Modeling and Optimization of Commercial Buildings and Stationary Fuel Cell Systems

2013 Fuel Cell Seminar and Energy Exposition

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October 23, 2013
Columbus, Ohio

NREL/PR-5400-60904

STA44-5

Acknowledgements

This project is supported by the U.S. Department of Energy's Fuel Cell Technologies Office

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Introduction

Tool Name: Distributed Generation Building Energy Assessment Tool (DG-BEAT)

DG-BEAT is designed to allow the stakeholders (OEMs, end users, building energy managers) to assess the economics of installing stationary fuel cell systems in a variety of building types in the United States.

It enables sizing and controls optimization between commercial buildings, fuel cells, energy storage, and renewables.

Compiled version is available (for free).

Questions the Model Answers

1. **What size fuel cell or size of other DG technology is best for my building?**
2. **What are optimal system sizes that can serve the broadest market in the most economical fashion?**
3. **How should fuel cell systems be dispatched to achieve benefits (energy, emissions, economics)?**
4. **How much do thermal and electrical energy storage systems benefit stationary FC installations?**

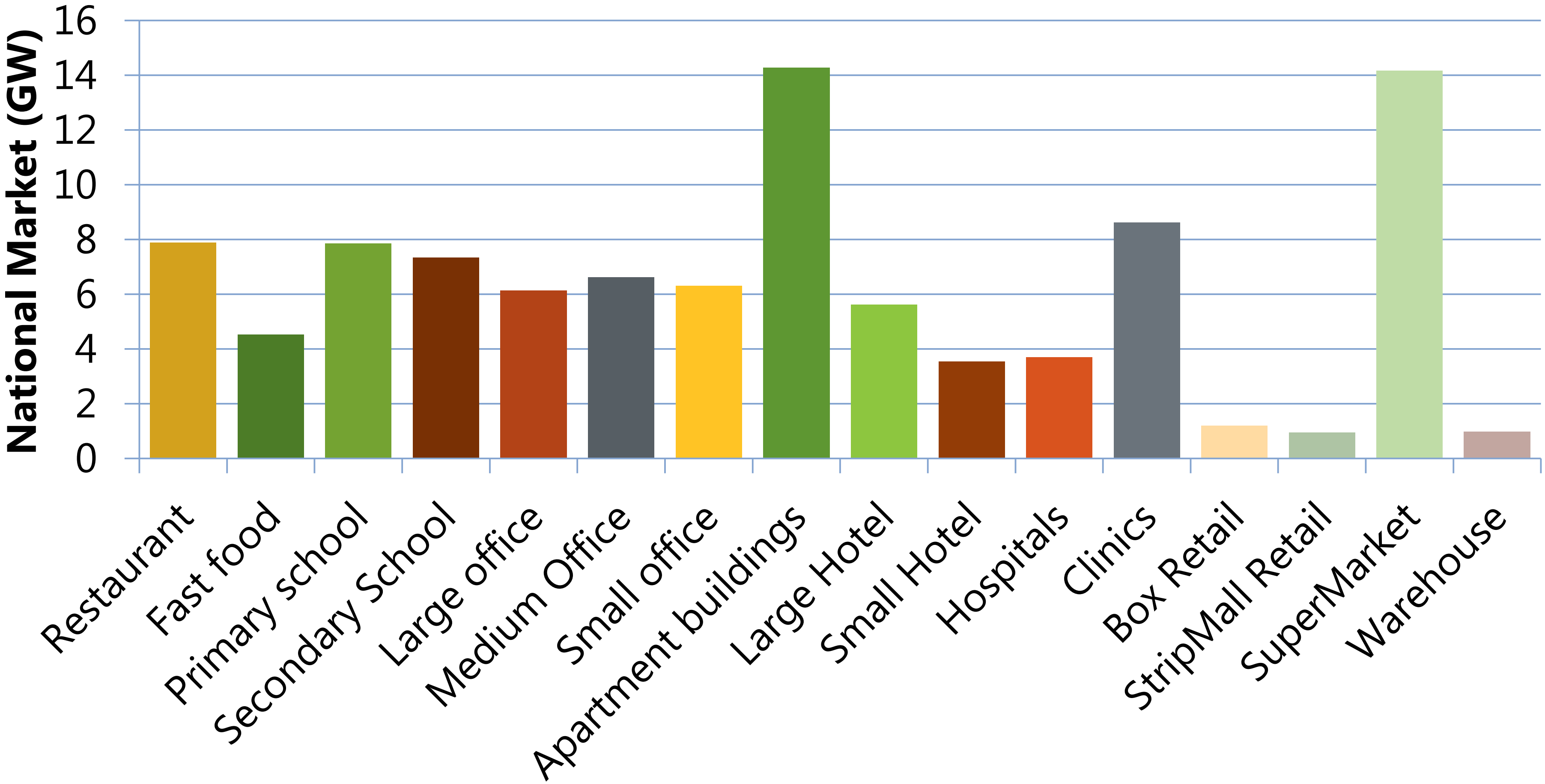
Software Layout

- **DG-BEAT**
  - **Components**
    - Fuel Cell
    - Chiller
    - Thermal Storage
    - Batteries
    - Solar
    - Wind
  - **Demand**
    - 16 Building Types
    - 16 ASHRAE Climates
    - 3 Vintages
    - CEC Building Data
  - **Controls**
    - Base Load
    - Diurnal Dispatch
    - Weekly Dispatch
    - Load Following
  - **Economics**
    - Component Costs
    - O&M Costs
    - Grid Costs
    - Nat. Gas Costs
    - Manufacturing Scale Up
  - **Analysis**
    - Single Scenario
    - Multi-Building
    - Sensitivity
    - Validation
    - National Survey

