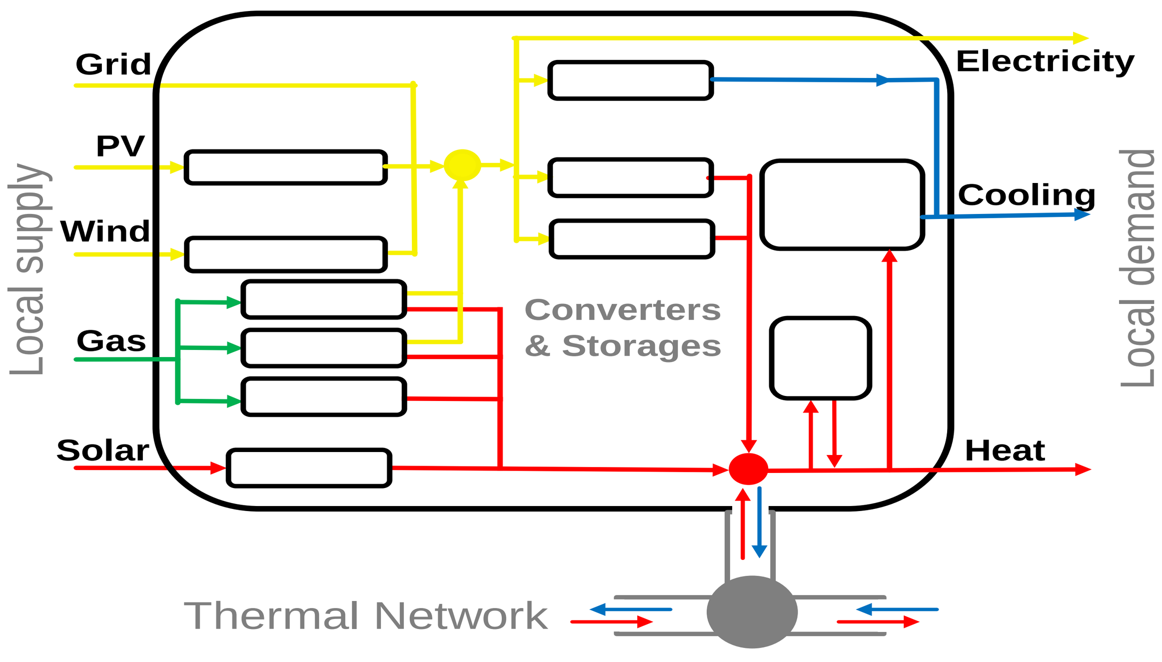
Empa
Materials Science and Technology

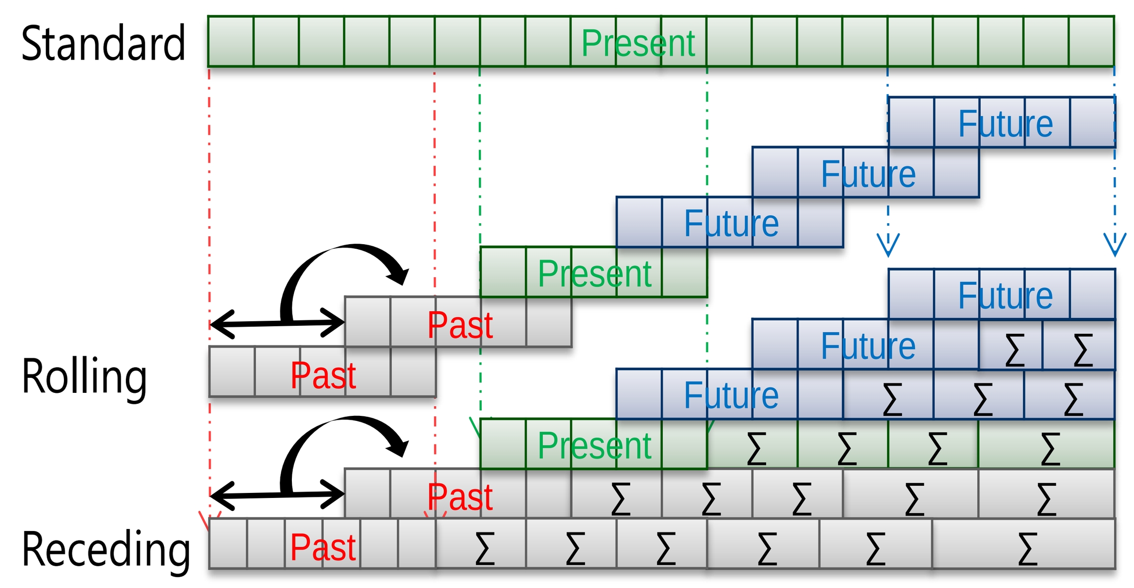
Urban Energy Systems Laboratory
Modelling and Optimization Group

