# University of Toledo Transactive Campus Project

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University of Toledo

# Thank-you to our sponsors:


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U.S. DEPARTMENT OF ENERGY

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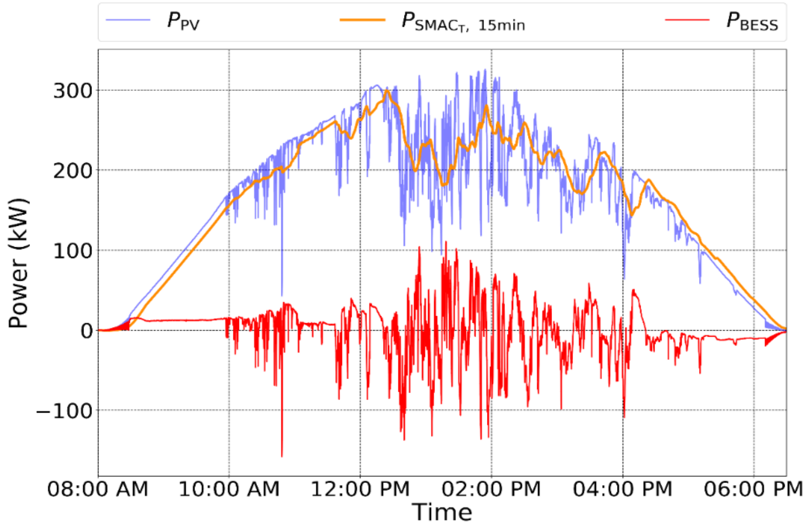
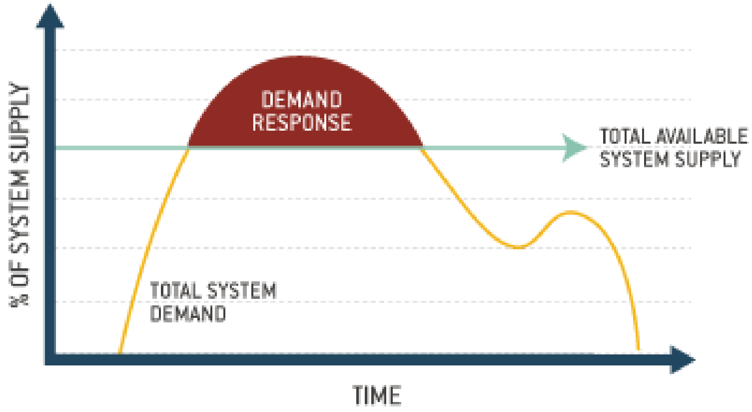
# Introduction

- Grid complexity due integration of distributed energy resources (DER)
  - Short term renewable energy variability (PV)
  - Balance between supply and demand
- Requirements for management of complexity
  - Sensing & data
  - Communication
  - Operational control
  - Objectives
  - Mechanism for coordination

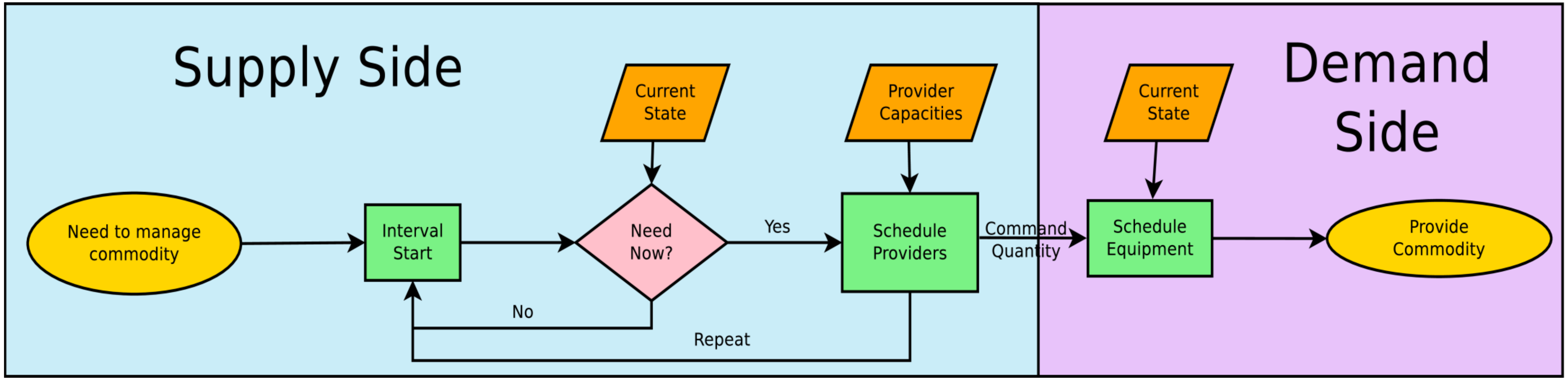



[ http://encorp.com/demand-response/ ]

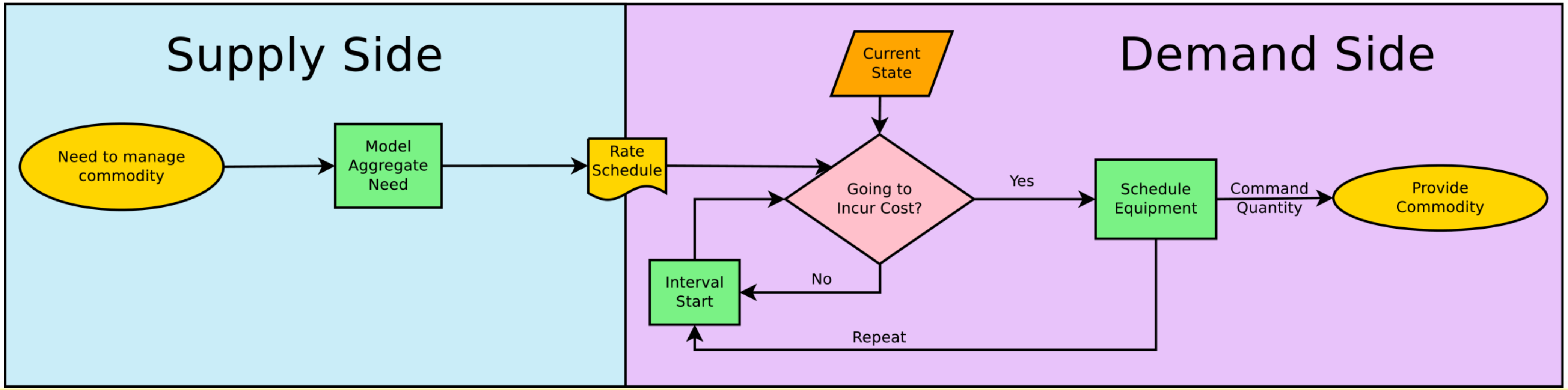
# Command-based strategies

- Load adjusted in response to external signal.
- Signal sent to specific recipients.
- Excess reserve still required to manage missed targets.



