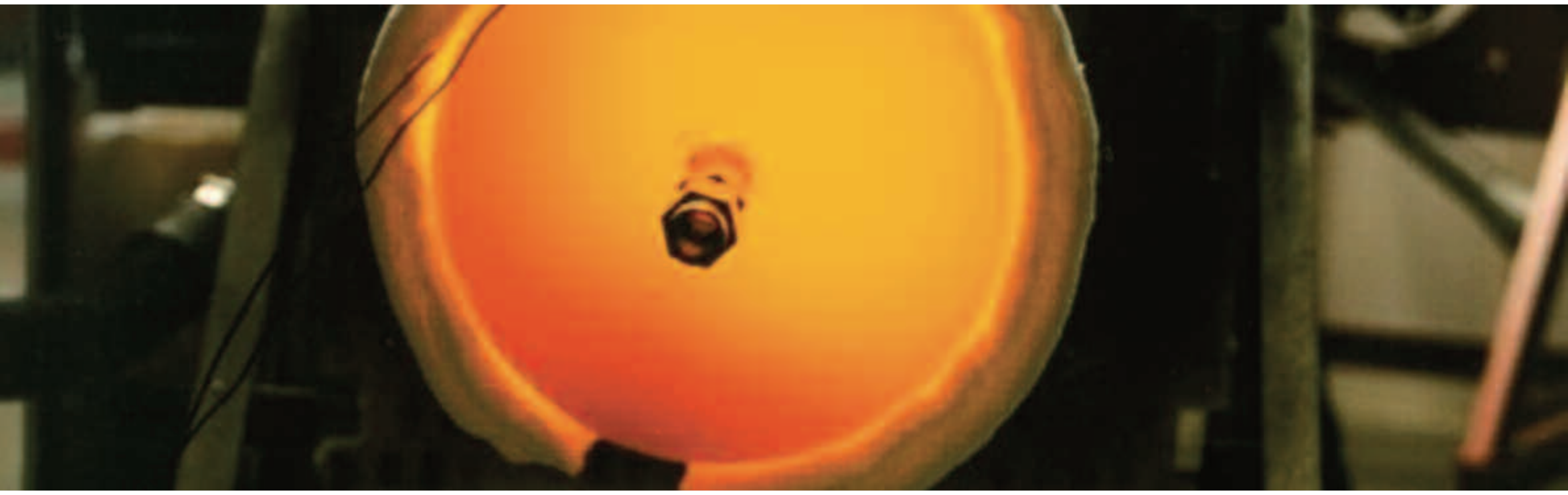
Heat from biomass



The sun’s energy stored in the form of biomass can be converted directly into heat. The thermal conversion technology used for this is combustion. This technology has already reached an advanced level. Heat from biomass is also produced in combined heat and power plants.

The potential of biomass energy for heat production in Germany is at least 10% of current energy consumption. The German government's ambitious targets for the use of biomass as a source of energy require new concepts that will provide for competitive generation costs along with improved energy payback and ecological impacts.

Research and development requirements

More research needs to be directed towards affordable, low-emission and low-corrosion combustion technologies in the field of conventional (combustion) heat generators for the use of solid biomass. Furthermore, innovative energy conversion systems must be researched and developed so that residual heat can be better utilized in cogeneration units fired by biomass for heating and cooling.

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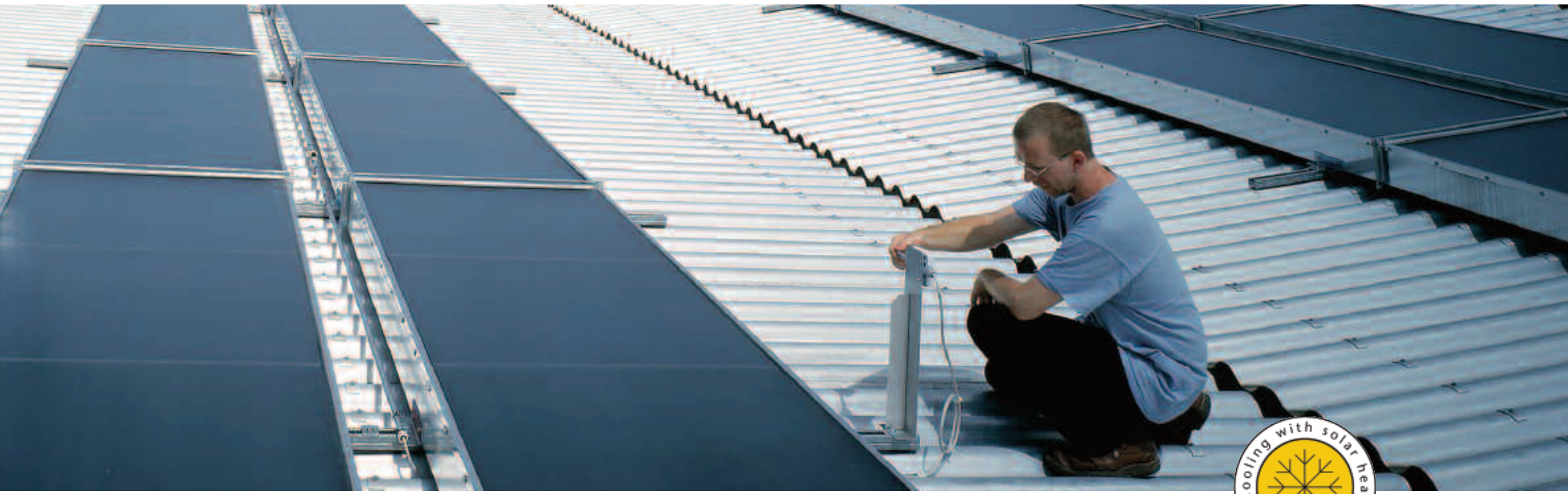
Cooling with solar heat



