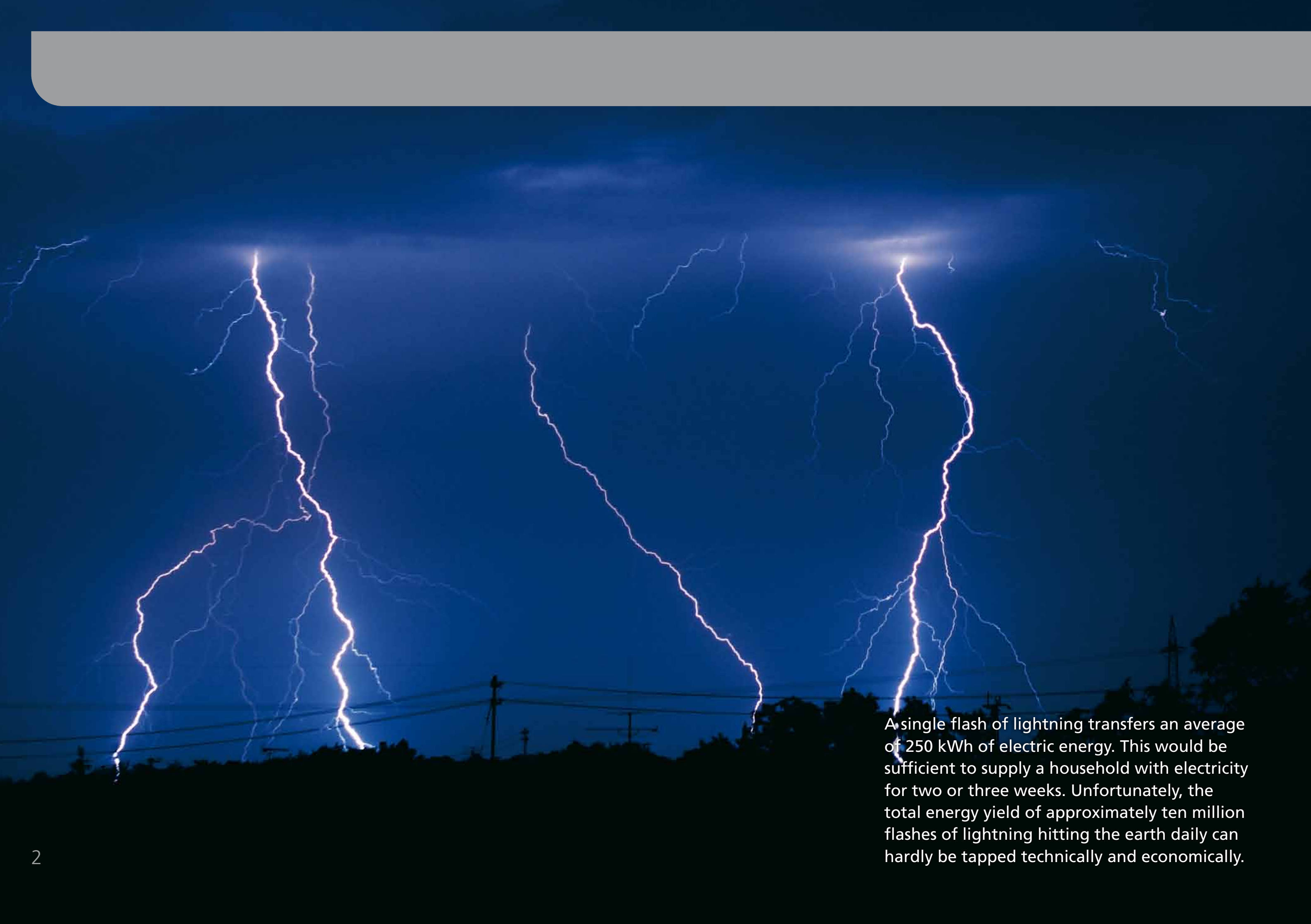
Karlsruhe Institute of Technology

Energy for Tomorrow

KIT ENERGY CENTER

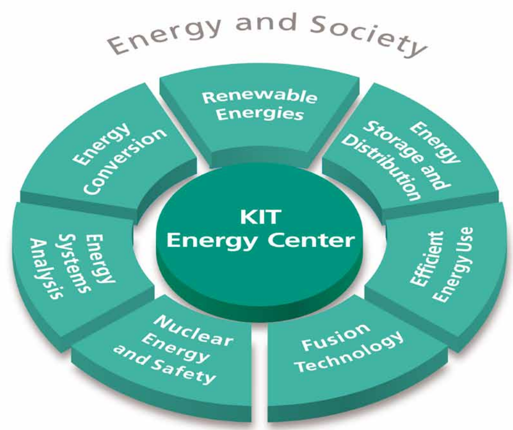
KIT – University of the State of Baden-Wuerttemberg and
National Research Center of the Helmholtz Association



