Potentiale der vorhersagebasierten Steuerung von Flexibilitäten in Energiegemeinschaften

Energy Lunch #67

01.10.2025

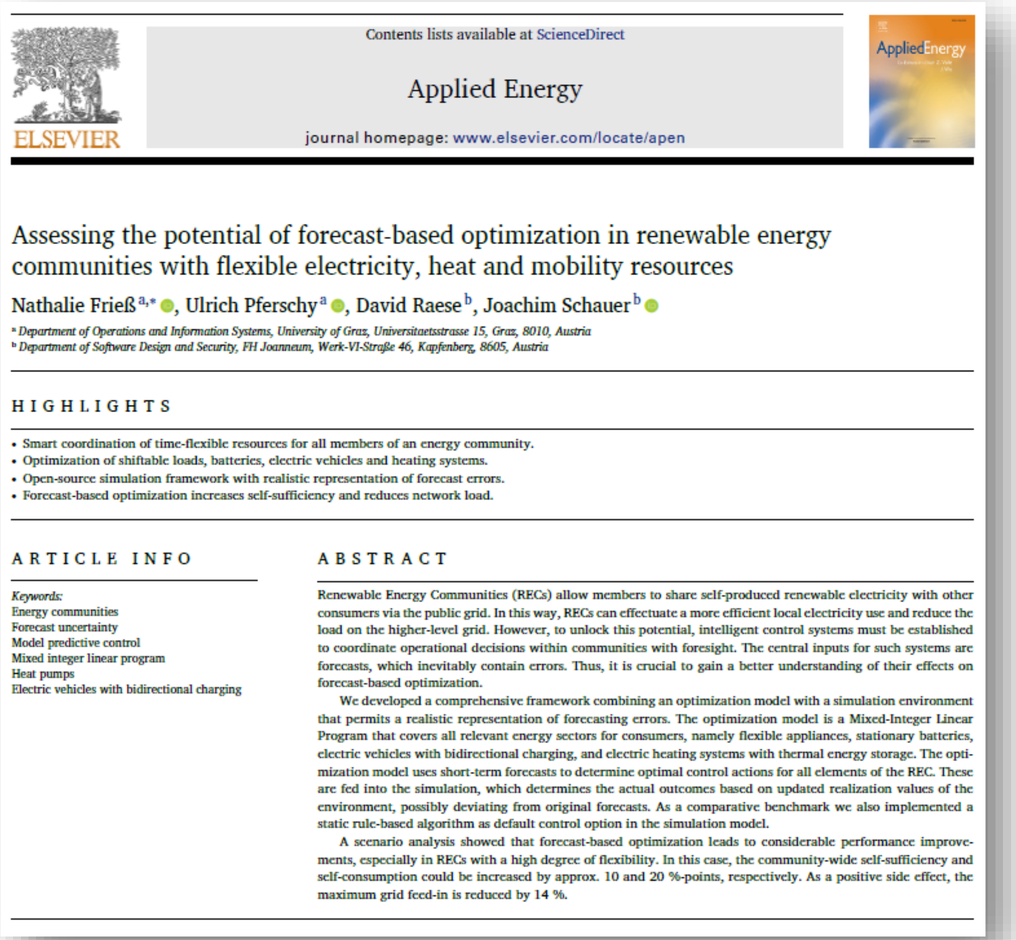
Nathalie Frieß

Institute for Operations and Information Systems

UNIVERSITÄT GRAZ

Grazer ENERGIEAgentur

Aktuelle Studie



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Applied Energy

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Assessing the potential of forecast-based optimization in renewable energy communities with flexible electricity, heat and mobility resources

Nathalie Frieß [a,*], Ulrich Pferschy [a], David Raese [b], Joachim Schauer [b]

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HIGHLIGHTS

- Smart coordination of time-flexible resources for all members of an energy community.
- Optimization of shiftable loads, batteries, electric vehicles and heating systems.
- Open-source simulation framework with realistic representation of forecast errors.
- Forecast-based optimization increases self-sufficiency and reduces network load.

ARTICLE INFO

Keywords:
Energy communities
Forecast uncertainty
Model predictive control
Mixed integer linear program
Heat pumps
Electric vehicles with bidirectional charging

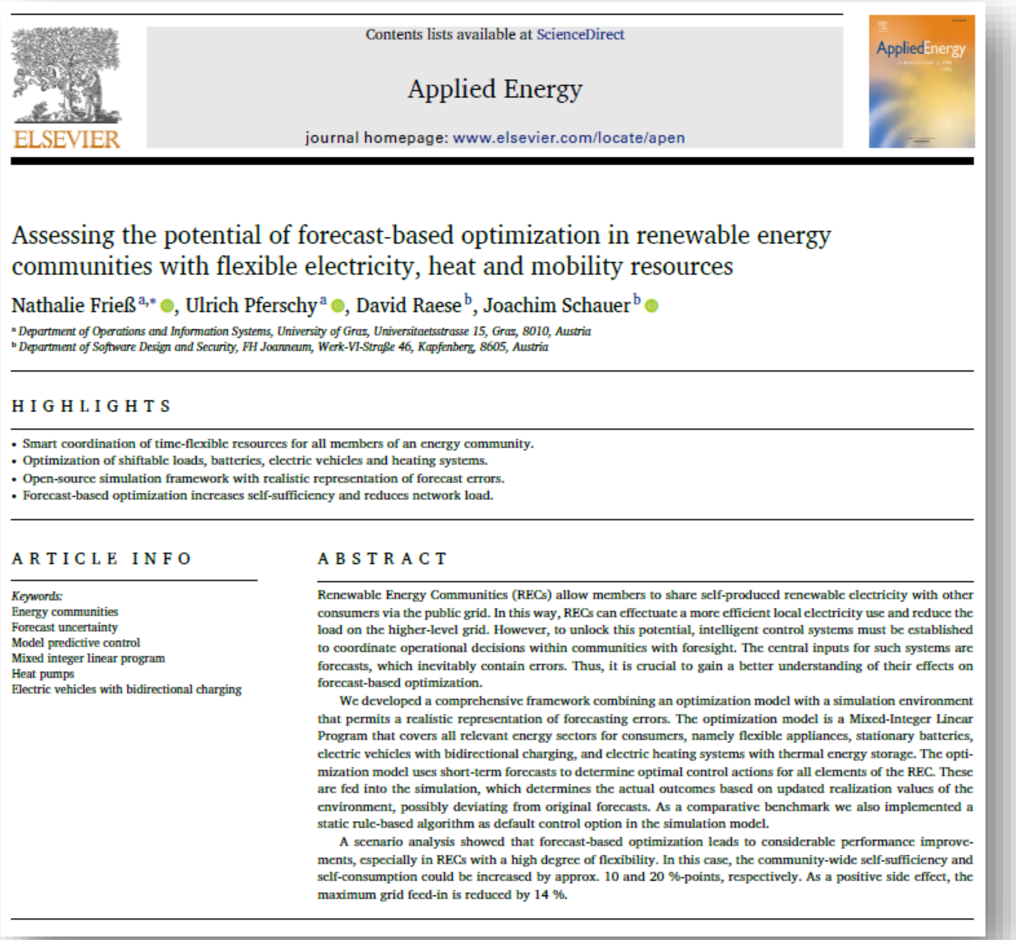
ABSTRACT

Renewable Energy Communities (RECs) allow members to share self-produced renewable electricity with other consumers via the public grid. In this way, RECs can effectuate a more efficient local electricity use and reduce the load on the higher-level grid. However, to unlock this potential, intelligent control systems must be established to coordinate operational decisions within communities with foresight. The central inputs for such systems are forecasts, which inevitably contain errors. Thus, it is crucial to gain a better understanding of their effects on forecast-based optimization.

