Energy+Environmental Economics

Strategies and incentives for integration of renewable generation using distributed energy resources

CSI RD&D Round 3 Project

Hosted by UCSD

July 10, 2013

Eric Cutter

Priya Sreedharan, PhD, PE

Jamil Farbes

Using UCSD Microgrid for Renewable Integration

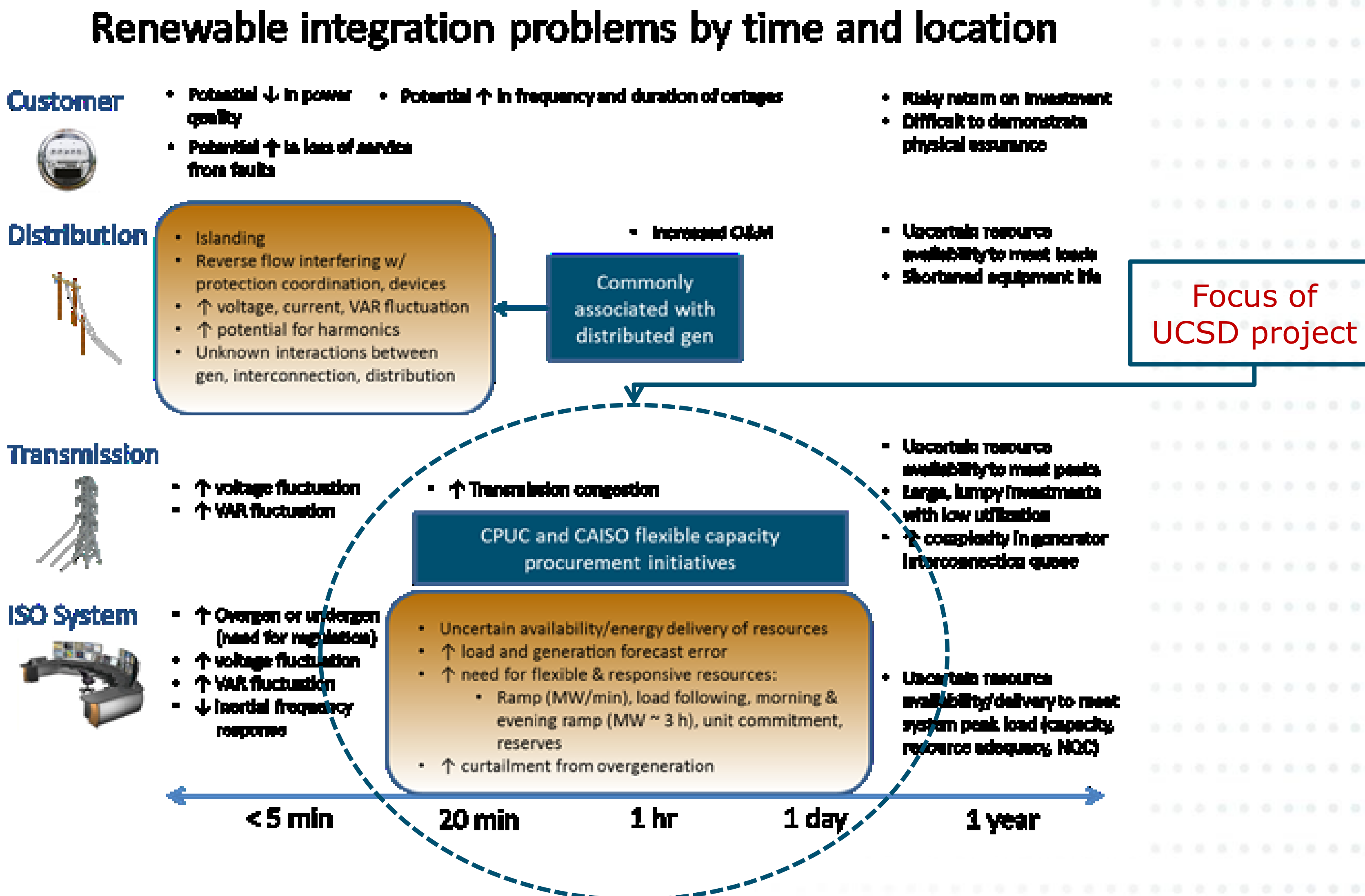
Acknowledgements

+ **UCSD**
  - Byron Washom, John Dilliott and Jan Kleissl
+ **Viridity**
  - Nancy Miller, Chuck Richter, Laura Manz
+ **Itron**
  - Ann Peterson and Jonathan Wanjiru

Policy Context

- The Million Solar Roofs initiative, net energy metering (NEM) and zero net-energy (ZNE) goals encourage high penetration PV
- California's *Energy Action Plan* places distributed energy resources (DER) at the top of the 'loading' order
- Distribution system challenges a key barrier to increased penetration of renewable DG.

Potential Grid Problems from Increased Renewables



Not intended to be comprehensive.

Research Questions

- **Does integrating additional resources in dispatch decisions reduce costs/increase flexibility**

  Yes

- **Can integrated dispatch strategies**
  - Increase peak load shifting?
  - Balance campus resources?
  - Balance grid resources?

  Yes

- **Are strategies cost-effective at current rates/prices?**

  Marginally so

- **If not, what incentives and policies are needed to encourage participation?**

Contribution of This Study

1. **Documents potential to engage existing DER for renewable integration**
2. **Develops an optimization framework to model the dispatch, costs and benefits of microgrid to**
   - Provide customer <u>and</u> utility grid benefits.
   - Optimize electric <u>and</u> thermal resources
3. **Compares costs and benefits over a full year with high resolution, validated historical data.**

Key Findings

- Accurately representing thermal resources is critical for developing accurate microgrid optimization strategies
- Existing tariffs can significantly inhibit otherwise beneficial DER dispatch
- Direct participation in energy and AS markets is cost-effective, but unlikely to mobilize DER on its own
- Payments for flexible capacity can help if designed to include and enable DER
- Establishing <u>local</u> avoided cost benefits for integration of distributed generation is essential

Energy+Environmental Economics

PROJECT APPROACH

Overview of Key UCSD Resources

- **The central plant is rich with dispatchable resources**
  - Two 13 MW natural gas generators
  - One 3 MW steam generator
  - Three steam driven chillers (~ 10,000 tons capacity)
  - Eight electric driven chillers (~ 7800 tons capacity)
  - 3.8 million gal thermal storage tank
  - Backup diesel generation
- **>1 MW of solar PV**
- **~ 1.4 MW of DR-ready reducible building load**
- **Visibility at the building level**