A single flash of lightning transfers an average of 250 kWh of electric energy. This would be sufficient to supply a household with electricity for two or three weeks. Unfortunately, the total energy yield of approximately ten million flashes of lightning hitting the earth daily can hardly be tapped technically and economically.

Energy Research at the Karlsruhe Institute of Technology

In the near future, more than seven billion people will need to be supplied with energy. Karlsruhe Institute of Technology (KIT) fulfilling the mission of a university of the State of Baden-Wuerttemberg and that of a national research center of the Helmholtz Association accepts this challenge and operates the KIT Energy Center for this purpose.



KIT Energy Center: Mission and Strategy

The KIT Energy Center, whose 1100 staff members make it one of Europe's largest energy research establishments, pools the energy research conducted by KIT, the merger of Universität Karlsruhe and Forschungszentrum Karlsruhe, together with renowned cooperation partners. Its interdisciplinary approach links fundamental research with applied research into all energy resources for industry, households, services, and mobility.

Competences in engineering and science, but also in economics, the humanities and social sciences as well as law, result in a holistic assessment of the entire energy cycle at the KIT Energy Center. Research includes the societal side of innovative energy technologies.

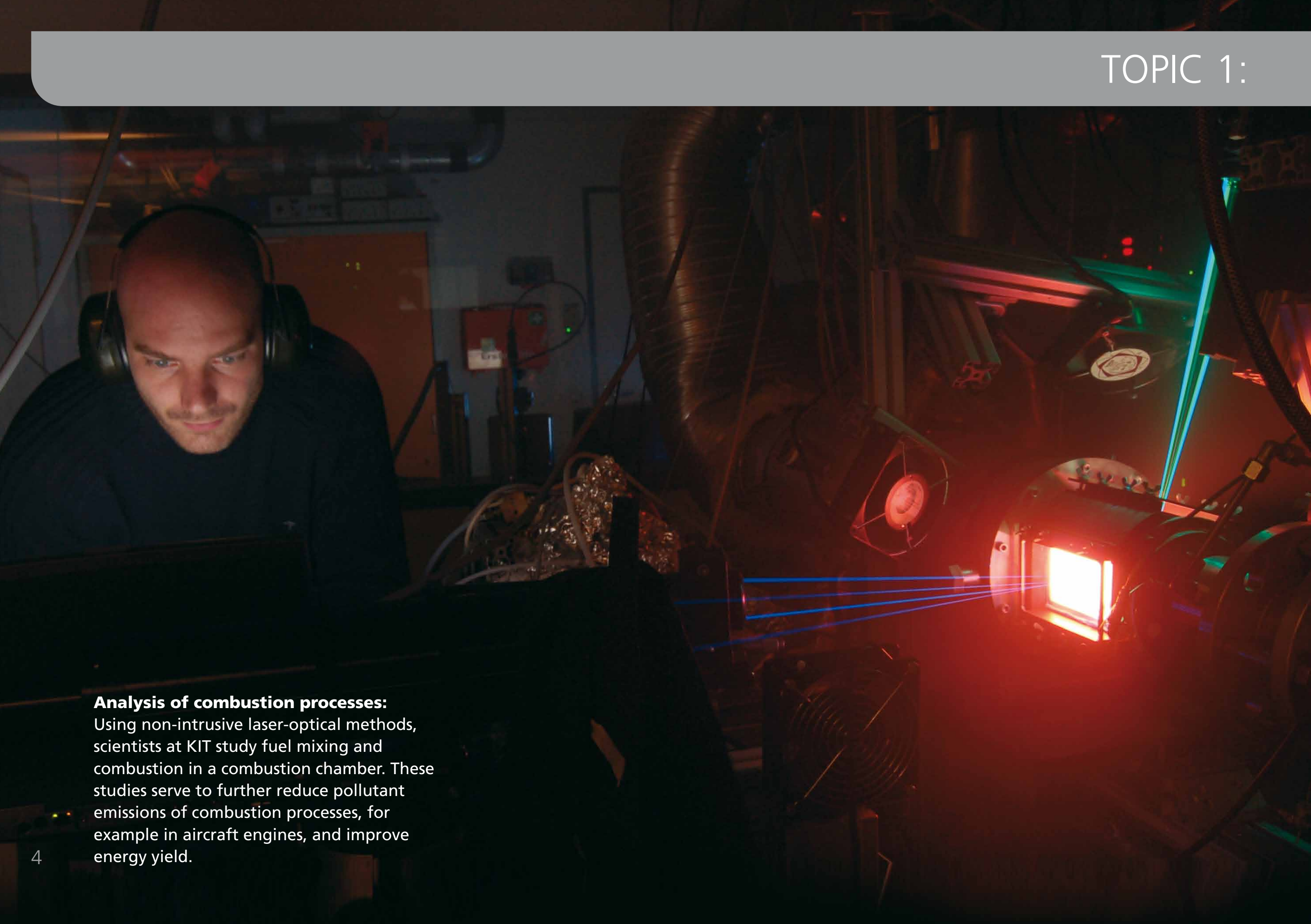
The activities of the KIT Energy Center are clustered in seven topics:

