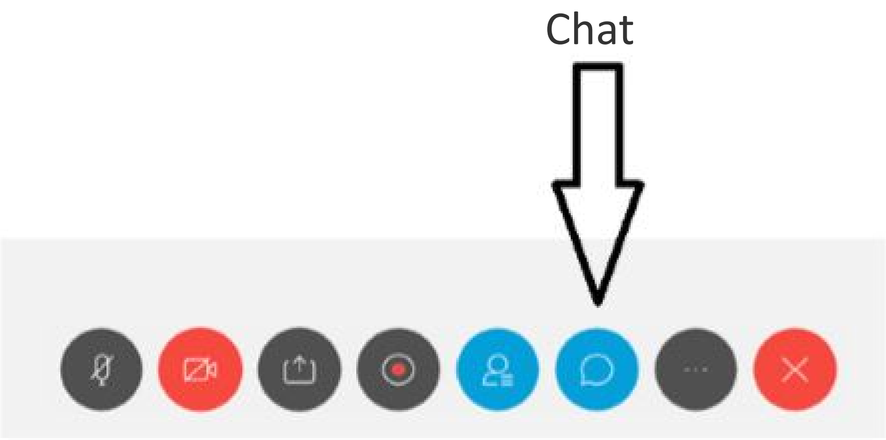
Autonomous Energy System Simulation Capabilities – Ultra-Large Scale DER Deployment

Deepthi Vaidhynathan and Jennifer King
Autonomous Energy Systems Workshop 2020
August 20, 2020

Workshop on Autonomous Energy Systems

August 20, 2020

- Attendees will be muted throughout the duration of the workshop
- If you have a question, please type it into the chat box. This chat box will be monitored throughout the meeting.



Workshop on Autonomous Energy Systems

August 20, 2020

Agenda

Introduction
8:30 – 9:00: Autonomous Energy System Simulation Capabilities – Ultra-Large Scale DER Deployment - ***Jen King and Deepthi Vaidhynathan, NREL***

Session 3: Grid-Interactive and Efficient Buildings
Moderator(s): Kalpesh Chaudhari, Matt Moniot

9:00 – 9:45: Learning-boosted Optimal Power Flow - ***Kyri Baker, University of Colorado – Boulder***

9:45 – 10:30: Capacity characterization of on/off and variable flexible loads providing virtual energy storage - ***Prabir Barooah, University of Florida***

10:30 – 11:15: Cloud-based Fault Detection: Leveraging Big Data to Reduce HVAC Energy Usage - ***Bryan Rasmussen, Texas A&M***

11:15 – 12:00: Scalable Distributed Model Predictive Control for Building and Renewable Energy Systems - ***Rohit Chintala and Christopher Bay, NREL***

12:00-13:00 **Break**

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Session 4: Transportation and Mobility
Moderator(s): Rohit Chintala, Christopher Bay

13:00 – 13:45: Online optimization as feedback control for dynamical systems - ***Emiliano Dall'Anese, University of Colorado - Boulder***

13:45 – 14:30: Transactive Control in Transportation Systems - ***Anuradha Annaswamy, MIT***

14:30 – 15:15: Adaptive Charging Network Research Portal - ***Steven Low, CalTech***

15:15 – 16:00: Modeling and Management of Electric Vehicle Loads - ***Matt Moniot and Kalpesh Chaudhari, NREL***

16:00 – 16:15: Workshop Wrap up - ***Ben Kroposki, NREL***

Acknowledgements – AES Simulation Framework

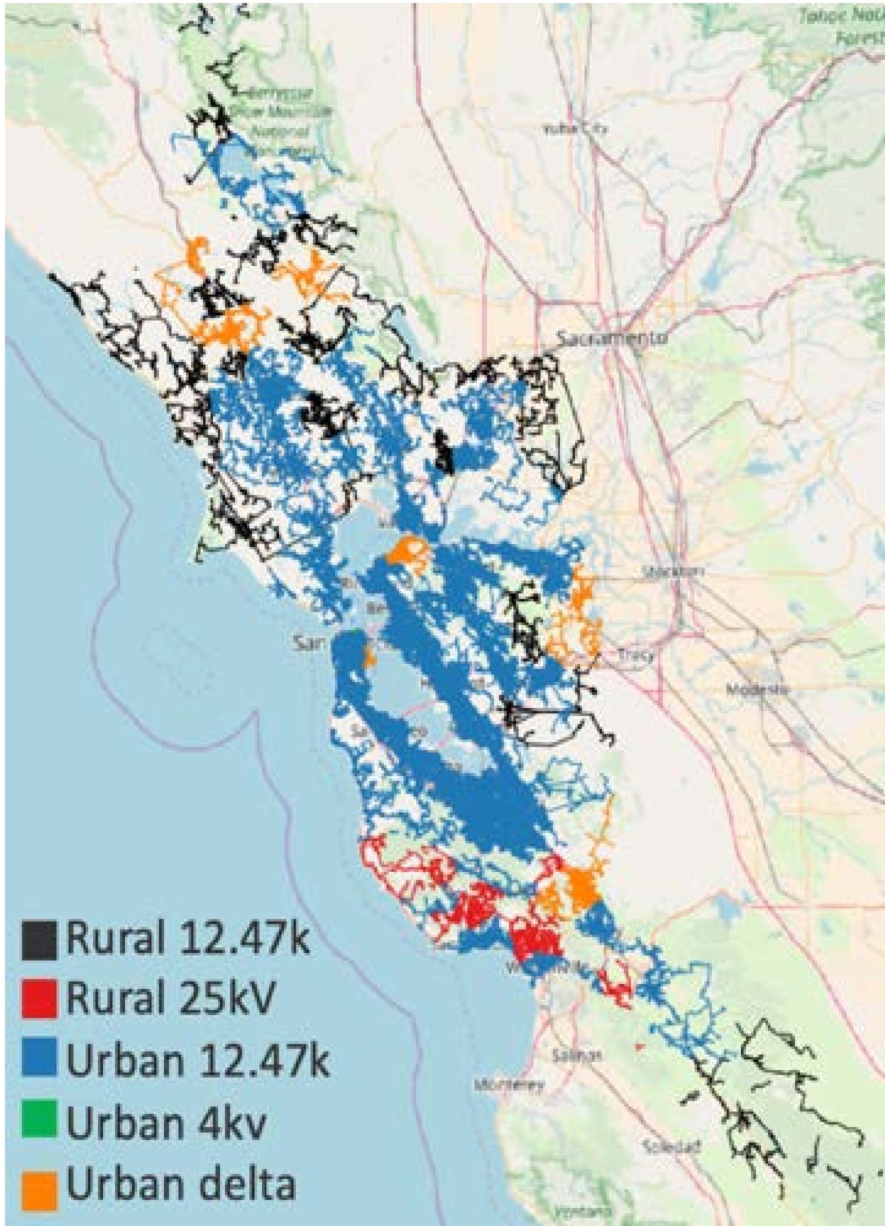
AES Computational Framework
Lead Developer: Deepthi Vaidhynathan
Monte Lunacek, Slava Barsuk, Wesley Jones and Abinet Eseye

Visualization
Developers: Kenny Gruchalla, Nicholas Brunhart-Lupo

Integrated Buildings Models
Developers: Rohit Chintala, Chris Bay

Electric Vehicles – HIVE
Developer: Matt Moniot

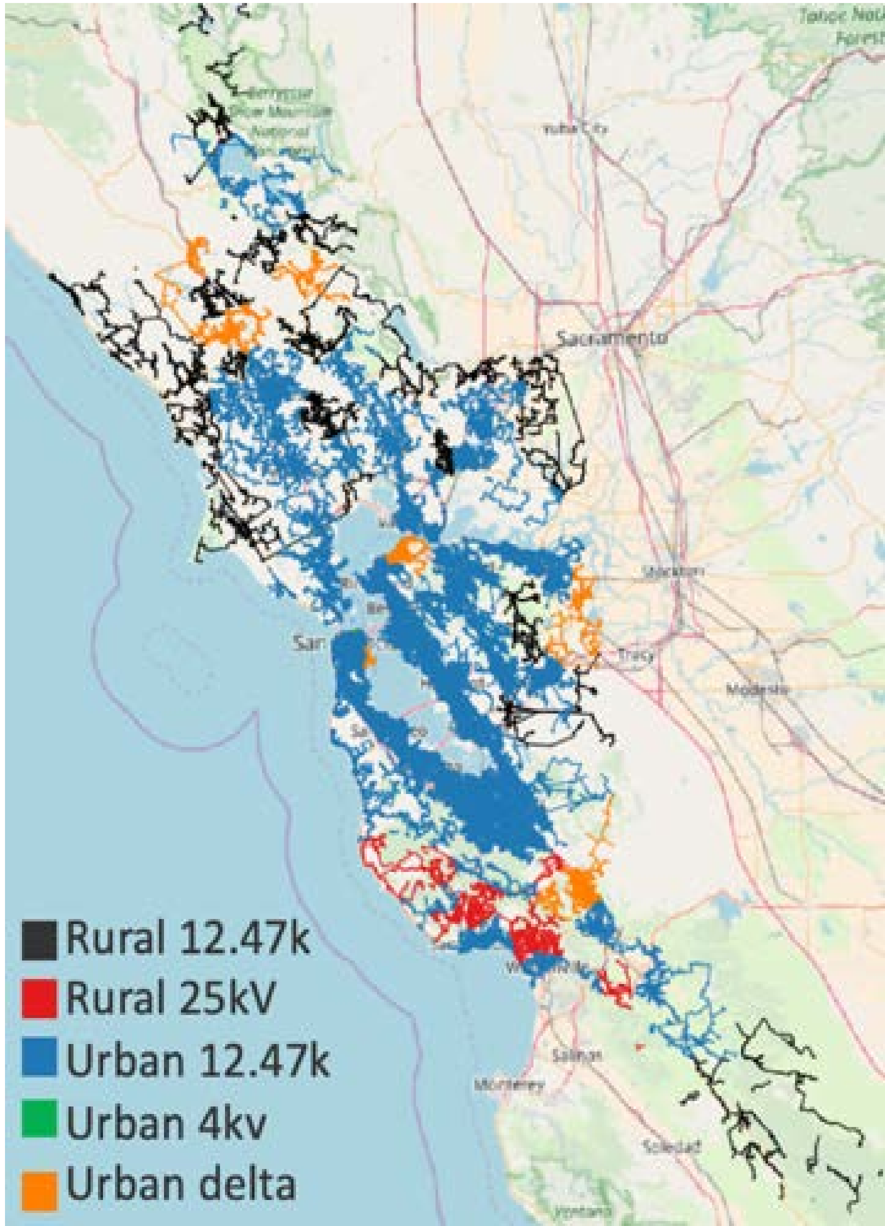
Data Integration
Developers: Jordan Perr-Sauer, Dylan Wald