Chilled water tank at UCSD campus

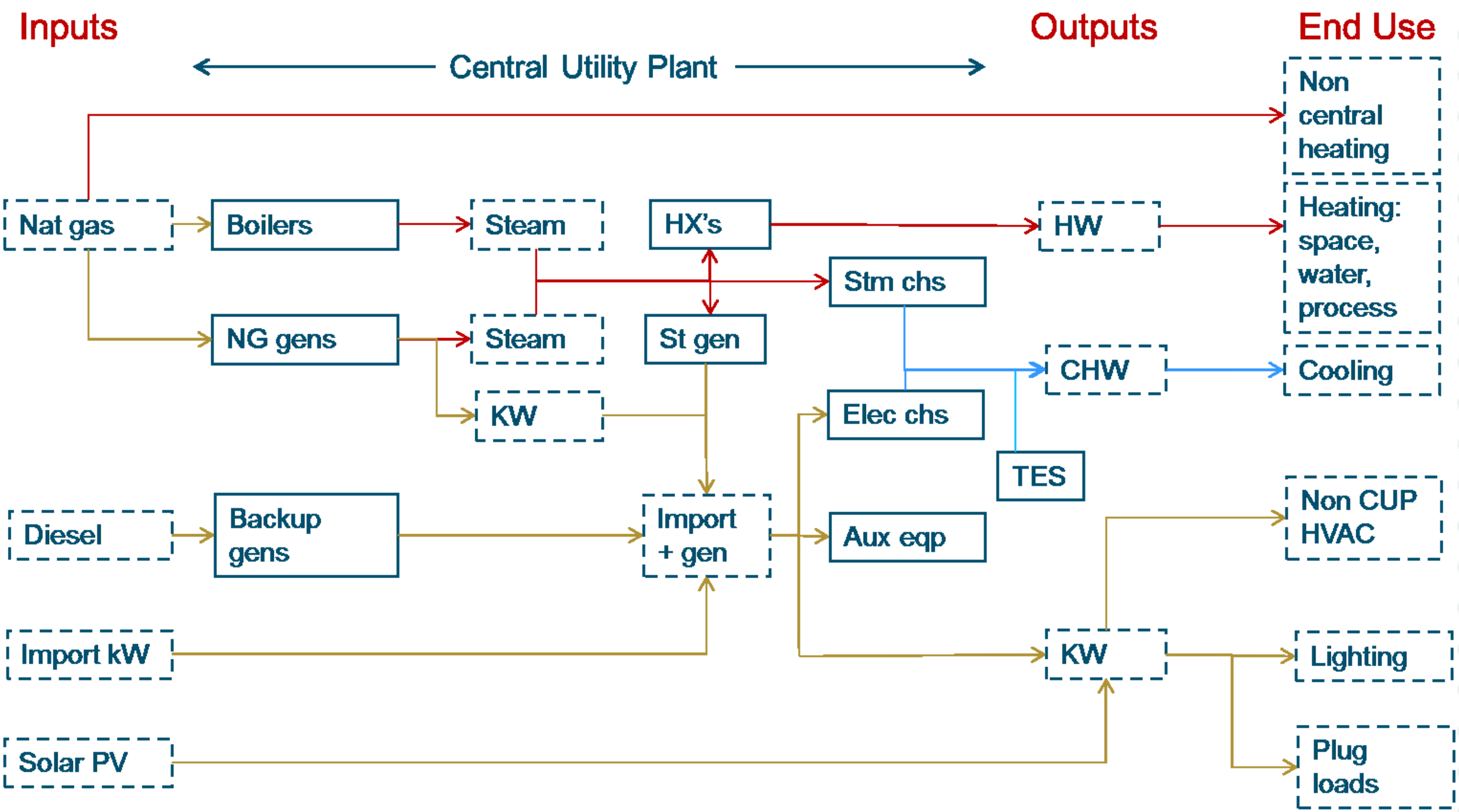
UCSD Data Resources

- MSCADA system: 15-minute power data
- Johnson Control Metasys System: thermal storage tank data
- ‘BOP’ System: steam data for boilers, generators
- ‘Efftrack’ chiller diagnostic system: chiller data
- Daily central plant logs: gas usage
- UCSD expert knowledge; especially John Dilliott, Energy Manager
- Solar data from Prof. Jan Kleissl

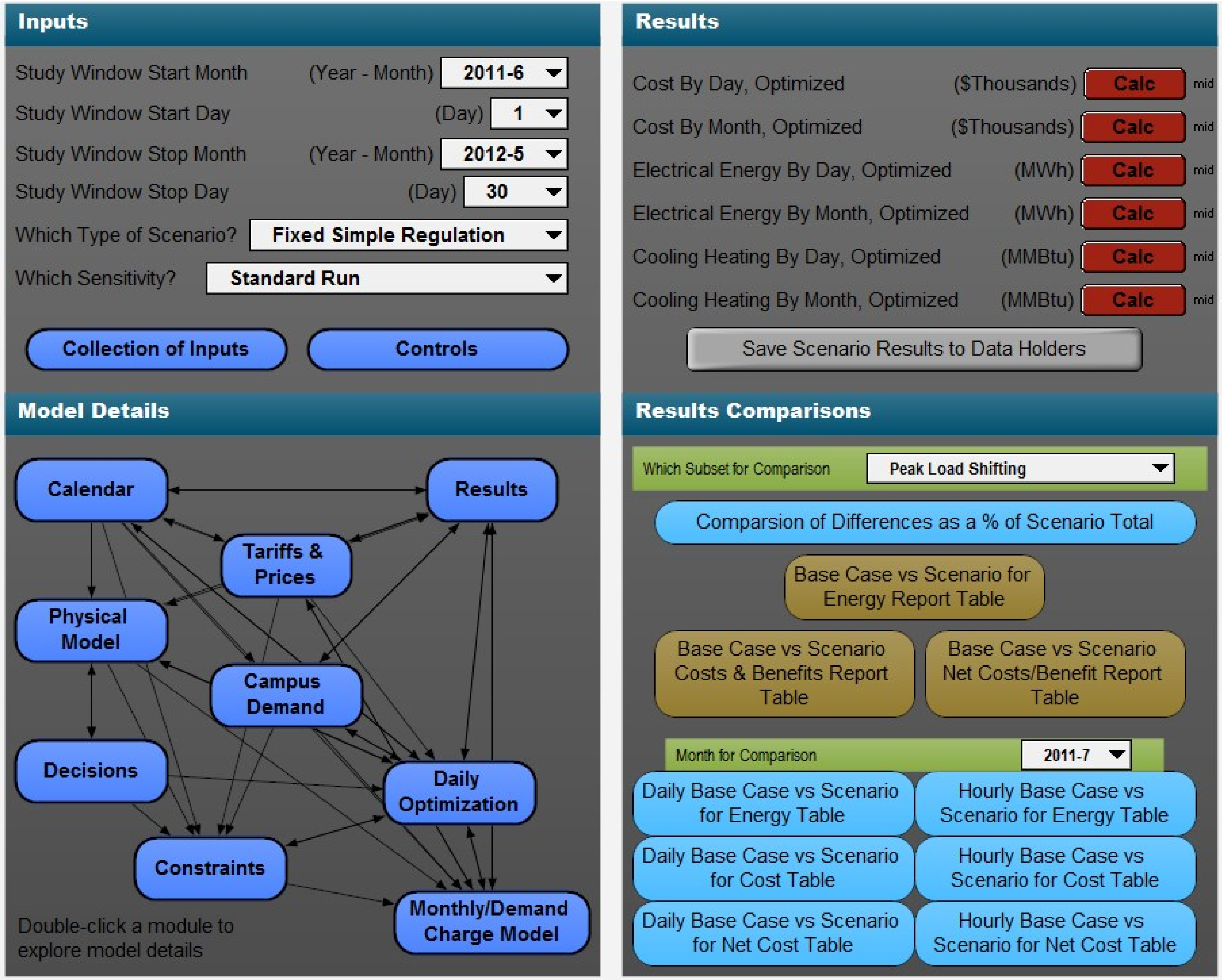
UCSD Dispatch Optimization Tool

- E3 developed an engineering and economics dispatch tool in the Analytical modeling platform
- The tool determines which resources to dispatch on an hourly basis in order to minimize daily and monthly energy costs
- Main thermal & electrical systems of the central plant are modeled (see next slide)
- Model determines the least cost dispatch that satisfies campus thermal and electrical demand, subject to equipment operating constraints