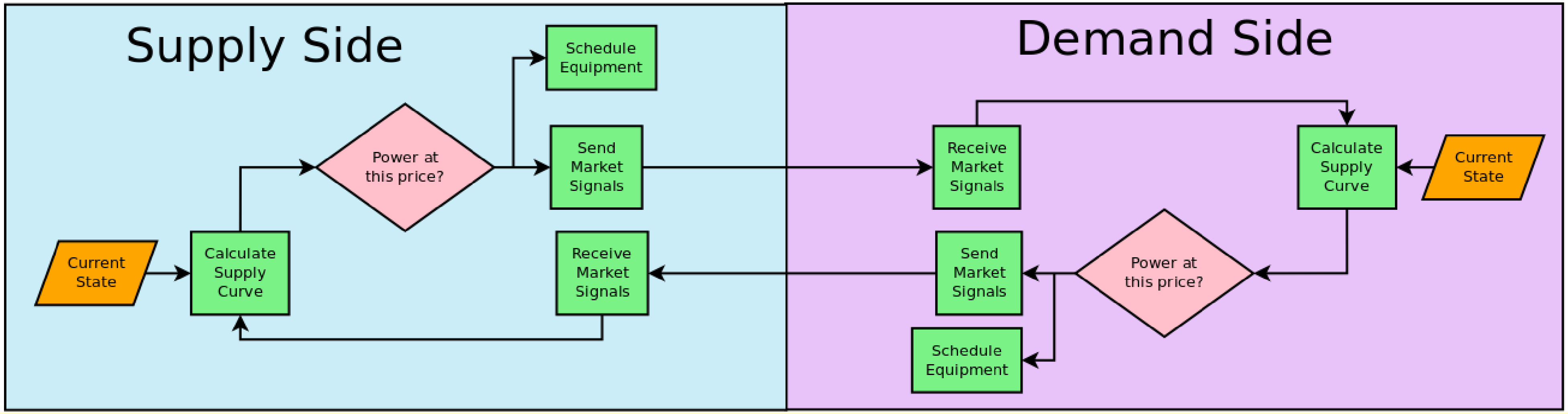
# Price-based strategies

- External incentive built into tariff structure.
- Decision making is entirely local.
- Simplest example: metered energy.
- Widespread use of riders – e. g. demand charges.



# Transactive strategies

- Bi-directional signaling.
- Better efficiency than commanded response.
- Better coordination than incentive response.
- Does not require sharing internal data.



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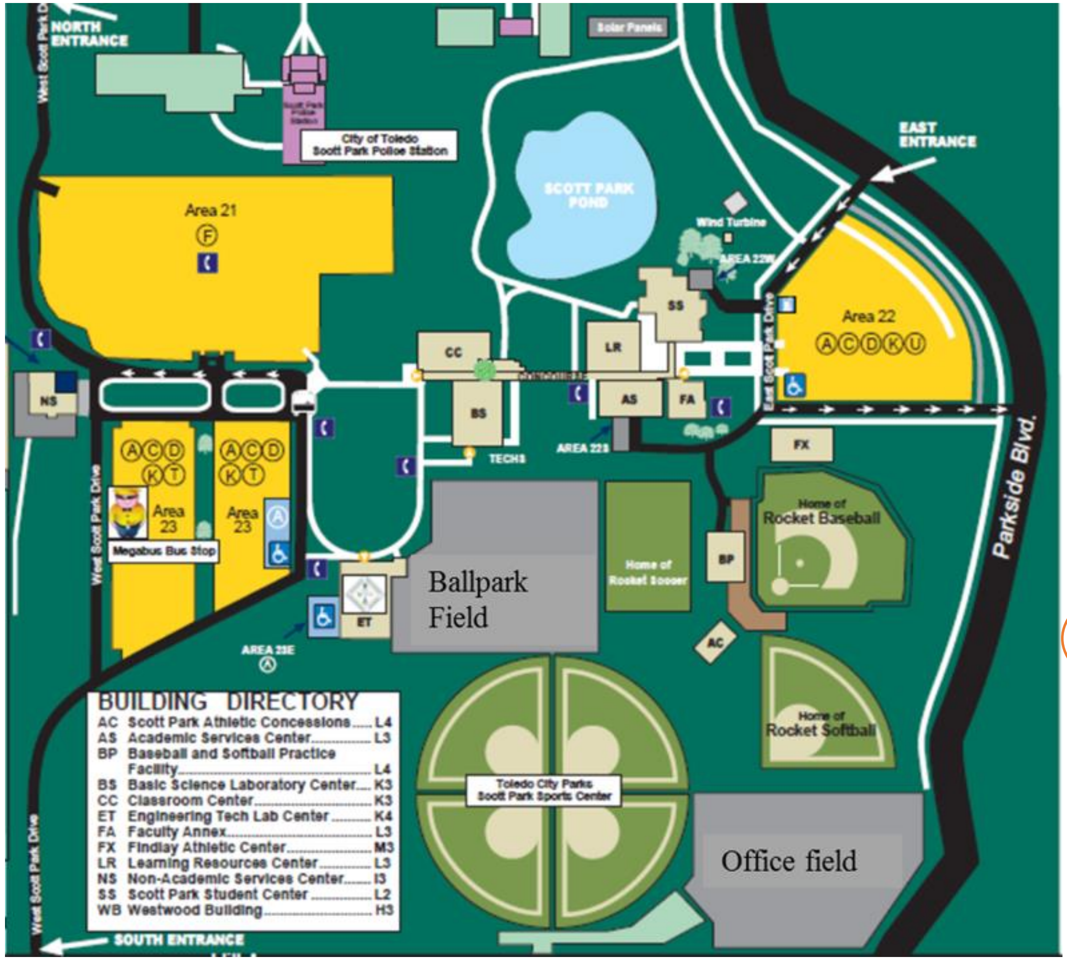
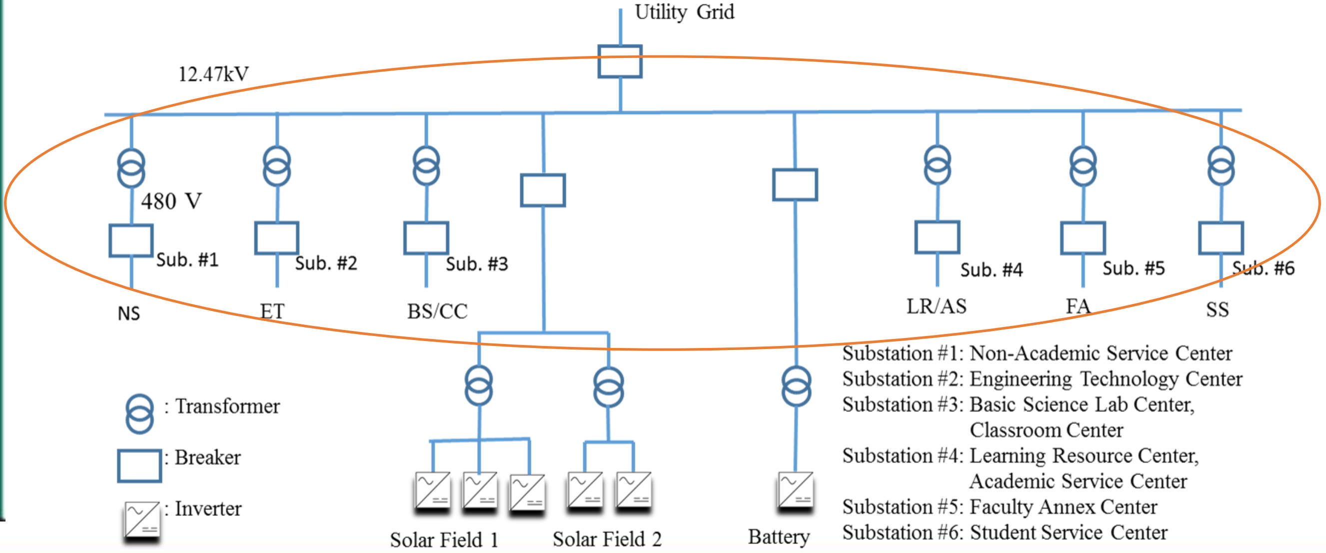
# Established Communication at Scott Park Campus by using Eclipse VOLTTRON$^{TM}$


https://www.marketing91.com/five-types-of-communication/

# Scott Park Campus (SPC)




- 8 buildings:
  - 4.6 MW of controllable loads
  - 730 kW average campus load
- 1 MW photovoltaic generation:
  - (Ball park field – 360kW)
  - (Office field- 640 kW)
- Battery energy storage system (BESS):
  - 130kWh
  - 125kw