- Energy conversion
- Renewable energies
- Energy storage and energy distribution
- Efficient energy use
- Fusion technology
- Nuclear energy and safety
- Energy systems analysis

The Knowledge Triangle

Like the European Union, KIT emphasizes the knowledge triangle: Research – Education – Innovation. Its proximity to top-ranking research makes education and training at KIT highly attractive. At the same time, KIT uses its enormous innovative potential in cooperation with industry to ensure that excellent research findings are turned into commercially viable products in near real time.

TOPIC 1:



Analysis of combustion processes:
Using non-intrusive laser-optical methods, scientists at KIT study fuel mixing and combustion in a combustion chamber. These studies serve to further reduce pollutant emissions of combustion processes, for example in aircraft engines, and improve energy yield.

Energy Conversion

Energy conversion turns natural energy resources into end user energies which can be tapped. The KIT Energy Center is involved in all kinds of energy conversion, such as electrochemical processes in fuel cells or electromechanical processes in generators. The focus is on combustion: chemical energy is turned into thermal energy.

Combustion and Its Optimization

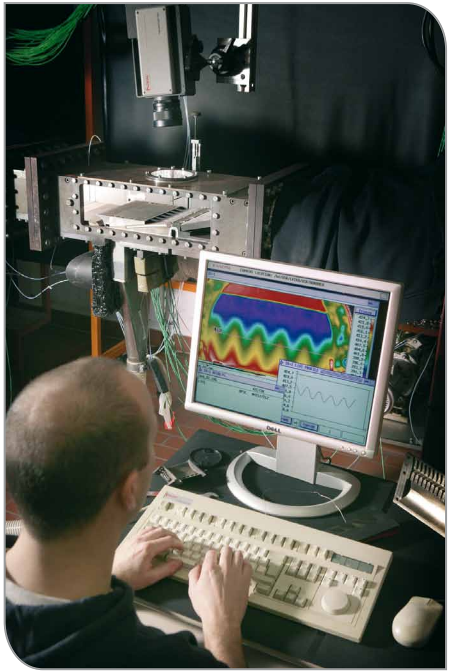
Energy research at KIT looks for ways to convert fuels with a maximum of resource conservation and a minimum of emissions. The efficiency and non-polluting characteristics as well as the reliability and service life of turbines and engines must be further improved.

Synthetic Fuels

Future fuels should release as little CO_2 and other pollutants as possible. It is for this reason that scientists at KIT are also developing new types of synthetic fuels, partly from organic residues, and optimizing them for their respective uses and with a view to future emission regulations.

Energy Conversion Systems

To allow the benefits of new fuels to be fully exploited, KIT scientists work on matched and coupled technical systems. One of the challenges lies in achieving optimum combustion quality even of variable fuels. Work at KIT is centered on internal combustion engines with direct fuel injection, gas turbines, and new power plant processes as well as cogeneration systems. At the same time, scientists develop cooling technologies, study materials, and conduct computer simulations of physical and chemical processes.