Analytical Framework: How the Resources Fit Together



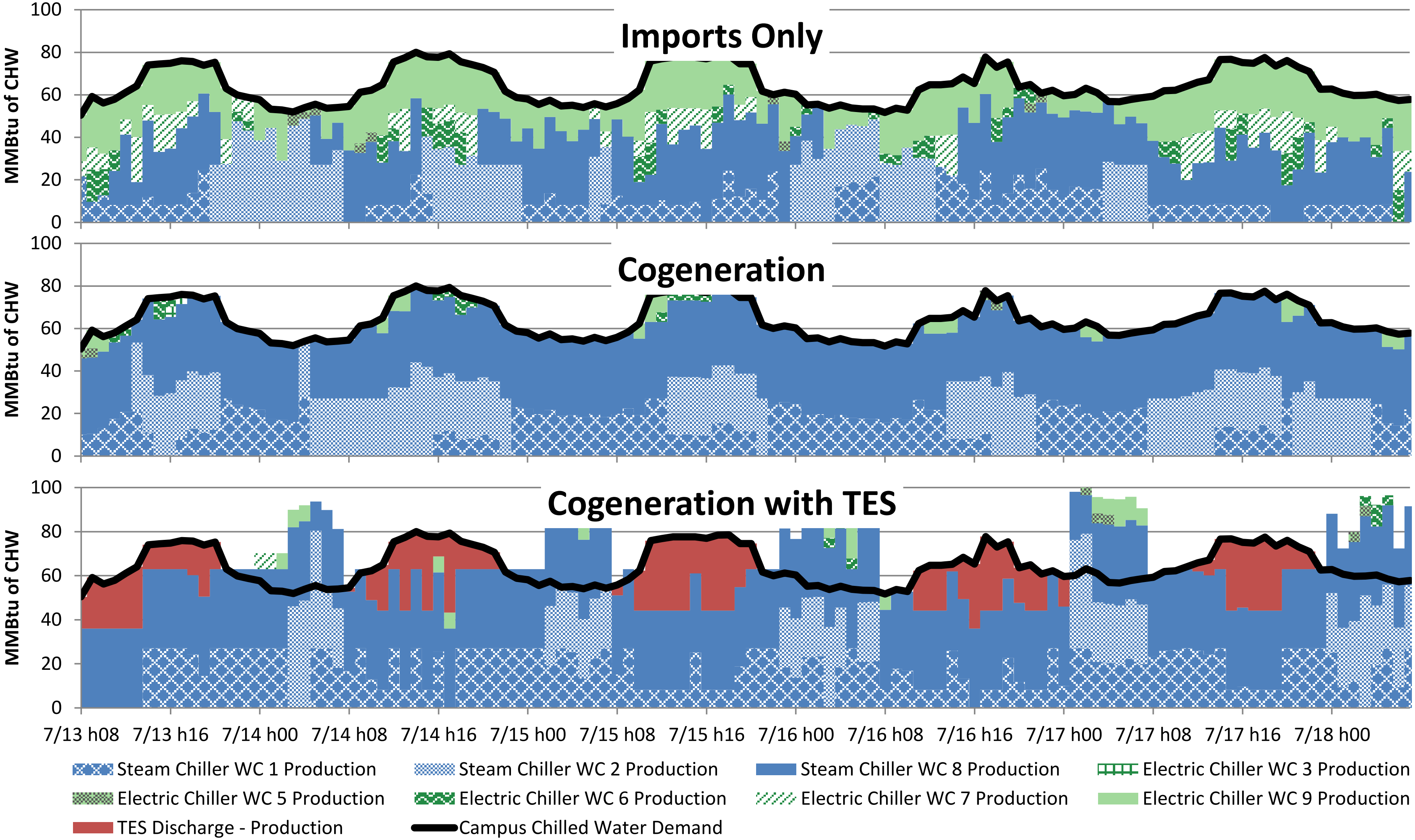
Campus Electric and Thermal Dispatch Optimization Model



Dispatch Example

- **The next slide shows how the chilled water needs are met under three different scenarios**
  - **Imports only:** all electrical needs are forced to be met through imported electricity (no onsite generation)
  - **Cogeneration:** electrical needs can be met through either onsite generation or imported electricity
  - **Cogeneration and thermal energy storage:** all flexible resources in the microgrid are permitted to operate

Chilled Water Provision



Broad Strategies Investigated

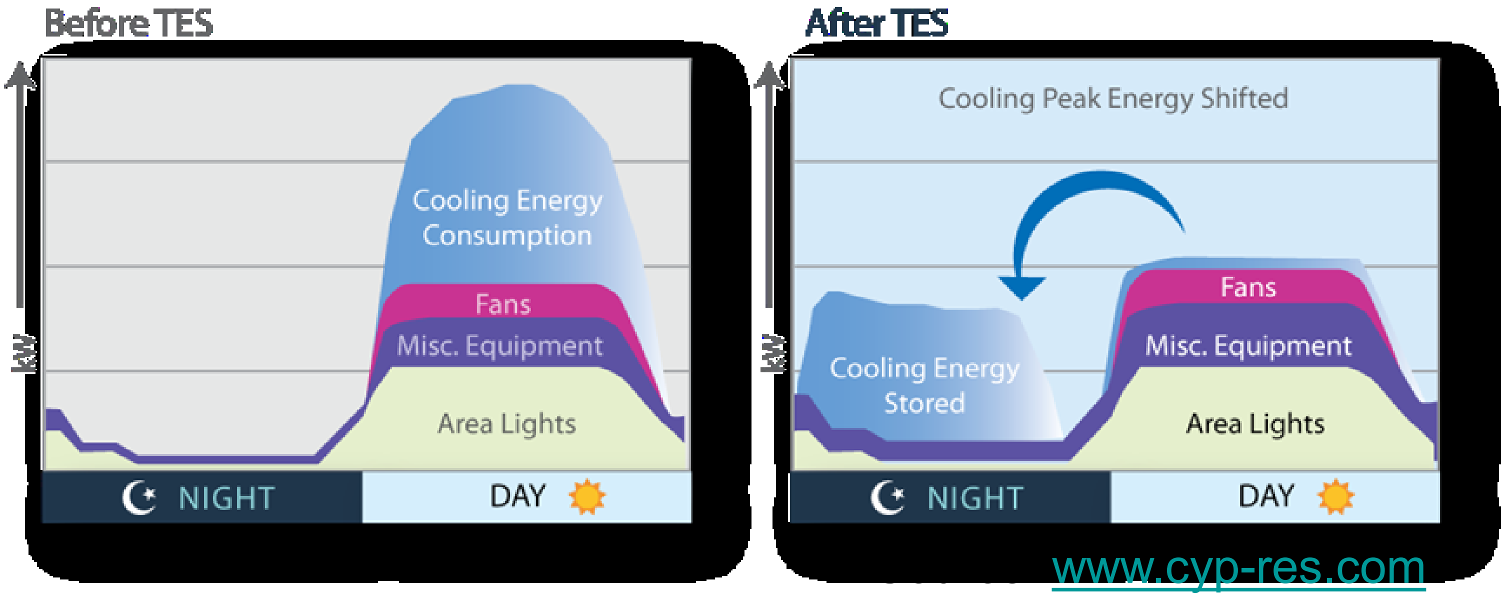
+ **Peak load shifting (PLS)**
  - Reducing peak load is a primary motivation for DER
  - Investigated tariff changes to increase potential/reduce cost of PLS
+ **PV firming strategies**
  - PV variability imposes costs, but 'leaning on the grid' is currently free
  - Investigated scenarios with higher PV penetration and with penalty for deviations from day-ahead schedule
+ **Grid support**
  - Can DER compete with grid resources in providing ancillary services to integrate renewable generation?
  - Used 2011 frequency regulation prices for illustrative case study

Criteria for Evaluating the Strategy

- **Does the strategy save UCSD money, relative to their baseline operations?**
- **Is the strategy cost-effective today?**
  - If not, is the strategy likely to be cost-effective in the future?
  - What policies would make it cost effective?
- **Net costs = scenario cost *minus* base case cost**

