HAW HAMBURG | CC4E

Solutions for the energy transition.

Competence Center for Renewable Energy and Energy Efficiency (CC4E)

Imprint

UNIVERSITY OF APPLIED SCIENCES HAMBURG (HAW HAMBURG)
Competence Center for Renewable Energy and Energy Efficiency (CC4E)
Steindamm 96
20099 Hamburg

Press
T + 49.40.428 75-5828
www.cc4e.de

Editor
Head of the CC4E
Prof. Dr. Werner Beba

Editors
The staff of the CC4E

Images
Pieter-Pan

Illustration
Jana Garberg & Louis Fraser

Conception and design
Jenny Capel & Nina Laskowski

Society

How we get involved

We transfer our practice and research relevant knowledge into studies and further education.

We want to take interested parties on the journey of the energy transition, inform them about the current state of research and create a joint dialogue.

We view the energy transition as a challenge for society as a whole and find solutions within a framework that is feasible for the market economy and socially sustainable.

With our research, we make a sustainable contribution to effective climate and global protection – for the preservation of a world worth living in.

Partners

The added value for you

We have unique research facilities with the Energy Campus Technology Center and the attached wind farm.

We apply a high level of interdisciplinarity in our research and in finding solutions.

We distinguish ourselves through many years of experience in energy research, strong project know-how and future innovation management.

We are strongly networked in the Hamburg metropolitan region and maintain a trusting relationship with our partners from science, business and politics.

The Future of Energy

Sustainable solutions for society‘s energy problems.

Our motivation is the passion to develop ways of achieving a sustainable energy supply – for the preservation of a world worth living in.

THE CC4E

The Competence Center for Renewable Energy and Energy Efficiency (CC4E) is a central scientific institution of the University of Applied Sciences Hamburg (HAW Hamburg) that addresses the current and future challenges of the energy transition in an interdisciplinary manner. Practical solutions are developed for a broad spectrum of technological, social, political and economic problems – from the idea to the implementation. In this way, the CC4E makes a sustainable contribution to effective climate and environmental protection.

Our motivation is the passion to develop ways of achiving a sustainable energy supply – for the preservation of a world worth living in. We also see it as an important task to engage in an extensive exchange with society about future changes in the context of tomorrow's energy supply and to galvanize and excite them for the energy transition through the content and results of our research projects.

Strongly anchored in the Hamburg metropolitan region, we assume an important interface function between science, business, politics and society. In doing so, we rely on the triad of research, mediation and networking.

The aim is to conduct research together with industry and research partners in order to exploit synergy potential.

With our Energy Campus Technology Center and the adjacent Curslack Research Wind Farm, we have created a strong infrastructure and are constantly expanding our competencies in the context of the diverse research projects. Through the successful implementation of innovative projects in the field of renewable energy, we increase the visibility of the HAW Hamburg and are one of the most important scientific institutions in northern Germany in this field.

The basis for the successful implementation of our goals is our respectful interaction with each other and our partners. Through this, we also open ourselves up beyond the projects to the topics of sustainability and environmental awareness.

Research Focuses

Understanding the energy transition as a challenge for society as a whole means approaching finding solutions in an interdisciplinary way.

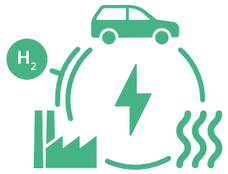
ENERGY RESEARCH

The spectrum of areas of expertise in combination with the technical research equipment at the Energy Campus Technology Center and the close cooperation with partners from industry, science and politics are the main features of the research activities at the CC4E. The core areas of expertise of the CC4E are in:

- Sector coupling and hydrogen
- Heat
- Wind energy
- Social transformation and acceptance

With regards to its projects, the CC4E has a high level of expertise across all content-related research focal points – from the idea, through conception, application and control, to content-related execution. Within this framework, the CC4E also places special emphasis on innovation management, which is particularly relevant in this context and is primarily concerned with the systematic management and planning of projects. In addition, technology and market evaluations must be carried out and innovations brought to market.

