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A model for the identification and optimal planning of emission reduction measures in urban energy systems

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Introduction

- Cities declare emission reduction targets & climate protection plans
- Renewable energy & efficiency potentials exist, but their exact extent, optimal combinations and contribution towards reaching overarching goals are unknown
- Investment decisions are long term and capital intensive
- High complexity due to interdependencies and uncertainties

Mathematical models can provide decision support for urban planning.

Related work

- Many models for decision support in urban energy systems have been developed
- Mostly tailored to a specific use case (city)
- Usually not possible to apply these models in other cities as the required data is not available
- Data collection is very time-consuming and in many cases limited by privacy protection issues
- A transferable model should exploit freely available data sources and calculate missing data automatically

A model that should be universally applicable has to provide methods for the automated acquisition of the required input data.

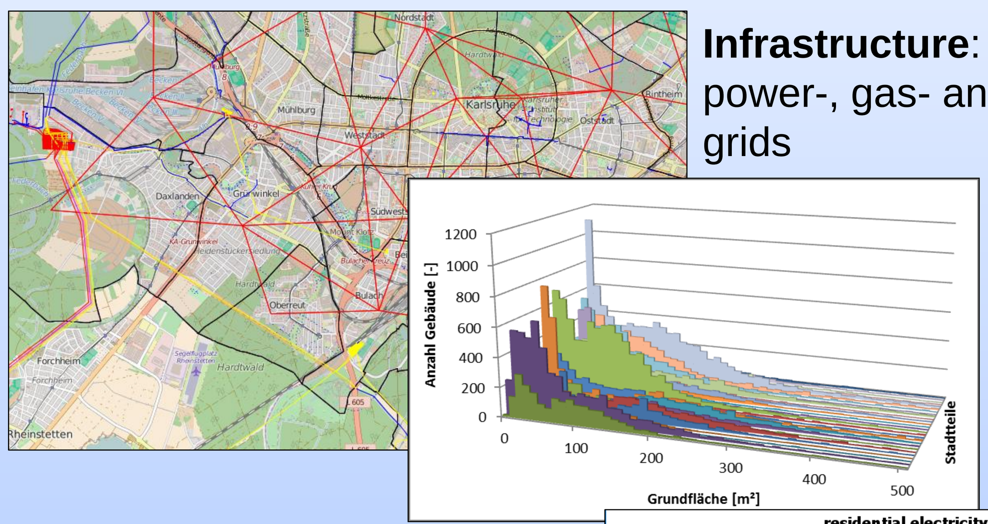
Requirements for model development:

1. Analysis & Optimization of urban energy systems
2. Unit commitment and investment planning
3. Determination of potentials for renewable energies and energy efficiency
4. Technologies on supply and demand side
5. Transferability of the method

1	2	3	4	5	
x	-	-	-	-	Several models, for a review see e.g. [Keirstead 2012]
x	x	-	-	-	deeco [Bruckner 1996]; URBS [Richter 2004]
x	x	-	x	-	iPlan [Winkelmüller 2006]; EnyCity [Gerbracht 2009]
x	(x)	-	x	-	KomMod [Eggers 2015]
(x)	-	x	x	-	Regionenmodell [Steinert 2015]
-	-	x	-	-	Many potential studies, for a review see [Angelis-Dimakis 2011]

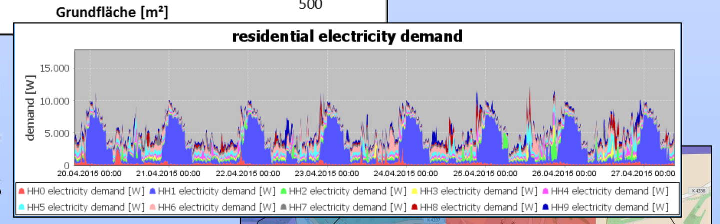
Transferrable methods for data acquisition in urban energy systems