We developed a comprehensive framework combining an optimization model with a simulation environment that permits a realistic representation of forecasting errors. The optimization model is a Mixed-Integer Linear Program that covers all relevant energy sectors for consumers, namely flexible appliances, stationary batteries, electric vehicles with bidirectional charging, and electric heating systems with thermal energy storage. The optimization model uses short-term forecasts to determine optimal control actions for all elements of the REC. These are fed into the simulation, which determines the actual outcomes based on updated realization values of the environment, possibly deviating from original forecasts. As a comparative benchmark we also implemented a static rule-based algorithm as default control option in the simulation model.

A scenario analysis showed that forecast-based optimization leads to considerable performance improvements, especially in RECs with a high degree of flexibility. In this case, the community-wide self-sufficiency and self-consumption could be increased by approx. 10 and 20 %-points, respectively. As a positive side effect, the maximum grid feed-in is reduced by 14 %.

Aktuelle Studie



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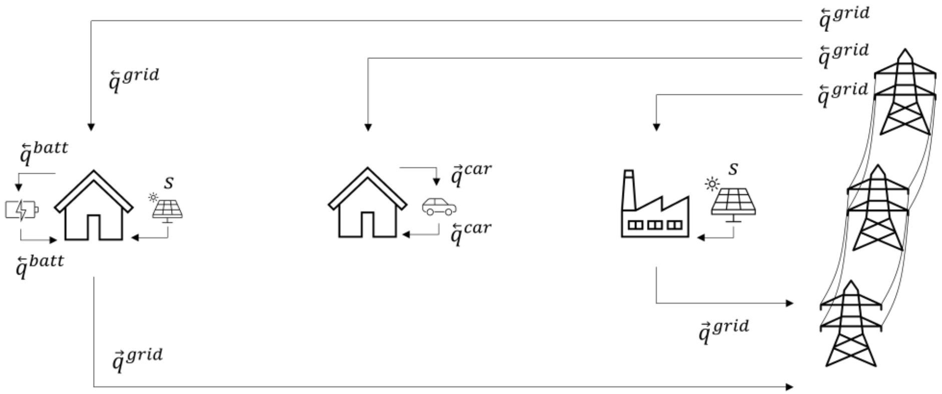

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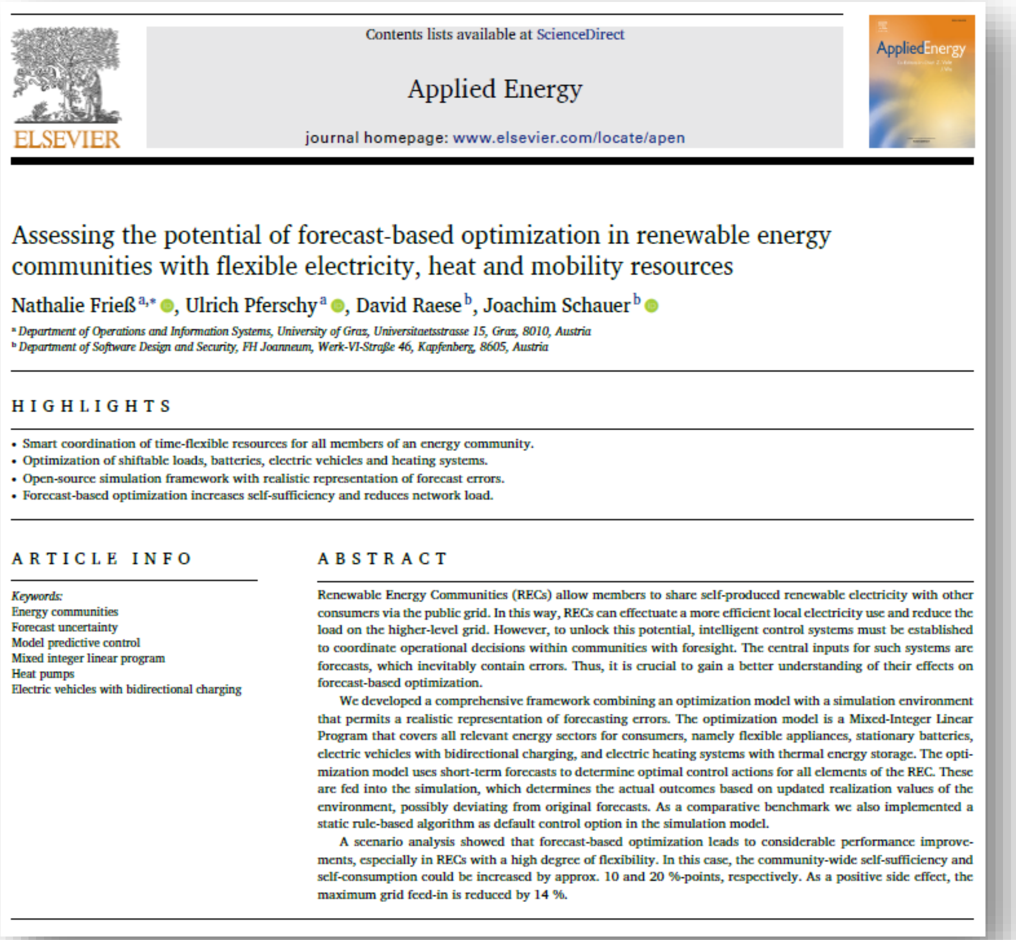

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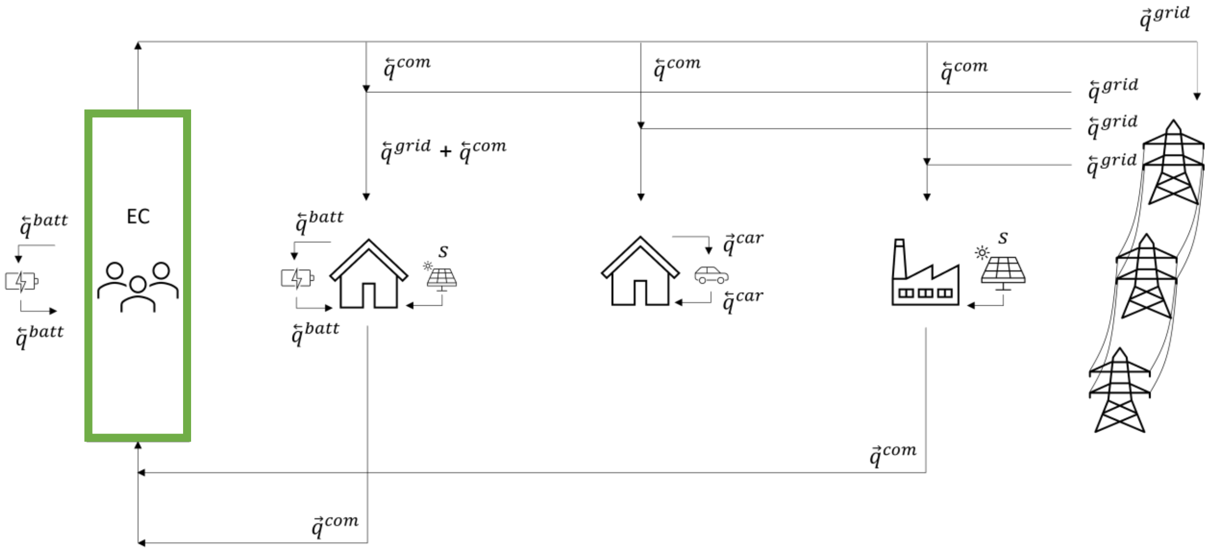
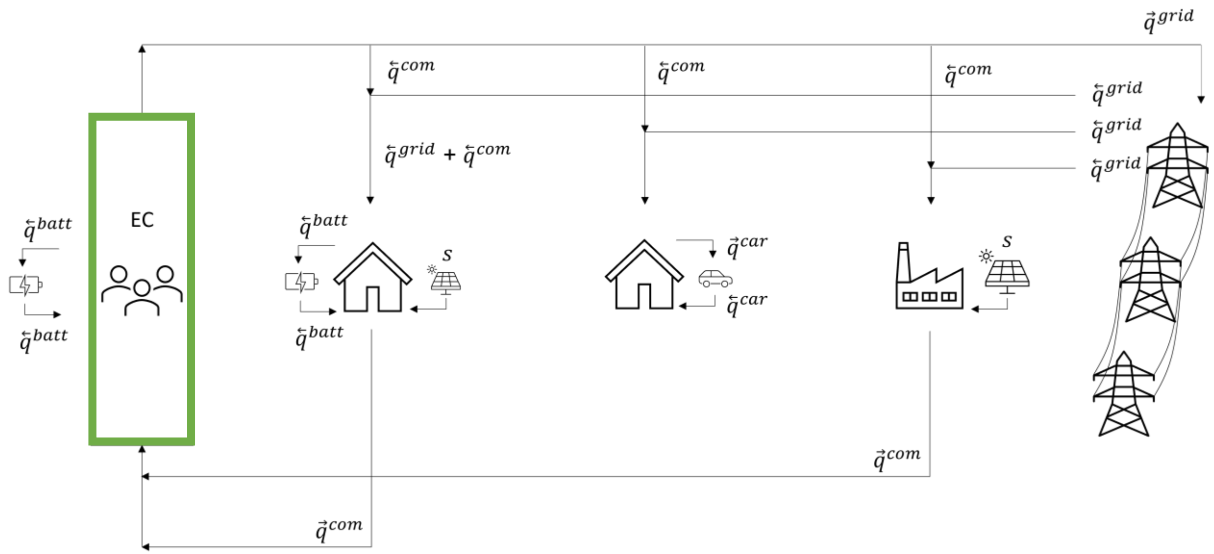