The overriding goal under the German government's new climate protection law is to achieve a mandatory reduction of 65% in greenhouse gas emissions by 2030 compared with 1990 levels, and a reduction target of at least 88% by 2040. Germany is to achieve greenhouse gas neutrality as early as 2045, and the German government is aiming for negative emissions by 2050. At that point, Germany is to bind more greenhouse gases than it emits. To be able to achieve these goals, the CC4E is conducting intensive research. Together, we are making our contribution to the success of the energy transition.



SECTOR COUPLING AND HYDROGEN

Sector coupling plays a key role in the overall energy transition. In particular, this includes linking renewable energy generation with demand in the industrial, mobility and building heat sectors . To accelerate the energy transition in a targeted and consistent manner, the various sectors' technologies, infrastructures and markets – both cross sectoral and intrinsic – must be more closely coordinated in order to establish a comprehensive, intelligent energy system. This raises new concerns for the entire energy supply system. One specific requirement is the system's flexibility, or its ability to respond to fluctuations in generation. Power-to-gas technologies play an important role in this process. By converting electrical energy into hydrogen using a process known as electrolysis, energy can be stored in the medium and long term and used in a variety of ways. If required, the energy can be converted back into electricity in fuel cells and hydrogen-capable power plants – ideally using the waste heat. Alternatively, the hydrogen can be used to drive fuel cell vehicles, in applications where battery electric vehicles are not operational. Furthermore, hydrogen and hydrogen derivatives can be used in industry to replace fossil feedstock materials.

The CC4E focuses on green hydrogen research. The electricity required for electrolysis is obtained from renewable energy sources. Another research topic is the production of turquoise hydrogen. This is produced by splitting methane into hydrogen and elemental carbon. The powdered, pure carbon, also known as carbon black, is thus bound long term as a solid or can be used in industrial processes if required. Thus, the research work aims to produce CO_2-neutral or even negative hydrogen. In addition, the CC4E operates a unit for the separation of CO_2 from ambient air (CO_2 Direct Air Capture) and subsequent use (see page 5).

For the concrete testing of the various technologies in the field of sector coupling, the CC4E uses the technical research equipment at the Energy Campus Technology Center, which is operated as a "grid-responsive building" (see page 16 f.). In addition, work is being done on equipment provided by partners for research purposes.

Grid serviceability, grid integration, storage and charging management are key research areas: The demand side integration research field is particularly concerned with the use of electricity from renewable energy sources for grid support. For this purpose, both energy producers and different, flexible electricity consumers are integrated at the Energy Campus Technology Center. Various storage concepts are being developed and tested in the field of energy storage, including battery, hydrogen, methane, heat and cold storage systems. In order to explore solutions for the system integration of renewable energy, a battery storage system was also operated at the Curslack Research Wind Farm as part of a research project*. In addition, research is being conducted to determine how intelligent and variable control concepts can be used to optimize energy efficiency and carbon dioxide reduction. This includes intelligent charging management, which increases the share of locally generated renewable energy and maximizes charging capacities. Software solutions, in turn, support grid-serving charging operation.

*After completion of the research project, the battery storage provided by the project partner was dismantled. The infrastructure and subcomponents are still available and follow-up projects are being planned.

Heat

In recent years, the public perception of the energy transition has focused almost solely on the electricity sector. However, it is not only in the electricity sector, also in the areas of heating, cooling and transport that fossil energy fuels must be successively replaced by renewable energy. In the heating sector in particular, considerable potential for decarbonizing the energy system is becoming increasingly apparent. Currently, about half of the final energy demand in Germany is used for heating, so ensuring a climate-friendly, reliable and affordable heat supply is central to the success of the energy transition.

The structure of the heat supply is fundamentally different to that of the electricity supply. Unlike electrical energy, heat is not suitable for transport over long distances due to the high losses involved. Heat generation must therefore be much more decentralized and, above all, closer to the point of consumption than electricity production. In Germany, most buildings have their own heat generation. Buildings that obtain their heat from district heating systems (DHSs) are rare exceptions. Such supply systems must be further expanded and optimized in order to switch the heat supply to renewable heat sources, such as geothermal energy, solar thermal energy, heat pumps, surplus heat from industry and commerce, and combined heat and power (CHP) based on renewable and synthetic fuels. This is the starting point for several research projects at the CC4E.