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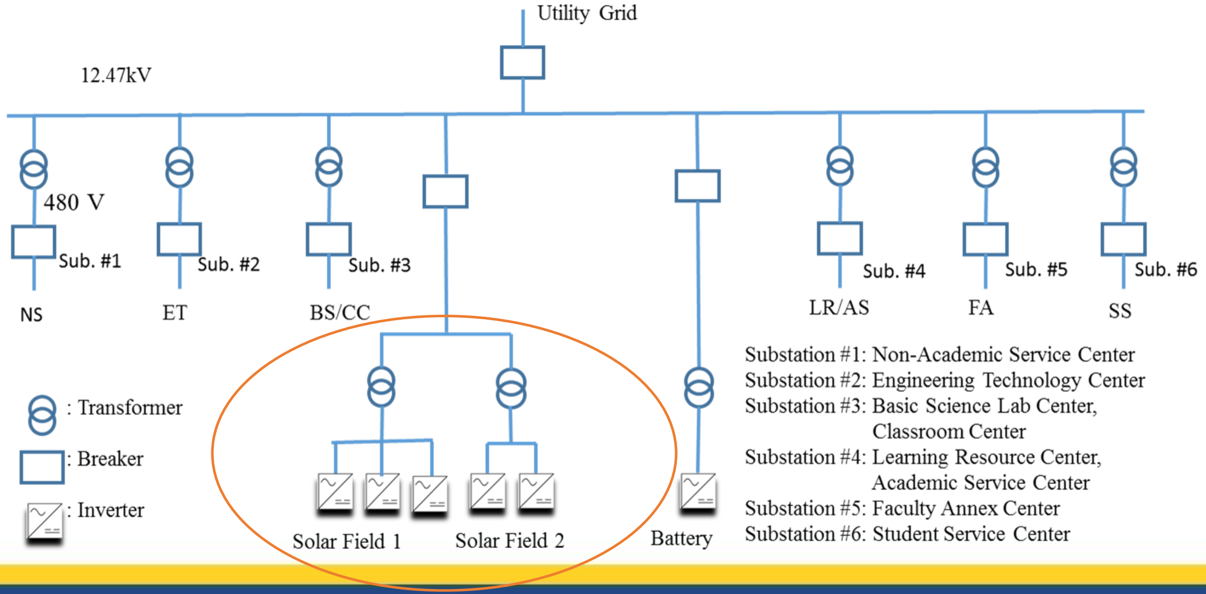
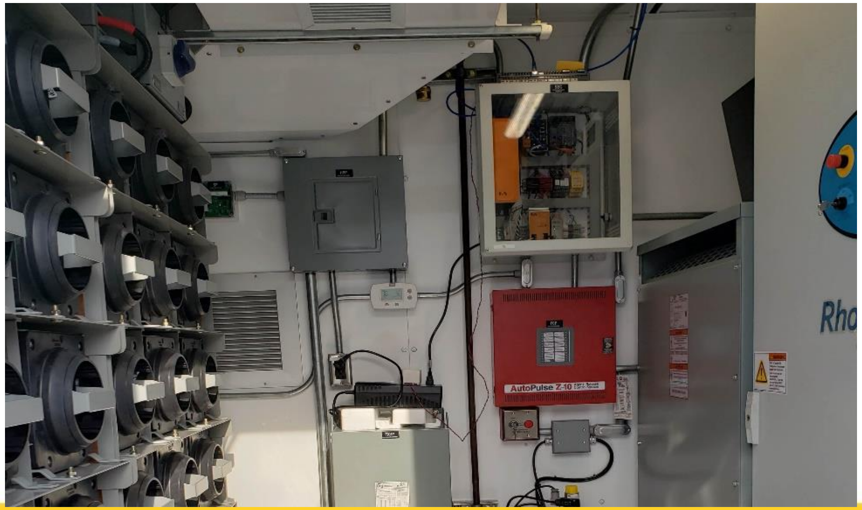


# Scott Park Campus (SPC)

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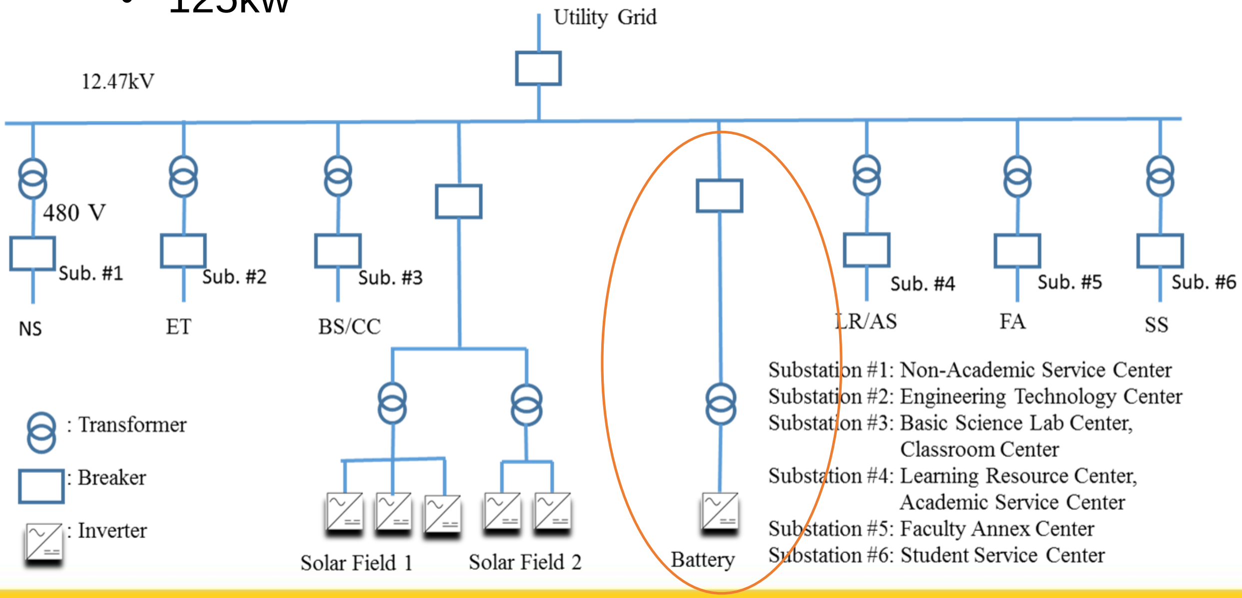

