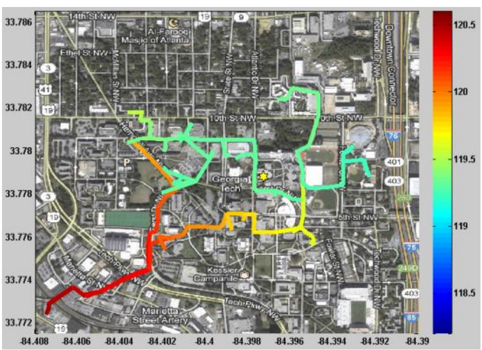

Smart Energy Campus

A Smart Grid Test Bed for Advanced Modeling, Simulation and Decision-Making

ECE Research Group

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Smart Energy Campus

- Objective:

  The test bed has been built to explore various possibilities for the future smart grid in order to
  - improve system reliability,
  - enhance system capacity to host renewable energy, and
  - allow interactions between energy providers and consumers.

- The smart energy campus

  is a living smart grid test-bed of Georgia Tech, which
  - Covers 200 buildings and
  - Has more than 400 smart meters,
  - 3 years of AMI data (15 minutes resolution),
  - State-of-the-art IT system for data collection and management

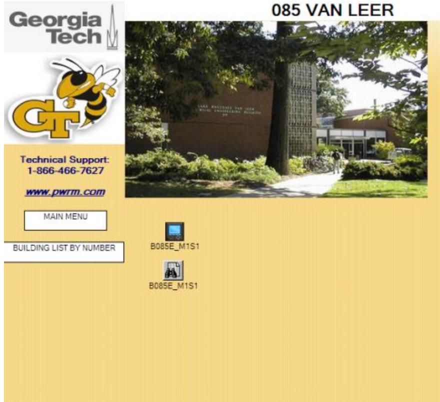
Outline

- Data Management
  - AMI data management
  - GIS data integration
  - Robust distribution system state estimation
- Advanced Load Modeling
  - Roof-top solar systems
  - Electric vehicles
  - Time-variant load modeling
- Long Term Planning
  - Campus renovation and expansion
  - Shuttle electrification
  - Energy Storage
- Visualization
- Demand Response & Real-time Pricing

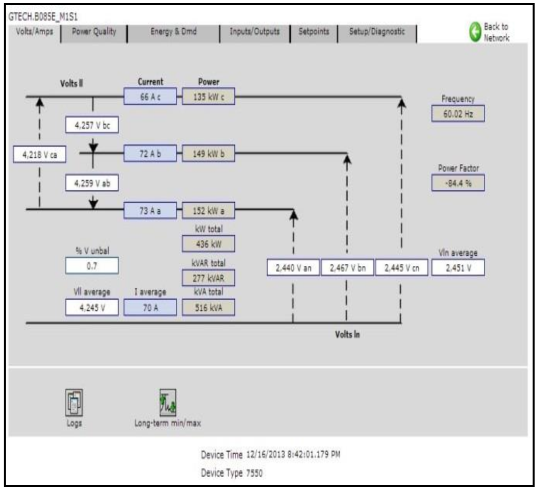
AMI Data Management

- Smart meters
  - Installed in more than 200 buildings
  - 400 main meters and sub-meters
  - Real-time data acquisition
- Historical database
  - ION database (facility)
  - SQLite database (research)
- Data Access
  - API request (upon authorization)
  - Web-based dashboard through desktop or smart phone
  - Interactive visualization (Java-based)

