Investigation of cross-sectoral energy concepts for urban districts using key performance indicators

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Introduction

Initial situation

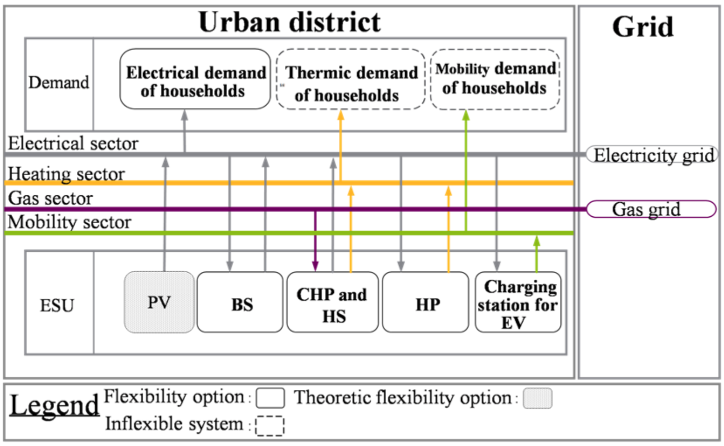
- In course of the energy transition new generation units but also new loads will be installed in city districts
- Peaks in demand and supply make a cost-effective, ecological and reliable energy distribution difficult
- New concepts for managing the demand und supply of energy in city districts are needed

Aim of this investigation

- Development of key performance indicators to evaluate energy concepts for districts
- Simulation of different use cases for using demand response in a city district in Wuppertal (Germany)
- Evaluation of the use cases with the developed key performance indicators

Methodology

Flexibilities and sector coupling



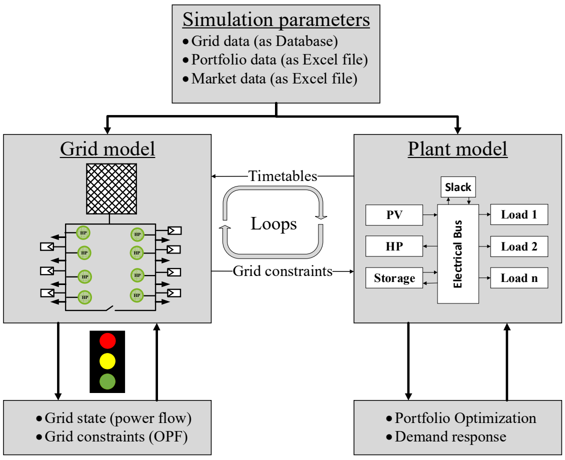
Definition flexibility

A flexibility is defined as the adaptation of the demand or supply of an energy system unit (ESU) by an extern signal, with the aim to maintain the system stability or for cost effective manners

Considered flexibilities

- Heating pumps (HP)
- Electric vehicle charging (EV)
- Conventional household applications

Modelling of plants and the grid

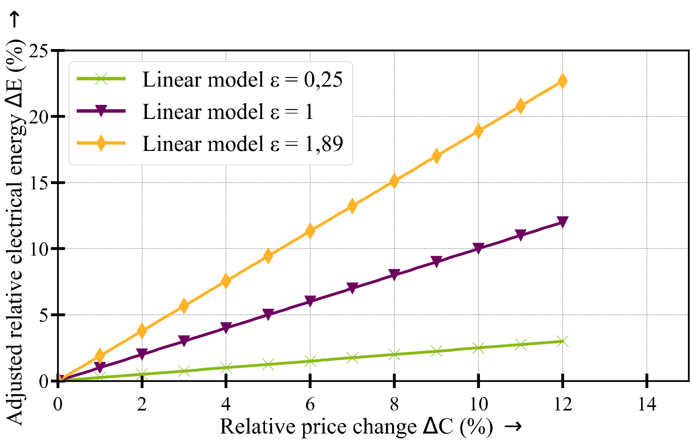


For the simulations a grid model is coupled with a plant model

The plants are defined through time series, technical restrictions, marginal costs for energy generation/consumption and the information if the plant is flexible

The optimal power flow of the grid model calculates a power corridor for the flexible units

Modeling of demand response (DR)



Demand response is divided in direct (EV and HP) and indirect (household applications) flexibilities

For indirect flexibilities incentive signals with different price elasticities for the participants were used

Direct flexibilities are modelled with a linear optimization with the objective to minimize costs