Heat can be used in combination with sorption technologies to drive thermodynamic circulation processes that produce high-quality heating or cooling (thermochemical heat pump).

Here, a distinction is made between adsorptive systems that work with solids (such as silica gel and water) and systems that work with fluids (such as lithium bromide and water).

Typical temperatures for single-stage systems range from 60°C to 120°C. They are therefore ideal for operation with solar heat, district heat, waste heat from cogeneration units, or fuel cells. Because cooling is mainly needed in the summer when there is generally an excess of solar energy and waste heat available, these environmentally friendly sorption technologies (no CFCs) are ideal for air-conditioning and refrigeration.

Another advantage of these cooling systems is that in most cases they can be set to a second operational mode to function as heating systems as well. At the same time, sorption systems also offer capabilities for the efficient long-term storage of thermal energy – a major advantage of the widespread use of solar energy systems.

The technical feasibility of solar-operated systems has been demonstrated successfully in many projects in recent years. Today there are already market segments in which it makes economic sense to use these systems. Investigations reveal a large number of approaches to improvement, which if implemented would enable additional markets to be opened up to their use.

Research and development requirements

- Material research in the field of absorbance
- For the development of small thermal cooling systems (compact, efficient heat exchangers, internal heat recovery)
- Development of electric/thermal hybrid systems
- Research into system technology for system concepts, design, controls, maintenance, and equipment management

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Heating and cooling with geothermal energy

The use of geothermal energy for heating purposes and the use of water saturated rock formations below ground for cold water storage in connection with seasonal air-conditioning and cooling is already established on a commercial basis. Particularly, heating by means of geothermal energy is presently experiencing a period of considerable growth in Germany. Shallow geothermics is used for heating and/or cooling in connection with vertical heat exchangers and heat pumps. But the enormous technical potential of geothermal energy sources is still far from being fully exploited in Germany.

Research and development requirements

The main R&D task consists of providing this technology dependably and predictably. For geothermal energy to become economically competitive, the efficiency of geothermal systems has to be be increased which is indicated by seasonal performance factor (SPF) that describes the ratio of useful energy output (heat generated) to the energy input (electricity), averaged over an entire heating season.

Depending on the heat source SPF of 3 to more than 4 are attained for ambient air and water (in vertical heat exchangers), respectively. Larger supply systems should be improved by a cost effective seasonal storage of heat or cold below ground. Additionally, deep heat sources have to be exploited more economically. Research can be divided into two main categories:

1. **Shallow geothermics**
- An optimization of systems above ground will profit from an improved knowledge of the geological and geothermal situation below ground.
- Higher energy efficiency additionally requires a program for SPF increase to > 5. The competitiveness of absorption heat pumps needs to be improved.
- The integration of underground heat and cold reservoirs in local energy supply systems must be developed.

2. **Deep geothermics**
- Exploration technologies have to be developed to increase the accuracy of expensive drillings and to enable forecasts on the behaviour of the subsurface during long-term operation.
- Geothermal technology development requires the systematic continuation of research aiming at the exploration and exploitation of productive sources at low costs and lower risk so that various locations with different geological settings can be used as energy sources.

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Heat storage

Efficient energy storage facilitates the integration of renewable energy sources into energy systems. Because of temporal variability in the availability of solar and industrial process heat, thermal storage systems are key components for the effective utilisation of this heat in solar thermal power stations, heat recovery processes, solar local heat projects, air-conditioning systems in buildings, and service water systems.

With large seasonal heat storage facilities, around half of the total heat requirements of large building complexes in Germany can be covered by solar energy.

Research and development requirements

New storage technologies require a comprehensive research and development. The development of new storage materials based on phase-change and sorption materials basically opens up entirely new approaches to heat storage with little loss, higher energy density, and the use of decentralized heat supply systems.