Model thermal analysis of a cooled turbine blade: The thermogram recorded by an infrared camera illustrates the periodic temperature field between the ribs of the model.

Motor fuel from straw: The bioliq® concept developed at KIT makes use of residues arising from agriculture and forestry, such as straw and wood waste, to produce synthetic biofuels. These residues need neither additional areas for cultivation, nor are they suitable food or feed; consequently, there will be no competition between fuel tanks and dinner plates. As this biomass has but a low energy density, it cannot be transported economically over long distances. For this reason, a liquid intermediate product of high energy density is first produced in decentralized plants close to the sources. This intermediate product is then converted into fuel or source materials for the chemical industry on an economic scale in centralized large facilities.

Renewable Energies

Fossil fuel reserves are limited. Moreover, these fuels release CO_2 into the atmosphere and, thus, intensify the greenhouse effect. This is why the share of renewable energies shall be increased in Germany and worldwide. Wind and sun are not available for energy generation on a steady scale. The scientists at KIT are therefore focusing on studying renewable energy resources capable of supplying base load power.

Biomass

Burning biomass in effect releases only as much CO_2 as the plant absorbed from the atmosphere during its growth period. This makes for a more favorable CO_2 balance than the combustion of fossil energy sources. The bioliq® process allows biological residues to be turned into high-grade synthetic motor fuels. A large-scale pilot plant is being built at KIT to demonstrate all process steps, from bales of straw to the filling station.

Renewable Hydrogen

Hydrogen can also be obtained from renewable energy sources: KIT works on a process of a hydrothermal gasification to produce hydrogen from wet biomass, such as sewage treatment sludge or liquid manure. The VERENA pilot plant allows trials to be conducted under near-industrial conditions.

Fast pyrolysis in the bioliq® plant: Biomass is converted into a liquid intermediate product for transportation.

Geothermal Energy

The interior of the earth is considerably hotter than its surface. As a consequence of its location in the Rhine Valley, Karlsruhe has excellent geologic conditions for tapping geothermal energy. KIT's research into shallow and deep geothermal energy sources is about energy conversion for heating and cooling, electricity generation, cogeneration, and combined cold and power schemes.

Geyser in Iceland: Hot water from the depths of the earth can erupt to the surface in some places.

European-wide interconnection of electricity grids: Three-phase power technology used to be considered state of the art in designing high-voltage power grids. As more and more electricity from non-steady sources, such as wind and sun, is being fed into the grid, high-voltage direct-current transmission (HVDCT) grids are showing advantages. Large thyristor switching stations are needed to convert the high-voltage direct current into alternating current for consumers. Thanks to HVDCT technology, the grid frequency is extremely stable even under highly varying loads. The photograph shows the valve hall of the HVDCT station at Moyle, Northern Ireland.

Energy Storage and Energy Distribution

Innovative technologies of energy storage and efficient grid structures for energy distribution are produced at KIT in holistic approaches. These allow new operating facilities to be developed. At the same time, systems integration into grids can be studied and technological impacts assessed.

Protection against short circuits: This high-temperature superconductor wound up as a coil is a component of a current limiter protecting power supply grids against short circuits.

Superconducting Components

Employing the latest materials technology, scientists and engineers turn high-temperature superconductors into innovative superconducting components for energy technology. This adds to the quality, reliability, and efficiency of electric power grids. Superconductivity is among the main areas of KIT energy research.

Facilities for Electric Power Grids

Research in this area serves to ensure the continuity of electricity supply despite increasingly complex and, in part, aging high-voltage systems.

Intelligent Power Grids

More and more small decentralized electricity generators are connected to the grid system especially in Europe. This adds to the need for frequency and voltage stabilization. Supply can only be ensured on a long-term basis by intelligent control of national and international grids (smart grids). Scientists at KIT elaborate structures for the different voltage levels in Europe.

Batteries and Accumulators

Nanomaterials enhance the performance and storage capacity of batteries. Applications include lithium batteries for mobile equipment, high-performance batteries for hybrid vehicles, and stationary battery storage banks.

Hydrogen for Energy Storage

Hydrogen is considered an important energy resource of tomorrow, for example, for use in fuel cells. KIT scientists develop novel nanomaterials to raise the capacity of hydrogen stores and make filling easier.