The main research focus of the CC4E is DHS transformation. This mainly includes the development and control of smart thermal grids as well as the elaboration of transformation strategies for DHSs towards a fully renewable supply. The core competence lies in modeling, distributed simulation of thermal systems and in the development of monitoring and control algorithms.

Against this backdrop, the CC4E investigates how, for example, flexible CHP plants can be used. The aim is to be able to react actively to fluctuating electricity production. At the same, researchers are examining how heat storage potential can be increased with the help of urban infrastructures. In this context, they are also investigating how aquifer thermal energy storage can be integrated into a smart thermal grid. Aquifers are natural, confined rock formations that carry groundwater deep underground. In this groundwater, thermal energy can be stored long-term. Aquifer storage facilities thus serve primarily to cover seasonal fluctuations in demand and production. Another relevant area for controlling the demand or customer side is intelligent demand side management. This increases potential savings and can contribute significantly to increasing the efficiency of DHS operation. In the various research approaches, complex simulations are used, the results of which are also tested in field trials. In addition to the technical side, the market economy side is also being considered: for example, research is being conducted into how innovative trading, marketing and detection mechanisms can contribute to the decarbonization of district heating. This competence area also makes use of the infrastructure of the Energy Campus Technology Center and is continuously working on the further development and operation of the Smart Grid Laboratory established there.

Wind Energy

Due to the rapid expansion of wind energy in Germany both onshore and offshore – wind turbines must make an ever-greater contribution to security of supply. An important aspect here is the provision of balancing power. This is needed to compensate for short-term imbalances between generation and consumption. In the past, this imbalance was compensated for by fossil energy sources, as neither regulations nor technical requirements made it possible for wind energy to provide system security. How to enable short-term provision of balancing power in the future is one of the research questions that the CC4E is addressing.

Much of the research also examines energy yield and lifetime optimization of wind farms. The special feature here is the research on real turbines in the CC4E's own research facility, Curslack Wind Farm, which is directly connected to the Energy Campus Technology Center (see pages 16 & 19). The knowledge gained here can be transferred to new wind farm projects. Particularly important, for example, is the study of wake turbulence and the effect it has on the mutual interaction of wind turbines. Intelligent sector management can reduce loads on downstream turbines and optimize wind farm layouts. In the context of research on the topic of wind farm efficiency, the focus is on increasing turbine reliability while reducing the use of materials. Component damage is to be predicted as accurately and early as possible to reduce failures and turbine downtimes. A Condition Monitoring System installed in the research wind farm provides support in this regard.

An innovative research approach is the development of concept designs for multi-rotor and two-bladed wind turbines. The motivation is, on the one hand, to adapt wind turbines to the environment and influencing forces in the best possible way through their design and, on the other hand, to develop maintenance-friendly designs in order to reduce service and repair costs. In conjunction with the two-bladed turbines, floating platforms are also being investigated to enable deployment in next-generation wind farms for deep-water sites.

Another aspect of our research is the acoustic optimization of wind turbine gearboxes and generator housings. The goal is not only noise reduction as such, but also the use of acoustics for early fault detection. To this end, the CC4E research team is working with a weatherproof acoustic camera based on MEMS micro-phones (Micro-Electronic-Mechanical Systems) that have been optimized for continuous measurements. Here, there is a connection in terms of content to another area of focus, the virtual auralization of the research wind farm. The focus is on the audiovisual (sound-)landscape, which reproduces the soundscape of the wind farm and its surroundings in a virtual space. In addition, a so-called noise-watchdog will measure sound emissions from the wind turbines in real time and automatically link the results to the wind farm's control system in order to optimize the noise reduced operation mode. Here, the CC4E creates an impor-tant interface for science and citizen communication.