Overview

- Developing **distributed, scalable optimization and control algorithms** that can operate millions of controllable devices in 1s

- **Complex simulation framework** that integrates buildings, wind/solar, vehicles, grid
    - Runs with HELICS and Co-sim
    - Parallelized to run on Eagle for large simulations



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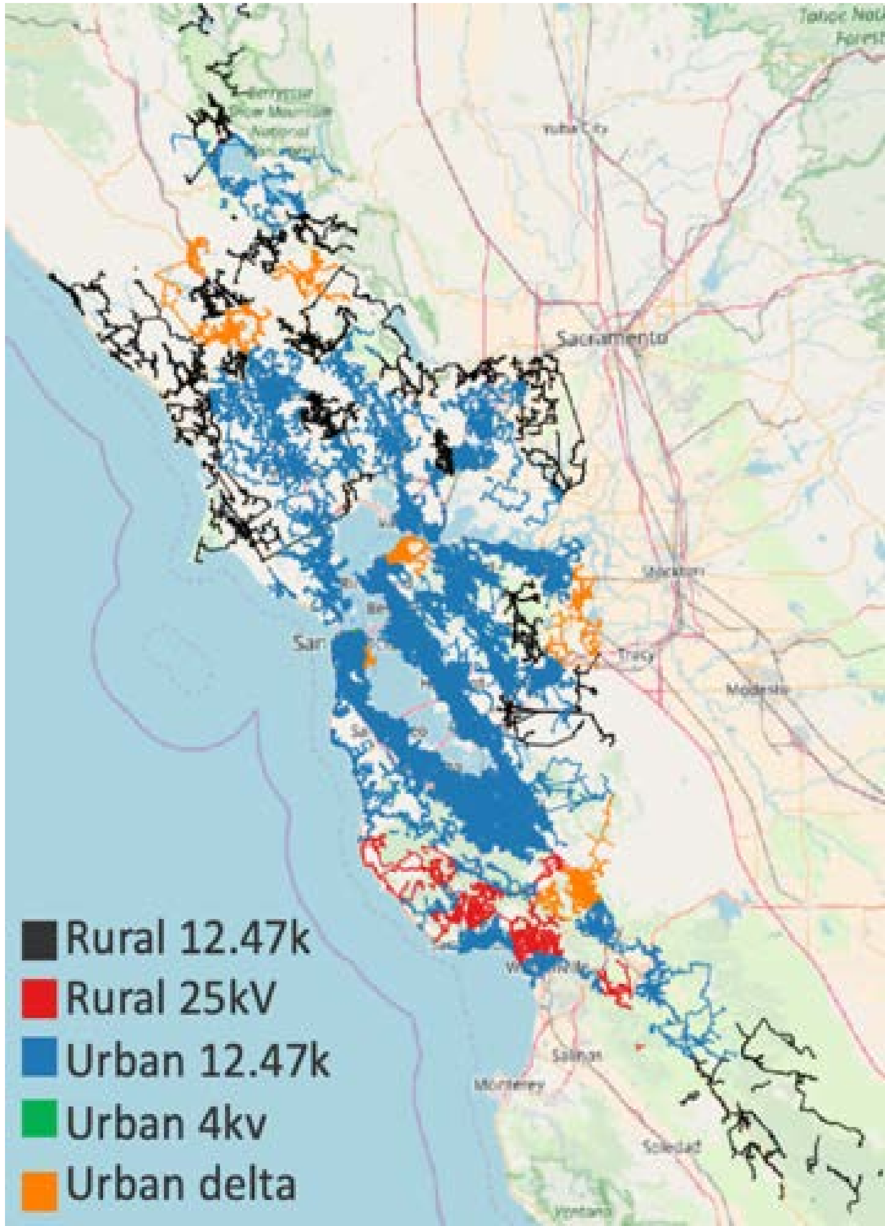


Outline

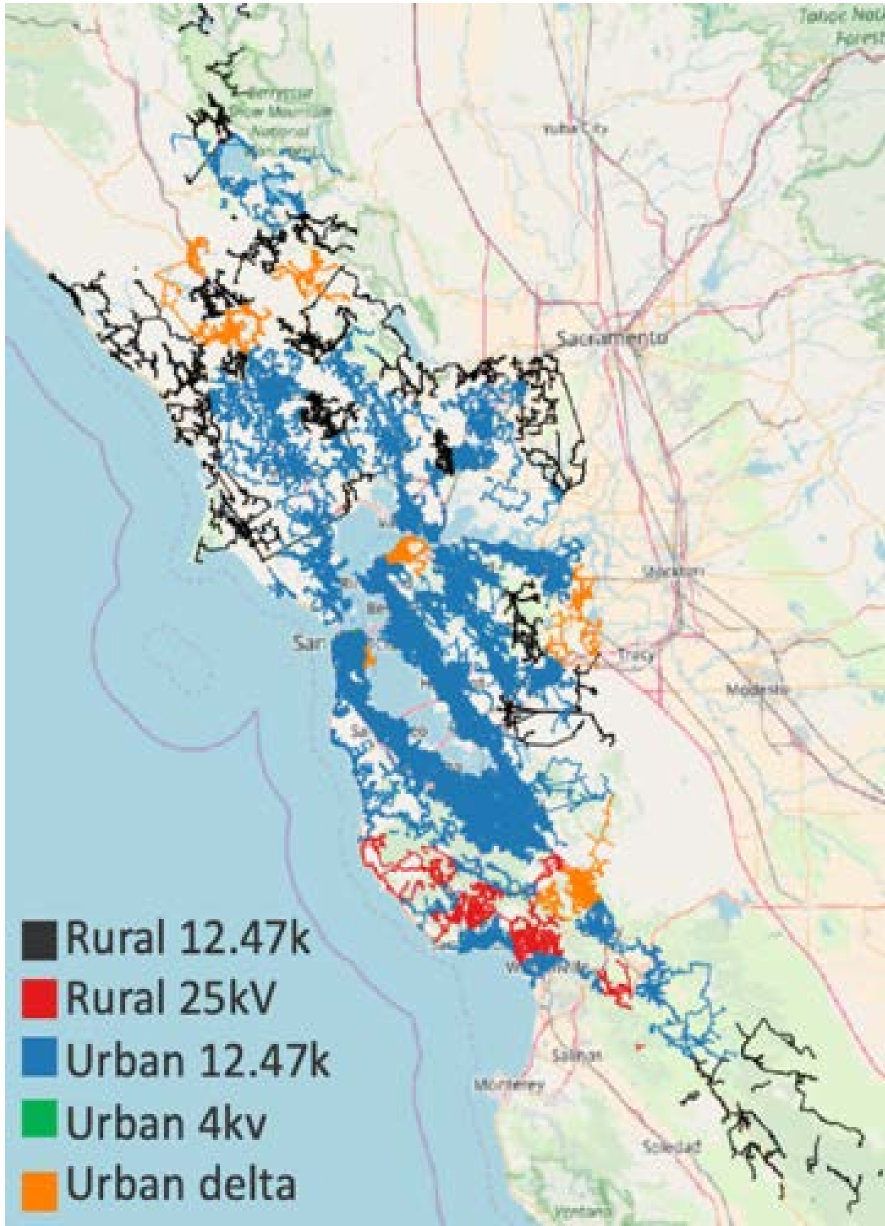
- San Francisco Bay Area Use Case

- Models used in computational framework
  - Vehicles
  - Buildings
  - Solar
  - Optional: wind

- Computational Framework
  - Communication and HPC capabilities
  - Controller Integration

