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Energy

Our focus is on renewable energies, efficiency technologies, smart grids and the digitization of the energy industry. Small and medium-sized enterprises have access to a wide range of research and development services.Always the focus is always on a secure, sustainable, economical and socially just supply of energy.

Test Phase Started: Charging Structures In Comparison

The Amperix energy management system from the "Green by IT" group of the „High Performance Computing" division enables the efficient use of battery storage systems, heat pumps and charging stations for e-vehicles and optimizes their control. The in-house solution is also in use in the Fraunhofer ITWM building. Currently, the team is testing eight different charging devices for electric cars.

Fill it up, please! The Fraunhofer ITWM tests charging on-site charging systems.

When is the optimal time to charge the e-car? From the driver's point of view, the charging process should be as incidental as possible, during an appointment, working hours, shopping or parked at home. Those who operate a charging station are driven by the question of when the electricity stored in the vehicles is particularly cheap and when it is better not to use too much electricity. The Amperix energy management system, which is suitable for private households as well as for both private households and businesses.

Theory and Practice Combined on Site

In order to optimally further develop the system to meet the requirements of electromobility, eight different wall boxes are in use at Fraunhofer ITWM. "We test different operating and control strategies live at our institute and gain practical experience, which we then incorporate into our Amperix," describes group leader Matthias Klein-Schlößl. "This brings us significantly further overall further, because we combine theory and practice."

Exceeding the Load Peak Is Expensive

Special attention is paid to the topic of "peak load shaving". Load peaks occur in many companies that have significantly higher electricity consumption at certain times. This aspect is very important for businesses, because it can quickly become expensive: Anyone who exceeds their load peak once a year for a quarter of an hour can be charged additional grid usage fees in the five-digit range," explains Klein-Schlößl.

This means that if electric cars are also charged during a peak period of electricity consumption, for example at lunchtime when a company's cafeteria is in full operation, this can quickly and unnoticeably drive up costs. But not if a reliable energy and load management system like Amperix is in place. Grid-serving measures such as avoiding load peaks and keeping consumption as constant and predictable as possible also help to keep the power grid stable and trouble-free.

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District Heating – Mathematics Heats Up

In the "District Heating" project, a team from our "System Analysis, Prognosis and Control" department is working on modeling digital twins of buildings using modern mathematics. Together with the Swedish institute Fraunhofer Chalmers Centre for Industrial Mathematics FCC, the aim is to use simulations to optimize heating with district heating.

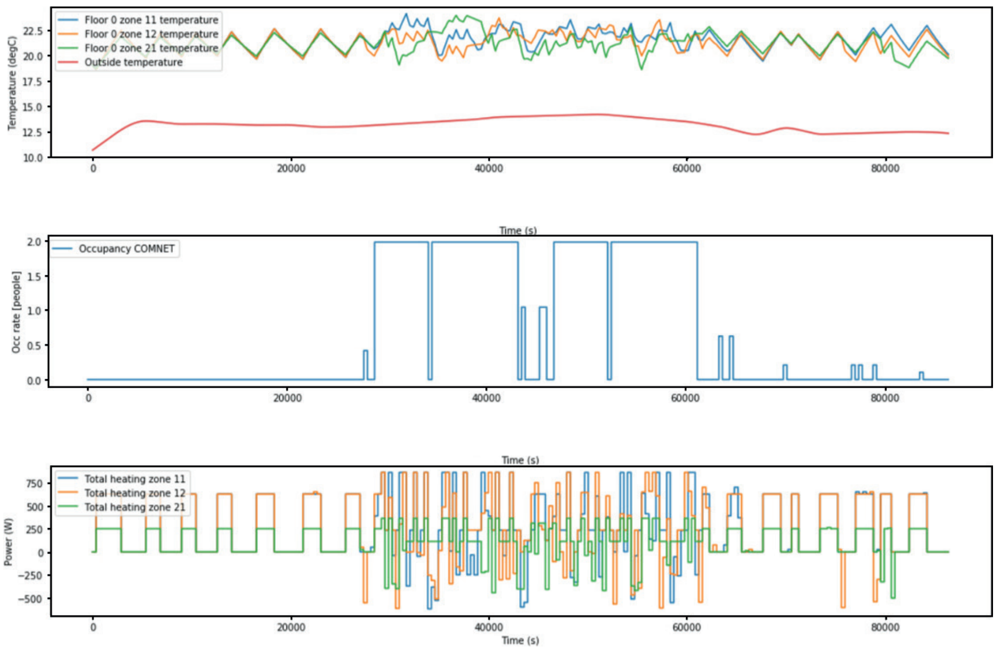
73

percent of EU inhabitants live in urban areas.