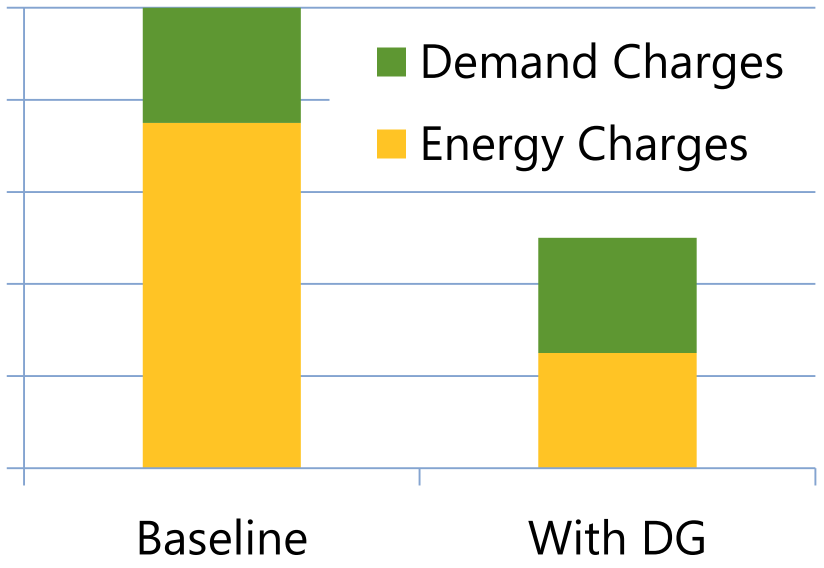
16 Building Types Modeled

Modeled buildings represent ~67% of national inventory

Sizes range from 5 kW to 1,500 kW



Economics



Utility Costs

- EIA forecasted NG costs
- Time-of-use electricity rates
  - 20+ pre-loaded rate structures
  - State average energy costs

Equipment Costs

- Installation costs, scales with capacity (kW)
- Operation/maintenance costs, scales with capacity and operation (kW and kWh)

Energy costs vs. demand charges

Zero-export constraint

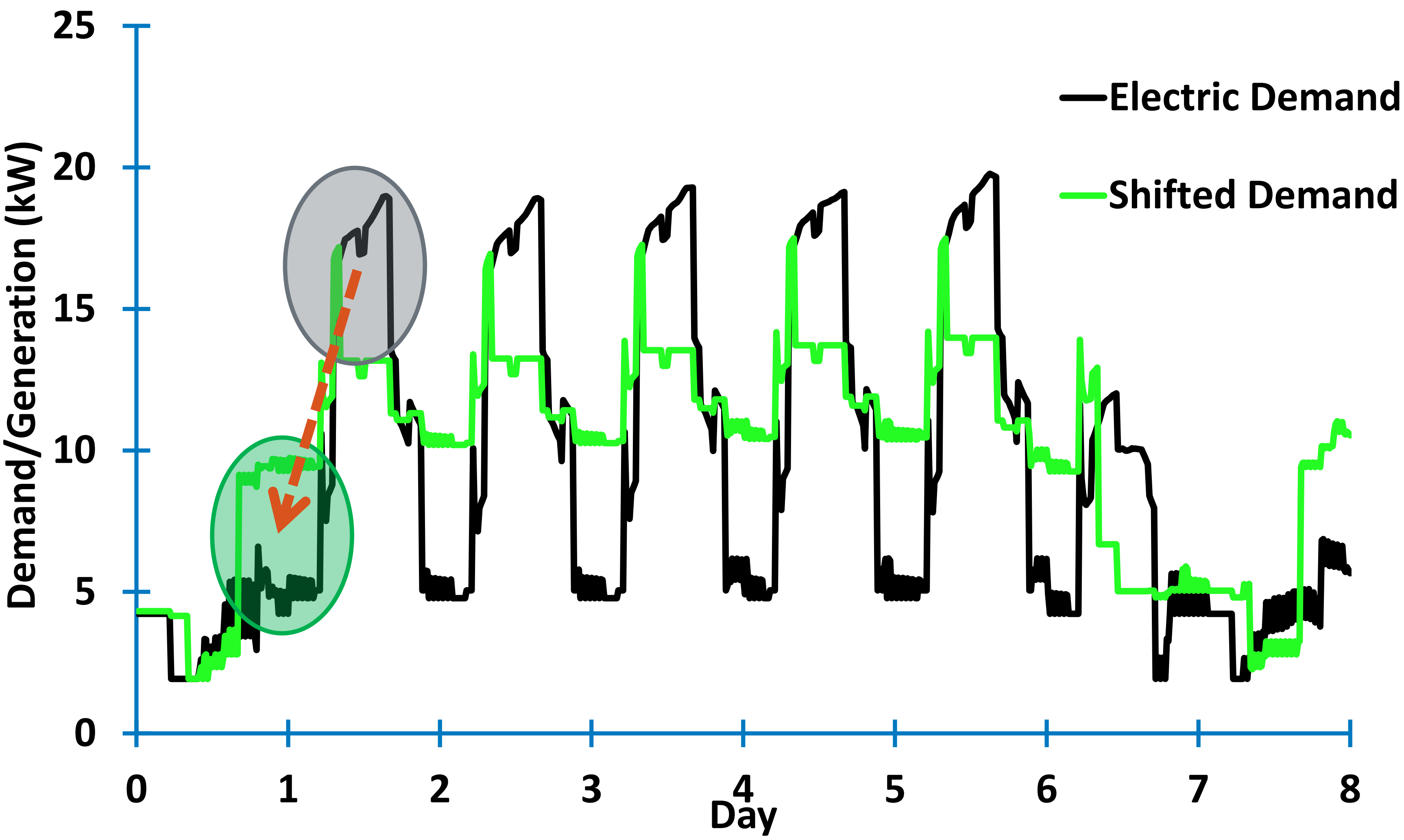
20-year NPV analysis

- Includes stack replacement
- Analyze financing methods, interest rates, offset electricity charges

