Comparing model predictive control and reinforcement learning for the optimal operation of building-PV-battery systems

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IAQVEC 2023

Indoor Air Quality Ventilation and Energy Conservation

Optimal control for microgrid operations

- Microgrids: energy consumers (buildings), distributed energy generation (renewable), energy storage
  - Potential of carbon reduction, cost saving, etc.
  - Schedule-based rules: unsatisfactory performance (uncertain boundary conditions)
  - Optimized energy management needed

- Control strategies
  - Model predictive control (MPC): dependent on model reliability, unscalable
  - Reinforcement learning (RL): long period of training, uninterpretable
  - Pros and cons are theoretical and general

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Phase I (Warm Up Round): Completed | Phase II: Completed | Phase III: Completed

NeurIPS 2022

CityLearn Challenge

Using AI For Building's Energy Management

15,000 USD Cash Prizes + 3 Travel Grants

Co-authorship in Competition Solutions Paper

By Intelligent Environments Lab & AIcrowd

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- NeurIPS 2022: CityLearn Challenge Starter Kit
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Introduction

Buildings are responsible for 30% of greenhouse gas emissions. At the same time, **buildings are taking a more active role in the power system** by providing benefits to the electrical grid. As such, buildings are an unexplored opportunity to address climate change. Energy storage devices such as home **batteries** can reduce peak loads of the grid by shifting the energy use of buildings to different times. **Solar photovoltaic** generation can reduce the overall demand to the grid while also

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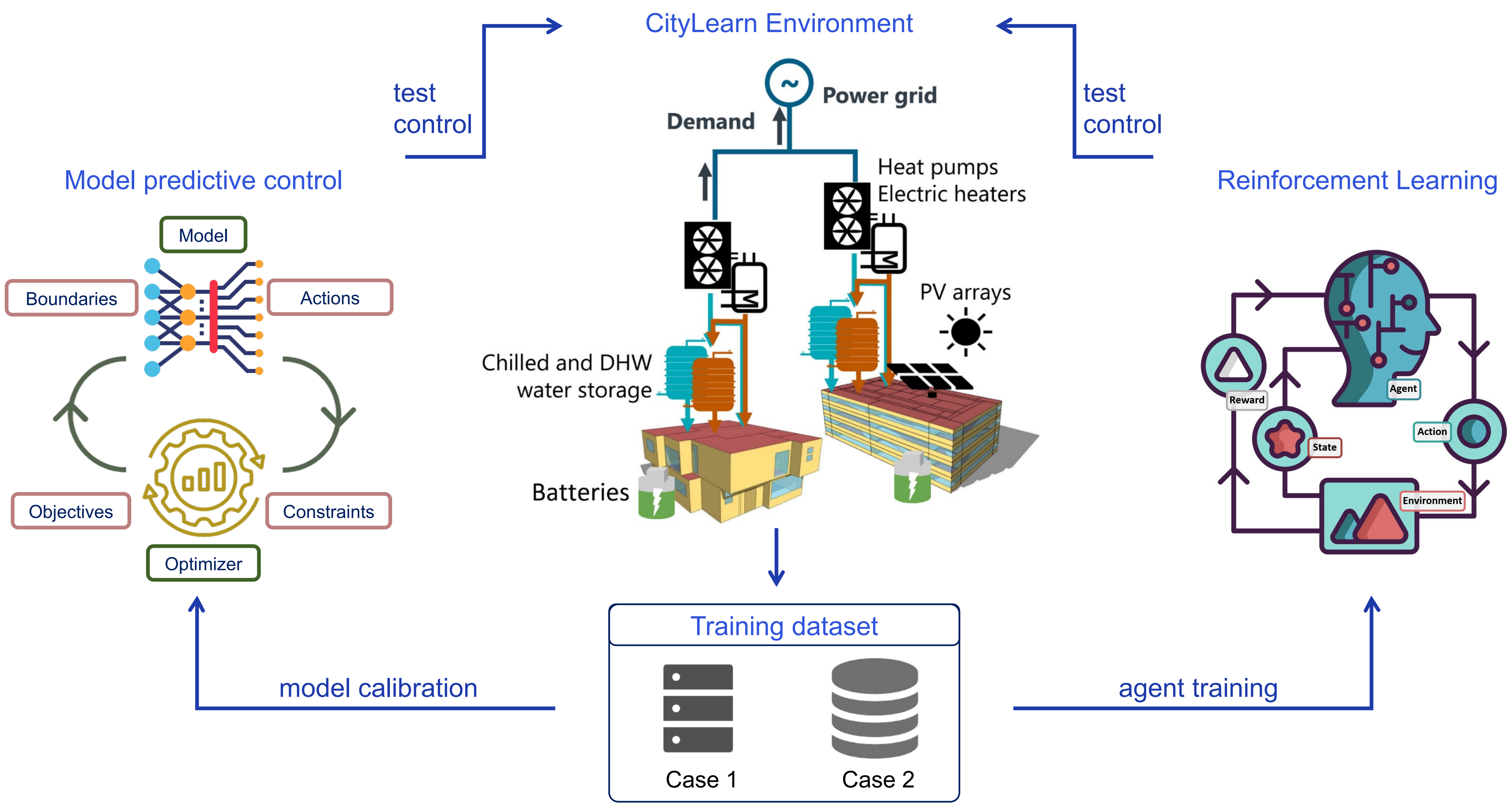
9 Going below 1.0 score with stablebaseline3 4


