Tackling Climate Change with Machine Learning Workshop at ICML 2021

A Reinforcement Learning Approach to Home Energy Management for Modulating Heat Pumps and Photovoltaic Systems

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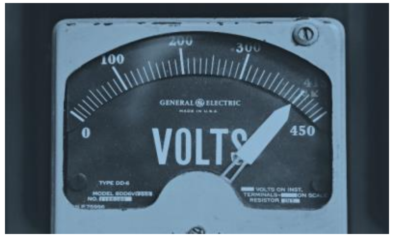
Motivation

Climate Change

European Union:
- At least 55% CO_2 reduction by 2030
- Carbon neutrality by 2050

Renewable Energy Sources

Germany:
- 19% of final consumption in 2020
- 45% of electricity consumption in 2020



Demand Response

Opportunities:
- Frequency/voltage regulation
- Self-consumption of local renewable generation
- Benefits from dynamic prices

Smart Homes

Buildings globally:
- 30% of energy consumption
- 28% of CO_2 emissions

Sector coupling critical:
- Heating: 65%
- Hot water: 14%

of energy consumption

Flexibility:
demand and supply adjustments via PV, heat pumps, and storage technologies

Umweltbundesamt (2021), Dengiz et al. (2019), Kazmi et al. (2019) pics: unsplash.com + https://www.extremetech.com, eurostat 2016

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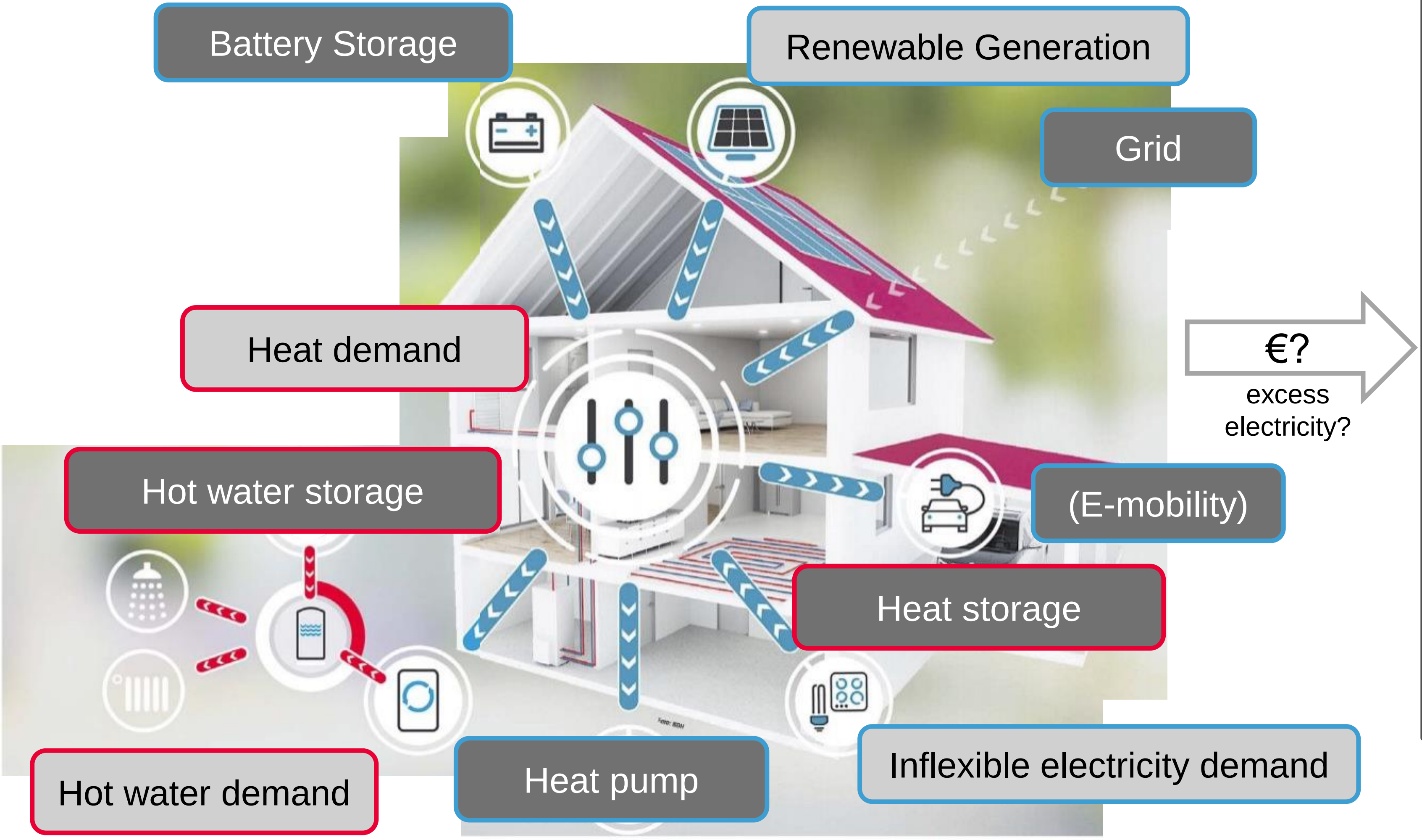
Smart Home - Energy Management System (SHEMS)



