Energy research at DLR

DLR

Contents

Energy research institutes at DLR

Energy research for our future

The share of power supplied from renewable sources in Germany has now reached approximately 30 percent, and the last nuclear power plant in the country will be closed down in 2022. We are in the midst of the long transformation process of the energy transition.

However, this process will not advance by itself and enormous challenges still lie ahead. Achieving the first 30 percent of energy from renewable sources was relatively easy, but with increasing progress, each additional percentage point becomes more difficult. The ambitious, science-based energy policy objectives set by the German Federal Government are far from being reached. In 35 years, greenhouse gas emissions are set to be reduced by at least 80 percent compared to the levels in 1990 and primary energy consumption should be reduced by 50 percent. At the same time, the reliability and cost-effectiveness of the supply must be guaranteed.

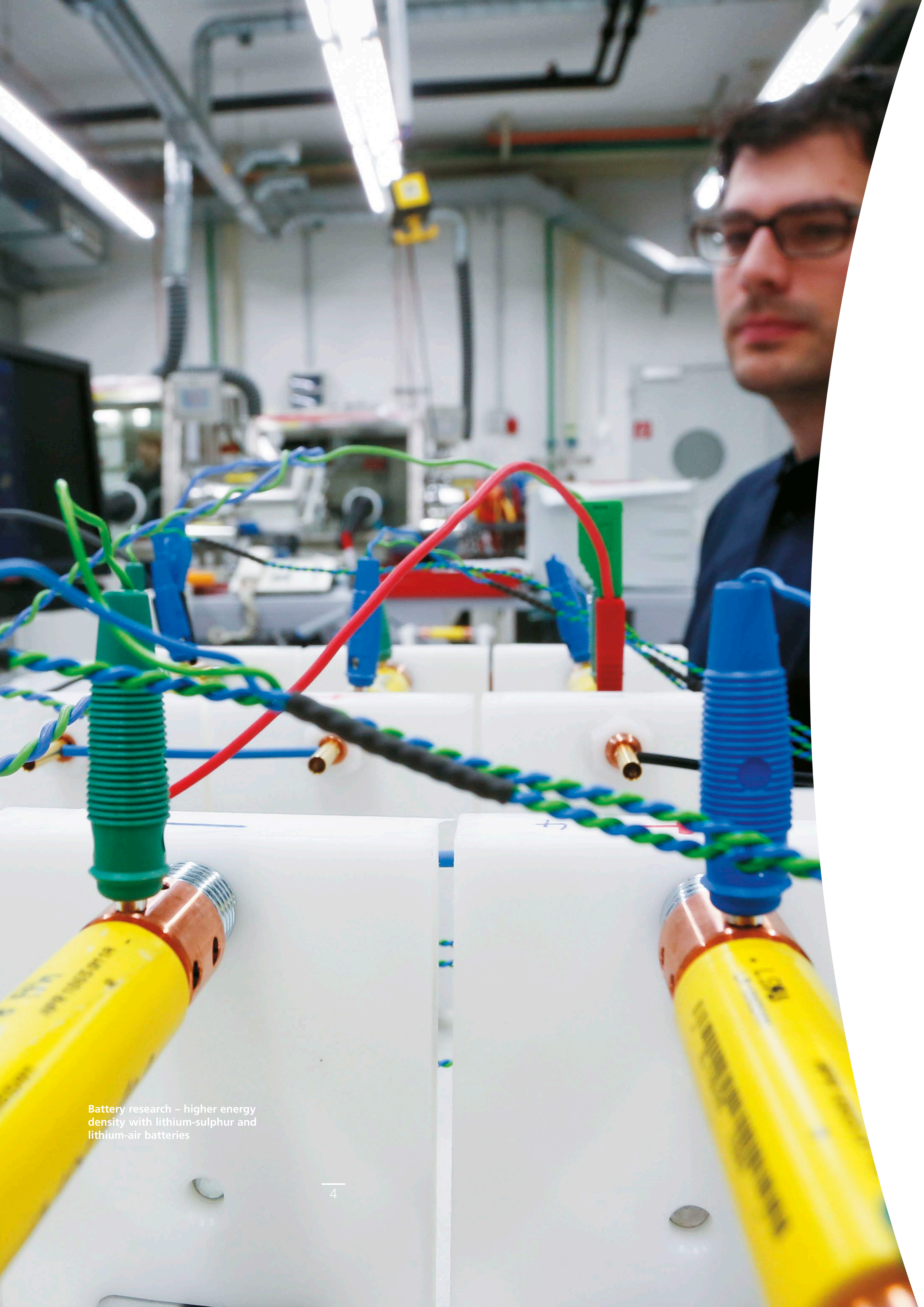
The changes to the energy system will be very far-reaching, and research remains a key strategic element of energy policy. In addition to the main tasks of further developing existing technologies and making new technologies available, more emphasis is being placed on system aspects. How do new technologies interact with one another in the energy system? What new challenges will arise as a result of this and what is required to overcome them? These questions apply on a decentralised, as well as a national scale, between the various levels in the power grid and also between the electricity, heat and mobility sectors.

Energy research at DLR is active in the technology field, as well as in the modelling of the overall system. A high proportion of funding from industry and public research programmes demonstrates the high level and productivity of DLR energy research. Here, the many synergies with aeronautics, space and transport research are paying off, combined with collaborations with national and international partners.

The following pages will provide you with an overview of our research topics. DLR – the best energy research for our future!

Bernhard Milow, Energy Programme Director

DLR solar research – scientists check the quality of mirrors and other components in solar thermal power plants and set standards



Battery research – higher energy density with lithium-sulphur and lithium-air batteries

DLR energy research – solutions for the world

DLR has been working on energy research and making important contributions to a sustainable energy system since the mid-1970s. Multidisciplinary teams with access to the unique test facilities and extensive computing capabilities of a major research institution are working on various key issues. DLR has adopted a nationally and, sometimes, internationally leading role in many of these areas.

Key topics

Energy research at DLR is primarily focused on innovative techniques for power generation, developing energy storage systems and modelling the energy system. This brochure gives an overview of the diversity of these research areas.

Combustion and gas turbine technology is aimed at improving gas turbines in terms of their efficiency, reducing emission levels and increasing flexibility. In addition to conventional gas turbines for power plants in the several hundred-megawatt output range, micro gas turbines with outputs of just a few kilowatts are being researched and optimised.