Status Quo & Fragestellung

Ex-post Zuteilung der Energiemengen zur Abrechnung

Reduktion der Netzentgelte für Strombezug innerhalb der EEG



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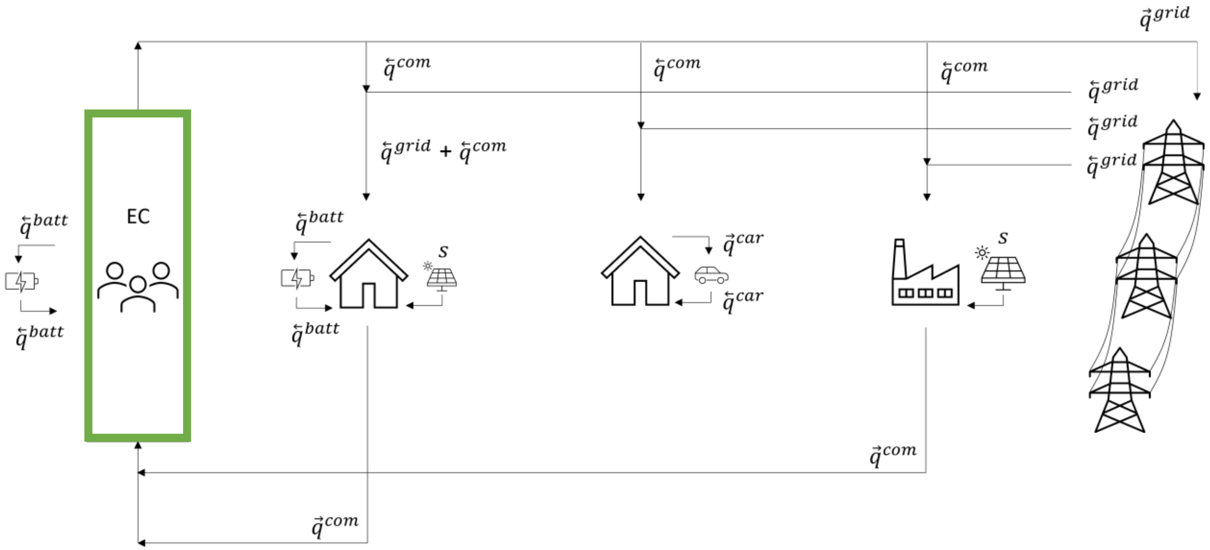
Wird eine messbare Verbesserung in der lokalen Energienutzung erreicht?



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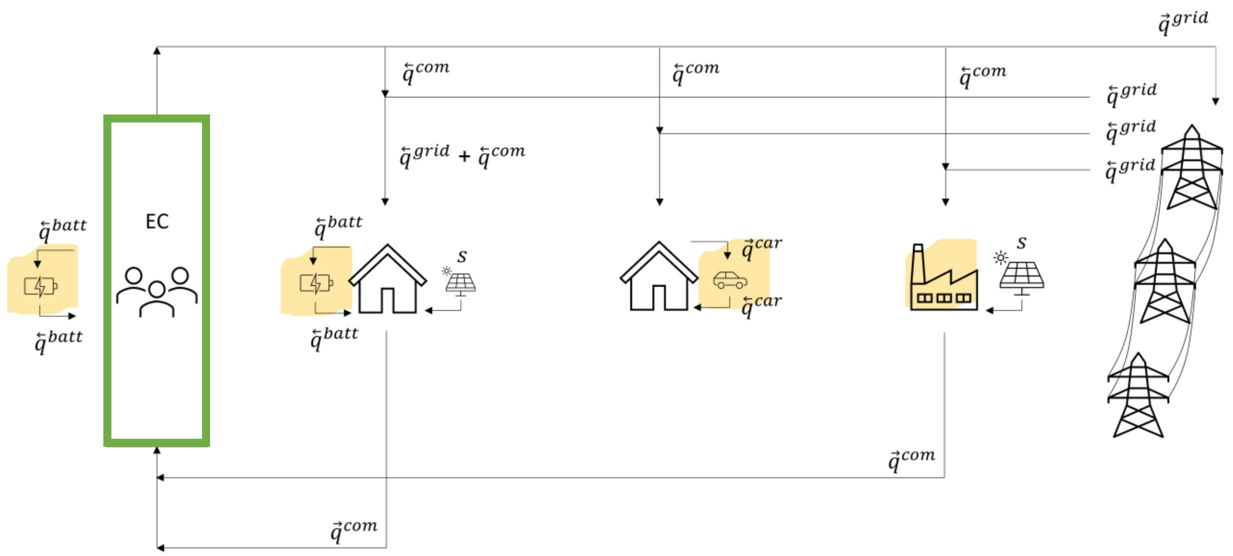