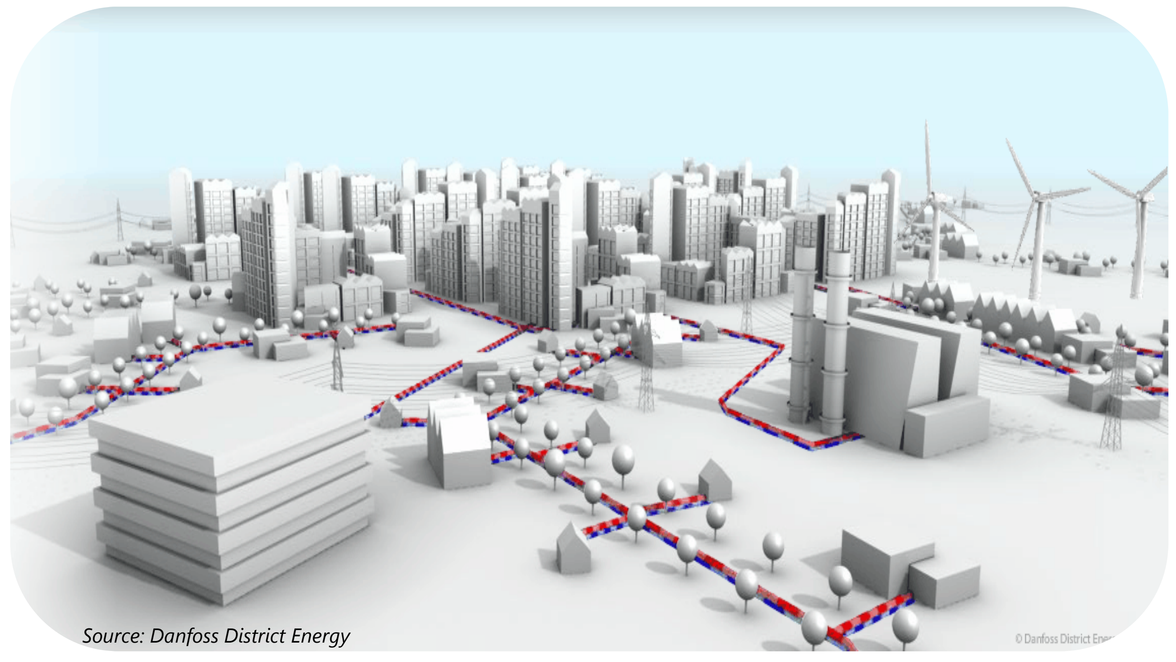
ETH zürich

Facilitating Multi-Scale Urban Energy Systems Modelling



Holonic energy hub formulation





Aim

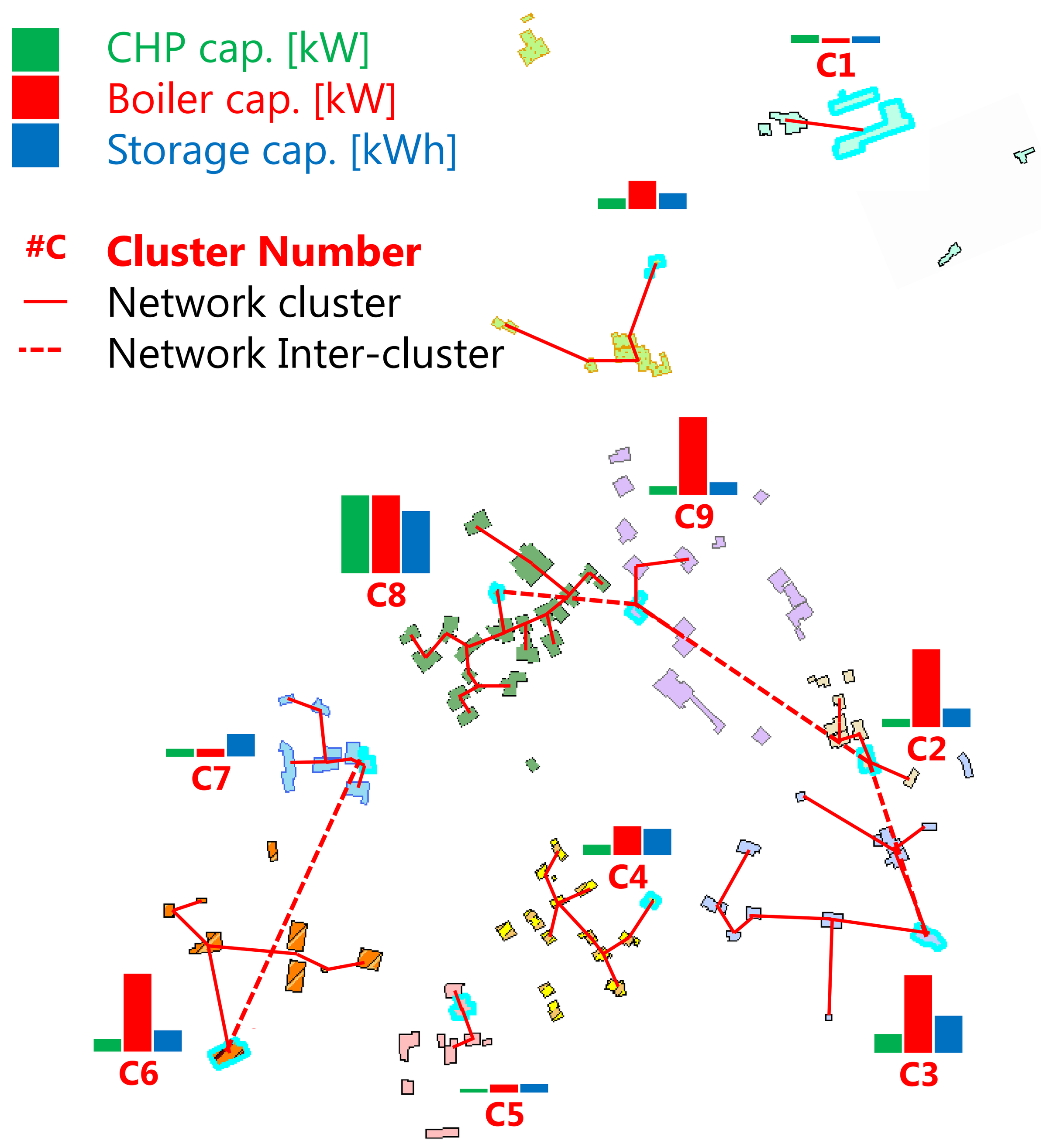
Network-level energy optimisation approaches can determine the optimal siting/location of generation technologies within a region and the optimal layout of energy distribution networks to link them.
This is a multi-scale problem as it must encompass decentralisation at the building, district, city and regional scales. However, computational limitations arise at larger spatial scales if full resolution is retained, and difficulties emerge in the quantification of different urban agglomeration levels when attempting to model network behaviour at multiple spatial scales.
Nevertheless, a tractable multi-scale optimisation of a large urban area is possible using a clustered, aggregated energy hub representation combined with temporal approximations.

Improving solvability

Solving the optimal design and operating strategy of networks of multiple energy hubs can become computationally demanding depending on the temporal and spatial resolution required. Different temporal approximation methods are implemented and also combined with spatial approximation.
The rolling horizon method applies the model to successive short time periods instead of one long period. The receding horizon method is a combination of a rolling horizon and time aggregation as a function of the horizon. The method can consider long-term (seasonal) storage systems and better address uncertainties in energy demands (e.g. weather predictions). The figure below shows how temporal and spatial resolutions relate to the solving time: from green to red, faster to slower depending on the approximation methods.