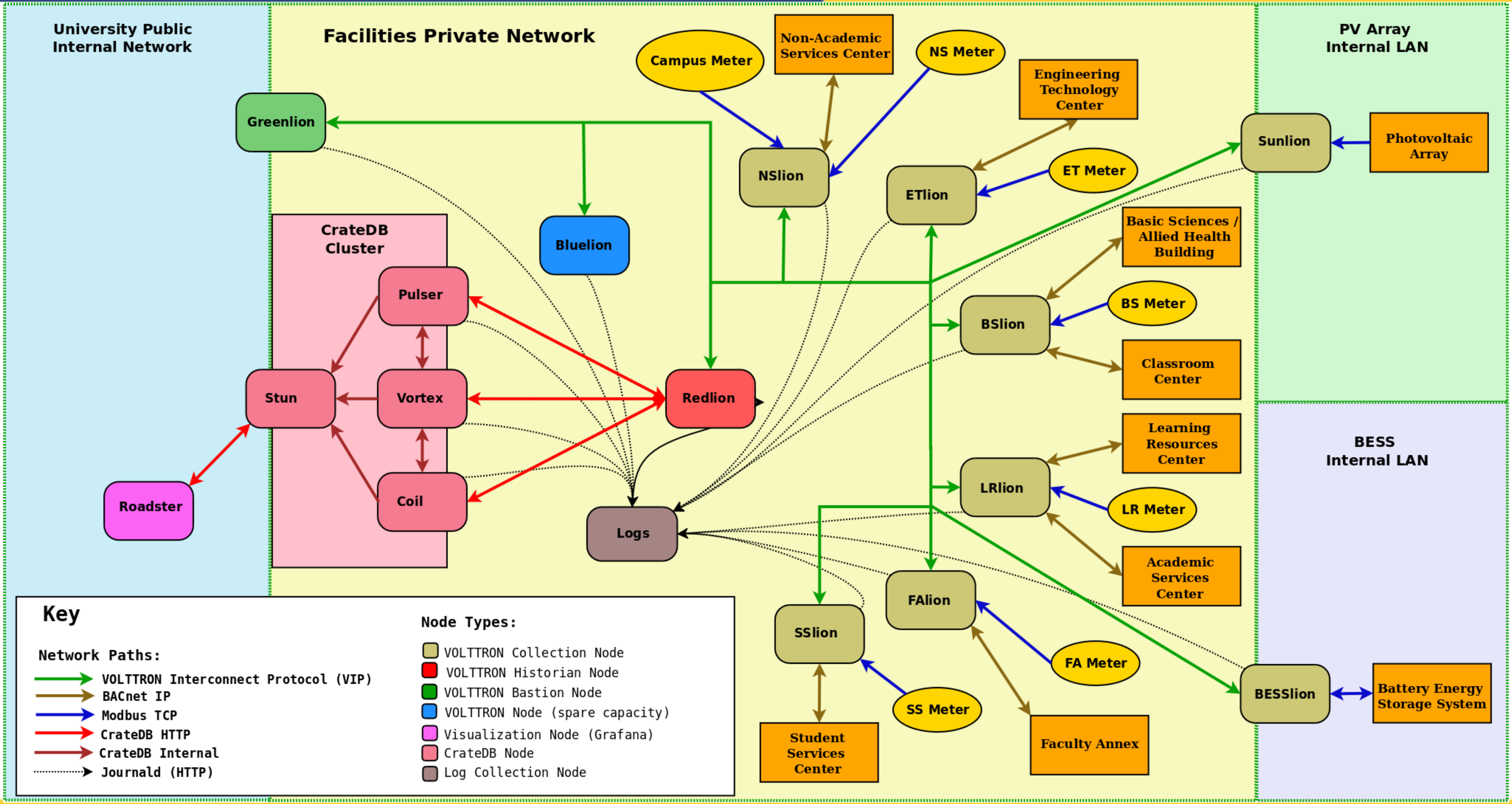
University Public Internal Network
Facilities Private Network
PV Array Internal LAN
BESS Internal LAN
CrateDB Cluster
Greenlion
Bluelion
Pulser
Stun
Vortex
Coil
Roadster
Redlion
Logs
Campus Meter
Non-Academic Services Center
NS Meter
NSlion
Engineering Technology Center
ET Meter
ETlion
Sunlion
Photovoltaic Array
Basic Sciences / Allied Health Building
BS Meter
BSlion
Classroom Center
Learning Resources Center
LRlion
LR Meter
Academic Services Center
FAlion
FA Meter
Faculty Annex
SSlion
SS Meter
Student Services Center
BESSlion
Battery Energy Storage System
Key
Network Paths:
VOLTTRON Interconnect Protocol (VIP)
BACnet IP
Modbus TCP
CrateDB HTTP
CrateDB Internal
Journald (HTTP)
Node Types:
VOLTTRON Collection Node
VOLTTRON Historian Node
VOLTTRON Bastion Node
VOLTTRON Node (spare capacity)
Visualization Node (Grafana)
CrateDB Node
Log Collection Node

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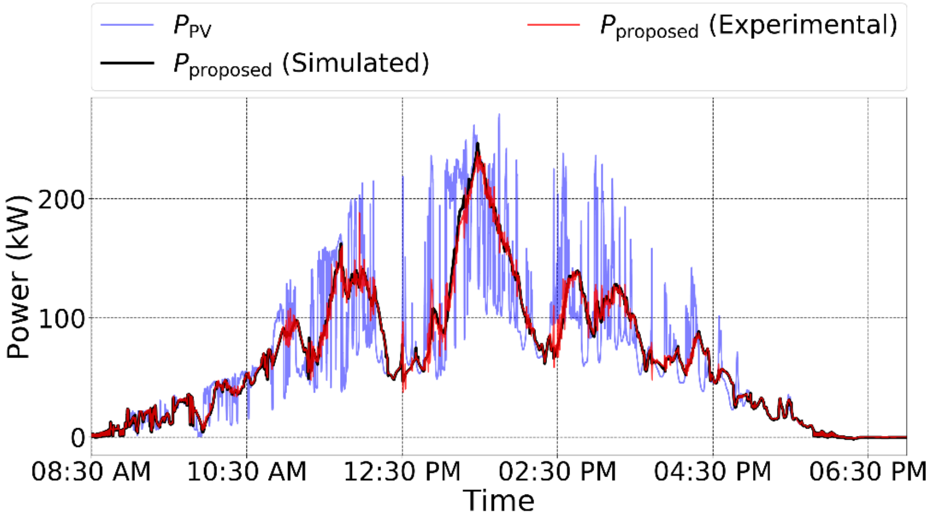
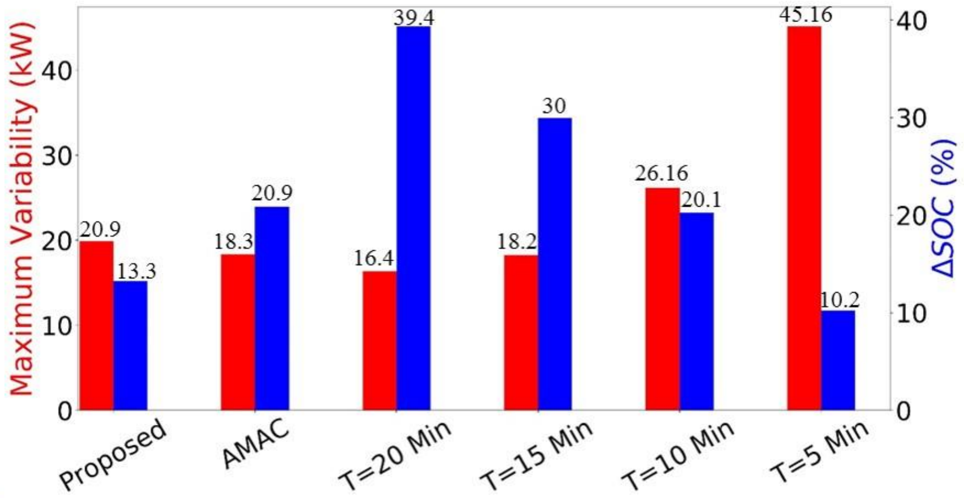
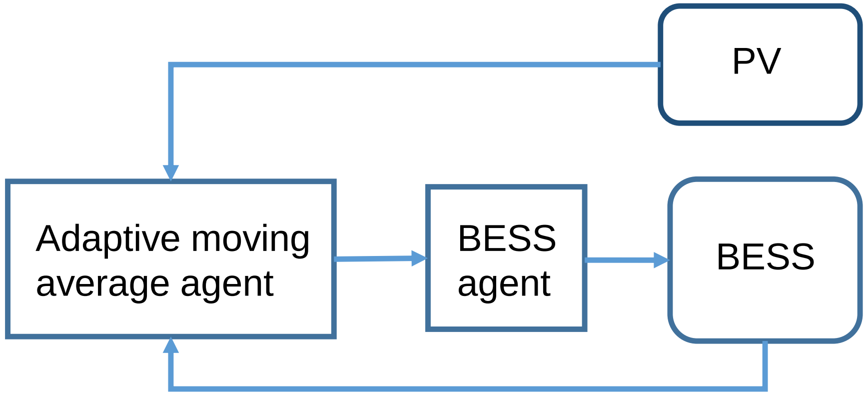
# PV Variability Mitigation