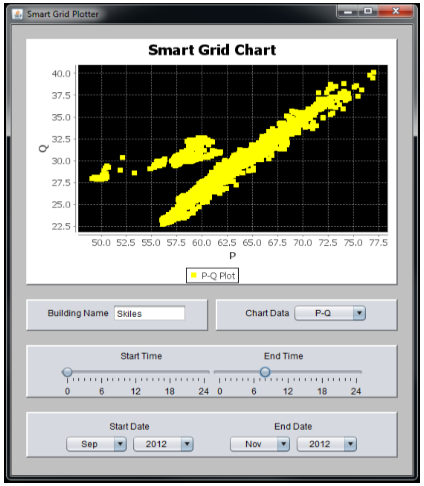
ION Webreach Main Menu



Building Menu

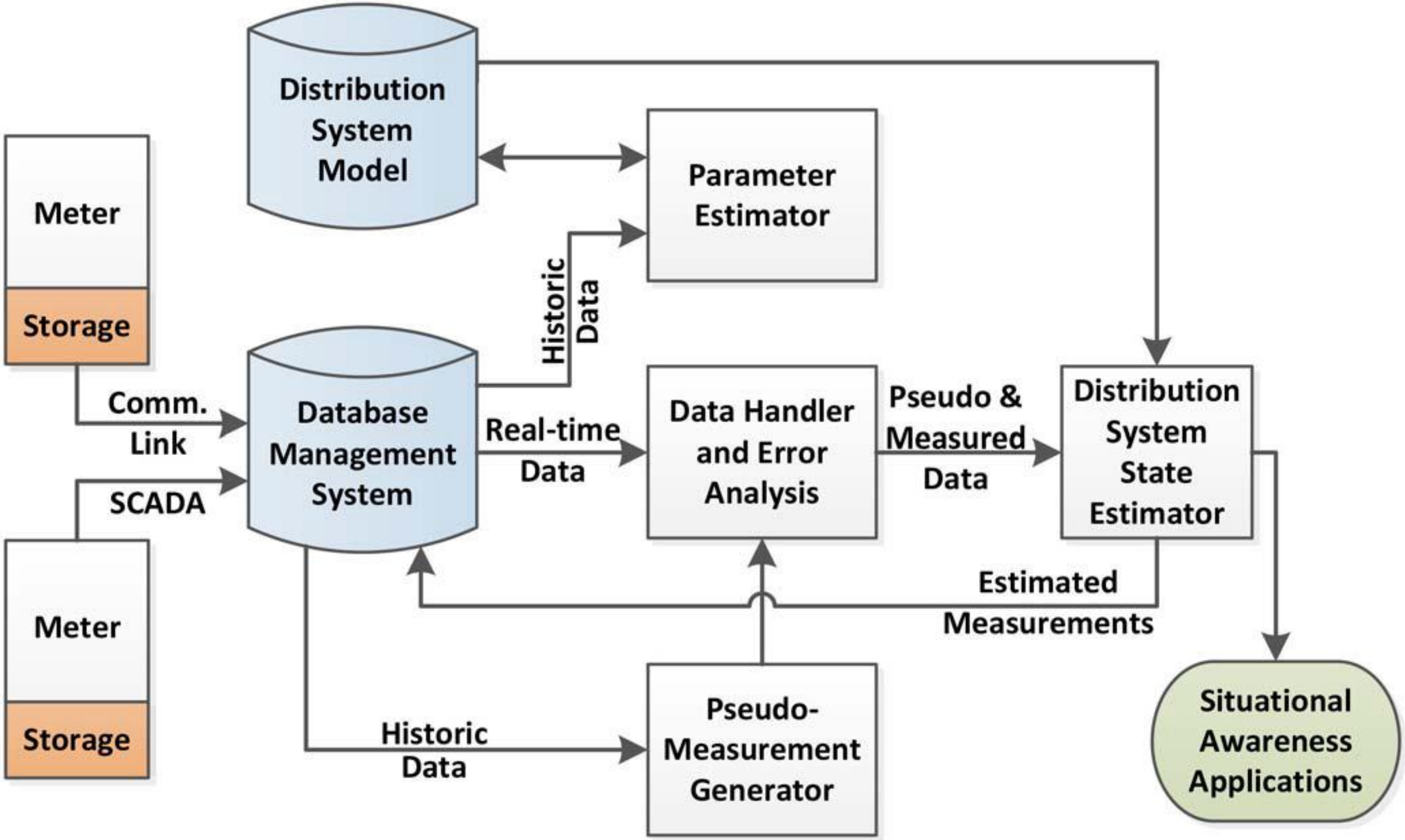


Building Meter Measurements



Interactive Tools

Robust Distribution System State Estimation

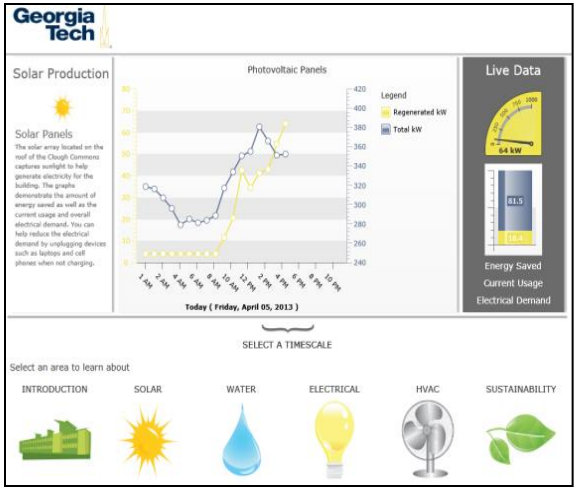


Advanced Load Modeling

- Roof-top Solar Systems
- Electrical Vehicle Charging Load
- Time-variant Load Model

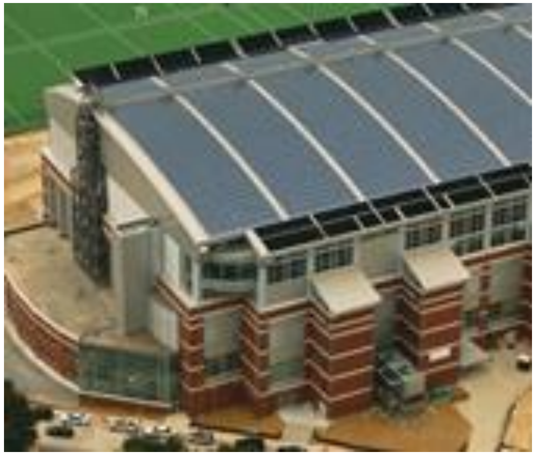
Load Modeling: Solar Photovoltaic

- Three roof-top PV systems:
  - Campus Recreation Center (CRC)
  - Carbon Neutral Energy Solutions Laboratory (CNES)
  - Clough Undergraduate Learning Commons (Clough)
- CRC PV array was installed in 1996, which was one of the largest roof-mounted PV system.
- Continuous monitoring cumulate valuable data.



ION Webreach Interface

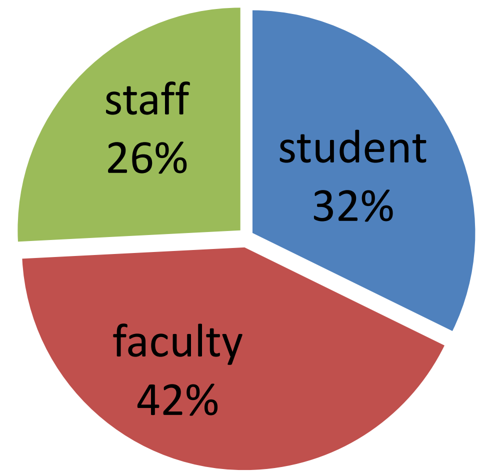

Clough

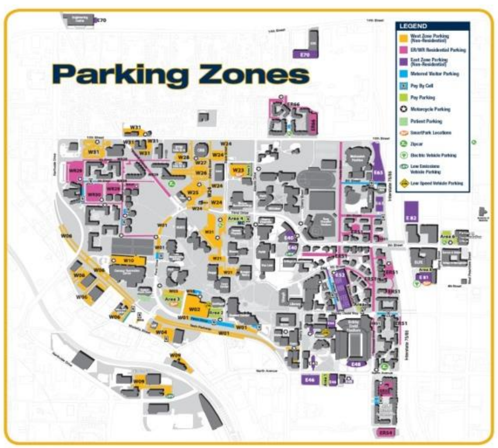

CRC


CNES

Load Modeling: Electric Vehicles

- Steady growth of EV charging demand:
  - As of Feb. 2014, there were 155 EVs on campus.
  - EV type: Leaf 90%, Tesla, BMW i3…
- Charging Infrastructure
  - Three Level I charging stations
  - Six Level II charging stations
- A statistic model for EV charging demand has been developed