PEAK LOAD SHIFTING

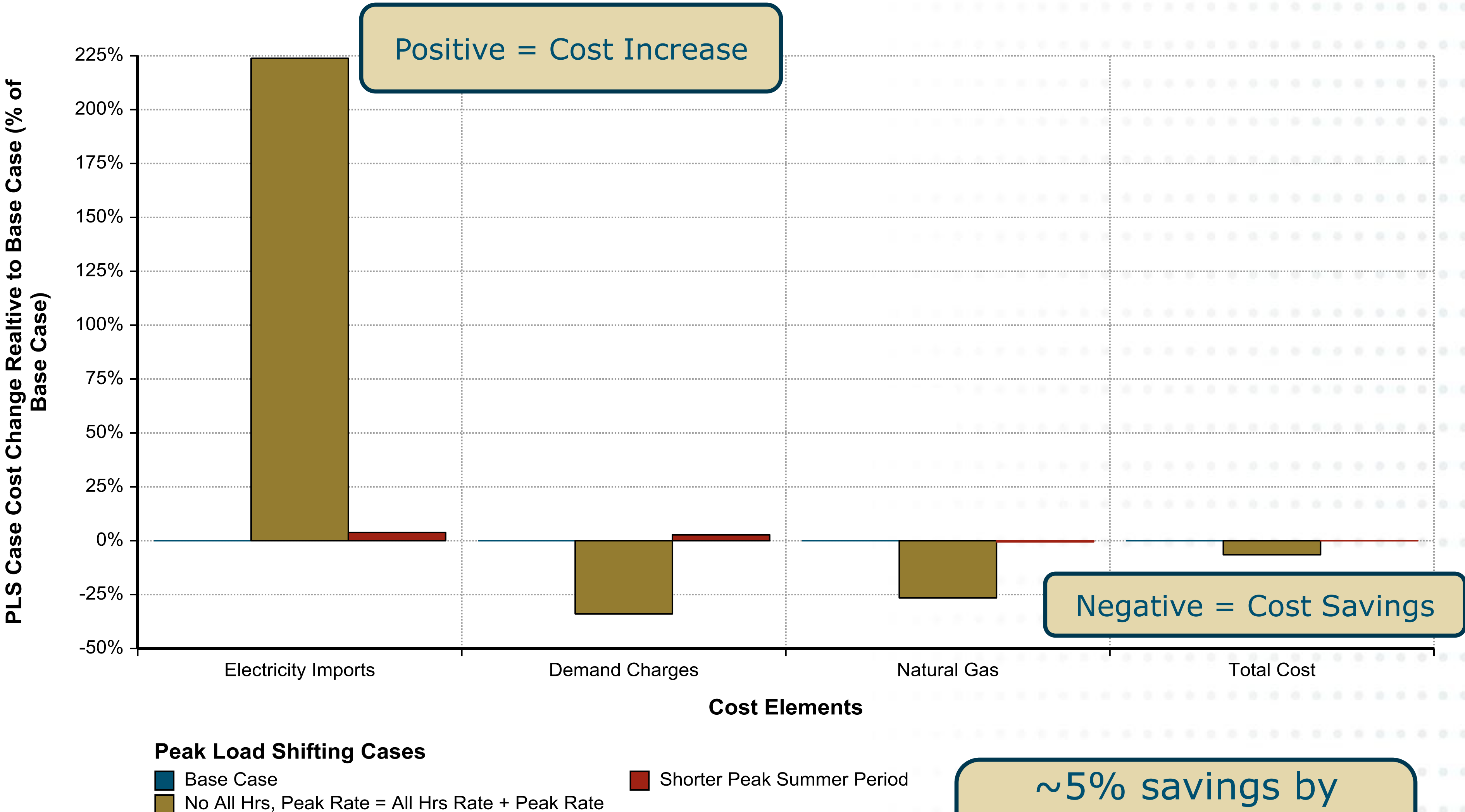
Peak Load Shifting Description



www.cyp-res.com

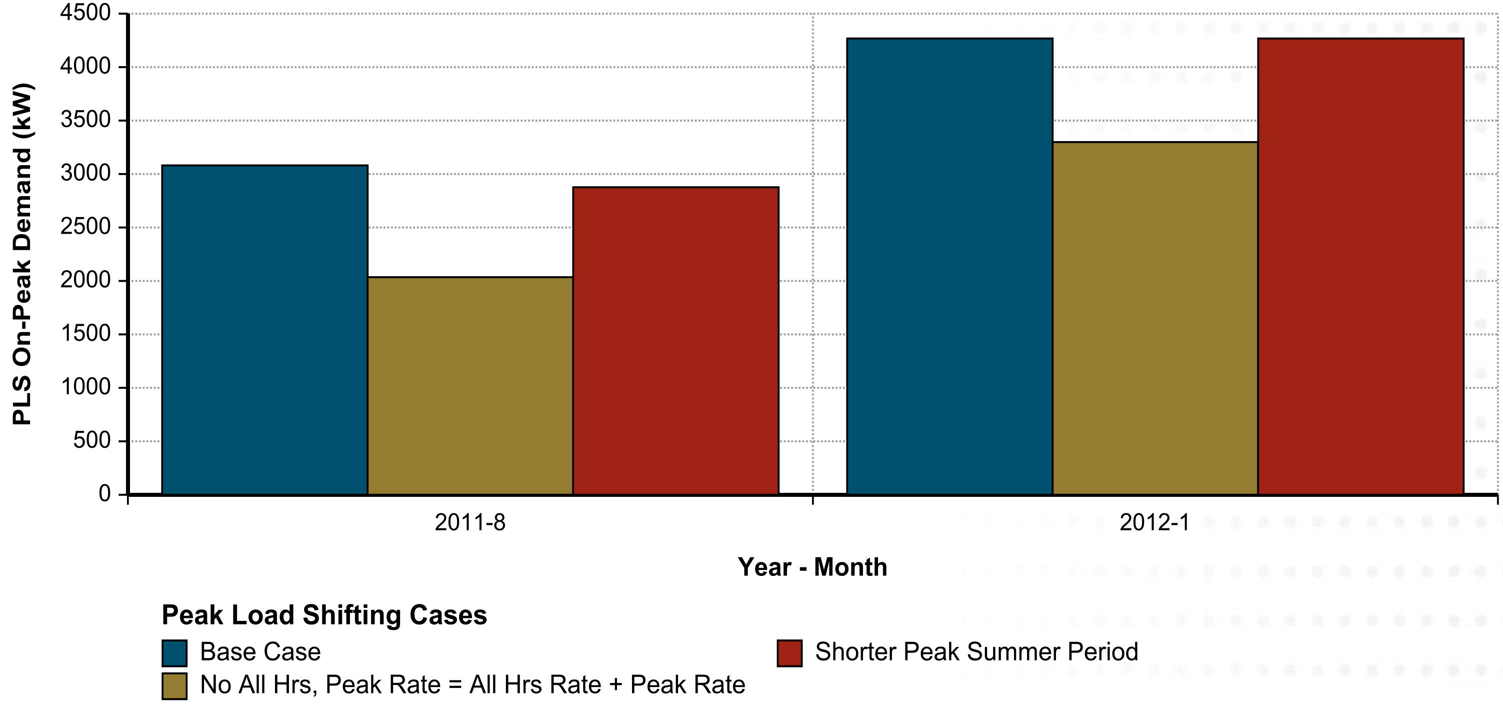
- UCSD already shifts substantial portion of peak load with thermal energy storage
- Can peak loads or campus costs be reduced further?
- Do existing tariffs sufficiently promote (or inhibit) peak load shifting?

Peak Load Shifting: Comparison of Scenario Costs to Base Case, 2011-8



~5% savings by removing all hours demand charge

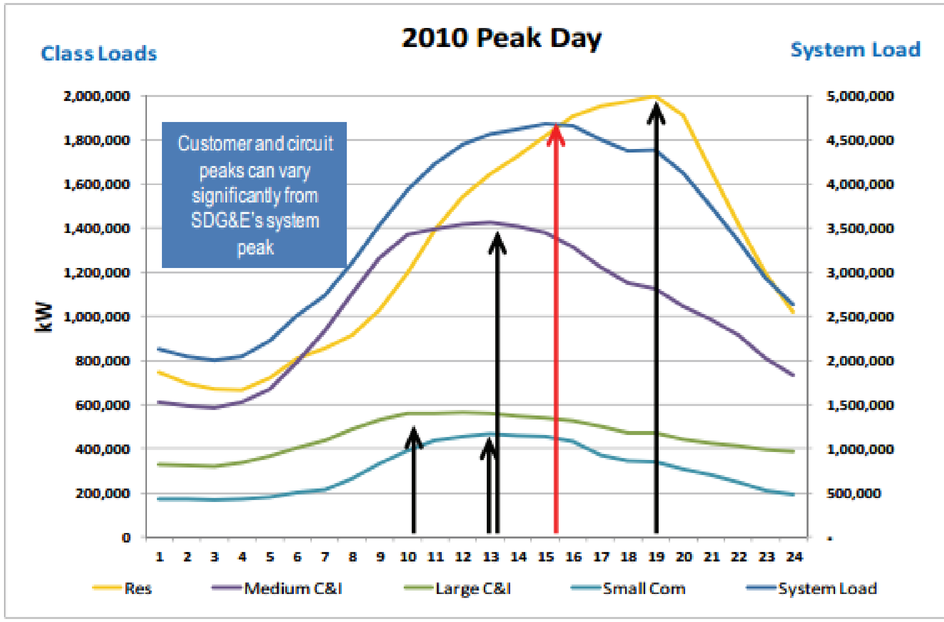
Peak Load Shifting: Peak Load Reductions



