Occupant-Centric Grid-Interactive Buildings

1. Introduction & Overview

CE397

Spring 2024

Prof. Dr. Zoltan Nagy

The Plan for Today

- Me
- You
- Course Introduction
  - Motivation
  - Syllabus
  - Ground rules
- Example project
- Questions

Instructor

- Prof. Dr. Zoltan Nagy

  ECJ 5.436

  e-mail: nagy@utexas.edu

  web: nagy.caee.utexas.edu

- Class times: W 9–12

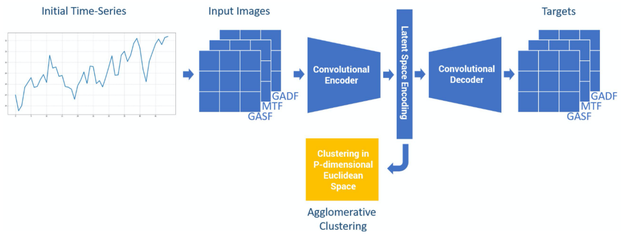
- Office hours
  By appointment

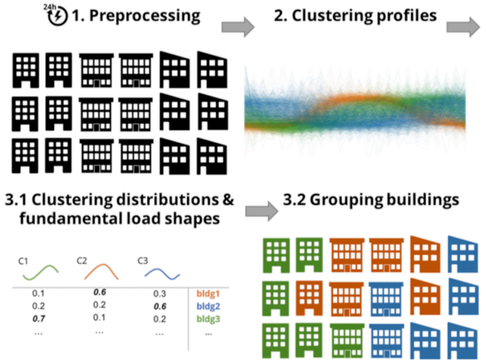
What about You?

- Who are you?
  - Grad/Undergrad
  - Speciality
- Why are you here?
  - What are you excited about?
  - What are your expectations?
  - What are your concerns?

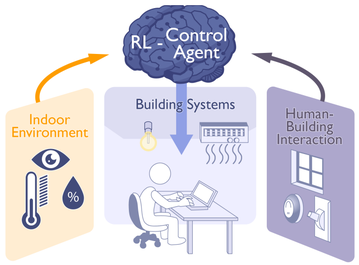
Research @ Intelligent Environments Lab

Unsupervised Learning

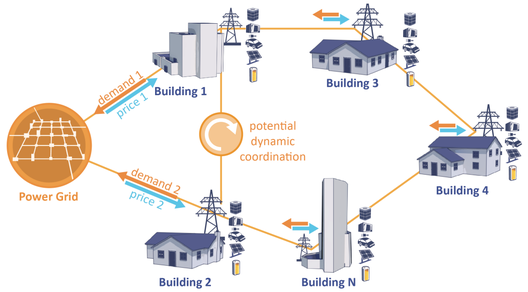




Reinforcement Learning



Green Electronics Council Award Finalist 2018



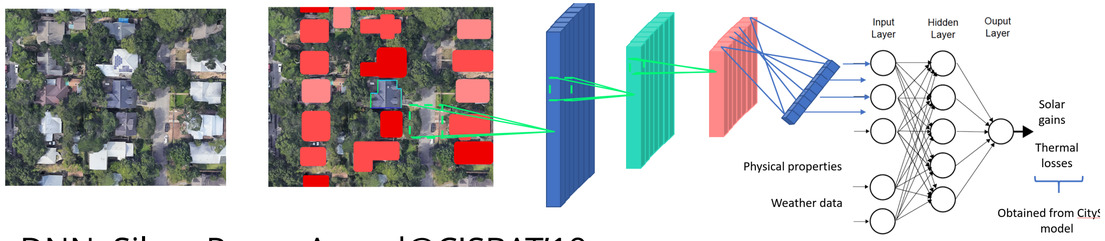
Editor's Choice (Applied Energy)

Highly Cited Paper Award (Applied Energy)

THE CITYLEARN CHALLENGE
MULTI-AGENT REINFORCEMENT LEARNING FOR INTELLIGENT ENERGY MANAGEMENT

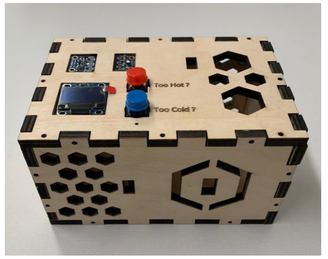
www.citylearn.net

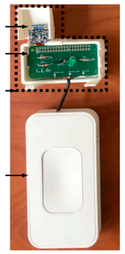
Supervised Learning

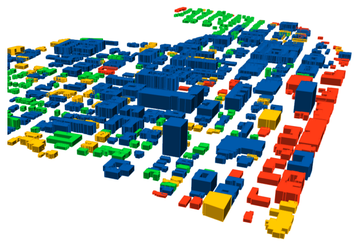


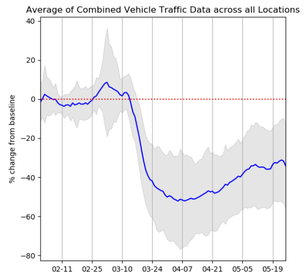
CityDNN: Silver Paper Award@CISBAT'19

IoT, Analytics & Systems Integration









What you will learn

1. **Understand** the and **describe** the most common machine learning algorithms
2. **Understand** and **model** the impact of occupants on building energy use
3. **Simulate** grid-interactive buildings
4. **Use** Python for data analysis applications

What I am NOT covering:

- Detailed mathematical proofs and derivations of the algorithms

Notes

- Open door policy & Office hours: Use them!
- Suggestion are welcome
  - Tell me what you like
  - Tell me what you don’t like

Course Overview

- Communication via Canvas -> Overview
- Lectures streamed & recorded via **zoom**
- Lecture notes & files on **GitHub**
- Assignment/Quiz submission on Canvas

Hands-On Programming Course

- Machine learning and data analysis are a form of art that need to be mastered through doing it.
- Therefore, a large part of this course will focus on hands-on programming
- We will review Python programming basics first, and as the course evolves, we will move towards more free programming and application.

GPT-TA for programming and course

- Developed a GPT-TA trained on lecture notes and homework to act as your virtual TA
- https://chat.openai.com/g/g-OFAttq2Or-gpta
- Use it to ask questions about lectures, and programming tasks, and project.
- Report on its use (anonymously) on Canvas as weekly Quiz (required)
- We will need a name - make suggestions & vote !

Guest Lectures

- By industry experts, so far seven confirmed
- Typically 10.30-11.30
- Via zoom (different zoom link that class!)
- Lecture series advertised publicly as webinar

Project

- Final project related to applied grid-interactive buildings
- **Goal**: Use CityLearn to model and train residential home to reduce energy use, maintain comfort and resist power outages
- More details as we progress.
- Undergrads: work in groups of 2
- Grads: work alone
- Project replaces the final exam

Tentative Course Outline / Schedule

Week	Class	Topic	Guest Lecture
1	01/17	Introduction / Overview / Python	
2	01/24	Machine Learning I	
3	01/31	Machine Learning II	
4	02/07	Machine Learning III	Justin Hill (Southern)
5	02/14	Occupant Behavior Modeling	
6	02/21	Occupant Behavior Modeling	Tanya Barham (CEL)
7	02/28	Occupant Behavior Modeling	Jessica Granderson (LBNL)
8	03/06	Occupant Behavior Modeling	Hussain Kazmi (KU Leuven)
9	03/13	Spring Break	
10	03/20	Advanced Control & Calibration	Ankush Chakrabarty (MERL)
11	04/27	Calibration	Donghun Kim (LBNL)
12	04/03	Introduction to CityLearn	
13	04/10	Project Work	Siva Sankaranarayanan (EPRI)
14	04/17	Project work	
15	04/24	Project work	

Midterm Exam (take home)

- Midterm exam as take home
  - Hand out: 3/20 (after spring break)
  - Return: 3/27
- Covers the first two modules (Programming/ML & occupant behavior)

Grading

Homework assignments		30%
Project		30%
Mid-term exam		30%
Participation / Quiz / In-class Activity		10%