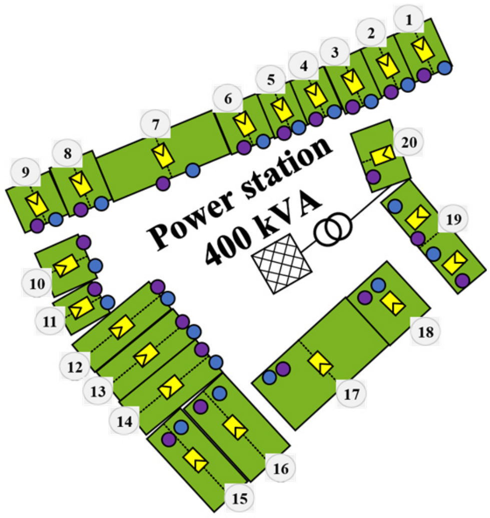
Key performance indicators (KPIs)

KPI

Ecological aspects			Economic aspects			Operational aspects		
Carbon dioxide exhaust			Marginal cost			Self-sufficiency		
Heat	Mobility	Electricity	Heat	Mobility	Electricity	Heat	Mobility	Electricity
						Distribution efficiency		
						Max. voltage drop		
						Min. voltage drop		
						Max. load		

Simulation results

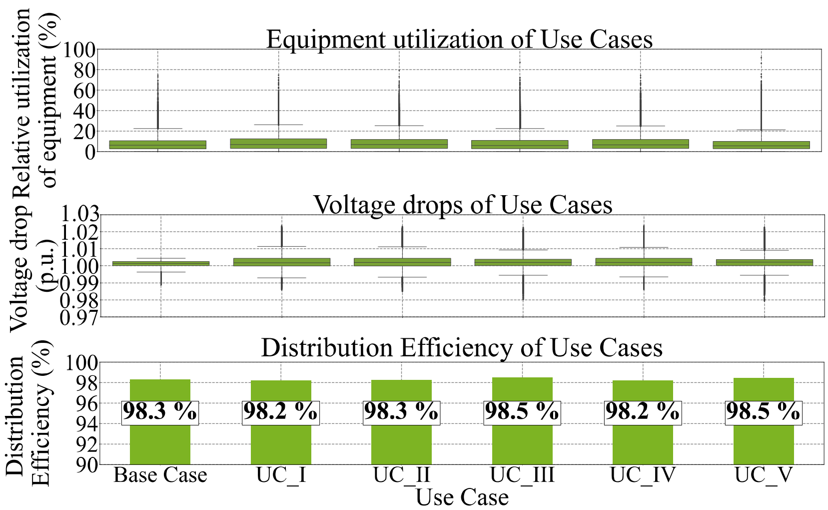
Object of investigation



Use Cases	
Base Case	Status Quo
UC I	Installation of PV, HP and EV without DR
UC II	UC I with DR for household applications
UC III	UC I with DR for HP
UC IV	UC I with DR for EV
UC V	Combination of UC II – UC IV

KPI for operational impacts

Electrical grid

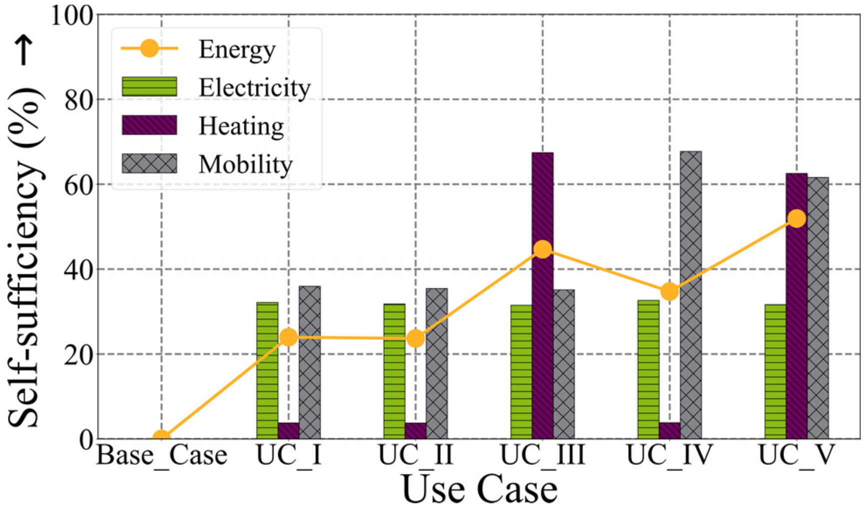


Installation of PV, EV and HP leads to higher equipment utilization and higher voltage deviation, but not to grid congestions