Solar research is primarily concerned with optimising solar thermal power plants that use concentrated solar radiation to generate sustainable base load power using a steam-power process and thermal storage systems. Here, DLR further develops known concepts and implements new approaches for, among other things, the production of fuels using solar energy. The objective is to improve the technology, reduce costs and thereby accelerate entry into the market. In the field of wind energy research, DLR uses its extensive expertise in aeronautics to improve the design of wind turbines.

Materials research at DLR is a cross-disciplinary area that makes substantial contributions to various energy topics. It plays an important role in the development of lighter rotor blades for wind power generators, heat-resistant combustion chambers, lighter blades for gas turbines and more robust radiation receivers for solar tower power plants.

Energy storage systems will play a substantial role in the energy system of the future. DLR energy researchers are working on thermal, chemical and electrochemical storage systems. With regard to electrochemical storage systems, DLR is collaborating closely with other centres in the Helmholtz Association of German Research Centres to investigate the generation of batteries and new applications for fuel cells.

DLR energy systems analysis assesses the various energy technologies and uses multiple scenarios to investigate what the energy mix of the future might look like. Systems analysis provides the basis for decision-making in both government and research.

Data and facts

Approximately 600 employees in various disciplines work on energy research at DLR sites in Cologne, Stuttgart, Braunschweig, Göttingen, Jülich and Almería, in southern Spain. In 2014, DLR committed funds of approximately 25 million euro to energy research from its core funding, provided by the German Federal Ministry for Economic Affairs and Energy and the German states. Third party funds raised from public research programmes and industry amounted to approximately 44 million euro in 2014. High third party funding – 64 percent of the total – has put DLR at the forefront of energy research institutions in the Helmholtz Association for some years.

From basic research to applications

A system of programmatic controls is used to manage and focus DLR energy research topics; this ensures that the necessary capabilities are available for dealing with relevant issues successfully. While some work is more focused on the fundamentals, other research is directed towards the needs of industry. It is an established principle at DLR that the entire scope is covered – from the fundamental mechanisms to industrial applications. For this reason, and together with its expertise in the areas of aviation, aerospace and transport, DLR is able to offer a unique spectrum of capabilities that can perform well in the face of competition and secure competitive advantages for its industrial partners.

Collaboration

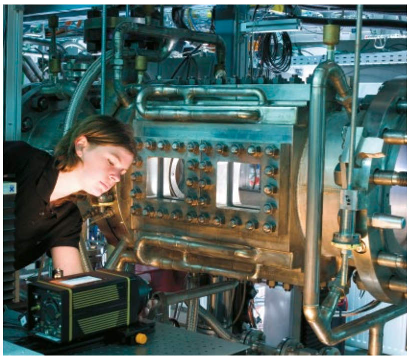
DLR energy research is involved in numerous national and international networks. It cooperates with various universities that are active in this field and, by so doing, attracts competent young researchers. Generally, DLR institute and department heads also teach at universities. Intensive and wide-ranging collaboration with industry ensures both the linking of energy research to current issues and the funding of associated research projects. DLR energy research also cooperates with other national research institutes and selected international partners from science and industry.

In addition to undergoing internal scientific assessments, DLR energy research is subject to evaluation every five years in the context of the Helmholtz Association. This involves reviewing the medium-term orientation and strategic coordination between the member centres of the Helmholtz Association.

Less carbon dioxide – efficient and flexible gas turbines

Thermal power plants are capable of generating power on demand and, as such, are able to compensate for seasonal and temporal fluctuations in the availability of wind and solar energy. Furthermore, the construction of new power plants or the modernisation of existing plants offer the option of replacing old facilities with modern, high-efficiency power plants worldwide.

In recent years, major advances have been made in increasing power plant efficiency and in reducing pollutant emissions. The efficiency of power generation using combined cycle gas and steam turbine power plants has increased from less than 40 to over 60 percent; at the same time, there has been a significant reduction in the emission of nitrogen oxides (NOX). Energy researchers are working on further increasing the level of efficiency, for example by using improved combustion techniques. Every percentage point by which the efficiency of power generation in Germany is increased corresponds to the power produced by a conventional large power plant and meets the needs of 500,000 people.



A glass combustion chamber offers a view of the combustion process in a gas turbine

Better combustion – with a steady flame

Researchers at the DLR Institute of Combustion Technology in Stuttgart are developing new combustion systems, one of which is based on FLOX® (FLameless OXidation) technology. This technology provides a particularly homogeneous and stable flame, significantly reducing the emission of pollutants while lowering the thermal load on the materials of the combustion chamber walls. In addition, this type of combustion chamber can be operated using different fuels so that, with this technique, future gas turbines will have the capacity to make better use of natural gas with fluctuating quality and biomass-based fuels. New combustion chambers for gas turbines can be tested under real conditions in the high-pressure combustor rig in Stuttgart.