Energy Storage Shift

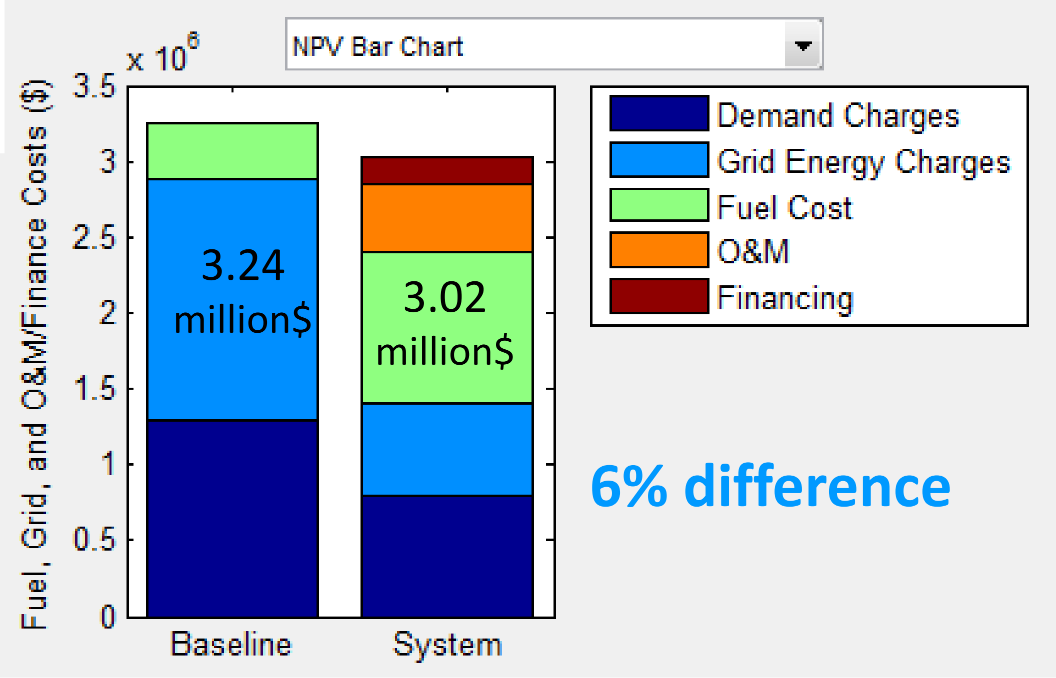
Motivation

Move demand to lower-cost times by using cold or hot water storage



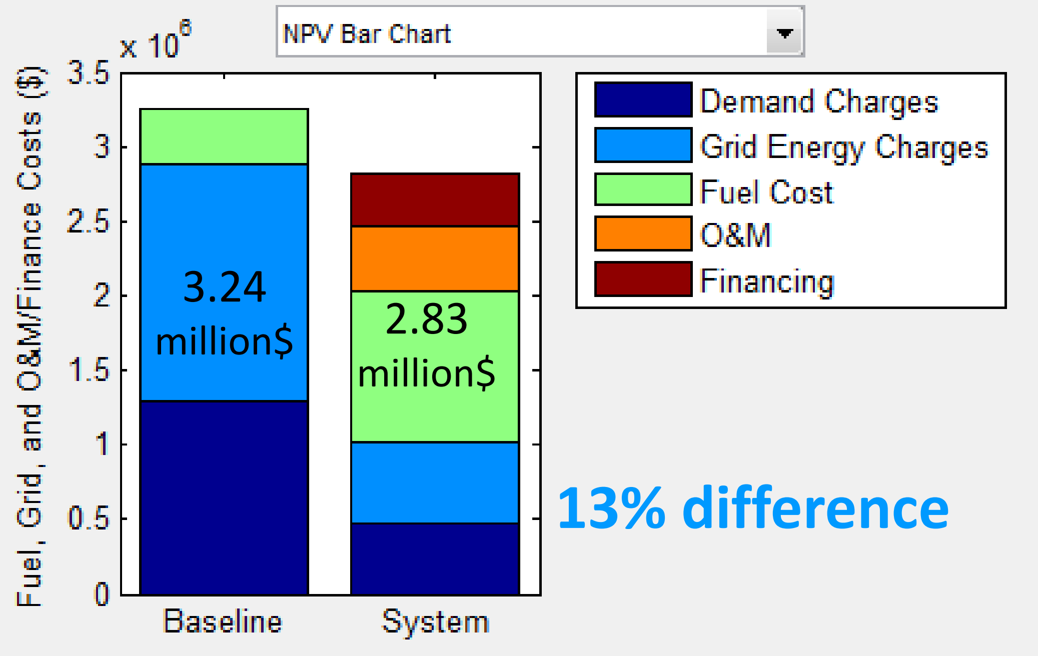
Preliminary Results—Without Storage

- **Building:** L.A. Clinic/Small Hospital (avg. demand ~100 kW)
- **Utility:** SoCal Edison
- **Control Strategy:** Base Load
- **Results:**
  - Base load = 34 kW ~23.7% of demand
  - Grid cost is $0.126/kWh delivered
  - 20 year savings (NPV) is 6%



Preliminary Results—With Cold Water Storage

- **Building:** L.A. Clinic/Small Hospital (avg. demand ~100 kW)
- **Utility:** SoCal Edison
- **Control Strategy:** Base Load
- **CW Storage**: 3,600 kWh
- **Results:**
  - Base load = 34 kW ~23.7% of demand
  - Grid cost is $0.126/kWh delivered
  - 20 year savings (NPV) is 13%

