Research & News

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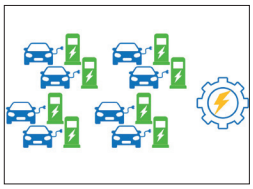
Topics of this issue

FlexFleet develops flexible charging strategies for electric vehicle fleets



To protect the charging infrastructure and local distribution networks against overloading, the PGS Institute and its Grid Integration and Storage System Analysis research section have teamed up with other project partners in the FlexFleet project to develop smart charging strategies for electric vehicle fleets. Page 2

Study analyzes effectiveness of relief programs

To cushion the impact of rising energy prices on private households, the German federal government adopted three relief programs, each one comprising different individual measures. Researchers from FCN have now published a brief study analyzing the financial relief these three packages provided in 2022 and 2023. Page 6

Editorial

Dear Readers,

RWTH Aachen University now has a unique research infrastructure focusing on battery-electric energy storage and the associated power electronics: CARL. E.ON ERC maintains close ties with the new center through two chairs, but that is not all. We also plan that CARL is supplied with electricity via the local medium-voltage DC network. This issue of Research & News also once again showcases the diverse range of research topics studied at our center, in many cases on an interdisciplinary basis: from electric mobility to grid digitalization and from efficient energy supply to buildings up to economics and social science topics.

I wish you happy reading!
Rik W. De Doncker

PGS I Energy storage

CARL accelerates innovation in storage systems and power electronics

The interdisciplinary Center for Ageing, Reliability and Lifetime Prediction of Electrochemical and Power Electronic Systems – **CARL** – officially began operating right next door to E.ON ERC on the Melaten campus of RWTH Aachen University in the spring of 2023. The new research center occupies some 5,000 square meters of lab and office space. In terms of content, the center is connected with the well-known energy research center at RWTH Aachen University through the two chairs at PGS in particular: Electrochemical Energy Conversion and Storage Systems (Prof. Dirk Uwe Sauer) as well as Power Electronics and Electrical Drives (Prof. Rik W. De Doncker). It is also physically connected to the medium-voltage DC network operated on the Melaten campus by E.ON ERC.

Thus, RWTH Aachen University is home to an interdisciplinary research infrastructure like no other, focusing on the aging and life spans of energy storage systems and power electronics. Envi-

Source: Bernd Class, BLB

High-ranking guests attended the opening of CARL (from left): Gabriele Willems, BLB NRW (state building and real estate management agency for North Rhine-Westphalia); Prof. Ulrich Rüdiger, Rector of RWTH Aachen University; Prof. Martin Winter, Helmholtz-Institut Münster (HI MS); Ina Brandes, Minister of Culture and Science of the State of North Rhine-Westphalia; Ute Willems, BLB; Prof. Dirk Uwe Sauer, CARL spokesperson; Dr. Stefan Jung, German Federal Ministry of Education and Research ; Prof. Rik W. De Doncker, spokesperson for the power electronics research area at CARL.

ronmental tests on battery cells, battery modules, and battery packs and on power electronic structural elements, i.e. power semiconductor modules, and systems, are performed in the various areas of the building. The back part of the property is home to 40 test cells with up to 5,000 test circuits, which are used for the ongoing cycling of a wide range of different battery cells.

CARL receives its energy supply through the local medium-voltage network, with a connected load of 7 megawatts. The solar panels on the roof the building reach a peak output of 99 kilowatts.

Climate-controlled underground lab rooms, also shielded against electromagnetic fields, are available for operating sensitive computed tomography (CT) scanners and electron microscopes. Three shakers and vibrations are used to identify potential mechanical influences on batteries and power electronics.

The chemical lab, which occupies some 500 square meters, is used to analyze and characterize the composition of materials in battery cells and their changes in a wide range of ways. A dry room makes it possible to set up prototype cells at humidity levels corresponding to a temperature of -60°C. A cleanroom is also available for work to set up power electronics modules.

