# Taking energy further

**Digitalisation:** Research for the Energy Transition

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# Digitalisation: Research for the Energy Transition

Dear visitor,

The successful transformation of our energy system is extremely important for the German economy, and digitalisation will have a crucial role to play. The German Aerospace Center (Deutsches Zentrum für Luft- und Raumfahrt; DLR) is working on the digitalisation of the energy system in all areas of energy investigation. Our research is application-based and conducted in close cooperation with industry. The DLR-specific links between the research areas of transport, energy, aeronautics and space, security and digitalisation allow us to exploit valuable synergies, such as the digital interaction between the energy and mobility sectors.

Here at the Hannover Messe, we are pleased to present the current status of our energy research: learn how we will need to supply the energy grid of the future in order to make better sustainable use of our planet's resources – from energy generation through to networking and storage. DLR is making a major contribution to transforming the energy system and successfully withdrawing from coal-fired power generation.

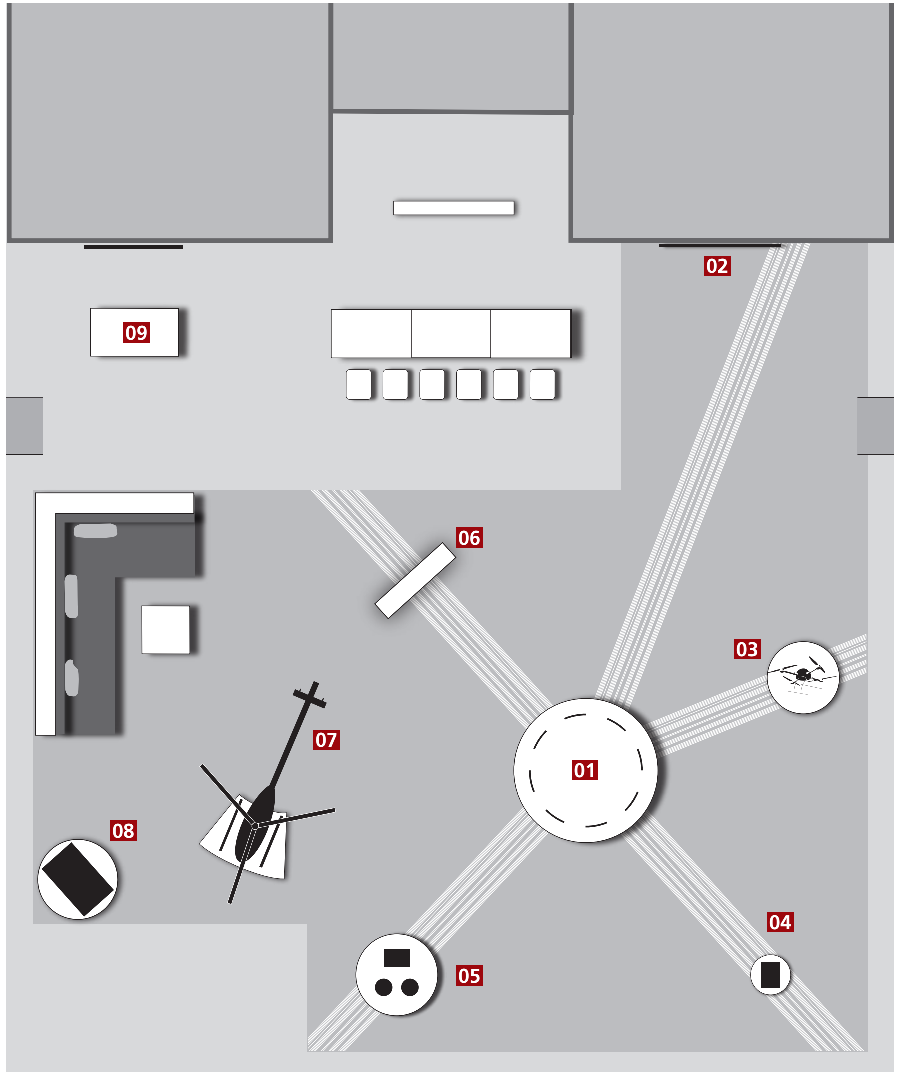
For over 40 years, DLR has been conducting research with the aim of making energy supplies safe, efficient and environmentally friendly, taking social and economic interests into account. Our strategic approach to manageable eco-power embraces energy storage and renewable energies, as well as sustainable fuels and energy converters. Our systems technology focuses on the development of energy grids; our energy system analysis accompanies technical research while developing and evaluating system solutions. This systemic research approach is on display here at Hannover: this year, our stand allows you to share our expertise and showcases components for the energy system of the future.