CC4E's Curslack Research Wind Farm, approx. 1 km from the Energy Campus Technology Center

SOCIETAL TRANSFORMATION AND ACCEPTANCE

In addition to technological research and development, the CC4E is engaged with issues relating to environmental impact, social acceptance and transformation processes in the context of the energy transition. The CC4E strives to understand the growing complexity of the challenges of the energy transition as a task for society as a whole and to translate it into approaches that are both feasible in market terms and socially sustainable. This area of competence is characterized by a particularly high level of interdisciplinarity: CC4E has gained extensive experience through numerous projects which are implemented in large collaborative projects – such as X-Energy and NRL – together with partners from science, industry and politics. The broad professional expertise enables ecological, social science, didactic as well as economic perspectives on current issues of the energy transition.

Environmental and social research at the Curslack Wind Farm is investigating the possible effects of wind turbines on local residents and the environment. Among other things, research is being conducted to determine the collision risk of bats with wind turbines using technical detection systems. In addition, the influence of an aircraft detection lighting system on the acceptance of wind energy is being investigated. For this purpose, the obstruction lighting of wind turbines, which is necessary for aviation safety is reduced by more than 90% using a technical system. Whether this leads to a significant increase in acceptance among residents and how the introduction process of the technology takes shape in practice is one of the social science research questions at the CC4E.

The economic focus of the CC4E lies in researching new market and business models. At the forefront is the question of which structures and regulations must be fulfilled so that developed technical innovations can be implemented on the market. Specifically, this involves identifying areas of application for hydrogen technologies that are suitable for the economy as a whole and providing scientific support to practice partners from the fields of production, mobility and industry in the precise implementation of these technologies. In addition, work is being done on ESG due diligence. ESG describes criteria from the areas of the Environmental, Social and responsible corporate management (Governance). The aim is therefore to develop a tool for auditing companies on the basis of sustainability criteria that is based on current EU requirements (e.g. Taxonomy Regulation). Such a tool will be crucial for the evaluation of companies and investment decisions in the future.

A further focus is on pairing technological projects with socio-economic issues. The focus of social research here is on how the industrial use and thus the market ramp-up of sector coupling technologies can be accelerated by involving all relevant stakeholder groups in each case.

As part of the university, the CC4E is engaged in further education and qualification beyond classical teaching. To this end, demand-oriented learning opportunities and suitable learning platforms are (further) developed for the wider society as well as for qualified personnel for both in person and online teaching (see page 12).

The research projects carried out at the CC4E are always accompanied by appropriate project and result communication. The aim is to engage in an intensive exchange with citizens and social representatives about the future changes in energy supply in the spirit of participation and transdisciplinarity. This includes not only the communication of relevant knowledge and information, but also the surveying of interests and attitudes, as well as joint dialogue about future action. This is intended to increase acceptance and support for sustainability and the energy transition in the social environment.

Research on biological methanization at the Energy Campus Technology Center in Hamburg-Bergedorf.

Studies and Further Education

Education, digitalization, climate protection: free learning portals on the topic of the energy transition.

The CC4E sees itself as responsible not only for researching and informing on the energy transition, but also for actively transferring knowledge to the wider society. A looming shortage of skilled workers could be seen as an obstacle to the successful implementation of the energy transition. To counteract this, the CC4E provides among other things, publicly accessible and free learning portals.

AVAILABLE RESOURCES CAN BE FOUND HERE

HowToChangeARunningSystem.info is aimed at younger, interested youth and adults from high school through career entry. The learning portal under Creative Commons license conveys background knowledge on the climate crisis and the energy transition in a straightforward and clear way. In the five sections, climate crisis, energy sources, system change, change in way of thinking and personal initiative, the story of the energy transition is told with the help of vides, infographics and short texts in an engaging way. In this way, inspiration to take action is given. The website also offers numerous opportunities to delve deeper into various aspects of the energy transition.

Energiewende-Campus.de offers specialized information on the energy transition. Thus, the portal is primarily aimed at career changers who want to expand their know-how in the field of renewable energy and are looking for a first professional entry point. The learning portal shares education and training opportunities around topics of climate change, acceptance research, smart balancing, digital leadership and change management. In addition, the platform includes many other explainer videos on research-related and hands-on work at the CC4E.