- Results with Region 1

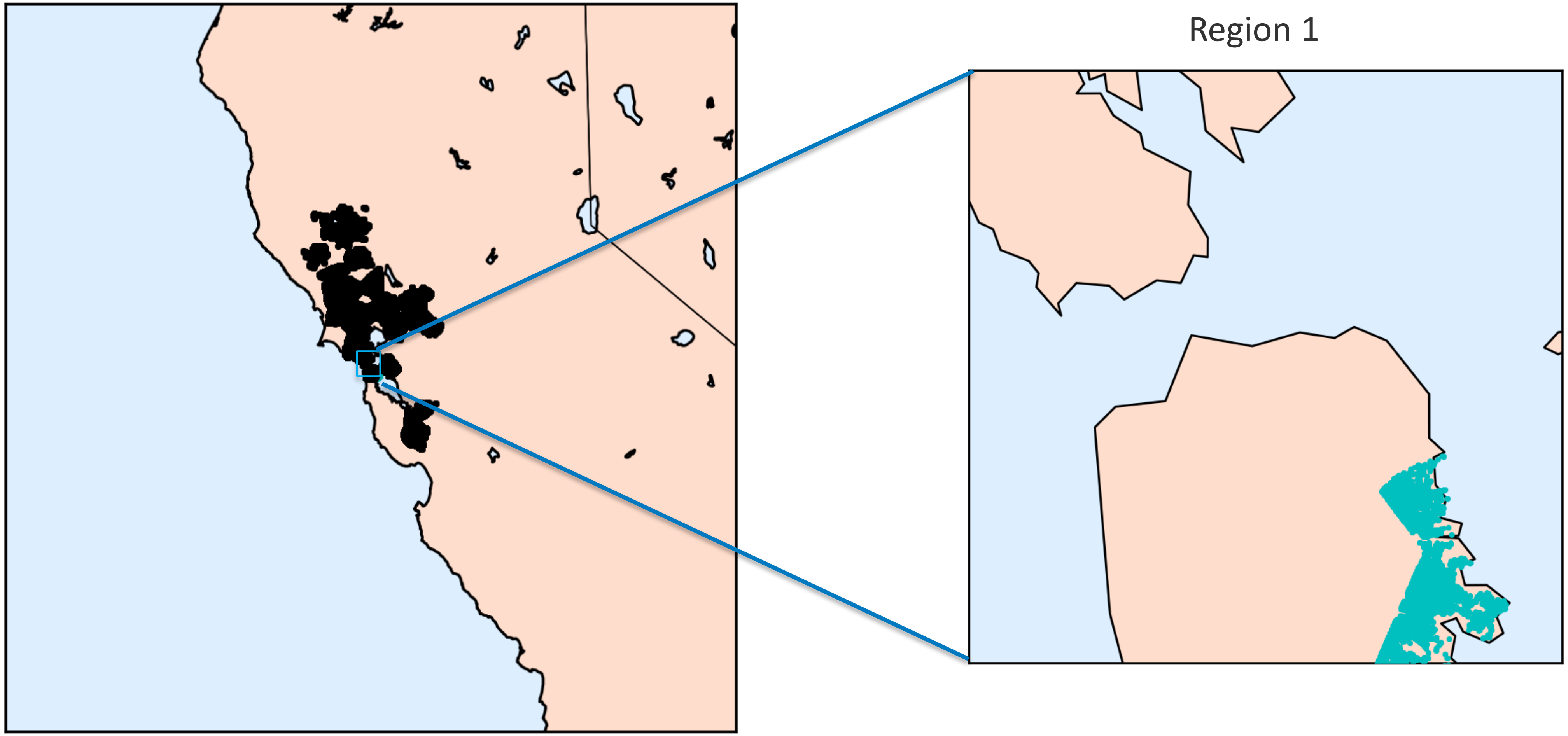
- Future work



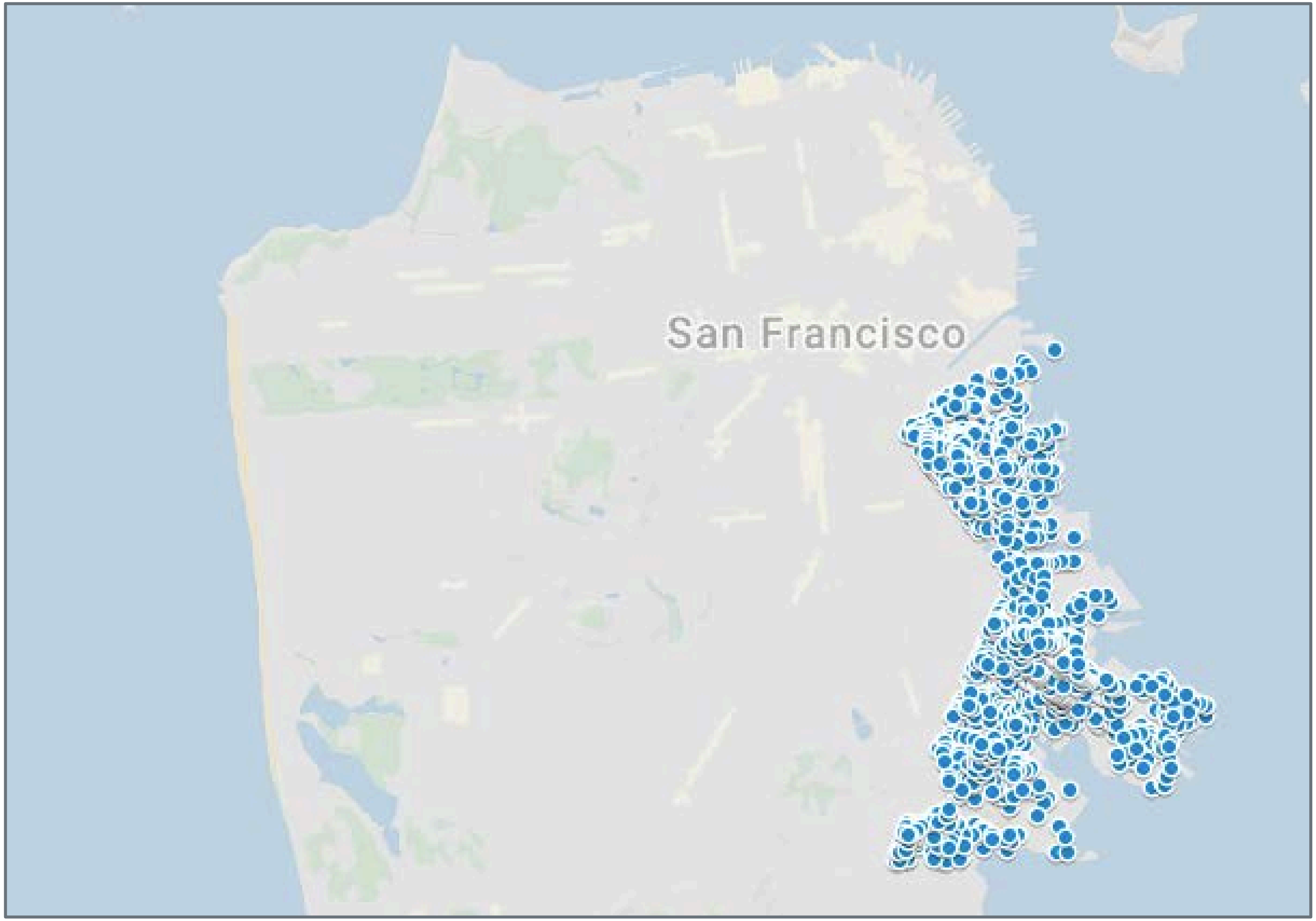
San Francisco Bay Area

15 regions in the Bay Area

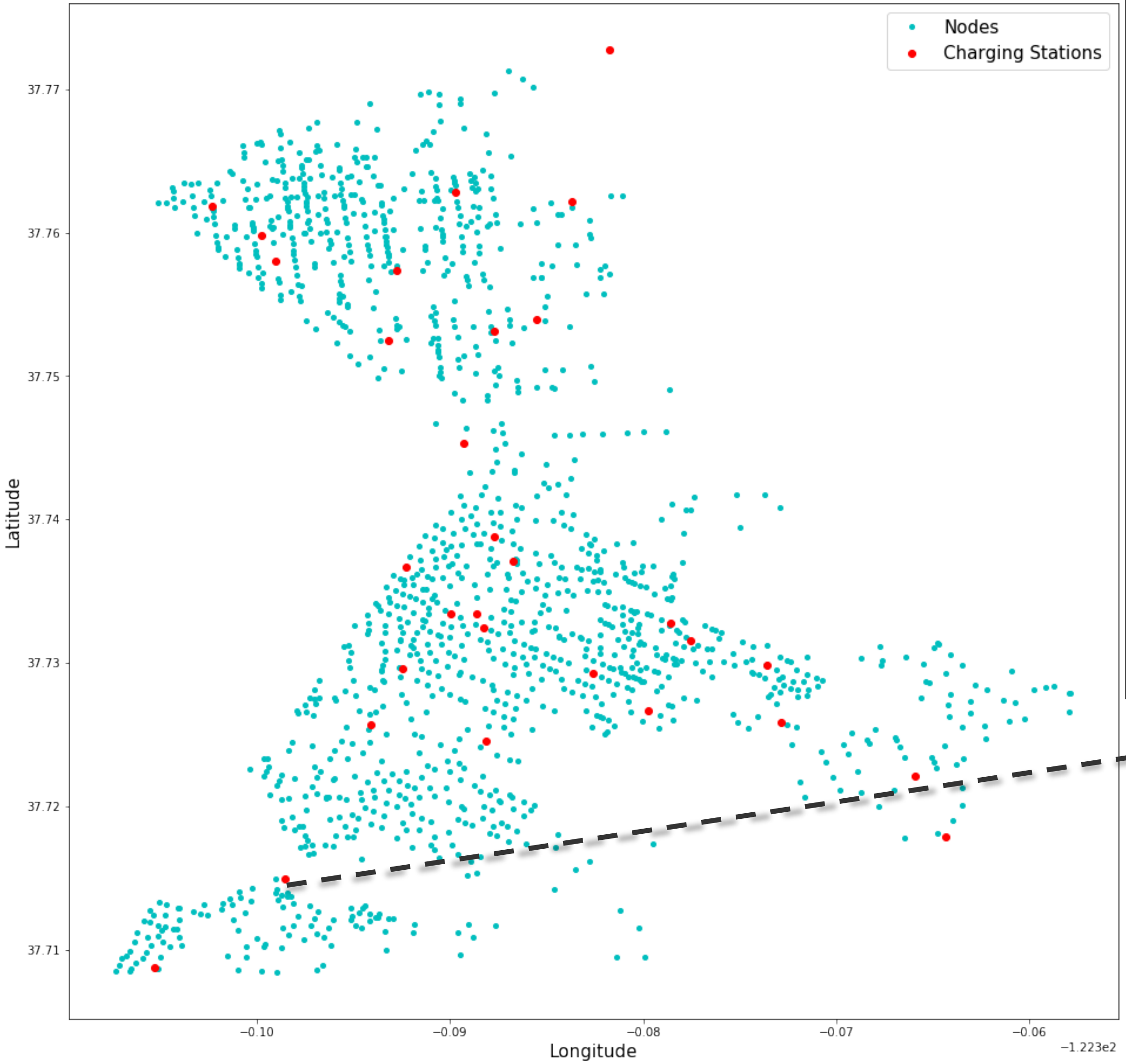
Region 1



San Francisco Bay Area - Region 1

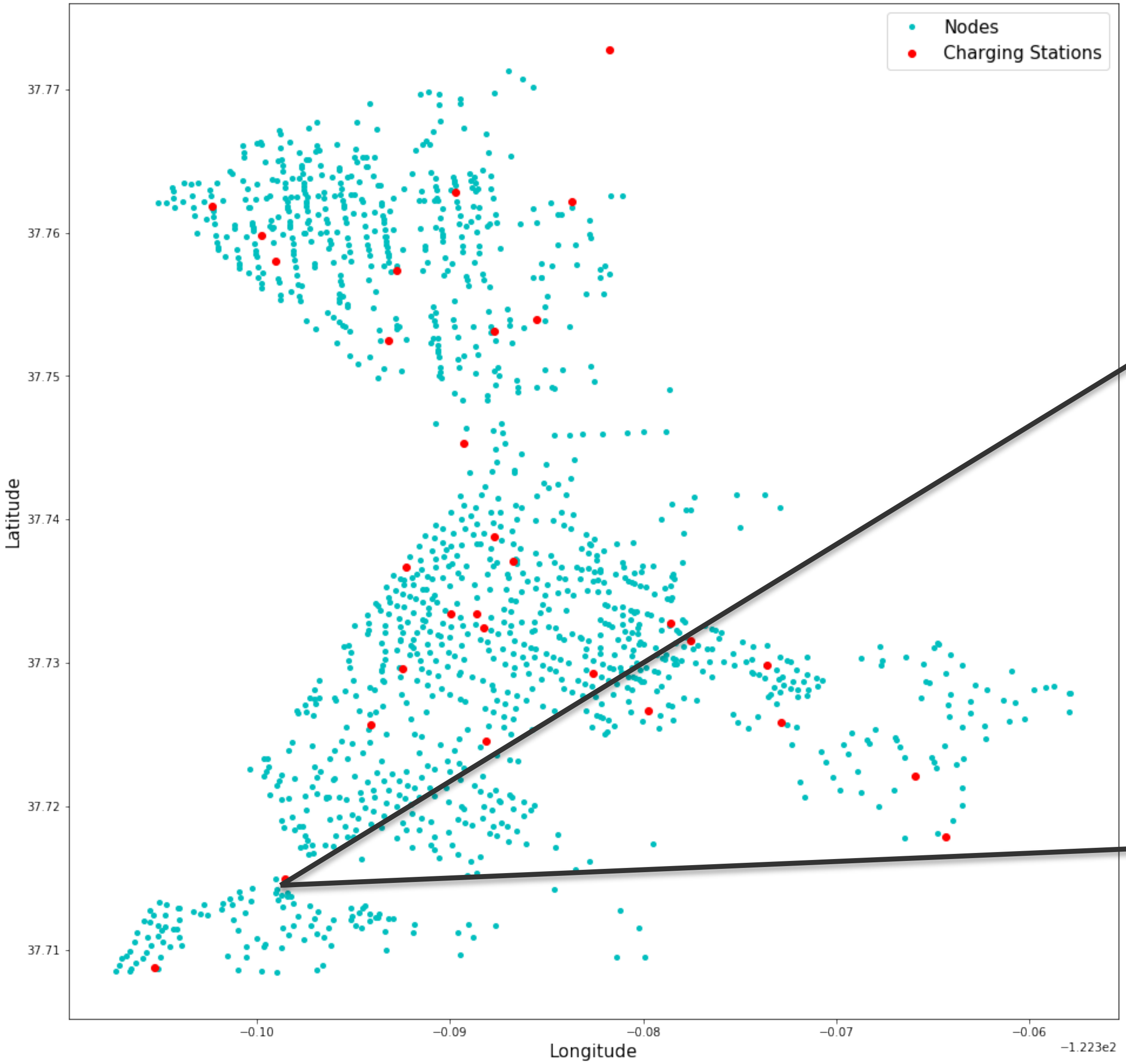


Region 1 – Charging Stations with HIVE

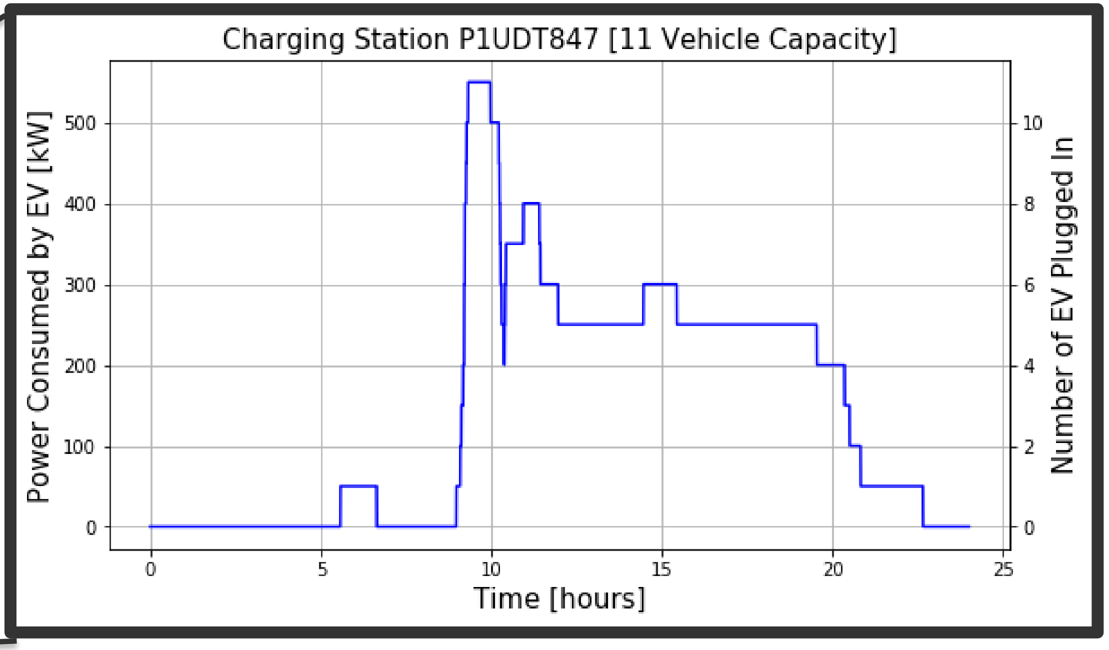


Highly Integrated Vehicle Ecosystem

Region 1 – Charging Stations



*Currently: uncontrollable load

