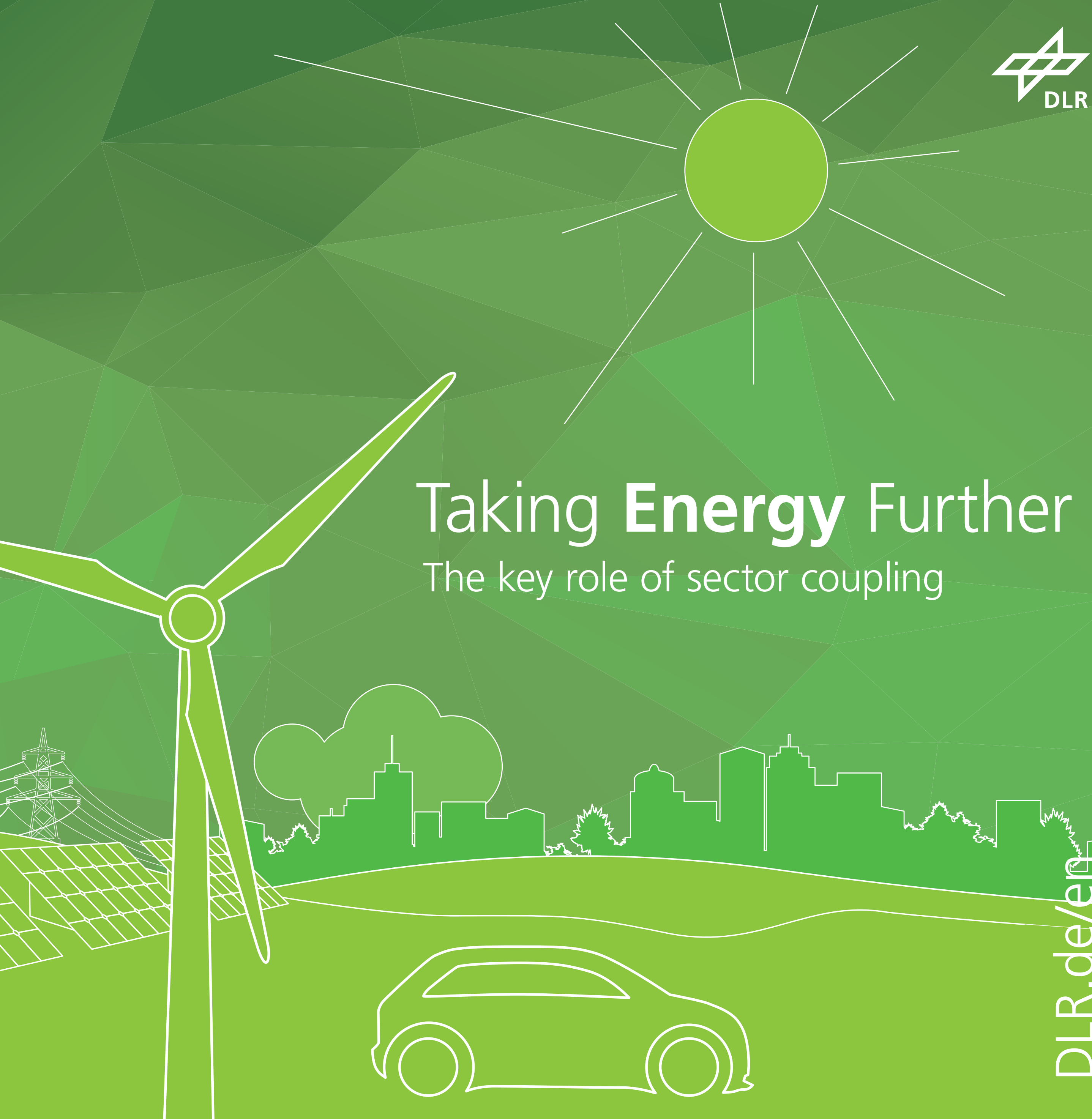
Taking **Energy** Further

The key role of sector coupling



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Dear visitor,

Germans consume most of their energy for electricity, heat and mobility. Renewable energies are increasingly able to cover these requirements. But the availability of these resources fluctuates, so the importance of storage, use optimisation, system transformation and user acceptance to create a climate-neutral, connected energy system is growing. It follows, therefore, that a purely capacity-based approach and the expansion of renewable energy production facilities will not be sufficient. None of this is possible without a flexible system, storage solutions and a cross-sectoral approach.

The consideration of electricity, heat and mobility within a holistic energy system will both reduce greenhouse gas emissions and lower costs. After all, transformation of the energy system must be economically viable in order to succeed. The DLR Energy stand is entirely dedicated to a cross-sectoral approach: we are presenting elements of DLR’s energy research as interconnected solutions within an integrated energy system of the future – accommodating the needs of buildings, the industrial sector and mobility.

For over 40 years, the German Aerospace Center (DLR) has conducted research with the aim of making energy supply safer, more efficient, greener and compatible with societal and economic interests. Our strategic approach on the road to controllable green electricity considers energy storage systems and renewable energies as much as it does sustainable fuels and energy converters. Technical research is accompanied by energy systems analysis that develops and assesses system solutions, while systems engineering concentrates on the development of energy grids. This systemic research approach is vividly presented here in Hannover: this year, our trade show exhibition invites you to share our expertise and showcases components for the energy system of the future. Experience science, find inspiration and feel free to approach us!!