Intelligente Koordination aller Flexibilitäten

Mögliche Flexibilitäten

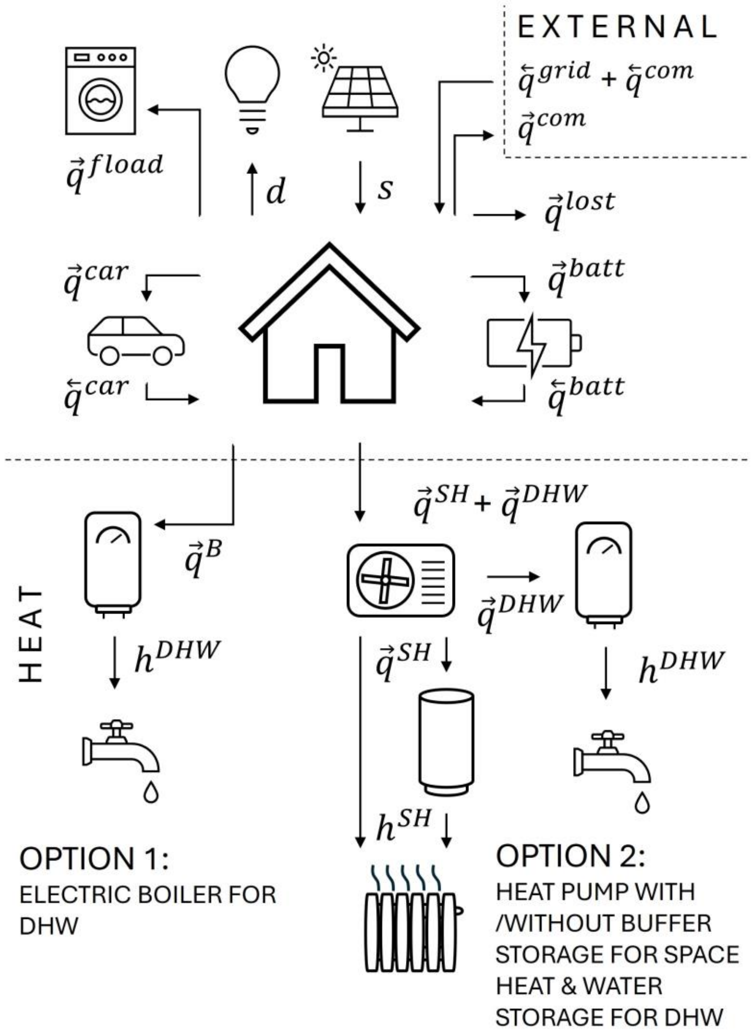
a) zeitlich verschiebbare Lasten

b) stationäre Batteriespeicher

c) E-Autos (bi-direktional)

d) elektrische Warmwasserspeicher

e) Wärmepumpen und Bufferspeicher



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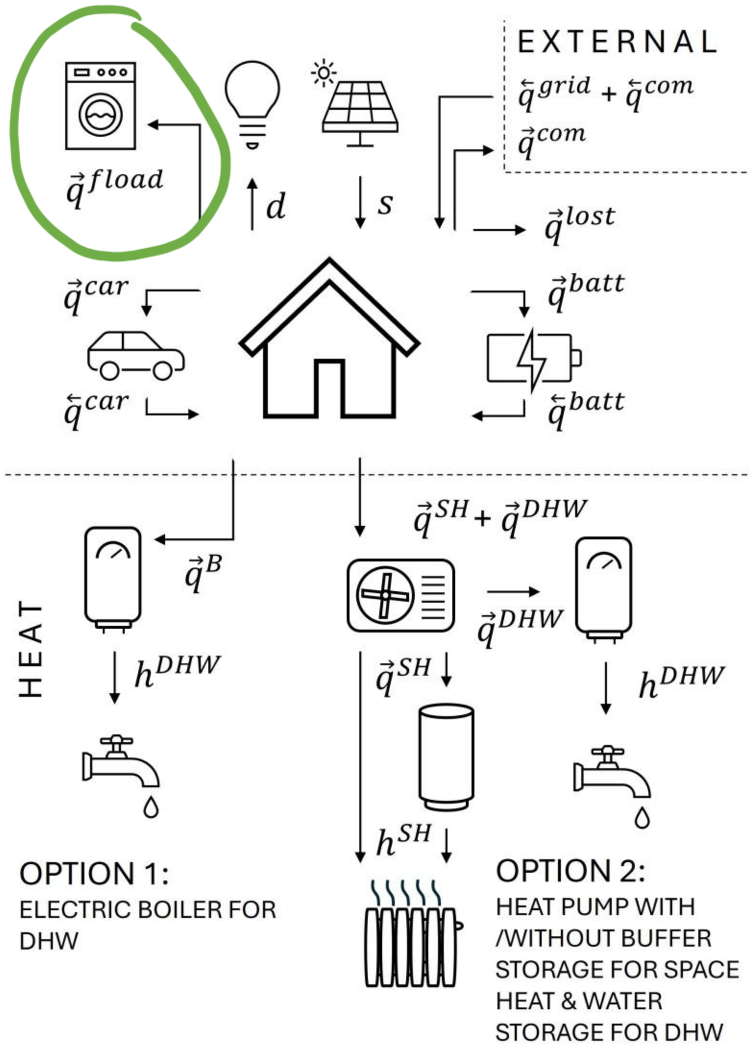

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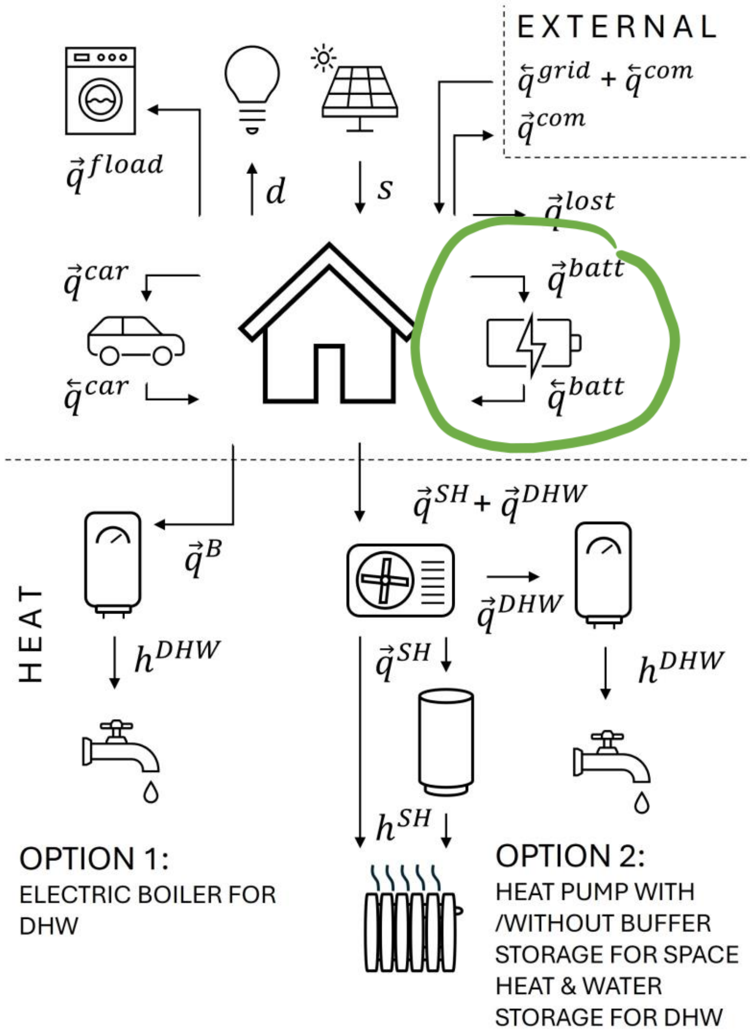

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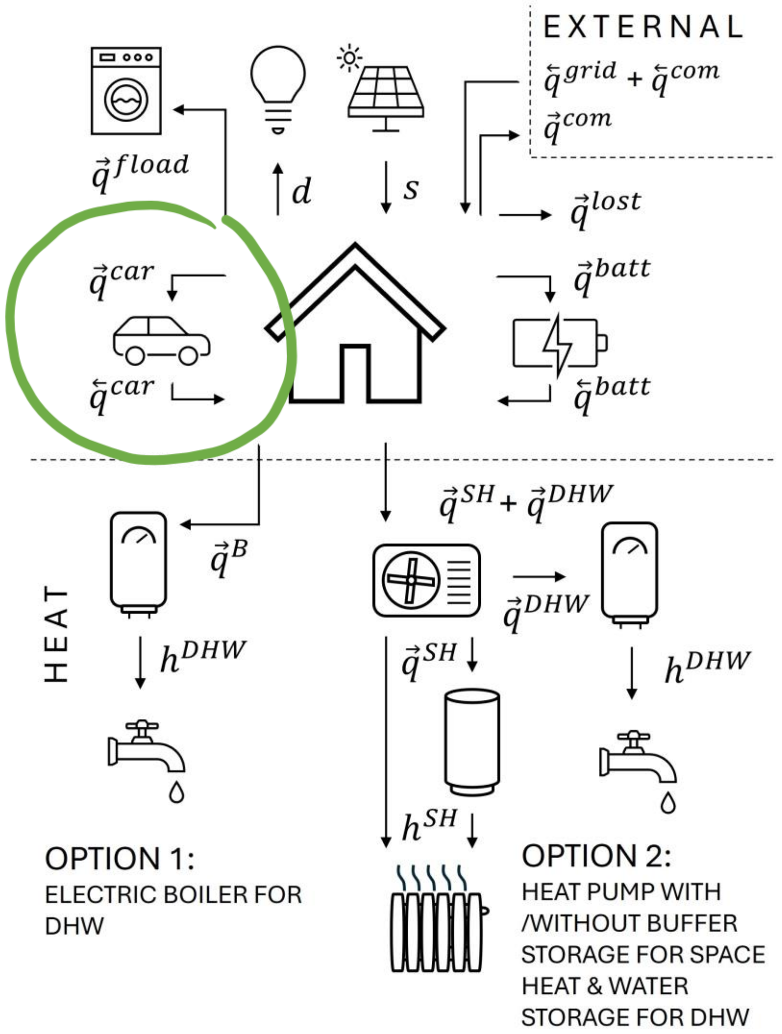

