Empa
Materials Science and Technology

Urban Energy Systems Laboratory
Modelling and Optimization Group

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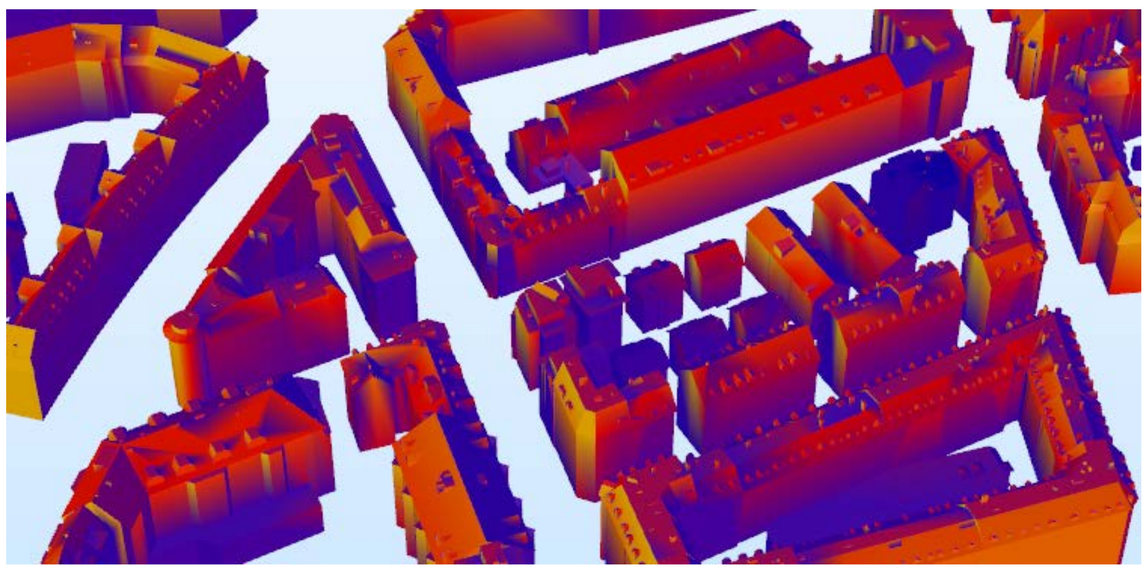
Hyper-Heuristic Framework for Multi-Objective Optimization of Urban Systems

The Role of Urban Morphology

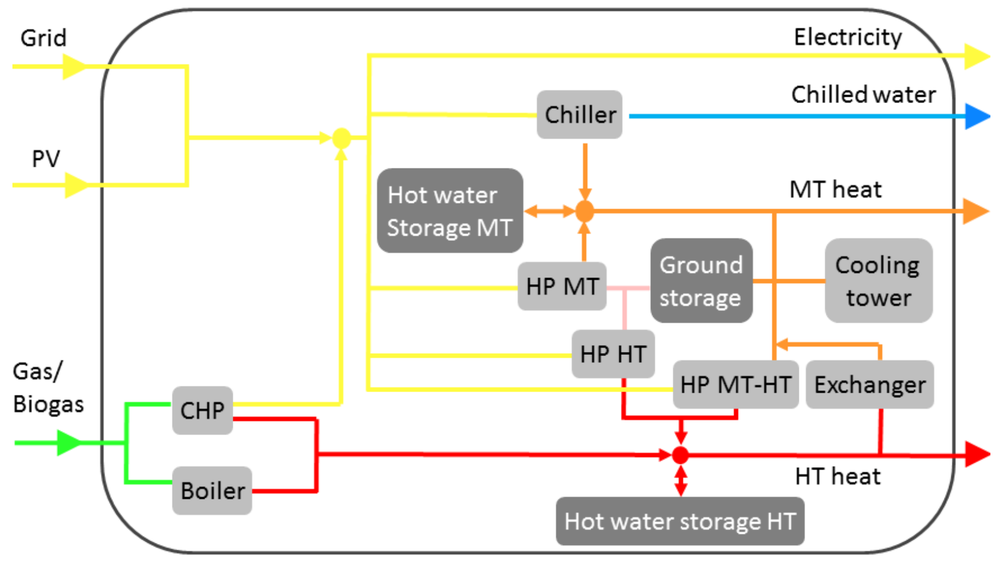


Urban solar energy potential analysis

Urban morphology has an impact on renewable energy potentials for solar, wind and ground-source heat as well as on demands for heating, cooling and lighting. Future energy networks (energy hubs) will be optimized to suit a given urban district, where the energy demands of the buildings and the renewable energy potentials of the district define constraints for the energy hub.

Recent research indicates that there is a high sensitivity to these constraints. It is therefore beneficial to consider urban district design as a multi-level optimization problem, where building shapes and layout are considered together with energy hub design. Synergies between urban morphology and energy hub design could lead to significantly better overall energy, monetary and emissions performance.