Pascale Ehrenfreund
Chair of the DLR Executive Board

Karsten Lemmer
Executive Board Member

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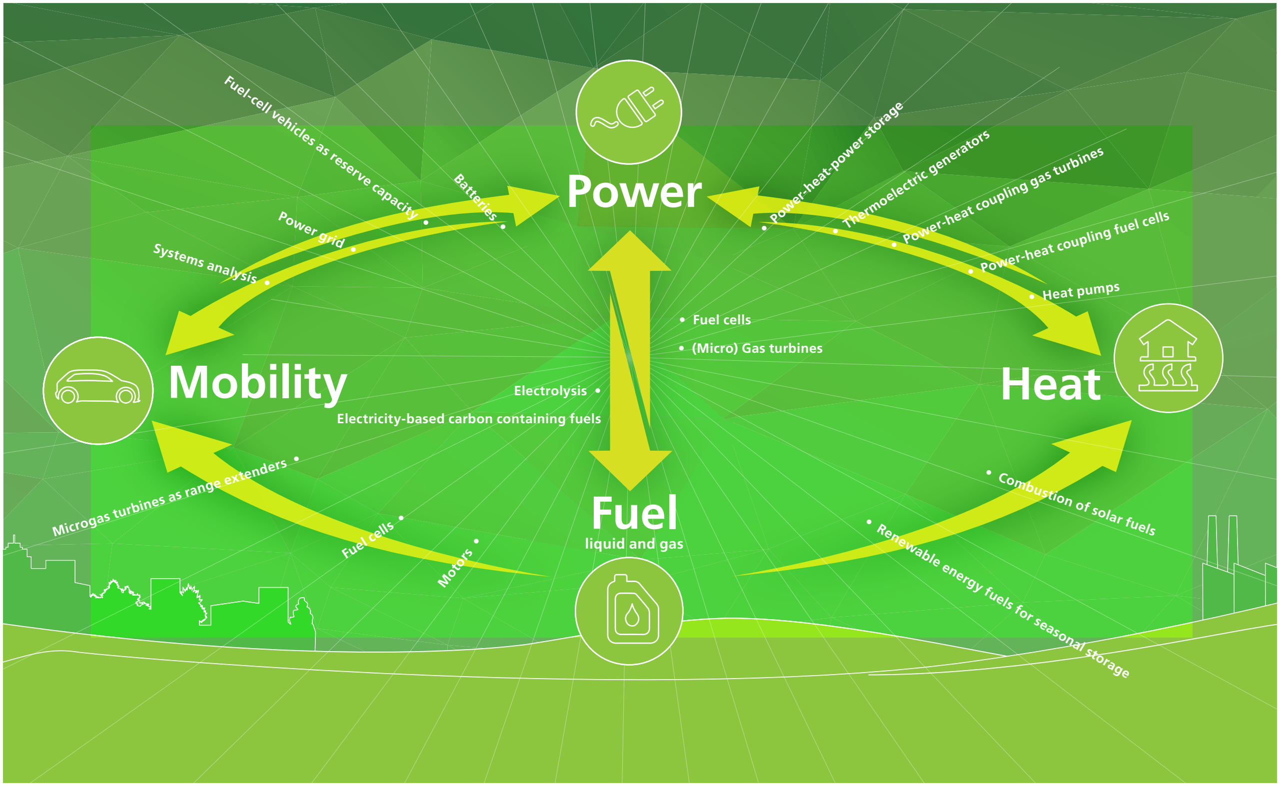
The key role of sector coupling

Connecting electricity, heat and mobility flexibly



Taking energy further

The key role of sector coupling

A functioning sector coupling is the prerequisite for further increasing the share of solar energy and wind power in our energy system. When there is a surplus of electricity, energy can be ‘shifted’ into the heat and mobility sectors, and vice versa when there is a power shortage. In an energy system with a high proportion of fluctuating renewable energy sources, sector coupling is an important flexibility option for a stable power supply. In short, it plays a key role in the Energy Transition.

Energy is more than electricity. Much of the energy is consumed in the heat (heating and cooling) and transport sectors. Here, the proportion of renewable energy is much lower than in the power sector. While in 2017 more than one third of the power came from renewable sources, they accounted for just under 13 percent of German heat consumption and just five percent in the transport sector. For a successful Energy Transition and compliance with the climate protection goals, the heat and transport sectors must also switch to renewable energies.

Here, too, sector coupling is a viable solution, as it enables the use of power from renewable energy sources in the heat and transport sectors. One example is electromobility, which is based on electricity, ideally from renewable sources, instead of fossil fuels.

DLR is one of the leading research institutions in the field of sector coupling. Its energy and transport research provides ideal and unique opportunities to couple the two areas. A comprehensive systemic approach is used to carry out research in close collaboration with industry. From combined heat and power generation with micro gas turbines to production processes for solar fuels and flying with fuel cells, DLR researchers are working on numerous projects to efficiently link all energy sectors. The DLR stand will be showing a selection of research projects at the Hannover Messe 2018 (Hall 27, Stand H84).

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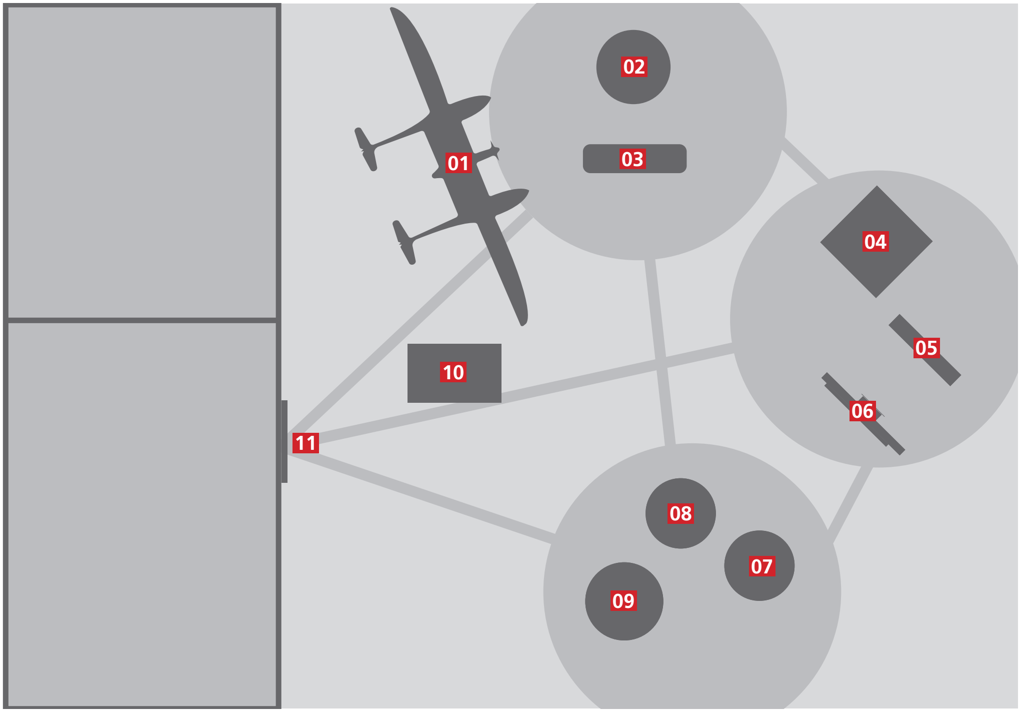
Taking energy further

Stand overview



- 01 HY4 fuel-cell aircraft
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- 12 (Outside) MovR with FCREX – fuel-cell-powered cargo bike

HY4 fuel-cell aircraft

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Fuel-cell powered flight

Brief description

The HY4 is the world's first four-seat passenger aircraft powered solely by a hydrogen fuel cell battery system. The aircraft has a range of 1500 kilometres and is powered by both a battery and a hydrogen fuel cell. The aircraft is being used as a test platform for the research of novel electric drive concepts.

