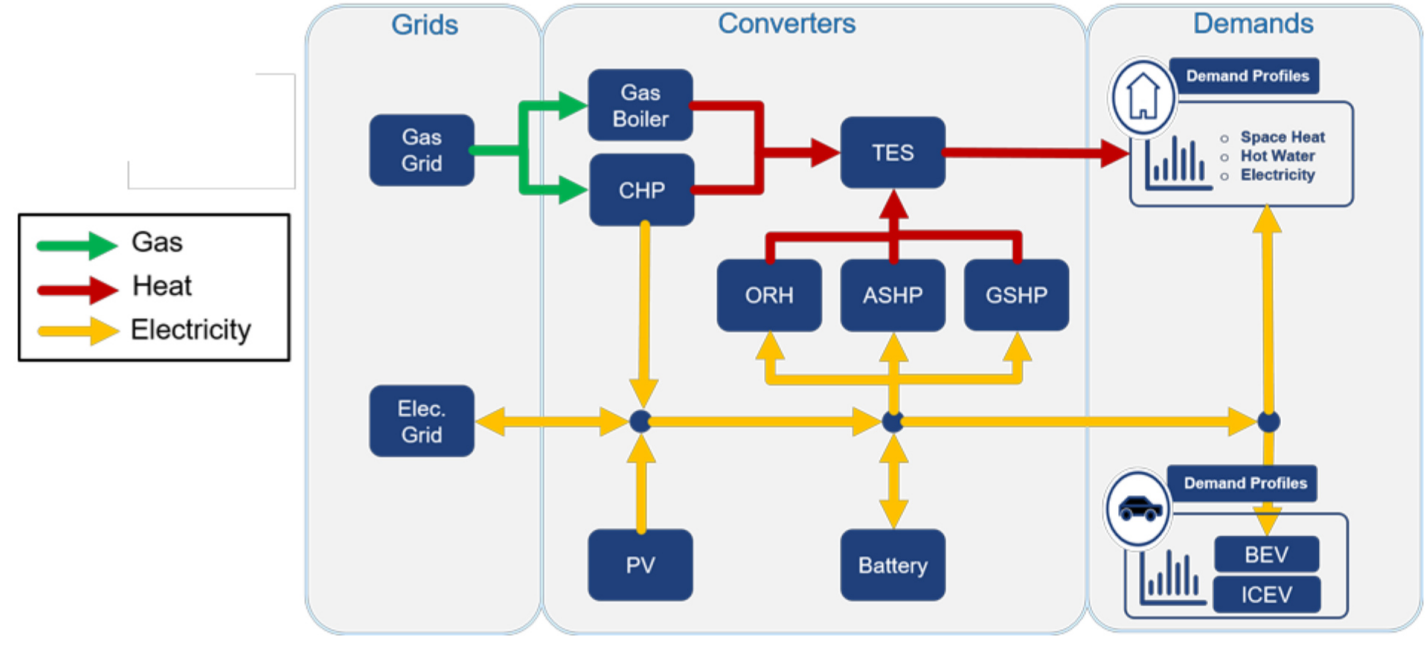
HEAT AND ELECTRICITY FROM RENEWABLE GAS

Renewable energies from solar, hydropower and wind power plants play a central role in the future energy supply. In addition, cogeneration plants powered by biofuels can contribute to a low-carbon energy supply for the Swiss residential and mobility sectors. This is the conclusion of a study by the Swiss Federal Institute of Technology Zurich (Eidgenössische Technische Hochschule Zürich/ETHZ), which has developed a simulation tool that can be used to characterize the energy supply with decentralized production and storage units depending on real-time inputs.



Schematic representation of the production, conversion and storage units of the energy platforms ('energy hubs') investigated in the ETHZ study. LW-WP stands for air-to-water heat pump, SW-WP for brine-to-water heat pump, BEV for electric vehicle and ICEV for car with combustion engine. Illustration: SFOE final report DISCREET

A technical report about the results of a research project in the field of combustion, which is financially supported by the Swiss Federal Office of Energy. The report has been published in the technical magazine Energierundschau (issue Oktober 2022).