Currently, heating is a major topic of discussion, especially with regard to the energy transition. In order to be more independent of gas, one hears more and more often that district heating and heat pumps should replace or supplement gas heating. District heating is a centralized heating system. In this system, heat reaches the building via pipelines from a power plant. There is no need for a separate heating system. Centralization allows the use of different energy sources, which are still mostly a mix of natural gas, waste incineration and hard coal. In the future, renewable energies are to be predominant.

District Heating Has Potential

The heating technology is particularly suitable for urban areas and building complexes, because the laying of the networks and the construction of the generation plants pays off when as many people as possible are connected to the district heating network. In 2010, about 73 percent of all 502 million EU inhabitants already lived in urban areas. The potential is therefore great, but district heating still plays a relatively small role. In Germany in particular, not much use is made of the technology compared with the rest of Europe. In Swe-



Simulation results on three levels: Simulated temperature curves of three rooms and outdoor temperature (top), room occupancy in persons (middle), energy gain and loss of the rooms under the district heating consideration (bottom).

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den, on the other hand, almost all cities have district heating powered by biomass, and more than 50 percent already run on the central heating solution – and the trend is rising.

European Mathematics Optimized District Heating Technology

No wonder, then, that our Swedish Fraunhofer colleagues are driving research there. In the "District Heating" project, an ITWM team led by Sophie Hertzog has been modeling digital twins of buildings with researchers from Fraunhofer FCC since 2019 in order to optimize district heating technology. "At the beginning, there were very simplified models and we worked, among other things, with Modelica, a modeling language for modeling, simulating, optimizing, and analyzing dynamic systems," the scientist explains. First, various basic properties of the building are included: for example, the size, number of floors, location and orientation, number of windows or building materials. "The digital twin is then supplemented by more complex stochastic input and we consider questions such as: How many people are statistically in this type of building? How do they use the windows for ventilation? Or the blinds for shading? What kind of hot water consumption is there? Which electrical devices radiate heat?" the researcher says.

Currently, a software tool that has been developed is used to forecast heat in buildings in this way. In the future, the focus will then be on energy consumption. In addition, the control of heating systems is also being looked at on the basis of the work. Model predictive controllers (MPC) could then ensure that the amount of energy needed flows depending on the time of day.

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Digitalization and Artificial Intelligence for Energy Management 2.0

Whether as an action to contain the climate crisis, to reduce energy imports or simply to save money: Saving energy is more necessary than ever. With the help of digitization and artificial intelligence (AI), researchers at Fraunhofer ITWM are working on an integrated energy management system that reduces energy consumption and increases the share of renewable energy. Both in industry and in private households.

Energy management 2.0 is the goal of the ENERDIG project. To this end, researchers from the divisions "Optimization" and "High Performance Computing" as well as the departments "Transport Processes" and "System Analysis, Prognosis and Control" are bringing their expertise together to develop new digitization and AI-based strategies. The project is located in the High Performance Center Simulation- and Software-based Innovation.

"The team's research work addresses four topics," explains project leader Dr. Dietmar Hietel. "Energy management in residential buildings and industry, in plastics production, in chemical production and in nonwovens production."

Electricity, Heat and Mobility in Residential Buildings and Industry

An important way to reduce greenhouse gas emissions in the residential and commercial sectors is to use renewable electricity in conjunction with heat pumps and solar thermal energy. "In doing so, people ask themselves, for example, what their consumption will be tomorrow and what their photovoltaic and solar thermal systems will do then. And what role the weather plays in this," said Hietel. "To answer that, we're developing new methods of AI to use forecasts to charge electricity storage systems, which in turn can charge heat pumps and electric cars with as much renewable energy as possible."

Within the framework of ENERDIG, Fraunhofer ITWM is developing new AI methods and procedures to manage the coupling of electricity and heat in buildings and industry on the basis of forecasts.

Ministerial Director Daniel Stich presents Prof. Dr. Anita Schöbel and Dr. Dietmar Hietel with the funding decision for the ENERDIG project amounting to around 1.8 million euros. The funding comes from the European Regional Development Fund.

Optimization of Aerodynamics in the Nonwoven Production

There is also great potential for savings in industrial production, for example in nonwovens production. The challenges in nonwovens production are very high production speeds and turbulence in the production process. Both often lead to fluctuations in fabric quality. With the help of different software solutions, Fraunhofer ITWM contributes to the aerodynamic optimization of nonwoven production. This leads to a more stable product quality and to significant energy savings.