Aims

- Passenger aviation without noise, soot particles and carbon dioxide emissions
- Development and integration of a hydrogen fuel cell drive in an aircraft
- Use of the fuel cell under aviation conditions (low temperatures and low pressure)

Parties involved

DLR Institute of Engineering Thermodynamics, H2FLY, Hydrogenics, Pipistrel, University of Ulm, Stuttgart Airport

Applications

- Use of fuel cells in aviation
- Hybridisation of the low-temperature fuel cell with a high-performance battery
- Scientific investigation of the operating parameters of a hydrogen fuel cell at low pressure

Outlook

- Emission-free short-haul flights with Electric Air Taxis from over 60 regional and international airports across Germany
- The modular drive provides a view of larger electrically powered aircraft with a capacity for up to 40 passengers

Facts and figures

Wingspan: 21.36 m
Length: 7.4 m
Empty weight: approx. 630 kg
Maximum weight: 1500 kg
Range: 750 to 1500 km
Maximum speed: 200 km/h
Cruising speed: 165 km/h
Engine output: 80 Kilowatt
Fuel cell/battery continuous output: each 45 kW
Engine output when cruising: 26 kW

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HY4 fuel-cell aircraft

Fuel-cell powered flight

The HY4 is the world's first four-seat passenger aircraft powered solely by a hydrogen fuel cell battery system. The research aircraft is thus paving the way for passenger aviation without noise, soot particles and carbon dioxide emissions. The exhibit displays a 1:4 scale model of the HY4.

The powertrain developed for the aircraft consists of a hydrogen storage, a low-temperature hydrogen fuel cell and a high-performance battery. The fuel cell converts hydrogen directly into electrical energy. The only waste product from this process is water. An electric motor uses the power thus generated to propel the aircraft. The high-performance lithium battery covers peak power loads during take-off and when climbing. If the hydrogen required for the fuel cell is generated via electrolysis using power from renewable energy sources, the HY4 can fly without generating any emissions at all. The HY4 took off on its maiden flight in September 2016 from Stuttgart Airport.

Long-standing aerospace and energy research activities in the fields of batteries, fuel cells and hydrogen technology have made DLR and its partners experts in the fields of More Electric Aircraft (MEA) and All Electric Aircraft (AEA). Under the auspices of the DLR Institute of Engineering Thermodynamics, which is responsible for the overall integration of the power train, the following partners have joined forces to achieve the world's first fuel cell passenger aircraft: the fuel cell manufacturer Hydrogenics, the Slovenian aircraft manufacturer Pipistrel, the University of Ulm as a scientific partner, as well as Stuttgart Airport as the home airport for the HY4. The DLR spin-off H2FLY operates the HY4 and is responsible for the certification process The project was funded by the DLR and Stuttgart Airport. The current research project and the fundamentals of fuel cell technology were funded by NOW GmbH (National Organisation Hydrogen and Fuel Cell Technology).

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Emission-free fuel

Electrolysis – conversion of solar power into hydrogen

Brief description

The DLR Institute of Networked Energy Systems demonstrates the emission-free conversion of solar power into hydrogen with its model for electrolysis and reconversion. The coupling of the power and mobility sectors is a promising option for emission-free transport in the future – with a view to hydrogen-powered fuel-cell vehicles.

Aims

- Location-independent hydrogen generation through the use of renewable energy
- Emission-free mobility through the use of fuel cells
- Long-term energy storage
- Pollutant-free, efficient powering of vehicles
- Coupling of the mobility and power sectors
- Cross-sectoral flexibility potential for the design of future energy systems

Parties involved

DLR Institute of Networked Energy Systems

Applications

- Use in the mobility sector
- Integration of mobility into urban energy concepts
- Coupling of power and mobility sectors
- Combined usage with fuel-cell technology
- Direct conversion of self-generated solar power

Outlook

- CO_2-neutral traffic
- Emission-free drive systems
- Decentralised energy supply
- Renewable energy conversion
- More efficient use of own contribution to solar power
- Greater supply reliability due to the option of reconversion

Facts and figures

- Demonstration model, based on electrolysis and fuel cell, functioning
- Prepared by the DLR Institute for Networked Energy Systems to show the emission-free production of hydrogen from solar power

Scientific support:
Alexander Dyck

Emission-free fuel

Electrolysis – conversion of solar power into hydrogen – Coupling the power / mobility sectors

The shift from fossil fuels to renewable energy sources presents a challenge, particularly in the mobility sector. Hydrogen is an alternative fuel, as it can be obtained from renewable energy via electrolysis in an emission-free process. When used in conjunction with fuel cells as energy converters in vehicles, this makes the emission-free and highly efficient operation of vehicles possible.

At the 2018 Hannover Messe, the DLR Institute of Networked Energy Systems will be demonstrating the possibilities of this energy conversion on a model scale: a simple light source is sufficient to fill a hydrogen storage tank using solar cells and an electrolyser. This feeds a miniature fuel cell car with hydrogen, which takes a mighty ride in toy format. In this way, a small experimental setup can be used to illustrate the power/mobility sector coupling – and the far-reaching dimensions of this technology.

Unlike internal combustion engines, fuel cells enable emission-free mobility. There is considerable potential for optimisation – particularly with hybridisation in combination with batteries – which should increase systemic efficiency and the longevity of products in mobility-related applications. Initial series models make it clear that such applications are ready for the market. However, the advent of broad-based commercialisation also shows that numerous research topics still need to be addressed in order to increase customer acceptance, including longevity, range, fuel quality and infrastructure.

The Institute of Networked Energy Systems is looking into these issues. The scientists there are developing, among other things, optimisation strategies for combining fuel cells and batteries at system level, based on driving cycles. In addition, the Institute is researching how drive technologies based on electricity, hydrogen and synthetic hydrogen compounds can efficiently be fed back into the power grid. This cross-sectoral potential for flexibility is considered a key element in the design of future energy systems.

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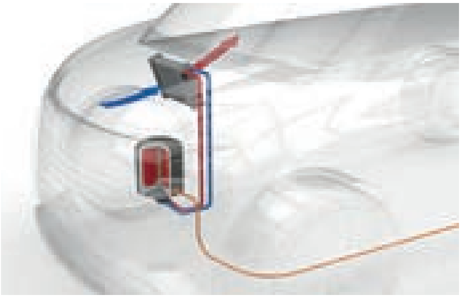
High-performance thermal storage

Greater range for electric vehicles



Brief description

High-performance thermal storage is based on innovative metallic phase-change materials. These are able to store large quantities of energy in a very small space and make it available once again through a highly efficient process. They offer huge potential for increasing the range of electric vehicles and reducing system costs.

Aims

- Meeting the heating requirements of electric vehicles, which will:
  - increase range
  - reduce costs
- Reducing demand for scarce raw materials
- Developing design methods and tools
- Application-oriented demonstration of technology

Parties involved

DLR Institute of Vehicle Concepts
DLR Institute of Materials Physics in Space
DLR Technology Marketing
Partners from the auotomotive and supplier industry

Applications

- Battery-powered electric city buses
- Fleet operators (car sharing and delivery services)
- Urban mobility
- Inter-urban private transport
- Sector coupling/SmartGrid

Outlook

- Efficient, cost-effective storage batteries for electric vehicles
- Reduction in transport emissions

Facts and figures

Sample storage material:
Aluminium-silicon (AlSi) alloy
Operating temperature:
100°C – 600°C
Phase-transition temperature:
577°C
Storage capacity:
300 Wh/kg
780 Wh/l

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High-performance thermal storage

Greater range for electric vehicles

Electric propulsion is an important building block in the development of a climate-friendly transport system. One of the associated challenges is the loss of range in such vehicles during winter.