Energy efficiency squared: Right next to the Alfred Ritter chocolate factory at Waldenbuch is the "Ritter Museum." The new building on a square floor plan, which harbors the art collection of Marli Hoppe-Ritter, is characterized by an energy-efficient, ecologically sustainable facility technology concept developed on behalf of the owner: The energy for heating and air conditioning is largely extracted from renewable sources, such as solar power, biomass, and geothermal energy. KIT scientists have assumed responsibility for energy monitoring and for optimizing facility operation.

Efficient Energy Use

Energy used efficiently: The MIRO Mineral-ölraffinerie Oberrhein, an oil refinery, uses waste heat and cogeneration schemes to enhance energy efficiency.

Enhanced Energy Efficiency

Using energy more efficiently saves costs and protects the environment. The KIT Energy Center is focusing on two sectors: on the one hand, energy consumption in industrial processes must be reduced. On the other hand, building construction for energy conservation is an important topic of KIT energy research.

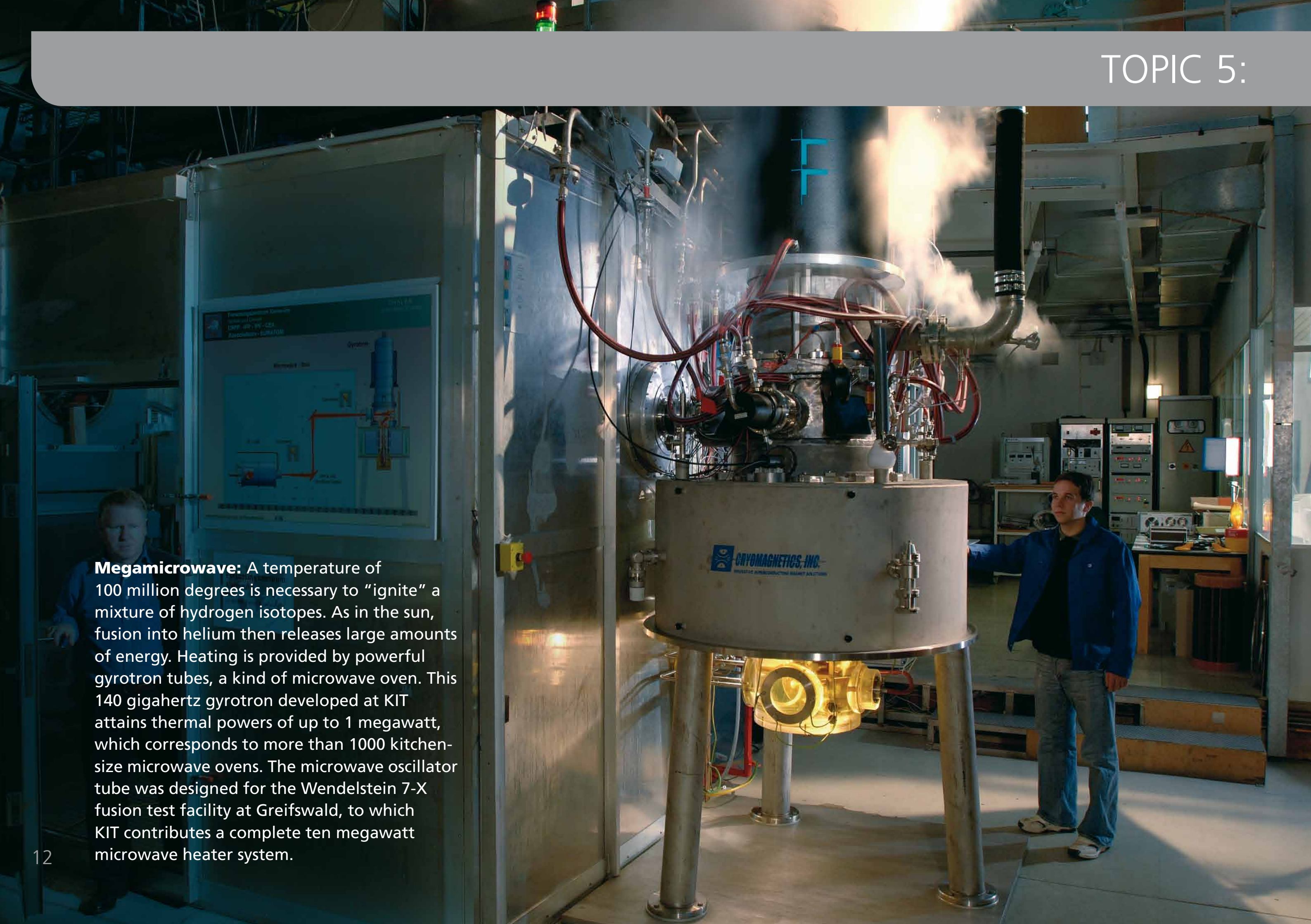
Optimized Process Technology

Energy consumption in manufacturing and processing technologies can be reduced by process intensification, by integrating process steps, and by achieving intelligent combinations of materials and energy. New materials and manufacturing technologies also improve energy efficiency. Thus, scientists in the KIT experimental center of the world's largest microwave process plant, HEPHAISTOS, are developing new ways of producing carbon fiber-reinforced lightweight composite structures for vehicle and aircraft construction.

Energy-optimized Buildings