Urban Energy Simulation

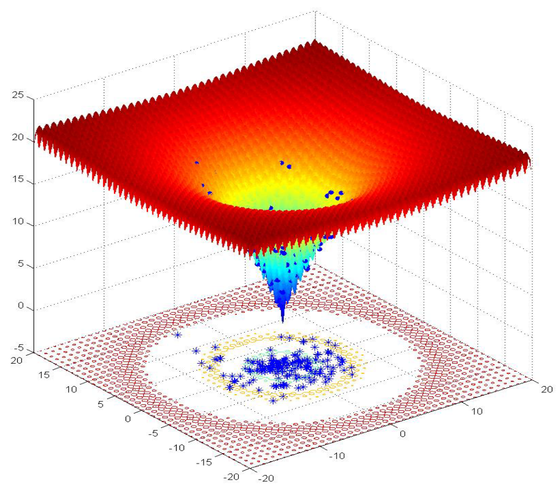


Example of an energy hub for the Empa campus

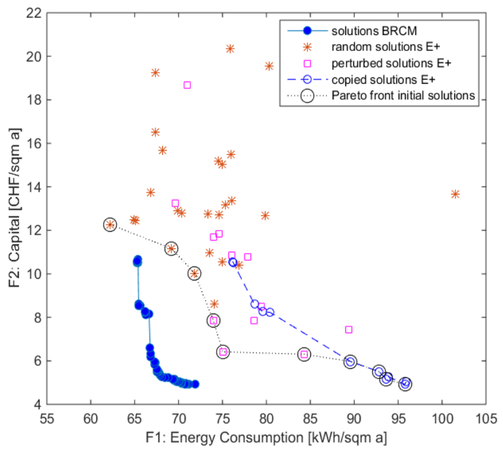
A set of urban energy simulation models, spanning different levels of detail and computational complexity, are used to evaluate the performance of urban morphologies and energy systems designs. They include building energy models to assess energy demands, solar radiation models to obtain solar energy potentials and ground models to assess the long-term potentials for geothermal energy.

Energy hub models provide solutions to the optimal operation and design of energy infrastructures, where multiple energy carriers are transformed, converted or stored in various forms to efficiently supply the demands of urban districts. Additionally, spatial models such as district accessibility, walkability and visibility models are included to account for the interdependent and multi-disciplinary nature of cities.

Optimization



Non-convex and non-linear test function for optimization algorithms

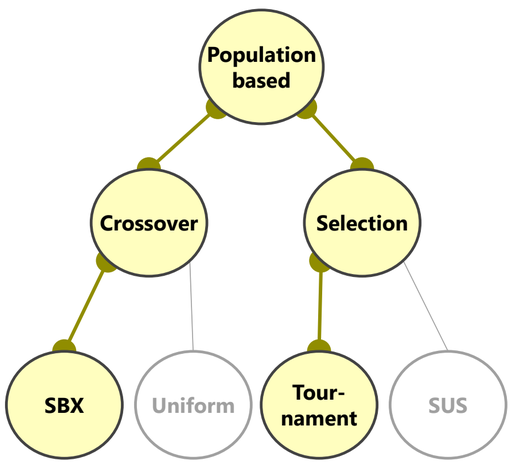


Self-adaptive sequential model assessment

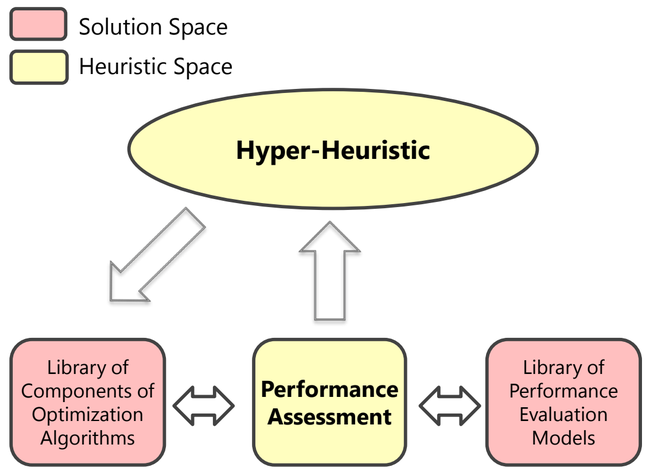
Holistic optimization methods can inform the design process by exploring vast numbers of design solutions across multiple performance criteria simultaneously. One of the practical challenges lies in the selection of appropriate optimization algorithms best suited to specific problem formulations.

This research develops a repository of various optimization methods, able to cover diverse problems of holistic urban systems design. Deterministic methods such as Mixed Integer Linear Programming are implemented for energy hub formulations. Metaheuristics such as genetic algorithms are implemented to solve non-linear, non-convex, multimodal or black-box global optimization problems typical of urban morphology and building design.

Hyper-Heuristic Framework



Genetic-programming approach for generation hyper-heuristic



General hyper-heuristic framework

Hyper-heuristics are a high-level method for automatically selecting and tuning a tailored heuristic from a set of operators and components. They tackle the issue of identifying the heuristic best suited to a specific problem, or even adapting a heuristic online during the solving of a difficult problem. This research focuses on the study and development of a hyper-heuristic framework in the context of multi-objective urban design, and its application to appropriate case studies.

The framework consists of components working on the solution space and others working on the heuristic space. The components working on the heuristic space assess the performance of an optimization algorithm in its ability to solve certain problems. Based on this the hyper-heuristic adapts to find the best optimization algorithm.

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