Experience science, be inspired and talk to us!

Pascale Ehrenfreund
Chair of the Executive Board

Karsten Lemmer
DLR Executive Board Member for Energy and Transport

# DLR stand floor plan

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# Energy for tomorrow – city of the future

Cross-sectoral energy management in urban areas

## Brief description

The model on display visualises the challenges presented by the future energy system using different scenarios. It depicts a city, together with power producers and energy storage facilities. The energy footprints are displayed visually. Icons provide information about the main research areas of the Institute of Networked Energy Systems.

## Aims

The model is intended to illustrate issues relating to the transformation of the energy system. Energy demand and consumption are addressed in various scenarios, as are energy storage capacities. In this way, the exhibit visualises which essential elements of power generation and demand are part of the Energy Transition and what solutions the Institute is investigating against this background.

## Parties involved

DLR Institute of Networked Energy Systems

## Applications

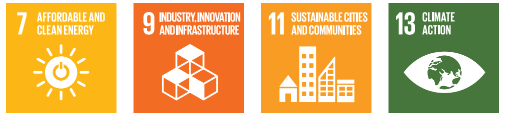
- Researching the energy system of the future
- Dimensioning energy storage systems
- Simulating energy management scenarios
- Energy meteorology
- Sector coupling
- Integrating mobility concepts into future energy systems

## Outlook

- Conveying an integrated understanding of more complex future energy systems
- Discussion basis for strategic-political decisions
- Predictions for the Energy Transition
- Sector coupling

## Facts and figures

- Demonstration model for visualising energy flows at various projection levels
- Illustration of power generation and usage, and energy storage systems – based on renewable energy sources
- Presentation of sector coupling in buildings, mobility and gas technology
- The accompanying presentation visualises research topics and potential solutions to future energy issues.

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The future energy system will be characterised by extreme surpluses of electrical power and adequate energy storage capacity to securely cover demand. New groups of consumers and types of vehicle propulsion, such as hydrogen-powered fuel cells, the use of decarbonised gases and bidirectional charging stations for electric cars, will shape the energy system.

However, in contrast to today's predominantly centralised energy system, the future supply will be based on numerous decentralised systems – from offshore wind farms to solar panels on residential rooftops. Consequently, energy management is becoming increasingly important. In order to provide stability in such a complex system, energy research is focusing on management strategies and possible flexibilities in generation, consumption and storage. In particular, connecting buildings, mobility and gas technology with the electricity sector – referred to as sector coupling – opens up such options.

The demonstration model is intended to show the resulting questions and possible solutions, based on different scenarios. A city was chosen as an example power consumer and is simulated in simple terms in the model. This applies to both generators, such as photovoltaic and wind power plants, and to battery and gas storage facilities.

Power demand and generation are visualised, depending on the scenario, as are the actual energy flows between generators, consumers and storage systems. In addition, overall energy quantities are displayed as balances in the outer circle of the model, in the form of illuminated bars. Individual theme icons arranged around the city symbolise selected research priorities and the potential solutions developed at the DLR Institute of Networked Energy Systems. Content and information about these and other research topics can be accessed via tablet presentations.

@DLRen

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# Thermal storage power plants

Leaving coal behind?

## Brief description

The film shows the conversion of coal-fired power plants into emission-free thermal storage power plants using the existing power plant infrastructure. Renewable forms of energy are used to generate electricity. This energy is then stored in large thermal storage tanks in the power plants until it is required by the consumer.

## Aims

A thermal storage power plant is to be built as a real-world laboratory at a power plant site in the Rhineland region. The aim behind the construction and operation of this pilot facility is to subject liquid salt thermal storage to comprehensive testing at a coal-fired power plant and thus demonstrate its potential as an option for converting such power plants.