Fuel-powered vehicles are heated by the waste heat created by the combustion process in the engine. In the case of electric cars, on the other hand, the same battery that drives the car must also provide the power to keep the vehicle at a comfortable temperature. As a result, the battery loses more energy, reducing the car's range by up to 50 percent on cold days.

The heat storage technology developed by DLR scientists at the Institute of Vehicle Concepts in Stuttgart, in conjunction with the Institute of Materials Physics in Space at the Cologne site and other partners from the fields of industry and research, can take over the heating function in an electric car and thus substantially increase the range of electric vehicles at low outdoor temperatures.

Using metallic latent heat storage, the researchers were able to develop an energy storage system that can store heat at a very high energy level and thus completely relieve the drive battery of the requirement to heat the interior of the car, too. Metallic latent heat storage materials, such as aluminium-silicon alloys, have a very high specific energy density, resulting in small, lightweight storage systems.

In a phase-change material, latent heat is absorbed by the material and it changes from one phase to another, for instance from solid to liquid. This heat can be released again by the opposite phase transition. One familiar example of this is pocket warmers, which release energy when the liquid inside them solidifies. With a small volume and tiny mass, they store more energy than other types of thermal storage materials and are therefore well suited for space-saving installation in electric cars.

In addition to increasing range and comfort, heat accumulators should also reduce costs for electric vehicles. By using cost-efficient, readily available storage materials, combined with a simple system design, high-performance thermal storage materials are much less expensive than the traction batteries in electric vehicles, and can thus contribute to sustainable and affordable mobility.

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Direct evaporation in energy storage

Energy conversion and thermal energy storage processes for industrial process and power plant technology

Brief description

DSG-Store (Direct Steam Generation Storage) is a system based on phase-change materials (PCMs) for storing process and power plant steam at high saturated steam temperatures and pressures. Through the development of suitable heat exchanger structures and materials, these reservoirs represent a cost-effective alternative to previous systems.

Aims

- Greater flexibility for existing and new power plants
- Materials research, component development and system integration
- High-energy density storage using phase-change materials

Parties involved

Research & Development: DLR Institute of Engineering Thermodynamics, Linde AG. Rib and storage production: F.W. Brökelmann GmbH & Co. KG, Streicher Maschinenbau GmbH

Applications

- Integration into industrial processes for coupling the power and heat sectors, reducing peak loads and securing the availability of steam
- Use in direct-evaporation solar-thermal power plants and solar process heating

Outlook

- Further development of thermal energy storage > 100°C
- Cost- and function-optimised design
- Hanging heat exchanger, designed for easy upscaling

Facts and figures

- **Storage material** $NaNO_3$ with a melting point of 306°C and heat of fusion of 175 kJ/kg
- Pipework for operating pressure > 100 bar
- Heat exchanger structure made of extruded aluminium with proven clamp attachment
- Aluminium content < 9%

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Direct evaporation in energy storage

Energy conversion and thermal energy storage processes for industrial process and power plant technology

The DLR Institute of Engineering Thermodynamics conducts research into energy storage, heat management and heat transfer. It is pursuing storage concepts for different heat transfer media in the 100 – 1000°C range: sensible (that is, without phase change) storage based on liquids and solids, latent heat storage and thermochemical storage.

In addition to applications in the fields of industrial process heat, combined heat and power, and conventional power plant technology, thermal energy storage is being developed and validated for solar-thermal power plants. While DSG-Store (Direct Steam Generation Storage) is essentially suitable for numerous applications, it was originally developed for thermal solar power plants. These are able to supply energy round the clock, almost like a conventional power plant. Optimised heat management also improves the operating characteristics, reduces partial-load operation and uses the power plant hardware in a more efficient way. Overall, this increases its profitability. A solar-thermal power plant works particularly efficiently and cost-effectively if it is operated at the highest possible temperature. This can be achieved with direct solar evaporation of water, whereby the superheated steam for the steam turbines is generated in the collector. At a pressure of 120 bar, it reaches temperatures of over 500°C. This almost matches the steam parameters common in conventional power plants.

Approximately 65% of the solar energy is used for the evaporation process alone. The latent heat storage that absorbs this type of energy plays an equally important role. The storage medium is sodium nitrate, which melts at 306°C. It is located in a thermally insulated container that is in direct contact with heat exchange tubes, through which the steam flows during the charging process. In doing so, the steam cools down and condenses. For discharging, the feed water flows through the transfer tubes. The liquid salt solidifies and transfers its solidification energy to the feed water, which evaporates.

Both the geometrical structure and the individual components have been optimised in terms of their technology and cost-effectiveness in a pilot-scale test storage facility within the DSG project. In the process, the scientists have built upon the insights gained from the previous DISTOR and ITES research projects, as well as the parallel TESIN project. The project's funding code is 0325333A,D.

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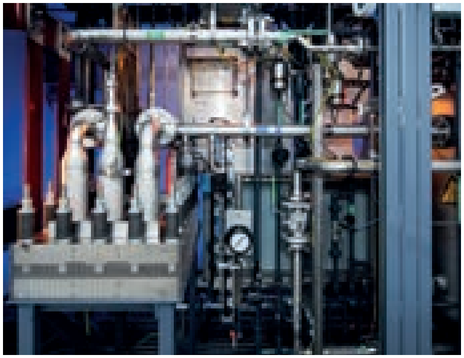
Water electrolysis

Efficient and cost-effective generation of renewable hydrogen



Brief description

Water electrolysis involves the conversion of regeneratively produced electricity into hydrogen, which can be used as a fuel for mobility, for industrial purposes or for energy storage. Modern electrolysers are being enhanced to increase durability and to reduce acquisition and operating costs.

Aims

- To increase efficiency
- To reduce costs by lowering the amount of expensive materials used
- To investigate and increase durability
- To investigate and demonstrate water electrolysis in technical systems

Parties involved

DLR Institute of Engineering Thermodynamics

Applications

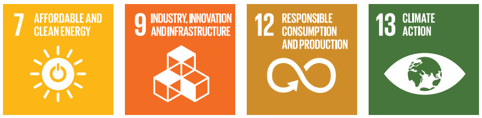
- Power to hydrogen and gas
- Generation of other fuels from renewable hydrogen
- Green hydrogen for industrial applications,for example in metallurgy, refineries
- Provision of network services
- Energy storage

Outlook

- Power/mobility sector coupling
- Power/gas sector coupling
- Mobility without CO_2 emissions

Facts and figures

- New catalysts for PEM electrolysis with 2.6-fold increased catalytic activity (at reduced iridium content)
- Plasma-coating of bipolar plates (reducing material costs)
- Increased durability by investigating degradation mechanisms



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Water electrolysis

Efficient and cost-effective generation of renewable hydrogen

Reducing the emission of greenhouse gases such as CO_2 is one of the most important societal challenges. Hydrogen generated from renewable energy sources via water electrolysis can be used in a variety of ways. In mobility, hydrogen can enable emission-free mobility with short refuelling times and high vehicle ranges. When used in industrial applications, the CO_2 emissions caused by these industries can be significantly reduced. By feeding into the gas supply network, the dependence of the heat supply system in Germany on imported natural gas can be lowered and the overall CO_2 emission of the heat supply reduced. By storing hydrogen in the gas network or in underground caverns, electricity can be generated at a later time, so that the fluctuating input of renewable power can be decoupled from power consumption.