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Smart Home Owner

Overall prices in Germany:

- Electricity: ~0.30 €/kWh
- Grid feed-in: max. 0.10 €/kWh and continuously decreasing

Objectives:

- Maximize self-sufficiency
- Stay within comfort bounds
- Make some extra profit selling excess electricity (need better incentives to do that system beneficially)

Decision Variables

Exogenous Factors

Image: VDI Nachrichten

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Some advertisement for more background…

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An optimal home energy management system for modulating heat pumps and photovoltaic systems

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Publication: https://doi.org/10.1016/j.apenergy.2020.115661
Arxiv: https://arxiv.org/pdf/2009.02349.pdf
Code: https://github.com/lilanger/SHEMS

Initial publication:
- Detailed description of building model and input data
- Model Predictive Control (MPC) model formulation
- Rolling Horizon implementation
- Derivation of demand fulfillment priorities

energies
MDPI

Article

An Optimal Peer-to-Peer Market Considering Modulating Heat Pumps and Photovoltaic Systems under the German Levy Regime

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Publication: https://doi.org/10.3390/en13205348
Code: https://github.com/lilanger/PEERS

Extension:
- Model Predictive Control (MPC) model formulation
- Small peer-to-peer network implementation
- Detailed German levy regime (taxes, surcharges,…) implementation