## Parties involved

DLR Institute of Engineering Thermodynamics,
DLR Institute of Solar Research

## Applications

- If successful, the technology will be able to be applied at thousands of coal-fired power plants in Germany, the rest of Europe and worldwide, thus making an important contribution towards the decarbonisation of the global energy system.

## Outlook

- Thermal storage power plants are not only capable ofcontributing towards the reliable and sustainable supply of electrical power worldwide, but also provide high-temperature heat for industrial processes.

## Facts and figures

- DLR and RWE feasibility study in 2019
- Laboratory planned for the Rhineland region
- If successful, technology roll-out across Germany, Europe and the rest of the world

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"In terms of security of supply, the energy system must be made highly flexible on all levels in order to balance electricity supply and demand, even with a high proportion of variable generation using renewable sources. This includes the coupling of the electricity, heat and transport sectors," says Karsten Lemmer, DLR Executive Board Member for Energy and Transport.

The success of the Energy Transition depends on the development of new storage technologies. "Thermal storage has the potential to be an ideal energy storage system on a gigawatt-hour scale," explains André Thess, Director of the DLR Institute of Engineering Thermodynamics. "We need highly-efficient, high-performance energy storage that is also both location-independent and cost-effective. This is of vital importance if we are to achieve a future energy system based on renewable energy sources." Storage systems are the only way of ensuring that the considerable variability in the production of environment-friendly wind and solar power can be balanced against the highly dynamic demand for power.

Bernhard Hoffschmidt, Director of the DLR Institute of Solar Research, says: "Converting existing power plants into large storage power plants offers a number of benefits. Such repurposing means that the majority of the existing power plant technology, some of which is still young and very efficient, can be retained. In addition, as the infrastructure from the 'first life' of the power plants can largely be transferred to their 'third life', such a conversion saves enormous financial expenditure and allows jobs to be maintained." The existing power plant infrastructure, such as grid connections and turbines, can continue to be used, while only the supply of raw materials and the storage facilities change. As an intermediate step on the path towards a fully carbon-dioxide-free 'third life' for coal-fired power plants, a hybrid system is possible – with electricity generated by a mix of thermal storage and gas-fired steam.



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# QFly

Drone-based monitoring and optimisation of solar power plants

## Brief description

Power and heat obtained from solar energy are produced in power plants that are spread across several square kilometres, usually located in inhospitable desert regions. QFly uses drone-assisted imaging to deliver information about their performance. The data can then be used to optimise their efficiency and service life. The heart of the system is its automated analysis software.

## Aims

A project financed by DLR Technology Marketing was aimed in particular at the monitoring of CSP plants using parabolic trough technology. This involved developing an automated analysis tool and bringing it to market readiness. Other R&D activities are focusing on expanding the technology for use in CSP tower power plants and PV facilities.

## Applications

- During commissioning, quality control ensures that systematic errors are detected and corrected early on.
- Regular optical and thermal analysis of the solar field can be used to optimise the operation of current systems.

## Outlook

- Autonomous analysis in (solar) power plants worldwide.
- Measurement of soiling levels in order to minimuse water consumption cleaning CSP and PV plants.
- Detection of safety-relevant events (leakage/mechanical damages).

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## Parties involved

DLR Institute of Solar Research, DLR Technology Marketing, CSP Services GmbH, TeAx Technology GmbH

## Facts and figures

- Scheduled to run for two years, the project is financed by DLR Technology Marketing with a budget of 0.7 million euro
- Achievements include a complete survey of a typical parabolic trough power plant with a rated electrical output of 50 MW in just a few hours
- Data acquisition is largely independent of the measurement technology employed
- Measurement results include optical efficiency and thermal losses

Drone-assisted characterisation of the optical and thermal properties of solar power plants is the most efficient method of detecting weaknesses in operational systems and identifying measures to improve their performance. DLR has developed a system – QFly – specifically for service providers and plant operators that enables the characterisation of CSP plants. QFly delivers highly precise data for geometric checking, tracking and heat losses in CSP plants. These data are used as a basis for acceptance tests, quality control and optimisation of operations and maintenance of solar power plants. Validation against independent benchmarks has shown that QFly is currently the most advanced system for the optical characterisation of CSP plants. The system received the SolarPACES Technology Award 2018*.