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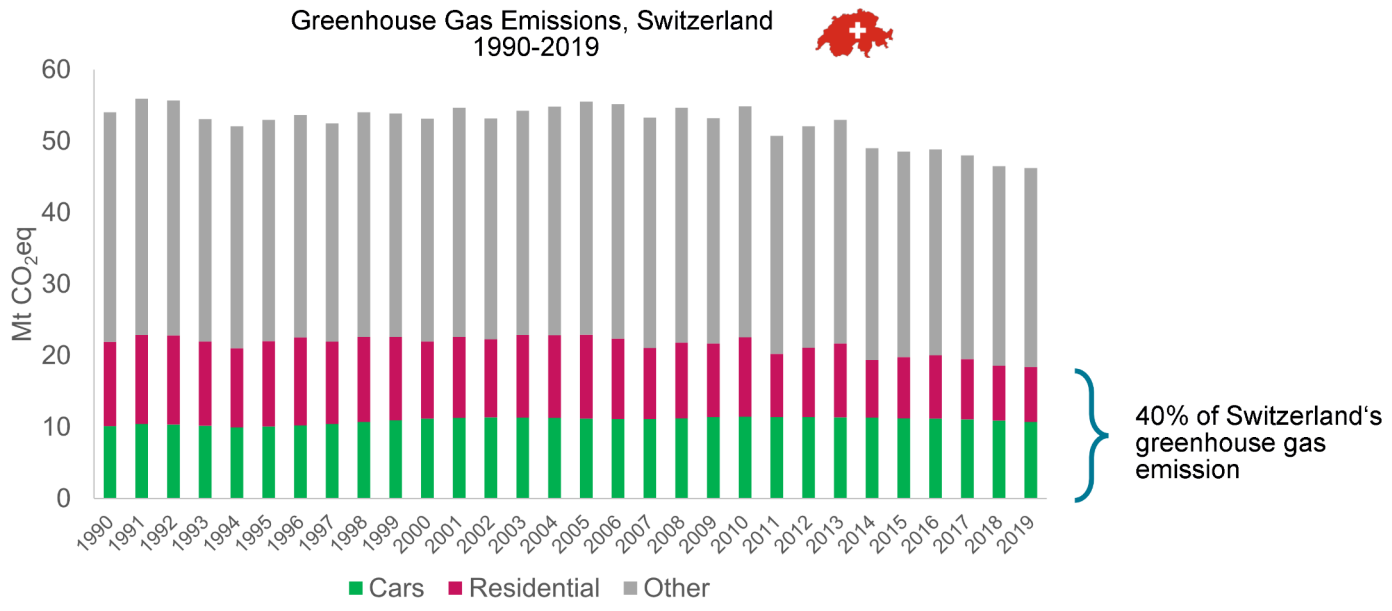
Decentralized production and storage are playing an increasingly important role in Switzerland's energy supply. Decentralized energy hubs use different energy sources and energy converters to provide electricity, heat, hot water and energy for cooling. Scientists from the Laboratory of Aerothermochemistry and Combustion Systems at ETHZ have now developed a simulation tool that shows the contribution these energy hubs can make to a sustainable, economical and secure energy supply for Switzerland.

Energy for residential buildings and personal transport

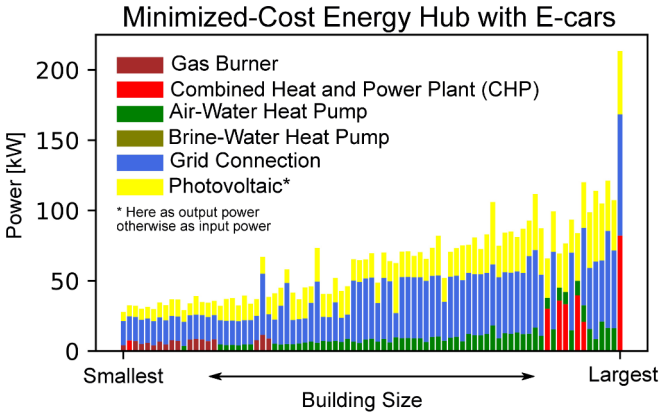
Scientists at ETHZ have shown in an earlier study that decentralized combined heat and power (CHP) plants could cover 10 % of Switzerland's heat demand and 12 % of its electricity demand with renewable energy if the country's biomass potential were consistently exploited (by converting wood and organic waste into methane, which is then used to produce heat and electricity). In 2020, 1.1% of electricity in Switzerland was generated from wood and biogas. Thus, there is still a large untapped potential.