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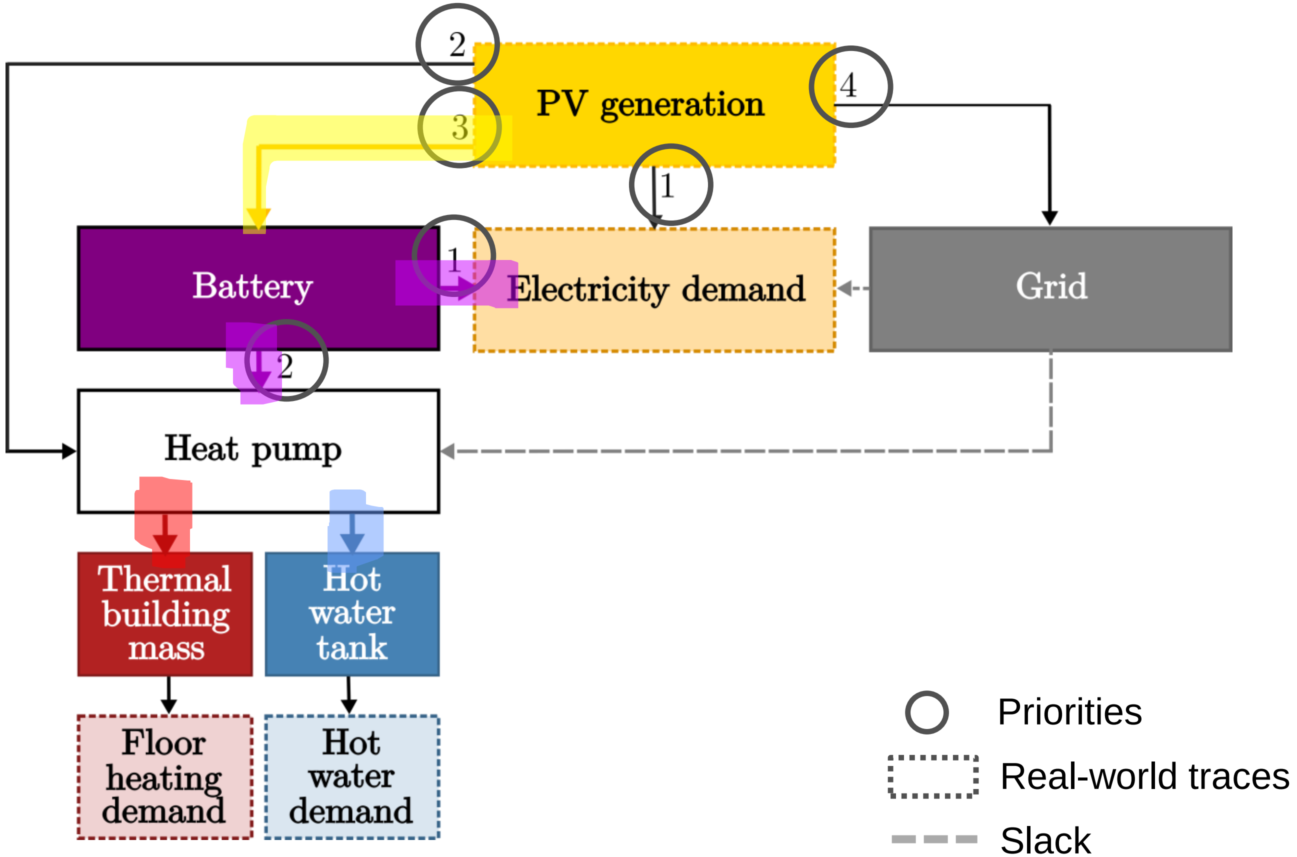
Reinforcement Learning implementation



Uncertainties:

- Exogenous demand and generation implemented via real world traces

Setup:

- State space: $[SOC_b, SOC_{fh}, SOC_{hw}, d_e, d_{fh}, d_{hw}, g_e, t_{out}, h]$ (exogenous: $d_e, d_{fh}, d_{hw}, g_e, t_{out}, h$)
- Fulfillment priorities from MPC results
  - Results in much smaller action space (2 instead of 10 dimensions)
- Slack variables cover mismatches

Actions (continuous):

- Battery: Discharging + Charging = [-1, +1]
- Heat Pump: Hot water + Floor heating = [-1, +1]