A variety of methods are available depending on the objective. The QFly SURVEY approach enables rapid characterisation of the entire power plant in just a few hours, delivering information about the concentrator geometry and tracking. QFly HIGH RESOLUTION mode provides accurate and high-resolution results on the concentrator geometry for small parts of the solar field. QFly THERMO uses infrared radiation to provide information about thermal losses. In addition, QFly can be used to monitor power plants and their components.

Among other things, the results are geo-referenced and displayed with an adjustable degree of detail in Google Earth. In order to enable worldwide use, there is a clearly defined interface between data acquisition and processing.

Current research and development activities aim to add heat transfer fluid leakage detection, as well as measurements of soiling levels. A project funded by the German Federal Ministry for Economic Affairs and Energy (BMWi) is seeking to extend the application area to CSP tower power plants. In addition, the measurement technology will be adapted for PV power plants, especially to enable future optimisation of CSP/PV hybrid plants.

* Note by the authors:
SolarPACES is a IEA Technology Collaboration Programme (Technologie-Kooperationsprogramm der internationalen Energieagentur)
https://www.solarpaces.org/csp-research-tasks/about-the-solarpaces-tcp-with-iea/
SolarPACES is the leading international network of researchers into thermal solar for dispatchable power and solar chemistry technologies.
https://www.solarpaces.org/about/solarpaces/solarpaces-vision-and-mission/



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# SegBatt & Microstructure Simulation

Current collectors and microstructure-resolved electrode simulation in battery research

## Brief description

As part of various cooperative efforts, the experimental and simulation groups are working together in order to glean a whole-system understanding of battery cells. While simulations can reveal the processes down to the molecular level, the segmented cell developed at DLR enables the cell to be monitored in operation.

## Aims

A better understanding of what is happening within batteries, and what this means for secure operation that is stable in the long term. In addition to the ongoing improvement of the cells, this allows the development of operating strategies to ensure performance, safety and service life in the various areas of application.

## Applications

- Research & development of Li-Ion, post-lithium and solid electrolyte batteries
- Online monitoring during operation and optimisation of the operating mode
- Ensuring performance, long-term stability and safety

## Outlook

- Better understanding enables further development in terms of performance, long-term stability and safety
- Supporting the progressive electrification of society with renewable energy

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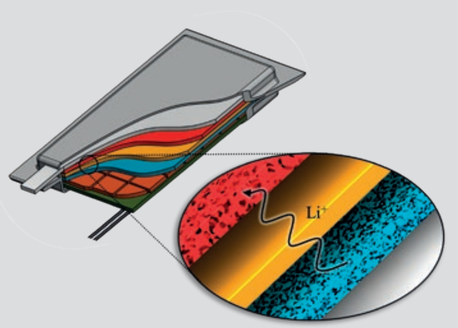

Image: © www.tbecker-illustration.de

## Parties involved

DLR Institute of Engineering Thermodynamics, DLR Technology Marketing, Helmholtz Institute, Ulm, ZAHNER-Elektrik GmbH

## Facts and figures

**SegBatt:**
- Patented DLR technology, supported by DLR Technology Marketing
- Recording of temperature, current density and electrochemical impedance as functions of the charging and discharging conditions

**Microstructure simulation:**
- Participation in the PoLiS (Post Lithium Storage) Excellence Cluster
- Optimisation of electrodes for Li-Ion batteries with 3D structure-resolved simulation

**Battery research at DLR:** the functioning of a Li-Ion cell is based on a complex interplay between electrochemical processes and transport mechanisms, which are dependent on the chemical composition, application and corresponding design of the cell. Understanding these processes is key to ensuring that the stringent requirements – in terms of cost, energy density, long-term stability and safety – are satisfied for the different fields of application, and for continuously improving the cells. DLR experts from a wide range of disciplines, including simulation, material synthesis, electrochemistry and systems analysis, are working together for this purpose. In the simulation, researchers derive mathematical equations for the electrochemical processes from thermodynamics. In doing so, they simulate ion transport in microstructure-resolved electrodes and optimise entire battery cells in conjunction with research groups conducting experiments. The construction of models grants them an insight into nanoscale processes taking place at interfaces that determine the performance and service life of electrochemical energy storage devices.