Such new approaches are especially promising in modern buildings with lower energy consumption. Furthermore, new storage materials open up new applications for high-temperature solar thermal stations and improve the use of industrial process heat.

Storage systems for small combined systems (power, heat and cooling) are interesting because electricity generation determines overall output, and the heat generated could be stored for several days.

The installation of heat storage units could increase the capacity utilize a nation of solar thermal stations as well as lower the cost of electricity generation. Considerable research is still required for the development of such storage systems so that the properties of active storage materials can be optimized, new materials found, and costs reduced. In addition, high performance for the entire service life and a minimum service level at a desired temperature need to be improved.

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Solar and energy-efficient architecture – building envelope and system technology

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Solar and energy-efficient architecture deal with the use of renewable energy and a reduction of energy consumption in the construction and operation of buildings. In Germany, 46 % of final energy consumption occurs in buildings. 90 % of this is accounted for by low temperature heat (< 80°C), chiefly used in heating. Renovation of old buildings has shown that it is possible to save 70 % of final energy consumption using currently available technologies. In newly built homes it has been possible to reduce consumption by over 80 % using the available standard technologies.

Many different concepts are available:

- 3-liter home
- Passive solar home
- Zero energy home
- Plus-energy home

Architects and their clients thus have a wide range of options to choose from when designing a solar energy building. For new residential buildings, the three-litre standard is currently the advanced standard; here, the house is designed so that residents can make do with 3 litres of heating oil per square meter per annum.

Passive homes are a further development that includes a ventilation system with heat recovery. Both of these methods primarily attempt to reduce heat loss. Zero energy homes have also proven successful in practice, though they have not been produced in such numbers to make them generally affordable. However, a proper marketing strategy could increase sales of such homes enormously in the next few years.

In office buildings, integrated total energy concepts (heating, cooling, electricity, light) and the use of passive systems (such as cooling with night ventilation or heat-storing materials) can achieve a 50 % reduction in energy consumption – for the most part without adding greatly to the cost of construction.

Research and development requirements

R&D should aim to conserve energy in buildings and increase the share of renewables used while simultaneously offering the same or higher standards of comfort. The tasks of research and development can be divided into system technologies and technological/ conceptual improvements to the building envelope.

The building envelope is the interface with the environment, influencing heat flows through windows and walls. Loss can be reduced through good insulation, heat can be gained through transparent thermal insulation, and daylighting can be used. It is a functional and design element into which new technologies from the field of renewable energy sources can be integrated (such as photovoltaics, facade collectors).

In the past few years, the development of highly insulating vacuum panels has been an important step in the optimization of building envelopes. Such panels offer the same installation as conventional insulating layers that are some five to ten times thicker. In particular, research is required for the optimization of service life and the integration of systems in buildings and the construction process.

While opaque walls ensure very low thermal conductivity (K value), windows are still thermal weak points in the building envelope – unless we take account of solar energy gains. Double or complex triple glazing provides for values below 0.5 W/(m^{2}K).

Vacuum glazing represents an interesting option. Here, the space between the panes is evacuated down to below 10-3 mbar, which almost completely eliminates thermal conductivity. HVAC systems used play a decisive role in a building's energy efficiency (heaters, control systems, and use of the overall system).

A focal point of research is the replacement of high-performance, active systems based on fossil fuels by systems that use heat sources and heat sinks in the environment, such as in the ground, ambient air, or groundwater (low exergy systems or “LowEx” for short). For instance, the heat storage capacity of light-weight construction can be improved to the level of heavy construction if phase-change materials (PCMs) can be used inside. Rooms would then heat up much less. The heat stored during the day in the PCMs could then be released again at night, when the outdoor area is cooler. If such systems are properly designed no other cooling technologies will be aditionally necessary anymore.

Natural and artificial lighting in indoor meeting points also provide practical visual ambience. At the same time, building illumination must also be included in the calculation of the building’s overall energy consumption. Researchers have developed a number of planning instruments that allow for natural and artificial illumination concepts to be created and optimized. Entire facades can be designed to optimize energy consumption for illumination, and tests can be conducted to determine how these facades affect the energy demand for lighting.

In addition to the further development of materials and encapsulation procedures, system development plays an important role today. Furthermore, robust overall concepts need to be developed so that new components and systems can work together smoothly without a reduction in building comfort. Current approaches utilize simulation-based building management concepts, some of which even take into account weather forecasts and user response.