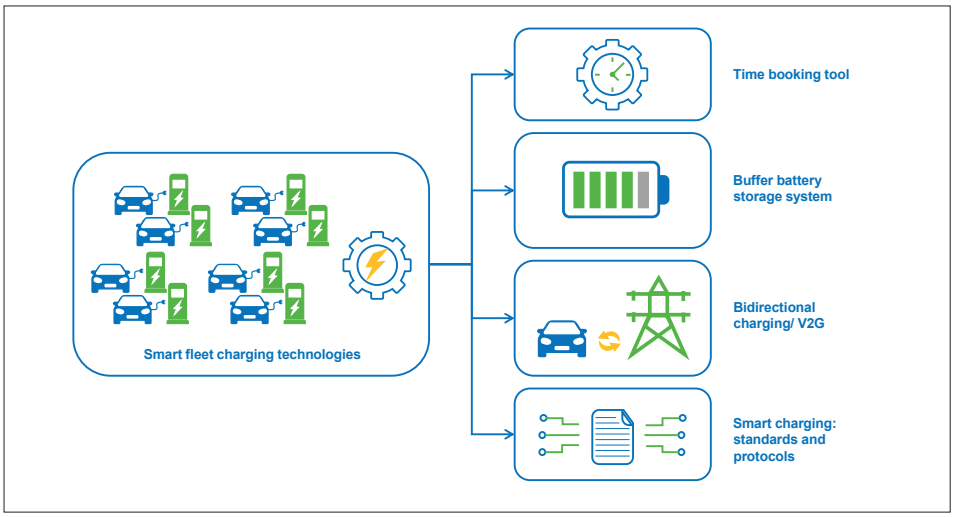
“In CARL, we have a unique opportunity to study and characterize the operating behavior of batteries and power electronics holistically, from the vehicle down to the crystal level of the materials. This unlocks opportunities to develop and use new materials and products faster, which is something we now need more than ever to advance the energy and transportation transition and protect the climate,” as Professor Dirk Uwe Sauer, the CARL spokesperson, explained at the opening of the research center.

Speaking on behalf of the power electronics research area at CARL, spokesperson Professor Rik W. De Doncker added, “Power electronics are a key element in bringing about the energy transition. New high-performance wide-bandgap semiconductors unlock much higher power density. CARL helps us understand the aging effects of these new components so we can develop reliable converters for the next generation of carbon-neutral energy systems.”

PGS | Electric mobility

FlexFleet develops flexible charging strategies for electric vehicle fleets

The future of mobility is electric. In light of this expected development, there is a need to protect the charging infrastructure and local distribution networks against overloading. In the FlexFleet project, the Grid Integration and Storage System Analysis (NIS) research section of PGS have teamed up with other project partners to develop smart charging strategies for electric vehicle fleets.



The flexible charging technologies developed as part of FlexFleet helps to prevent peak loads.

Many companies are currently looking at battery-based mobility as an advantageous path forward for them. To lower fuel costs and improve operating efficiency, they are focusing on building and expanding electric vehicle fleets. But increasing the number of electric vehicles inevitably also increases the load on the charging infrastructure and local distribution networks, which can lead to significant issues, especially at peak load times. Peak loads can require costly grid expansion and/or bring plans for the rapid spread of electric mobility to a halt.

Within the framework of the FlexFleet project, engineering researchers have teamed up with partners from the business sector to develop smart fleet charging strategies to lower peak electricity needs, along with a booking tool that makes it possible to supply a fleet with the existing charging infrastructure. The charging strategies developed within the project are being validated with a real-world pilot fleet of about

100 electric vehicles operated by RegioNetz, the grid operator for the Aachen area. There are also plans to perform a detailed analysis involving the clientele of Aachen-based company smartlab Innovationsgesellschaft to study the relationship between annual peak load and installed charging capacity for various electric vehicle fleets, including at the national level.

The practical experiences gained from the validation process, combined with the results of the data analysis, will make it possible to pinpoint detailed recommendations for action that electric fleet operators can take, with special attention to making the guidance understandable to third parties with no prior technical expertise.

In this project, NIS and the Institute for Power Electronics and Electrical Drives (ISEA) are mainly responsible for analyzing the data, developing and validating charging strategies for smart fleets, and crafting recommendations. SMART/LAB is handling the supply of data to the electric fleet and the development of a time booking tool. In addition to RegioNetz, Berlin-based Carano Software Solutions is another associated partner.