**Segmented cell:** the process of characterising the operation of the cells is also contributing towards improving their safety and longevity. The aim here is to understand what is happening while the cell is being charged, and how this changes over the cell's service life. The segmentation of current collectors, including measurement technology, developed by DLR allows spatially resolved measurement of different operating data, such as temperature, current distribution or impedance during operation and in real time. Implementing this technology allows continuous monitoring of the actual condition of the cell across the whole surface of the electrode. Knowledge about how this condition changes depending on the cell design and the charging and discharging conditions can be applied to the development of cell components, cells and battery systems. It also has applications in the field of cell diagnostics.



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# Limestone storage

Renewable long-term heat supply

## Brief description

The use of the chemical reaction in which hydrated lime is converted to quicklime and steam offers the possibility of storing energy from renewable sources in a highly cost-effective and low-loss way, over long periods of time. The key to the widespread adoption of this storage system is the development of highly-efficient reactors, which are the subject of current research at DLR.

## Aims

The aim of the project is the technological verification of a storage system in the 10 kW power class, which is suitable for a single-family house. A complete and fully functional system will be designed, constructed and put into operation in the laboratory. Upon completion of the project, a scalable storage technology will be available, which will then be transferred to an application in the field for the first time.


Image: © stefan-wirkus.de

## Parties involved

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

## Applications

- Seasonal energy storage in single- and multi-family buildings to provide emission-free heat
- Coupling between the power and heat sectors through cost-effective, low-loss, long-term storage

## Outlook

- Contribution towards the Energy Transition and climate protection goals. Potential savings of up to 30% of Germany's entire energy-related carbon dioxide emissions
- Various potential applications: centralised storage of renewable energy, industrial heat supply and small, decentralised systems

## Facts and figures

- Duration: 10-2018 to 09-2019
- Cost: €235,000 (DLR Technology Marketing)
- Power class: 10 kW electric
- Storage capacity: 100 kWh thermal
- Storage efficiency in a single-family house: 70–80%

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While considerable progress has been achieved over recent years in the implementation of renewable energy sources, the heating of buildings is still predominantly covered by fossil fuels. As a result, the heating sector accounts for approximately 30 percent of annual energy-related carbon dioxide emissions across Germany. The project will thus develop and demonstrate a long-term thermochemical storage system for seasonal balancing between periods when there is a surplus of renewable electricity and the heat demand of buildings.

The technology is based on the reversible gas-solid reaction in which hydrated lime ($Ca(OH)_2$) is converted into quicklime and water vapour, and offers promising advantages. The material is extremely inexpensive and available worldwide on an almost unlimited industrial scale. All of the materials involved in the reaction are completely ecologically harmless and can easily be disposed of. In addition, the technology is ideal for the long-term storage of thermal energy due to its loss-free storage principle.



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# Decentralised energy supply

Micro gas turbines for combined heat and power systems

## Brief description

Micro gas turbines can be used in combined heat and power units for the decentralised generation of electricity and heat. They enable high overall efficiencies, achieve low pollutant emissions and can handle a wide range of fuels – from natural gas and biogas/wood gas to hydrogen.

## Aims

The analysis and evaluation of new cycle variants for micro gas turbines permits a wide range of new application scenarios. Optimised heat exchangers increase the achievable efficiency and new combustion chamber concepts allow the use of new fuels and at the same time lower emissions of pollutants.

## Parties involved

DLR Institute of Combustion Technology
DLR Technology Marketing
with project partners: EnBW AG, MTT B.V., Dürr AG, Hi-Flux

## Applications

- Decentralised combined heat and power generation for residential buildings, businesses and schools
- Further possible fields of application: range extender for hybrid-electric vehicles, power generation in shipping, auxiliary power unit for aircraft

## Outlook

- Decentralised, low-emission and secure energy supply
- Use of renewable and sustainable fuels
- Increase in efficiency – low-emission multi-fuel burner for gaseous fuels (calorific value from 5 – 50 MJ/kg)

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## Facts and figures

- 2014 – world's first FLOX® combustion chamber system used in a natural gas-powered micro gas turbine. CO emissions < 5 ppm and NOx emissions < 25 ppm
- Micro gas turbines and combustion chamber systems in the power range of 6 – 333 kW (fuel output) investigated to date

Micro gas turbines for the decentralised generation of electricity and heat can significantly reduce the overall demand for primary energy, since very high overall efficiencies can be achieved through coupled power and heat production. Compared to conventional engine-based combined heat and power plants, micro gas turbines achieve very low pollutant emissions even without exhaust after-treatment. They also offer advantages in terms of maintenance costs and lower noise emissions.

