Energy
National Research Programmes 70 and 71

Project

Control of multi-energy hub systems

How Do Coupled Energy Systems Do What Is Expected of Them?

How Do Coupled Energy Systems Do What Is Expected of Them?

Decentralised energy systems must coordinate many things independently: how do they distribute the available energy to the connected buildings, or how do they deal with the public power grid? Researchers at the ETH Zurich have now developed a control method for such systems and compared different energy management strategies.

In future, neighbourhoods could produce and manage their own energy thanks to photovoltaic systems and other decentralised power plants. *Source:* peart/iStock

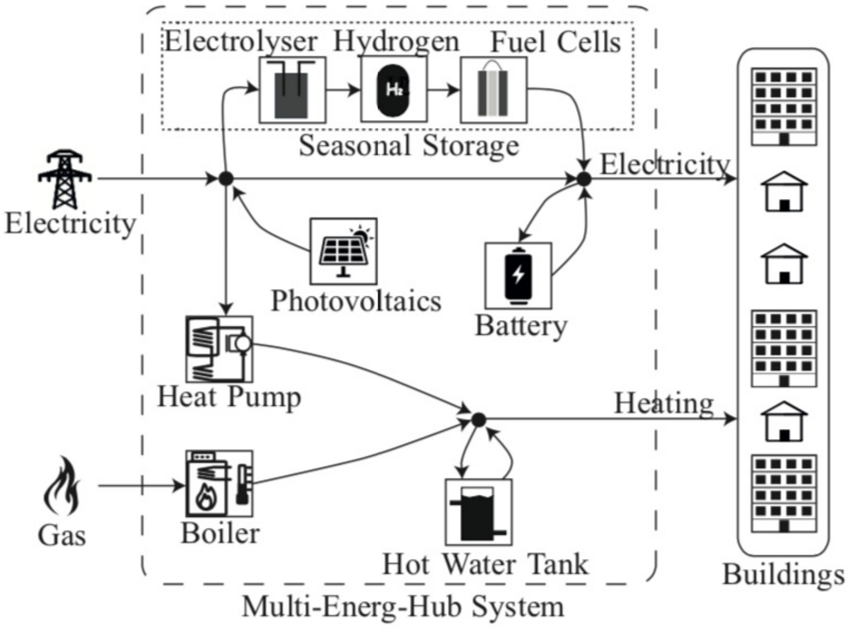
At a glance

- Decentralised energy systems are chosen according to local conditions. They need to be coordinated with each other in order to guarantee a cheap and secure energy supply. Researchers at the ETH Zurich have developed a control method for such systems.
- A computer program regulates the facilities within a multi-energy system as well as the distribution of energy to all connected buildings. It also controls the exchange with the public power grid and, if need be, with the public gas supply network.
- The researchers have tested their method in two case studies: one in the village of Zernez in the canton of Graubünden and one in the Zurich district of Altstetten. At both locations, CO_2 emissions dropped considerably; in Zernez even below the threshold set by the Energy Strategy 2050.

In the future, many small power plants, in addition to some large ones, are likely to produce renewable energy for individual houses, housing estates and neighbourhoods or entire cities. This strategy calls for three components: firstly, energy production systems such as solar or wind power plants. Secondly, conversion plants such as heat pumps, electrolytic cells or fuel cells. The latter two store energy in the form of hydrogen: electrolytic cells produce hydrogen using electricity, while fuel cells use the opposite process. And thirdly, energy storage systems, such as batteries, hot water storage tanks or hydrogen storage tanks.

However, installing these systems in not sufficient. They also need to interact in the best possible way: not only must these systems, also known as multi-energy hubs, be interlinked, but also controlled in a concerted manner. In addition, an energy hub must coordinate the connection to external energy sources such as the public power grid: when does the system feed excess electricity into the grid and when does it draw electricity? When do the buildings in the system need additional gas or other fuels to produce heat or hot water? The system must answer these questions according to the given circumstances and control the installation accordingly. In addition, it must be able to react very quickly to changes in energy production or consumption. This requires a sophisticated control and monitoring mechanism. The group leaders Turhan Demiray and Roy Smith and their research teams at the ETH Zurich have developed such a mechanism in a subproject of the joint project "Sustainable Decentralised Power Generation".

In a first step, the investigators created a mathematical computer model of a complex multi-energy hub. A photovoltaic system in the hub produces power that is either consumed immediately, stored in a battery or converted into hydrogen for long-term storage. The system also includes a conventional hot water boiler, a heat pump and a hot water storage tank for heating.



The multi-energy hub, as calculated in the model: energy is mainly produced directly in the hub by solar systems, but can also be introduced into the system as gas or electricity from the public network. The energy is either directly consumed, stored or converted into another form prior to storage. Demiray et al./ETH Zürich

Modelling uncertainties

The design and specifications for this modelled energy hub were provided by the research team's cooperation partners, involved in the technological evaluation of suitable production and storage facilities within another subproject. In addition, the scientists modelled a number of buildings to be supplied by the hub, as well as their energy balance (e.g. the amount of heat lost through windows and walls).