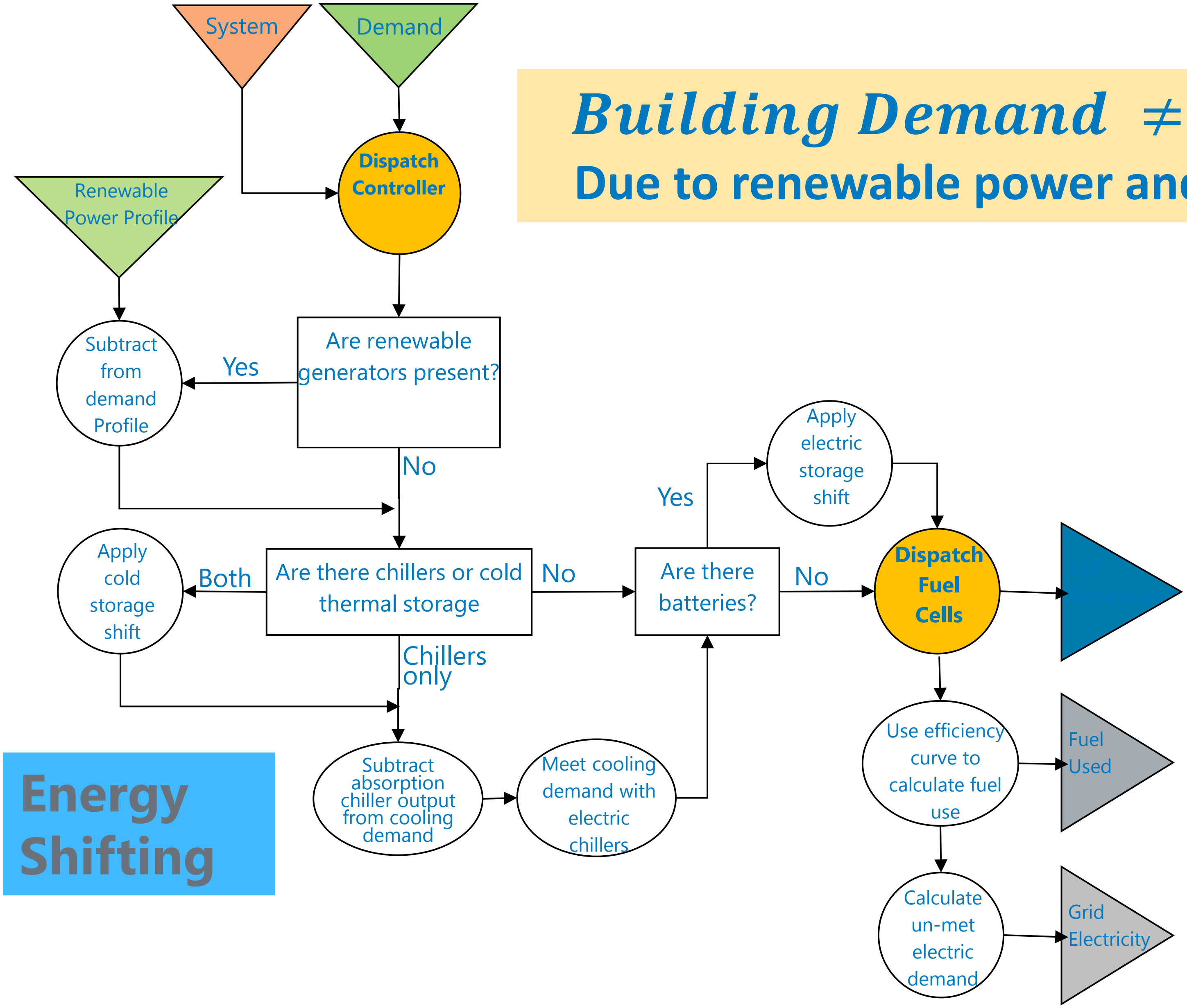


Takeaway: Hybridizing fuel cell systems for buildings can result in significant savings (double, in this one case)

Dispatch Controller Flowchart: How it Works

Building Demand ≠ Generation

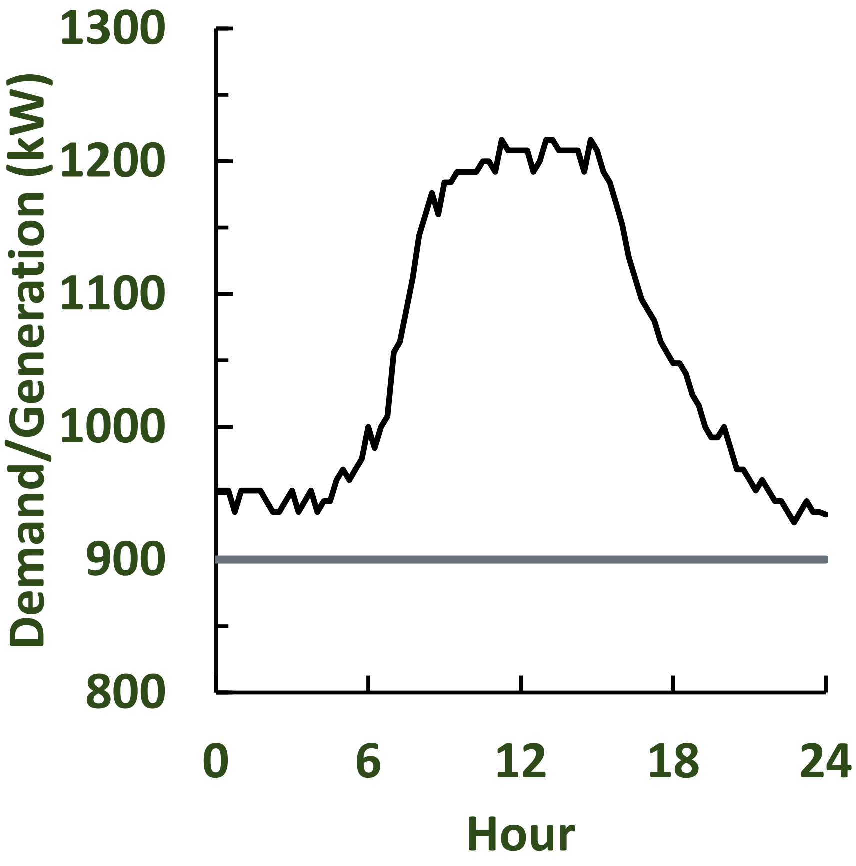
Due to renewable power and energy storage