Distribution efficiency descents with installation of loads and PV without DR, but can be increased with DR for the heat pumps

KPI for operational impacts

Self-sufficiency



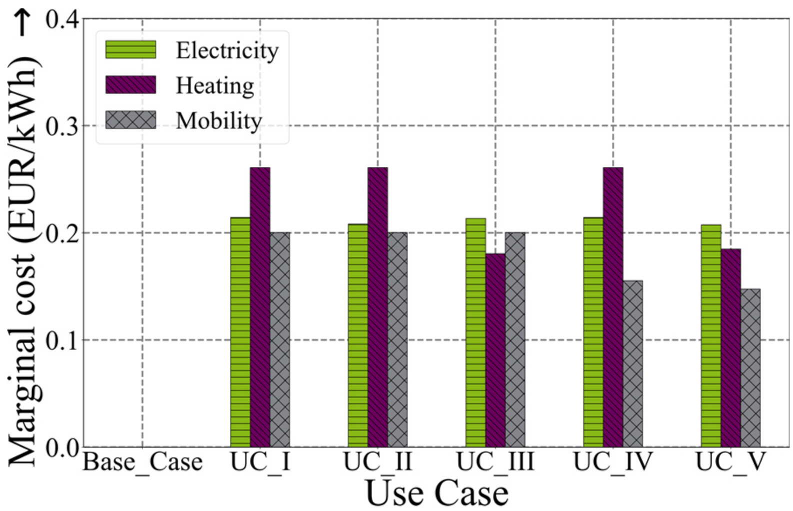
Without demand response a cross-sectoral self-sufficiency of 23 % can be achieved

Demand response for household applications doesn‘t lead to higher self-sufficiency

With Demand Response for mobility and heating the cross-sectoral self-sufficiency can be increased to 50 %

KPI for economic impacts

Marginal cost



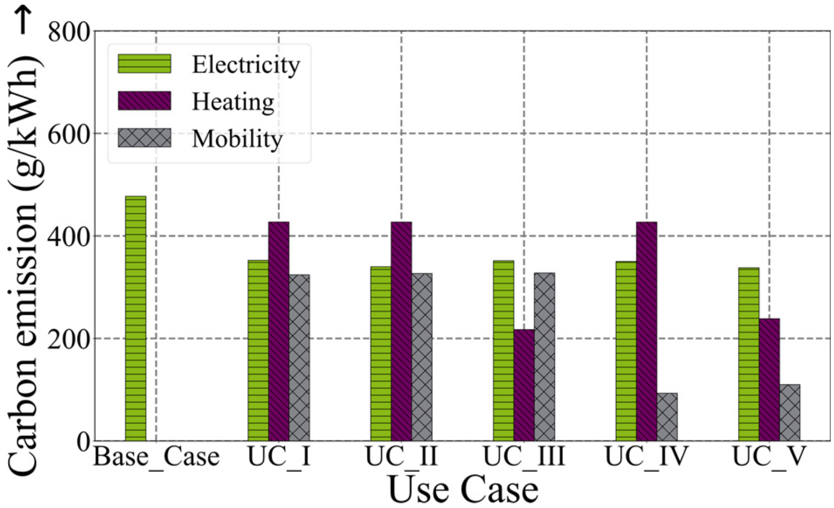
Demand response has only an minor effect on marginal costs for household applications

Demand response for the heating sector can decrease the costs from 0.25 €/kWh to 0.18 €/kWh

Demand response for the mobility sector can decrease the costs from 0.20 €/kWh to 0.15 €/kWh

KPI for ecological impact

Carbon emission



Demand response has only an minor effect on carbon emissions for household applications

Demand response for the heating sector can decrease the carbon emissions from 427 g/kWh to 217 g/kWh

Demand response for the mobility sector can decrease the carbon emissions from 324 g/kWh to 93 g/kWh

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Conclusion

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Conclusion

Modelling of cross-sectoral energy systems for city districts and the development of key performance indicators are presented

Simulation of different use cases for demand response in an urban city district in Wuppertal are conducted and evaluated with the developed key performance indicators

In the investigated district demand response has only a minor impact on operational aspects of the electrical grid

Demand response for conventional household applications has only a minor impact on ecological and economic aspects of the energy system in the city district

With demand response for the heating and mobility sector the self-sufficiency can be increased and the carbon emissions as well as the costs can be significantly reduced

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