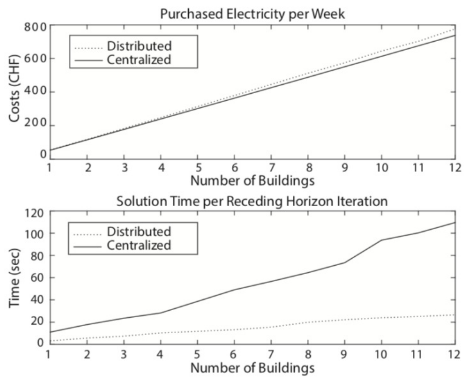
In order to describe the control mechanisms for the systems and buildings, the researchers used, among other things, probability calculation methods, thus bestowing on the model the ability to deal with uncertainties - a prerequisite for the system to be able to react to unforeseen events. The investigators incorporated into their model a so-called model predictive control that calculates the future behaviour of a modelled process. Thus, the energy system can for instance react to weather forecasts, such as a cloudless, sunny day with above average solar energy availability. In addition, it was necessary to introduce certain operational restrictions into the model: on the one hand, upper limits to prevent an overload of the system and the power grid and, on the other hand, lower limits to ensure that a minimum amount of energy is available for comfortable living conditions in the buildings.

Comparison of various energy supply strategies

The task now was to determine how best to control the networked energy systems. "From the point of view of the housing estate and its inhabitants supplied by the energy hub, the goal is to have to purchase as little energy as possible", explains project manager Demiray. At the same time, the system must be safe and always provide enough energy for comfortable living.

To determine the best way to achieve this, the researchers tested two different strategies: a centralised as well as an individualised control system. The centralised variant examined several multi-energy hubs, each of which supplies a different housing complex. The systems not only draw energy from the public grid, but can also exchange energy among each other through a shared network. By doing so, they establish their own local energy market. The control programs of the individual hubs must reach a consensus regarding prices and other conditions for the purchase and sale of energy. A virtual hub manager then determines the distribution of the energy within the hubs to the individual buildings.

In the individualized strategy, the emphasis is on the individual buildings. They each communicate their requirements to the hub's control program. The virtual hub manager reacts accordingly, for example by increasing the price of energy when the demand within the housing estate is very high, which is why the buildings and the hub manager need to agree on the minimum amount of energy required and an upper limit for energy prices. In a comparison between these two strategies, the individualised one proved to be more advantageous. Although the energy is not provided at a lower price in this variant, the control system is easier to scale: providing energy for several estates or even an entire city in this way requires significantly less computing power than a centralised strategy.



Comparison of the two control strategies: the energy costs (top) for the individual buildings are approximately the same for both strategies. But even

The researchers combined their results with those of the other subprojects, which dealt with the technological and economic evaluation of multi-energy systems, and developed a multi-energy hub planning method for housing estates of very different sizes and configurations.

The method was tested in computer simulations by means of two case studies: one in the village of Zernez in the canton of Graubünden and one in the Zurich district of Altstetten. For each of these two areas, a multi-energy hub and its control system were planned and the effects analysed: in both locations, the coordinated use of renewable energy sources considerably reduces CO_2 emissions, and in Zernez even leads to values when including only a small number of buildings, the centralised variant requires much more computing time. This difference increases when additional buildings are connected to the system. Demiray et al./ETH Zürich

below those set by the Energy Strategy 2050.

Produkte aus diesem Projekt

- A Stochastic Optimization Approach to Cooperative Building Energy Management via an Energy Hub
  Date of publication: 01.01.18
- The Power of Diversity: Data-Driven Robust Predictive Control for Energy Efficient Buildings and Districts
  Date of publication: 01.01.18
- Scalability through Decentralization: A Robust Control Approach for the Energy Management of a Building Community
  Date of publication: 01.01.18
- A Data-Driven Stochastic Optimization Approach to the Seasonal Storage Energy Management
  Date of publication: 01.01.18
- Operational Optimisation for Multi-Carrier Networks
  Date of publication: 01.01.18
- OPERATIONAL OPTIMISATION FOR MULTI-CARRIER NETWORKS
  Date of publication: 01.01.18
- A Stochastic Optimization Approach to Cooperative Building Energy Management via an Energy Hub
  Date of publication: 01.01.18
- Scalability through Decentralization: A Robust Control Approach for the Energy Management of a Building Community
  Date of publication: 01.01.18
- A Data-Driven Stochastic Optimization Approach to the Seasonal Storage Energy Management
  Date of publication: 01.01.18
- The Swiss Energy Strategy 2050 – Future Challenges from a Control Theory Perspective for an Efficient Energy Management
  Date of publication: 01.01.18
- Optimal Energy Management of Buildings and Districts
  Date of publication: 17.02.16

Contact & Team

Dr. Turhan Hilmi Demiray
ETH Zürich
FEN-ETH
Sonneggstrasse 28
8092 Zürich

+41 44 632 41 85
demirayt@ethz.ch

Turhan Hilmi Demiray
Project direction

Andrea Giovanni Beccuti

Georgios Darivianakis

Annika Eichler

Roy Smith

All information provided on these pages corresponds to the status of knowledge as of 10.05.2019.