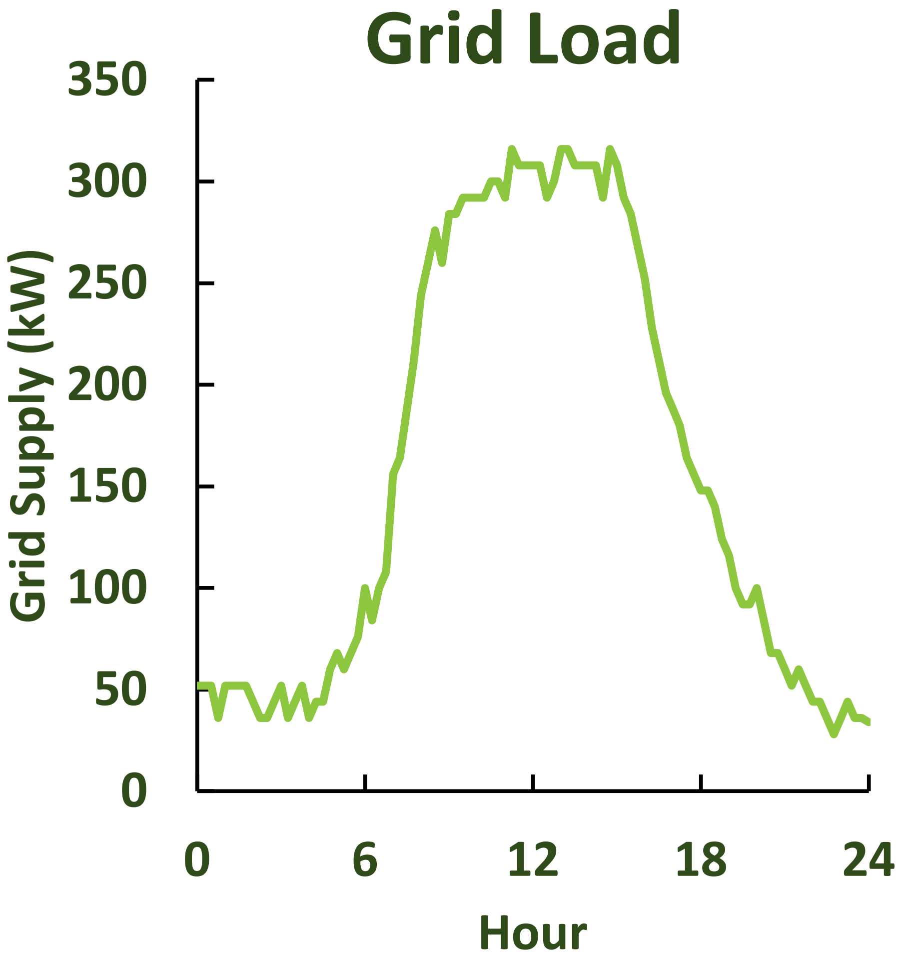


Energy Shifting

Base Load

Simplest type of dispatch





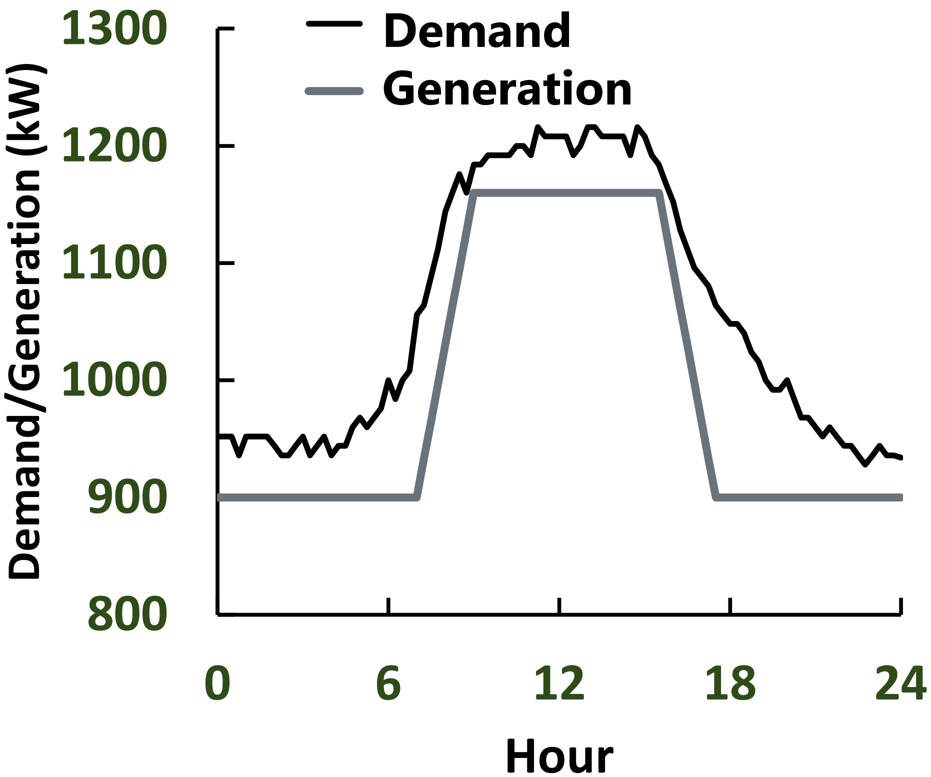
Diurnal Peaking

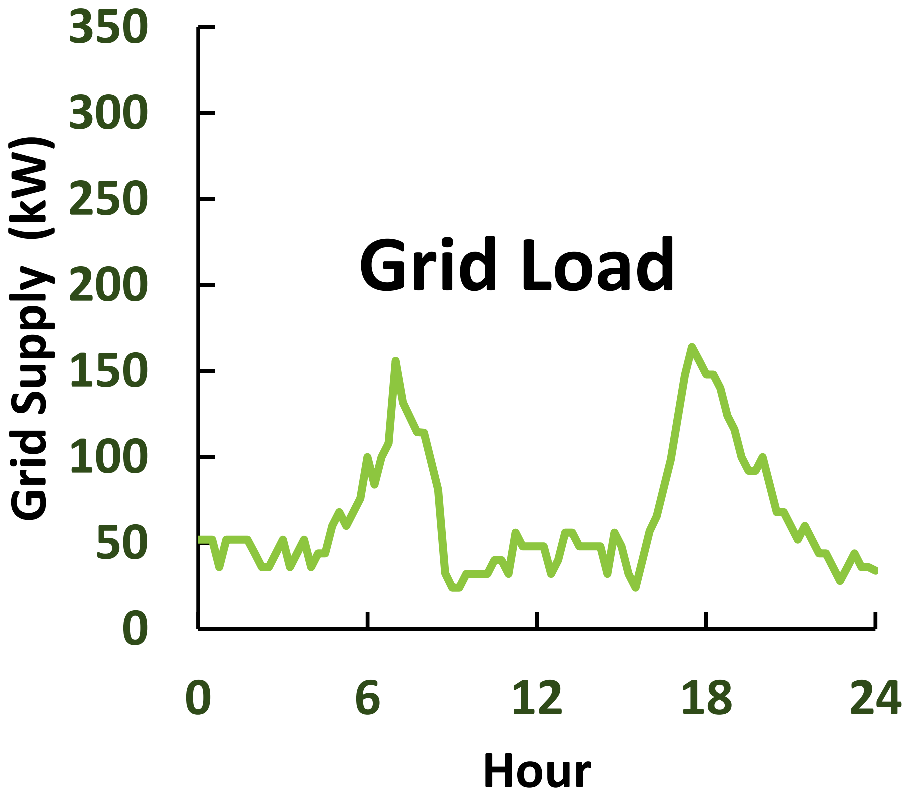
Motivation

Increased stack life (~equal kWh spread over longer time)