Demand structure

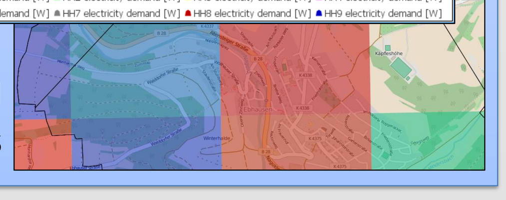


Infrastructure: Availability of power-, gas- and district heating grids

Buildings: Creation of typology, based on sizes and age distribution

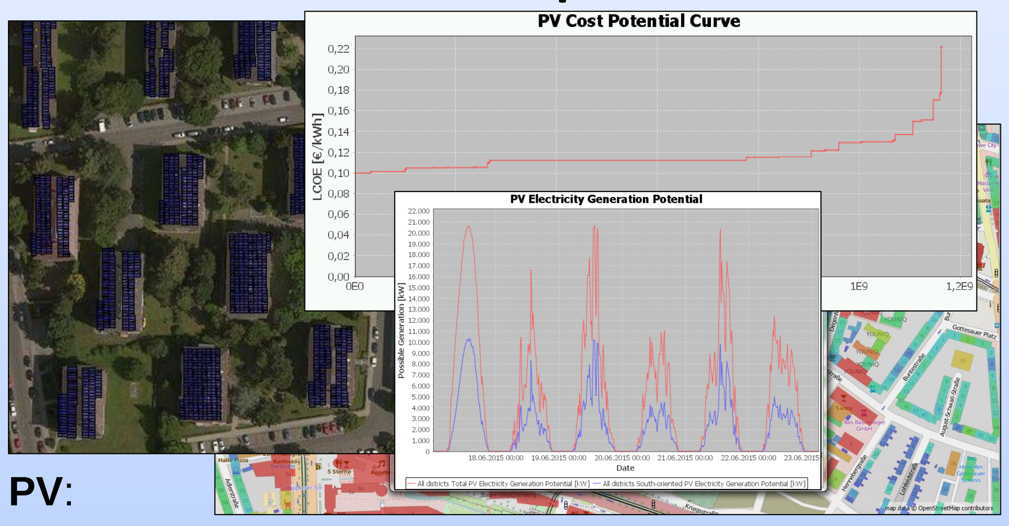


Electricity demand simulation based on appliance ownership and user activity profiles



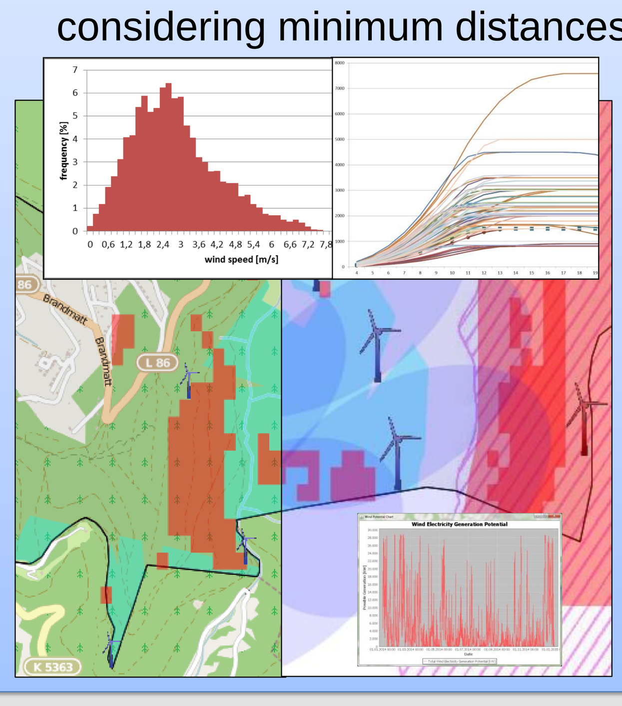
Heat demand mapping based on building types and technology configurations

Cost and potentials for renewable energies

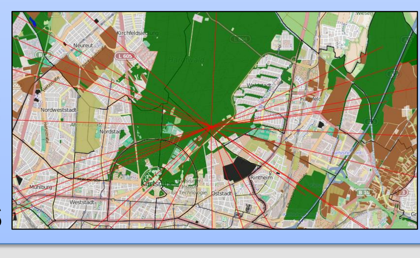


PV: Building roof detection using image recognition and neural networks; area calculation & module placement; simulation of irradiation

Wind: Choice of best turbines based on wind frequency distribution and technical characteristics; placement considering minimum distances