75%

of all US electricity
is consumed within
buildings

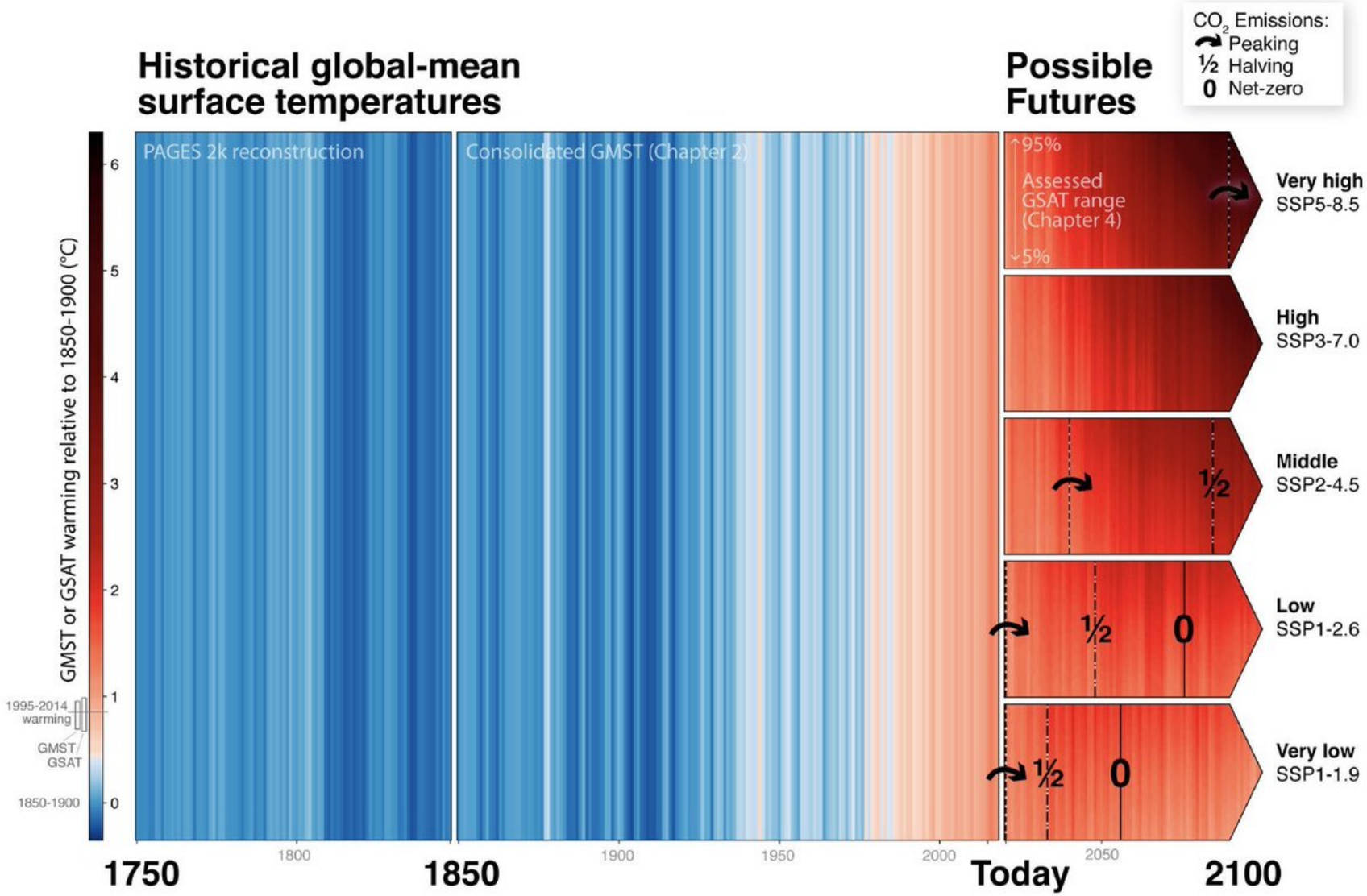
US Energy Information
Administration, 2018

30%

of US greenhouse gas emissions stem from **buildings**

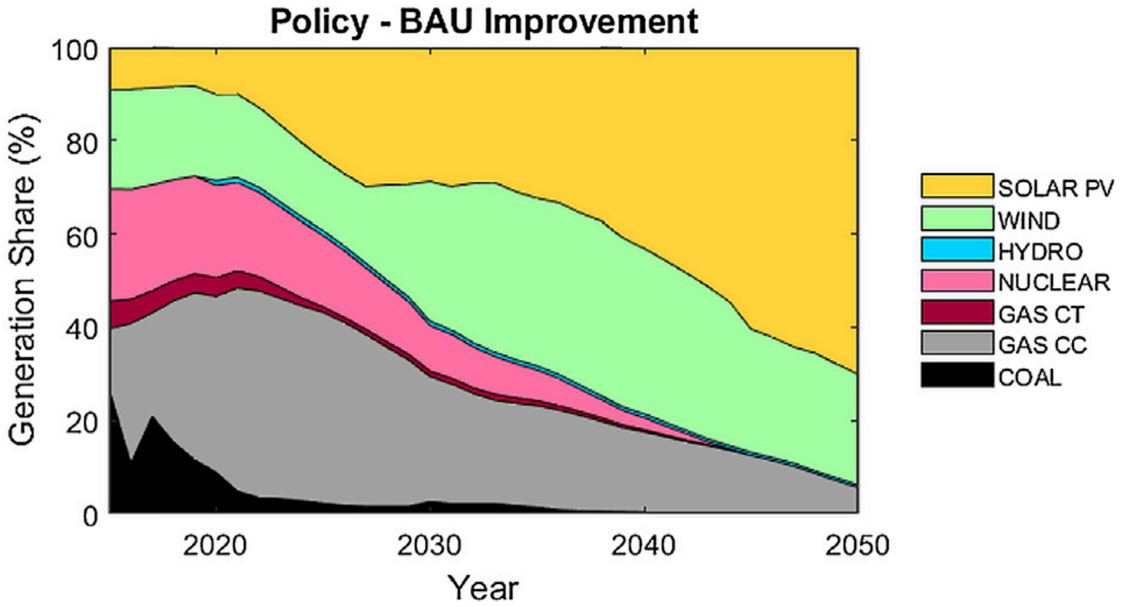
mostly for **heating** and **cooling**

u/Restaurantmenu2



IPCC, AR6, 2021

Emission reductions through electrifying of end use while decarbonizing the grid



Leibowicz et al, *Applied Energy, 2018*

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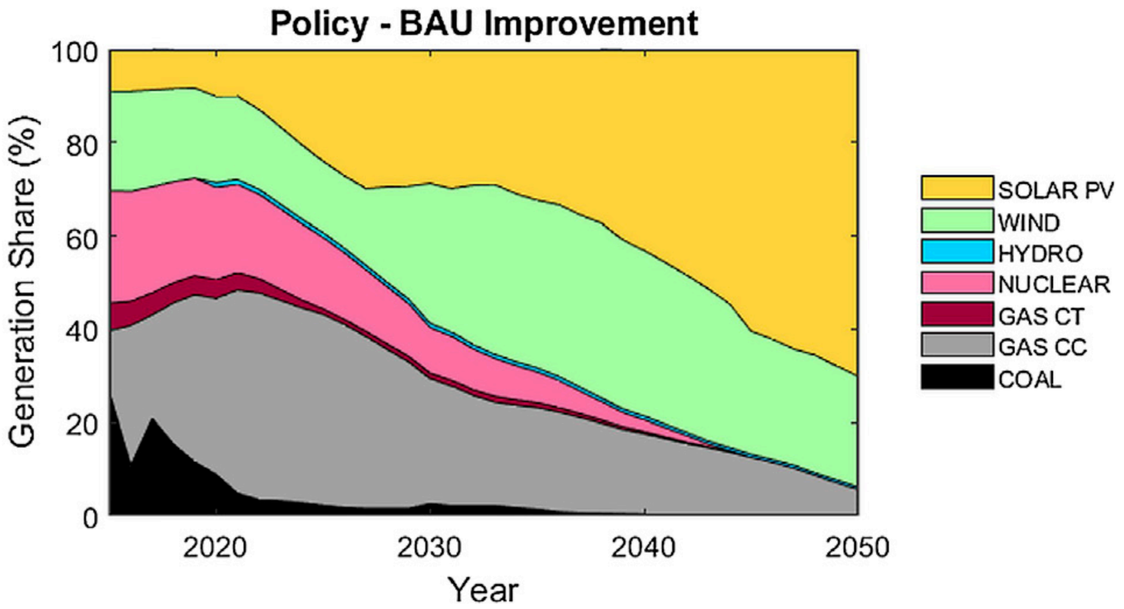
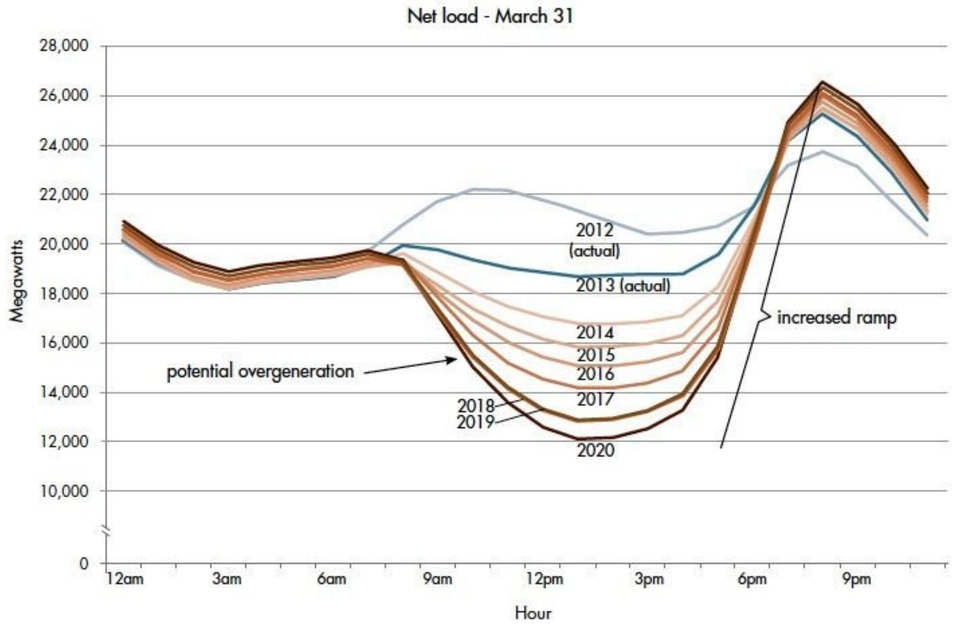