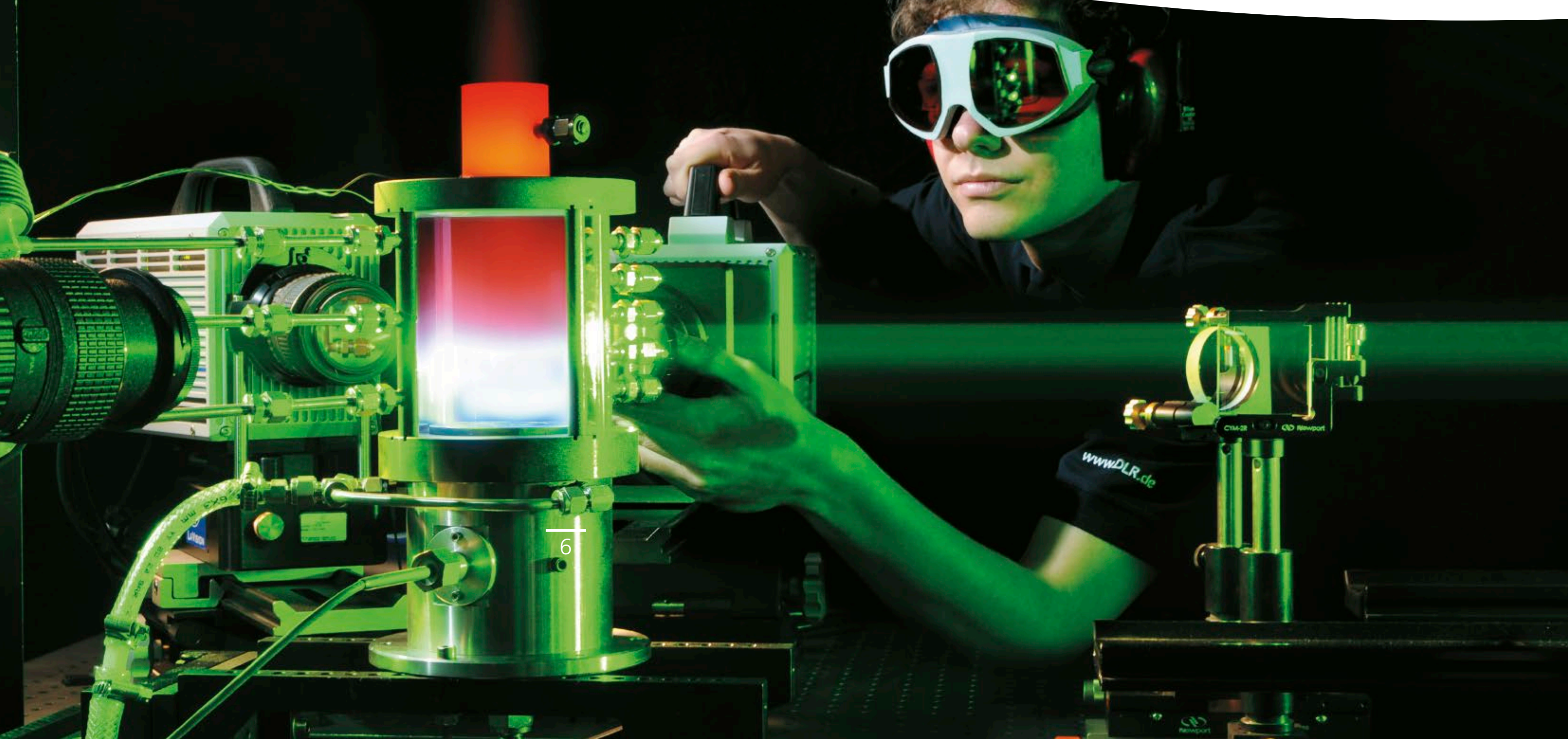
Alternative fuels

Alternative fuels and 'designer' fuels are playing an increasingly important role in energy supply and, particularly, in environment-friendly individual mobility. DLR researchers are working on generating such fuels from renewable energy sources. These fuels can also be produced by the gasification of biomass and coal. They are characterised by a high content of hydrogen and carbon monoxide and have different combustion properties than natural gas.

Contactless measurement for low-emission combustion

Making combustion processes more efficient and environmentally friendly requires understanding what is occurring in the flame and how to control it. DLR researchers are using contactless laser measurement techniques to examine the properties of and processes in a flame. In contrast to measurement probes, laser measurement methods do not disturb the flow field or interfere with the chemical reactions. Data can be acquired with greater temporal and spatial resolution; up to 10,000 measurements per second are possible. The interaction between the flow field and the chemical reactions can be measured, as can the temperatures of

DLR researchers use laser measurement technology to determine the properties of a flame



the combustion chamber walls and the flame. Also of importance is the ability to measure the concentrations of substances involved in the reaction.

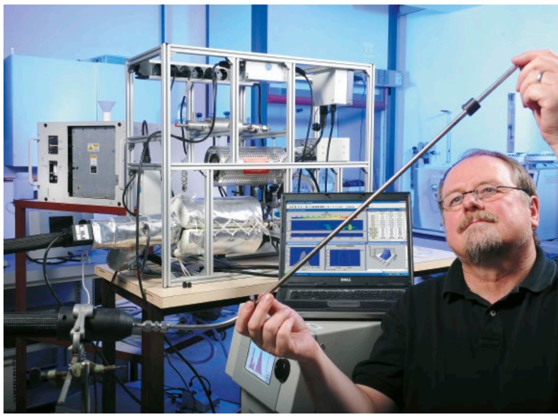
Simulations for better combustion chambers

The DLR Institute of Combustion Technology has developed powerful numerical methods to test future burner and combustion chamber concepts using a computer and without the need for expensive trials. These methods are used to simulate the formation of pollutants (particularly nitrogen oxides) in combustion chambers, as well as the noise and oscillation of flames. Using computations, the researchers can also make important predictions about the thermal load on combustion chamber walls and the spark ignition or compression ignition characteristics of fuel/air mixtures.

New requirements for large power plant turbines

The power grid of the future will place new demands on fossil fuel power plants – they will have to generate power efficiently and conserve resources – not only during baseload operation but also when operating at partial load. At the DLR Institute of Propulsion Technology in Cologne, researchers are working closely with partners in industry to improve power plant gas turbines. They are investigating the pressure and temperature in combustion chambers of various performance classes under realistic conditions. The plant manufacturers and researchers are aiming to make power plants more productive, environmentally friendly and flexible.

To this end, the researchers are investigating how both axial and radial compressors can be optimally designed for baseload and partial load use. They are also simulating the aerodynamic behaviour of larger turbine blades to ensure that there are no dangerous vibrations, which are referred to as 'blade flutter'. The aim of the research is also to make power plants more efficient by reducing the need for cooling air in the turbines as temperature of the gas increases. To do this, the flow calculation tools designed at DLR for industrial applications are being continuously developed and tested using extensive experiments.



Alternative fuels – improved combustion properties and lower emissions

DLR researchers are developing more flexible and powerful power plant gas turbines

Tower power plant in Almería – greater efficiency in solar thermal power generation by using higher temperatures

Concentrated solar radiation – solar research at DLR

The Sun provides an abundance of energy; it has the potential to meet the needs of Earth's entire population 10,000 times over. The challenge is to exploit this climate-neutral energy source efficiently and cost effectively. Solar thermal power plants, which DLR has been researching for over 30 years, can make a substantial contribution to this exploitation and so to the energy supply of the future.

Power around the clock

Solar thermal power plants concentrate direct sunlight to produce temperatures high enough for technical use. Thus, they can be used to provide large quantities of environment-friendly power from renewable sources in sunny regions. This technology has another important advantage; energy can be stored in the form of heat at a relatively low cost. Using a thermal storage system such as large salt storage tanks, for example, these power plants can also be relied upon to provide power during the hours of darkness.

The DLR Institute of Solar Research is one of the world's leading organisations in the field of solar power plants. The scope of research at the Institute ranges from laboratory and fundamental research through to operational testing of complete solar power plants. The aim of the research work is to improve the processes and materials used in construction, and to optimise the system design and operation of the facilities. To do this, DLR scientists are carrying out important research and development work to accelerate innovation cycles and reduce power generation costs.

Better mirrors and absorber tubes

The QUARZ test laboratory in Cologne (Test and Qualification Center for Concentrating Solar Power Technologies) is highly application-oriented in its work. Here, DLR researchers are investigating the quality of industrially manufactured mirrors and absorber tubes using test rigs developed at the centre. As one of the world's leading research institutions in this area, DLR is currently working to establish international standards for quality control of components and the associated measurement methods.