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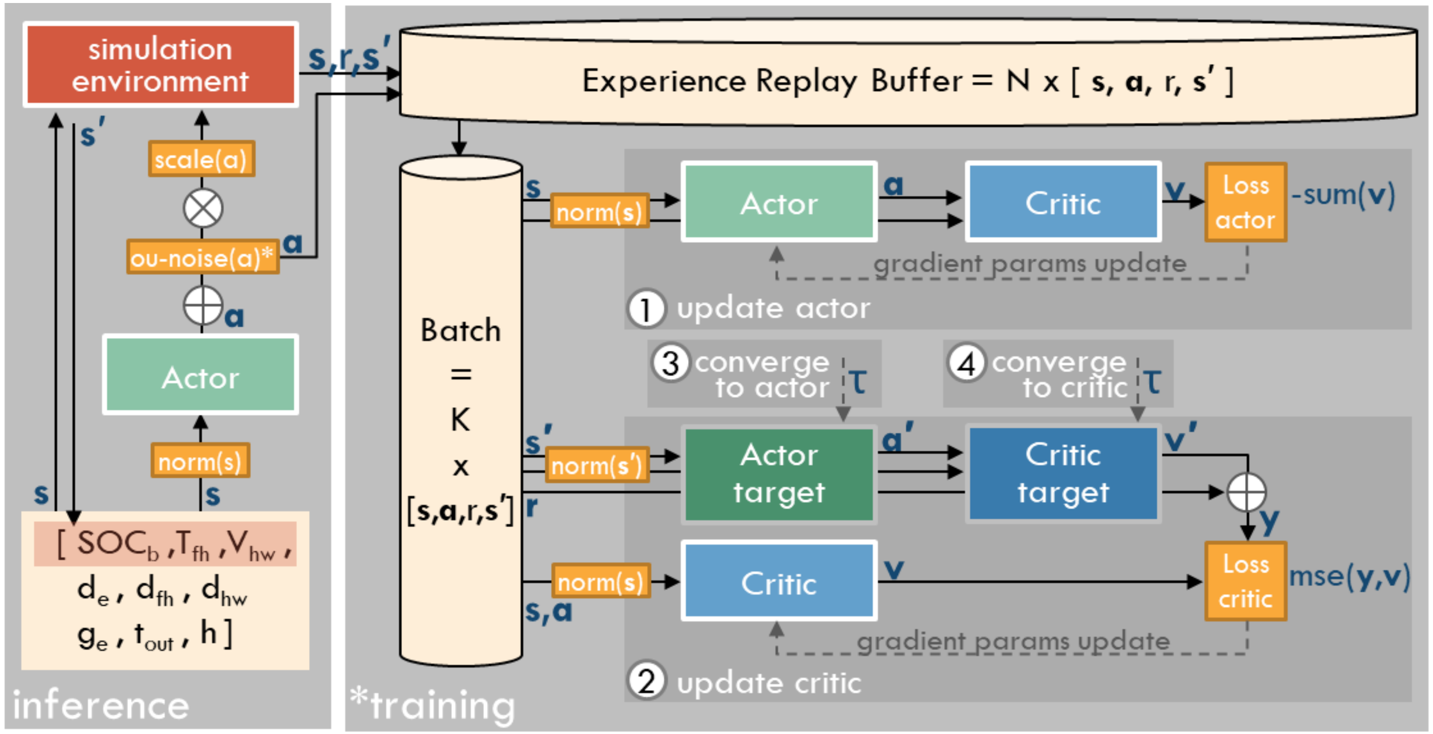
