The CITIES project delivers digital and data-driven energy solutions for green transition
Through seven years of research, CITIES supported by the Innovation Fund Denmark has shown how digital solutions based on data-driven methods (AI, IoT, forecasting, optimization, etc.) make energy systems talk to each other. It saves money and CO2. Now CITIES continues as a platform for sharing knowledge, software and solutions that help make the world fossil-free.

Municipalities across the country are currently expanding the district heating network. This is good for the climate because district heating can contribute at least a third of the CO2 reduction of 70 per cent, which is Denmark's climate goal. The research in the CITIES project (Center for IT-Intelligent Energy Systems - supported by the Innovation Fund Denmark) has created data-driven solutions to make district heating even more efficient.

- We estimate that the digital solutions developed in CITIES can provide savings of over one billion DKK per year alone in Denmark, says project manager and professor at DTU Compute Henrik Madsen.

In a report, CITIES, together with Damvad Analytics and the think tank Green Energy under the CITIES partner Dansk Fjernvarme, has shown that the district heating sector can save between 240 and 790 million DKK by introducing data-driven temperature control of the flow temperature because the temperature in the pipes can be lowered 3-10 degrees. Lower temperature results in lower heat loss, savings in energy production and at the same time save CO2. The analysis methods have since been further improved so that the savings are estimated at DKK 200 million extra.

This is just one of the results of the CITIES' research. The 43 partners (universities - including DTU and AAU, industry, utilities and Energinet) have also developed software programs, mathematical models and AI that ensure that digitalisation speaks directly into the green transition.

For example, through digitalisation and coupling between energy systems, CITIES has developed solutions for energy storage without the use of rare minerals such as cobalt and lithium. With intelligent control, supermarkets' cooling systems, treatment plants, district heating and more can help the electricity market so that the wind turbines - unlike today - can continue to spin merrily in windy weather, even if production exceeds demand.

- Based on price signals, the automatic model will be able to temporarily turn up cooling, heating and industrial processes so that they act as virtual batteries, and turn down when the electricity market can again use electricity and extra down during peak loads - and thereby utilize flexibility, explains Henrik Madsen.

Along the way, CITIES has developed several state-of-the-art methods (models, forecasting, control and optimization) implemented through cloud, fog and edge computing, as well as IoT and service-oriented solutions for users. In addition, **a spinoff company** has just seen the light of day, while two other spinoffs with former CITIES 'PhD students from DTU are in the making.

In addition to data-intelligent solutions, CITIES has mapped the importance of coherence between energy planning and energy systems in large cities and the rest of the country. Research has shown that it is becoming increasingly difficult for citizens to become co-owners of wind farms, although local

co-ownership could facilitate the establishment of wind farms, which today are often met by citizen protests. A tool has been developed that makes it possible to include consumption flexibility in energy planning. Finally, a CITIES task force group has proposed new principles for energy taxes and grid tariffs so that prices support the green transition.

CITIES has contributed to the establishment of two digital platforms for global infrastructure in the energy system: **Center Denmark**, which contains a 'data lake' for storage and processing of raw and anonymised energy data from thousands of households, so that researchers and companies can use data in the development of new business models and digital, green solutions. **Uni-lab.dk**, which brings together living labs and makes it easy for industry partners to find a lab to test solutions. In addition, **several new EU and fund-supported** projects are based on research in CITIES.

Selected research results

If energy taxes and grid tariffs are designed so that prices vary and support the wish of being energy flexible, CITIES 'research shows the following benefits - both economically and in relation to the reduction of greenhouse gases:

- Up to one billion DKK in annual savings by temperature optimization in district heating
- Up to 90% savings by data-intelligent cooling of data centres, where the cold is created when the conditions are optimal, and stored in phase change material for use at times when, for example, the CO_2 content in the stream is high
- 10-30% savings by being able to predict the heat demand from heat pumps
- 5-15% savings by integrating intelligent planning tools into home heat control
- 10-40% savings on electricity and heat consumption by using forecast tools that retrieve local weather forecasts from various weather services
- Up to 30% savings in greenhouse gases by smart control of both electricity consumption and processes in the wastewater management itself (minimization of nitrous oxide emissions)

Find research results, recommendations and software tools on the CITIES website: https://smart-cities-centre.org/

Facts about CITIES

The research project CITIES (Center for IT-Intelligent Energy Systems) ran in the period 2014 to the end of 2020 with a total budget of 74 million DKK. 44 million DKK came from the Innovation Fund Denmark (formerly the Strategic Research Council - grant 1305-00027B), while the rest came from the project's 43 partners (universities, industry, utilities) in Denmark as well as the EU, Asia and the USA.

The CITIES project has published over 300 scientific publications, among these more than 140 journal papers, completed 21 demo projects and trained 25 PhDs and postdocs.

CITIES has worked with digitalization and IT intelligence in relation to five main themes: Planning and operation of energy systems - including sectoral coupling of energy sources, Market mechanisms, Smart buildings that interact with the surrounding energy system, and CITIES taskforce has proposed changes to framework conditions (tariffs and energy taxes) so they encourage green transition.

From 2021, CITIES will be continued as a centre for anchoring and disseminating solutions for smart energy systems in collaboration with Center Denmark and Energy Cluster Denmark.

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