Adaptive moving average can achieve following goal:

- Better trade-off between battery utilization and degree of smoothness
- Better battery life
- Require lower capacity of battery

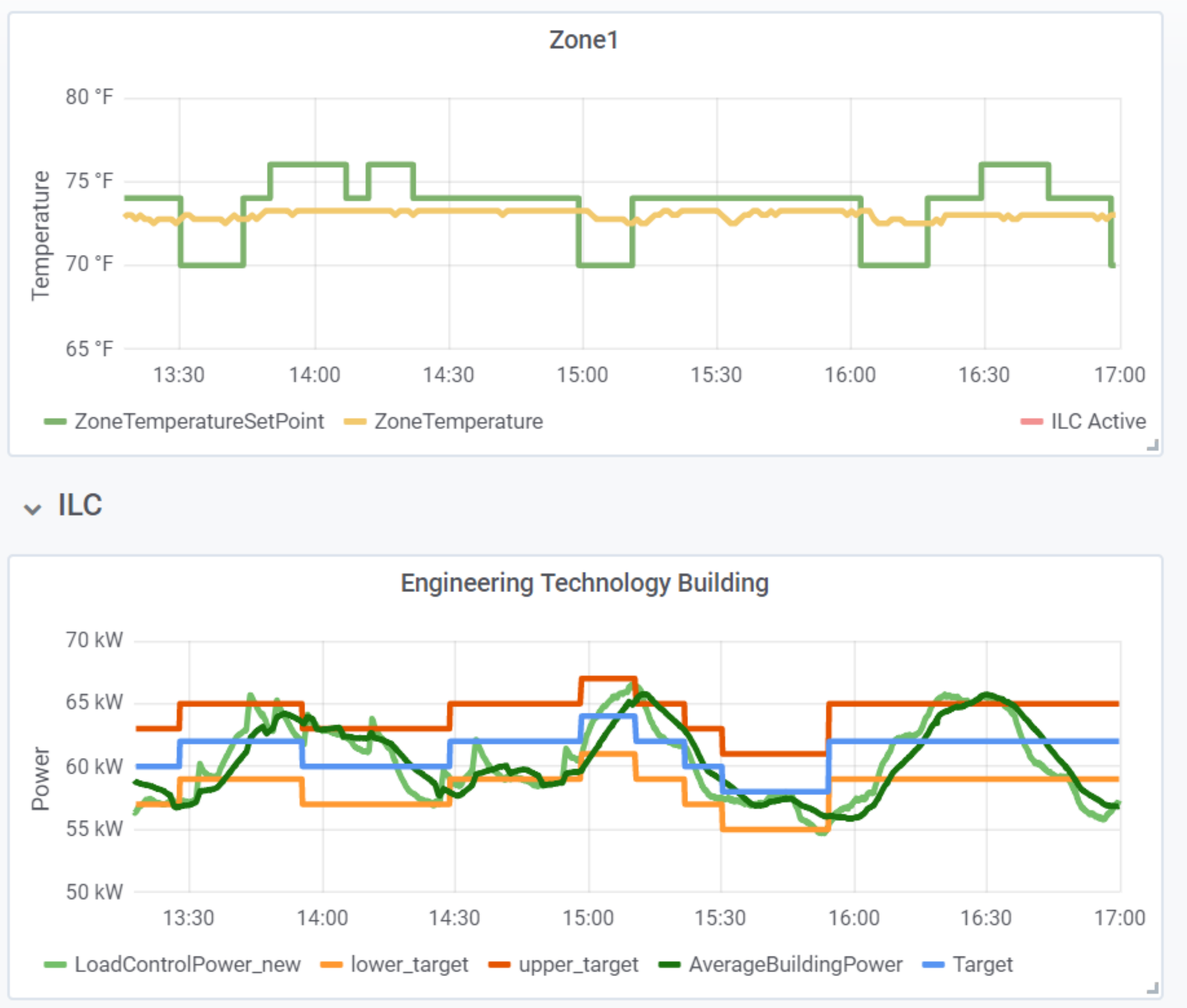


# Intelligent Load Control (ILC)

- Developed by PNNL
- ILC has been tested with six buildings of SPC
- Three basic elements of ILC:
  - Goal (Target): maintain peak consumption, maintain energy budget
  - Criteria: room types, rated power, zone airflow
  - Actuation: temperature set point

# Bi-Directional ILC

- Can both curtail and augment power
- Able to follow power schedule using the flexibility of building
- Uses
  - More aggressive load shaping
  - Contract power level in a transactive market



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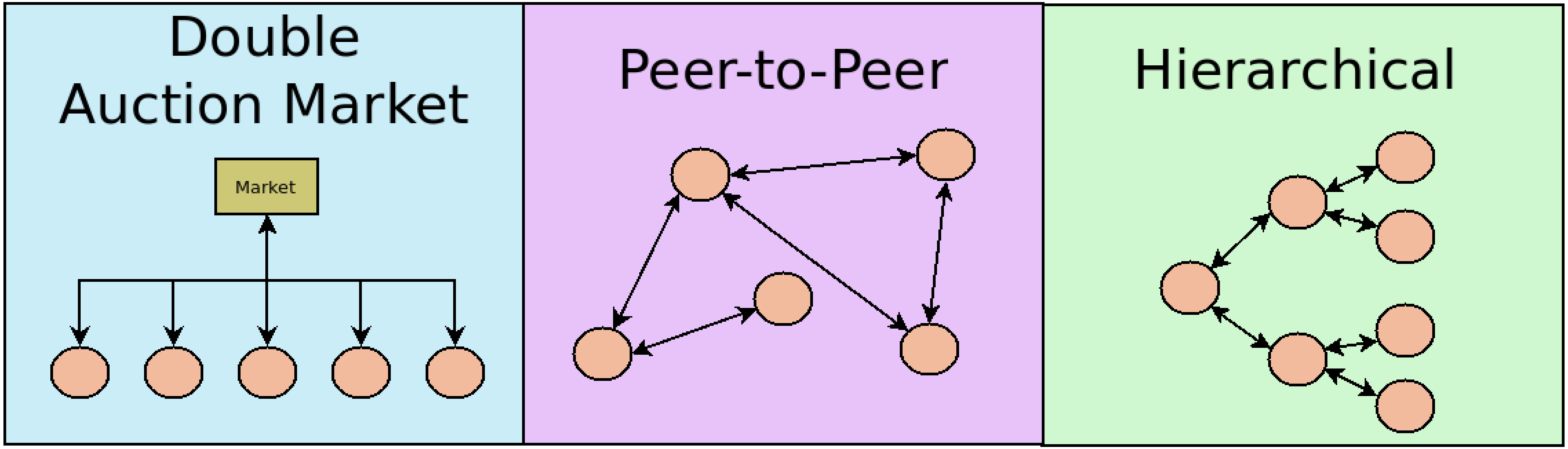
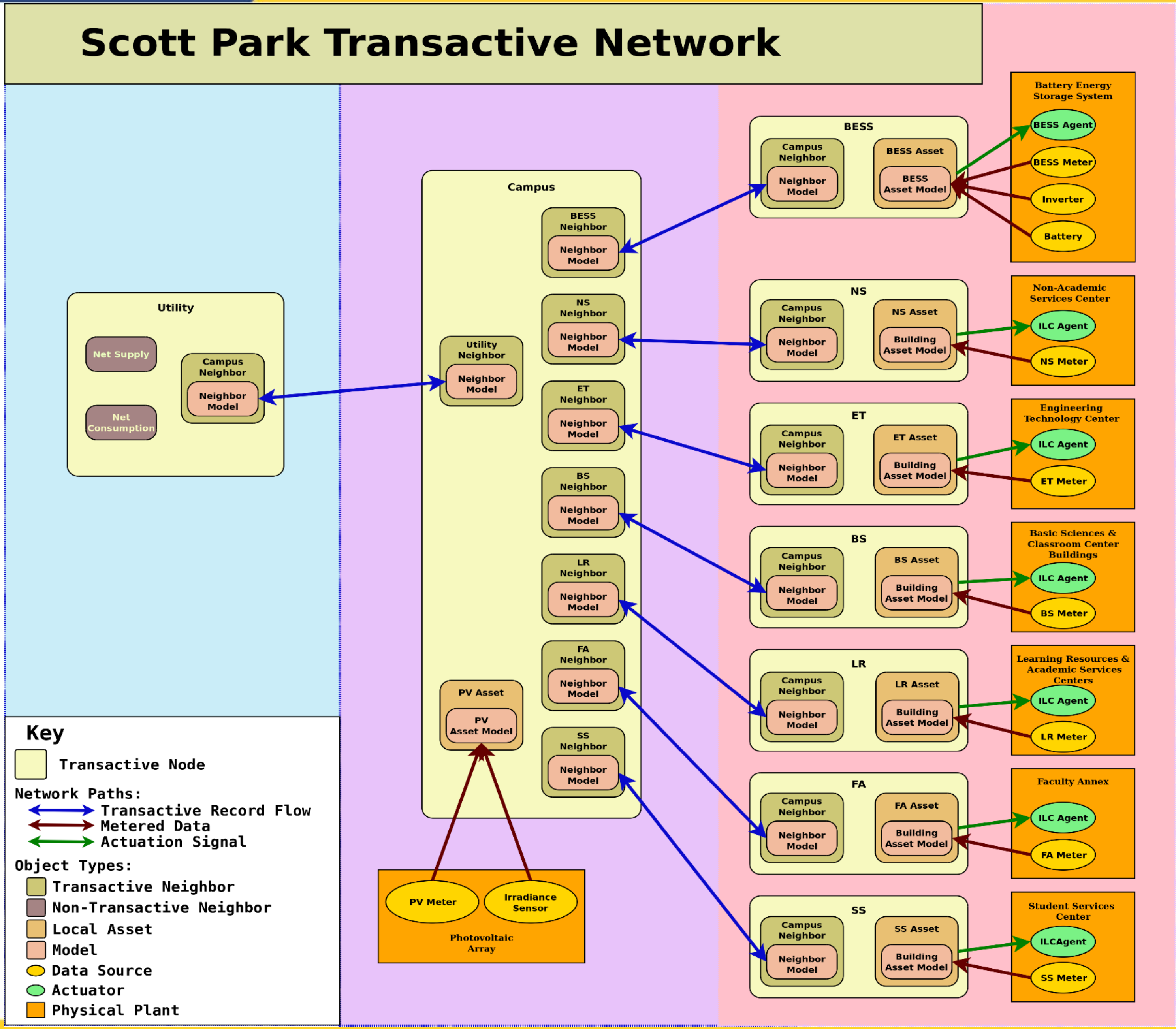
# Different Market Strategies