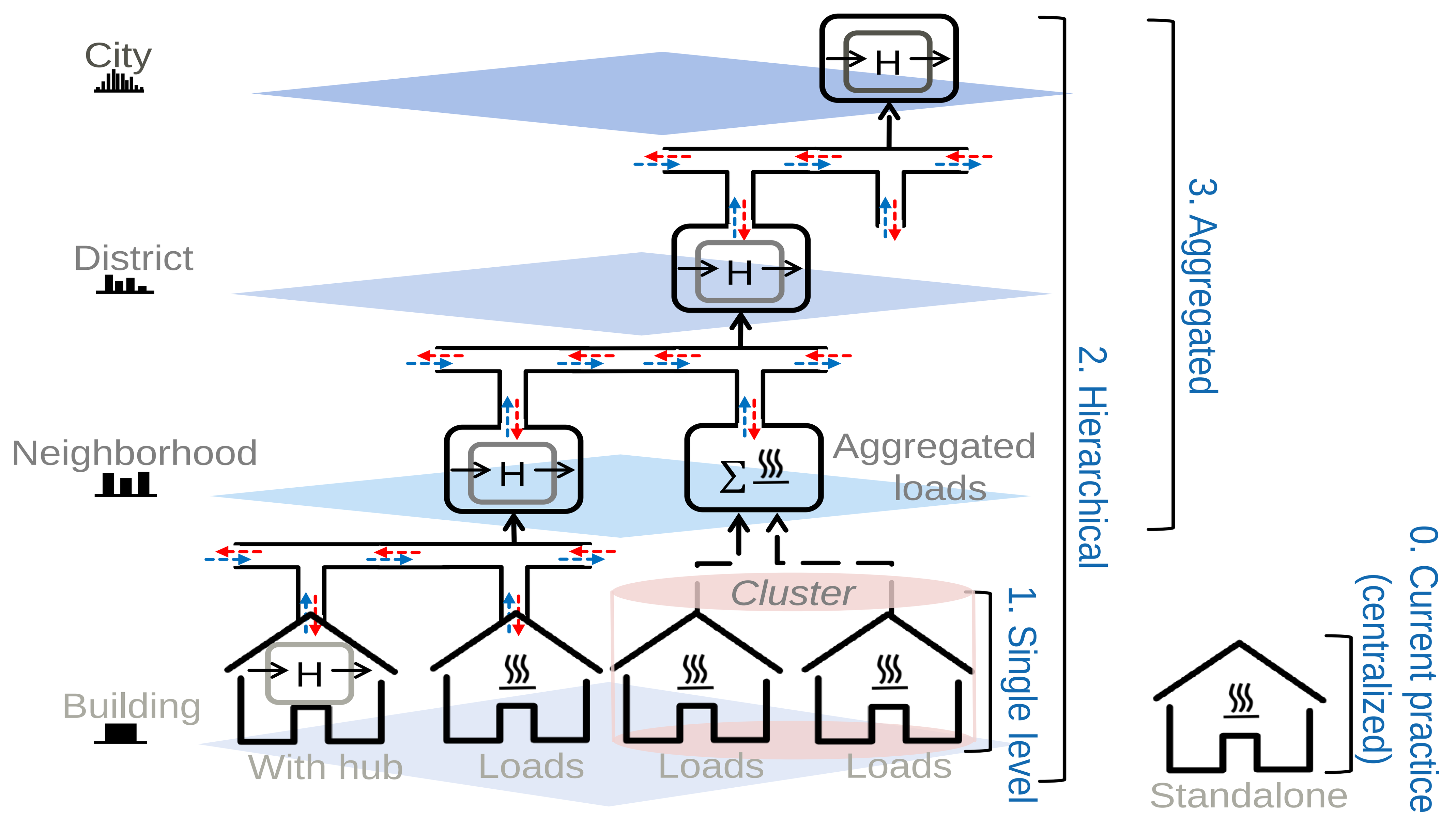
Large-scale case study

A large city case is selected to demonstrate the application of the methods developed. The study will consider the design and optimal operating strategy of the city energy system including the trade-off between centralised and distributed energy resources. In a sensitivity analysis, energy network typologies are studied, as well as the influence of the clustering and approximation methods.