CityLearn Environment
test
control
test
control
Power grid
Demand
Heat pumps
Electric heaters
PV arrays
Chilled and DHW
water storage
Batteries
Model predictive control
Model
Boundaries
Actions
Objectives
Constraints
Optimizer
Reinforcement Learning
Agent
Reward
Action
State
Environment
Training dataset
Case 1
Case 2
model calibration
agent training

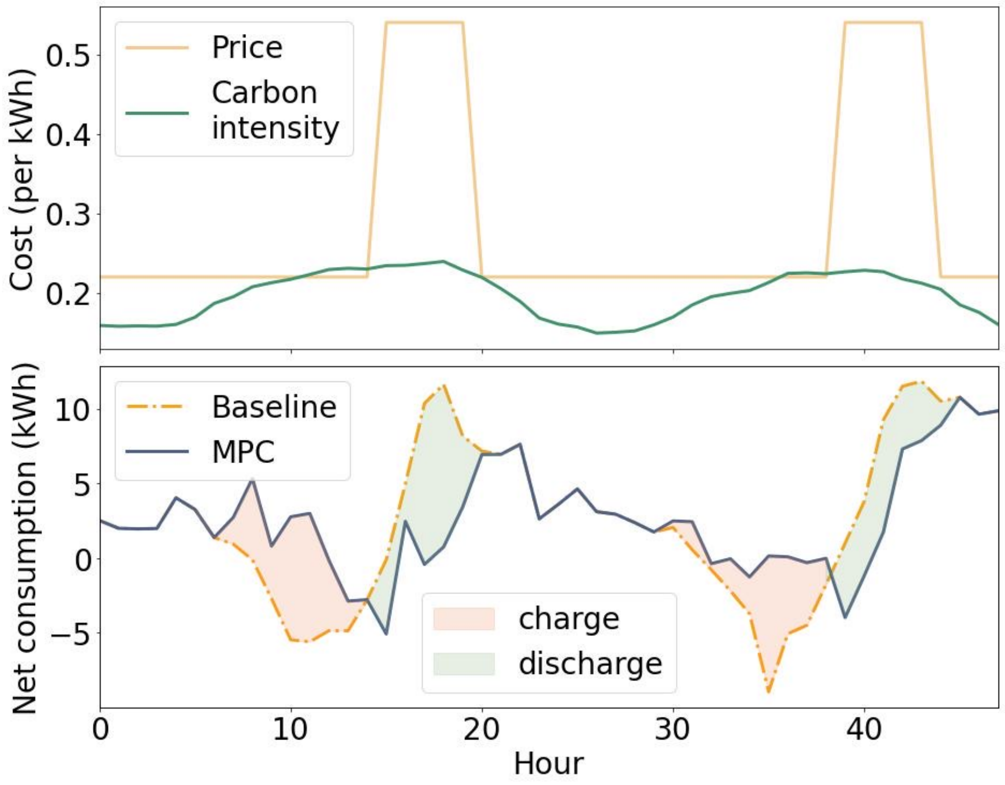