Higher-value generation during on-peak hours

Larger FC installation



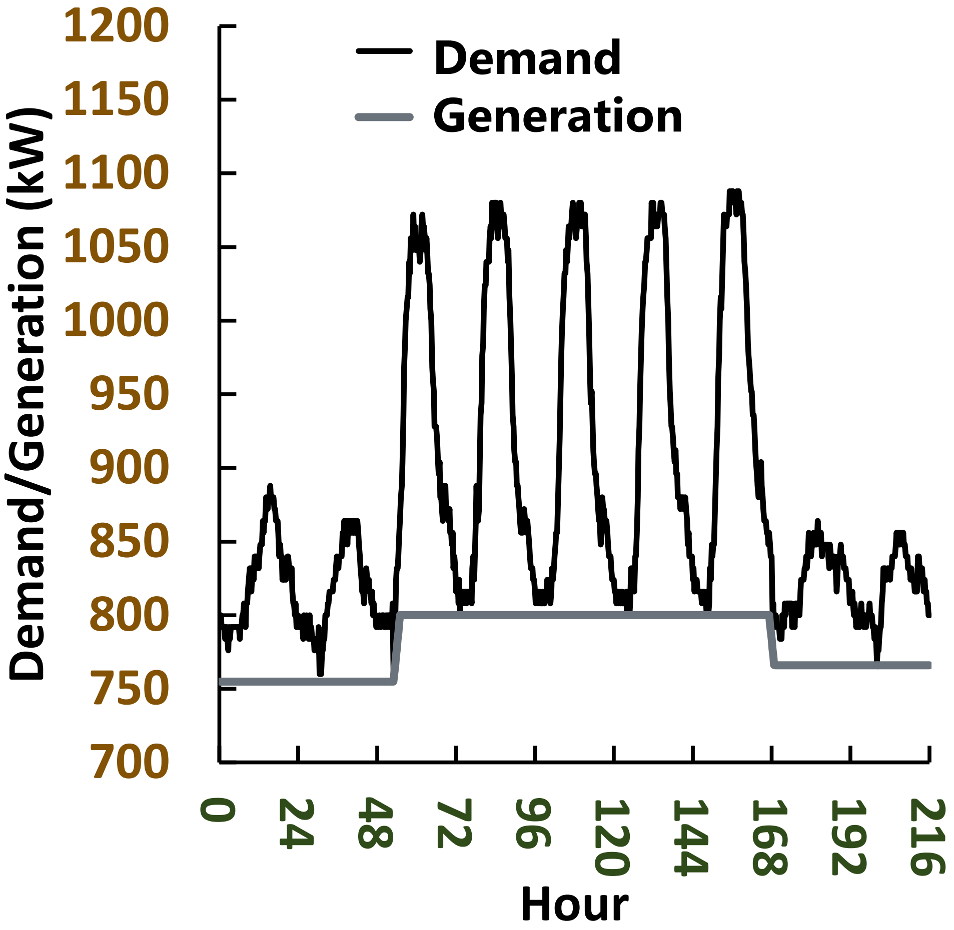


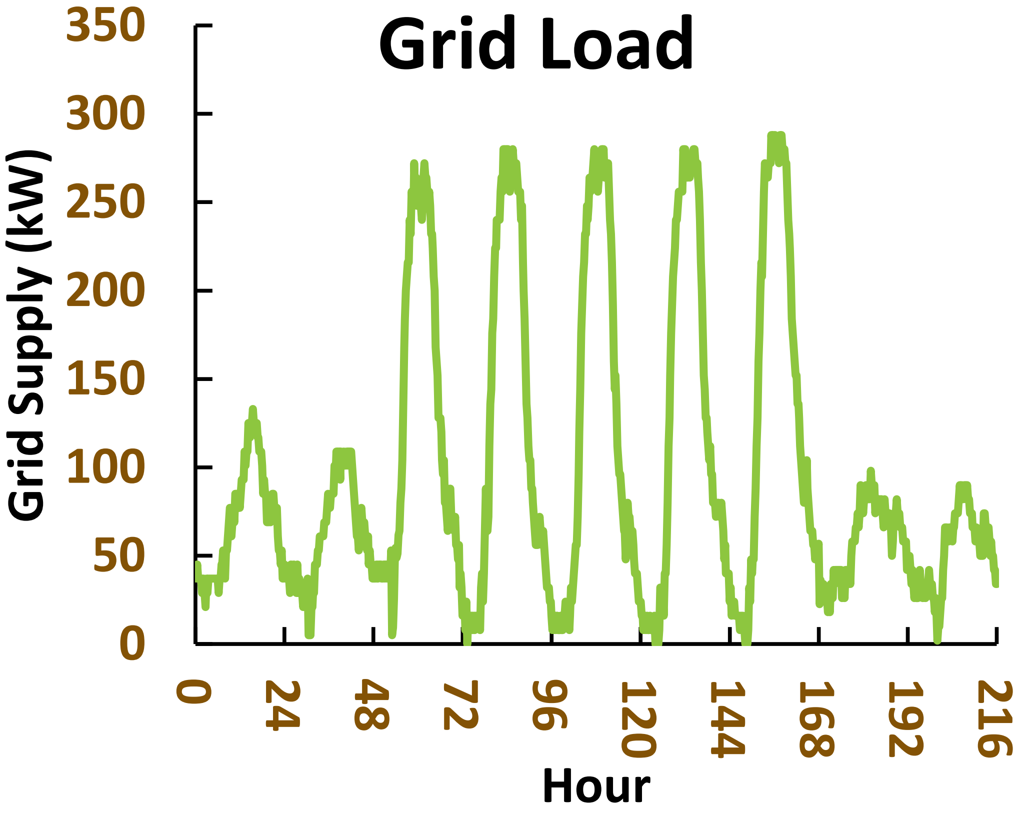
4 x DFC300 = 1,200 kW, 4:3 turndown ratio, 10%/hour slew

Weekend Dip

Motivation

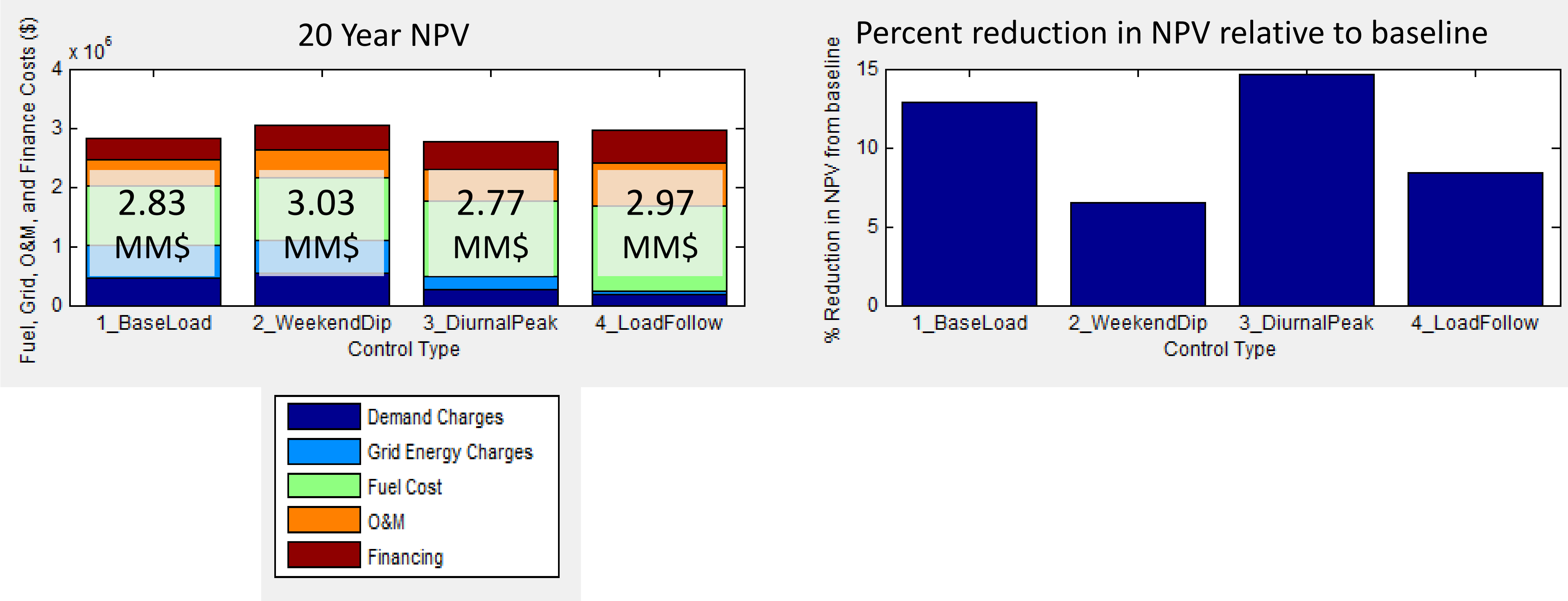
Same as daily dispatch, but with fewer fuel cell transients