Scientists at the DLR Institute of Solar Research use the solar furnace in Cologne to conduct fundamental research. This furnace is equipped with a 60-square-metre mirror array to concentrate solar radiation. Initial tests for generating hydrogen directly using solar energy were among the tests carried out here. The DLR solar power tower plant in Jülich serves as a large-scale research facility for experiments involving high-temperature solar technology.

DLR researchers also have access to the Plataforma Solar de Almería (PSA) research facility in southern Spain. The facilities in Germany can be used for fast technology development from the laboratory scale to industrial prototype, whereas in Almería, long-term experiments can be carried out under 'real-world' conditions. DLR scientists in Cologne and Stuttgart are conducting research into better heat transfer fluids for parabolic trough systems and into receiver technologies and are evaluating future solar tower systems.

Higher temperatures for greater efficiency

DLR scientists are also investigating solar power plants with higher process temperatures. Such power plants have increased cycle efficiencies, and hence require fewer collectors per kilowatt-hour generated, which reduces power generation costs. One important, innovative approach in parabolic trough power plants is direct steam generation. With this system, the steam that drives the turbine is generated directly in the absorber tube. This removes the 400-degree-Celsius limit that applies to conventional heat transfer fluids (thermal oil). DLR is also investigating new heat transfer media such as molten salt, particles and gases to achieve even higher process temperatures.

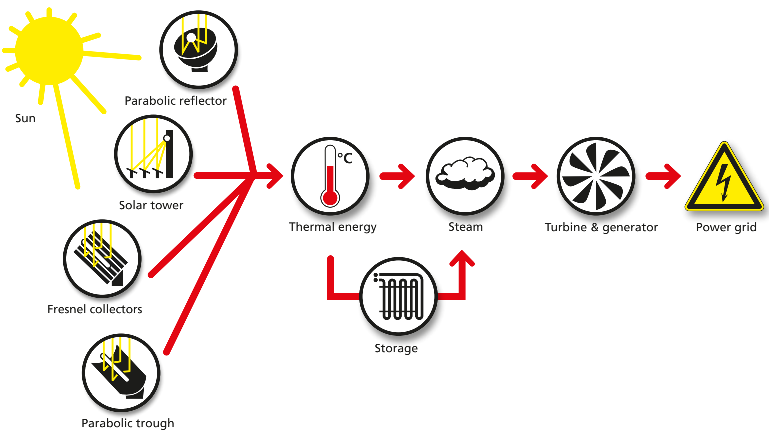
Reflectors under test – quality measurements at the Plataforma Solar in Almería (southern Spain)

DLR solar tower in Jülich – research power plant for further development of high-temperature process technology

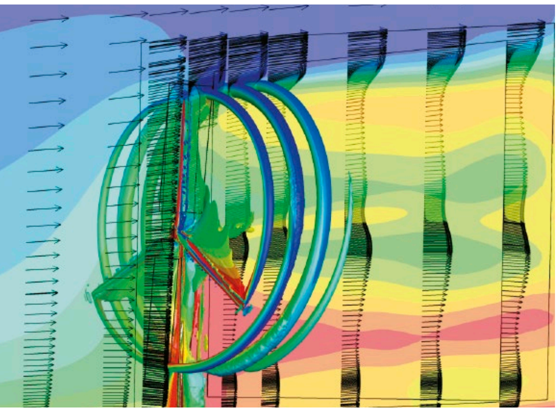
Solar power plants

Solar thermal power plants use mirrors to concentrate solar radiation and convert it into thermal energy. This process is called Concentrating Solar Power, or CSP. The concentration enables temperatures of 400 to 1200 degrees Celsius to be reached. This thermal energy can be used to generate power as in a conventional thermal power plant or with a Stirling engine.

Depending on the type of power plant, the solar radiation is concentrated using four different mirror shapes. In parabolic trough power plants, trough-shaped mirrors concentrate the radiation onto a tube mounted at the focus of the parabola. If the large, curved mirrors are divided into long flat strips, Fresnel collectors are created; these also concentrate the radiation onto a tube. With tower power plants, a number of flat mirrors direct the radiation onto a receiver at the top of a tower. Lastly, dish units involve a stand-alone parabolic reflector that concentrates the solar radiation to a point.



Synergies for wind energy research



The latest scientific and research methods are interconnected in a multidisciplinary simulation environment to improve the design of wind turbine rotors

More output, less noise

At almost eight percent, wind energy is already making an appreciable contribution to power generation in Germany. According to the Federal Government's energy policy targets, it should be supplying 30 percent of the total power demand by 2030.

To achieve these targets, it is not only necessary to expand the area available for wind farms, but also to further reduce the cost of generating power. This might, for example, be achieved by increasing the output of wind energy facilities by increasing their reliability through alternative control options or by improving the efficiency of the production processes. In future, offshore wind turbines are expected to reach an output of up to 20 megawatts. To do this, the turbines, their construction and the materials used will have to undergo substantial development. In addition, wind power units will have to rotate more quietly than they do now, especially onshore.

DLR can make important contributions to wind energy exploitation using expertise and technology from aeronautics and space research. To optimise wind energy facilities from an aerodynamic, aeroelastic and structural perspective, DLR researchers are working with both numerical simulations and experiments in wind tunnels that are unique in Europe. DLR has considerable experience in modelling the entire system of a wind power facility. In future, intelligent materials and structures from adaptive systems research should make controllable rotor blades possible to achieve higher efficiency, especially in strong winds. In addition, using lidar systems – laser-based optical scanning systems – wind flows and their interactions within an entire wind farm can be recorded. Satellite images also help with wind forecasts for the site of a wind farm, enable optimum control of the individual units and allow prediction of the power input into the grid.

Lighter and bigger – wind turbines of the future

If wind turbines using current designs were to be enlarged to have an output of 20 megawatts, they would need rotor blades 125 metres long and weighing more than 100 tons. The fibreglass materials used at present are too heavy for blades of this size. With carbon-fibre reinforced composites, it is possible to make rotor blades that are five times stronger and stiffer. DLR researchers are working on the integration and automated production of carbon-fibre reinforced rotor blades to make them significantly lighter and more stable without increasing costs.

Expertise from DLR aeronautics research for more powerful, quieter and lighter wind turbines

New options with new materials

Almost all work in energy research is related to issues concerning materials – whether it involves robust, durable power plant components or highly heat-resistant combustion chamber walls. In its activities developing and investigating high-performance materials in various fields, the DLR Institute of Materials Research contributes to enabling innovative components and systems for energy technology.