- **Peak demand is reduced significantly with all hours demand charge removed**
- **Reduction of 0.5 MW on average, as high as 1 MW**

Restructuring All-Hours Demand Charge

- All-hours demand charge designed to recover fixed distribution costs regardless of when peak occurs
- Individual customer classes all peak between 10 am and 7 pm
- PLS is a specialized case where load can be shifted to super off-peak hours
- GRC Phase 2 testimony supports excluding super off-peak period from fixed cost recovery[1]



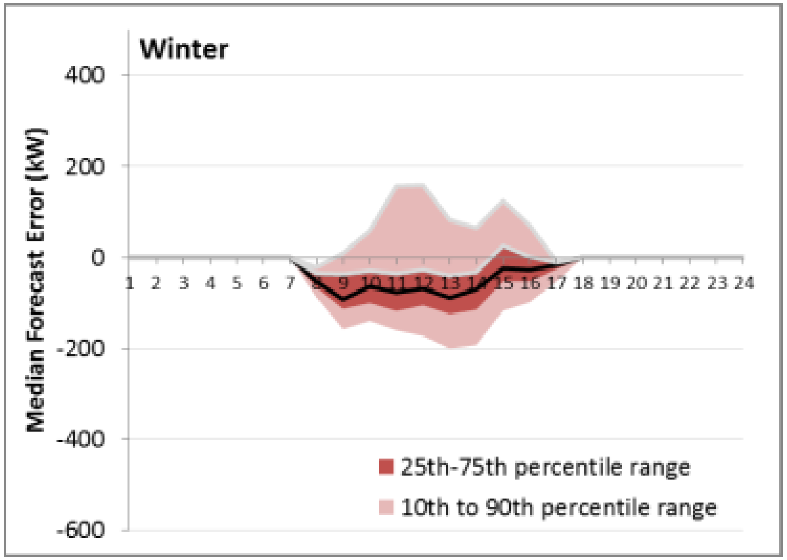
1. Doc #254237, CY-7, http://www.sdge.com/sites/default/files/regulatory/Ch-1-Yunker.pdf

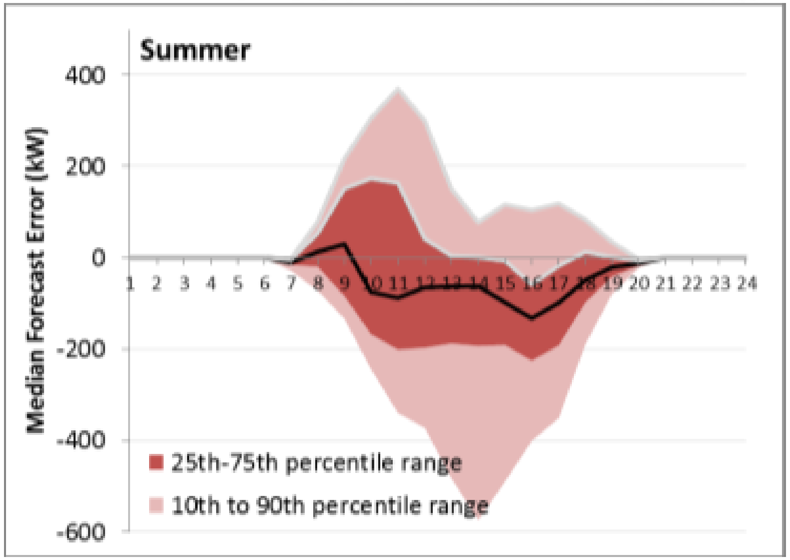
Energy+Environmental Economics

PV FIRMING

PV Firming: Description

- **Managing day-ahead (DA) forecast error**
  - Relatively small at existing penetration, greater issue at high levels of penetration
- **PV Firming counter balances forecast error to match day-ahead schedule**

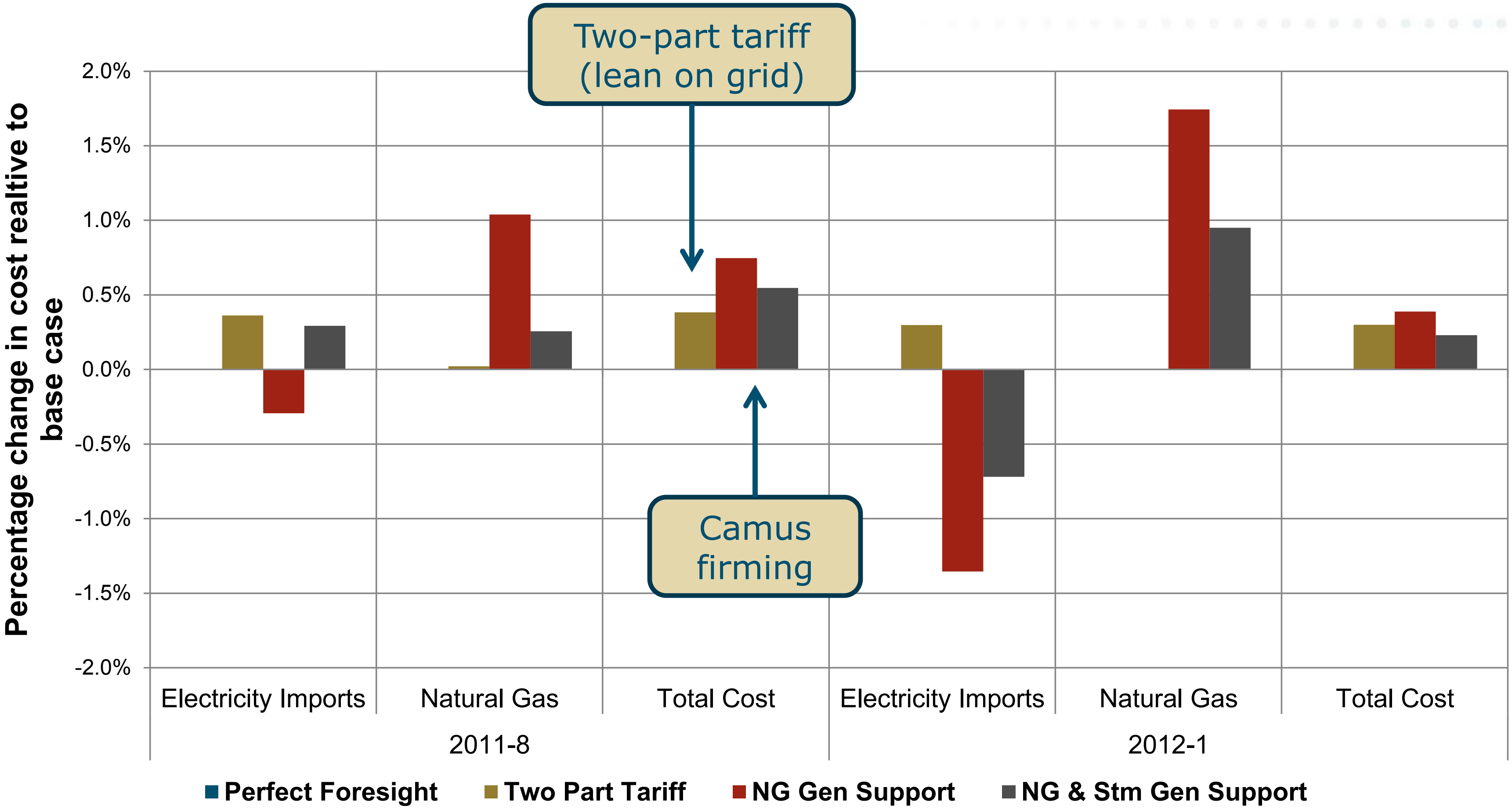




PV Firming: Strategies

- **Base case (today) no cost for forecast error**
  - → No incentive to firm PV
- **Two-part rate**
  - Base rate for DA schedule, 'penalty' rate for deviations
  - Imposes cost to lean on grid
  - $8/MWh of production → $31/MWh of forecast error
- **PV firming using natural gas and steam generators**
  - Offset forecast error with natural gas generation alone
  - Offset forecast error with natural gas and steam generation
- **Investigated scenarios with higher PV penetration; 200% results shown**