There is also a cooperative relationship with the Beijing Institute of Technology, which is carrying out a similar project in China. The two sides will bring their results together to develop smart strategies and map out recommended actions.

FlexFleet is receiving funding from the German Federal Ministry for Digital and Transport. The project was launched in August 2022, with plans to conclude it by the spring of 2026.

ACS I Energy systems research

Shared European “data spaces” drive digitalization

Across multiple projects, the ACS Institute is heavily involved in the further development and evolution of a European data strategy. Structured collection and processing of data is becoming more and more important as a resource for economic growth, development of innovation, job creation, and ultimately for progress as a society. The goal of the European Union’s data strategy is to create an internal market for data that ensures that the bloc can compete on the global stage while also guaranteeing European data sovereignty. Data for research, business, and society should be available in shared European data spaces, with companies and individuals alike being required to meet stringent criteria during both data generation and processing.

The OPEN DEI project, part of the Horizon 2020 program, has performed foundational work on data spaces across multiple sectors. ACS supervised the energy sector for this project. Energy is one of the key areas of the EU’s digitalization strategy, alongside manufacturing, agriculture, and healthcare. The research institutions involved in the OPEN DEI fundamental project aimed to identify gaps, possible synergies, and potential regional and national cooperative efforts to create a broad working basis for innovative activities as the EU moves toward digital transformation while at the same time intensifying communication among the players involved.

Another project receiving funding as part of Horizon 2020 is OneNet, the largest EU-funded research project in the area of electrical networks, which is being coordinated by Professor Antonello Monti. Among other things, the project has developed a software package called OneNet Connector, which can be integrated into any existing energy platform to simplify the exchange of data through user-friendly interfaces. The International Data Spaces Association (ISDA), which reviews architectures, interfaces, and sample code with an eye to data security, has acknowledged the connector software as trustworthy.

At the European level, ACS is also involved in ENERSHARE. This Horizon Europe project brings together 31 international partners from business and research to create a shared European energy data space and implement it as a role model for subsequent activities.

At the national level, ACS is involved in a consortium called nfdi4energy (National Research Data Infrastructure for the Interdisciplinary Energy System Research) against the background of the European data strategy. The consortium’s aim is to improve communication and sharing of data and software in energy systems research. The German Research Foundation (DFG) has committed up to ten million euros in funding for the project for an initial term of five years.

Academia and the research sector give rise to research data in various forms and in large volumes, from historical weather data to forecast parameters of technical systems and infrastructures and beyond to software systems. To make these kinds of data more accessible, set standards, and establish those standards in the relevant disciplinary communities, an association called National Research Data Infrastructure Germany (NFDI) was created. This entity consists of consortia that provide infrastructure facilities for research data across Germany. nfdi4e-

nergy focuses on data and software in energy systems research, which are needed for purposes such as research on forward-looking technologies having to do with all aspects of the German energy transition and for the digitalization of energy systems. The goal here is to make these data usable and optimally reusable from the initial project idea to the discourse with society at large and beyond to the point when they are transferred to industry or the political sphere.

ACS I Energy networks

New cooperation focusing on grid stability in Taiwan

In the DYNASTY (Dynamic inertia analysis and estimation in low-inertia grids) project, ACS and the Institute of High Voltage Equipment and Grids, Digitalization and Energy Economics (IAEW) at RWTH Aachen University have embarked on a cooperative relationship with researchers at the National Kaohsiung University of Science and Technology, in Taiwan.

The research project is part of a cooperative program agreed between the Ministry of Science and Technology of Taiwan (MoST) and the German Research Foundation (DFG). DYNASTY was approved as a transnational fundamental research project, which formed the basis for the partners' collaboration.

Renewable energy is growing more and more important to a carbon-free, sustainable supply of electricity. Since it is fed into the grid using power electronics components, the inertia of supply networks decreases as this trend continues, so the electricity supply system becomes low in inertia. In weak grids, particularly in relatively small island grids like Taiwan's, the associated impacts are highly pronounced and easy to observe. Taipower, the Taiwanese transmission system operator, naturally has a considerable interest in overcoming the challenges associated with increasing feed-in of renewable power.