Greater efficiency in conventional power generation

New materials with better high-temperature stability, corrosion resistance and the ability to withstand thermal shock are needed for a new generation of efficient power plants that produce significantly less pollutant emissions. WHIPOX®, the all-oxide fibre-reinforced ceramic matrix composite developed by DLR, meets these requirements. In cooperation with industry and other research partners, materials researchers are manufacturing components made of WHIPOX® and creating numerical models of the material's behaviour.

Materials capable of withstanding 1000 degrees Celsius or more

When hundreds of mirrors are directing radiation from the Sun onto a single point – the radiation receiver – in a tower power plant, temperatures of over 1000 degrees Celsius are reached, and large temperature gradients occur. Researchers at the DLR Institute of Materials Research are therefore identifying when and how the materials can be damaged, carrying out ageing tests over accelerated timescales, and so predicting the operating life of a radiation receiver.

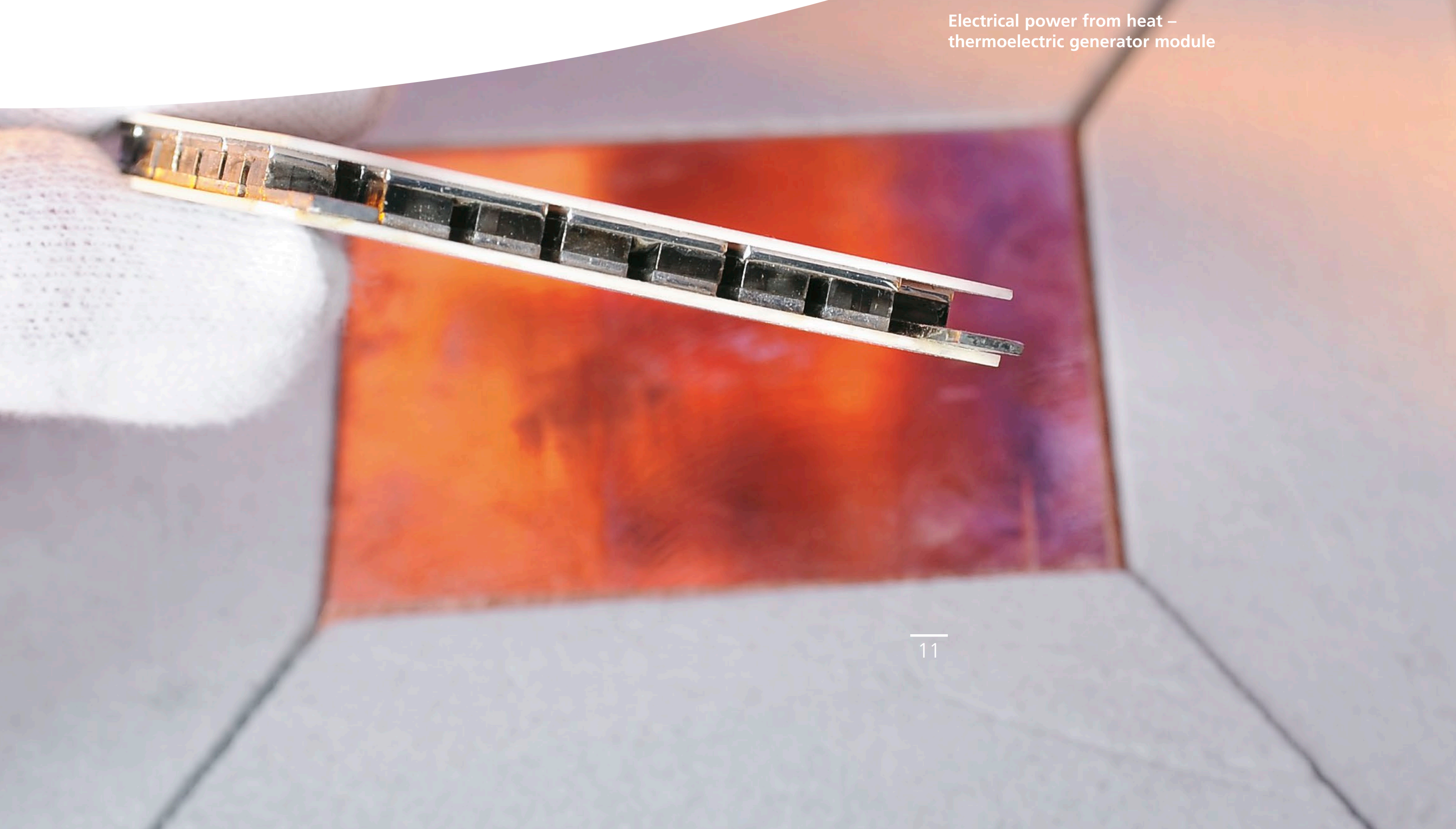
Another focus of research is the production of hydrogen from water using solar energy. There has already been some success using concentrated solar radiation to produce hydrogen in a ceramic reactor coated with iron oxide. Currently, materials researchers are working with solar researchers to develop improved functional ceramics for a higher hydrogen yield and longer operating life.

Power from waste heat

Thermoelectric materials can convert heat flow directly into electrical power. This means that some of the waste heat in vehicles and heat flows in heating and industrial facilities can be exploited. DLR researchers are developing materials and manufacturing processes for higher operating temperatures of the materials to expand the scope of application and increase the energy conversion efficiency. Scientists at the Institute are producing both thermoelectric materials from the raw material, a high-purity powder, and complete thermogenerator modules.

Aerogels – ultra-light super insulators

Aerogels are ultra-light solids that have exceptional insulation properties due to their nanoporous structure. Making simple chemical changes can create soft, flexible materials from the most brittle substances. DLR researchers have developed lightweight concrete with outstanding insulating properties by adding aerogels to a cement mixture. They are also combining different types of aerogels with plastic or metal; in this way, they are developing superinsulating composites for thermal isolation in spacecraft and satellites.



Electrical power from heat – thermoelectric generator module

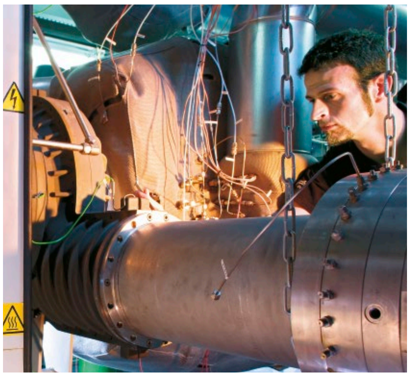
Decentralised power plants – energy where it is needed

Additional decentralised power plants situated close to consumers are needed to reduce environmentally harmful emissions and make better use of fuels. Together with a number of project partners, the DLR Institute of Technical Thermodynamics and the DLR Institute of Combustion Technology are investigating pioneering, sustainable technologies for energy supply using combined heat and power generators based on micro gas turbines and fuel cells.