DOE

Energy flexibility needed to align supply with demand

Leibowicz et al, *Applied Energy, 2018*

70%

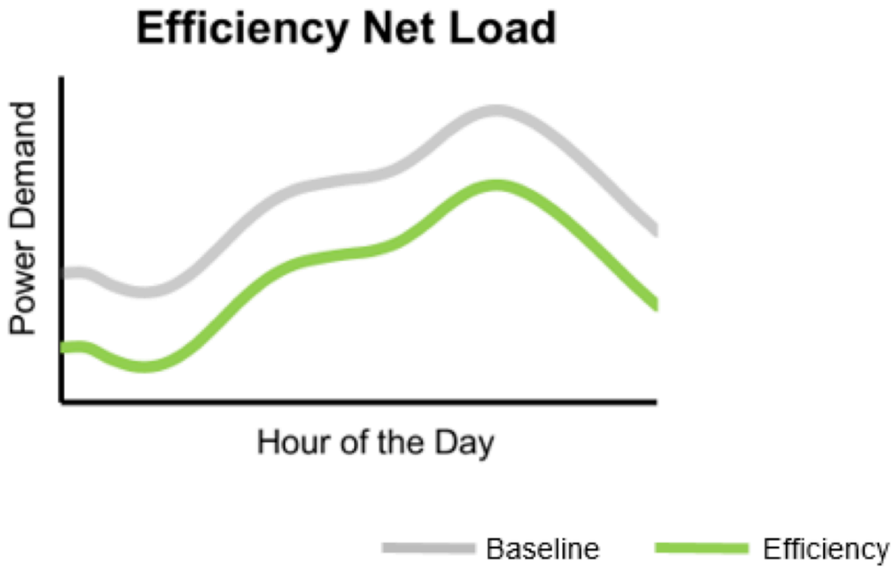
of US residential buildings are **single family homes**

70%

of US residential buildings are **single family homes**

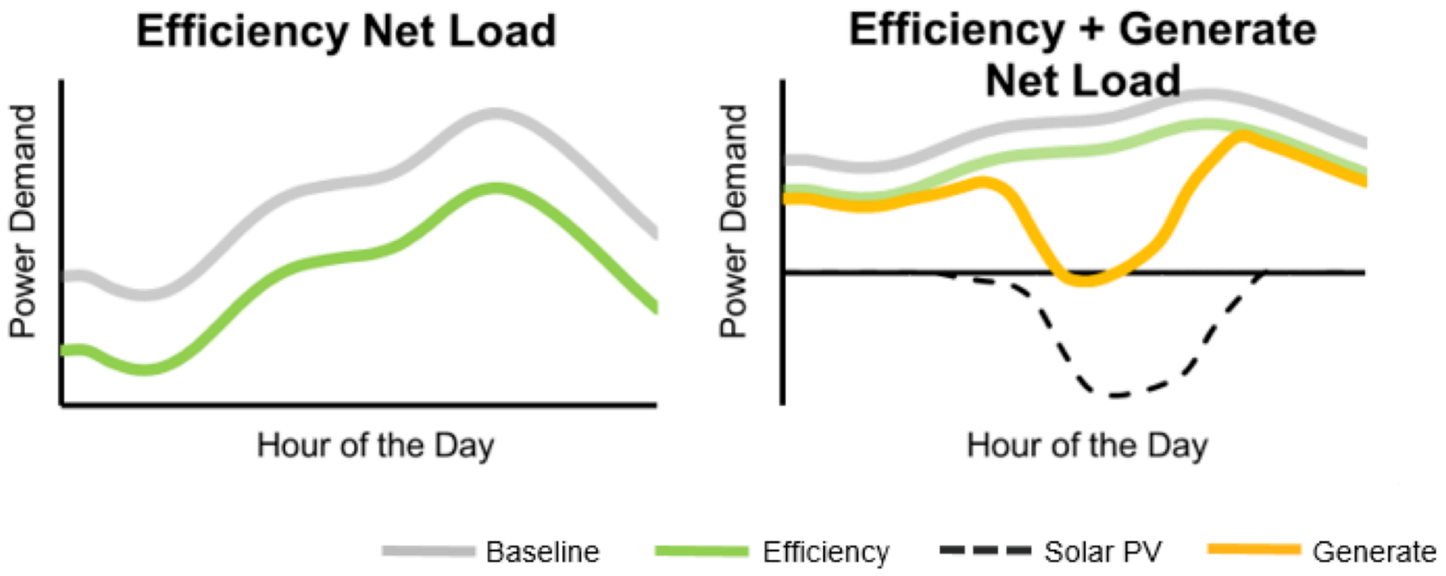
an **untapped potential** for energy flexibility

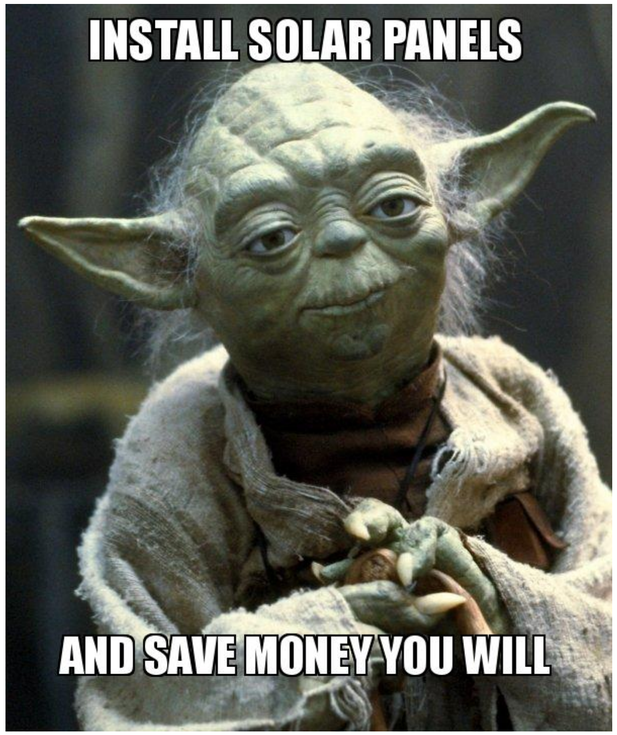
Grid-interactive communities can provide flexibility



US Dept of Energy, 2019

Grid-interactive communities can provide flexibility





US Dept of Energy, 2019

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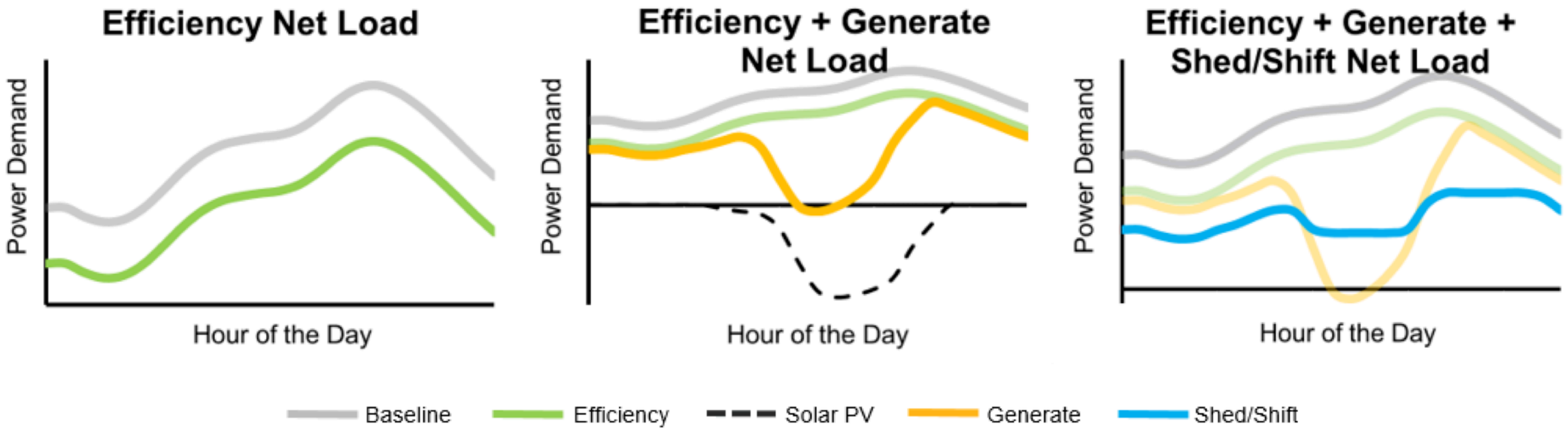
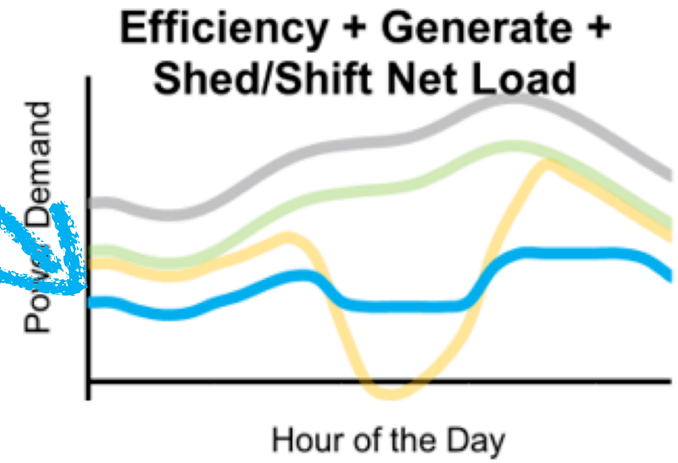


US Dept of Energy, 2019

How do we get to here?