Today's water electrolysers must be further developed in order to ensure lower investment and operational costs as well as a better durability in highly dynamic operations. Through the development of new production methods for catalysts, as well as the use of modern coating techniques, the DLR Institute of Engineering Thermodynamics has been able to address these goals. The investigations range from material and component characterisation to the operation of single cells and cell stacks, as well as demonstration in technical systems. Any developments are thus being successfully put into practice.

Different techniques of water electrolysis are available depending on the required application. Dynamic, highly efficient systems are based on polymer electrolyte membrane (PEM) electrolysis, alkaline electrolysis is used for cost-effective, very long-lived systems, and ceramic oxide electrolysis is used in highly efficient systems that include an on-site heat source. All techniques are studied and further developed at the DLR Institute of Engineering Thermodynamics. The work is carried out in national and international cooperation ventures with industry, research institutions and universities.

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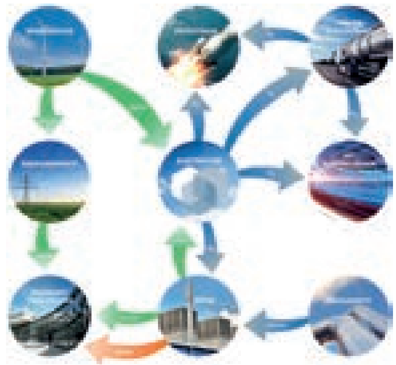
Projekt H_2ORIZON

Sector coupling with wind-hydrogen



Brief description

The H_2ORIZON project deals with the generation of hydrogen from local wind energy. The gas is used to provide heat and electricity, and as fuel for rocket engine test stands. It is also supplied for hydrogen mobility and industrial applications. This project demonstrates the coupling of the space,energy and transport sectors at a megawatt scale.

Aims

- Demonstration of local coupling of the space, energy and transport sectors
- Investigation and optimisation of this networked energy system in terms of its contribution towards the implementation of international climate goals and the Energy Transition
- Sustainable on-site heat and electrical power supply
- Provision of green hydrogen for fuel cell electromobility

Parties involved

DLR Institute of Space Propulsion
ZEAG Energie AG

Applications

- Use of the plant infrastructure to address research questions
- Provision of network services
- Sustainable on-site heat and electrical power supply
- Provision of 'green' hydrogen for fuel cell electromobility

Outlook

- Establishment of the 'H_2ORIZON Test Field' in order to develop new technological and conceptual hydrogen-based solutions in cooperation with industry and academia
- Extension of the plants to include 'Power-to-X' applications
- Expansion of the production capacity for green hydrogen up to 10 MW power input

Facts and figures

Hydrogen production:
PEM electrolyser (0.9 MW, 14.1 kg H2/h, 99.999% H2) with a direct connection to the Harthäuser Wald wind farm
Hydrogen storage:
Tube trailers up to 350 bar and DLR site network up to 800 bar
Heat and electricity production:
Two gas-engine cogeneration units (total: 1.6 MWth, 1.4 MWel), fuels: natural gas and hydrogen

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H_2ORIZON

Sector coupling with wind-hydrogen

DLR's Lampoldshausen site, which lies 50 kilometres north of Stuttgart, is currently creating another element of the energy future. The Institute of Space Propulsion in Lampoldshausen is one of Europe's largest consumers of hydrogen and is situated next to what is currently the biggest wind park in Baden-Württemberg. Taking this infrastructure as their starting point, the DLR Institute of Space Propulsion and ZEAG Energie AG are currently working together to create a hydrogen-based, networked energy system. This will see the energy, transport and space industries coupled on a megawatt scale.

The plant concept of the H_2ORIZON project consists of two main components. One is renewable hydrogen production based on wind energy. The polymer electrolyte membrane electrolysis (PEM electrolysis for short) system has a power input of around one megawatt and is directly connected to the Harthäuser Wald wind farm. Hydrogen is processed, compressed and pumped directly into special transport vehicles, known as tube trailers, for distribution. H_2ORIZON will also be used to construct a new plant to supply the DLR site with heat and electricity. The two gas-engine cogeneration units with a total output of 1.6 MW (thermal) and 1.4 MW (electric) will also be directly connected to the hydrogen production plant, as well as the conventional natural gas supply.

The DLR Institute of Space Propulsion is bringing its knowledge as Europe's largest consumer of hydrogen to bear on the H_2ORIZON project and is drawing upon the highly developed expertise of the whole of DLR, where the study of hydrogen links the fields of aerospace, aeronautics, energy, transport and security. ZEAG Energie AG is the world's longest-established three-phase supplier. As such, it knows the energy sector and is familiar with the challenges of operating renewable energy plants and power grids, as well as the conditions for successful participation in the energy market.

The infrastructure and expertise of the two project participants will be made available to potential industrial partners – especially small and medium-sized enterprises – and scientific institutions from January 2019, and will be known as the 'H_2ORIZON Test Field'. In creating the H_2ORIZON Test Field, DLR and ZEAG are aiming to enable new hydrogen-related technological and conceptual solutions to be researched, developed, demonstrated and validated at the DLR site in Lampoldshausen.

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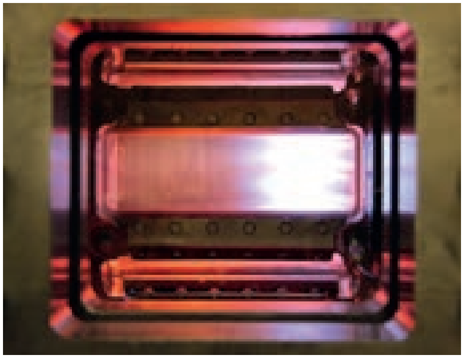
FLOX® combustion chamber

Micro gas turbine for decentralised energy supply



Brief description

The exhibit shows two particularly low-emission FLOX® micro gas turbine combustion chambers for the decentralised generation of electricity and heat. FLOX® combustion chambers are notable for their even temperature distribution, resulting in low NOx emissions.