Parking Map

Level I Charger

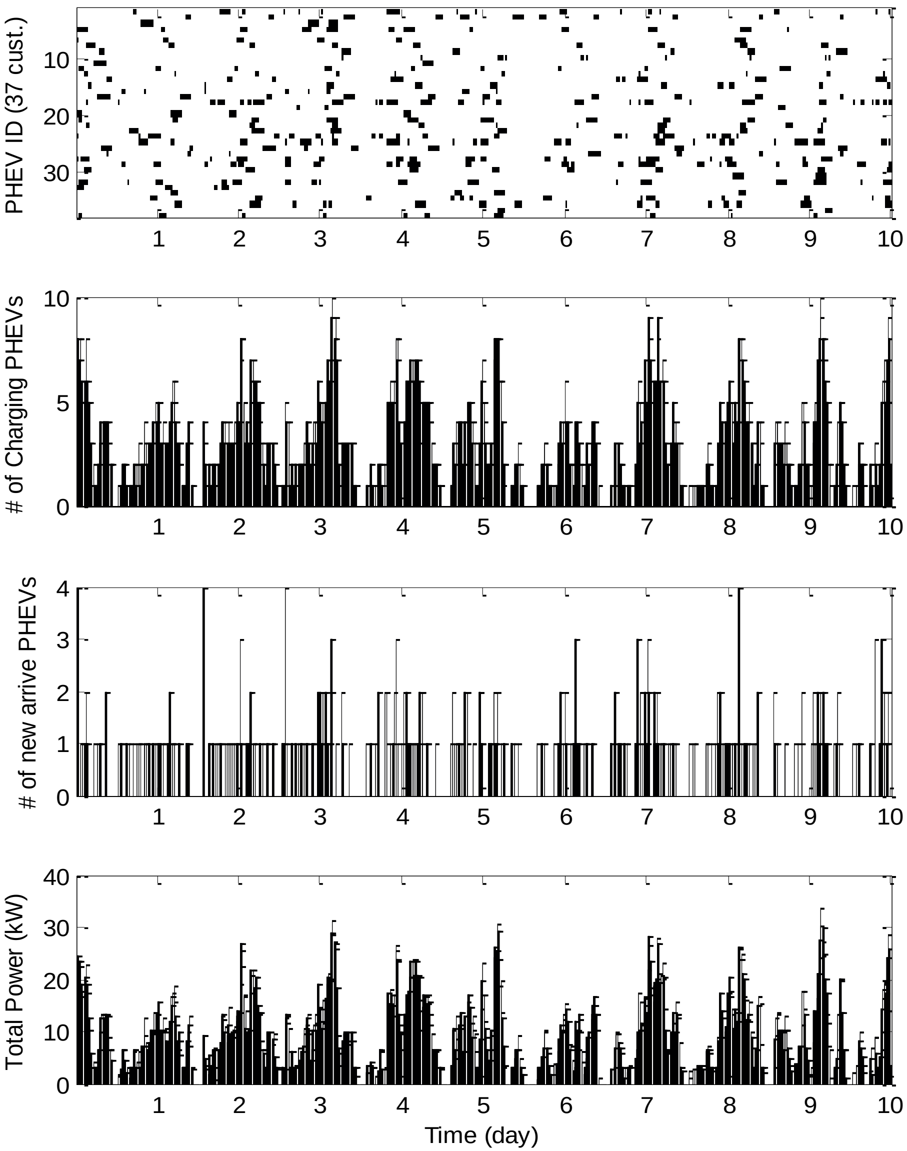
Level II Charger

Load Modeling: Electric Vehicle

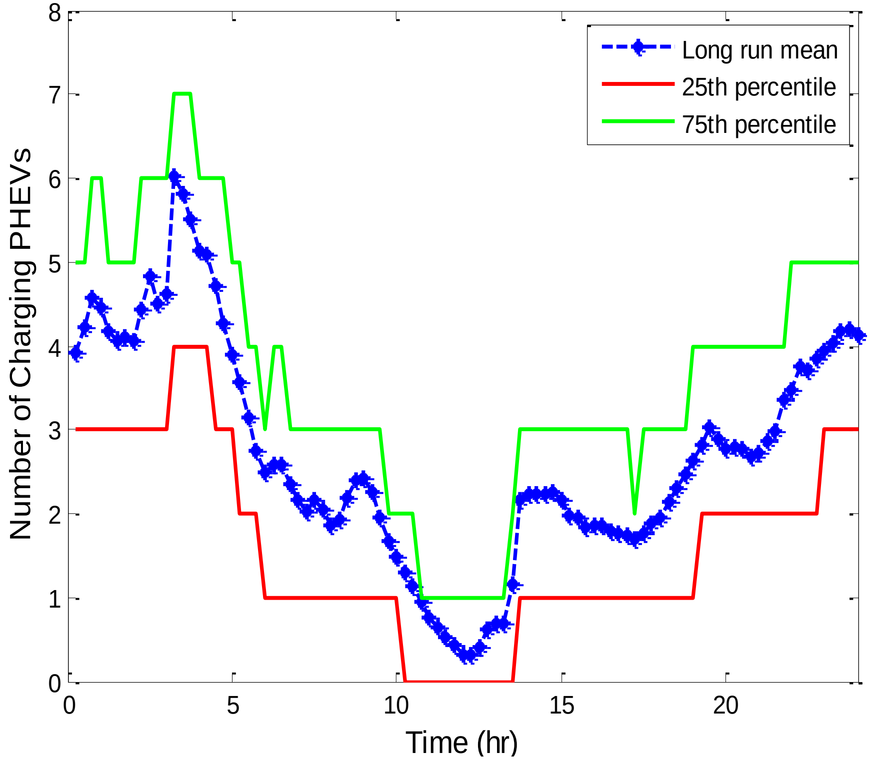
Objective:

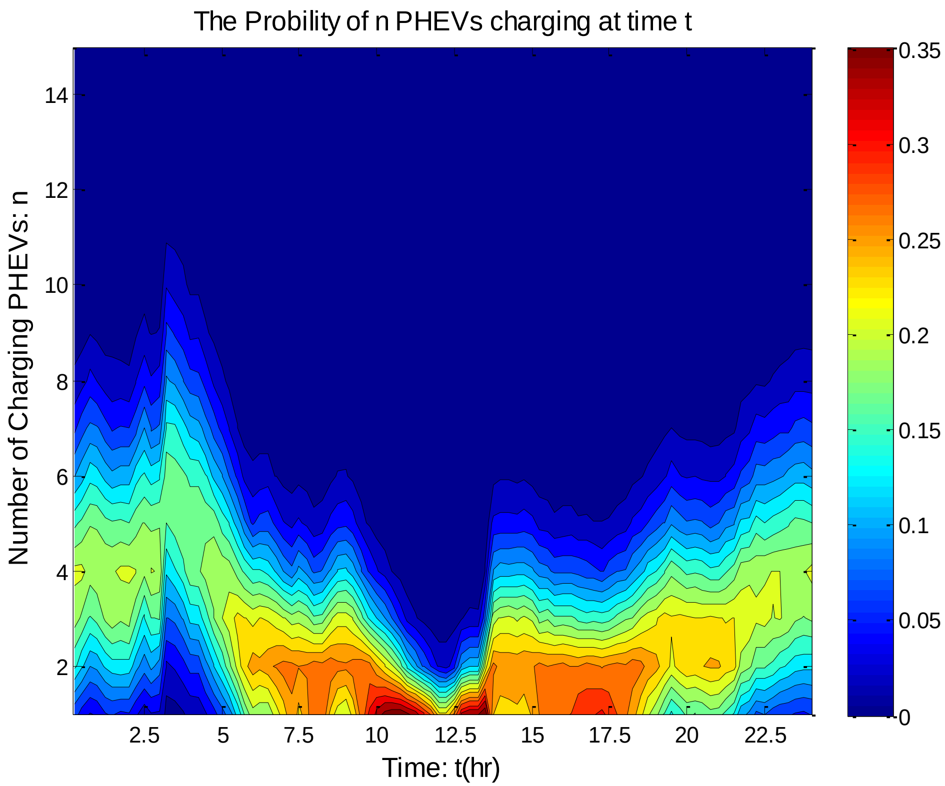
we seek to model the PHEV charging behavior through a $M_t/G/\infty/N_{max}$ queue with finite calling population

- M_t means the periodic non-homogeneous arrival rate is a function of time t;
- G stands for the empirical distribution of PHEV charging duration;
- ∞ means the charging system is a self-serve system with no waiting time;
- N_{max} is the total number of PHEVs, which is known.



Load Modeling: Electric Vehicle





According to the central limit theorem, we could construct the confidence interval for the long run average mean values, which follows the t distribution.

Conclusion: The actual charging intensity coefficient is around 0.25.

Load Modeling: Time-variant Model

- ***The vast deployment of smart meters***

  producing massive amount of data and information yet unexplored

- ***Load Model Definition***

$$P = P(V) \qquad\qquad Q = Q(V)$$

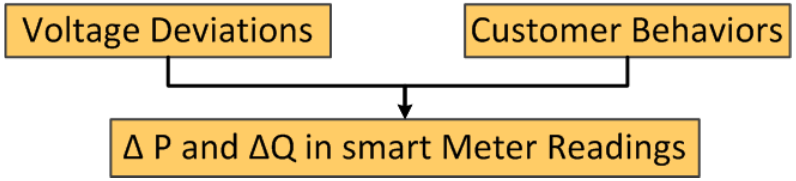
- ***Current load modeling methods***
  - *Component-based approach*
  - *Measurement-based approach*

- ***Hence, we propose a time-variant load model based on smart meter historical data***

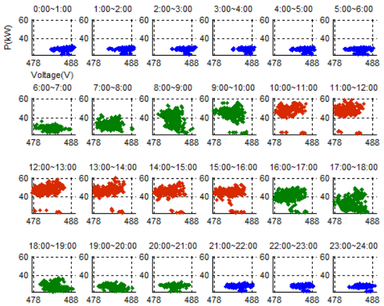
Load Modeling: Time-variant Model

- ***The Load Condition Assumption***

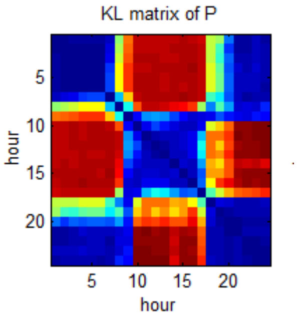
It is possible to create a load model through data-mining processes.



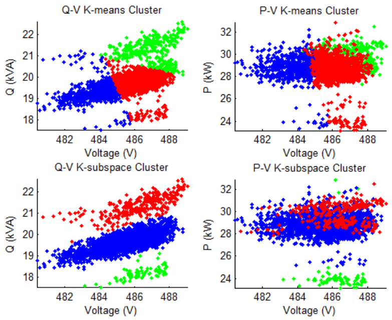
- ***Data Mining Technologies***



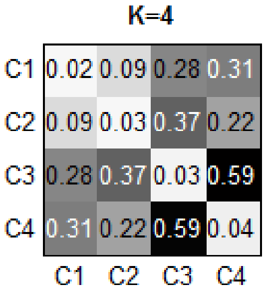
Data Filtering



KL divergence



K-subspace Method



Cluster Evaluation

Long-term Planning

- Campus Renovation and Expansion
- Shuttle Electrification
- Energy Storage

Future Campus Renovation & Expansion

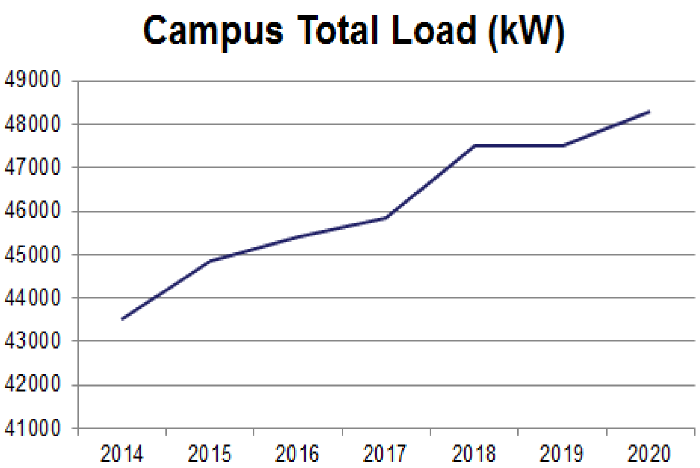
Objective:

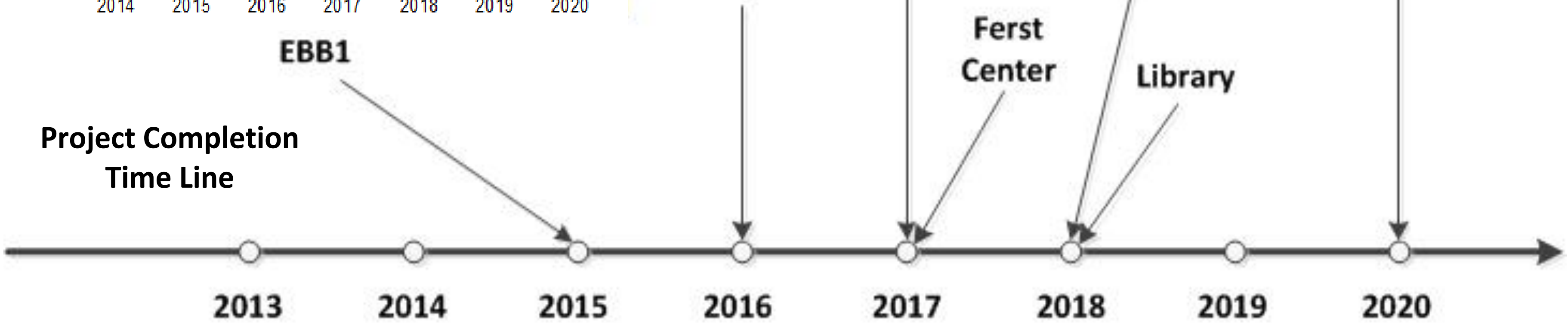
Optimize the distribution system in order to meet the campus future needs.