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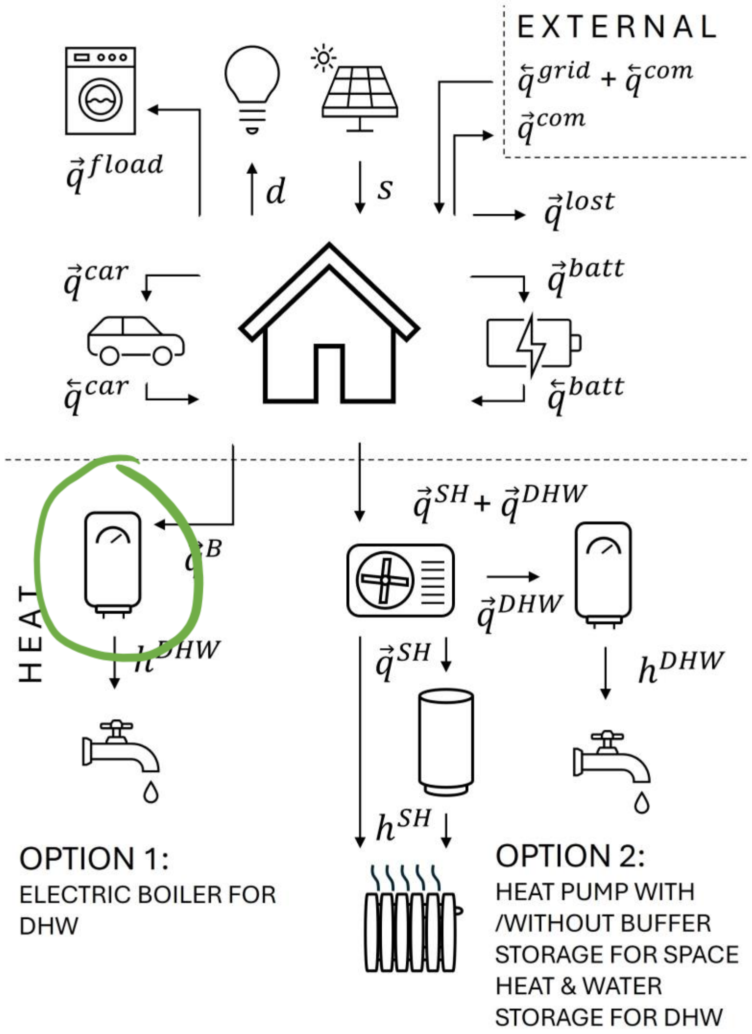

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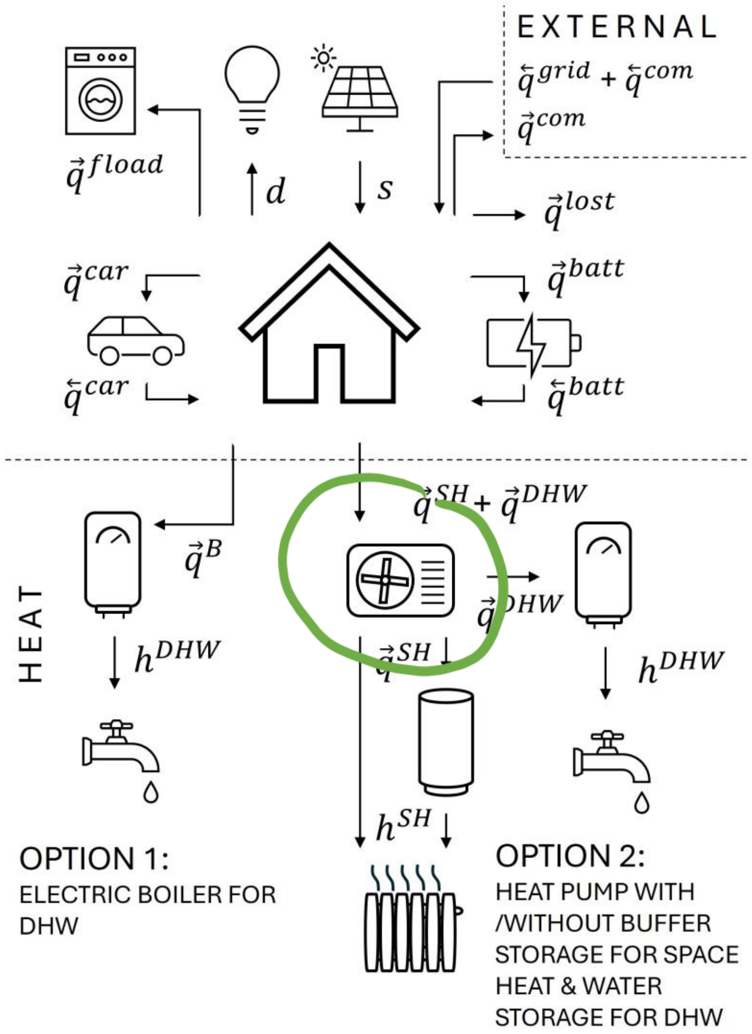

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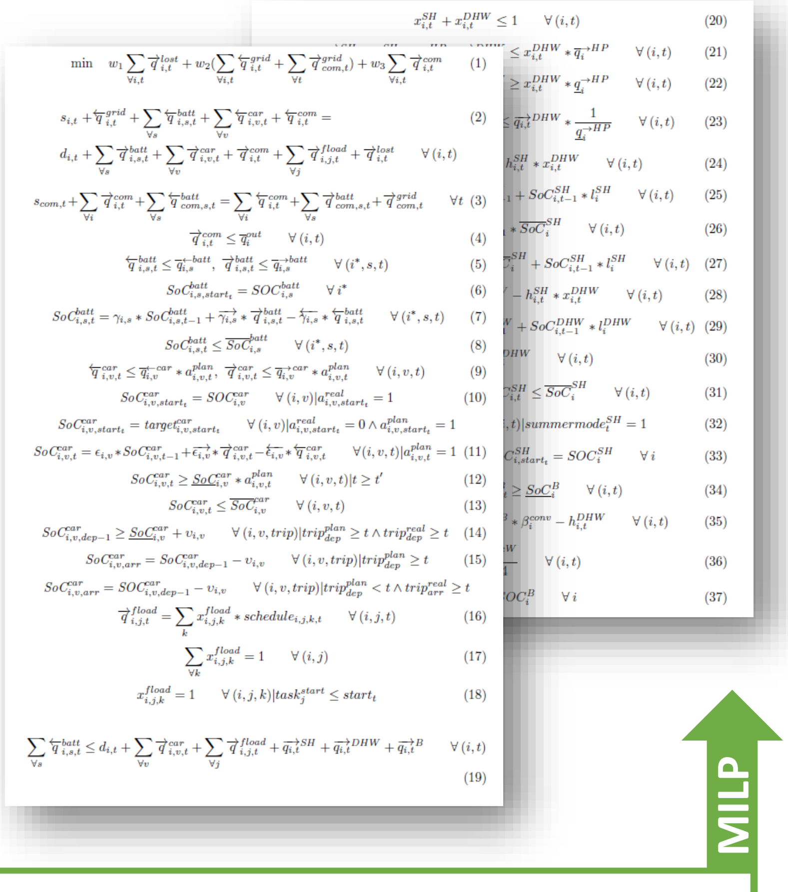