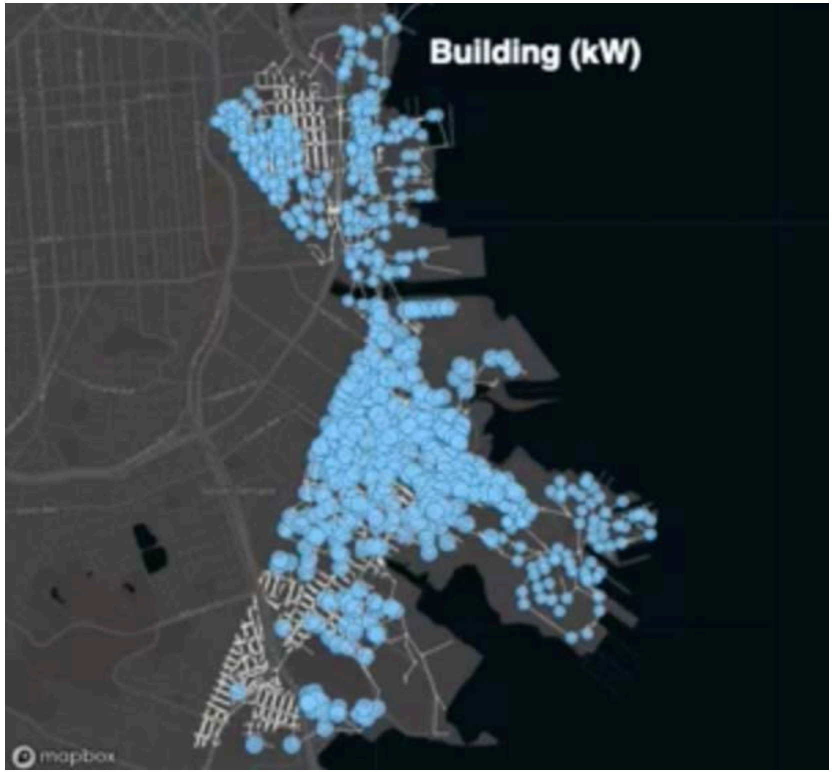


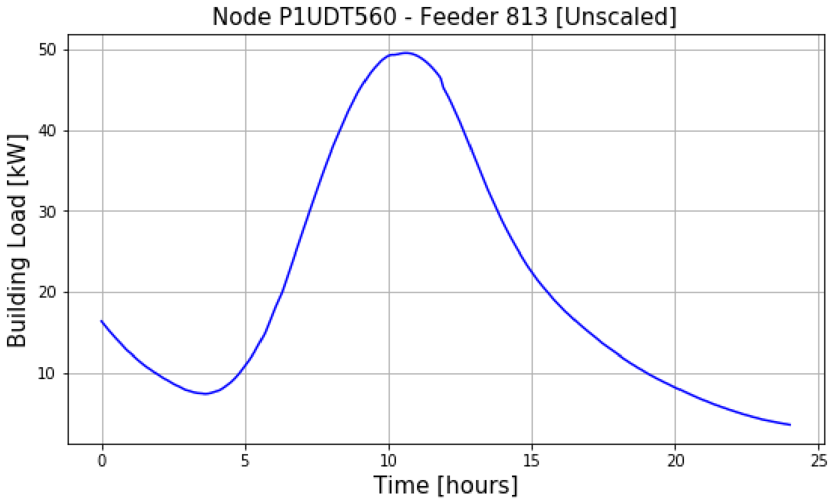
In progress: integrating charging control

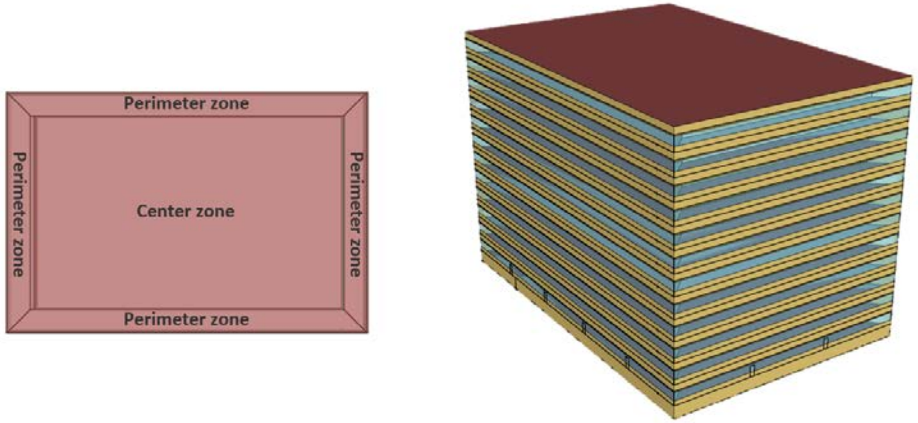
*Details on HIVE and charging control to be provided in presentation at 3:15am

Region 1 – Building Models

- Model the thermodynamics of a small office building
- Internal load + integrated with weather data
- Scaled buildings for each of the nodes





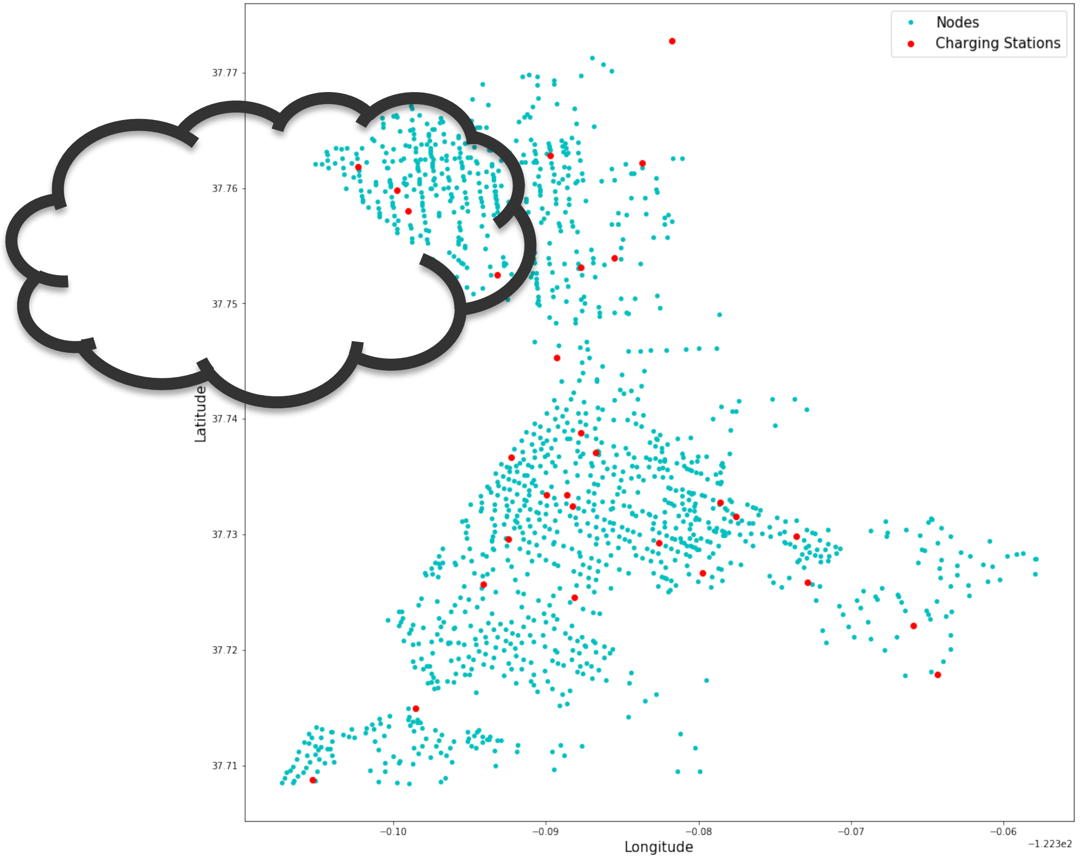