Baseline Efficiency Solar PV Generate Shed/Shift

US Dept of Energy, 2019

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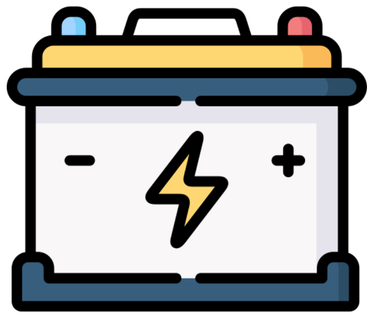
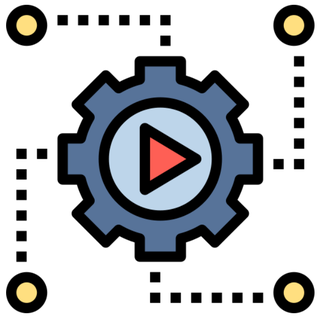
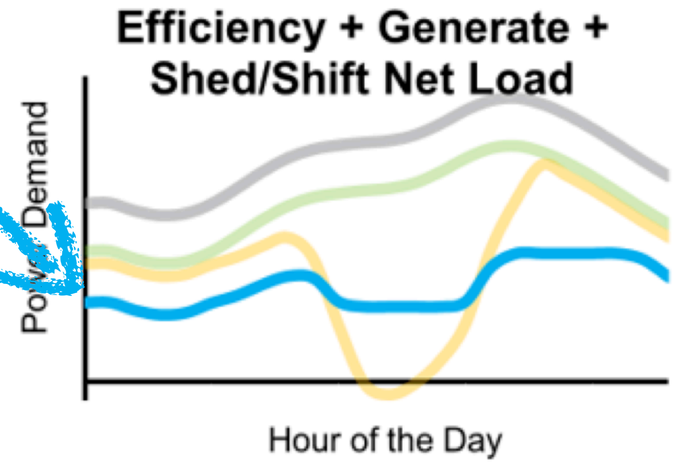


Storage



Control



US Dept of Energy, 2019

icons created by noomtah and Freepik

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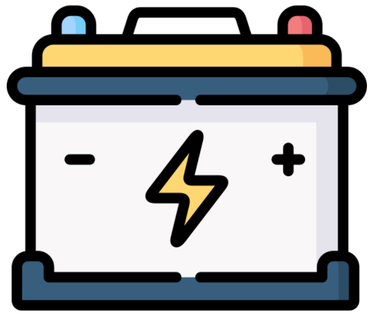
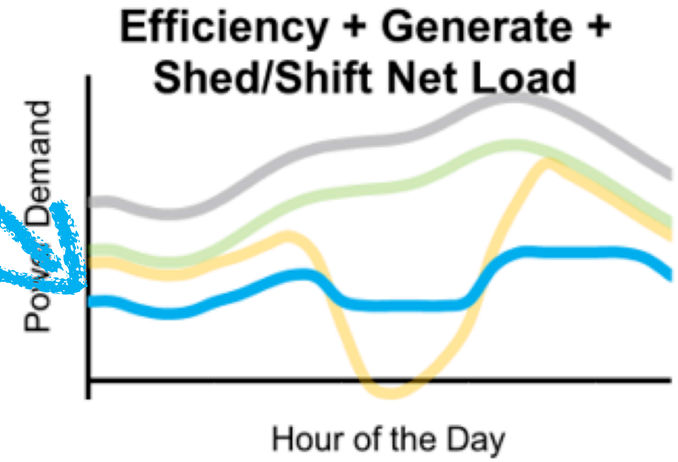


Storage

Electric Battery
Domestic Hot Water
Thermal Storage



US Dept of Energy, 2019

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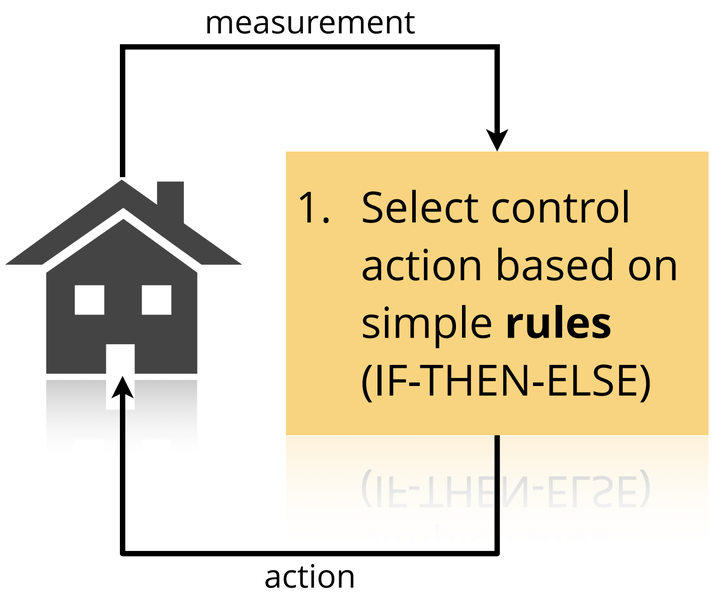
Control strategies for building energy management

Rule based control (RBC)



Control strategies for building energy management

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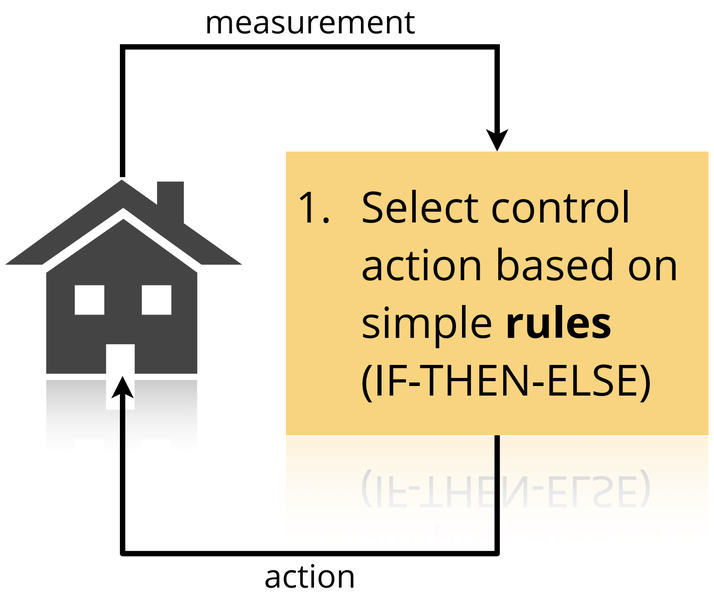
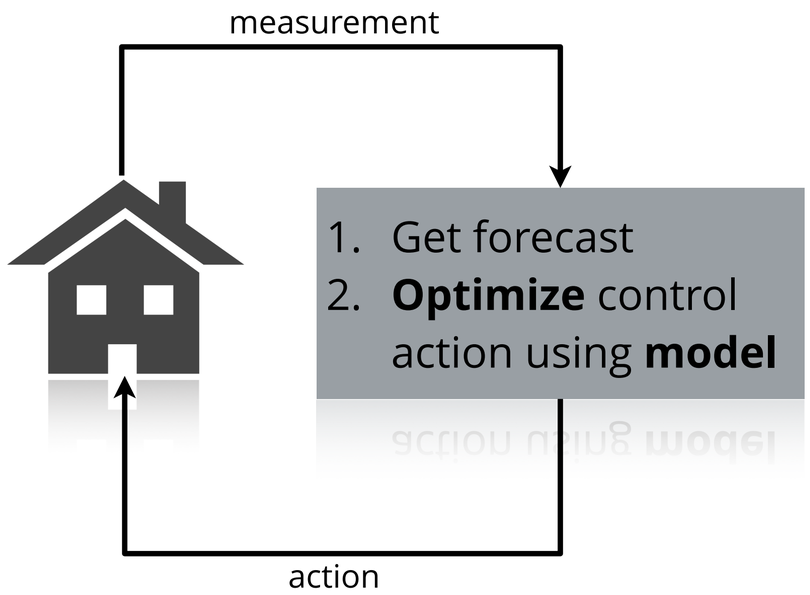
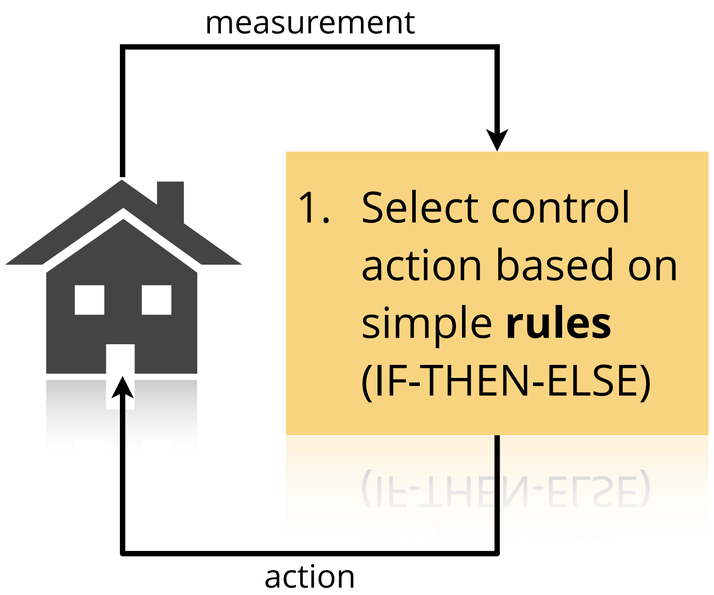