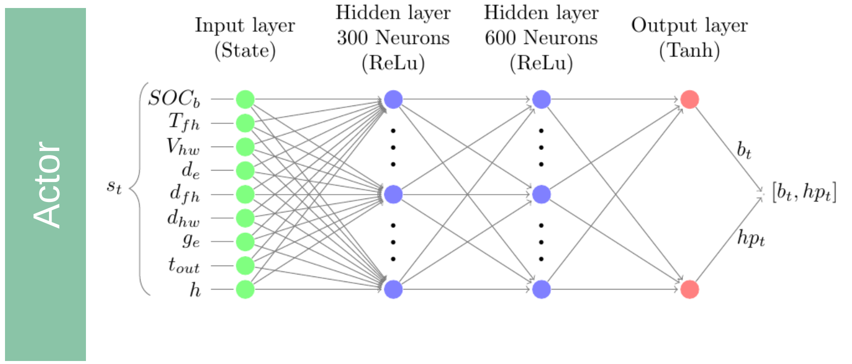
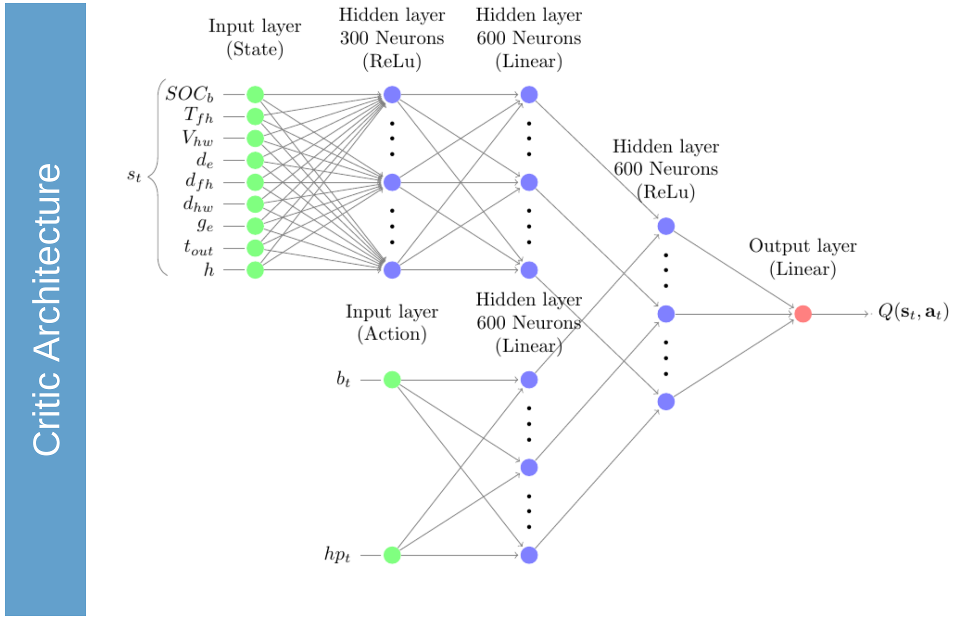
DDPG SHEMS workflow and networks