Solution:

- Estimate campus future needs
  - Natural load growth
  - New buildings and expansions
  - Location of new loads
- Simulate the future scenarios through integrated simulation environment
  - Pin the new loads through google earth.
  - Incorporate new system components to the OpenDSS model, such as new transformers, secondary lines.
  - Serving new load with new feeders or existing feeders.
  - Check system reliability.

Future Campus Renovation & Expansion





Shuttle Electrification

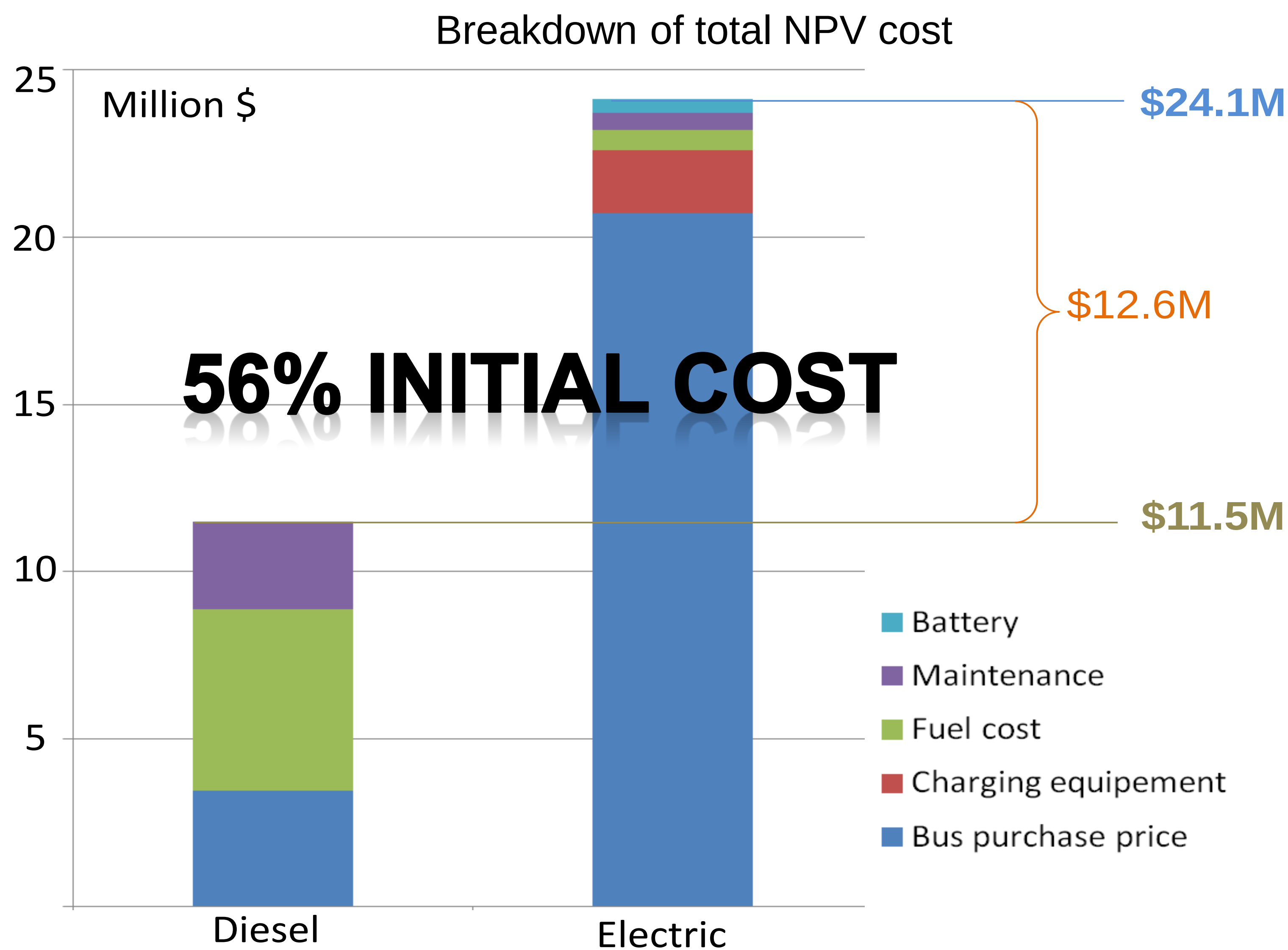
Objective:

Upgrading the current diesel shuttles with electric buses, while maintaining current services.

Solution:

- Replacing 23 existing buses with 23 electric buses ($900K/unit)
- Charging Infrastructure:
  - 2 fast chargers ($600K/unit)
  - 10 stop chargers ($70K/unit)
- Lithium titanate battery (6 years)

Shuttle Electrification



Energy Storage

Objective:

Estimate the feasibility of introducing energy storage systems on campus.