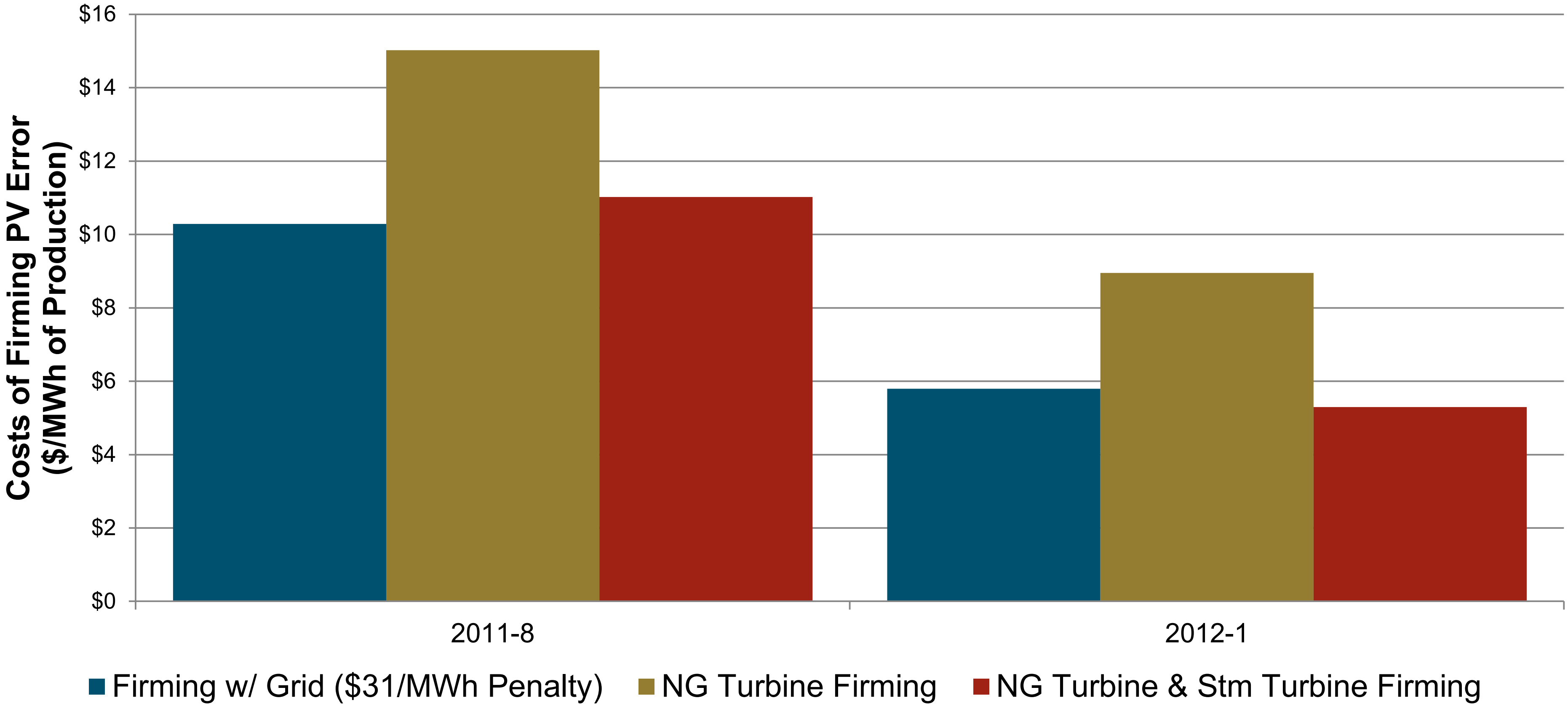
PV Firming 200%: Comparison of Scenario Costs



Two-part tariff (lean on grid) cheaper than firming with campus resources in most months

PV Firming 200%: Implied Cost of PV Firming by PV Production

+ **Difference in cost per MWh of production**



PV Firming: Summary

- **Using grid level estimates of integration costs, it appears more cost-effective to lean on grid**
  - Differences in total costs relatively small
- **However - local distribution costs for integration costs could be higher**
- **Using additional campus resources could reduce costs of PV firming**
- **As penetration increases, so does costs to firm using microgrid**

GRID SUPPORT

Grid Support: Description

- **Use campus resources to support grid operations**
- **Bid into CAISO frequency regulation market**
  - Used historical 2011 market prices for frequency regulation
  - No pay-for-performance or flexi-ramp
- **Use frequency regulation as illustrative case study for DER providing flexible resources to grid**
  - Methodology applicable for load following and ramp