Design of experiments

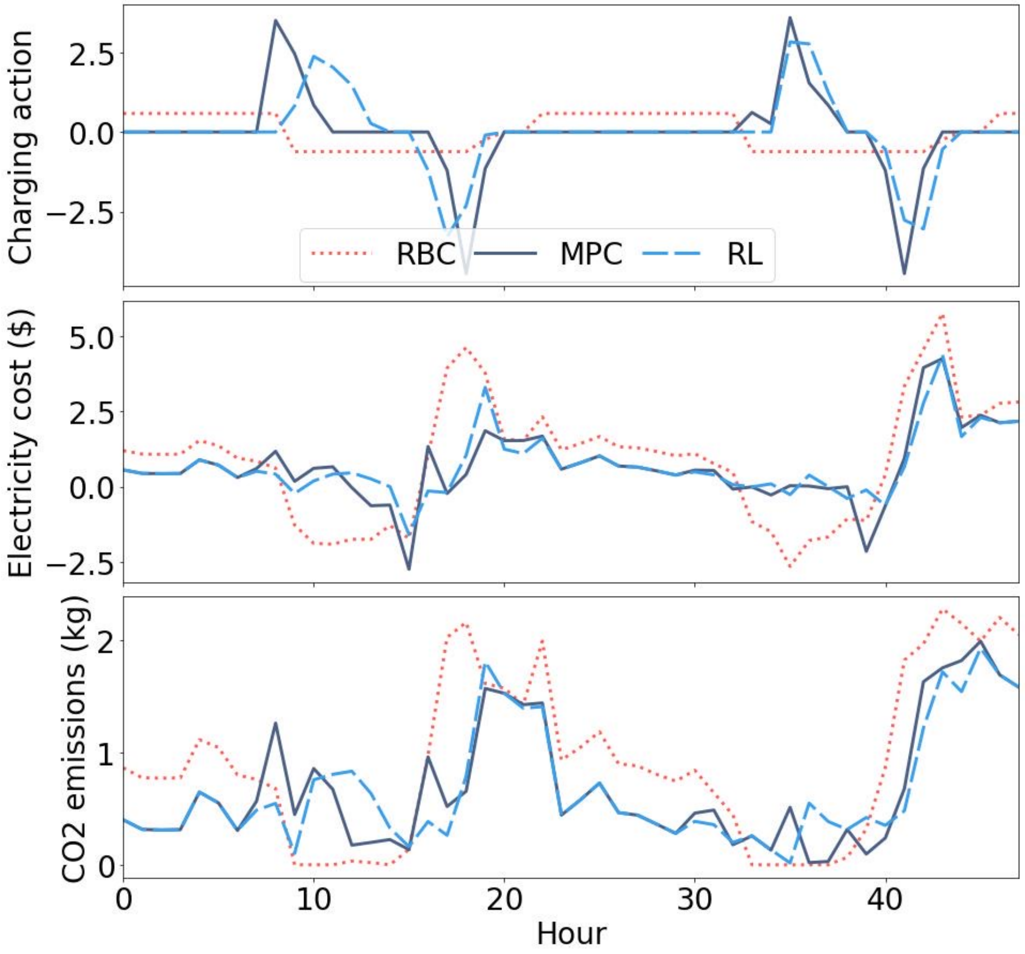
	Case 1 (CA)	Case 2 (IL)
Buildings	5 different single-family houses	9 with different types
Batteries	All buildings have, different capacity and nominal power	
PV	All have	Only 4 have
Training data	1 year	1 year
Testing condition	Training data	Unseen 3 years

Charging decision in the coming 12 hours to minimize energy cost and carbon emissions