Solution:

- NaS Battery (Sodium-Sulfur Battery)
  - Battery life (up to 13 years)
  - Efficiency: 78% (including PCS efficiency 95%)
- Fixed costs
  - Battery long-term cost ($250/kWh)
  - Power Conversion System ($150~$260/kW)
  - Balance of Plant ($100/kW)
- Operation and Management Costs
  - Fixed O&M cost ($0.46/kW-year)
  - Variable O&M costs: ($0.7cents/kWh)

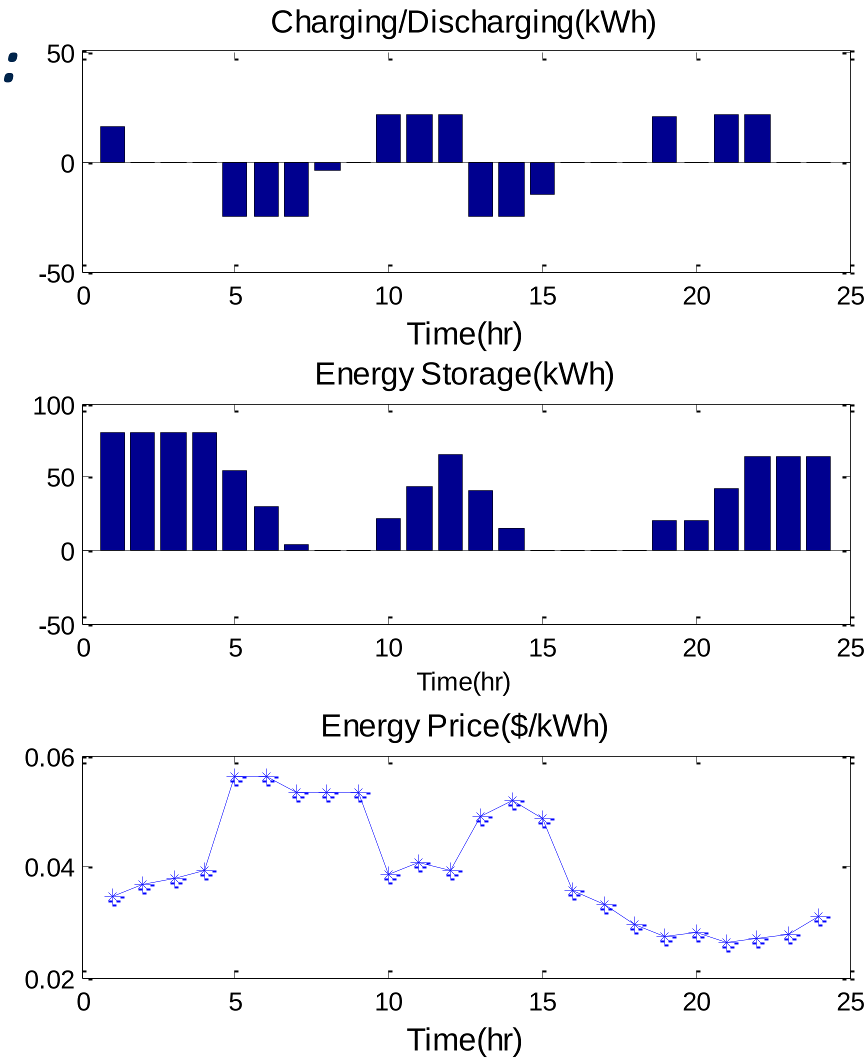
Energy Storage

Energy Storage Control Optimization:

Gurobi Optimization

Objective:

- Minimize total cost:
  - Fixed cost along the battery life
  - O&M cost
  - Charging Cost
  - Discharging revenue
- Constraints:
  - DOD or Battery capacity
  - Efficiency
  - Peak charging/discharging rate