Aims

- Reduction of pollutant emissions from micro gas turbines combined with low pressure loss in the combustion chamber
- Greater flexibility in terms of the fuel used

Parties involved

DLR Institute of Combustion Technology, other project partners for development of the demonstration units: EnBW AG, Dürr AG

Applications

- Combustion chambers for micro gas turbines with decentralised cogeneration as their primary area of application
- Other potential areas of application: range extender for hybrid electric vehicles, auxiliary power unit (APU) for aircraft

Outlook

- Further reduction of pollutant emissions
- Reduction of wall thermal load
- Extension to liquid fuels
- Low-pollutant multi-fuel burner for gaseous fuels (calorific value 5 – 50 MJ/kg)

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Facts and figures

- In 2014, the world’s first FLOX® combustion chamber system was used in a natural-gas-powered micro gas turbine. CO emissions < 5 ppm and NOx emissions < 25 ppm.
- Successful coupling of a micro gas turbine with a FLOX® combustion chamber system and an atmospheric fixed-bed gasifier for woodchips
- Previous burner systems cover the power range from 6 – 333 kW (engine output)

FLOX® combustion chamber

Micro gas turbine for decentralised energy supply

Modern gas-turbine combustion chambers must satisfy many requirements. In addition to load and fuel flexibility, low-pollutant emissions are also mandatory under all operating conditions. The FLOX® concept meets all of these requirements, while its high combustion stability represents a promising alternative to conventional swirl-stabilised combustion chamber systems.

The exhibit shows two FLOX® burners for use in micro gas turbines (MGT). The larger burner is designed for a Turbec T100 MGT burning natural gas and with maximum electrical output of 100 kilowatts. The smaller burner is designed for an MTT EnerTwin with maximum electrical output of three kilowatts, designed for use with biogases having a low calorific value. The air inlet temperatures in this burner are over 700°C.

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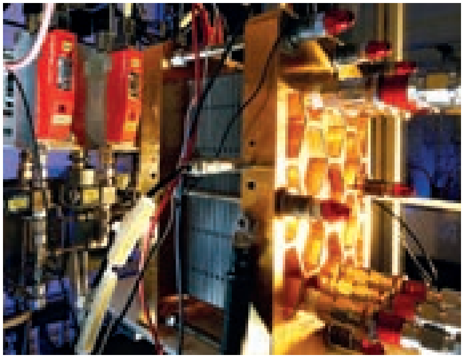
Low-temperature fuel cells

Direct generation of electrical energy from hydrogen



Brief description

Fuel cells convert chemical energy – contained, for example, in hydrogen – directly into electrical energy through an electrochemical process. Low-temperature fuel cells typically function at around 80°C and are ideal for electromobility applications due to their low weight and compact size.

Aims

- Increase in efficiency and life cycle
- Cost reduction by decreasing precious metal content
- Development into a product suitable for mass production

Parties involved

DLR Institute of Engineering Thermodynamics

Applications

- Hybrid systems of batteries and fuel cells for car ranges of ≥ 500 km
- Public transport and taxis
- Special mobility applications, for example airport apron, forklift trucks
- Cold start capability

Outlook

- Emission-free energy supply
- Urban CO_2-free goods delivery with daily service range

Facts and figures

- Reduction of platinum content from 0.6 mg/cm² to 0.25 mg/cm² with unchanged performance
- Up to 22% increase in power density due to a simple, scalable structuring process
- Spatially resolved real-time monitoring with controlled operational management allows the reversal of degradation phenomena

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Low-temperature fuel cells

Direct generation of electrical energy from hydrogen

Reducing the emission of CO_2, nitrogen oxides and particulates is one of the key challenges for future mobility. Using hydrogen as an energy source instead of conventional, carbon-based fuels for mobility, heating and industry holds the potential to achieve emission-free power generation.

A hydrogen-based economy in Germany or even in the whole of Europe could be primarily based on renewable energy, while using the converted natural gas network as the distribution infrastructure. In addition to improving air quality and quality of life, hydrogen technology can also stabilise the output variations in power networks that result from the inherent fluctuations of wind and solar energy. Electrolysers can be used to convert highly dynamic, fluctuating power generation into hydrogen, while fuel cells can generate electricity from hydrogen when required.

Due to their compact size and comparatively low weight, low-temperature fuel cells primarily have applications in the mobility sector, whether for private transport, public transport, 'last mile' delivery services or niche applications such as airport apron transport – they can be used wherever the accumulation of emissions from fossil fuels has a significant impact on air quality. For stationary applications in buildings and homes, there are other, ceramic-based technologies that also provide hot water in addition to clean electrical energy through combined heat and power.

Does hydrogen present any dangers? When combined with oxygen or air, hydrogen can form an explosive mixture called oxyhydrogen. However, the refuelling process works in a similar way to that used for liquefied-gas powered vehicles, thus eliminating any chance of oxyhydrogen forming. Modern hydrogen tanks are made from high-strength carbon-fibre composite material that can withstand a truck driving over them or being shot with a firearm.

The DLR Institute of Engineering Thermodynamics, which is part of an international network, is researching low-temperature fuel cells, starting with the materials themselves through to manufacturing technology, analytics and management, and finally the finished system.

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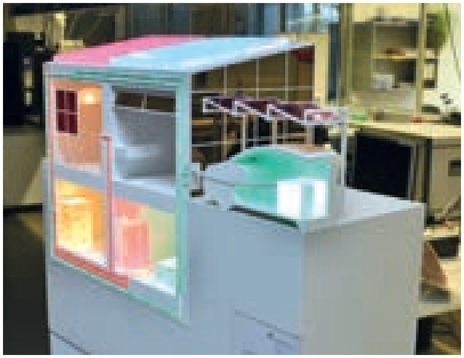
Efficient energy management for buildings

Energy flows in 'smart' residential buildings



Brief description

The house model devised by the DLR Institute of Networked Energy Systems visualises energy flows within an intelligently-networked residential building. The exhibit illustrates how power, mobility and heat can be coupled in home energy management, thus contributing towards a more efficient use of energy.

Aims

- Networked energy flows for residential buildings and districts
- Use of excess electricity for mobility or heat supply
- Energy supply based on an active building envelope
- Coupling of the power, heat and mobility sectors
- Integration of intelligent energy management
- More flexible, decentralised use of energy in residential buildings

Parties involved

DLR Institute of Networked Energy Systems

Applications

- Integration of new mobility technologies into the energy system
- Research into new network technologies
- Research into system services
- Gearing the energy system to suit individual load profiles
- Load management
- Cogeneration

Outlook

- Decentralised generation and use of power and heat
- Increased efficiency in the residential building sector
- Use of an active building envelope
- Reconversion of hydrogen
- Coupling of the power, heat and mobility sectors for residential buildings

Facts and figures

Demonstration model

Features: Visualisation of electricity and heat flows within a house

Created by the DLR Institute of Networked Energy Systems to demonstrate the concept of power, heat and mobility coupling in home energy management

Scientific support: Alexander Dyck, Karsten von Maydell, Martin Vehse

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Efficient energy management for buildings

Energy flows in ‘smart’ residential buildings – power/heat/mobility sector coupling

In the future, ensuring an energy supply based on renewables will require a fundamental transformation of our existing energy systems. In particular, the systems for supplying power, heat and mobility, which have previously been considered separately, will be increasingly coupled. The energy flows in our modelled residential building clearly show the benefits of this cross-sectoral use of energy. For all inhabitants, the basic requirement is that the supply of different types of power – for electricity, heating or drive systems for cars – must be reliable. In future, the previously separate supply channels for electricity, gas, oil, petrol or diesel will be interlinked in a decentralised, cross-sectoral system for ‘smart’ residential buildings.