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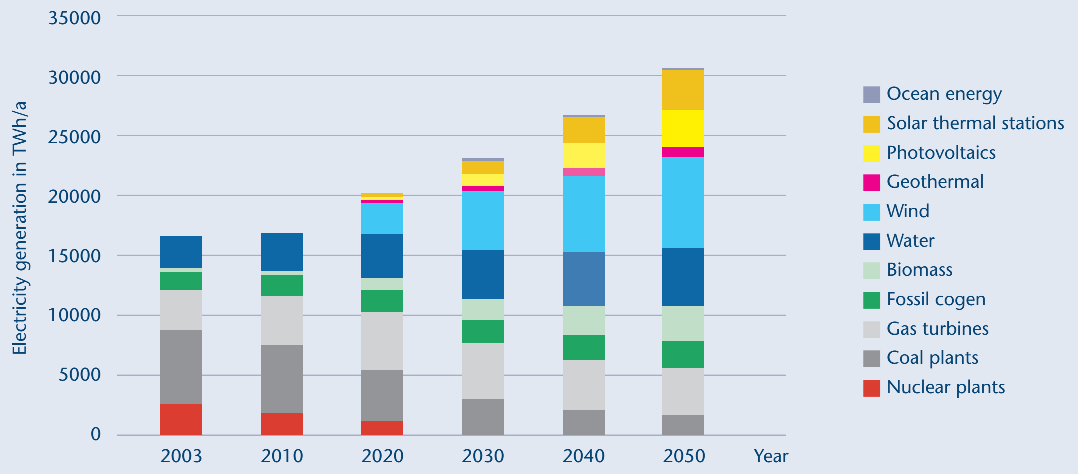
The main goals of solar architecture include:

- High-quality building outer shell with especially good heat insulation, consistent avoidance of heat exchangers, and airtight design.
- Compact structures to reduce heat-exchanging components in order to lower costs and reduce energy consumption.
- Solar-optimised windows with switchable transmission properties leading to a positive total annual energy balance whilst at the same time preventing overheating in the summer months and allowing extensive use of daylight, especially in office buildings (improved thermal insulating layers with high solar transmission, electrochromic and gas-chromic glazing, microstructured types of glazing in order to redirect daylight and give shading from the sun).
- Solar-active opaque facade elements to store solar heat in the exterior walls. In principle, transparent thermal insulationoffers great potential for use if technological systems can be successfully developed for simple practical application.
- Other very elegant approaches include systems that allow a variable amount of energy to pass through them so that solar heat can be used effectively in the winter even as a shade is provided in the summer (switchable insulation) as well as systems that combine the functions of heat and cold storage and the use of daylight by integrating phase-change materials in light-permissible components.
- Daylight systems for the interior lighting of buildings, systems for the redirection and distribution of daylight with implemented switchable transmission properties. They allow a better use of natural radiation for lighting, achieving greater lighting comfort and a reduction in the cooling load.
- Examples include optical fibres with low losses and great colour trueness, highly reflective light tubes, and sunscreen systems backed cast shade effectively even though they are transparent.
- New approaches in construction planning that allow for passive cooling in buildings not used for residential purposes, including concepts for nightly ventilation, for instance, and building-integrated water circulation for heat removal. Furthermore, with flat heat storage elements with great energy density should be developed for implementation in walls and ceilings (such as phase-change materials).
- Functional materials with low thermal emissivity can considerably lower the amount of energy that enters buildings through heat radiation in the summer. Such layers are therefore being optimized and means of application, such as woven glass fibres and materials for use in textile architecture, are being developed. The implementation of efficient technologies for passive cooling, such as radiative cooling, poses another challenge.

- New approaches for the development of the multifunctional facades. This field covers the function of energy generation and storage, shading, noise and heat insulation, visual protection and daylighting, ventilation, and design aspects. Examples include building-integrated photovoltaics facades that combine the use of daylight, provide shading and visual protection, and generate electricity.
- Interesting overlapping occurs here, such as when photovoltaics facades are combined with window blinds. Window blinds that react automatically to the amount of daylight or weather conditions also represent attractive, inexpensive architectural solutions that can be further optimized. Automatic thermohydraulic drives are also an interesting form of this combination.
- System management in buildings is the key to the effective integration of innovative technologies. Future system management concepts intelligently take account of current user behaviour and external conditions when computing controls for individual components. The development and implementation of such concepts is a crucial challenge in future research and development.
- Generally, high-quality energy carriers, generally fossil fuels, are used to heat and cool rooms. New developments aim to use the potential of the energy, called "exergy", sparingly. Keeping system temperatures down is one step towards that end. Therefore, innovative systems run with very small temperature differences between the heating/cooling medium and the target room temperature. In this way, renewable sources of energy can be used very effectively, such as thermal solar for heating and the natural cool of subsoil for cooling. Taking account of and optimizing exergy flows in buildings can help identify potential for additional increases in efficiency.
- The energy certificates for buildings that have been recently launched require the determination under standardized conditions of the energy demand of the planned new buildings or existing buildings if no consumption values are available. Parameters and tools that are suitable for our planning and consulting have to be developed so that values can be confirmed, feasibility studies undertaken, and properties optimized. Such tools must be further developed in order to fulfil the requirements of current building codes (such as DIN V 18599 for the assessment of a building's overall energy efficiency) and of future standards.