Model Predictive Control (MPC)



Control strategies for building energy management

Rule based control (RBC)



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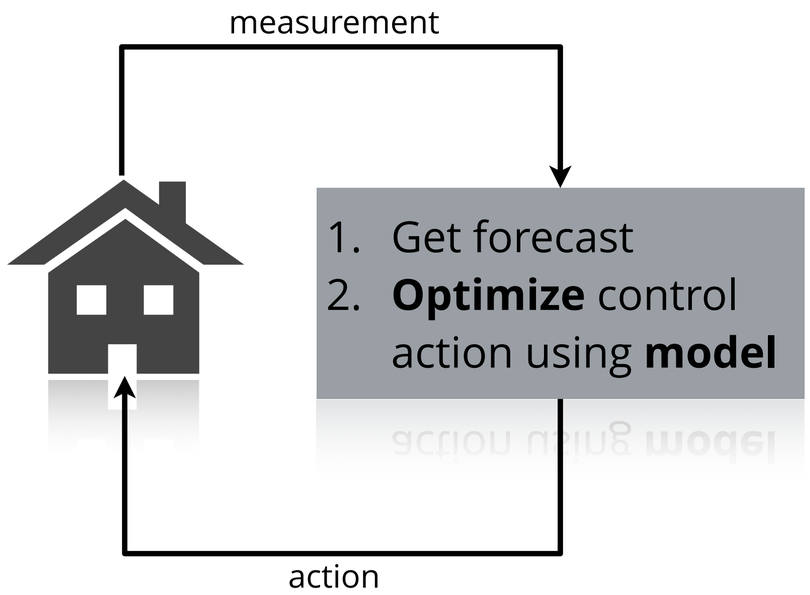
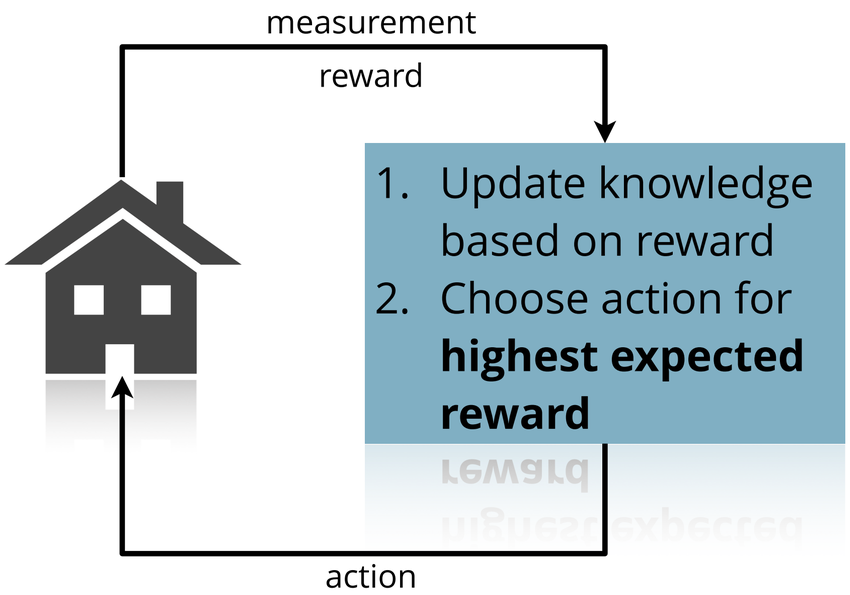


Reinforcement Learning Control (RLC)

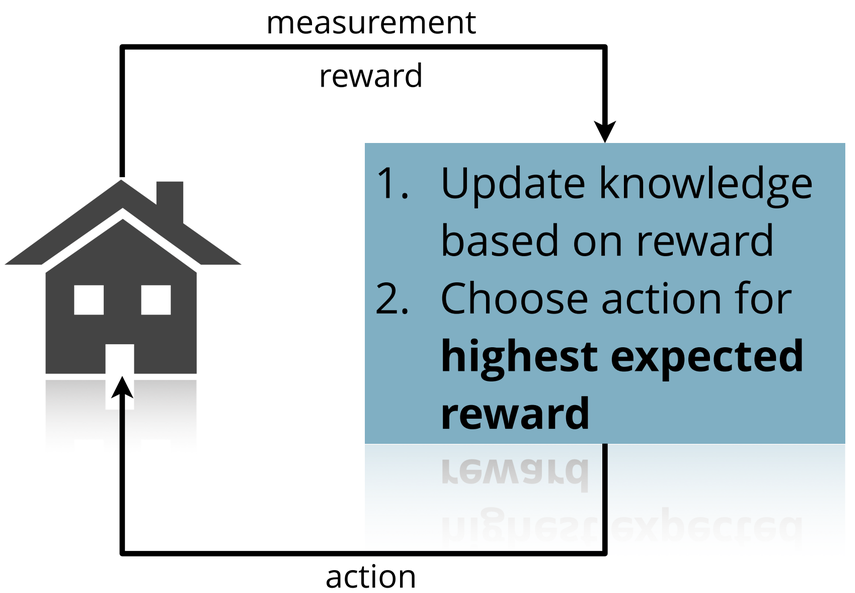


Control strategies for building energy management

Rule based control (RBC)

Model Predictive Control (MPC)

Reinforcement Learning Control (RLC)



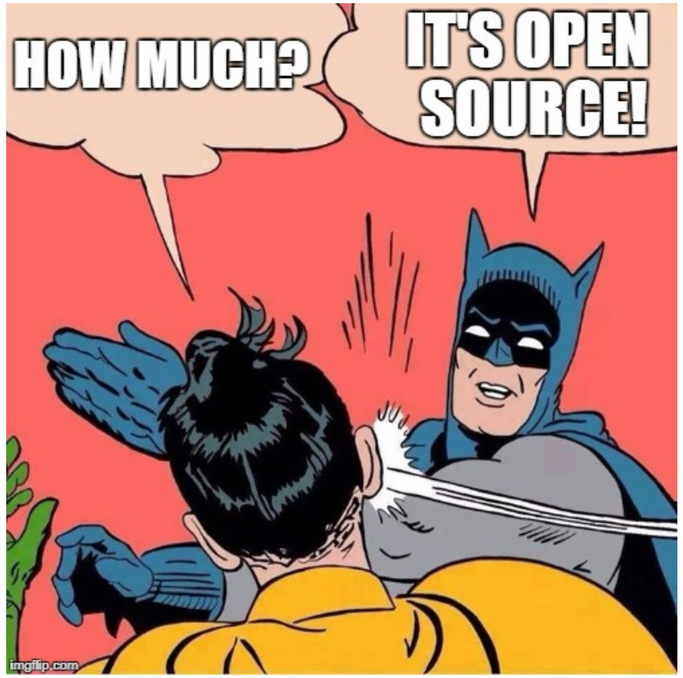
A formalized trial-and-error approach to map the actions to the states

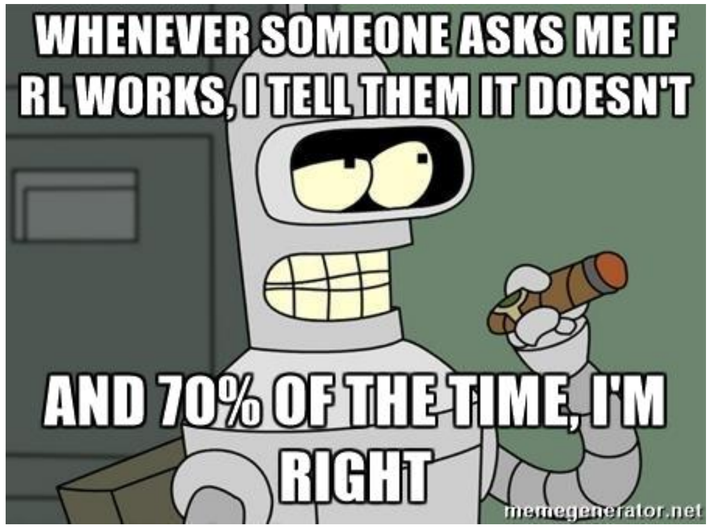
CityLearn provides standardization

- Gym environment to study neighborhood/community scale
- Buildings & systems are abstracted out in the library
  - Availability and size of systems can be configured (PV, thermal, electric storage)
  - Own buildings can be imported/used*
- In V1 - demand is precomputed
  - Active energy storage control (load shifting)
  - Focus on control algorithms (RLC, MPC, RBC)
- Code & Docu accessible through www.citylearn.net

```
[ ]: pip install CityLearn
```

- Open source: can be extended/adapted to your needs



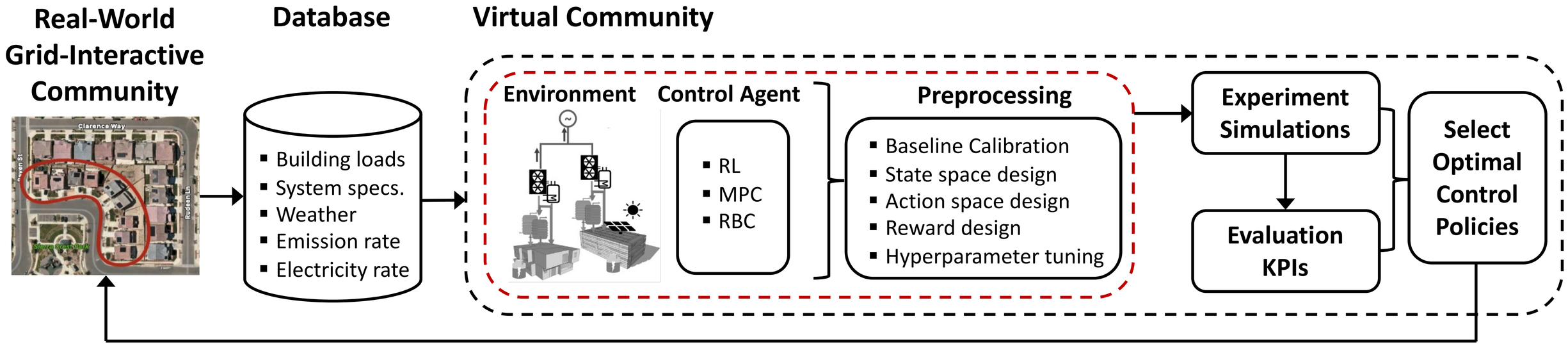


Can we learn from one building and deploy on another building? Can we learn to *flex*?