In its research work, DLR is looking at the overall micro gas turbine system with the aim of developing new cycle variants, developing new areas of application and optimising existing systems. To this end, cycle simulations and experimental investigations will be carried out.

Another focus is on the development of new combustion chamber concepts. The focus here is on maximum fuel flexibility so that, in addition to conventional fuels, biogases of various compositions and hydrogen can be used. Equally important is the achievement of high combustion stability and low pollutant emissions over the entire load range. Combustion chamber concepts based on the FLOX® principle are used for this purpose, as these offer considerable advantages over swirl-stabilised burners in the power range typically found in micro gas turbines.



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# superARTIS

DLR's unmanned research helicopter

## Brief description

Under the name superARTIS (Autonomous Rotorcraft Testbed for Intelligent Systems), DLR operates SDO 50 V2 helicopters, which have a maximum take-off weight of over 80 kilograms. With the help of these systems – supported by a complex simulation environment – sophisticated autonomous flight missions are being developed and tested.

## Aims

The research focuses on autonomous detection of the aircraft's surroundings, flightpath planning, flight control during agile manoeuvres, and navigation methods that take into account the possibility of satellite navigation system failure. With its high payload capacity, range and flight speed, superARTIS is capable of research missions close to customer scenarios missions.

## Parties involved

DLR Institute of Flight Systems

## Applications

- Testing of mission scenarios and procedures for unmanned aerial vehicles
- Realtime 3D sensor data processing for flight control applications
- Evaluation and extension of flight perfomance for various helicopter configurations

## Outlook

- Transport and delivery of relief supplies beyond line of sight
- Cooperative use of airspace by unmanned and crewed helicopters
- Demonstration of image-based navigation for autonomous Moon landings

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## Facts and figures

**Maximum take-off weight:** 85 kg
**Rotor diameter:** 2x 2.8 m
**Payload weight:** up to 30 kg
**Maximum endurance:** 2 h

- Payload power supply via generator
- Fully autonomous flight including take-off and landing
- Experimental flight control with full control authority

The DLR Institute of Flight Systems has been operating unmanned helicopters with a maximum take-off weight of over 80 kilograms under the name superARTIS since 2012. In 2015, two new SDO 50V2 helicopters, developed by SwissDrones Operating AG, became operational. Demanding automated flight missions are developed and tested using these systems, and supported by a sophisticated simulation environment. The research focuses on autonomous environment perception, flight path planning, flight control for agile manoeuvres and navigation methods considering satellite navigation interferences. Thanks to its high payload capacity, range and air speed, superARTIS is able to fly on demanding research missions over the sea, together with other aircraft, or as a platform for multi-sensor systems.

**Project highlights:**

- **Innovation in humanitarian aid with the World Food Programme and Wings for Aid**
  Objective: To test an airdrop concept for the delivery of relief supplies beyond line of sight, dropping them in a realistic operational area.
- **Manned-unmanned teaming**
  To safely operate manned and unmanned helicopters as a team in shared airspace.
- **Flight campaign in Vidsel (northern Sweden)**
  Objective: Operation of an unmanned helicopter beyond line of sight, under demanding environmental conditions and together with other aircraft.
- **ATON (Autonomous Terrain-based Optical Navigation)**
  Objective: To use an unmanned helicopter as a demonstrator for navigation procedures to be used during autonomous Moon landings (crater navigation and landing site reconnaissance).
- **Fast rotorcraft**
  Objective: Flight operations at the edge of the flight envelope, expansion of high-speed flight capabilities, flight test methods for uncrewed aerial vehicles.