- MPC: energy models based on metadata, LSTM forecast, Powell's method for optimization
- RL: MARLISA, soft actor-critic (SAC) agents

Case I

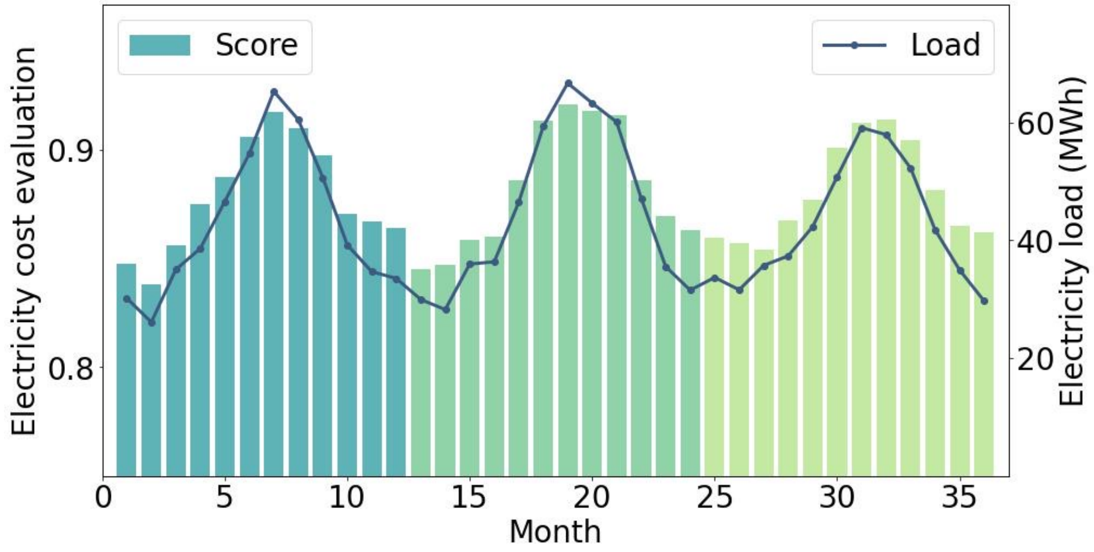


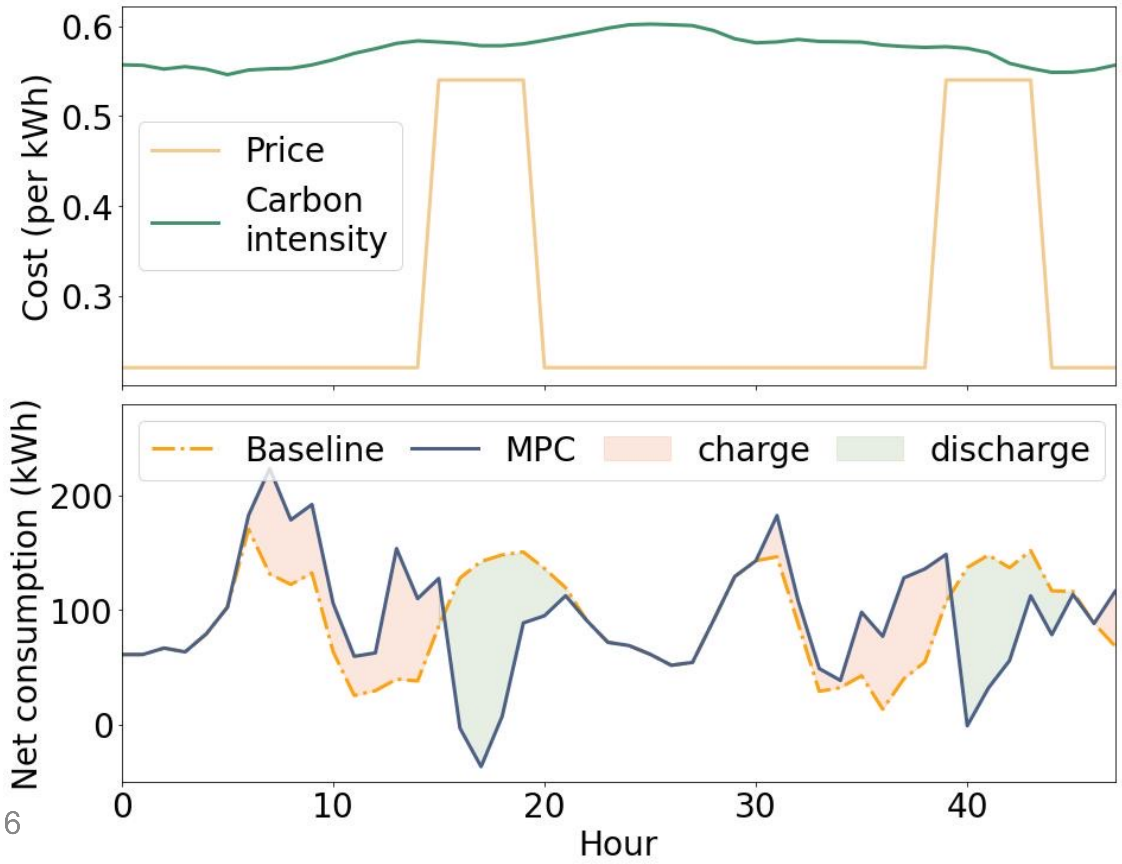


Metrics	RBC	MPC	RL
Electricity cost	1.033	0.652	0.678
CO_2 emissions	1.156	0.842	0.834

Case II - MPC

- Adjust objective weighting based on training data
- Update energy models based on metadata
- LSTM models for solar and building loads