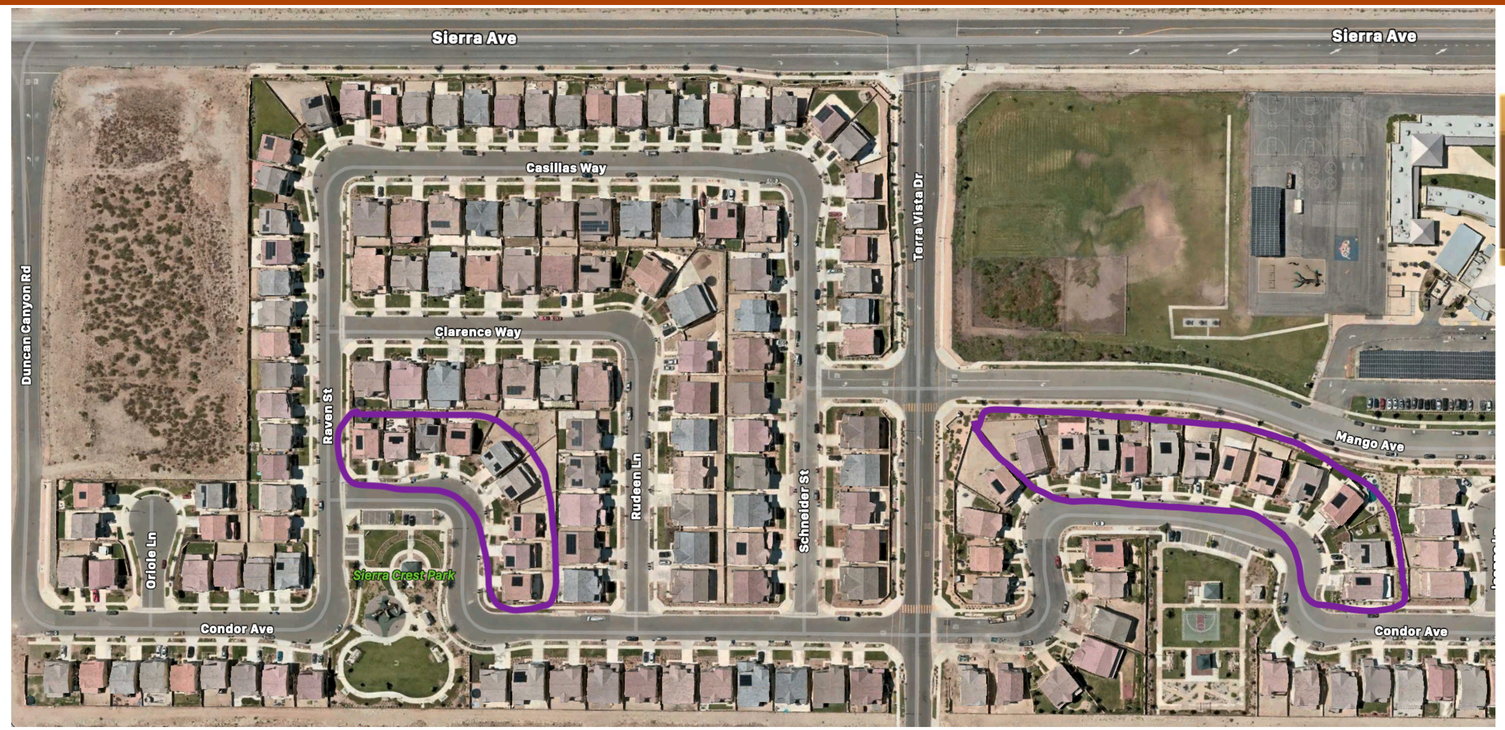
Can we learn from one building and deploy on another building? Can we learn to *flex*?

Yes, we can.

Can we learn from one building and deploy on another building? Can we learn to *flex*?



Nweye et al. "Multi-agent offline and transfer learning for occupant-centric operation of grid-interactive communities", Applied Energy (*In Press*), May. 2023, https://arxiv.org/pdf/2301.01148.pdf.

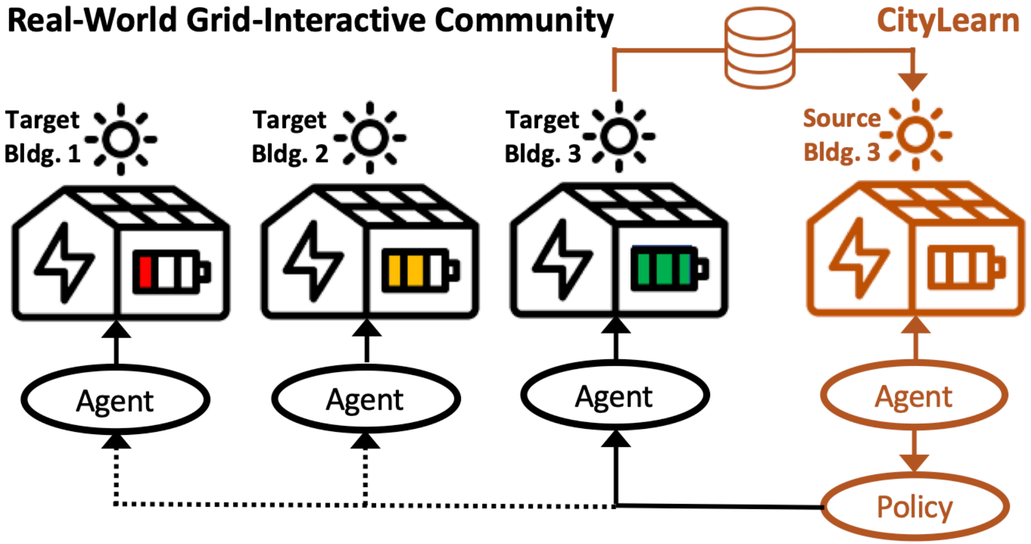


17 high efficiency SF homes in Fontana, Ca.
All with Solar PV and electric battery storage

Control task is to charge/discharge battery

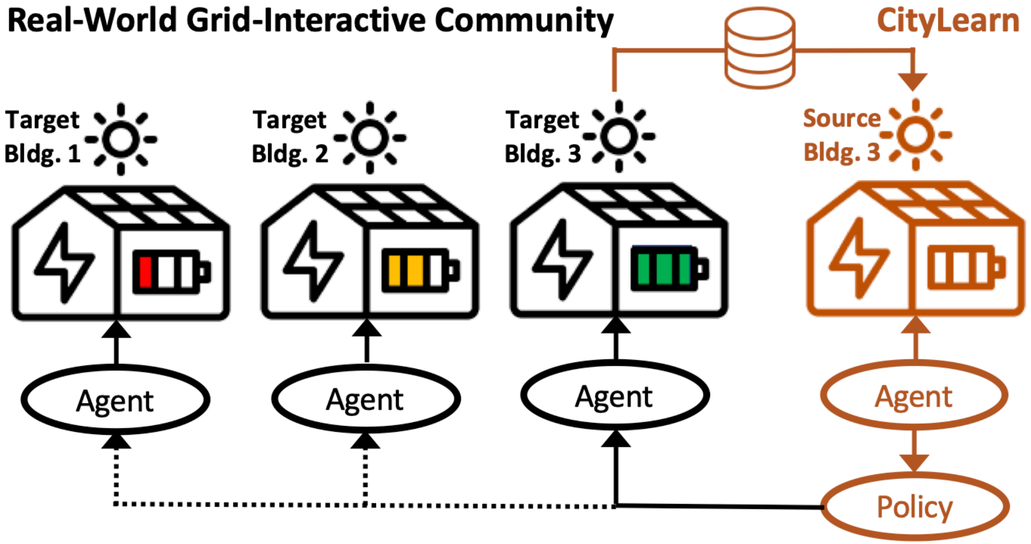
Electric Power Research Institute, *Grid integration of zero net energy communities*, 2017. URL: https://www.calmac.org/publications/CSIRDD_Sol4_EPRI_Grid-Integration-of-ZNE-Communities_FinalRpt_2017-01-27.pdf

Training & Deployment strategies



DS1: unique controller for each building with 12 months data (**perfect knowledge**)

Training & Deployment strategies



DS1: unique controller for each building with 12 months data (perfect knowledge)

DS3: train for 5 months of one building transfer policy to all other buildings and deploy on unseen 7 months **(transfer learning)**

Time of Use (RBC) & KPIs

Table 1
Time-Of-Use rate plan ($/kWh) used as electricity rate in simulation environment.