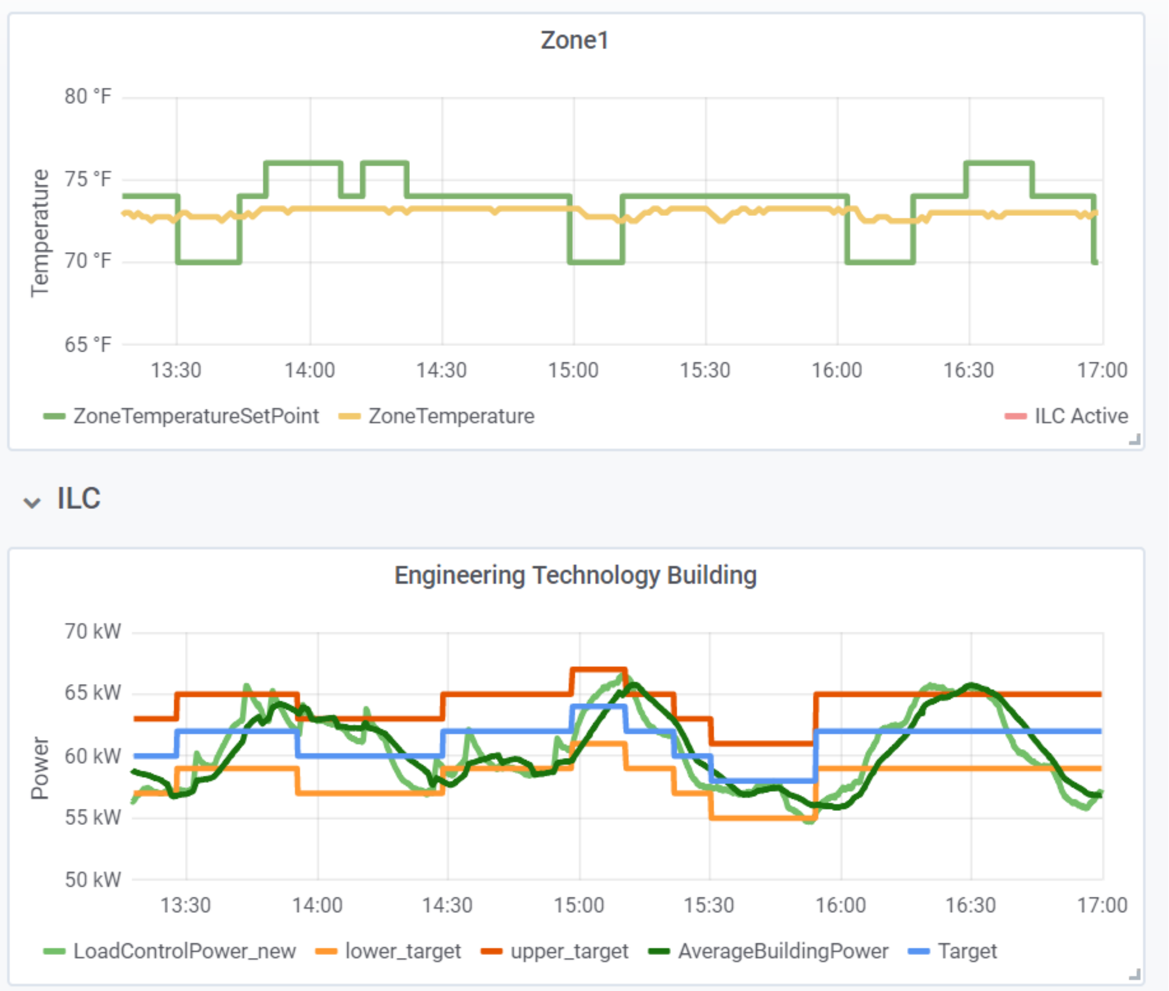
# Transactive Network System (TNS)

- Iterative process
- Signals passed hierarchically between levels
  - Downstream until a node fails to balance
  - Upstream until balance is restored
- Utility initiates market w/ supply curve
  - At Scott Park, dynamic utility pricing is modeled using LMP
- Each node:
  - Keeps models neighbors & assets
  - Optimizes its own internal objective
  - Actuates assets as needed