Technological impact assessment

Scenario for a global, sustainable electricity supply



The development of new energy technologies is taking place within a complex environment with numerous framework conditions involving technical, economic, ecological and energy policy aspects. Therefore a condition for a successful market launch is a preparatory and accompanying analysis of these relationships. New energy technologies and systems need to undergo continued comprehensive assessments in order to ascertain opportunities and risks, detect possible undesired developments early on, and develop alternative solution approaches.

At the same time, aspects such as the liberalisation and globalisation of the energy markets and the rules set by international climate protection policy need to be taken into account. System analyses provide a scientifically sound, reliable basis for decisions made in politics, the industry, and society so that the effects of new technologies can be assessed quickly and comprehensively. System analysis and technological impact assessment are therefore integral parts of the research strategy at the Renewable Energy Research Association.

Research requirements

- Technological and economic utilisation analyses to determine the best systems and their application potentials
- Life cycle analyses and ecological assessments
- System analyses for individual technologies to accompany research with improved technology foresight procedures
- Environmental and system analyses to support research planning and follow-ups
- Model calculations and scenarios for future energy supply systems
- Development of market launch and market penetration strategies with consideration of different geographical and chronological aspects and a derivation of recommendations for action in political consultancy
- Conceptional work to improve the integration and assessment of technologies from the point of view of sustainability
- Methodical approaches to further development of subsidy instruments close to the political process

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Generation and use of chemical energy carriers from renewables

Renewables can also be used to produce chemical energy sources (especially fuels for the transport industry). There needs to be increased development of strategies for the use of renewables in transport, which requires cost-effective and efficient chemical energy sources. However, before such energy sources can be employed, priority should be given to greatly enhancing the efficiency of the vehicles that are used. The European Union's target is to raise the share of biofuels in petrol and diesel consumption from today's figure of 0.2 % to 5.75 % by 2010.

Fuels made from biomass

Fuel cells

Hydrogen from renewable sources

for further information, visit www.FV-Sonnenenergie.de
or www.Renewable-Energy-Research-Association.org

Fuels made from biomass

Biofuels can be used both as substitutes for fossil fuels in present-day vehicles and to supply fuel cells in mobile and stationary applications. The extraction of hydrogen-rich energy sources from biomass can thus be seen as one building block in the long-term wider prospects for hydrogen.

When biomass is used as a source of energy, carbon derived liquid fuels can be extracted in conversion processes which are practically carbon-neutral. Biomass as a source of heat, fuel, and electricity has great development potential thanks to its high overall degree of efficiency. The optimized supply of electricity, heat, and fuels – called "polygeneration" – is especially promising because it provides a carbon-neutral energy source for the transport sector. Some 75 % of the energy stored in biomass can be made available as chemical energy – hydrogen – when biomass is gasified into synthesis gas. Compared to the use of biomass as vegetable oils (such as "biodiesel") or in biochemical processes (such as bio-ethanol), this method is a very efficient way of converting bioenergy into fuels. Biomass is therefore an excellent first step towards a sustainable scenario for the liquid fuel sector.

Research and development requirements

- Production methods for carbon fuels from biomass
- Synthesis gas with the highest possible hydrogen content from biomass
- Gas reformation for the use of synthesis gas and fuel cells
- Optimization of energy efficiency through the cogeneration of electricity, heat, and fuels
- Investigation of suitability for various energy systems such as internal combustion engines, fuel cells, combined heat and power (CHP) plants
- System technology investigations, optimisation of process management and heat management
- Better consumer acceptance thanks to lower toxicity of processes and a greater overall safety
- Basic research into the production of hydrogen from bio-resources
- Interface technologies for a future hydrogen economy

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Fuel cells

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Fuel cells are considered to be the energy converters of the future because in principle they achieve particularly high levels of electrical efficiency, a high overall utilisation ratio with simultaneous use of heat, and especially low pollutant emissions. They can operate both with hydrogen and with hydrocarbon fuels (after reformation) and are suitable both for decentralized electricity and heat supplies and for powering electrical vehicles. One highly promising possibility is onboard electricity generation in vehicles and on aeroplanes in place of the units currently used. This will enable considerable fuel savings and performance increases.

However, when the carbon emissions are considered, fuel cell operation based on fossil energy sources still won't bring any great relief to the climate system. For a sustainable improvement in CO_2 emissions, it is therefore essential to replace fossil energy with renewables for providing hydrogen.

The first experiments with car and bus fleets are now taking place worldwide, as well as field trials for supplying energy to buildings, in order to demonstrate their technical feasibility. Japan has begun the first phase of market launch for energy supply in households with 500 units. Germany and other countries are also stepping up product development. Field tests provide a number of insights into daily operation that can then be incorporated into the development of the next generation of products. Furthermore, inexpensive solutions are being developed both for core components (membrane, catalytic converters, and bipolar plates) and peripheral components (pumps, valves, and sensors).