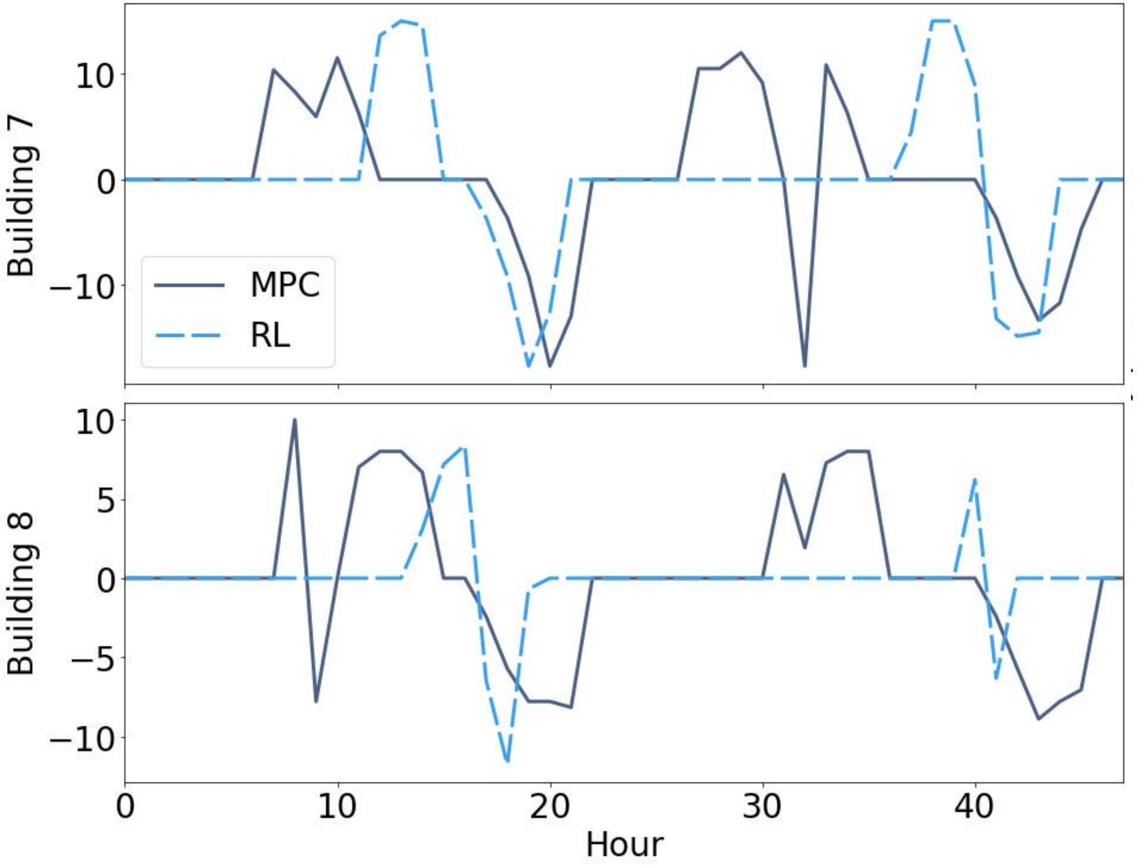


- Evaluation: 0.887 for electricity cost and 1.009 for CO_2 emissions (irregular short-term carbon intensity)
- Absolute saving decided by the PV/battery capacities, larger load (denominator) yielded smaller percentage

Case II - RL

- Adjust reward weighting based on training data
- Hyperparameter tuning by trial-and-error

	Runtime (Hr)		Performance	
	Y1	Y2-4	Y1	Y2-4
MPC	2	7	0.855	0.887
RL	15	1	0.933	0.949



- Longer training but faster decision
- Sub-optimal control performance
