Urban Energy Systems Laboratory, Empa
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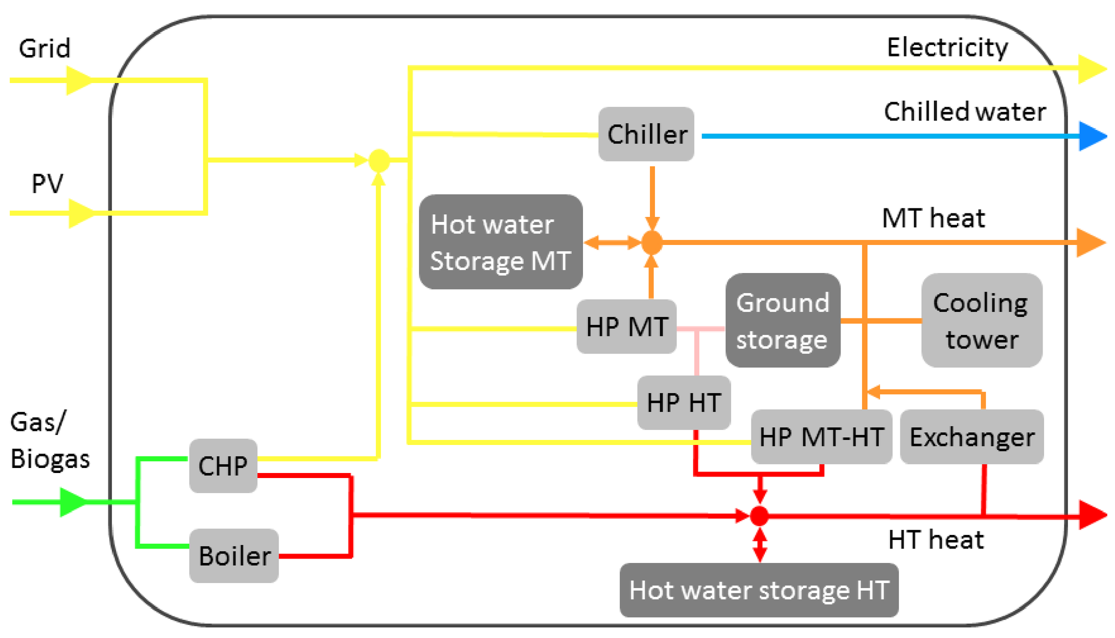
Local energy management systems for multi-carrier networks

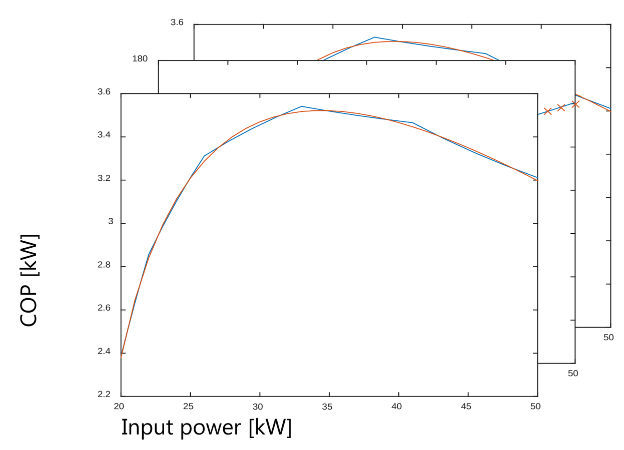
Real-time optimization of a residential multi-carrier energy network

Distributed energy systems require active control strategies in order to balance multiple energy streams and to ensure reliable, economic and environmentally friendly operation. Multi-carrier energy systems offer additional degrees of freedoms compared to single carrier operational schemes managing only electricity, gas or heat.
The objective is to increase energy efficiency, decrease carbon emissions and handle the uncertainty and intermittency of renewable energy sources. Active control strategies are therefore crucial to the transformation of energy systems, a central element of climate change mitigation measures. The objective of this work is to develop an improved central local energy management systems for urban districts.

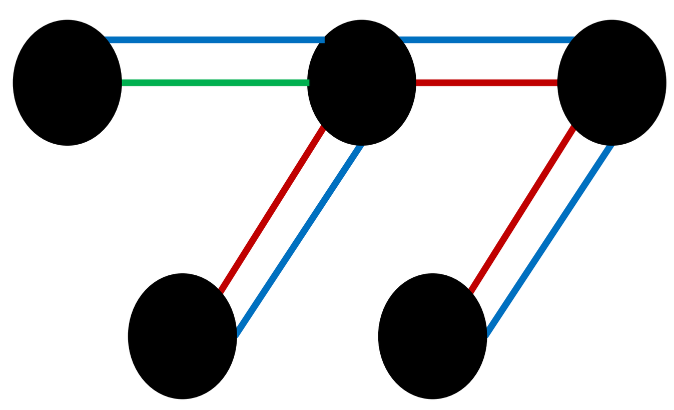


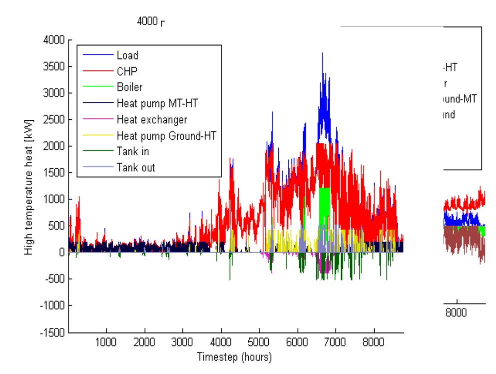
Example of a multi-carrier energy network