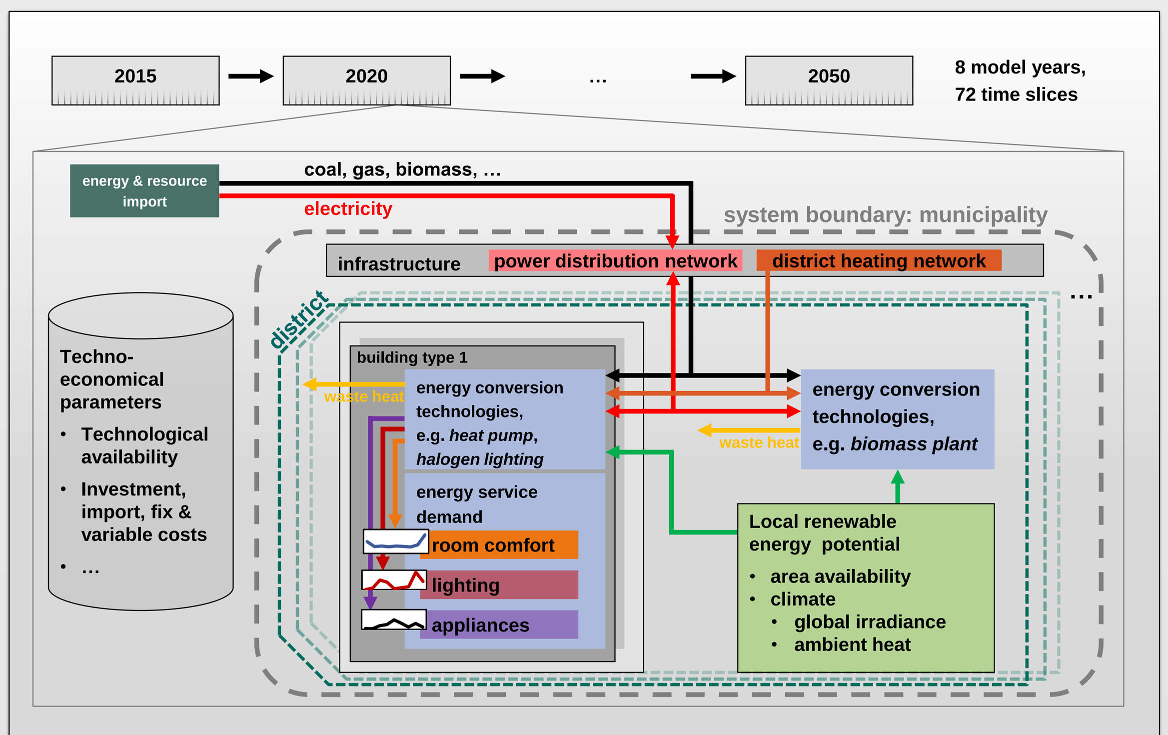


Biomass: Determination of suitable areas; minimization of transport distances



- **Technology-Database** *efficiencies, costs, …*
- **Climate data** *irradiation, wind, …*
- **Market data** *price development*
- **Statistical data** *no. & type of buildings, population, …*
- **Geodata** *OpenStreetMap: buildings, land use, …*
- **Scientific studies** *Consistent future development scenarios*

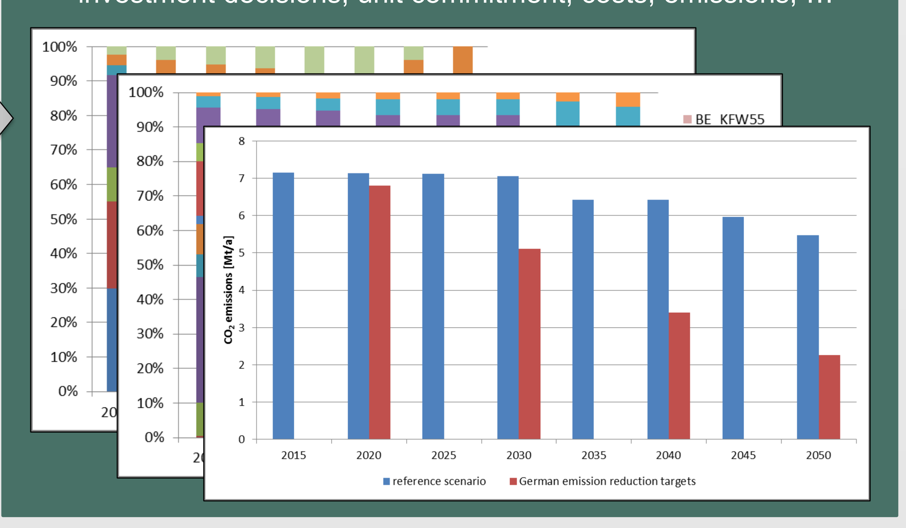
Techno-economical optimization of the urban energy system