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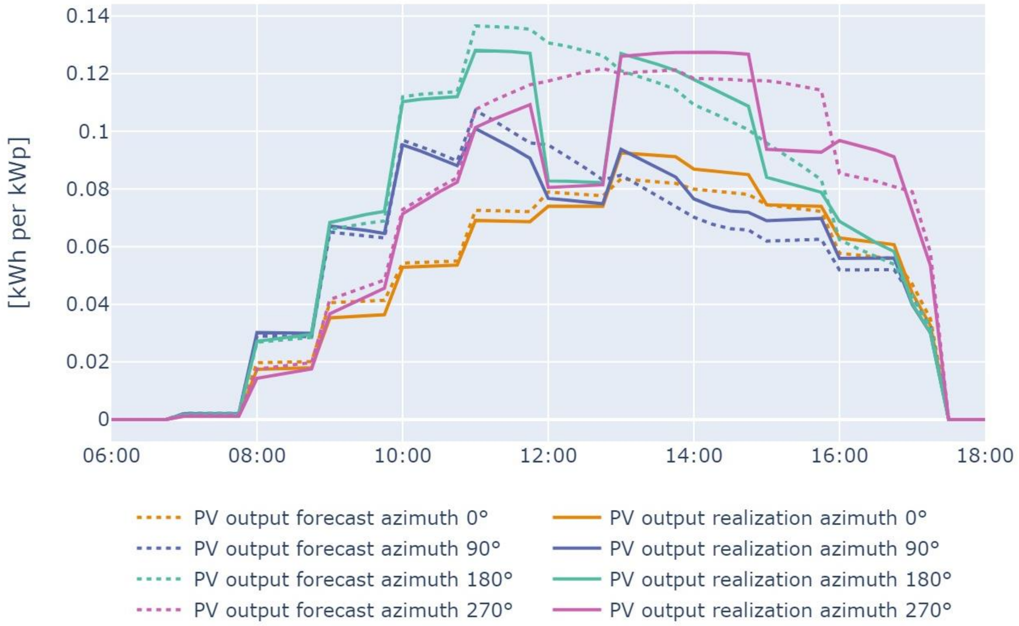
Status Quo & Forschungsfrage

MILP benötigt Prognosen als Input

Reality Check: fehler-behaftete Prognosen



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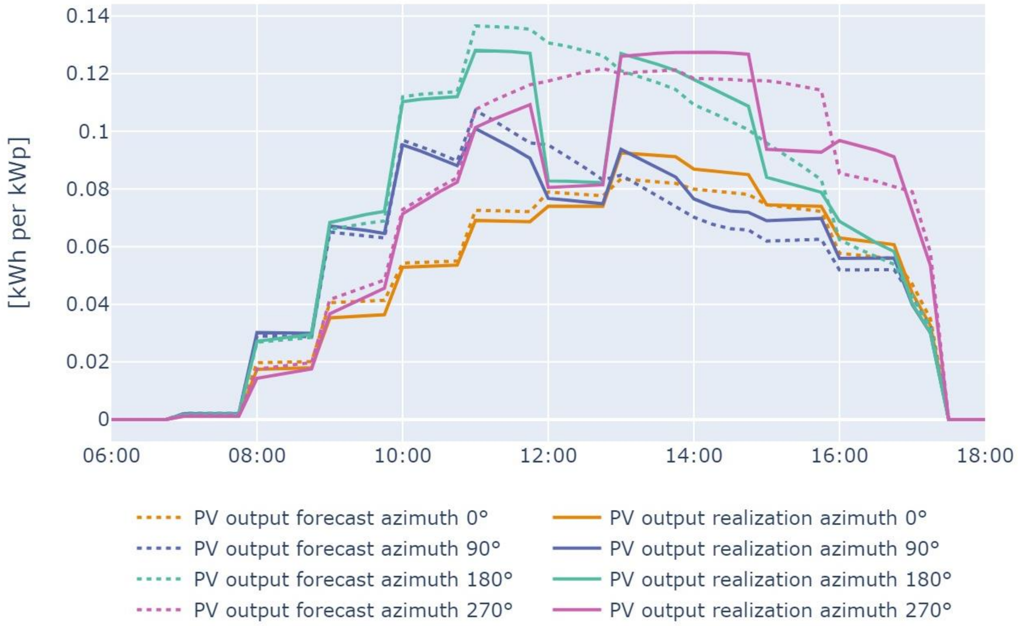
Durch MILP intendierte Effekte verwässern sich



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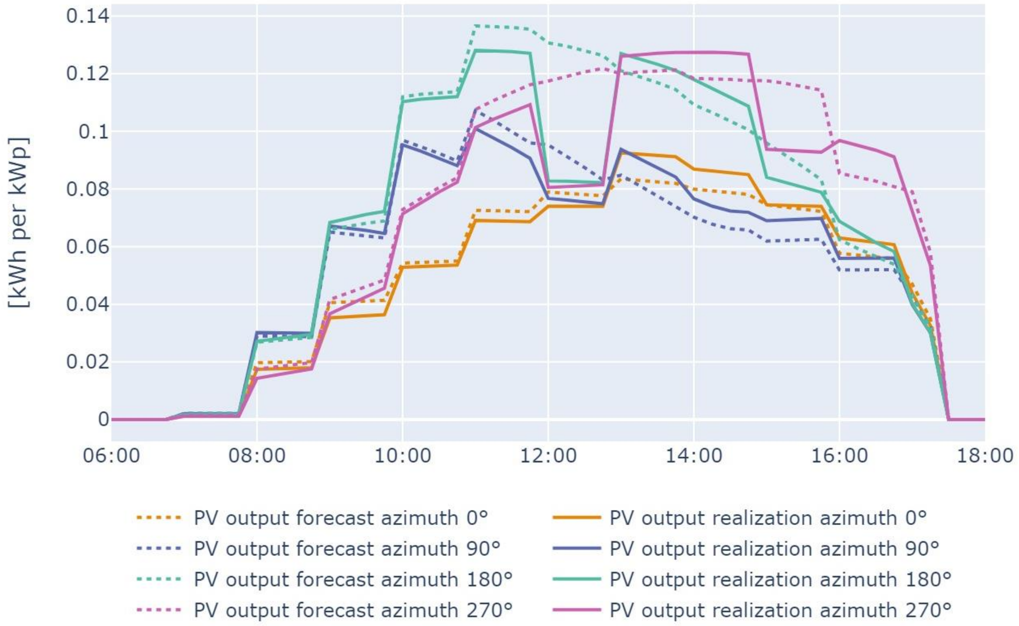
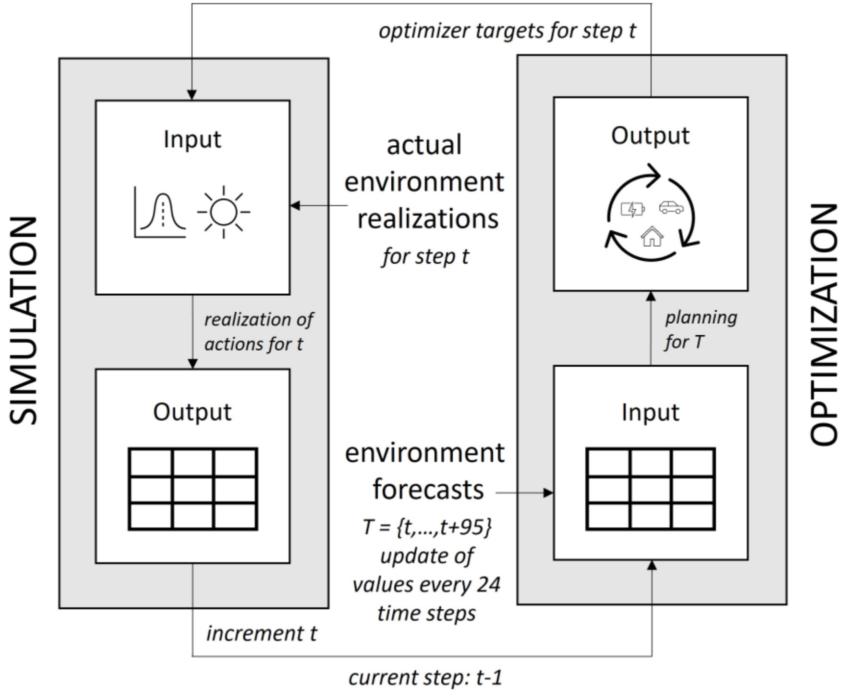