An active building envelope provides the basis for the energy supply. It converts sunlight into power and heat by means of photovoltaic or solar thermal energy. This energy is either used directly within the home, stored or converted into synthetic biogas, to give one example. As such, solar energy is not only usable after a time delay, but is also available as a suitable source of energy, for heating systems and other purposes.

The key challenge for reliable energy supply in decentralised systems is to achieve intelligent energy management. The DLR Institute of Networked Energy Systems focuses on this very topic by investigating system-oriented issues in its work on coupling the power, heat and mobility sectors efficiently. The scientists are looking at different levels of system, from individual units and ‘smart’ buildings through to networked residential districts and cities. In addition, the Institute is evaluating energy systems at a national and international level based on self-developed network structure models and technology assessment methods.

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Germany’s energy landscape

DLR energy system analysis

Brief description

This interactive exhibit shows what a power supply system based primarily on renewable energy sources might look like in Germany. Various energy sources, energy storage systems and technologies are used in different regions of Germany, depending on supply and demand.

Aims

- Demonstration of the different scenarios for energy supply using predominantly renewable sources
- Demonstration of possible interlinking of sectors and the networking of different regions in Germany

Parties involved

DLR Institute of Engineering Thermodynamics, DLR Institute of Networked Energy Systems

Applications

- Energy systems analysis uses scientific methods to identify and assess the economic, environmental and societal effects of new technologies and energy policy measures in a forward-looking way.
- Advice for decision makers on current technological and systems-related issues

Outlook

- Sustainable, secure and cost-effective energy supply in Germany
- Successful implementation of the Energy Transition

Facts and figures

German power system 2017 / 2060 (95% renewable energy scenario)

Total consumption:

2017: 654 TWh / 2060: 1040 TWh*

Supply:

- ‘PV: 2017: 40 TWh (6%) / 2060: 83 TWh (8%)
- Wind: 2017: 105 TWh (16%) / 2060: 477 TWh (45%)

* Increase in consumption due to electrification of transport + hydrogen production

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Germany’s energy landscape

DLR energy system analysis

How would the power supply system in Germany look if a large proportion of the electricity were generated using renewable forms of energy? This interactive exhibit shows different scenarios, depending on weather conditions and demand. For instance, what happens if solar and wind power produce more electricity than is being consumed? Conversely, what happens if the demand cannot be met during a time of very low solar and wind power production? The exhibit shows that achieving energy security in Germany requires different forms of technology and the networking of the various regions. It also illustrates how energy storage will play a key role in future systems, and that there may be certain scenarios where conventional power plants, ideally gas-fired power stations, will also enter into the equation.

DLR Energy Systems Analysis is examining the optimal use of energy as afforded by the options presented here. In doing so, it provides valuable insights that help facilitate the successful implementation of the Energy Transition. It uses scientific methods to identify and assess the economic, environmental and societal effects in a forward-looking way, by investigating the potential paths that such a transformation might follow. Emphasis is placed on a high level of transparency and the comparability of methods and data in order to ensure a sound, reliable basis for the development and assessment of different courses of action. Decision-makers from the fields of science, industry, politics and social affairs thus receive evidence-based guidance that contributes to the development of long-term research priorities and the drawing up of policy framework conditions relating to energy, the environment and research.

Due to its relevance for decision-making in Germany and abroad, energy systems analysis is an important part of DLR’s energy research. With about 60 researchers at present and plans to increase the number of employees to around 80, split between the Oldenburg and Stuttgart sites, there is wide-ranging and diverse expertise available to provide advice on and address current technological and systems-related issues.

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Carnot batteries

Low-cost and location-independent energy storage in the gigawatt hour range

Brief description

Carnot batteries are systems that provide cost-effective and location-independent storage for large quantities of electrical energy. In a Carnot battery, electricity is converted into heat using a high-temperature heat pump, stored and then converted back into electricity as required. DLR is working on innovative concepts for Carnot batteries in collaboration with industry partners.

Aims

- Development of a storage battery in the gigawatt hour range
- Development of location-independent storage batteries
- Construction of a demonstration unit
- Stabilisation of the power grid
- Development of tools for coupling different sectors

Parties involved

DLR Institute of Engineering Thermodynamics, Institute of Solar Research, Institute of Propulsion Technology, Institute of Networked Energy Systems, University of Stuttgart

Applications

- Efficient, cost-effective power-heat-power storage for energy companies, municipalities or large industrial operations
- Part of DLR's cross-sectoral GigaStore project

Outlook

- Energy storage in the range of gigawatt hours at any location worldwide
- Additional needs-based provision of heat and cooling
- Suitability as a heat-storage power plant for decommissioned coal power stations
- Cycle-proof storage batteries that can be charged and discharged as often as required

Facts and figures

- Electrical output in the 100 kW–500 MW range
- Electrical storage capacity between 1 MWh and 1 TWh
- Achievable storage efficiency between 35% and 75%, depending on configuration
- Heat supply at temperatures between 90°C and 500°C, cooling at temperatures between -20°C and +10°C

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Carnot batteries

Low-cost and location-independent energy storage in the gigawatt hour range

Given the increasing share of fluctuating renewable energy in power generation in Germany and across the world, there is a growing need to cost-effectively store large amounts of electrical energy over several days. Today and for the foreseeable future, battery storage is too expensive and their cycle lives are too poor for such purposes. Synthetic carbon-neutral fuels that are converted into energy in gas-turbine power plants possess the highest energy density of any energy storage system. However, their production requires huge quantities of biomass, which cannot be provided in sufficient amounts today or any time soon.

According to Robert Laughlin (Stanford University), winner of the Nobel Prize in Physics, power-heat-power storage units (known as Carnot batteries) will be the key technology for storing large quantities of energy in a carbon-neutral energy system of the future. In a Carnot battery, energy is converted into heat at a temperature between 90°C and 500°C by using a high-temperature heat pump. This heat is stored inexpensively in water (90°C) or molten salt (500°C) and reconverted into energy through a thermal power process, when required. A valuable added benefit of Carnot batteries is their ability to supply heat and cooling in addition to stored energy. The possibility of providing cooling is particularly important for decarbonisation in countries such as India and China.

The Institute of Engineering Thermodynamics is a scientific pioneer in the energy storage industry and has the ideal capabilities for the development of Carnot batteries thanks to its many years of experience in the field of high-temperature heat storage.

Since 2014, DLR and the University of Stuttgart have been working intensively on concepts for Carnot batteries and, together with the Karlsruhe Institute of Technology, are setting up the NADINE research infrastructure, which will allow Carnot batteries to be demonstrated and put to industrial use.

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MovR with FCREX – fuel-cell-powered cargo bike

A new ‘last mile’ logistics concept

Brief description

Packages are increasingly being delivered straight to the customer’s front door. DLR has developed an innovative fuel cell module as a sustainable and versatile solution to providing greater range. This will be used in a new kind of cargo bike for the company RYTLE GmbH.