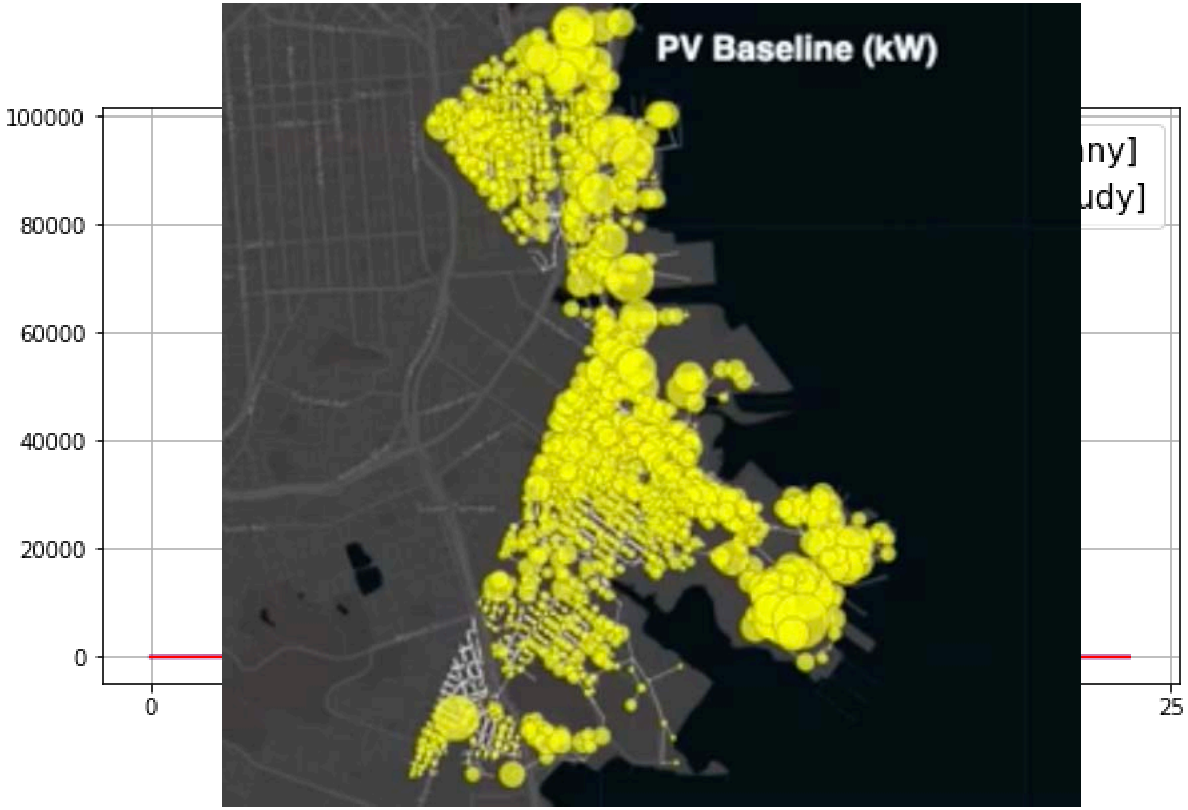
DOE Large Office Building Model

- Details to be provided in presentation at 11:15am

Input Weather Data

- Corresponding solar/cloud data across a region
- Limitations: 5 minute data that is scaled down to 1s data





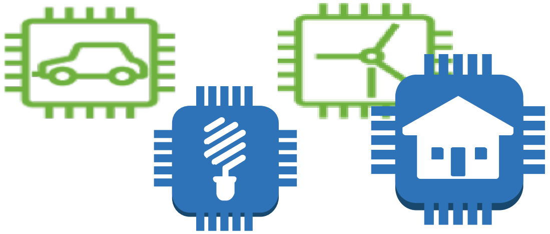
Computational Framework

Autonomous Energy Systems

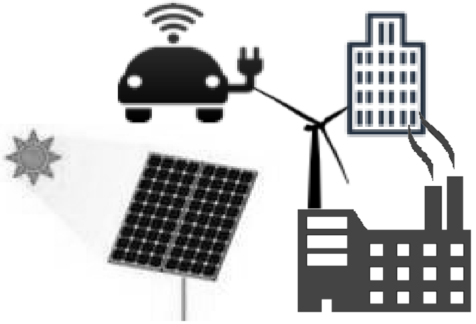
Scalable, reconfigurable, and self-organizing information and control platform.