Ist vorhersagebasierte Optimierung eine effektive Steuerungsstrategie für EEGen?

Methodischer Ansatz

Energy Community Optimization-Simulation (ECOS) tool



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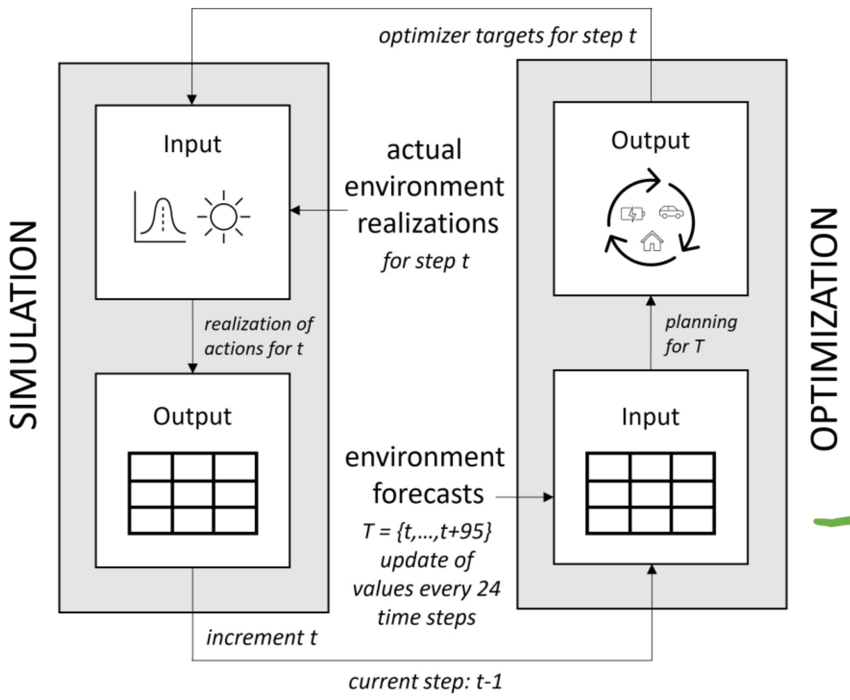

Optimierung eingebettet in Simulationsumgebung zur Performance-Evaluierung über längere Zeiträume

Methodischer Ansatz

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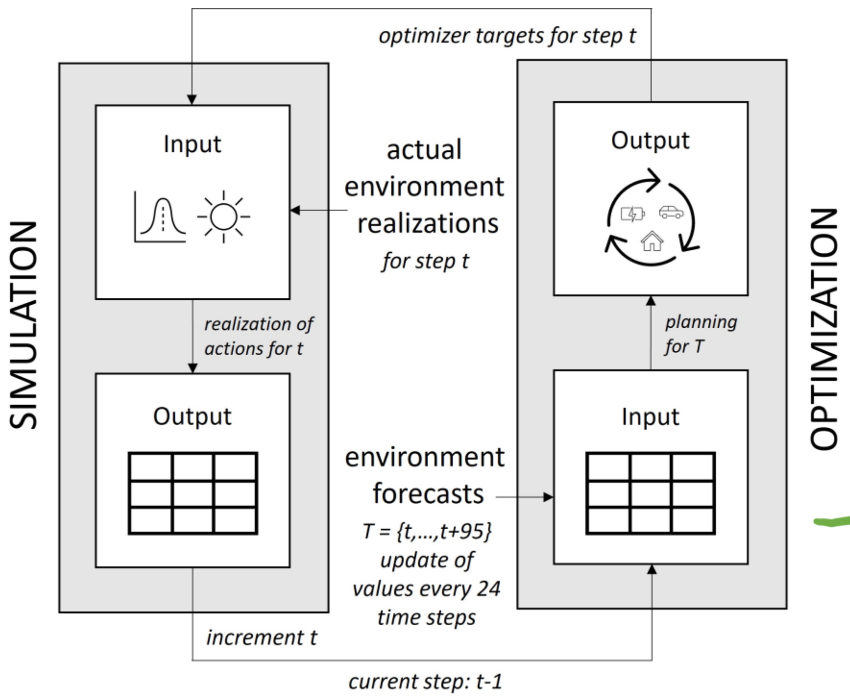


Optimierung eingebettet in Simulationsumgebung zur Performance-Evaluierung über längere Zeiträume

+ statischer regelbasierter Steuerungsansatz ohne Voraussicht als Benchmark

Methodischer Ansatz

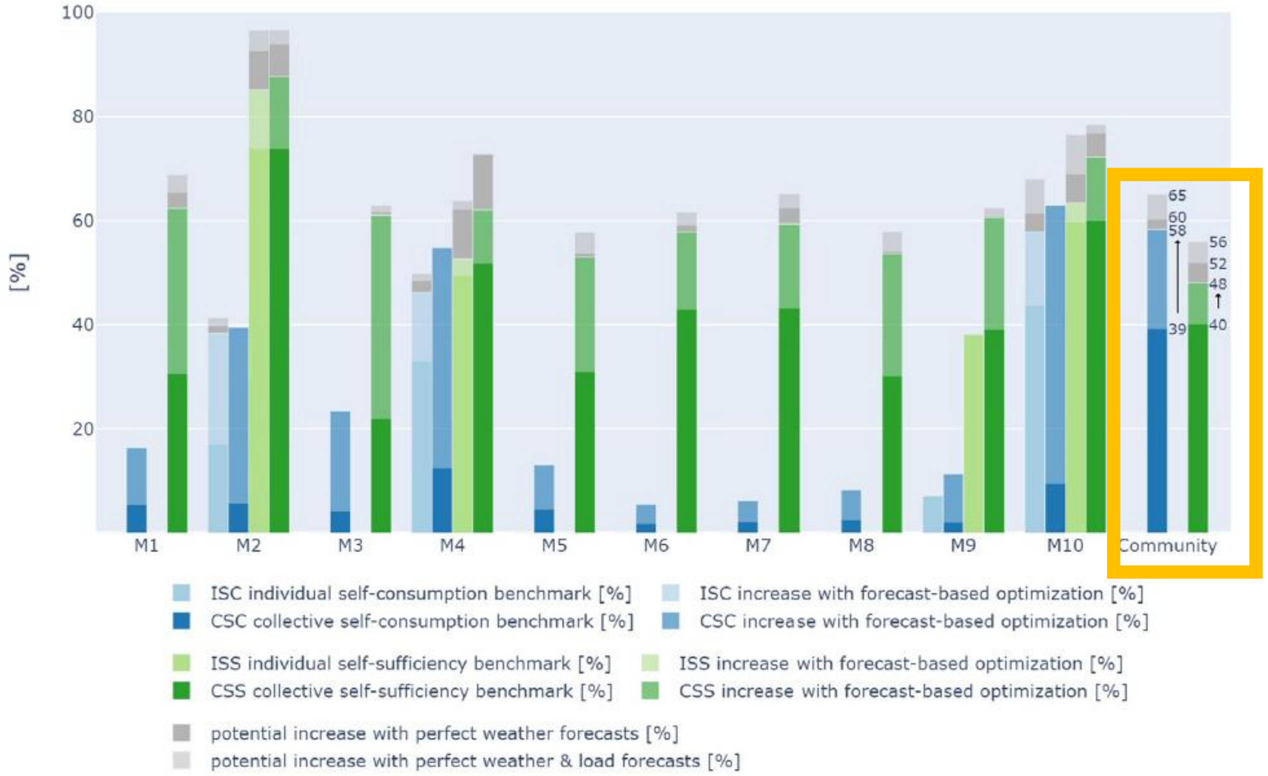
Table 5
Overview of community scenarios analyzed over a full assessment year.