Considerable R&D efforts are still required to deal with the many open questions that remain, before fuel cells are ready for use, cost-competitive, and ready for market launch. The systems must be made more reliable, efficiency must be maintained over their service life, and service life must be sufficiently long – all of these issues are part of the problems that have to be solved to lower costs.

Research and development requirements

- Development of cost-effective materials (catalysts, membranes etc.)
- Modelling and characterisation of fuel cells to increase their power density and operational reliability
- Development of technical-mathematical models for thermodynamic, electrochemical and mass transport phenomena (material and heat transport/electricity transfer) in fuel cells with the goal of optimizing the design of cells and stacks
- Research into mechanisms of degradation in various incinerator gas compounds
- Development of innovative diagnosis and investigation methods for fuel cells
- R&D into compact, cost-effective reformation technologies (e.g. natural gas and diesel) to take advantage of current energy source infrastructure as a transition technology
- Development of fuel cells suitable for synthesis gas (H_2 + CO)
- Development of "reversible" fuel cells/ electrolyser systems
- Improvement of low temperature fuel cells (PEFC)[1] for direct feeding and efficient transformation of methanol and related alcohols
- Further development of SOFC[2] and MCFC[3] fuel cells for higher power densities and various fuels
- Development of control strategies for fuel cells in hybrid systems
- Development of serial production methods for all fuel cell components in order to lower costs
- Fuel cell system technology, particularly power converter technology, remote status diagnosis and error forecasting, and optimised grid integration

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1 Polymer Elekrolyte Fuel Cell
2 Solid Oxide Fuel Cell
3 Molten Carbonate Fuel Cell

Hydrogen from renewable sources

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Renewable energy sources have the greatest potential for the sustainable production of hydrogen. Usually, hydrogen is made from biomass or generated by means of electrolysis, with electricity and heat produced from renewable sources. If the electricity market is developed extensively for renewables (share >50%), the availability of low-cost electricity could mean that the use of electrolysis for the energy industry will become economically viable. Then, electrolysis could be inexpensive and solar-compatible.

Concentrator solar power systems are also increasingly becoming interesting. They directly covert sunlight thermochemically into combustible fuels with very high conversion efficiencies. The reformation of methane from synthesis gas is the most advanced concept of such solar chemical processes.

Today, hydrogen is mainly made from natural gas, with large quantities of hydrogen also being created in the chemicals industry. The generation technologies used to serve as intrigue technologies towards a hydrogen energy system based on renewable sources. Advanced synthesis gas methods that already provide a very high level of hydrogen content at little process temperatures in a single gasification stage represent a new entry point for the production of hydrogen from biomass, and hence decentralized production for mid-size power generators.

Research and development requirements

- Development of synthesis gas production with high hydrogen content
- Solar-chemical procedures to reform methane in concentrator solar power units
- Direct water-splitting by means of thermo-chemical circulation processes for the production of solar hydrogen
- Solar heat to support high-temperature electrolysis for the production of hydrogen
- Highly efficient pressure electrolysis with small-scale units
- Development of inexpensive materials, such as catalysers' electrolysis units, membranes, gas distribution layers

Goals of the German government and the EU

by 2010

Germany
- Reduce CO_2 emissions by 23 million tons through utilisation of CHP
- Double the share of renewables in primary energy consumption to 8.4 %
- Increase electricity generation from renewables to 17 %
- Increase the share biofuels to 7 % from 6.6 % today
- Increase the share of renewables in heating supply to 8.6 %

European Union
- Increase electricity generation from renewables to 22 %
- Increase share of biofuels to 6% for both gasoline and diesel

by 2020

Germany
- 40 % reduction of carbon emissions relative to the level of 1990
- 16 % primary energy from renewables
- Increase electricity generation from renewables to 30 %
- Increase the share biofuels to 17 % from 6.6 % today
- Increase the share of renewables in heating supply to 14 %
- Increase share of electricity production from cogeneration units to 20 %

European Union
- 20 % reduction of carbon emissions relative to the level of 1990
- 20 % primary energy from renewables
- 20 % increase in energy efficiency
- Increase share of biofuels to 10 % for both gasoline and diesel

by 2030

Germany
- 50 % reduction of carbon emissions relative to the level of 1990
- 25 % primary energy from renewables
- 47 % electricity generation from renewables, 15 % of which from offshore wind parks
- Increase its share of biofuels to 24 %
- Increase the share of renewables in heating supply to 23 %

by 2050

Germany
- 80 % reduction of carbon emissions relative to the level of 1990
- Renewals make up 49 % of primary energy consumption
- Renewals cover 80 % of electricity generation
- Increase share of biofuels to 42 %
- Increase the share of renewables in heating supply to 48 %

European Union
- 60-80 % reduction of CO_2 emissions
- Renewables make up some 50 % of total energy supply

Renewable Energy Research Association (FVS)

In the past few years, the general conditions for research into solar and renewables have consistently improved: they have been intensively developed, have demonstrated their technical viability and gained recognition. This trend will logically lead to the need for significantly greater promotion of renewables.