The current ETHZ project uses the concept of CHP plants powered by biomass to support electricity production and integrated them as a component in energy hubs, and included the electricity demand for e-mobility in addition to residential building energy demand. It thus encompasses the entire energy demand for heat and electricity in the residential sector, including personal transport. As part of his doctoral thesis, ETHZ researcher Dr. Moritz Mittelviefhaus developed a simulation tool that can be used to calculate the investment and operating costs as well as the greenhouse gas (GHG) emissions of energy hubs. In the energy hubs, a variety of different energy systems such as heat pumps, photovoltaics, boilers, and even CHP systems are available, which can be selected and combined with the simulation tool. On the consumer side, buildings of different sizes as well as conventional and electric vehicles are also available for selection (see graphic p.1).

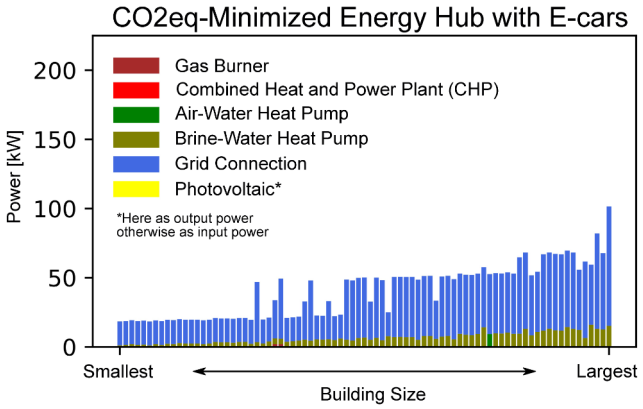
Thanks to the simulation tool, the researchers can compare the annualized total costs and GHG emissions of selected energy systems over their life cycles. In other words, they were able to calculate which energy systems would save as much CO_2 as possible in the most cost-effective way. Mittelviefhaus not only designed the tool, but also used it for con-



The residential sector and personal transport are responsible for around 40% of greenhouse gas emissions. According to the ETHZ study, a good half of the emissions could be saved by modernizing the systems (photovoltaics, heat pumps and biogas instead of natural gas) and electric vehicles without making energy production more expensive (viewed over the life cycle). According to the ETHZ researchers, the building sector accounts for about two-thirds of the GHG savings, and the mobility sector for about one-third. Graphic: FOEN/edited



The diagram shows the combination of energy generation systems that, according to the ETHZ study, can optimally cover the energy requirements for buildings and mobility if the aim is to achieve the most cost-effective energy supply possible. This is best achieved when electricity from the grid and electricity from one's own photovoltaic system are used. For small buildings, a gas boiler is also recommended, for medium-sized buildings an air-water heat pump and for large buildings (at least in part) the connection to a combined heat and power plant. Graphic: SFOE final report DISCREET



The diagram shows the combination of energy generation systems that, according to the ETHZ study, can be used to optimally cover the energy demands of buildings and mobility if the aim is to achieve an energy supply that is as low in CO_2 emissions as possible. This goal is achieved by drawing electricity from the grid and using a brine-to-water heat pump for heat production. This assumes an electricity grid of today's quality (CO_2 emission factor of the electricity mix currently in the Swiss supply grid) that is available to the end consumer in unlimited quantities and has slightly lower emissions than in-house electricity production from solar systems. Apart from the extreme case shown, in-house solar panels are very worthwhile across the board in the study, to relieve strains on the existing power supply and should be installed wherever possible, as the study authors emphasize. Graphic: SFOE final report DISCREET

crete calculations. He based his calculations on the general conditions before the Ukraine war. The extraordinary rise in energy prices in spring 2022 is therefore not taken into account in the results presented below. However, the tool enables the simulations to be carried out also with different parameters.

Drastically reduced greenhouse gas emissions

One of the study's main findings: electrification of residential and mobility sectors can greatly reduce greenhouse gas emissions from these sectors. "In the best-case scenario, up to almost 70 % and at comparable, and in some cases even slightly reduced, overall costs," says Mittelviefhaus, who is a co-author of the study. In this scenario, the researchers assumed that electricity from the grid would be available without restrictions. With this parameter, they calculated that in an average residential building with 8 residents, GHG emissions would be reduced from about 25 t CO_2eq/year to about 7 t CO_2eq/year, and the total cost of energy supply from about 30,000 fr/year to about 27,000 fr/year (the figures include the total cost of heat, electricity and mobility, including purchase costs for cars). The fact that greenhouse gas emissions cannot be reduced more than the 70 % mentioned is primarily due to the gray energy that is inevitably contained in heating systems, power plants and vehicles.