Power and heat at the consumer's location

Decentralised power plants enable the exploitation of the heat created during power generation. Using combined power and heat generation (Combined Heat and Power; CHP), the fuel can be used in an efficient and, hence, environment friendly manner, increasing cost-effectiveness and sustainability. The carbon dioxide emissions from CHP systems are up to 70 percent lower than comparable systems, where the generation of power and heat is separated. Mini cogeneration units are suitable for single and multiple occupancy households. Unlike the gas-fuelled systems used to date, a micro gas turbine can be operated using a variety of fuels, emitting fewer pollutants as it does so. Micro gas turbines have another advantage: longer intervals between maintenance checks and reduced maintenance costs. There is still a need for research and development on their electrical efficiency, which is lower than in those with gas-fuelled systems. DLR researchers are working on optimising the components, minimising pressure and heat losses, and using ceramic materials.

In the area of combined heat and power generators based on micro gas turbines, the Institute of Combustion Technology is also investigating new components and concepts for gaseous and liquid fuels. In doing so, the researchers are determining the combustion properties of conventional and alternative fuels. New, low-pollutant, fuel-flexible combustion systems for micro gas turbines are also being developed. The Institute operates a micro gas turbine test rig with an



Highly efficient hybrid power plant achieved by coupling a gas turbine to a high temperature fuel cell system

optically accessible combustion chamber to characterise and optimise the components under development and the system design concepts.

Efficient and reliable, even for aviation – fuel cells

Fuel cells can be used for static power supply (mostly in combined heat and power systems) or for vehicle propulsion. The electrical efficiency of fuel cells is up to 60 percent higher than with other technologies. The DLR Institute of Technical Thermodynamics is working on further development of both high tempe-

Tests with new materials – vacuum-plasma spray system for coating fuel cell components

rature fuel cells that can use natural gas directly and low temperature fuel cells, called polymer electrolyte fuel cells, that use hydrogen or methanol as fuel. The researchers are investigating new materials and cell designs and are working on industrial manufacturing techniques that will result in a reliable and highly scalable production. The challenge faced when developing fuel cells is slowing the ageing process, and thus extending the operating life. By measuring the current density distribution, scientists can monitor the degradation processes and thus improve fuel cells in the medium term.

One innovative application largely developed by DLR is the integration of fuel cell systems in passenger aircraft. A multi-functional fuel cell system is currently being tested. The system is used as an auxiliary power unit to supply electrical loads on the plane, and also to produce water for use in the cabin. The fuel cell also powers an electric nose wheel, which can substantially reduce the emission of pollutants during ground operations. The Antares DLR-H2 powered glider is the first manned aircraft in the world capable of taking off using only fuel cell propulsion. This research aircraft is used as a flying test platform for fuel cells in aviation.

Highest efficiency in hybrid power plants

Combining a gas turbine with a high temperature fuel cell system to create a hybrid power plant promises very high levels of efficiency in energy conversion. The primary advantage of doing this is that, as well as producing power, the waste heat from the power generation process can be used. With units of more than 10 kilowatts output, electrical efficiencies of over 60 percent can be achieved and over 90 percent of the energy can be used. This is possible because the gas turbine feeds preheated, compressed air into fuel cells, where power is produced by electrochemical processes. Controlling the complete system is a particular challenge, as the dynamic behaviours of the two components are very different. DLR researchers are using computer models to develop control strategies for this.

Fuel cells provide possible sources of emission-free transport and decentralised power supply

Flying with fuel cells – the DLR Antares H2 powered glider is the first aircraft capable of taking off using fuel cell power

Storage facilities – key components of a sustainable energy system

With the increasing exploitation of variable renewable energy sources, it is becoming ever more important for energy to be available to the consumer on demand. Energy storage systems will be a key component for achieving this in a sustainable energy economy.

Whether in the form of heat in rock or electrical energy in a battery, energy can be stored in a wide variety of ways. DLR researchers at the Institute of Technical Thermodynamics are developing thermal, chemical and thermochemical energy storage, adiabatic compressed air storage systems and batteries.

How thermal energy can best be stored

Energy is most cheaply and efficiently stored in the form of heat. Large molten salt storage systems are already being used in solar power plants. In the quest for more cost-effective, flexible, hightemperature thermal storage systems, DLR researchers are developing and using solid materials such as ceramics, concrete and rock. In Stuttgart, researchers at the 'Hotreg' high temperature thermal storage test facility are able to test the storage properties of various materials with and without pressure at temperatures of up to 850 degrees Celsius.

Latent heat storage systems – energy stored in the smallest space

Latent heat is 'hidden' energy that a substance absorbs during a phase change from solid to liquid or from liquid to gas – without changing temperature as it does so. Latent heat storage systems have the advantage of being able to store a great deal of energy in a small space with mini¬mal temperature change. DLR researchers are cooperating with partners in industry to develop latent heat storage systems filled with mixtures of salts. The salts change from a solid to a liquid state at an unchanged temperature. The energy in the system can be very efficiently transferred and absorbed through a phase change at constant temperature. An initial pilot plant, the largest high-temperature latent heat storage facility in the world, was successfully tested at Carboneras, in southern Spain, in 2010/2011.

Thermochemical storage – using heat of reaction

Inexpensive substances such as calcium hydroxide can be separated into calcium oxide and steam by adding heat. Using this separation, heat can be stored indefinitely without loss before it is released again in the reverse reaction. Thermochemical heat storage systems employ this principle. Fundamental questions concerning the reaction and the process engineering implementation are being solved at DLR, in cooperation with industrial partners for applications in process technology and solar power generation.

Chemical storage – hydrogen stores power from renewable sources

What should be done with surplus power when the wind is blowing and demand is low? It can be used to produce hydrogen through electrolysis. The stored gas can subsequently be re-used in a gas turbine or fuel cell to generate power, or for other purposes. Researchers at DLR are working on methods to generate hydrogen more efficiently and cost effectively. They have developed a coating for electrodes employed in alkaline electrolysis, which significantly reduces the electricity demand for the production of hydrogen. With polymer electrolysis technology, DLR researchers are improving the durability of the components that enable the benefits of high hydrogen yield and great flexibility of output to be exploited. High temperature electrolysis, which DLR is also working on, is still in the early stages of development.