One future objective of the KIT Energy Center is to reduce the amount of primary energy spent in construction and operation of buildings. At the same time, it is protecting the substance of buildings and keeping space climate inside pleasant. The ideal case is considered to be the zero-energy house.

Within a holistic supply concept, architects and engineers study components providing heat and cold, as well as concepts for ventilation and lighting. Preferably renewable energy resources are being used. Energy losses can be reduced by new insulation technologies and by means of heat recuperation, while effective thermal protection in the summer ensures low cooling loads.



Megamicrowave: A temperature of 100 million degrees is necessary to "ignite" a mixture of hydrogen isotopes. As in the sun, fusion into helium then releases large amounts of energy. Heating is provided by powerful gyrotron tubes, a kind of microwave oven. This 140 gigahertz gyrotron developed at KIT attains thermal powers of up to 1 megawatt, which corresponds to more than 1000 kitchen-size microwave ovens. The microwave oscillator tube was designed for the Wendelstein 7-X fusion test facility at Greifswald, to which KIT contributes a complete ten megawatt microwave heater system.

Fusion Technology

Nuclear fusion offers a safe, economically viable, non-polluting, and nearly inexhaustible energy source. Building a fusion power plant for electricity production is the objective of nuclear fusion research. The fuel is a mix of two hydrogen isotopes: deuterium and tritium. This fuel is heated to 100 million degrees, thus generating a plasma in which the atomic nuclei fuse.

Fusion Research

KIT has one of the world's leading fusion laboratories along with the best equipment for studying and developing fusion technology. This includes the TOSKA low-temperature test facility for superconducting magnet coils and other technical components. The Karlsruhe Tritium Laboratory offers an infrastructure unique in Europe.