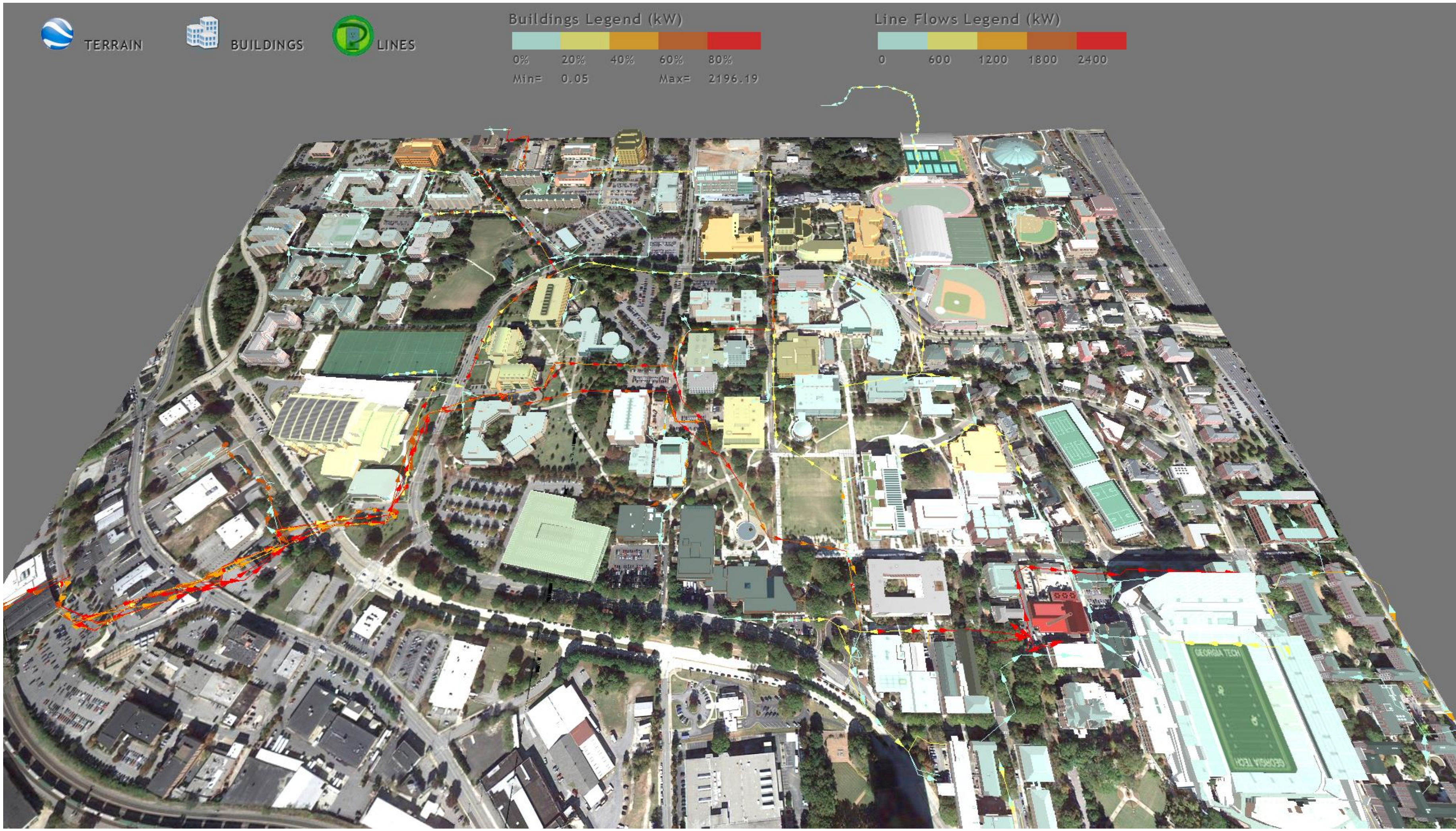


Loss 26$/day for a System with 100kWh Capacity

Visualization

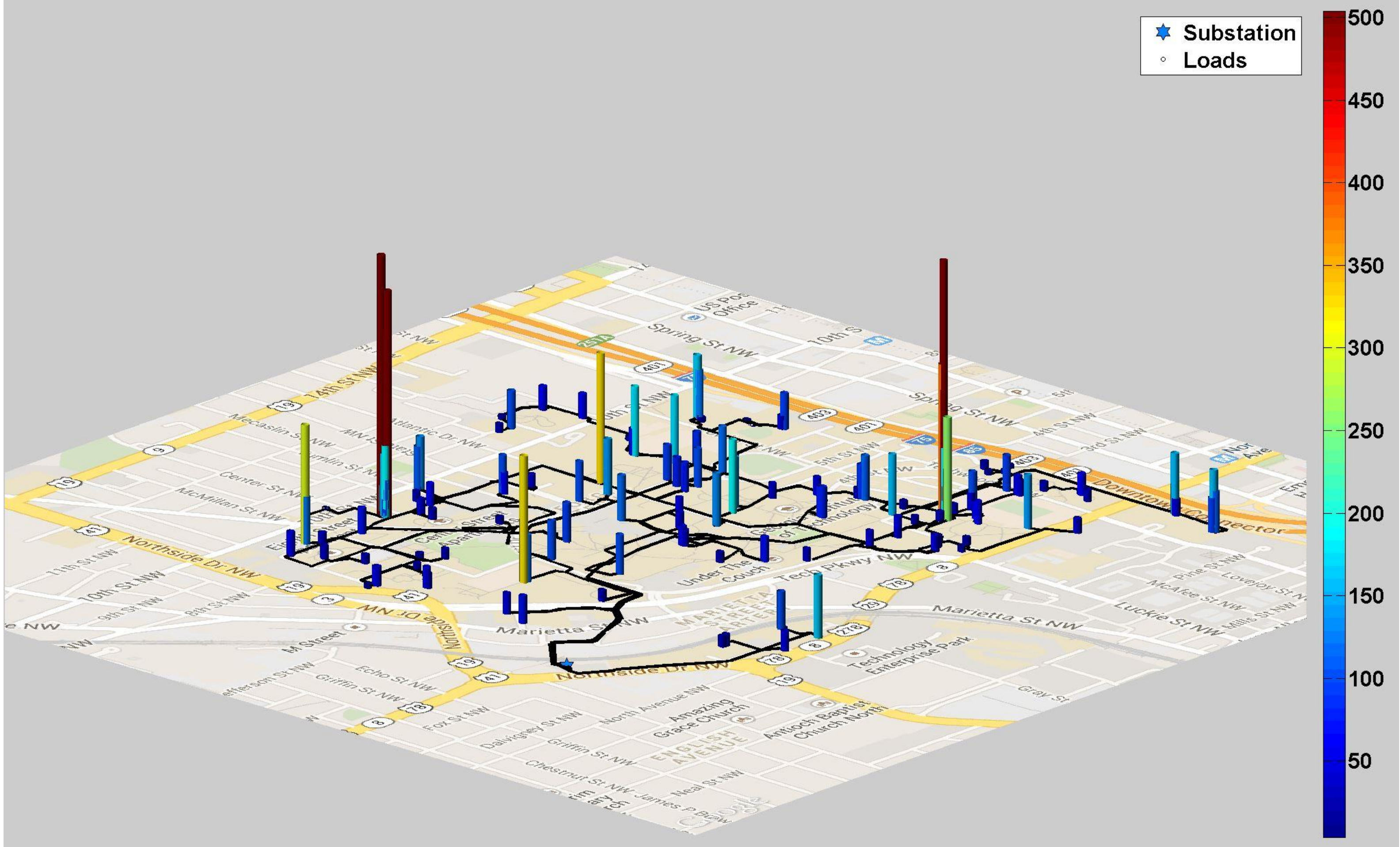
- Enhance situational awareness
- Expose consumer behaviors
- Encourage building-to-grid interactions