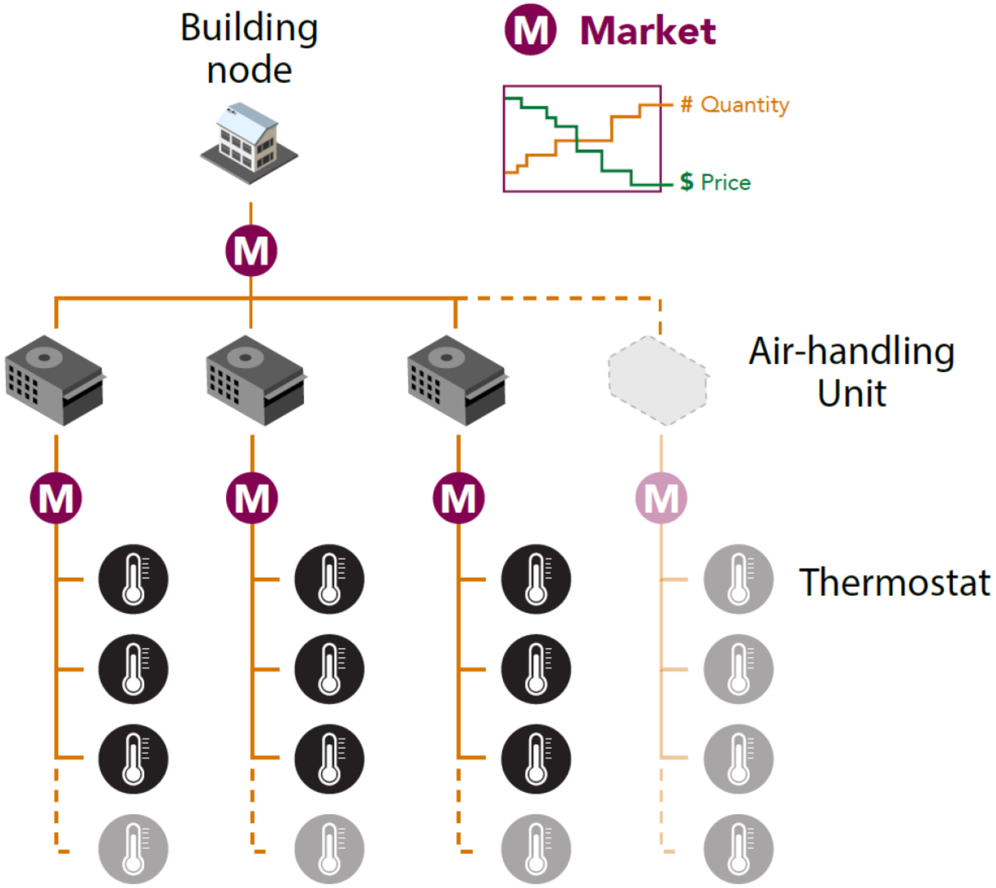
# TNS Building Control (ILC)

- Building demand & flexibility:
  - Predicted with ANN
  - Trained with historical data from building
- Control:
  - Bi-Directional ILC
  - AHP handles prioritization of zones
  - Zones are both augmented and curtailed
  - Used to follow a target schedule



# TNS Building Control (TCC)

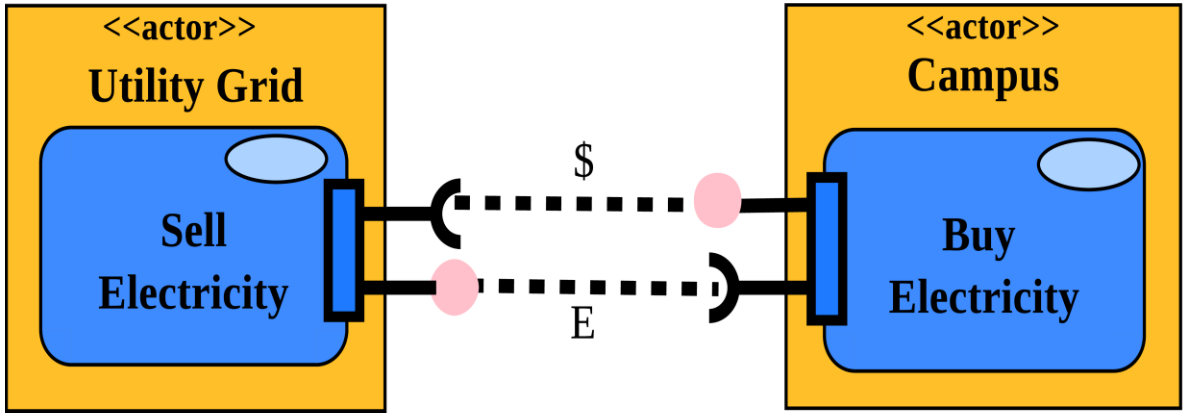
- Building demand & flexibility:
  - Demand curves are discovered using first order models of zones
  - Zones participate in intra-building double-auction market
- Control
  - Market clearing price corresponds to a point on demand curve for each zone
  - Each zone is always actuated in accord with its own demand curve




[ Robert Lutes, A Look at a VOLTTRON™ Use Case: Transactive Control and Coordination, Pacific Northwest National Laboratory VOLTTRON™ 2017 ]

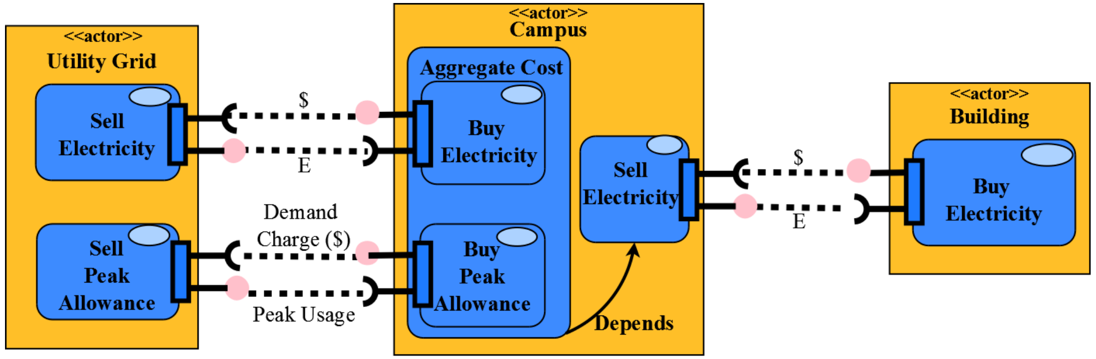
# Economic Market Interface

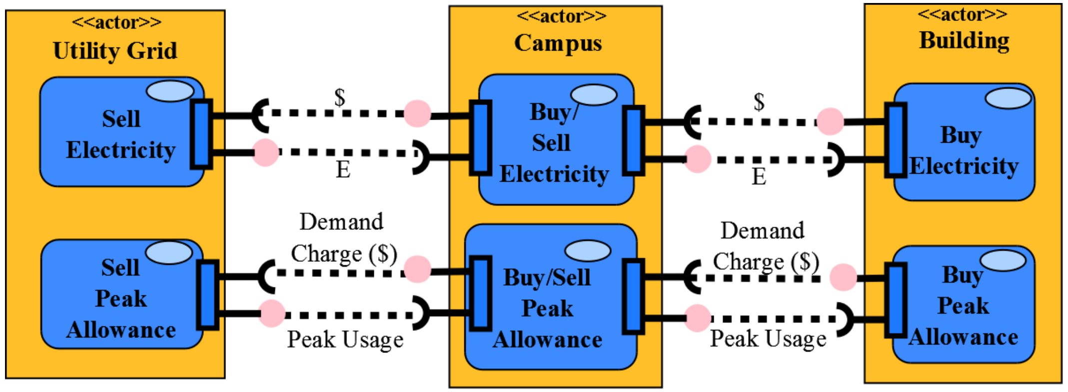
- Normal day dynamic pricing
  - λ depends on LMP.
- Constrained feeder
  - Manage constraint w/ changes to λ.
- Inflexible consumer
  - No flexibility in one or more directions.
- Spot market for excess of contract
- Contract at original bid price w/ higher prices for consumption greater than bid level.
- Unpredicted disturbance
  - One or more assets/actors fail to behave as modeled in short or long time-scale.