Fusion Technology

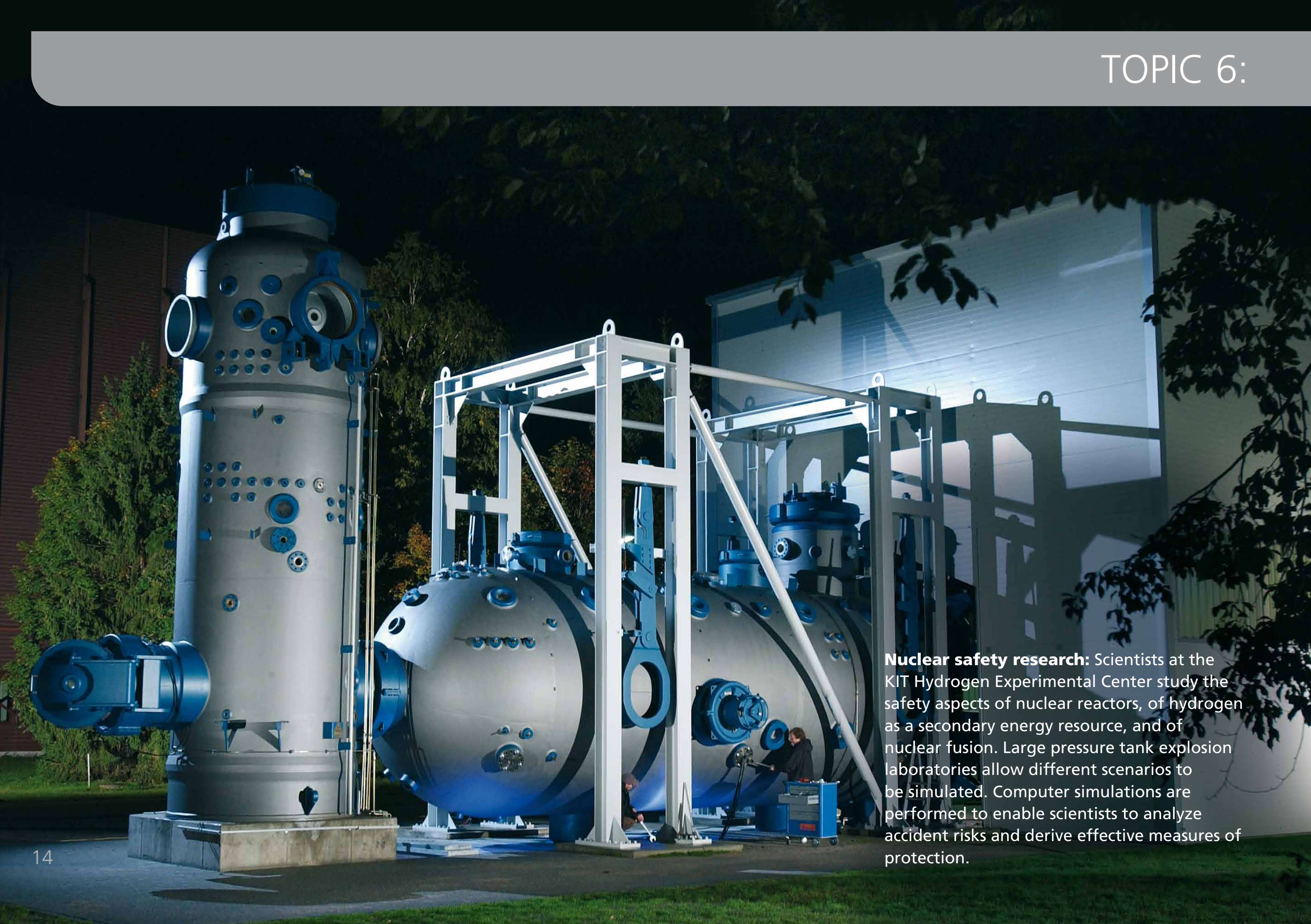
KIT develops indispensable technical components for nuclear fusion: superconducting magnet coils, microwave heater systems (gyrotrons), blankets for producing the tritium fuel and for energy extraction, and divertors for removing the helium "ash" and unspent fuel. In addition, there are developments of high-performance materials and components for the fuel cycle.

Fusion Projects

Fusion research at KIT is part of a variety of international and European large-scale projects: ITER, a large facility for testing technologies for nuclear fusion, is currently under construction in the south of France. At the same time, preparatory work is being conducted on the DEMO prototype power plant.

Inspection under the scanning electron microscope: The lithium orthosilicate developed as a tritium breeding material is subjected to strict quality control.

TOPIC 6:



Nuclear safety research: Scientists at the KIT Hydrogen Experimental Center study the safety aspects of nuclear reactors, of hydrogen as a secondary energy resource, and of nuclear fusion. Large pressure tank explosion laboratories allow different scenarios to be simulated. Computer simulations are performed to enable scientists to analyze accident risks and derive effective measures of protection.

Nuclear Energy and Safety

Irrespective of the decision about the further use of nuclear power in Germany, expert nuclear knowledge continues to be needed in the country in the sense of provident research for the benefit of society. This means ensuring the high safety standard of nuclear power plants and the safe disposal of radioactive waste.

Safety of Nuclear Reactors

Nuclear safety research at Karlsruhe has held a leading position for decades. Its purpose is to detect potential risks as quickly as possible and draw attention to gaps in safety at an early point in time. As there will be no international opt-out of the use of nuclear power, safety research increasingly addresses also new systems and technologies developed in Europe.

Quench experiments: In the Quench experimental facility, water is introduced into the superheated core of a light water reactor as a measure of temperature reduction.

Nuclear Waste Disposal

Scientists at KIT elaborate the fundamentals of a geochemically-based long-term safety assessment for nuclear repositories. Work in management and the conditioning of high-level radioactive waste concentrates on immobilization by vitrification and on studies to what extent long-lived radionuclides can be separated and converted into short-lived or stable isotopes by so-called transmutation.