Workflow of the DDPG algorithm applied in SHEMS.





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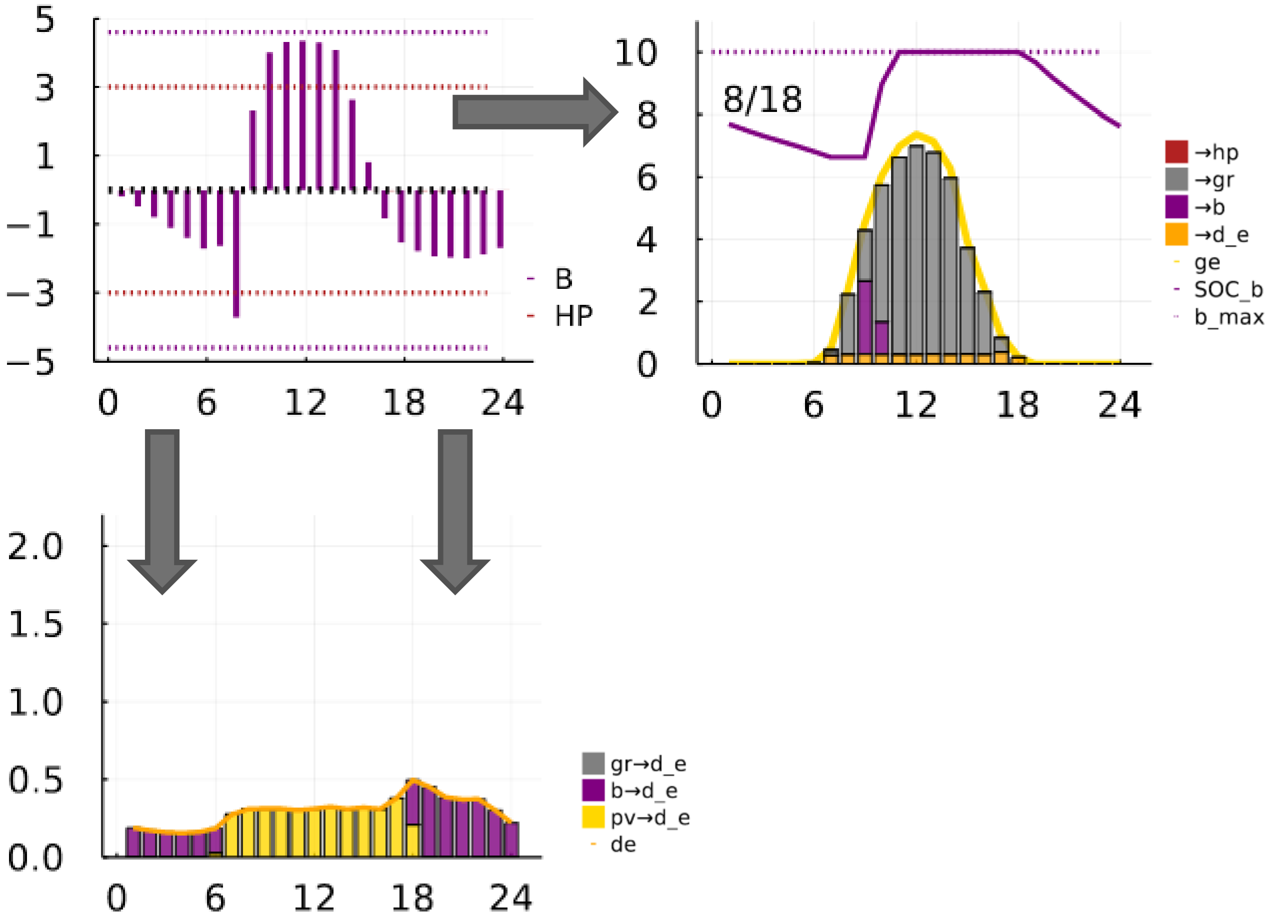
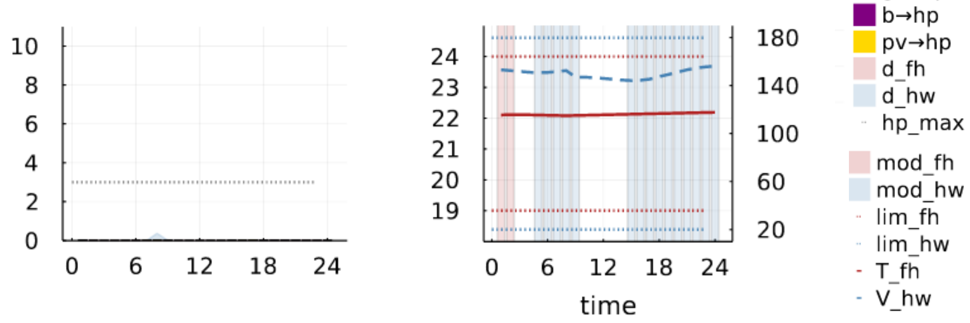
Some preliminary results…