- Batteries not fully charged given smaller state values
- Further engineering effort required to exploit the potential

Summary

Different factors jointly affect the control performance

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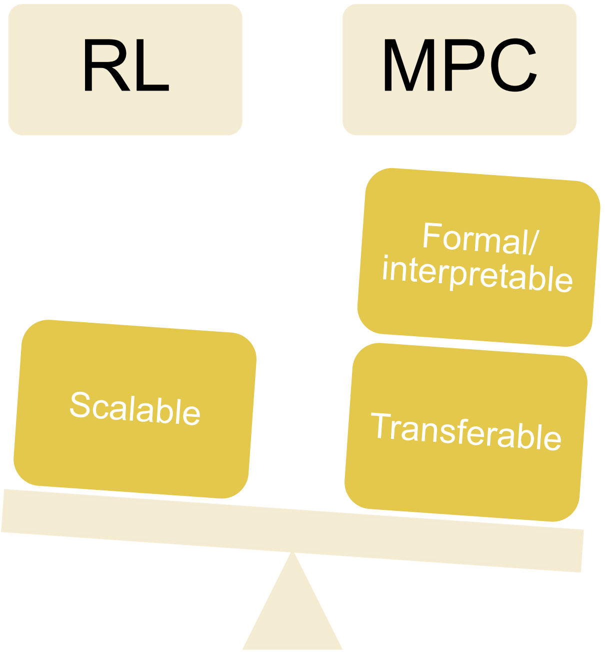
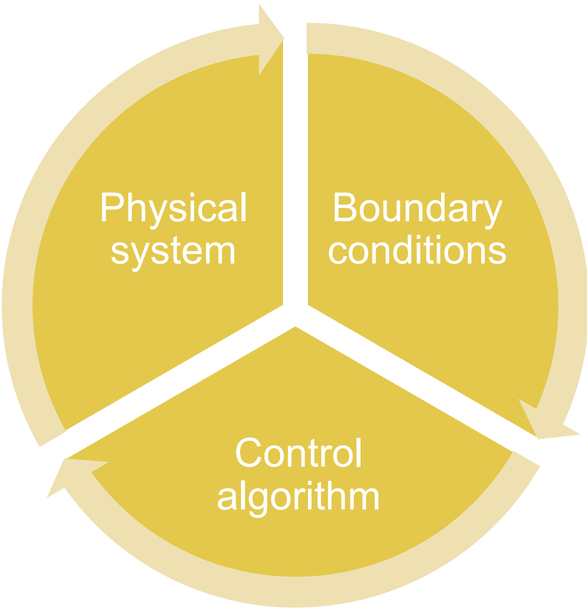
The need of standardized benchmark





- Lower data and modeling requirements for both in grid-scale applications
- MPC more suitable in most practical settings

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