Autonomous Energy Systems Building Blocks

- **Communication:** Drives the controllers and models. Enables communication between multiple agents and hierarchies.



- **Controller:** Supervisory controller to manage the device model to enforce system level constraints.



- **Model:** Represents the physics of the device being modeled. Examples of Distributed Energy Resources (DER) models include PV, Batteries, Wind, EVSE etc.

Models

- Data driven models that mimic the physics of the device being modeled:
  - Batteries
  - EVSE
  - Buildings
  - Wind
  - Solar

Controllers

- The Control algorithms that are proposed to integrate high penetrations of DERs on the grid.
- Examples include:
  - Distributed volt-var control
  - Realtime feedback-based optimization control - Virtual power plant control
  - Market based controls.

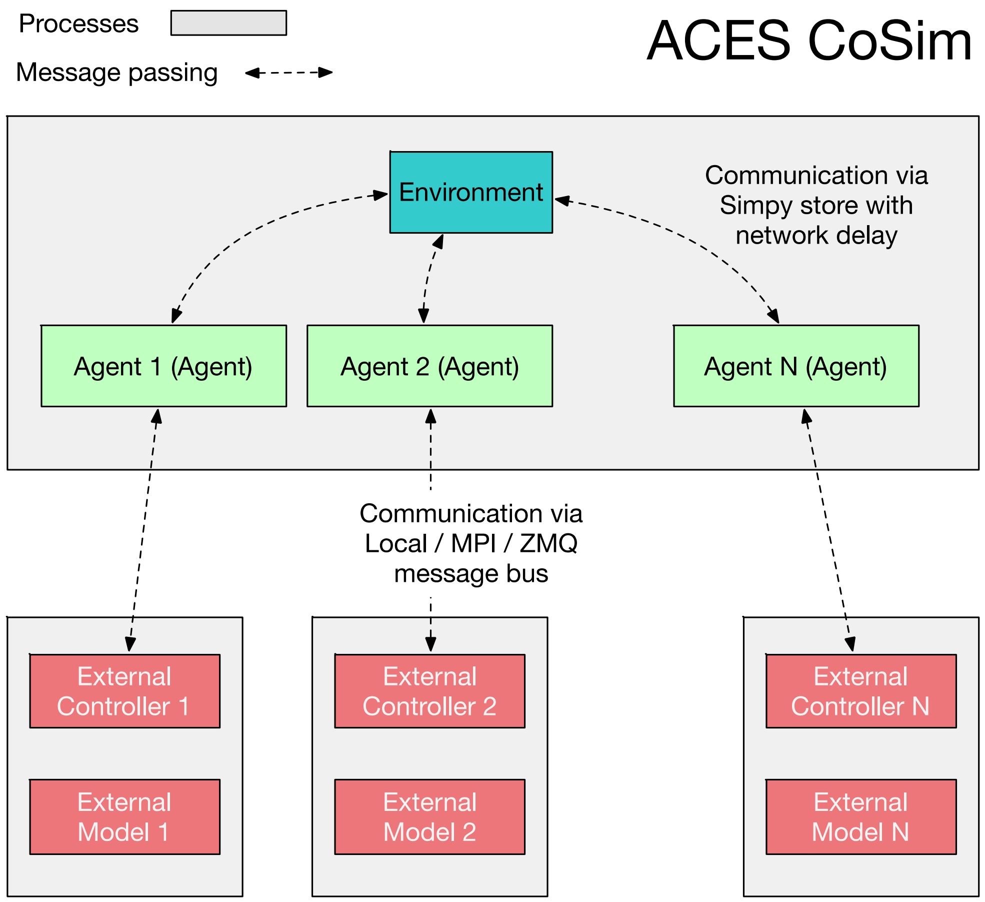
Communication

- Setup the communication hierarchy of the AES system.
- This includes communication pathways for different control architectures including hierarchical control.

Advanced Computational Energy Systems(ACES) CoSim

- **Co-simulation (ACES Cosim SWR-19-05)**
  - Multiple systems simulated together
  - Distributed
  - Degree of communication
  - Time coordination

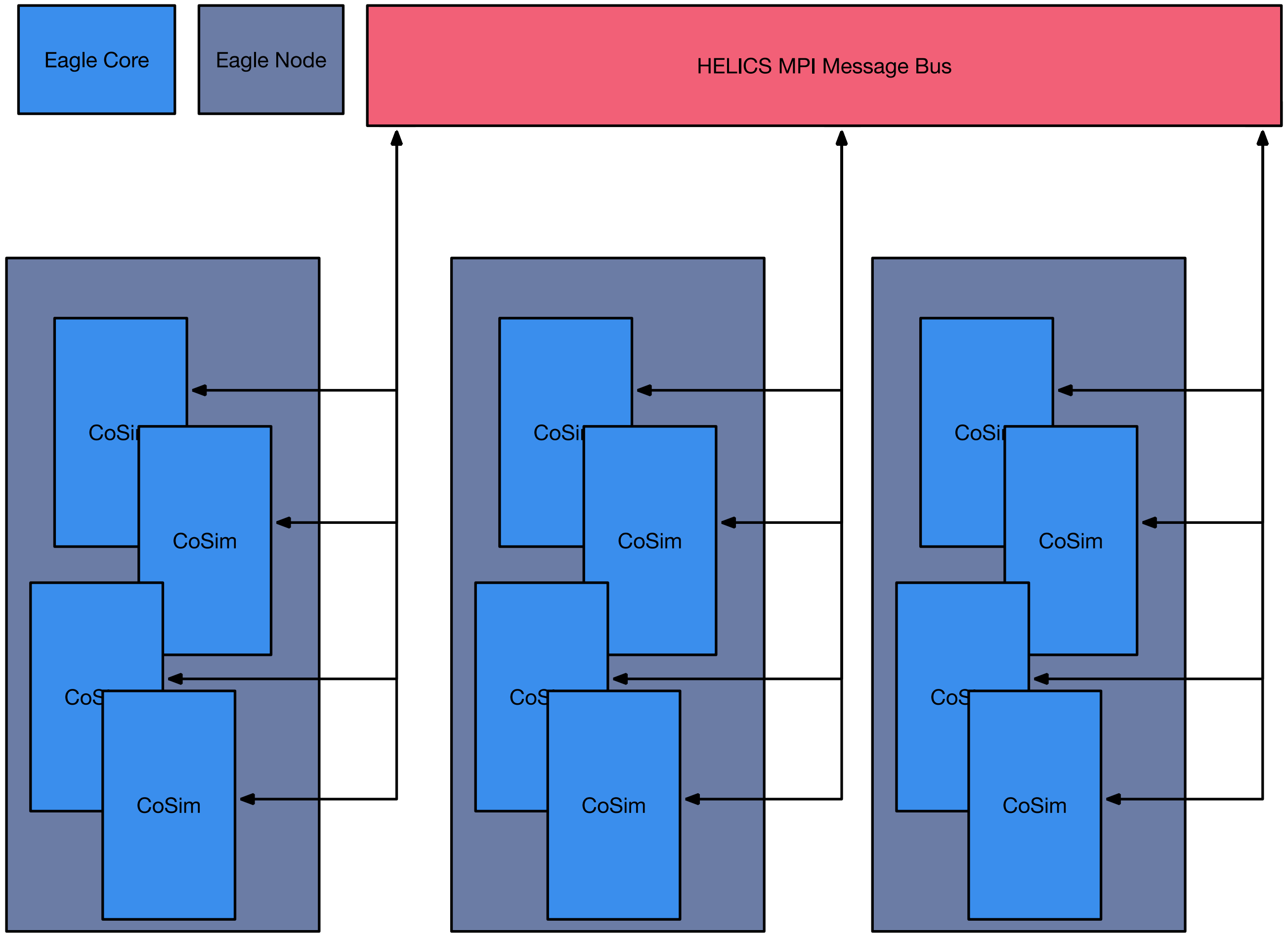
  OpenDSS+ controllers (HEMS, Pyomo, heuristic)