- Minimization of total system costs, CO_2 emissions, or net energy import, while taking technical as well as user-defined constraints into account
- Methodology: Mixed-integer linear programming (MILP)

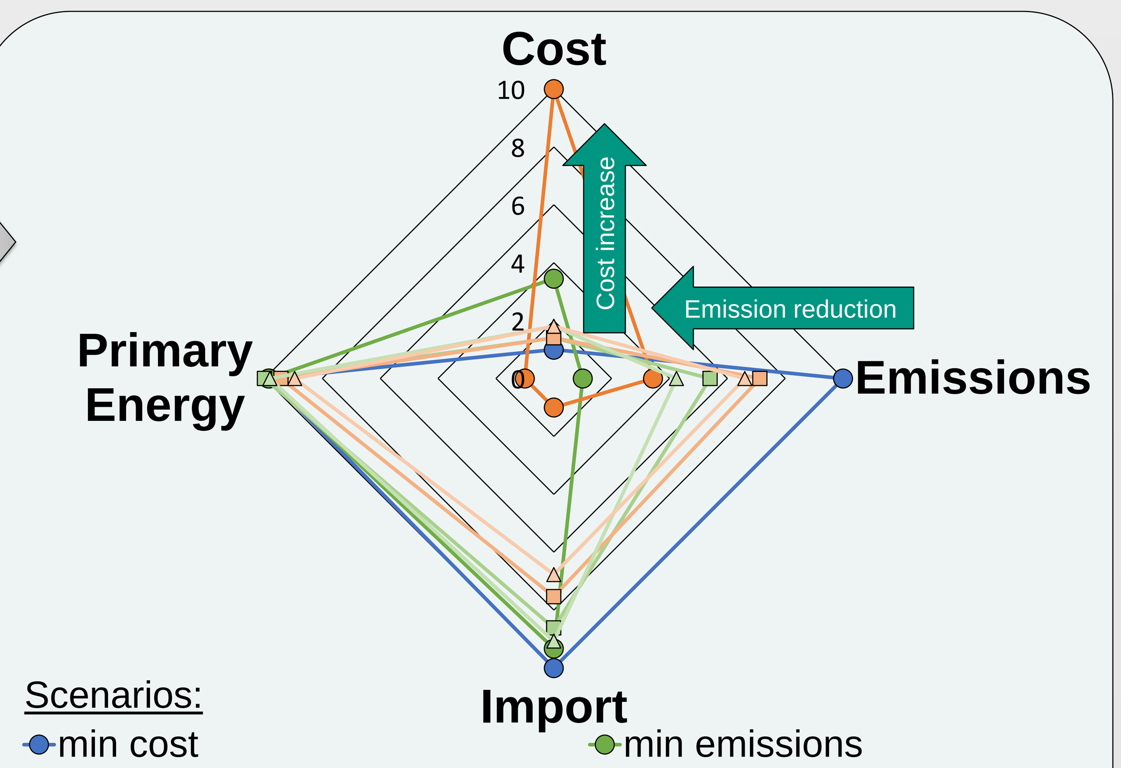
Detailed scenario results

investment decisions, unit commitment, costs, emissions, …



- Required investments in order to reach the optimal system design
- Optimal degree of renewable energy utilization
- Reasonable technology combinations
- Development of costs, emissions, energy import and primary energy consumption under different objectives for emission reduction and costs

Scenario comparison



Trade-offs: e.g. significant emission reduction can be achieved with only minor additional costs

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