Aims

- Scalable and flexible solution
- Rapid refuelling and long range due to an innovativefuel cell system
- Robust, winter-proof concept
- Use of alternative drive solutions for logistics

Parties involved

- DLR Institute of Engineering Thermodynamics
- DLR Institute of Vehicle Concepts
- DLR Technology Marketing
- Rytle GmbH

Applications

- Logistics – distribution services and parcel delivery

Outlook

- Integrated logistics concept, suitable for ‘crowdworking’
- Emission-free transport in urban areas (noise, pollutants)
- Future-oriented, sustainable and flexible transport solution for the ‘last mile’

Facts and figures

- Delivery vehicle with three wheels and rider’s cab
- Standardised, interchangeable cargo container
- Fuel cell system with nominal continuous power of 250 W
- Operating temperature from -20 to +50°C
- Scalable hydrogen tank capacity

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MovR with FCREX – fuel-cell-powered cargo bike

A new 'last mile' logistics concept

Electrically-powered cargo bikes are a future-proof solution for the transport sector. Developed specifically for the route between distribution centres and customers – referred to as the last mile – these achieve higher average speeds than cars or vans. In addition, they are more versatile and are emission-free at a local level, as well as constituting a quiet form of transport.

To produce the energy for this mobile application, DLR has developed the FCREX (fuel cell range extender) fuel cell module. This can be refuelled in a matter of seconds, and has a higher range and roughly twice the lifetime of battery-powered systems. The fuel cell stack is made of robust bipolar metal plates. It also has an innovative cold-start module that uses metal hydrides to pre-heat the system, without drawing energy from it and thus reducing the range. This means that the FCREX module can be put into use quickly and reliably even at low temperatures. Hilly regions, heavy loads, cargo that needs to be refrigerated, and even heated driver's cabins no longer present any problem for the DLR fuel cell module, which can cope with all such demands at any time of year. Due to the significantly higher amount of energy available, the vehicle load is now the limiting factor, rather than the range, which allows more practical logistics chains to be introduced.

The FCREX module will be used for the MovR cargo bikes operated by the company RYTLE GmbH. The underlying logistics concept consists of four components: the alternatively powered cargo bike (MovR), a standardised transport container (BOX), the distribution station (HUB) and the digital operating system (APP). With this intelligent software, all of the hardware components are networked within the cloud, and thus work closely together.

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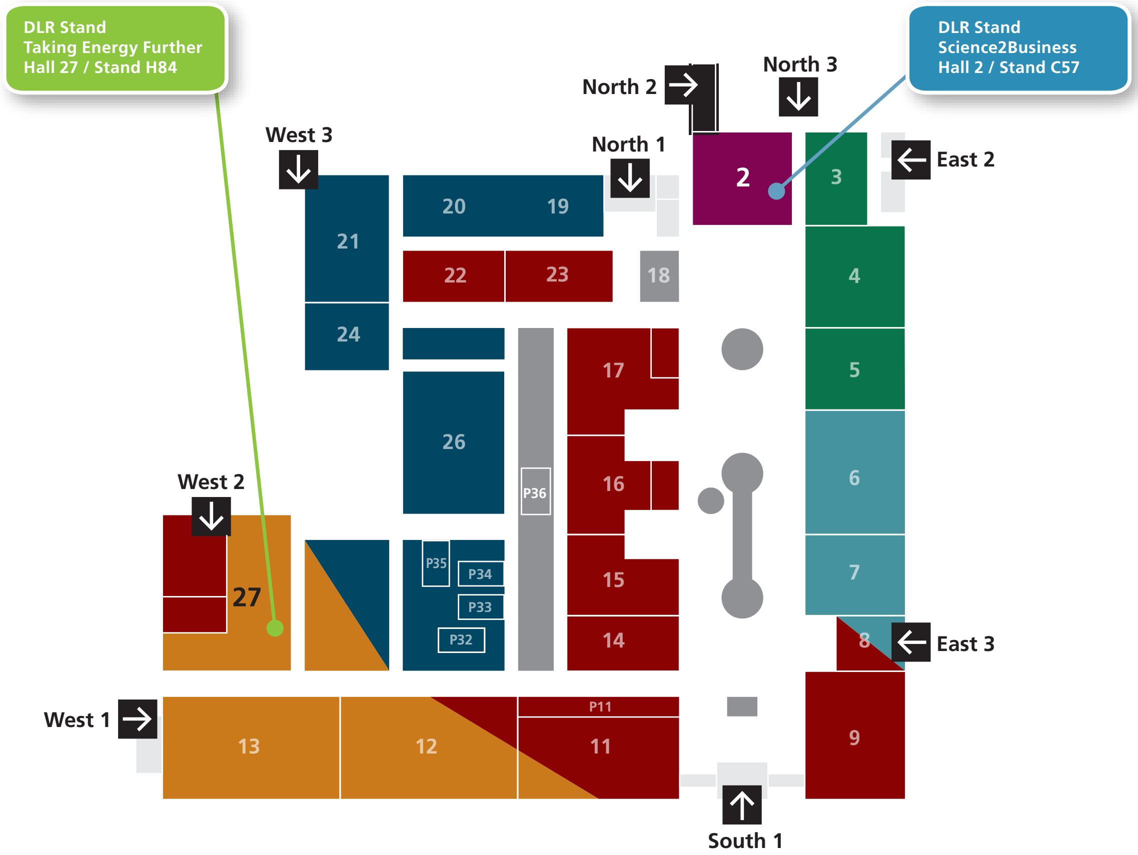
Hannover Messe map



Visit our stand: Science2Business in Hall 2 / C57

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Explanations

United Nations Sustainable Development Goals

Goal 1: End poverty in all its forms everywhere

Goal 2: End hunger, achieve food security and improved nutrition and promote sustainable agriculture

Goal 3: Ensure healthy lives and promote well-being for all at all ages

Goal 4: Ensure inclusive and quality education for all and promote lifelong learning

Goal 5: Achieve gender equality and empower all women and girls

Goal 6: Ensure access to water and sanitation for all

Goal 7: Ensure access to affordable, reliable, sustainable and modern energy for all

Goal 8: Promote inclusive and sustainable economic growth, employment and decent work for all

Goal 9: Build resilient infrastructure, promote inclusive and sustainable industrialisation and foster innovation

Goal 10: Reduce inequality within and among countries

Goal 11: Make cities and human settlements inclusive, safe, resilient and sustainable

Goal 12: Ensure sustainable consumption and production patterns

Goal 13: Take urgent action to combat climate change and its impacts

Goal 14: Conserve and sustainably use the oceans, seas and marine resources

Goal 15: Sustainably manage forests, combat desertification, halt and reverse land degradation, halt biodiversity loss

Goal 16: Promote just, peaceful and inclusive societies

Goal 17: Revitalise the global partnership for sustainable development

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