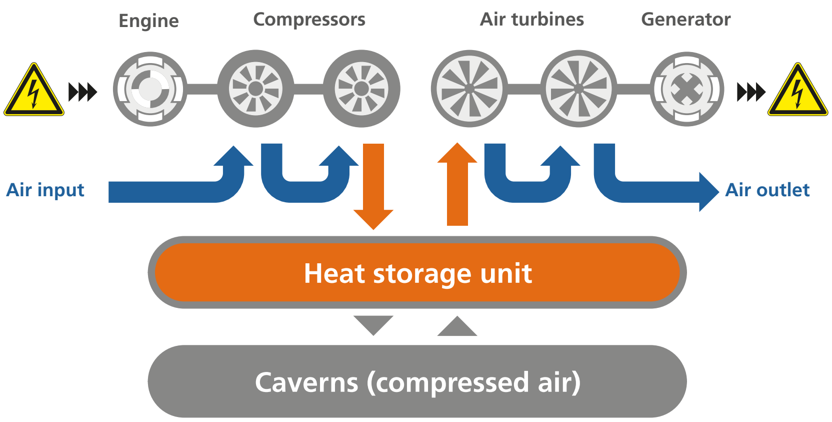
Underground – adiabatic compressed air energy storage systems

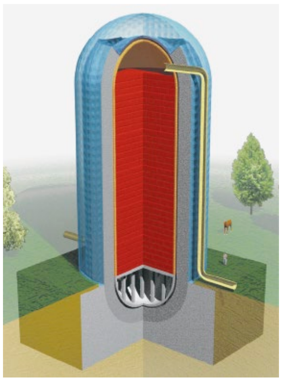
Working together with partners in industry, DLR researchers are investigating compressed air storage systems that will be capable of stabilising the power grid. If there is an excess of power, air is compressed and fed into subterranean salt caverns. When power is needed, the compressed air is released to drive a turbine. With adiabatic compressed air storage systems, the heat created during compression is stored temporarily. The thermal energy is then used to heat the compressed air to a high temperature prior to it being fed to the turbine. With this procedure, energy can be temporarily stored with an efficiency of up to 70 percent.

Electric storage systems – battery technology

Environment-friendly, inexpensive batteries are a key challenge for electric

Operating principle of an adiabatic compressed air storage system





Concept of a pressure-tight heat storage unit for adiabatic compressed air storage system power plants mobility. A major objective of the work at DLR is the development of radically new battery technologies, mainly lithium-sulphur and lithium-air batteries, which promise significantly higher energy densities using low-cost, environment-friendly materials.

For these next-generation batteries, DLR researchers are, for example, working on better electrode structures to keep them stable over as many charge/discharge cycles as possible. Other improvements are expected from a cathode construction whereby the cathode undergoes less structural change during the charge/discharge cycles. In addition, there is an innovative approach to electrode contacts, which can be used to achieve exceptional properties. In parallel, the researchers are working on thermoelectrochemical modelling of batteries. These models can be used to predict chemical processes related to operating life and safety at the sub-micrometre or nanometre scale.

Ceramic materials are tested in the 'Hotreg' high-temperature thermal storage test facility to assess their suitability

The full picture – energy systems analysis

The complete energy system is composed of various elements; each of these is being researched and further developed. The aim of systems analysis in DLR energy research is to create concepts for a coherent, secure and cost-effective system for the future.

Scenarios and strategies for the transformation of the energy system

The systems analysts use various scenarios to consider possible developments in energy supply. These scenarios, which are developed for Germany, other countries in Europe, in the MENA (Middle East North Africa) region or even worldwide, represent a fundamental basis for decision-making in government, industry and research. Using systems analysis, decision makers can make better assessments of the technical and economic possibilities and long-term development prospects for the energy system.

In their studies, the researchers investigate potential methods to achieve the transformation in line with the anticipated proportions of renewable energy or those determined by policy. Another important aspect of the studies is the calculation of the investment required to transform the energy system, as well as the economic advantages that could be attained in the long term by reducing fuel costs. In addition, as part of the studies, the resulting added value created in industry by the transformation (among other things, jobs) and the resulting enhanced competitiveness are also examined.

Dynamic simulation of the power supply system

At any time of year, power plants must be capable of meeting the needs of energy consumers, even in the case of fluctuating power generation through renewable energy sources. Using the 'REMix' simulation model developed by DLR, systems analysts can simulate this highly complex system. Data with high temporal and spatial resolution on renewable electricity generation potential and the power consumption in Germany and Europe are included in this model. Further elements of this model are energy storage, adjustable power plant capacities, load balancing and transfer, connecting the energy sector to the heating sector (for example, via electric heat pumps or systems for combined heat and power) and transport. The opportunities for balancing the demand and production of energy across Europe also play a role here, as well as importing dispatchable renewable energy sources as offset options. In this way, the model can provide