STUDY PROGRAMS

As a higher education institution, it is part of the CC4E's self-image that the application-related knowledge on technological, energy policy, economic and social issues from the research projects flows into the teaching. This means that the HAW Hamburg is constantly expanding its teaching and studies in the field of renewable energy and focuses on close links with innovative, application-oriented research and development. Numerous transfer partnerships with companies and institutions also ensure a high level of application proximity. Particularly in final theses and study projects, companies support the next generation with real world questions and receive creative solutions. HAW Hamburg is the second-largest university in Hamburg and one of the largest engineering educators in northern Germany. Together with the CC4E, HAW Hamburg is increasingly expanding the range of studies in the field of renewable energy, integrating relevant knowledge from research and industry and thus promoting the interdisciplinarity that is increasingly in demand in the industry. This forward-looking focus area currently comprises five bachelor's and five master's degree programs and educates around 2000 students.

As part of the doctoral program, it is also possible to do a cooperative doctorate in a chosen field at the HAW Hamburg.

STUDY PROGRAMS WITH A FOCUS ON RENEWABLE ENERGY

Faculty	BA/MA	Study Program
Life Sciences	B. Sc.	Environmental Engineering
	M. Sc.	Renewable Energy Systems – Environmental and Process Engineering
Engineering and Computer Science	B. Sc.	Renewable Energy Systems and Energy Management Regenerative Energy Systems and Energy Management – Electrical and Information Engineering
	M. Sc.	Sustainable Energy Systems
	M. Eng.	Renewable Energy

STUDY PROGRAMS RELATED TO RENEWABLE ENERGY

Faculty	BA/MA	Study Program
Life Sciences	B. Sc.	Process Engineering
	M. Sc.	Industrial Engineering
Engineering and Computer Science	B. Sc.	Applied Computer Science
	B. Sc.	Mechanical Engineering and Production
	M. Sc.	Automation Technology

Locations

AM SCHLEUSENGRABEN

One of the cornerstones of the CC4E is the infrastructure in Bergedorf. With the Energy Campus Technology Center, the CC4E has its own research center, where a large part of the scientific team works. At its heart are the smart grid laboratory and the wind laboratory. The Curslack Research Wind Farm is located in the immediate vicinity of the Technology Center – a constellation that is unique in Germany.

STEINDAMM

The Steindamm site is home to the project management of the major projects, the business development department, the strategic planning department and the CC4E management with central functions. From here, a total of around 30 ongoing projects with a total of around 80 employees are managed.

BERLINER TOR

Not far from our headquarters at Steindamm, our wind team is researching, among other things, how the rapid expansion of wind energy in Germany - both onshore and offshore - can enable wind turbines to make an ever-greater contribution to security of supply.

Energy Campus Technology Center

In an integrated network with the wind farm, the Technology Center represents a unique infrastructure that enables application-oriented research in a grid reactive building.

By 2030, Germany's greenhouse gas emissions are to be reduced by 65% compared with 1990 levels, and by 2040, by 88%. By 2045, greenhouse gas neutrality is to be achieved and Germany's energy needs are to be met by renewable sources – predominantly wind and solar.

For the power supply to be secure and stable, as much electricity as is consumed must be available at any given moment. However, renewable energy generation fluctuates depending on wind and solar conditions and does not always match consumption. So how can we enable a secure and stable power supply in the future?

There is a promising approach to the solution: the so-called smart grid, an intelligent energy network. Here, generation and consumption are intelligently coordinated, for example through flexible energy consumers, as well as heat, electricity and gas storage facilities (see page 6). This interaction is being developed and tested at the Energy Campus Technology Center in Bergedorf. For this purpose, components for energy generation and energy consumption are available and united under one roof in the building. In this way, the interaction of the various components can be investigated – either as a whole or in parts. The special feature here is that all components are integrated into the operation of the building.