Intensive research and development is necessary so that the renewables can rapidly take on their tasks in the energy industry, becoming a significant and sustainable economic factor.

The Renewable Energy Research Association is headed by the directors of the member institutes. The board of directors advises on the division of labour, teamwork and the coordination of joint research programmes. The association's spokesperson is elected annually.

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Various German federal ministries are involved in research promotion via project sponsorship and institutional support, as are the federal states in which the member institutes are based.

BMU
Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit (German Ministry for the Environment, Nature Protection and Reactor Safety)

BMBF
Bundesministerium für Bildung und Forschung (German Ministry for Education and Research)

BMWi
Bundesministerium für Wirtschaft und Technologie (German Federal Ministry for Economics and Technology)

BMELV
Bundesministerium für Ernährung, Landwirtschaft und Verbraucherschutz (German Ministry for Nutrition, Agriculture and Consumer Protection)

Office

The FVS office in Berlin is the Association's information and communication centre. It is the point of contact for the scientific, business and political communities and conducts the association's general public relations work.

FVS ForschungsVerbund Sonnenenergie
Renewable Energy Research Association

Visit the FVS website where you will find a host of free information:

www.FV-Sonnenenergie.de

or

www.Renewable-Energy-Research-Association.org

- Concise, easy-to-understand introductions to all research topics
- Links to the promotion programmes run by German ministries
- Downloads of special brochures and workshop proceedings
- Announcements of FVS event dates
- News and press materials
- Images related to renewals
- Renewable energy arguments for political discussion
- Information about member institutes

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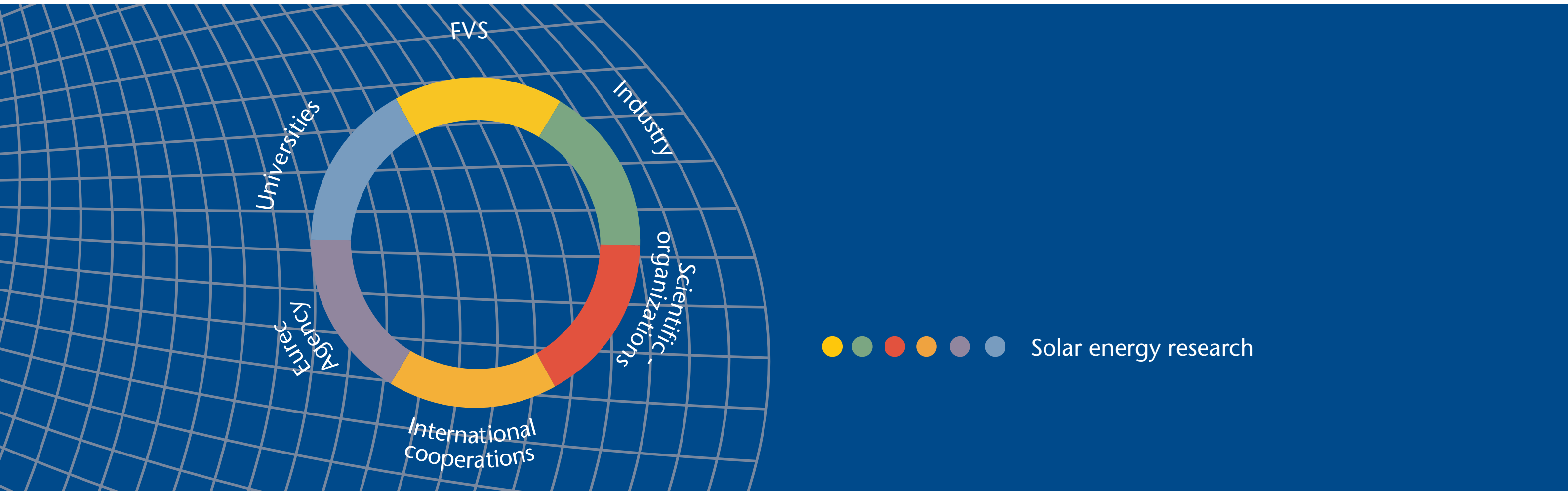
Networking research and development



In addition to collaboration with its member institutes, FVS offers an open cooperative structure for all interested parties from industry, universities and non-university institutions. This enables:

- Joint research projects,
- Joint workshops and
- Joint financing.

Cooperation with the business community is particularly important as application-oriented research can only lead to swift market launches – and hence success – in partnership with industry.