The DYNASTY project gives the two institutes at RWTH Aachen University an opportunity to further develop and refine their existing research approaches for estimating stability and inertia, and their experience in the real-time simulation by using experimental data from Taiwan and to examine the effectiveness of these approaches based on this concrete example.

Beyond the close cooperation taking place within this research project, there are plans for further cooperation between ACS, IAEW, and transmission system operator Taipower.

EBC/ACS I Energy efficiency

IT-Zauber makes high-performance computing more efficient

In the IT-Zauber project, EBC and ACS have teamed up to develop a holistic control system for computing and cooling processes at data centers in keeping with the "GreenHPC" funding guidelines issued by the German Federal Ministry of Education and Research. High-performance computing (HPC) is a must these

ACS Ticker

In the EU's TARGET-X project, ACS plans to team up with industry and research partners to accelerate the digital transformation of key industries such as energy, construction, the automotive sector, and manufacturing.

To this end, digital twins and functions such as localization and merging data between sensors and networks will be tested and evaluated in various test environments and industries using 5G and 6G technologies. Alongside transmission speeds and rates, the factors of sustainability, security, and data protection are particular areas of focus. Ultimately, TARGET-X is intended to help safeguard the leading role of European industry in the 5G and 6G segments.

* * *

Advanced energy systems are inconceivable without storage. At the same time, there are a wealth of different solutions with very different characteristics. The partners in the EU's InterSTORE project, which is being coordinated by ACS director Professor Monti, aim to develop innovative middleware – a term for software and cloud services that connect applications, data, and users – to integrate optimum storage solutions for various use cases quickly and automatically. The project partners' ultimate goal is to accelerate the build-out of storage solutions.

The developments involved in InterSTORE are to be offered on an open-source basis, but they can also be incorporated into commercial platforms. The innovative solution is being tested in four real-world test environments to study fitness for purpose, user acceptance, and cost effectiveness.

days across many scientific disciplines, such as climate modeling, astrophysics or biology. But it also uses a relatively large amount of energy, with data centers accounting for about three percent of all electricity usage in Germany. And that, in turn, means substantial potential for conservation.

The IT-Zauber project focuses on cooling, as it is responsible for a significant portion of the total energy needed by data centers. A significant leverage effect is attributed to the potential efficiency gains in this area.

The researchers' approach is based on creating a digital twin that processes data from the data center in real time based on models, using this as a basis for precise, dynamic forecasts and necessary adjustments. One central aspect is the integration of data from both energy and systems technology and the HPC operation into an innovative overall model. The digital twin developed in the IT-Zauber project is being tested live at two data centers. The efficiency gains made will be quantified using key indicators.

In principle, the thoughtfully designed innovative control system can be transferred to any number of data centers, enabling efficiency gains far beyond the scope of the project itself. Open-source components further expand the large reach that the researchers hope the project will have.

EBC/FCN | Building energy systems

Interdisciplinary team supports building renovation

In the STABLE (Social Transformation of the Building Sector) interdisciplinary research project, launched in March

2023, the EBC and FCN institutes will spend a four-year period working with the Social Research Centre at TU Dortmund and Berlin-based housing developer HOWOGE to study the process of renovating a multi-family building in Berlin. The goal is to examine and answer diverse research questions, which necessarily arise in the course of climate-neutral and socially compatible renovation and expansion projects, from a scientific standpoint.

The researchers aim to come up with a solution that is both sustainable and cost-effective, which means that many different overall energy-related, social, regulatory, and technical conditions must be considered as factors. This holistic approach is made possible by the interdisciplinary composition of the research team.

The first step is to optimize the multi-family building's energy system, taking into account the findings of the social scientists working on the project. The ultimate aim of this holistic approach is to find solutions for the landlord-tenant dilemma. At the same time, the researchers are also looking at ways to make the costs incurred, which are passed through to renters, bearable for both the housing developer and the renters themselves.

EBC Ticker

In early 2023, attendees at the Baumesse construction trade fair in Essen got the opportunity to learn more about the SmartQuart living lab for the German energy transition, which focuses on urban districts that receive smart supplies of energy and energy services. EBC was represented at the booth with its SmartQuart team. Two things became clear: first, that there is great interest in sustainable solutions for building energy systems, and second, that there are also considerable uncertainties concerning the cost-effectiveness of solutions to upgrade existing buildings in terms of energy usage.