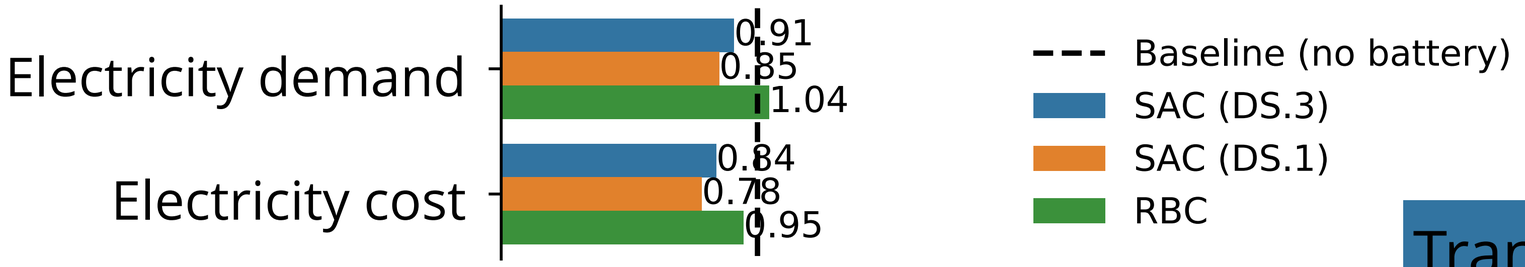
Time	June-September		October-May	
	Weekday	Weekend	Weekday	Weekend
8 AM-4 PM	0.21	0.21	0.20	0.20
4 PM-9 PM	0.54	0.40	0.50	0.50
9 PM-8 AM	0.21	0.21	0.20	0.20

Reference RBC based on time-of-use tariff
(charge when cheap, discharge when expensive)

Building level KPIs:
- net electricity consumption
- electricity cost
- carbon emissions
- zero net energy

Additional district level KPIs:
- Average daily peak
- Ramping
- 1-Load Factor

Some results: DS1 better than DS3 better RBC



Transfer Learning

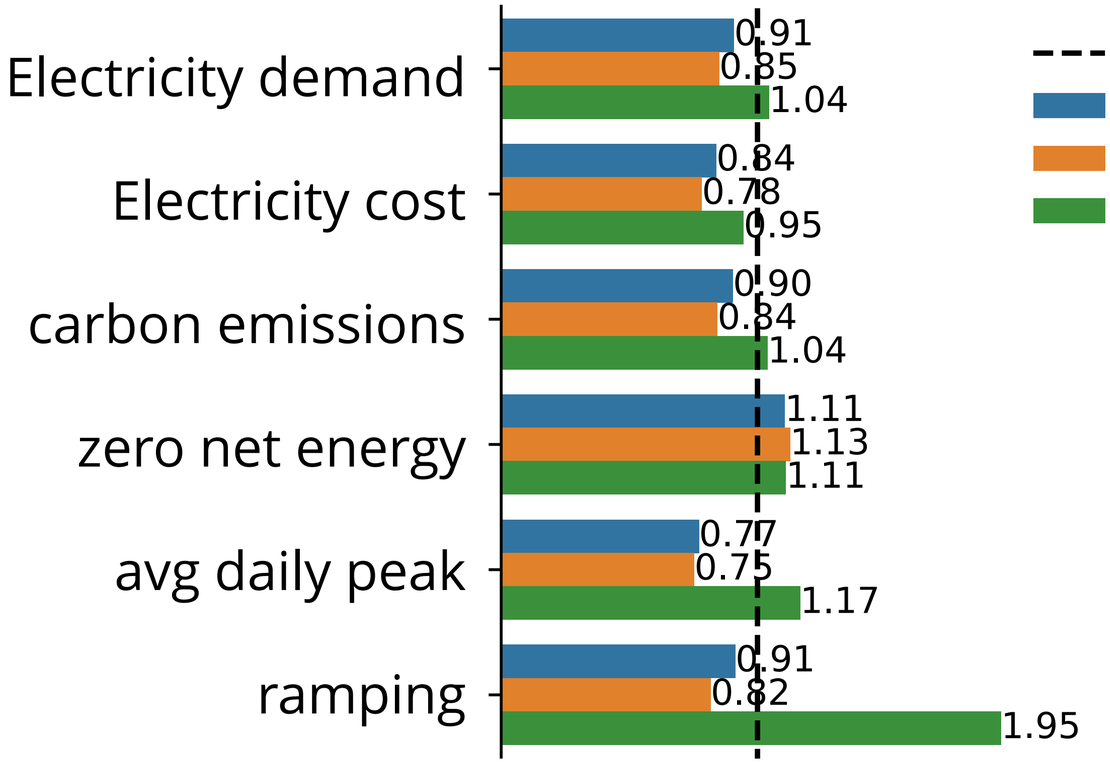
Perfect Knowledge

Time Of Use Tariff

Aggregated for all buildings

$$\mathrm{KPI} = \frac{\mathrm{KPI}_{\mathrm{control}}}{\mathrm{KPI}_{\mathrm{baseline\ (no\ battery)}}}$$

Some results: DS1 better than DS3 better RBC



Transfer Learning

Perfect Knowledge

Time Of Use Tariff

Aggregated for all buildings

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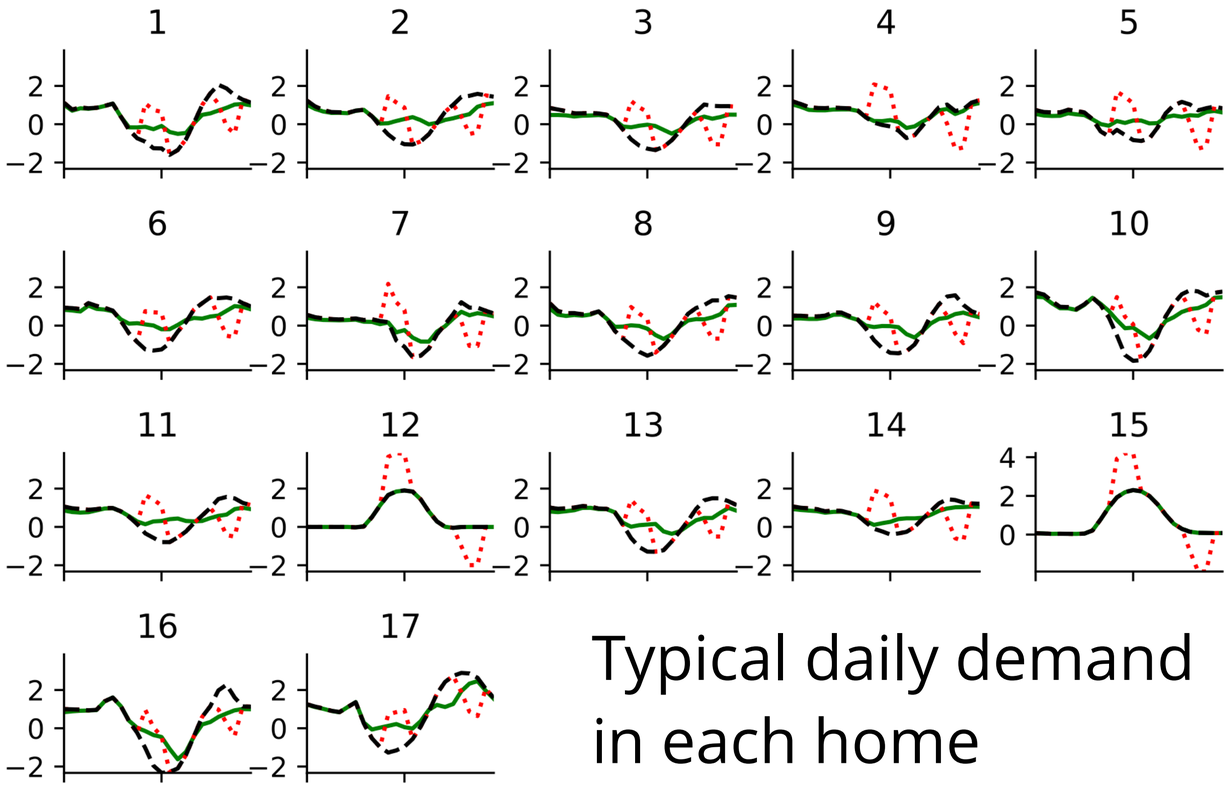
TOU shifts peak but we can *learn to flex* better



Typical daily demand in each home

No Control

RBC Control

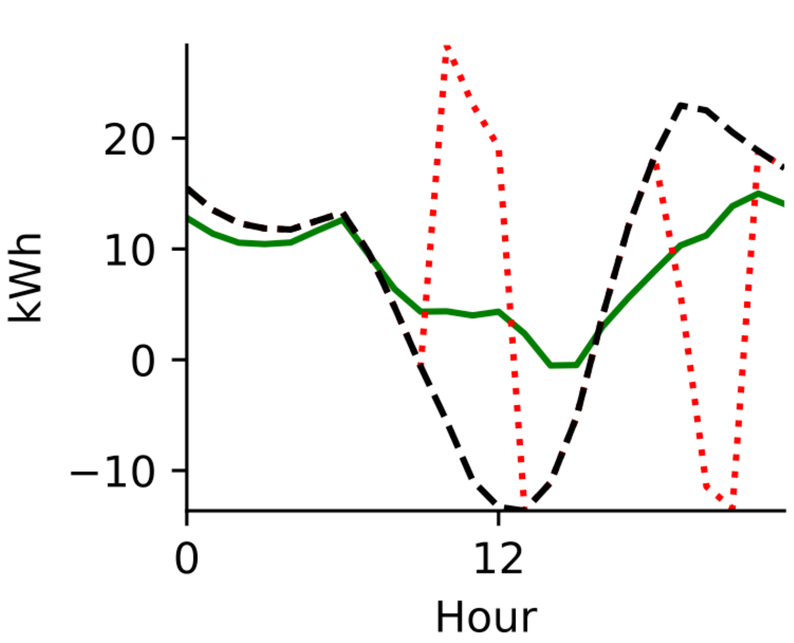
RL Control

(a) Building-level.