Radiation Protection

KIT radiation protection research focuses on individuals, their anatomical and physiological characteristics. Scientists develop methods to determine radiation doses on a personal basis, and recommend measures of radiation protection. The emphasis is on radionuclides in the environment, in food, and on radiation exposure in medicine.

TOPIC 7:

Bright lights all over Europe: This NASA picture taken from outer space symbolizes the manifold interconnections of energy systems. The KIT Energy Center is concerned not only with detailed questions of energy supply, but always bears in mind the totality of all energy systems. Interdisciplinary work gives rise to concepts and models of a future energy mix. KIT systematically combines competences in technology, economics, and the social sciences.

Energy Systems Analysis

What could the energy mix of the future be like? Developments in energy technology and key technologies, limited fossil resources and climate change, demographic change, political, social, and economic framework conditions, striving for sustainability – all these factors must be included in analyses of the whole energy system. KIT, in targeted interdisciplinary research, pools technical expertise, methodological know-how in modeling, knowledge in economics and about the societal environment.

Energy Systems and Interactions

KIT scientists consider the totality and the interactions of energy systems, among other things, with the commodities industry, the building trade, industry and transport. They model energy systems and study the interactions with technical, social, economic, and environmental change. Cross-cutting system aspects must be taken into account for the development of energy concepts for the future.

Research for tomorrow's energy mix: Natural, demographic, political, social, and economic factors contribute to energy systems analysis.

Concepts for Action

The KIT Energy Center develops energy systems models and models for power plant operation and expansion planning. KIT scientists study the long-term developments of energy systems, analyze process chains of heat, electricity, and fuel supply; they examine political instruments and elaborate market analyses for energy technologies and services. Knowledge generated in this way is introduced into international projects in the European Union, Southeast Asia, and South America.

The KIT Energy Center

The KIT Energy Center comprises 65 institutes of Karlsruhe Institute of Technology with, at present, a total of 1100 staff members. Technical and scientific coordination and strategic planning of the Center are the responsibilities of a Scientific Steering Committee. An International Advisory Council accompanies the further strategic development of the Center.

The participating institutes and research groups are the operating research units. By combining topics, establishing interdisciplinary cooperation among scientists, and making joint use of sophisticated equipment and facilities, the KIT Energy Center generates a new quality of research and teaching. An interdisciplinary KIT School of Energy establishes ideal framework conditions for teaching. For external partners from industry, the KIT Center develops solutions in energy technology from a single source. Moreover, it acts as a highly valuable consultancy institution for politics, business, and society in all questions of energy.

The KIT Energy Center cooperates closely with other universities and research institutions. Among the cooperation partners are the Universities of Heidelberg and Stuttgart, the German Aerospace Research Center (DLR), and the Research Centers of Garching and Jülich. The European Institute for Energy Research (EIFER) is located at Karlsruhe. This institution, which is run jointly by KIT and Electricité de France (EdF), concentrates on energy and the environment, future energy supplies of urban agglomerations, and energy technologies, such as micro-cogeneration plants, fuel cells, and micro gas turbines.

Please feel free to contact us for further information: www.energy.kit.edu

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The Karlsruhe Institute of Technology (KIT)

Karlsruhe Institute of Technology (KIT) represents the merger of Forschungszentrum Karlsruhe, member of the Helmholtz Association, and Universität Karlsruhe (TH). KIT has a total staff of almost 9000 and an annual budget of about EUR 730 million.

By the KIT merger, one of the largest research and teaching institutions worldwide was established in Karlsruhe, which has the potential to assume a global top position in selected fields of research. The KIT will be an institution of internationally outstanding research in science and engineering as well as a prominent location of excellent teaching setting standards in the promotion of young scientists and in advanced training. KIT counts on innovation through close cooperation with industry. It is a leading European center of energy research playing a visible role worldwide in nanoscience. KIT persues its tasks in the knowledge triangle of research, teaching, and innovation.

Imprint

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Photography Gabi Zachmann, Markus Breig, Martin Lober, Andrea Fabry, Uwe Logemann, NASA GSFC/NOAA NGDC, Siemens AG, Erlangen, Isländisches Fremdenverkehrsamt, Museum Ritter Waldenbuch, MIRO

Design, Layout Wilfrid Schroeder

Printing Wilhelm Stober GmbH, Eggenstein

October 2011