* * *

The Siemens Research and Innovation Ecosystem Aachen Conference with the topic of Sustainable Energy and Infrastructure was held in Aachen in late 2022. The event focused on the interaction between smart buildings and electrical networks. To align with the topic, EBC professor Dirk Müller gave a keynote address on the subject of buildings of the future.

On the second day of the conference, EBC associate Marco Wirtz offered information on current research activities in the field of energy system optimization for neighborhoods and introduced the nPro planning software, which was developed by a spinoff he operates.

The conference also hosted a competition in which three doctoral candidates presented their dissertation topics. EBC researcher Phillip Stoffel won over the judges with his presentation, Learning Strategies for Data-Driven Model Predictive Control for Building Energy Systems. He won first place and was rewarded with 3,000 euros in prize money.

In addition, the project participants are developing a user-oriented energy management system that ensures cost-effective, user-focused operation.

Plans also call for a kind of script to be prepared in the course of the work, outlining the key insights gleaned through the project. The script will be written at the end of the project, when workshops will also be held. The goal of both is to make it possible to transfer the insights gained to other existing buildings.

FCN I Energy prices

Study analyzes effectiveness of relief programs

Rising energy prices are among the main drivers of inflation right now. To cushion the impact on private households, the German federal government rolled out three relief programs, each one comprising different measures. Professor Aaron Praktiknjo and Jan Priesmann of the Chair for Energy System Economics at FCN analyzed the financial relief provided by these three packages for 2022 and 2023 in a **brief study**.

Among other things, the researchers showed that an average four-person household with gas heating spent about 1.9 percent more of its household income, some 1,599 euros, on electricity, natural gas, and fuels in 2022 than in 2021. This was offset by a relief of 1,206 euros. The same household is "only" paying about 1.5 percent more for electricity, natural gas, and fuels in 2023 than in 2021. Thanks to the relief funding, there is even a positive net relief amount of 243 euros per household.

When the price increases and the effects of the relief packages are considered by income group, it becomes apparent that the heaviest relative financial burden fell on low-income households, with high-income households feeling the least impact. At the same time, the measures enacted by the German federal government brought significant relief across all income groups. Relative to income, households with very low household income benefited the most,

FCN Ticker

In late January, Professor Reinhard Madlener (FCN) gave a keynote presentation titled "A Real Options Analysis of the Siting and Cost-Efficient Layout of Charging Infrastructure for Fuel Cell and Battery Electric Vehicles" at the 2023 Energy Research Talks Disentis (Switzerland), an event organized and supported by AlpenForce (see **presentation on the FCN website**). The presentation addresses the relative economic benefits of local investment in charging infrastructure for electric vehicles as compared to the same kinds of investment for fuel cell vehicles. It also discusses whether policymakers should switch to supporting the other type of charging infrastructure after a certain period (breaking from path dependence). Specifically, the two key questions are:

• What is the optimum number and spatial distribution of public fueling/charging stations for different market diffusion rates of the alternative vehicle types considered?

• What are the costs and political courses of action arising from the spatial distribution of the two types of charging infrastructure after they have been built out in spatial terms to meet demand?

Ultimately, it becomes clear that the overall costs of the supply infrastructure depend significantly on the costs of electricity and hydrogen, among other things.

The analysis, which takes into account the market diffusion of both types of vehicles until 2050, was performed as part of the ENSURE project, which falls under the Copernicus program umbrella. The Steinburg district, in Schleswig-Holstein (population 130,000), was used as an example.

* * *

Professor Madlener (FCN) worked with colleagues from Sydney and Singapore to study alternative supply chains for the export of hydrogen, ammonia, and methanol from Australia (to Singapore, Japan, and Germany). The team shows that the crucial factor in whether the combinations of electrolyzer and energy source considered (eight process chains in all) are economically advantageous is whether the purchase price of hydrogen (AU$/kg H2) or that of energy from hydrogen (AU$/GJ) is taken as the basis. In the former case, the combination of ammonia and an alkaline electrolyzer comes out ahead for all three destinations, based on the assumptions made, followed by liquid hydrogen. In the latter case, by contrast, methanol emerges as the winner, again followed by liquid hydrogen (and in both cases also using alkaline electrolyzers).