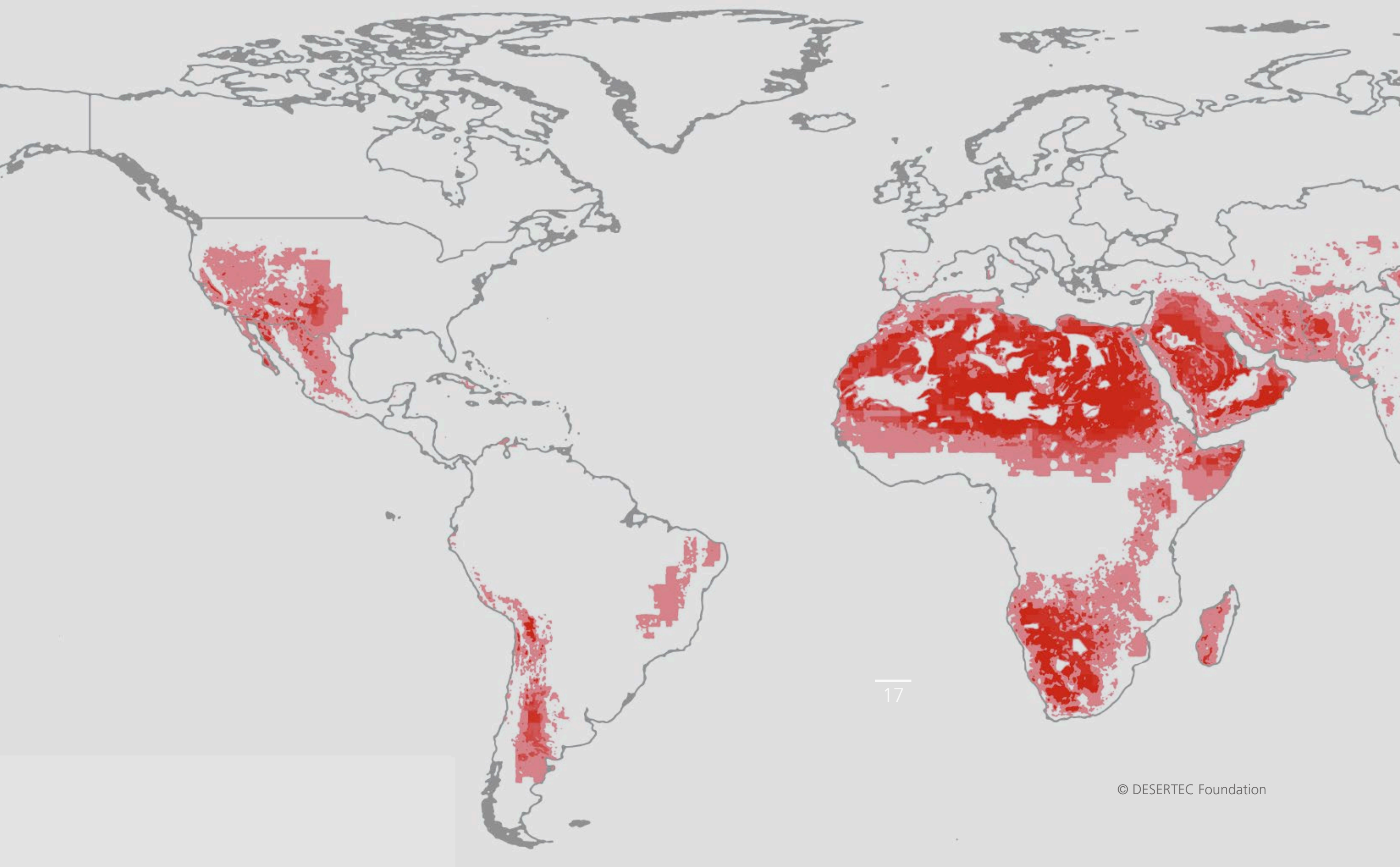
Scenarios for energy systems analysis reveal opportunities for a sustainable, safe and economical energy system answers that are best suited to implementing development measures for the energy transformation, from both technical and structural points of view, as well as from the perspective of the national economy.

In terms of the analysis of renewable resources and potentials, system analysts are working closely with remote sensing at DLR. On an international scale, DLR is involved in multiple initiatives to create maps of renewable energy resources, for example, within the framework of the Mediterranean Solar Atlas, the Global Atlas for Renewable Energy from the International Renewable Energy Agency (IRENA) and the Energy Sector Management Assistance Program (ESMAP) from the World Bank. In addition to the REMix model, which is focused on the overall energy system, innovative technical solutions are also being examined in simulation models, for example, combined desalination plants for seawater and load management.

Analysis and evaluation of energy policy instruments

The scientific results of systems analysis will only be effective if they are taken into consideration and implemented by industry and politics. To this end, DLR provides policy advice to a number of German Federal ministries that are crucial to the design of support programmes and laws for the efficient implementation of national goals in the field of renewable energy sources.

For the model-based analysis of research instruments, DLR has for several years been developing an agent-based simulation model, AMIRIS, which can conduct analyses on the impact of regulatory frameworks both at the micro-level of the participants as well as at the macro-level of the overall energy system. Agent-based modelling – with its roots in artificial intelligence research – provides a suitable approach here, because a learning participant is at the centre, embedded in a social system, with his appropriate perceptions and patterns of action. In energy systems economic analyses, this enables consideration of the behaviour of the participants, as well as the effects of their changes and repercussions on the energy system.



Potential analyses – suitable regions for solar power plants are determined from remote sensing data

Energy research institutes at DLR

Gas turbines

Institute of Combustion Technology (Stuttgart), DLR.de/vt/en
Institute of Propulsion Technology (Cologne), DLR.de/at/en

Solar research

Institute of Solar Research (Cologne, Stuttgart, Jülich, Almería), DLR.de/sf/en

Wind energy

Institute of Aeroelasticity (Göttingen), DLR.de/ae/en
Institute of Aerodynamics and Flow Technology (Göttingen, Braunschweig), DLR.de/as/en
Institute of Propulsion Technology (Göttingen), DLR.de/at/en
Institute of Structures and Design (Stuttgart), DLR.de/bk/en
Institute of Composite Structures and Adaptive Systems (Braunschweig), DLR.de/fa/en
Institute of Flight Systems (Braunschweig), DLR.de/ft/en
Institute of Atmospheric Physics (Oberpfaffenhofen), DLR.de/pa/en

Materials research

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Decentralised power plants

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Energy storage

Institute of Engineering Thermodynamics (Stuttgart), DLR.de/tt/en
Institute of Combustion Technology (Stuttgart), DLR.de/vt/en

Energy systems analysis

Institute of Engineering Thermodynamics (Stuttgart), DLR.de/tt/en

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Quality control – researchers use optical measurement techniques to check the dimensional accuracy of collecting mirrors for a solar power plant

DLR at a glance

DLR is the national aeronautics and space research centre of the Federal Republic of Germany. Its extensive research and development work in aeronautics, space, energy, transport and security is integrated into national and international cooperative ventures. In addition to its own research, as Germany's space agency, DLR has been given responsibility by the federal government for the planning and implementation of the German space programme. DLR is also the umbrella organisation for the nation's largest project management agency.

DLR has approximately 8000 employees at 16 locations in Germany: Cologne (headquarters), Augsburg, Berlin, Bonn, Braunschweig, Bremen, Goettingen, Hamburg, Juelich, Lampoldshausen, Neustrelitz, Oberpfaffenhofen, Stade, Stuttgart, Trauen, and Weilheim. DLR also has offices in Brussels, Paris, Tokyo and Washington D.C.

DLR's mission comprises the exploration of Earth and the Solar System and research for protecting the environment. This includes the development of environment-friendly technologies for energy supply and future mobility, as well as for communications and security. DLR's research portfolio ranges from fundamental research to the development of products for tomorrow. In this way, DLR contributes the scientific and technical expertise that it has acquired to the enhancement of Germany as a location for industry and technology. DLR operates major research facilities for its own projects and as a service for clients and partners. It also fosters the development of the next generation of researchers, provides expert advisory services to government and is a driving force in the regions where its facilities are located.

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