# Use Case 1- Utility Grid to Building Market

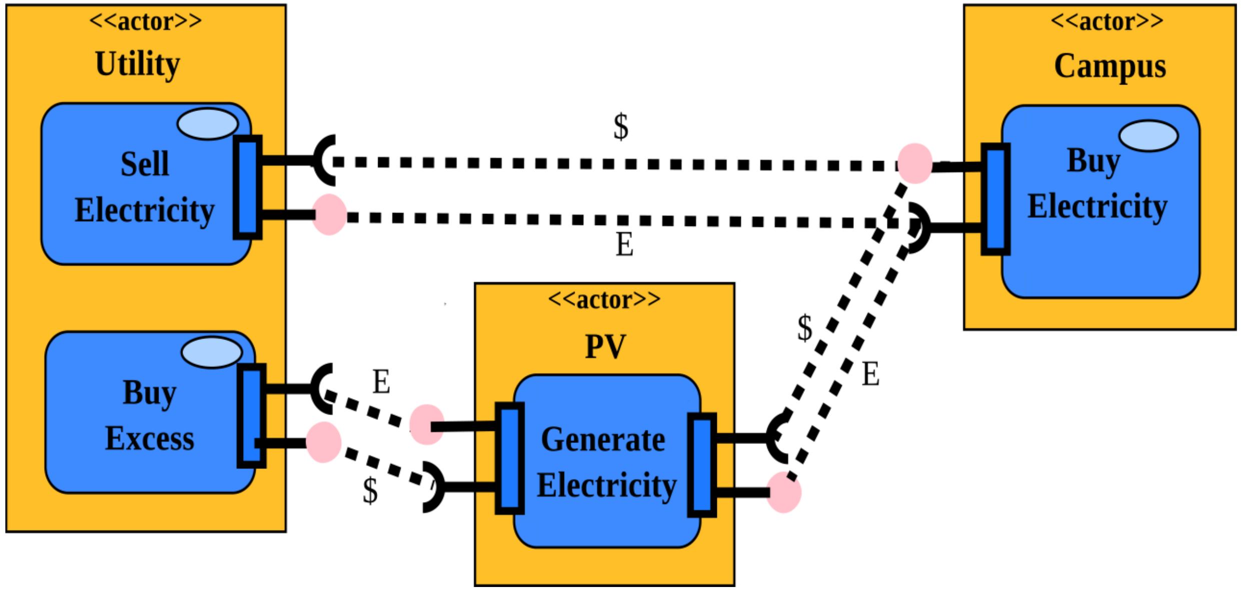
- Peak market
  - Demand Charges in Dynamic Pricing
  - DC added to objective and/or λ calculations. Sub scenarios
  - for penalty in rolling or following DC period.
- Peak-mitigation service
  - Consumer sells max-peak contract w/ penalty for
  - non-compliance.
- Buy allowances
  - No DC if allowance is honored, incur penalties if not.



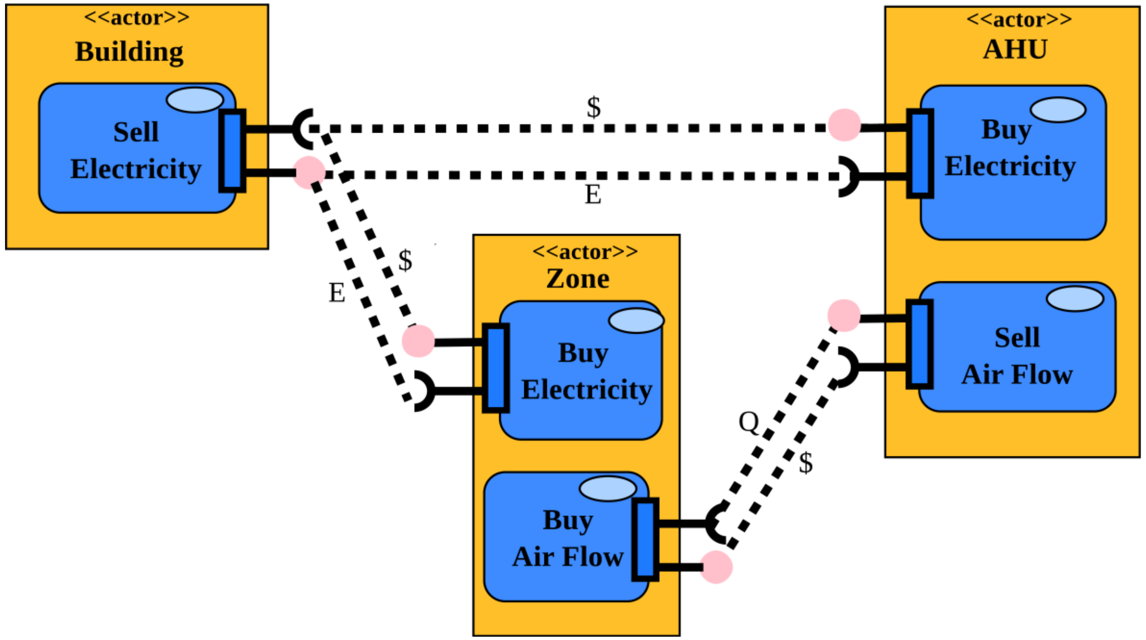



# Generation Use Cases

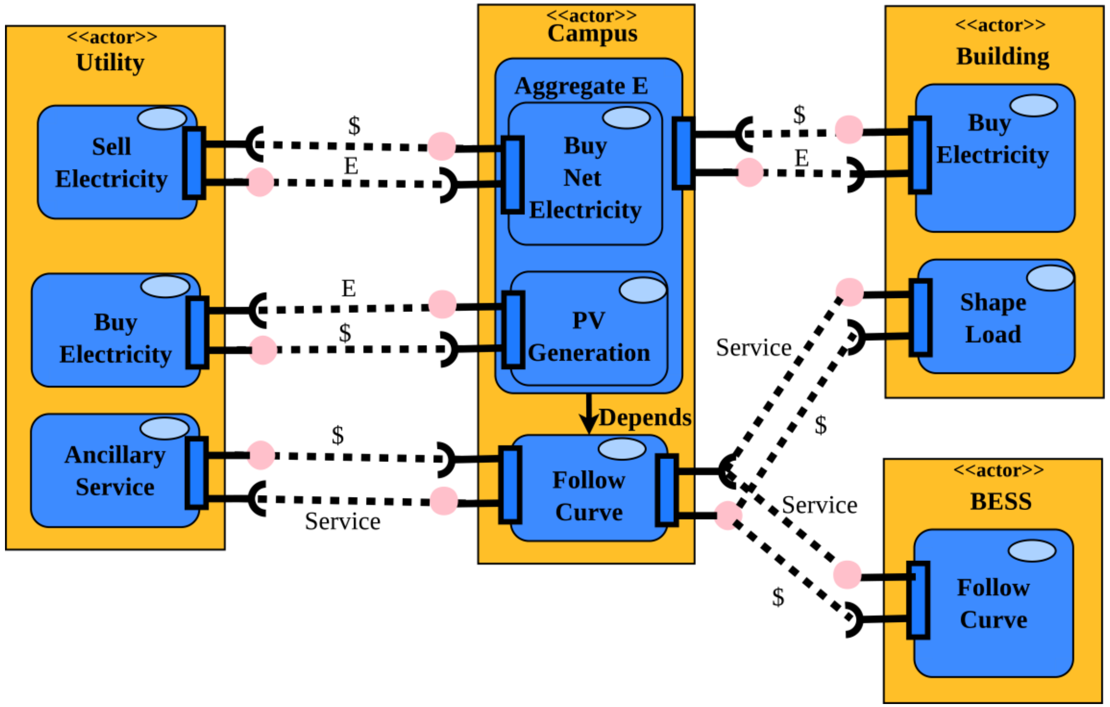
- Uniform rates:
  - Net metering w/ retail export.
- Stepped rates:
  - Different rates for export, possibly w/ or w/o net export.
- Dynamic rates:
  - Consumption and/or generation rates vary.



# Additional Use Cases




**Intra-Building Pseudo-Markets**




**Ancillary Use Cases**