The following industries are interesting for potential investors:

BMU

The German Ministry for the Environment, Nature Conservation and Nuclear Safety promotes research and development in the following fields:

- Geothermal
- Solar thermal power plants
- Solar thermal
- Electricity from wind energy
- Subsidy concepts for photovoltaics: research and the promotion of cluster research in PV
- Overall strategy for the further expansion of renewables

www.erneuerbare-energien.de/inhalt/20028/

BMBF

The German Ministry for Education and Research promotes research

www.bmbf.de/de/1398.php

BMWi

The German Ministry of Economics and Technology promotes research and development in the fields of energy efficiency and conversion/combustion technology

www.bmwi.de/BMWi/Navigation/Energie/energieforschung.html

BMELV

The German Ministry of Nutrition, Agriculture, and Consumer Protection promotes the “Research, Development, and a Demonstration Program for Renewable Resources“

www.bmelv.de

Project Management Jülich

offers an overview of means of project promotion and applications for the BMU, BMBF and BMWi.

www.fz-juelich.de/ptj/index.php

Electronic application system for online applications to German ministries

www.kp.dlr.de/profi/easy/index.html

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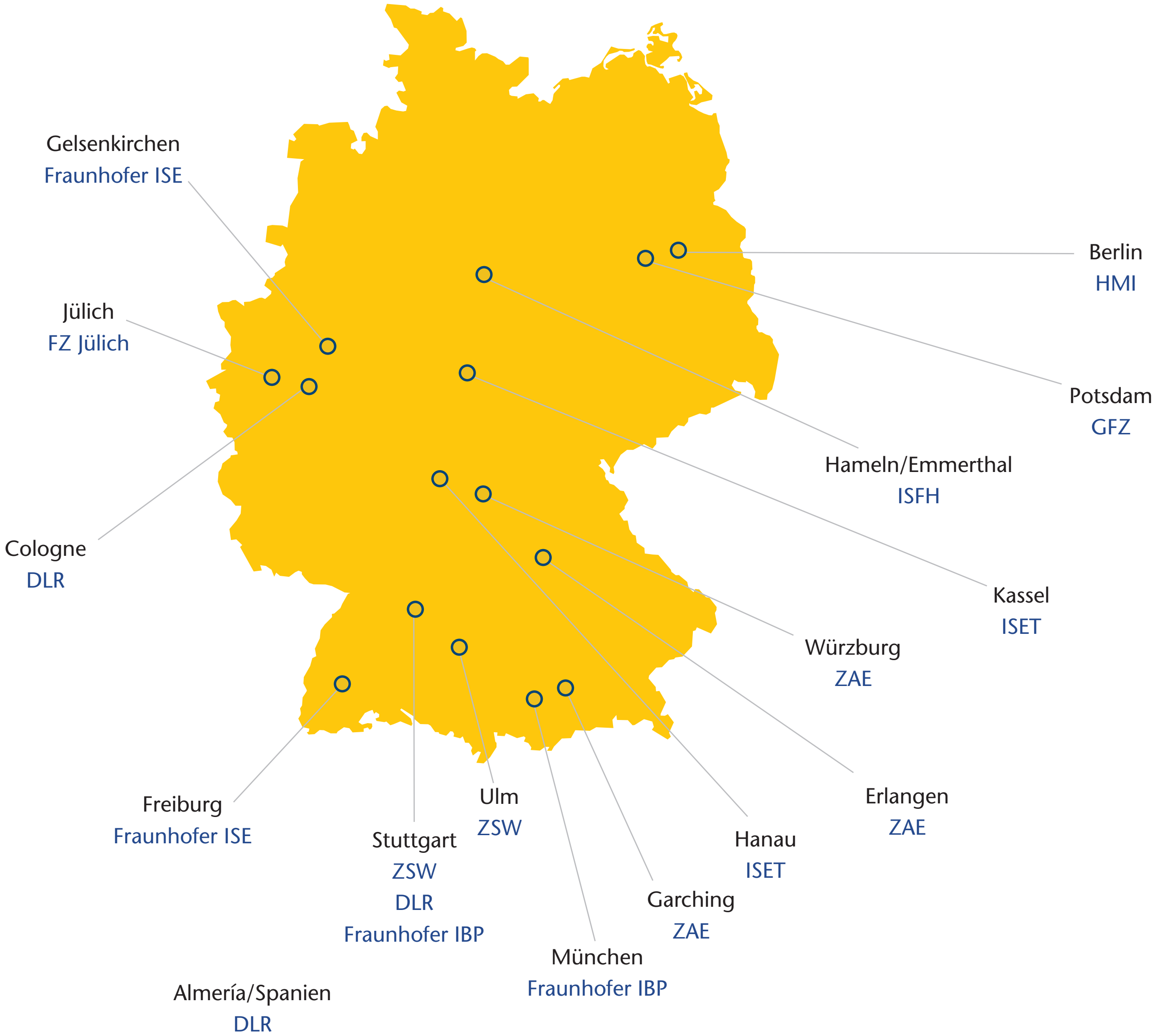

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