According to the ETHZ study, decarbonization of the energy supply can succeed thanks to "core technologies" that have been in vogue for years: Heat pumps are replacing oil and gas heating systems, electric cars are replacing combustion engines. In addition, there are decentralized photovoltaic systems, which are supplemented with stationary electricity storage systems or batteries in electric cars. Solar systems, the study assumes, will be subsidized by the government with one-off payments, as is customary today. Further subsidies would help to accelerate the change in the energy landscape outlined in the study, says Mittelviefhaus: "The potential for reducing greenhouse gases has not (yet) been fully exploited, because this would require much more investment in decentralized plants but also for e-vehicles."

CHP plants for bottlenecks in winter

If the aim were to achieve the most cost-effective energy supply possible, the study would reach a different conclusion. In

The city of St. Gallen (photo on the left) uses natural gas-fired cogeneration plants to replace oil-fired heating systems and thus reduce greenhouse gas emissions. Photo on the right: One of the two cogeneration units of the new Lukasmühle district heating plant with a capacity of 2 MW for heat and electricity production. Photo: City of St. Gallen / St. Galler Stadtwerke

this scenario, gas as an energy source is still necessary, Mittelviefhaus explains: "Especially for small buildings, gas boilers can be economical solutions, and for large buildings, CHP units that generate heat and electricity by burning gas" (see graphic p.3, on the left). CHP plants are also necessary because, according to the ETHZ researchers, the rapidly growing demand for electricity to operate heat pumps and electric cars cannot be met by renewable electricity alone, not least because the required PV electricity is not available in sufficient quantities in the winter. Here, CHP units powered by natural gas or biogas would offer "attractive solutions to ensure the power supply in winter."

Mittelviefhaus adds: "The permanent use of gas boilers and CHP plants with natural gas is only recommended if it really comes down to the last cent. However, CHP plants powered by biogas, which are used to bridge electricity shortages primarily in winter, make economic and climate policy sense." These plants are preferable to large gas-fired power plants (combined-cycle gas turbines), the study authors say. "In scenarios with minimum CO_2 as the target, CHP plants using biogas in the short term and green hydrogen in the longer term proved superior to centralized gas-fired power plants using carbon capture and storage (CCS)," says ETHZ professor Konstantinos Boulouchos, who oversaw the study but recently retired. According to the study, a second pillar for mitigating dependency on foreign energy sources, in addition to CHP plants, are large solar plants with a total nationwide capacity of 9 to 26 GW (installed PV capacity at the end of 2020: 3 GW). The study did not investigate the concrete implementation of this idea (siting, grid integration, energy storage for balancing summer/winter, etc.).

St. Gallen relies on CHP

The ETH researchers used the circumstances of the city of St. Gallen for their simulation of energy consumption. At the same time, their ideas are falling on fertile ground in this city, as Marco Letta, corporate director of the St. Gallen municipal utility, says: "The ETHZ study shows very impressively that the 2050 energy concept of the city of St. Gallen, with the coupling of the electricity, heat and gas sectors, is the only right way to decarbonize. Local heating networks with efficient combined heat and power plants in energy centers as band-load electricity production not only make a valuable contribution to the local supply in winter, but also relieve the electricity grid in the corresponding neighborhoods." St. Gallen plans to significantly expand electricity production from CHP units over the next few years, from 1.3 MW_{el} today to 40 MW_{el} in 2050. The plants should then cover around 20% of the city's electricity requirements.

Marco Letta points out that natural gas will have to serve as the medium for CHP in the next 10 to 15 years, until global production of biogas, hydrogen and synthetic gases ramps up. "However, we are already replacing many oil-fired heating systems with CHP local heating networks, thereby reducing greenhouse gas emissions. Today's CHP systems, which are still fossil-fired, will then be replaced during the next re-

newal cycle by CHP units that are 'H2-ready' or can run 100% on biogas or synthetic gas."

- The **final report** on the research project 'Distributed Co-generation supporting Renewable Energy sources for the Electrification of Transport' (DISCREET) can be found at: https://www.aramis.admin.ch/Texte/?ProjectID=40672
- For further **information**, please contact Stephan Renz (info[at]renzconsulting.ch), external head of the SFOE research program Combustion-based Energy Systems.
- Further **technical papers** on research, pilot, demonstration and flagship projects in the field of combustion can be found at: www.bfe.admin.ch/ec-verbrennung.

Gas from fermentation or organic matter makes it possible to produce heat and electricity from a carbon neutral energy source. Photo: Ökostrom Schweiz

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