AES Framework – current implementation

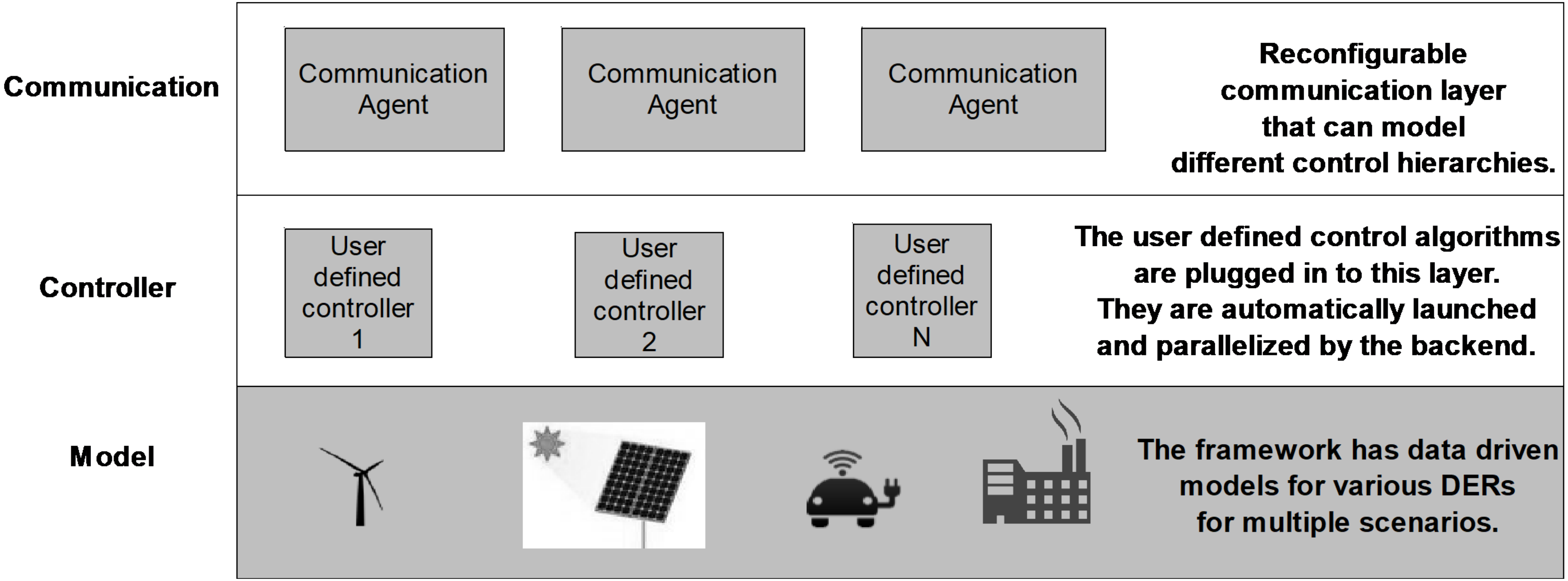
- Scalable HPC enabled co-simulation environment powered by CoSim and HELICS.
- CoSim is an agent-based modeling framework that excels at intra-node simulations while HELICS is a highly scalable hierarchical co-simulation engine that works well for inter-node communication.
- We require an intelligent way to distribute the components of the simulation across multiple nodes to enable better algorithm scaling as well as maximizing HPC performance metrics by taking advantage of HELICS and CoSim.

AES Framework using CoSim and HELICS on Eagle



Application of the AES Framework

- The AES computational framework provides a software testbed to rapidly develop, prototype and test emerging control algorithms and control hierarchies for DER integration.



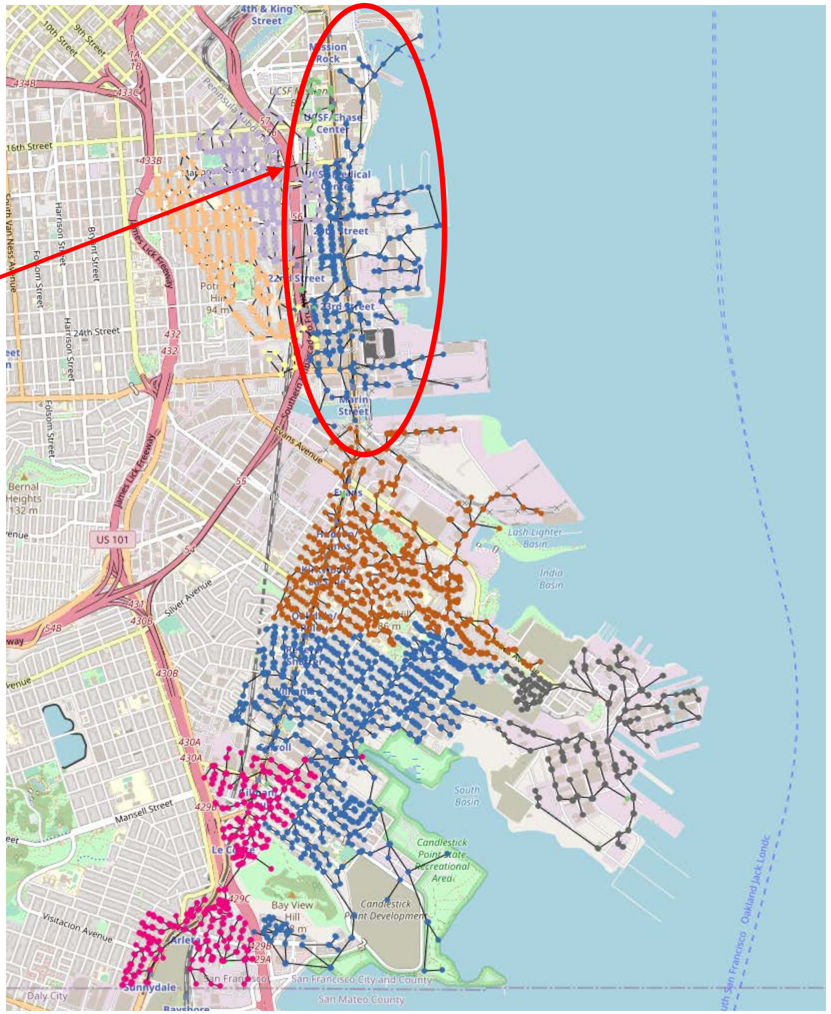
Simulations

A synthetic distribution feeder in region P1U of San Francisco, CA.

Simulating the impacts of integration distributed energy resources (DERs) on a single electric distribution feeder.

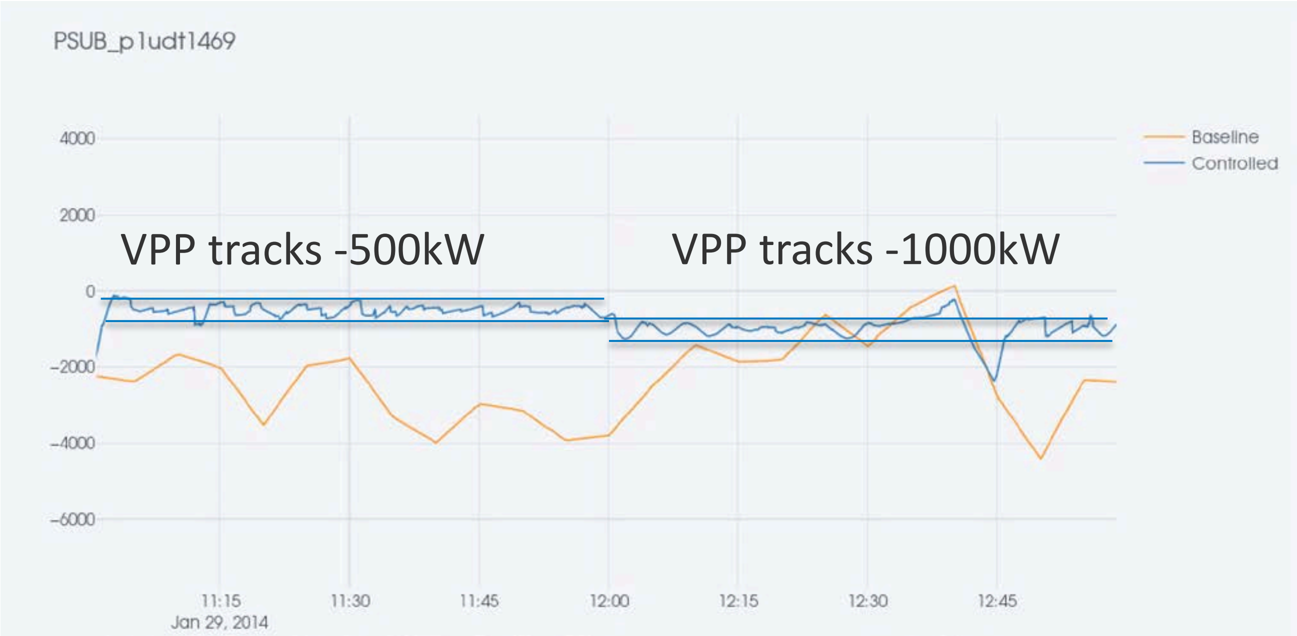
Synthetic feeders were obtained from the SMART-DS project.

Synthetic distribution network for region P1U of San Francisco, CA.