Control Strategy

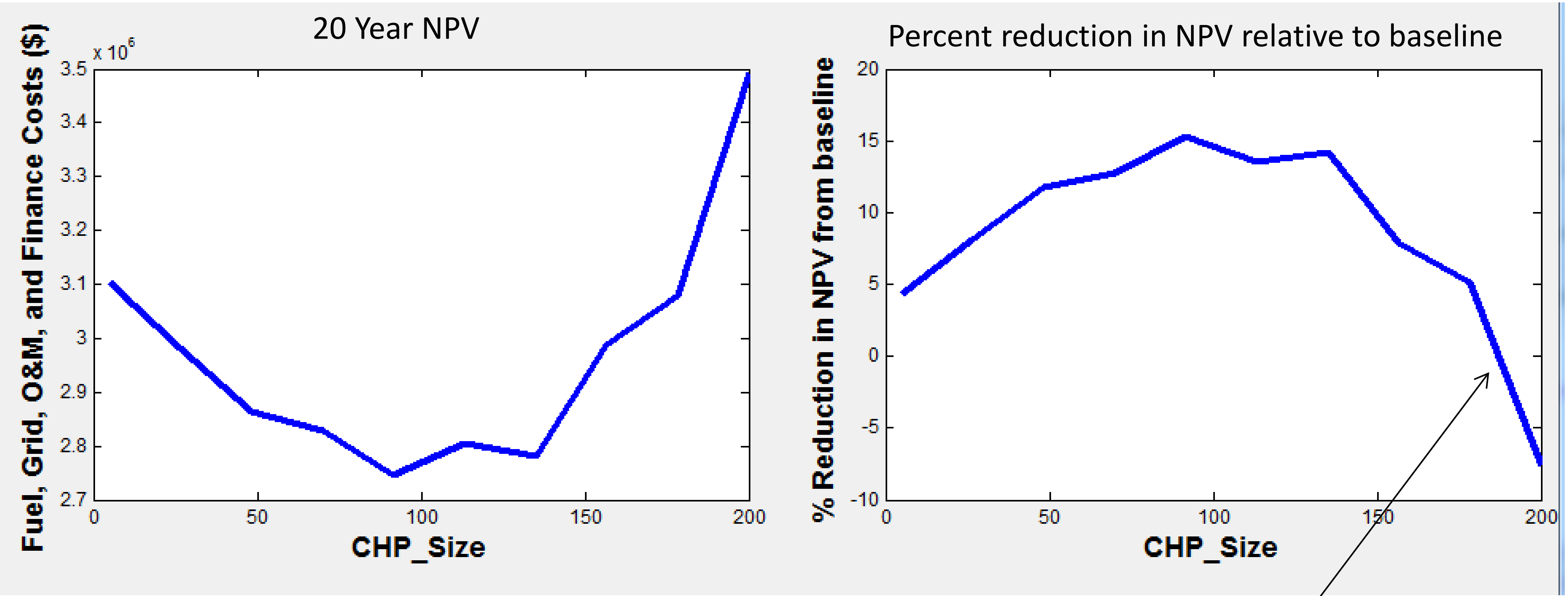
Comparison of dispatch for our LA Clinic example



Takeaway: With storage, proper dispatch of the FC can reduce NPV even further. Diurnal peaking increases %NPV saved from 13% to 15% (relative to no FC system).

Optimal Size

DG-BEAT can find the optimal (lowest lifecycle cost) system for an application (again, the LA Clinic example)