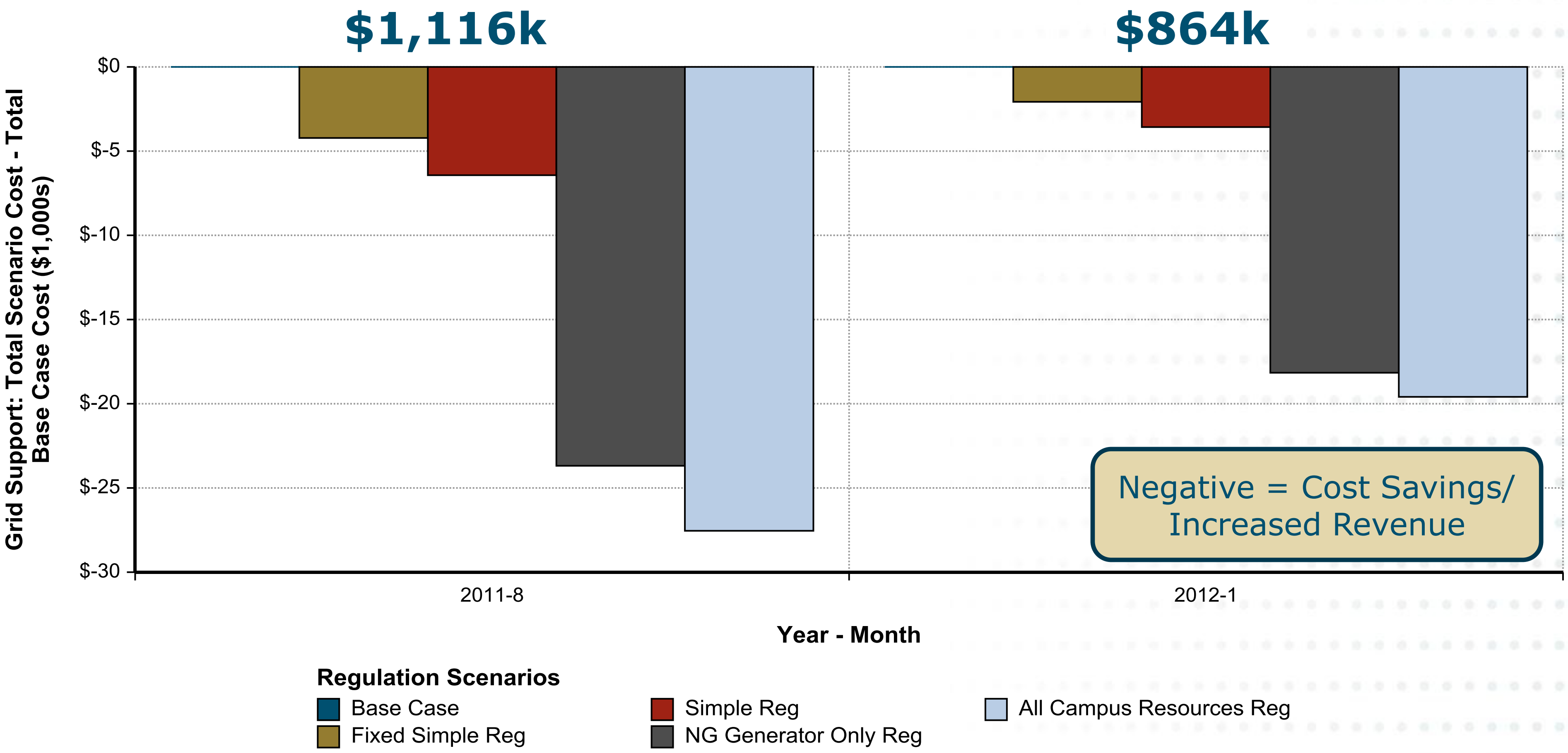
Grid Support: Scenarios

Increasing flexibility

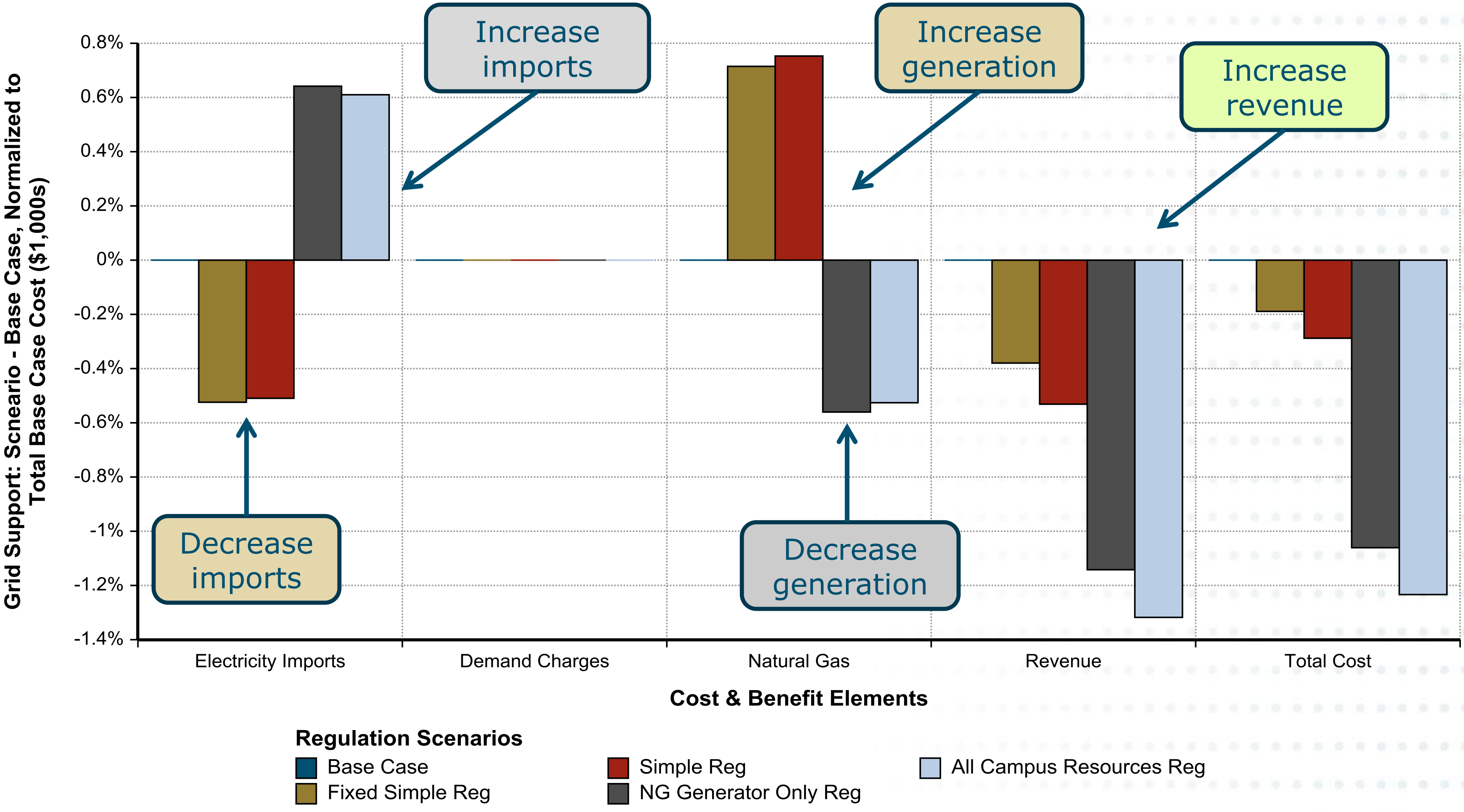
+ **Base case**
  - Establishes resource schedule, no regulation bids
+ **Fixed, simple regulation**
  - Use natural gas generator to bid 3.3 MW of Reg Up and Reg Down
+ **Simple regulation**
  - Use natural gas generator to bid 0-3.3 MW of Reg Up and Reg Down
+ **NG generator only regulation**
  - Bid 0-6.6 MW for either Reg Up or Reg Down separately
+ **All campus resources regulation**
  - Add steam turbine and electric chillers to bid 0-13.5 MW of Reg Up or Reg Down separately

Grid Support: Scenario Net Costs

Base Case Total Cost:

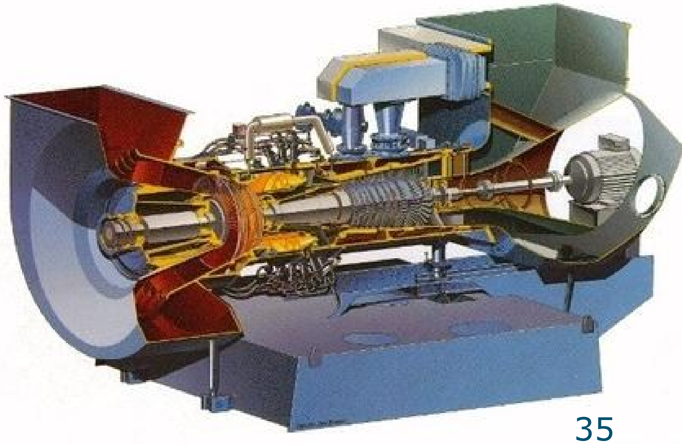


Grid Support: Scenario Costs by Component, 2011-8



Grid Support: Summary

- **Results suggest it is possible for UCSD to offer grid services at today's prices for a net profit**
  - But profit is relatively small: ~ 1-2% of total energy costs
  - Profit significantly increases with additional resources and greater flexibility in bidding strategy
- **Results in perspective**
  - Market may be small for regulation but larger for load following and ramp
- **Again, local distribution avoided costs may be needed to encourage DER participation**