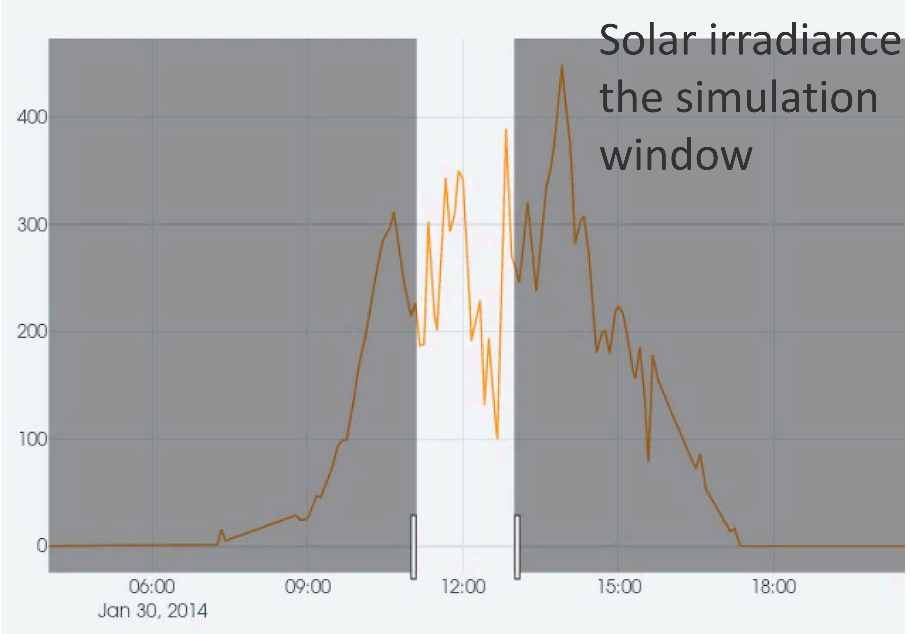


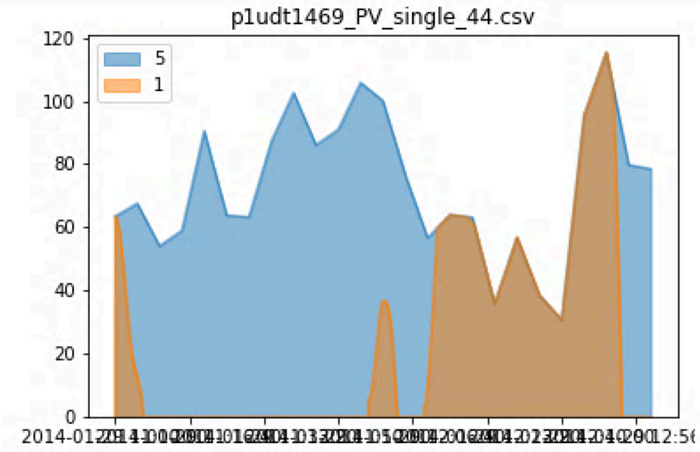
Simulating the impacts of integration distributed energy resources (DERs) on a network of electric distribution feeders.

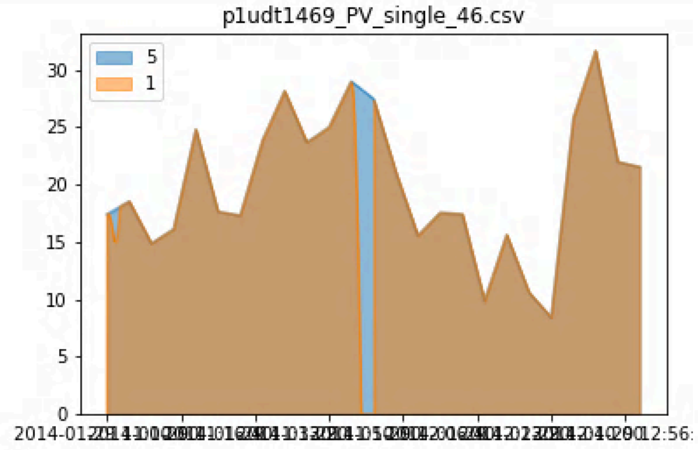
Feeder Level control

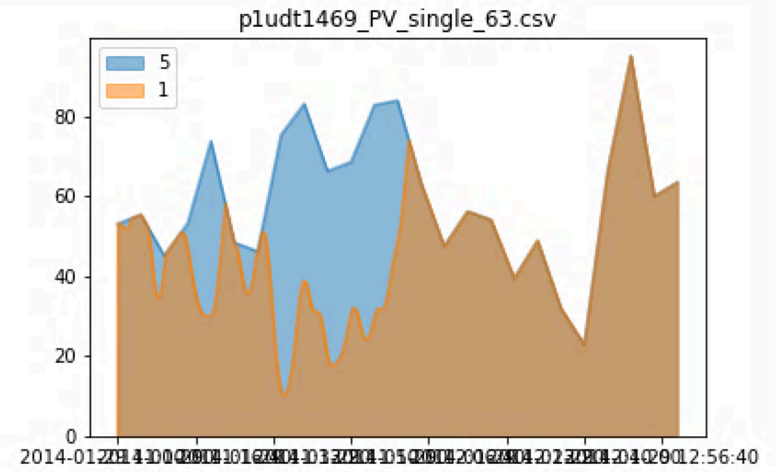


VPP controller from ARPA-E-NODES





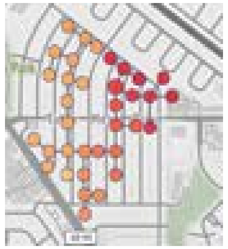




The blue color represents PV available,
The orange color represents the controlled PV.

Scalable software framework and control methods to address challenges in future energy systems

37-Node feeder



10s of DERs
10 AUs

10xDERs

123-Node feeder

100s of DERs
72 AUs

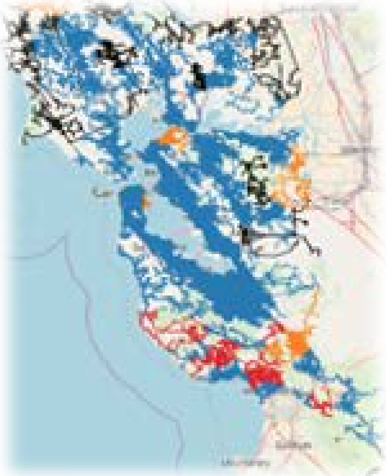
100xDERs

IEEE 8500-Node Feeder

>1000 DERs
10000 AUs

1000xDERs

Bayarea electric network



~ Millions of DERs
100000 AUs

Distributed Energy Resources (DERs) including Solar, Batteries, Wind, Controllable loads, Electric Vehicles etc.

Scaling to meet demands of future energy systems requires scalable control methods and communication architecture.

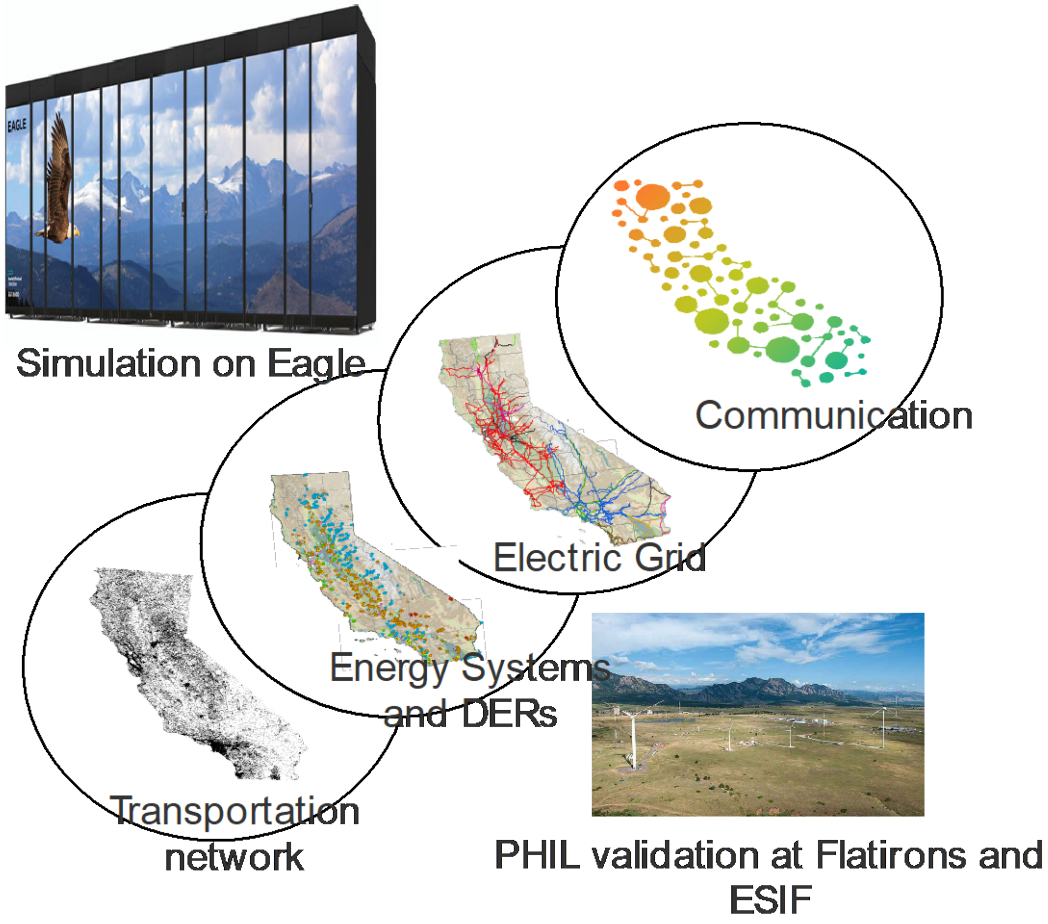
Future Work – Autonomous Urbanization

- **Immediate:** Uncontrollable loads -> Controllable loads
  - Building level control (presentation at 11:15am)
  - Charging station control (presentation at 3:15pm)

- **Up next:** Interactions of mobility and buildings

- Develop and demonstrate integrated **forecast**, **control**, and **intelligent infrastructure** capabilities of these edge devices on a large-scale simulation platform.

- Ability to demonstrate these capabilities on millions of devices using a **combination of simulation and HIL** at NREL's ARIES (Advanced Research on Integrated Energy Systems)



Thank you