Situational Awareness



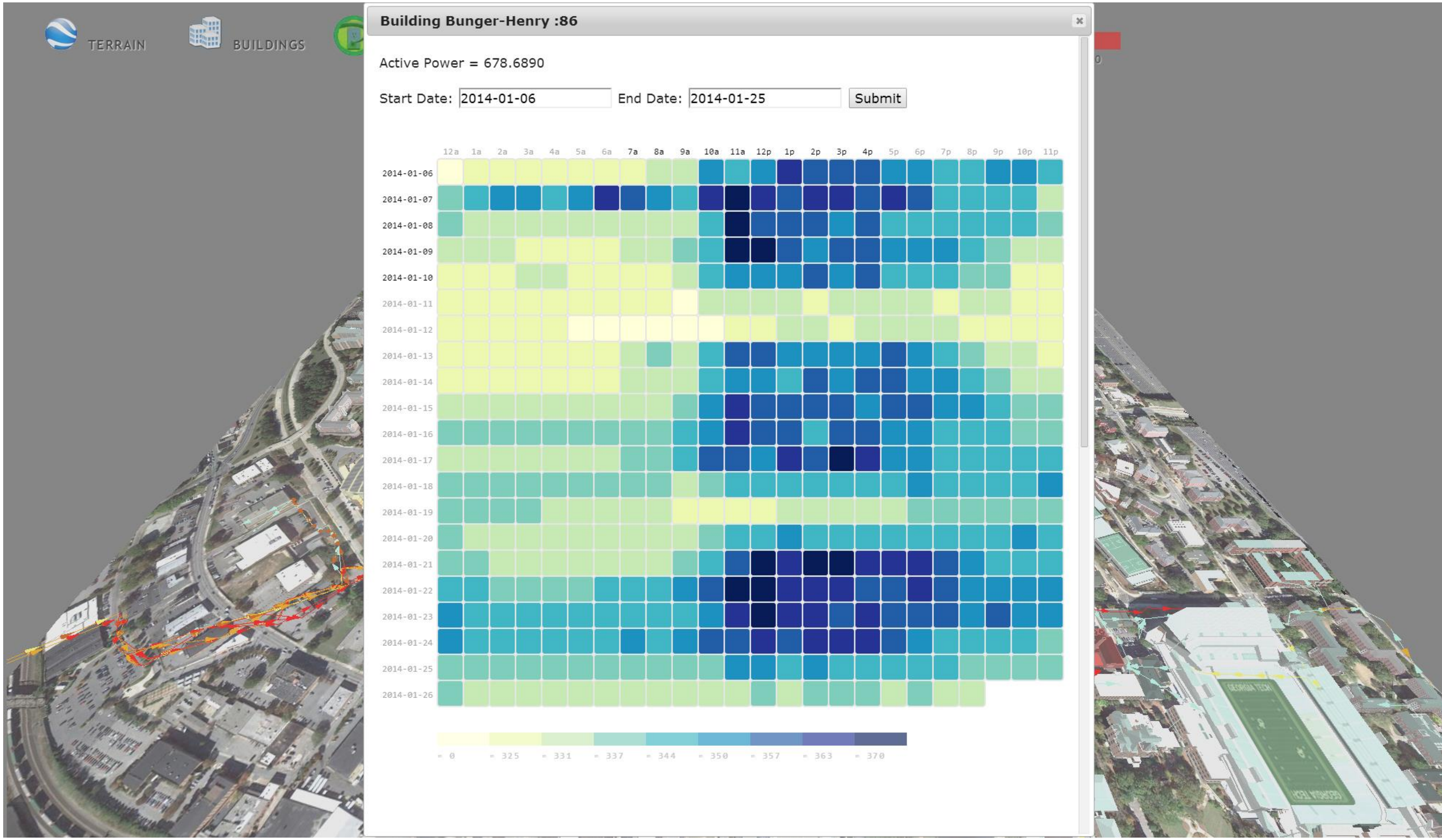
Test Bed Distribution System Over View

Situational Awareness



Bird's-eye View of the Campus Energy Consumption

Situational Awareness



Building Energy Consumption Intensity Log

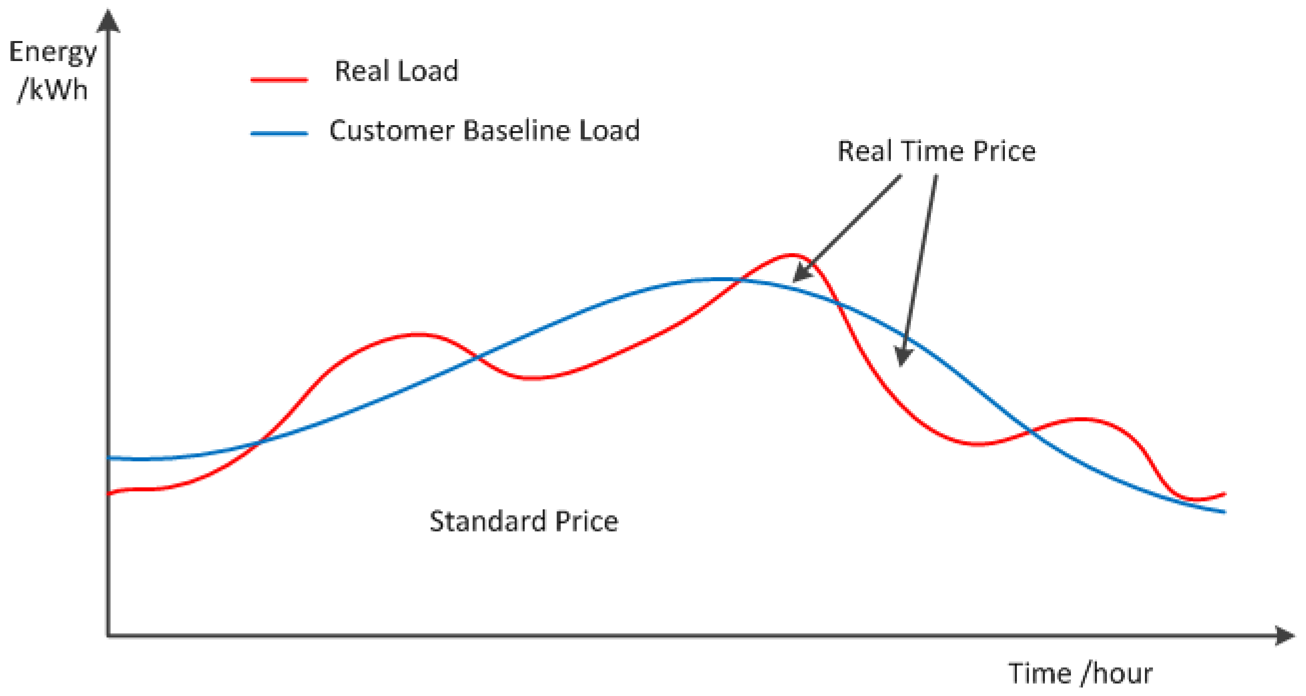
Real Time Pricing

- The test bed campus is served under "Real Time Pricing – Hour Ahead Schedule" (PTR-HA) tariff provided by Georgia Power.

$$Total.Bill = Std.Bill + RTP.Bill$$

where $RTP.Bill = \sum_{hr} RTP.Price \times (Load - CBL)$

- Customer baseline load (CBL) is developed for the test bed according to the energy consumption of the test bed from the previous calendar year.

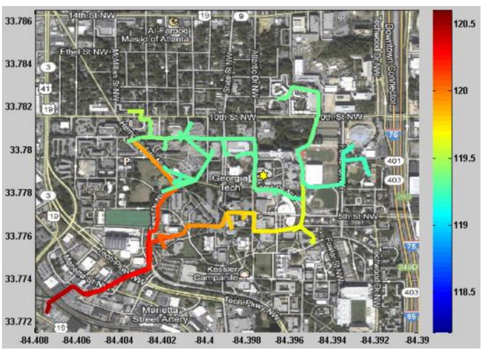


Demand Response Applications

- Metasys Software is used to integrate and control chillers based on price signals

- Demand Response Inputs
  - Real-time energy consumption
  - HAVC system setting
  - Chiller plant condition
  - Real-time price signals
- Demand Response Outputs
  - Update HAVC setting
  - Chiller plant control


Georgia Tech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118.5
14th St NW
10th St NW
Georgia Tech
Kessler Campanile
Marietta Street Artery


Georgia Tech

Thank you !