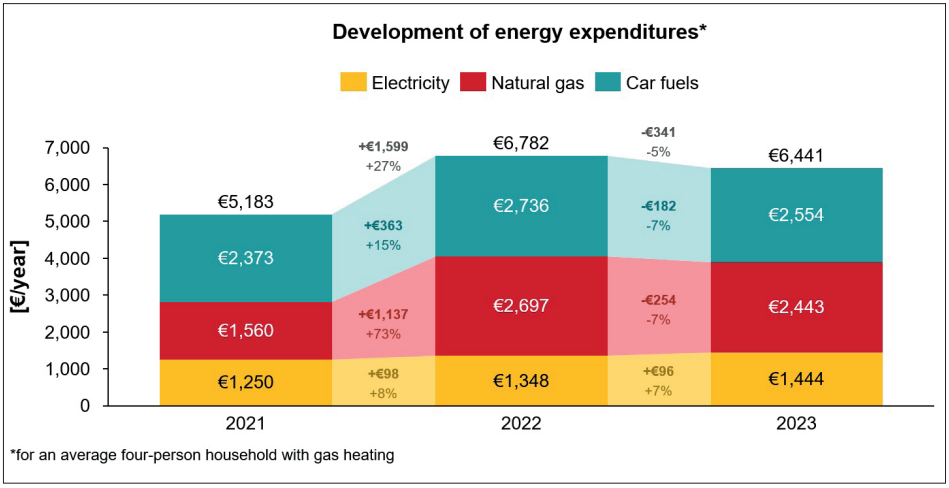
* * *

Once again, Professor Madlener (FCN) participated in the **NTNU Energy Transition Week** in Trondheim, Norway, as a member of a renowned international panel of experts in 2023. Together with other colleagues, he also organized a workshop on the topic of future energy market design.

while high-income households received the biggest benefit in absolute terms. The study showed that thanks to basic social security benefits and subsidies for heating costs, 12.6 percent of the overall impact of the relief ended up with households living below the poverty line, while 55.4 percent reached the upper half of the income distribution.

The biggest overall effects result from the adjustment of income tax rates to compensate for bracket creep, the lump-sum energy price allowance, and the increase in the minimum wage. The researchers view the gas price cap as providing only "moderate absolute relief" due to the reduction in procurement prices.

The study shows that the measures taken by the German federal government brought very broad, effective relief to private households. However, it is also clear that not all of the actions taken are in fact reaching households at significant risk of poverty. Therefore, the authors recommend that this tendency be countered by building structures that allow for more targeted aid to needy households. Specific transfer payments and an increase in the minimum wage should bring broad, lasting relief, for example. Price interventions, however, are not very well targeted to those who can benefit the most, and they can even be counterproductive if the goal is to conserve as much energy as possible.



FCN | Energy markets of the future

Technology Radar 2.0 yields precision-tailored findings

Within the "Technology Foresight and Technology Radar 2.0" project, researchers from both FCN chairs are further developing Technology Radar 1.0, which was created in a previous project (see **Research & News**, 3/22, p. 9), into an innovative tool for the systematic monitoring of technological developments in the energy sector.

The existing radar already facilitates searching for research findings on technologies in the energy sector and helps energy companies uncover "blind spots" in their own strategic planning. The new version, 2.0, uses various aspects, including what is known as a "surprise factor," to supplement existing criteria. Ideally, the improved radar will help to identify strategically valuable technologies and market trends while they are still under development in order to pinpoint potential solutions for future challenges for energy companies at an earlier stage than was previously possible.

Evaluations using commonly used radar tools are often based on subjective assessments. Limited adjustment options make it difficult to fine-tune results searches to reflect company-specific interests. The new technology radar can be used to modify search queries and filter results to provide insights tailored to specific companies.

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FCN-ESE | Energy Systems Economics,
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PGS | Power Generation and Storage Systems,
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