In this way, the individual components interact in an exemplary manner:

If not enough electricity can be produced from wind and sun on a cold winter day, the combined heat and power plant (CHP) is operated at the Energy Campus Technology Center. It produces enough heat and electricity for the building, and excess heat is stored temporarily. Unneeded electricity is fed into the power grid, where there is at that moment insufficient electricity from local, renewable energy sources.

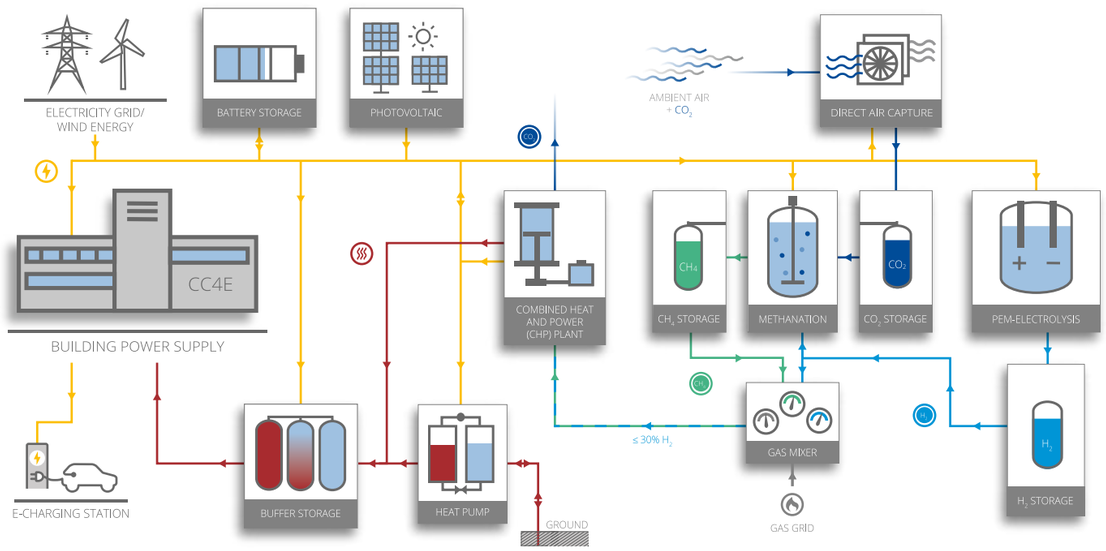
If the weather changes and more electricity is available from wind and/or sun, it is possible that there is too much electricity in the energy system as a whole. In this case, the CHP unit is switched off. The electricity that is available in the grid and is not needed can be withdrawn from the grid by consumers, such as PEM electrolysis, methanation, Direct Air Capture (DAC), heat pump or by a charging station for electric vehicles.

The electrolysis is used to produce hydrogen (H_2). The Direct Air Capture unit extracts CO_2 from the ambient air. The resulting gases are converted to methane (CH_4) – quasi synthetic natural gas – in a biological methanation plant. In this way, electricity can be made "storable" in the form of gases. If the weather changes again and the demand for electricity from renewable energies exceeds production, the stored synthetic natural gas can be used in the CHP to generate electricity and heat.

The different gases – synthetic methane, hydrogen and natural gas – are fed into the CHP unit using a gas mixer. Up to 30% of the (natural) gas can be substituted with hydrogen. Coupled heat and power generation by the CHP unit can thus be effectively decarbonized step by step and represents an important technology option in the course of the energy transition.

If the electricity supply is high, the electricity-driven heat pump can be added as a further consumer. Depending on the weather, this provides heat or cold from the ground with which the building is heated or air-conditioned accordingly. These temperature levels can be stored in water tanks, in so-called buffer storage tanks. In addition, it is possible, with the help of electric heating rods, to heat water in the heat storage tanks directly with electricity if the output of the heat pump is not sufficient or higher temperatures are required.

On top of this, the e-car and e-bikes are charged at the Technology Center via an electric charging station. For this, an intelligent charging management system has been developed to maximize the share of locally generated renewable energy.



Curslack Research Wind Farm

Wind, energy resource of the future.