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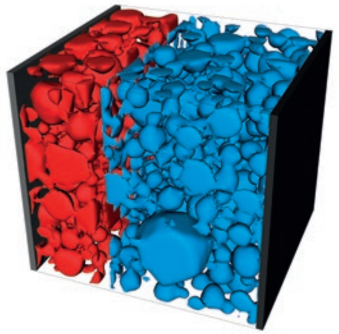
# DLRbat

Reliable battery systems for satellites

## Brief description

In the 'DLRbat' project, fundamental researchers and satellite developers are working closely together to get reliable satellite batteries into space more quickly and economically. The researchers' studies of a battery's inner functioning also provides the developers with information about how a battery module should be constructed.



## Aims

The aim of this DLR project is the development of reliable battery systems for satellites. On Earth, the findings will also help with the design of more efficient and higher capacity batteries for electric vehicles and electric aircraft, as well as for storage needed in connection with renewable energy sources such as photovoltaic cells and wind turbines.

## Parties involved

DLR Institute of Engineering Thermodynamics, DLR Institute of Composite Structures and Adaptive Systems, DLR Institute of System Dynamics and Control, DLR Institute of Optical Sensor Systems, DLR Institute of Space Systems

## Applications

- Satellite technology
- Battery systems for space
- Electric vehicles
- Electric aircraft
- Static energy storage

## Outlook

- Virtual development
- Sustainable energy systems
- Electric mobility on the ground and in the air
- Next-generation batteries and the generation beyond that

## Facts and figures

- 2019: tests under space conditions
- Cooperation of five DLR Institutes
- **Project duration**: 2017 - 2019


### Studying a modern battery's internal functioning

The aim of the 'DLRbat' project is to develop reliable satellite battery systems. What is unique is that fundamental researchers are working closely with satellite developers to get reliable satellite batteries into space more **quickly and economically**. Five DLR institutes are collaborating, each contributing their specialist expertise. The Institute of Engineering Thermodynamics is developing the **control electronics** and simulating the **battery's internal functioning**, in order to give the developers important information about its capacity. The Institute of Composite Structures and Adaptive Systems is developing an extremely lightweight yet mechanically stable **battery structure.** The Institute of System Dynamics and Control is simulating the battery's behaviour on the spacecraft, while the Institute of Optical Sensor Systems is researching how very **high power delivery** can be enabled on the satellite for short periods. The Institute of Space Systems is responsible for the qualification tests to determine, for example, whether the battery can withstand the **intense vibrations** it will experience during launch and its behaviour under **vacuum** conditions.

The battery system will be qualified and tested in 2019 for TRL 5 (technology readiness level). In the follow-up project, the battery will then be further developed to fly on a satellite. In future, reliable satellite batteries with the **latest battery technology** (such as lithium-sulphur) can then be used without having to undergo a number of lengthy, expensive tests. The findings will play a major role not only in space, but also on Earth. The knowledge gained will help to develop higher-capacity batteries for electric vehicles and electric aircraft, as well as for the static storage needed in connection with renewable energy sources, such as photovoltaic cells and wind turbines.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# Start your mission at DLR

Conducting research. Breaking new ground. Working on the great themes of the future of science. Helping to shape major developments. If this is how you envisage your personal mission, there is nowhere other than DLR that offers more scope for this: in space, in the air and on Earth.

In the areas of aeronautics, space, energy, transport, security and digitalisation, DLR researchers are working on groundbreaking innovations to develop potential solutions for the future. We invite you to work on fascinating projects involving basic and applied research in this unique environment. We will give you the freedom to implement your own ideas, and the encouragement required to optimally support you on your way to becoming a leading researcher.

At DLR, you can expect a corporate culture characterised by interdisciplinary exchange and appreciation. And we will provide the platform to present 'your topics' – even at an international level – and continue to shape these in collaboration with colleagues from all over the world.

We will give you the opportunity to make more of your ideas and shape the future. And not just after you graduate.

As a **student assistant or intern** at DLR, you will work independently in national and international research teams and gain initial practical experience.

As a **Bachelor, Master or Diploma student**, you will work on challenging research projects alongside reputable researchers.

As a **PhD student**, you will benefit from our unique DLR_Graduate_Program, where you will acquire key interdisciplinary skills for your academic career.