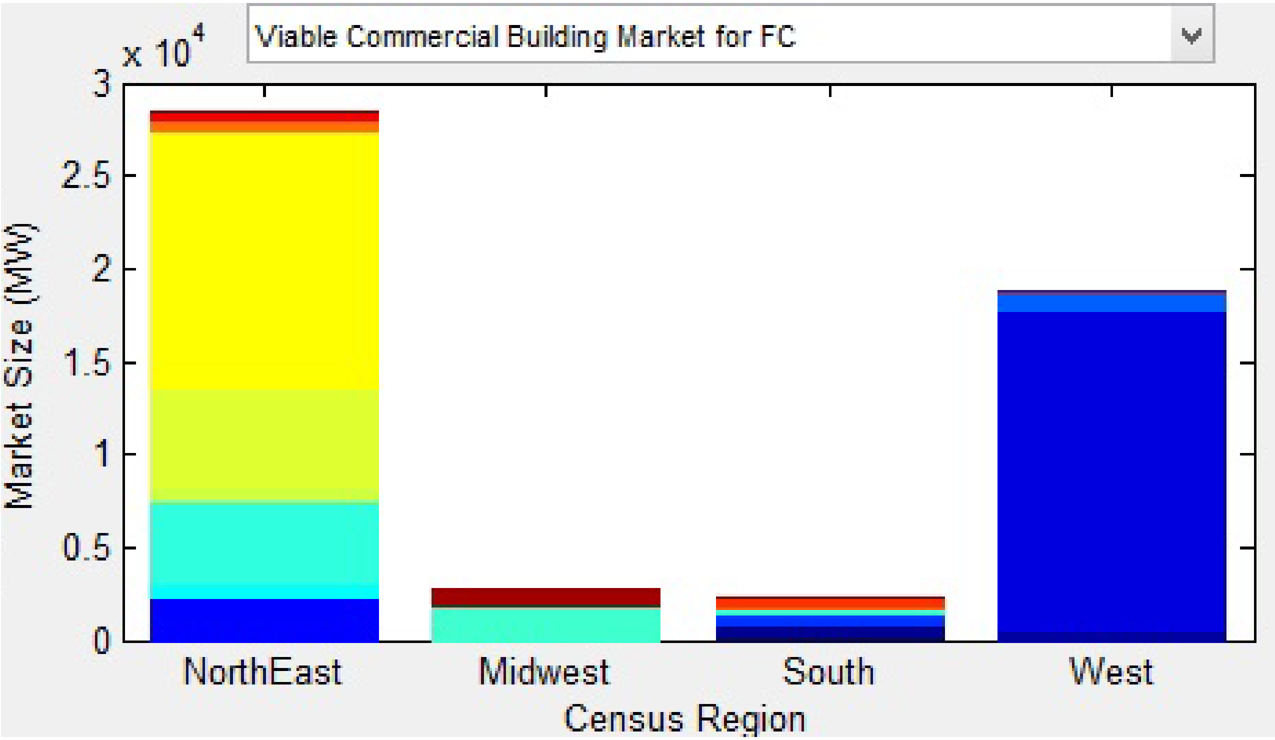


- » Optimal Size: 91 kW
- » NPV: Savings 15% over baseline

If the system is too large, it will actually cost more than the baseline. Negative % reduction

Viable Market

DG-BEAT can estimate the viable market for a particular size of fuel cell system, using commercial building inventory data

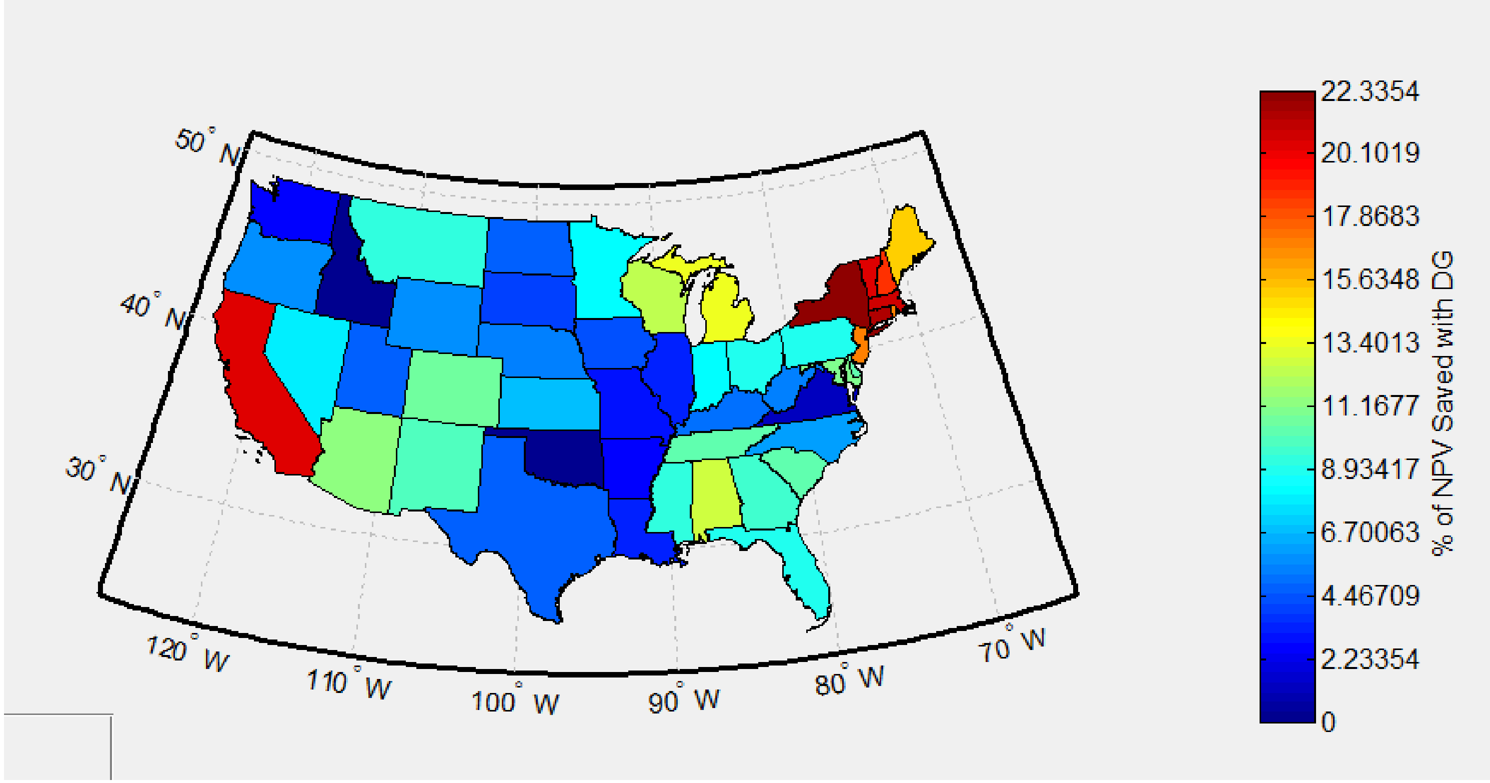


Takeaway: For this case, the most viable markets are the NE and California

Viable: Any building where 20-year NPV w/ FC is less than 20-year NPV w/o FC

Viable Regions for DG

Users can calculate state-by-state values for a system type under consideration (may be useful for OEMs)



Avg. Net Present Value: Weighted average of each building type (weighted by size and # buildings in state)

Includes buildings which lose money by converting to FC

Future Work Topics

- **Cost optimization instead of area under demand curve (brute force for energy charges only)**
- **Scale installation to demand with fixed FC size multiples of baseline system (e.g., 4 x 300 kW)**
- **Advanced controls (e.g., predictive control) with physical DG system models and comparison to ideal dispatch**
- **Additional building energy demand profiles**
  - PNNL building profiles
  - ASHRAE 90.1-2007 standard
  - Easier upload of different formats by users
- **CBECS**
  - Update building inventories based on output from CBECS 2012
- **Refinement of economics for scenario analyses**
  - State incentives database (DSIRE)
  - Projections for changes in utility prices
  - Regional NG prices
  - Regional variation in energy vs. demand charges
  - Variation in utility costs and energy vs. demand costs with scale of installation
  - Variation in building sizes of same class (e.g., not all hospitals = 1,200kW)

Summary of Functionality

1) Build a DG system out of any number of subcomponents (FC, chiller, batteries…)
2) Apply to 768 building types or build campus of multiple buildings
3) Choose from four dispatch strategies
4) Evaluate lifetime costs with 30+ real world utility rates, or build your own
5) Perform sensitivity analysis
6) Describe national market with detailed application-specific evaluation