The Curslack Wind Farm, host to five wind turbines of the 2.40 to 3.15 megawatt class is located about one kilometer from the Energy Campus Technology Center. Up to 11,000 two-person households can be supplied with electricity annually by the Curslack Wind Farm.

The system connection of the research facilities with the actual wind farm creates numerous research projects as well as synergy potentials. Examples of this are the investigation of the integration of wind power into the power grid and the enabling of fluctuation balancing through load management and storage components. For this purpose, a local lithium-ion storage system was set up at the wind farm*. Fluctuations in the grid can thus be balanced by control energy.

The research wind farm is equipped with a condition monitoring system. Numerous sensors record the condition of the wind turbines, which enables early fault detection, efficient control of wind farm operation and an increase in electricity production.

A 120-metre-high wind measurement mast, compliant with current IEC standards, is located directly adjacent to the wind farm. Anemometers, wind vanes and other sensors at various heights can be used to determine ambient conditions as well as to measure wind profiles and power curves. Two LiDAR (Light Detection And Ranging) systems installed on the wind turbines and a terrestrial LiDAR are available for this purpose.

For environmental research on the collision risk of bats, a radar is in continuous use at the Curslack Wind Farm to determine the presence of bats in a large detection volume. Acoustic detection devices have also been installed in the nacelles for species and presence determination. The simultaneous use of these devices and the correlation of the data should lead to the development of a special detection system that can be used in the future, for example, for the validation of existing shutdown algorithms for wind turbines.

*Since the research projects has come to an end, the battery storage provided by the project partner has been dismantled. The infrastructure and subcomponents are still available and follow-up projects are being planned.

Research partnerships in the Hamburg metropolitan region strengthen the innovation base and contribute to sustainable and independent security of supply.

Cooperations and Projects

As a contact for companies, authorities, associations and other scientific institutions, the CC4E brings together the right partners for a wide range of issues. The goal is always the expansion of the energy transition and the strengthening of the Hamburg metropolitan region as a location for innovation.

Especially with the Energy Campus Technology Center, the CC4E wants to promote the establishment of companies in the renewable energy sector and their research projects. Particularly small and medium-sized enterprises can benefit from potential cooperations and the associated research and development capacities. The same applies to new and start-up companies, which are to be supported within the framework of joint projects.

In order to achieve this, on the one hand, close cooperation with authorities and politics is crucial, but also with associations and societies such as the industry network Cluster for Renewable Energy Hamburg (EEHH) on the other. In addition, it is important to network the scientific institutions more closely with each other in order to promote the further training and qualification of specialists. In addition, joint research projects can further exploit the competence spectrum and thus the innovative strength. Within this framework, the CC4E works closely with the Energieforschungsverbund Hamburg (EFH) – an association of Hamburg's five major universities.

The CC4E has a large number of research projects, ranging from smaller study projects to larger collaborative projects. Such projects are often carried out in cooperation with partners from industry and science. Due to the diverse know-how in the individual focus areas and especially with the Energy Campus Technology Center, the CC4E forms an essential basis for further research projects and strategic partnerships. These include, in particular, close cooperation with Frauenhofer IWES (Institute for Wind Energy Systems) and the Frauenhofer Application Center ILES (Integration of Local Energy Systems).

Together with Frauenhofer IWES, a demonstration center for sector coupling is planned at the Hamburg-Bergedorf site.

DEMONSTRATION CENTER

The Demonstration Center for Sector Coupling and Hydrogen is intended to expand the Bergedorf site and strengthen the Hamburg metropolitan region as a driving impulse generator for science and industry. The challenges arising from the restructuring of the energy supply and climate protection required for this are manifold. In the coming years, it will be increasingly important to integrate the generation structures for renewable energies that have been created and are currently being expanded in a meaningful way by linking them with the sectors of mobility, as well as heat supply for buildings and industry. This is the only way to ensure a stable, environmentally sustainable and cost-effective energy supply in the long term. The focus is on the generation of green electricity and its conversion into other energy sources, as well as on storage and direct use. EU funding from the European Regional Development Fund (ERDF) is available for this purpose.

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CONTACT US.

Press
kommunikation@cc4e.de