On a day in summer…

With low hot water demand



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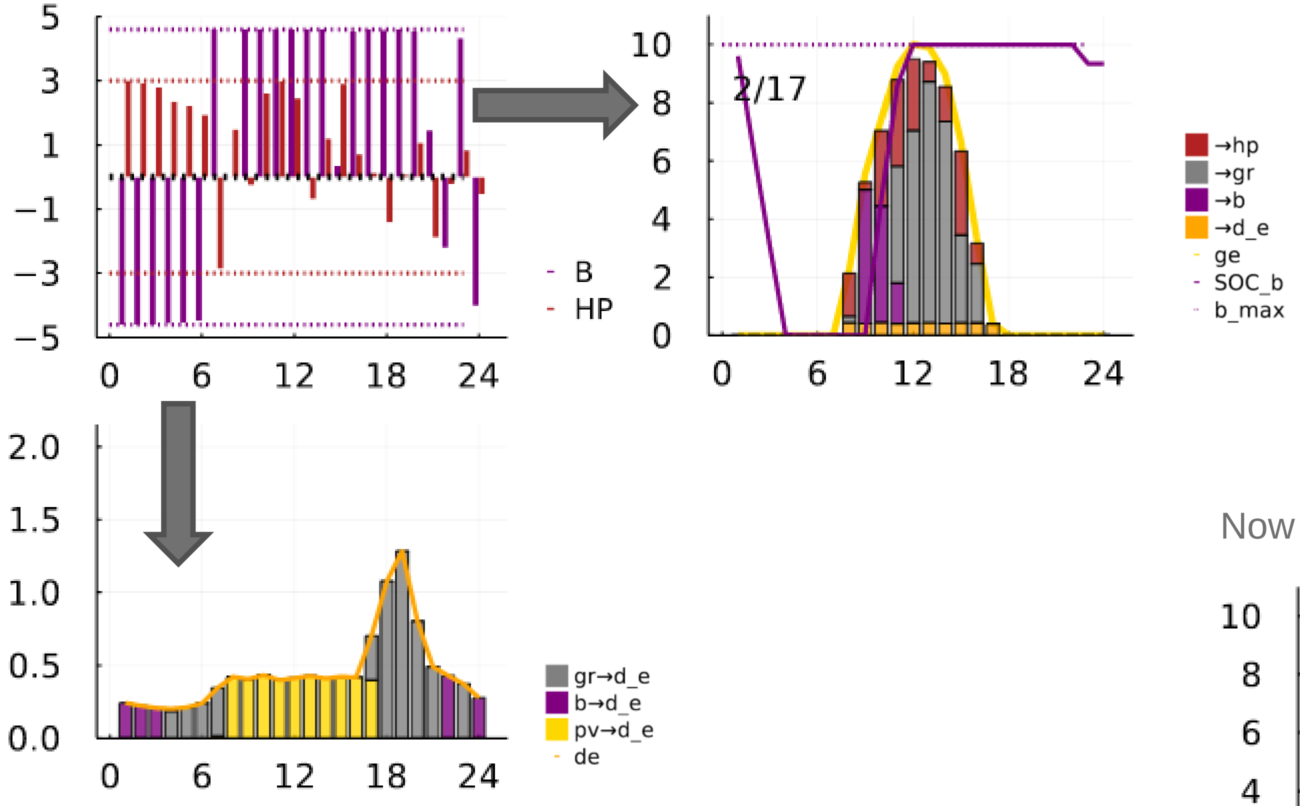
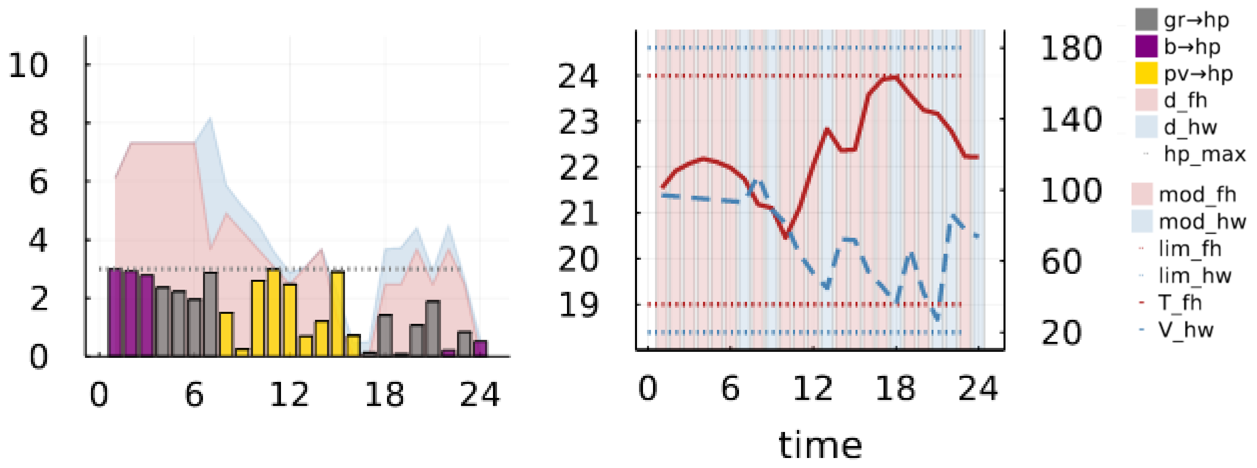
Some preliminary results…



On a day in winter…

Now with higher heating and hot water demand



Conclusions

- Still some finetuning to be done
- KPIs are not that informative at some point, digging deep into the actions more helpful
- One can easily get lost in hyperparameter tuning
- Tuning the simulation environment is key, expert knowledge and common sense is essential
- Simple rules can be quite tough benchmarks to beat!

		Optimum	Rule – Always charge with 70% SOC	DDPG
Electricity costs	Summer Test	141€	129€	**130€**
	Winter Test	-102€	**-153€**	-157€
Self-sufficiency	Summer Test	100%	**99%**	97%
	Winter Test	65%	**46%**	44%

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