As a **young professional**, the whole world of cutting-edge research at DLR is open to you. We will help you make the most of your skills, with a variety of innovative personnel development opportunities.

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Exciting insights and all the information about career opportunities is available at DLR.de/jobs/en and on our social media channels:

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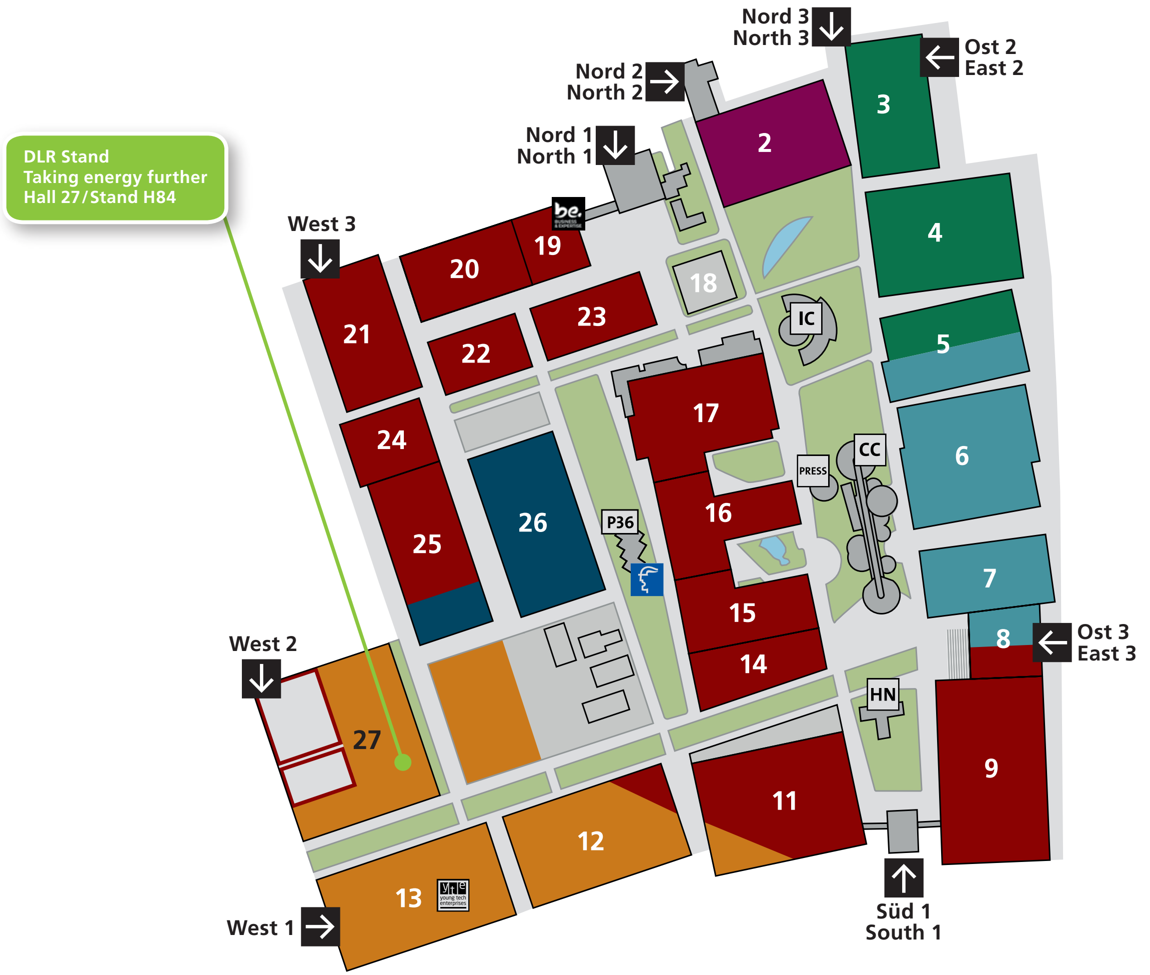
## Hannover Messe map




Please also visit the exhibits of the DLR Institutes of Networked Energy Systems and Engineering Thermodynamics (Hall 27/Stand D62) and the DLR Institute of Vehicle Concepts (Hall 27/Stand H75).

## Description

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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