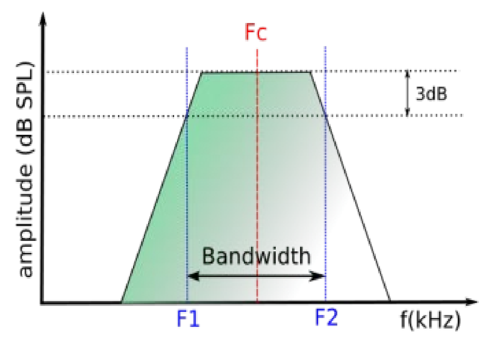
Energy systems modelling and controller architecture



Non-convex conversion characteristics


Multi-carrier energy network


Demand and weather predictions



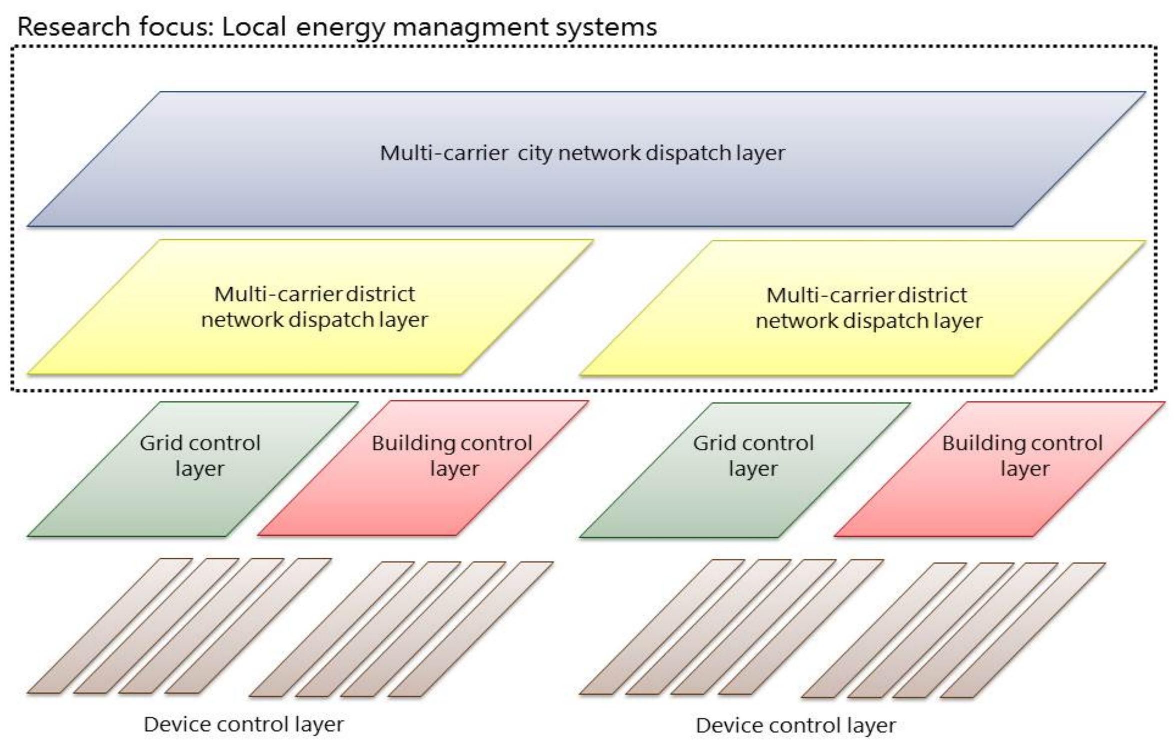
Aggregation and filtering techniques

Mixed-integer linear programming can accommodate non-convex system characteristics, but with a high computational load. This work focuses on the integration of the non-convex characteristics of energy conversion devices into the MILP energy hub formulation without too many binary variables. Furthermore, the temperature dependent characteristics of heat networks and a relaxed form of the constraints of electric networks are included in the model. Alternatives to MILP formulations are considered and compared in terms of modeling simplicity and computational load.

Given the cyclic nature of energy demand and generation patterns, an energy management system must decide on using short-term storages, long-term storages or non-renewable but efficient energy conversion plants such as combined heat and power plants (CHP). Possible schemes include the application of filters to demand and generation profiles, rolling horizon approaches and weighted terminal constraints. Notions from stochastic optimization and robust optimization are also considered.

Multiple agents and mechanism design

Energy management systems on different levels must be coupled to achieve optimal and cost-effective behavior. The focus is on a holonic architecture. Sub-agents, energy conversion and storage devices, together form the energy system of a district. The locational marginal pricing scheme is extended to include storage and the thermal inertia of buildings. Demand-response and dynamic pricing could be combined in this way. If the local energy management system is set up as a market, mechanisms based on game theoretic notions such as Nash equilibria and mechanism design must be considered in order to avoid suboptimal behavior.



Control layers of multi-carrier energy systems

Implementation and experimentation


NEST project

A local multi-carrier energy management system is implemented on the NEST platform. An energy hub is installed supplying the different research units via a range of energy carriers. Besides the electric network, three heat networks with different temperatures and a gas supply are available. Energy conversion components like heat pumps and fuel cells, and energy storage devices like batteries, tanks, geothermal storage and ice storage are installed. The degrees of freedom of the energy system allow various dispatch strategies. A controller layer that follows the set-points of a management algorithm is provided. Units, can be run independently, allowing the testing of different mechanisms. A cooperative energy management system is compared to traditional rule-based control in terms of energy use and energy balance mismatch.

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