community configuration		control strategy			
comm. abbr.	PSF[1] adoption level	default Static Rule	optimization with synthetic weather forecasts	optimization with perfect weather forecasts	optimization with perfect fixed-load & weather forecasts
REC-S0	average	REC-S0D	REC-S0S	REC-S0P	REC-S0PP
REC-S1	high	REC-S1D	REC-S1S	REC-S1P	REC-S1PP
REC-S2	average + CS[2]	REC-S2D	REC-S2S	REC-S2P	REC-S2PP
REC-L0	average	REC-L0D	REC-L0S	REC-L0P	REC-L0PP
REC-L1	high	REC-L1D	REC-L1S	REC-L1P	REC-L1PP
REC-L2	average + CS	REC-L2D	REC-L2S	REC-L2P	REC-L2PP

[1] Member-owned Production, Storage and Flexibility (PSF) resources such as PV panels, batteries, electric vehicles and shiftable loads.
[2] Community Storage (CS)

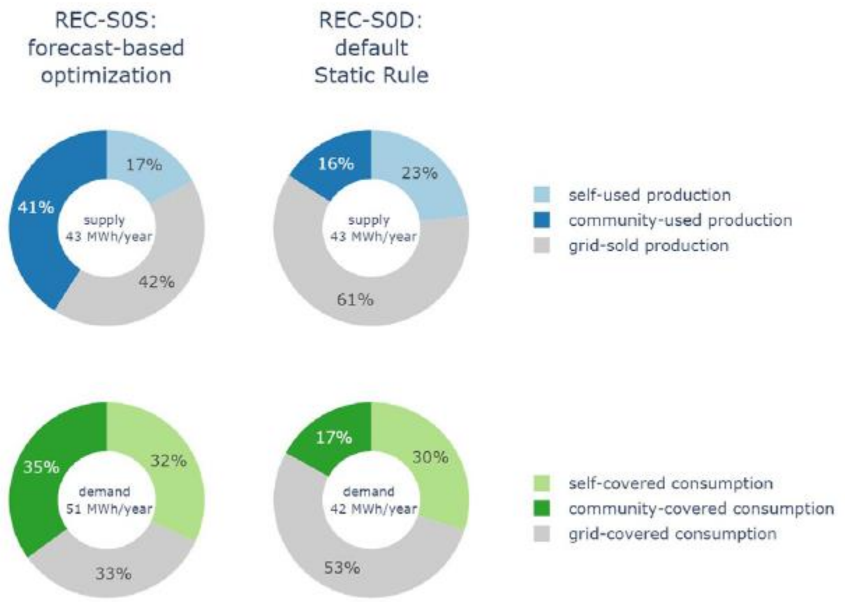
Ergebnisse

REC-S0: mittlere PSF Adoptionsrate



Eigenverbrauchsquote:
Erhöhung von 39 auf **58%**

Autarkiegrad:
Erhöhung von 40 auf **48%**



Take-Aways & Ausblick

1. vorhersagebasierte Optimierung ermöglicht eine deutliche Performance-Steigerung (trotz Prognosefehlern)
2. Planungstool für optimierte Konfiguration von Energiegemeinschaften
3. Verbrauchsdaten werden nacheilend in einer Auflösung von 15 Minuten benötigt

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Reale Umsetzung und Vergleich verschiedener Regelungsstrategien in Energiegemeinschaften im Forschungsprojekt Flex‘n EnErGie ab 11/2025

Fragen

Dr. Nathalie Frieß
Research Associate | Projektleitung

E-Mail schreiben
0316/811848-30

- Modellierung und Optimierung von Energiesystemen
- Angewandte Forschung
- Projektentwicklung und Projektabwicklung

Grazer ENERGIEAgentur

Backup

Methodischer Ansatz

Table A3
Configuration of REC–S0 community.

member	type	PV system		feed-in limit	battery storage[a]	electric vehicle[b]		building type[c]	heat pump	DHW storage[d]	buffer storage[e]	flexible loads[f]
		[kWp]	[° azimuth]	[kW]	[kWh]	type	[kWh]		[kW]	[liter]	[liter]	device
CHR01	couple	0	0	0	0	none	0	none	0	100 (B)	0	DW + WM
CHR02	couple	12	180	10	10	none	0	none	0	0	0	DW + WM
CHR03	family	0	0	0	0	none	0	B1A	5	150 (HP)	0	none
CHR04	couple	15	135	12	0	VA1.1	50	B2E	6	100 (HP)	400	none
CHR05	family	0	0	0	0	none	0	none	0	0	0	none
CHR06	single	0	0	0	0	none	0	none	0	0	0	none
CHR07	single	0	0	0	0	none	0	none	0	0	0	DW + WM
CHR08	single	0	0	0	0	none	0	none	0	0	0	none
CHR09	single	10	225	10	0	none	0	none	0	0	0	none
CHR10	single	8	180	100	10	none	0	none	0	0	0	none
SUM		45			20		50		11	350	400	

[a] See Table A5 for more details.
[b] See Table A7 for more details.
[c] See Table A8 for more details.
[d] (HP) represents a heat pump operated DHW storage, (B) a time-shiftable electric water boiler. See Table A6 for details.
[e] See Table A6 for more details.
[f] Different profiles for dishwashers (DW) and washing machines (WM) have been used, see Fig. A4 for examples.

Methodischer Ansatz

Table A4
Configuration of REC–S1 community.

member	type	PV system		feed-in limit	battery storage	electric vehicle[a]		building type[b]	heat pump	DHW storage[c]	buffer storage	flexible loads[d]
		[kWp]	[° azimuth]	kW	[kWh]	type	[kWh]		[kW]	[liter]	[liter]	device
CHR01	couple	12	270	10	0	VC1.1	100	none	0	100 (B)	0	DW + WM
CHR02	couple	12	180	10	10	VB1.1	75	none	0	100 (B)	0	DW + WM
CHR03	family	18	135	15	20	none	0	B1A	5	150 (HP)	0	DW + WM
CHR04	couple	15	135	12	10	VA1.1	50	B2E	6	100 (HP)	400	none
CHR05	family	15	180	15	0	none	0	B3U	4	150 (HP)	400	DW + WM
CHR06	single	0	0	0	0	none	0	none	0	75 (B)	0	none
CHR07	single	0	0	0	0	none	0	none	0	0	0	DW + WM
CHR08	single	0	0	0	0	none	0	B3A	4	150 (HP)	0	DW + WM
CHR09	single	10	225	10	10	none	0	none	0	0	0	none
CHR10	single	8	180	100	10	VB1.2	75	B1U	6	100 (HP)	0	none
SUM		90			60		300		25	925	800	

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