- Adapting to individual homes unlocks aggregated flexibility

TOU shifts peak but we can *learn to flex* better

(a) Building-level.



No Control

RBC Control

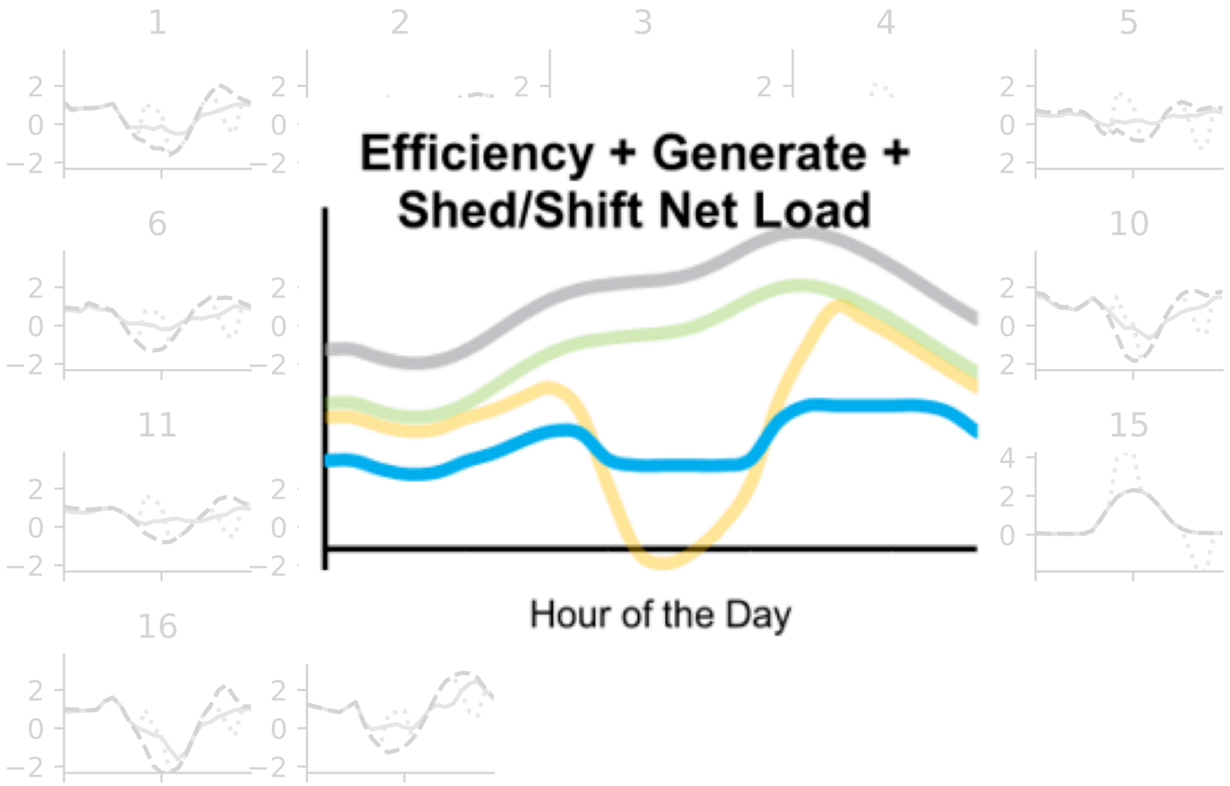
RL Control

SAC
RBC
Baseline (no battery)

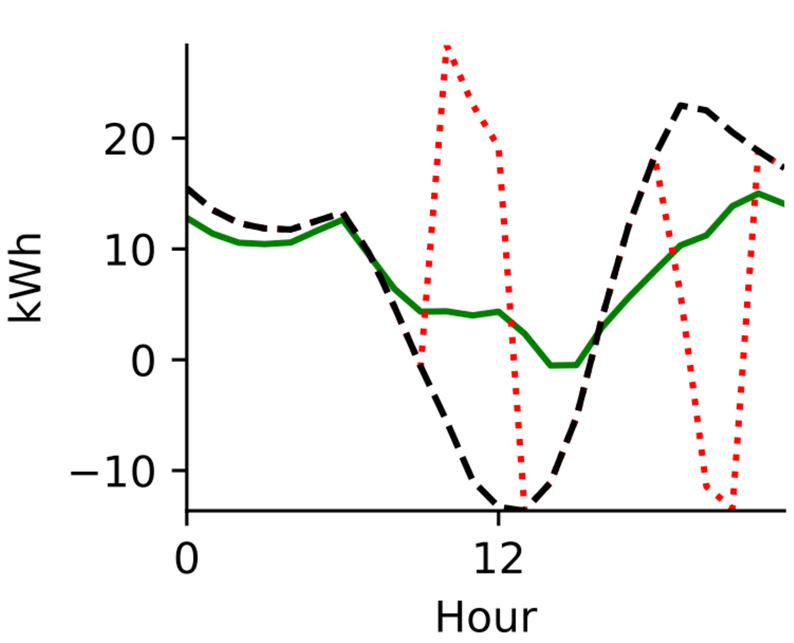
(b) District-level.

- Building level control can unlock community level benefits
- Flex load smoother than TOU

TOU shifts peak but we can *learn to flex* better



(a) Building-level.



No Control

RBC Control

RL Control

SAC
RBC
Baseline (no battery)

(b) District-level.

- Building level control can unlock community level benefits
- Flex load smoother than TOU

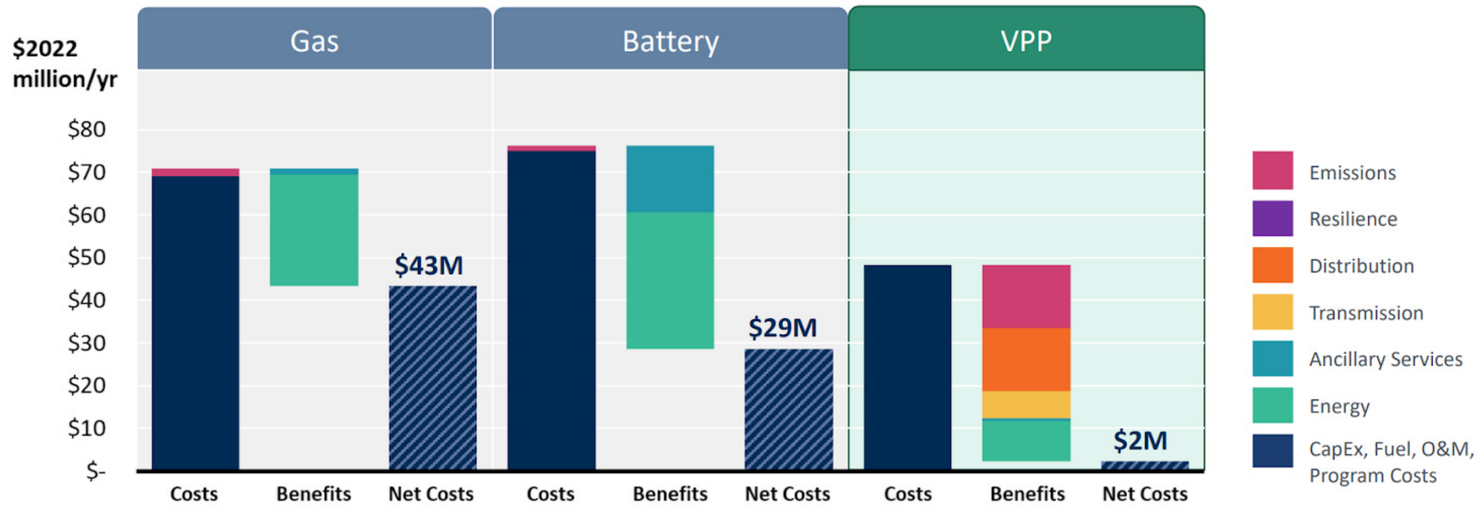
Flexing can avoid power plant & transmission costs

THE VALUE OF VPPS

Resource Adequacy… For Cheap

The VPP could provide the same resource adequacy at a significant cost discount relative to the alternatives.

Annualized Net Cost of Providing 400 MW of Resource Adequacy



Brattle

Real Reliability | 24

Questions?

Introduction to Python

- Tutorial / Walkthrough
- Homework 1