Flexibilization of Energy Use in Plastics Production

High cost pressure and growing complexity in production outline the area of tension in plastics production. By controlling the demand for electricity through the targeted switching off and on of loads, so-called demand-side management, the electricity required for production can be purchased more cheaply on the energy market and the product can be manufactured more cheaply accordingly. In addition to strengthening the market position, the operator of the demand-side management system thus contributes to increasing the share of renewable energies. With the aim to support especially SMEs on their way to an energy management 2.0, Fraunhofer ITWM develops algorithms for the identification and evaluation of energy consumption and flexibility based on digital twins of machines and production facilities. Innovative methods of machine learning (ML) with deep neural networks are used.

Energy Efficiency in Chemical Production Through Real-Time Optimization

A similar solution approach applies in the energy-intensive chemical industry: “Making energy consumption more flexible here means that the company adapts its processes to changing energy costs at short notice,” explains Hietel. “In addition, there are other variables that must be reacted to at short notice, such as the availability of raw materials.” Systematically taking these fluctuations into account when optimizing plants is one of ENERDIG’s goals. “Through improved real-time optimization of chemical processes alone, we can expect energy savings even in the double-digit percentage range.”

www.itwm.fraunhofer.de/enerdig-pm [only available in German]

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Microparticles With a Big Impact: Aerosols in Climate Models

Solid particles in our atmosphere play an important role in our climate system and consequently also for climate change. Their inclusion in microphysical climate models is a central challenge in the creation of global long-term forecasts. How machine learning can help here is being investigated in a paper from our "High Performance Computing" department.

The physical forces resulting from the motion and transformation of aerosol masses in the atmosphere are the greatest sources of largest sources of uncertainty in measuring man-made climate effects. Aerosols are produced, for example, by the burning of fossil fuels or volcanic eruptions. Depending on their type, they scatter or absorb atmospheric radiation, depending on their type, and thus cause either cooling or warming effects. So-called "condensation nuclei" also cause an extension of the lifetime of clouds by reflecting sunlight.

The Problem Lies in the Aerosol Detail

The computational detection and consideration of aerosol effects in climate models represents a major challenge for research. These are very marginal, microphysical changes and trends that are extremely time-consuming and costly to calculate. As a result, many models consider aerosols only as constant, external parameters and record them only once in the data collection process. In addition, they often do not distinguish between different aerosol types and simply assume that the particle mass is heterogeneous but one-dimensional with respect to the climate effect.

One of the models, which can model different aerosols is the aerosol microphysics model developed by the Max Planck Institute for Meteorology in Hamburg. Aerosol Microphysics Model. This distinguishes between different aerosol types such as sea salt, sulfates and black carbon. It also captures various physical processes such as nucleation (formation of condensation nuclei), condensation and water absorption.

Machine Learning as the Key to Optimization

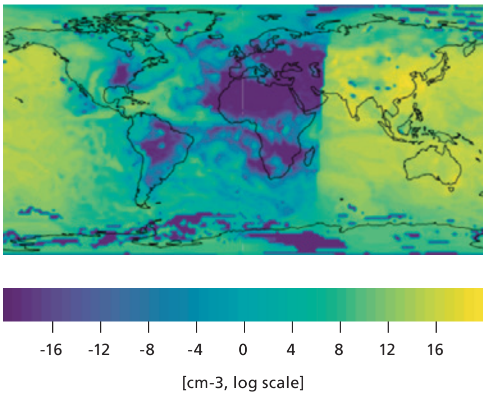
Our PhD student Paula Harder from the area of "High Performance Computing" focuses on the topics "Deep Learning" and "Climate Modeling" in cooperation with the University of Oxford. In her research work, she is developing, among other things, an emulator based on artificial intelligence that approximates the microphysics of the aerosol model and makes the calculations faster and more efficient.

In computer technology, an emulator is a system that emulates another system in certain aspects. Harder explains: "Our goal is to enable climate predictions on a global scale, with very high precision and over long periods of time through machine learning. Herein lies an opportunity to, if not prevent, at least detect and prepare for the consequences of climate change."

To accomplish this, 11 million input-output data pairs were first generated using the aerosol model. This data was then used to train a neural network to replace the costly origin model. Subsequently, additional computational constraints were incorporated to overcome physical constraints – such as conservation of mass and positivity – were taken into account.

A Promising Perspective

The results are extremely satisfactory: The replication of the aerosol model by the neural network works very well in the offline experiments so far – in fact, a higher precision is achieved. Finally, on a GPU, the computation time was recently accelerated to 64 times the value of the original model. By this procedure the emulator can be embedded again into an online global climate model, this is the next step.



The plot shows the predicted change in concentration of aerosols on a logarithmic scale.

The central problem of today's climate research – i.e., the short-term, cost-effective capture and calculation of aerosol masses – is thus expected to be overcome in the near future.

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