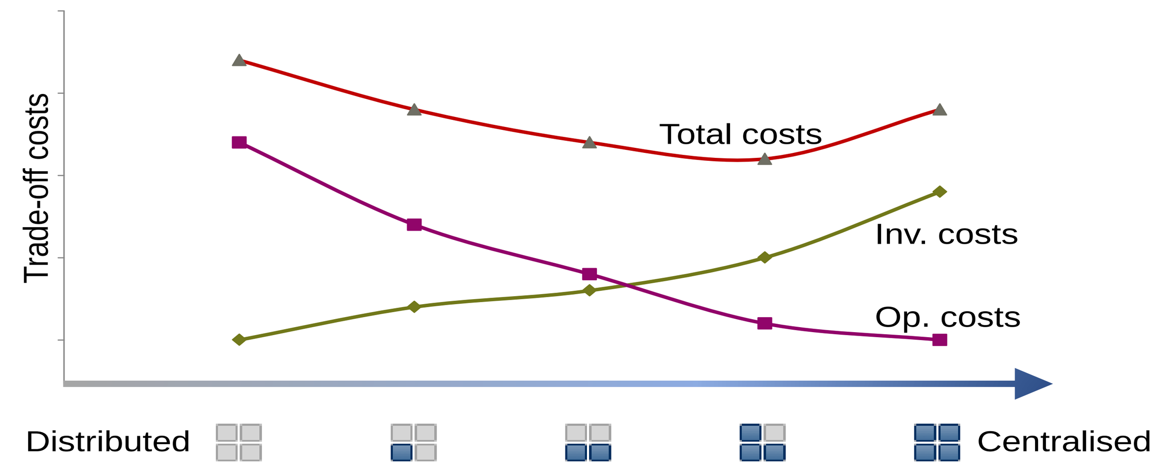


Network optimisation

Conclusions are drawn regarding design guidelines on the use of decentralized energy systems. Possible requirements to install distributed energy systems include building locations, district size and density, building types and network typologies.



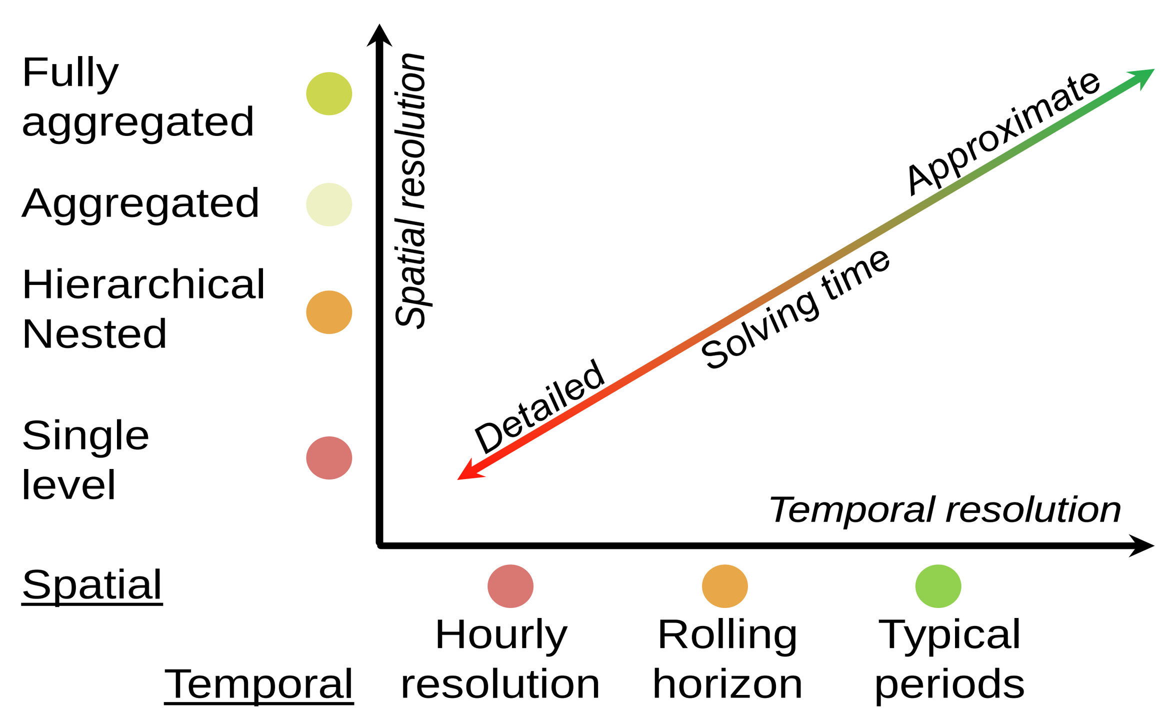
Multi-scale formulation



"Hump effect"

Multi-scale modelling

A hierarchical approach allows solving larger problems by pre-clustering the buildings and/or energy hubs at different levels to limit the number of possible connections between buildings based on location or routing constraints. This takes into account the trade-off between centralized and decentralized energy systems within a multi-objective optimisation environment.



Temporal and spatial scales vs. resolution

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