CONCLUSIONS

Conclusions

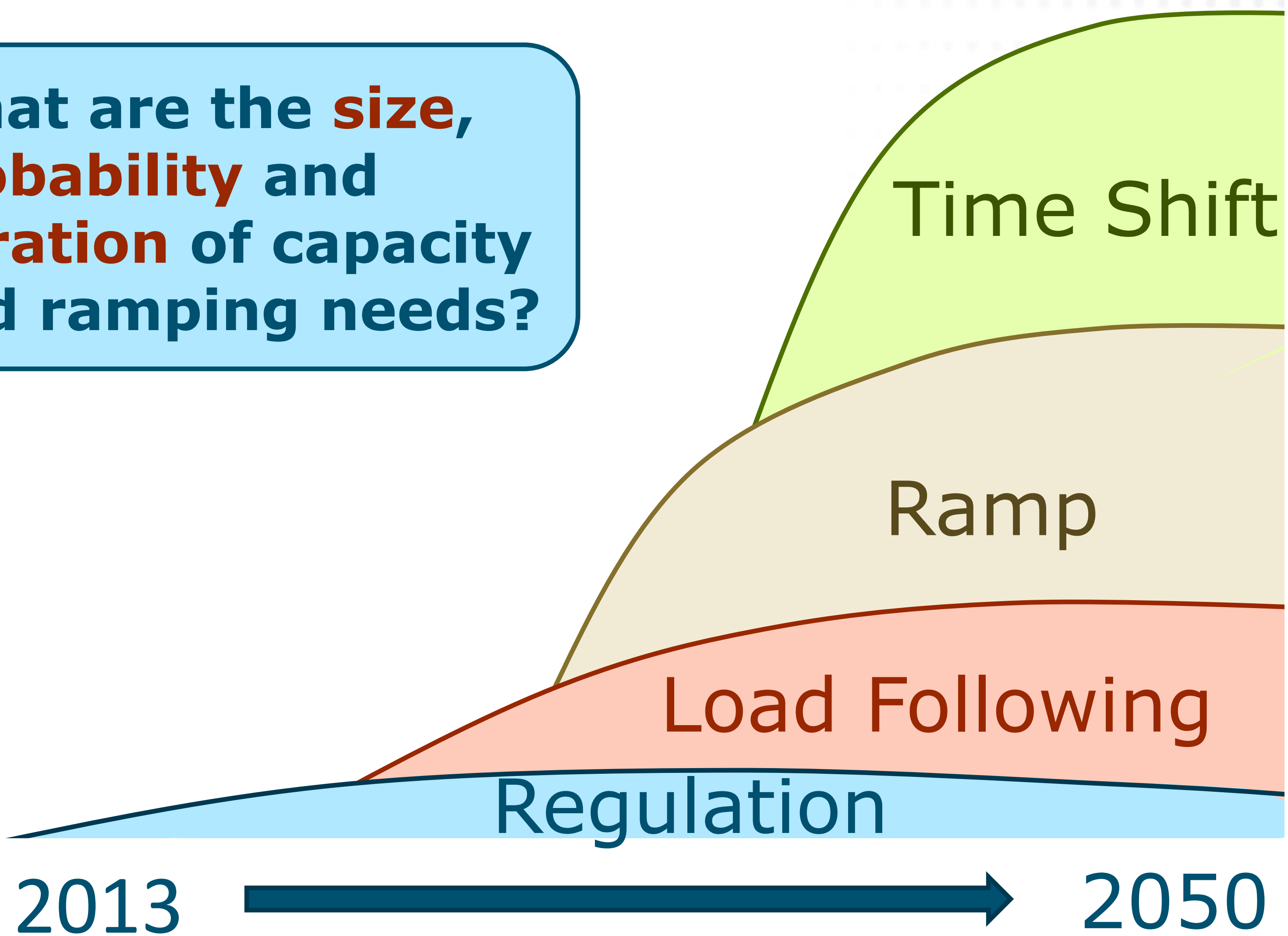
- Integrated optimization and dispatch of campus resources can reduce costs while providing flexibility
- Removing all-hours demand charge increases peak load shifting potential
- Leaning on grid is marginally more cost-effective than PV firming with campus resources
- Current prices for regulation provide net revenue, but it is small relative to total campus costs

Conclusions (con't)

- Incorporating load (non-generator) resources reduces campus costs of providing flexibility for renewable integration
- Tariffs and incentives to encourage integration of renewables with DER are both feasible and cost-effective (based on TRC)
- However, additional incentives based on local, distributed avoided costs and value of flexible capacity will be needed to encourage adoption

How will grid needs evolve over time?

What are the size, probability and duration of capacity and ramping needs?



Which needs do DERs fill best?

What DERs
do best

What grid
resources do best

How do DERs get a seat at the table?

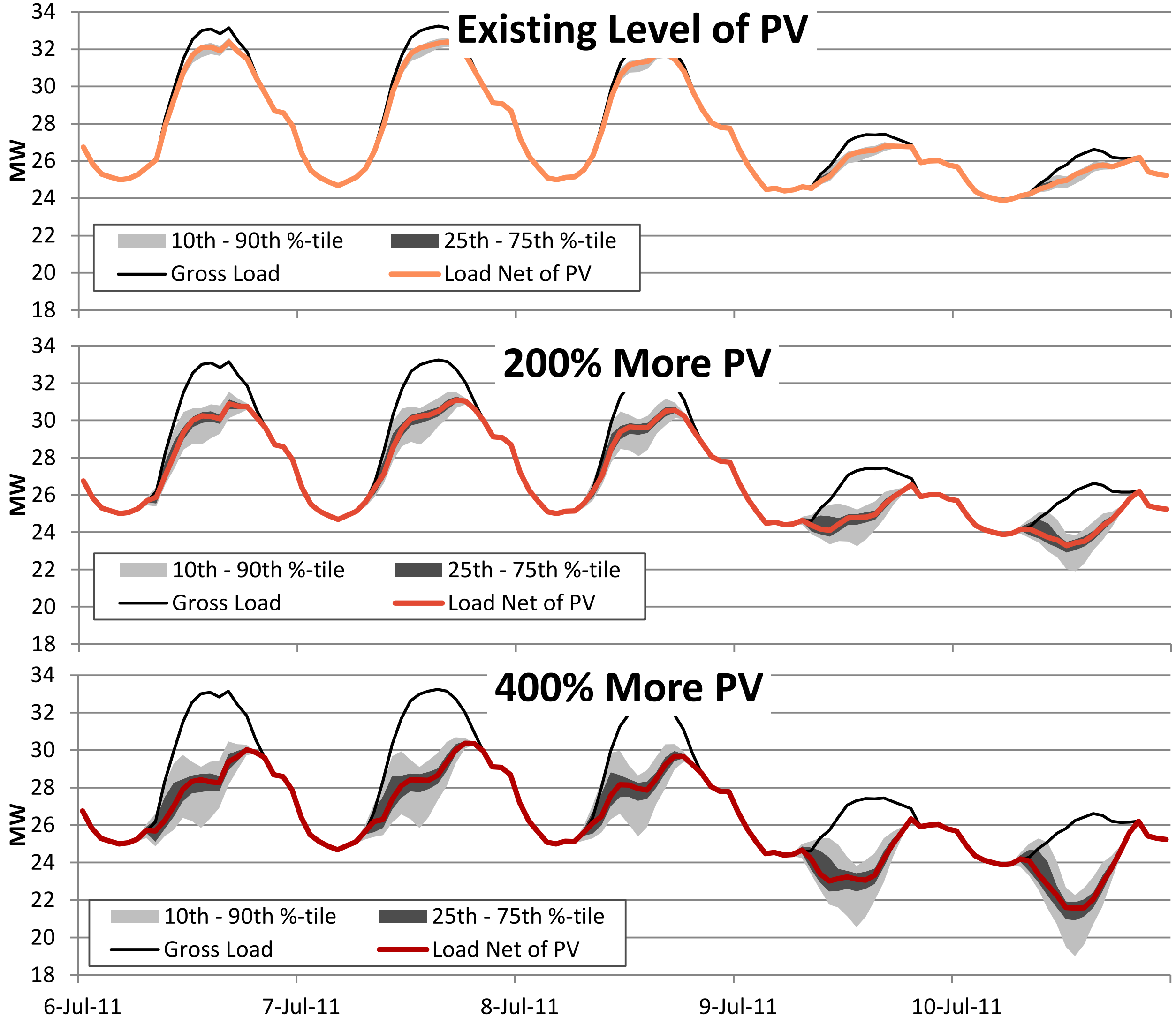
Energy+Environmental Economics

APPENDIX SLIDES

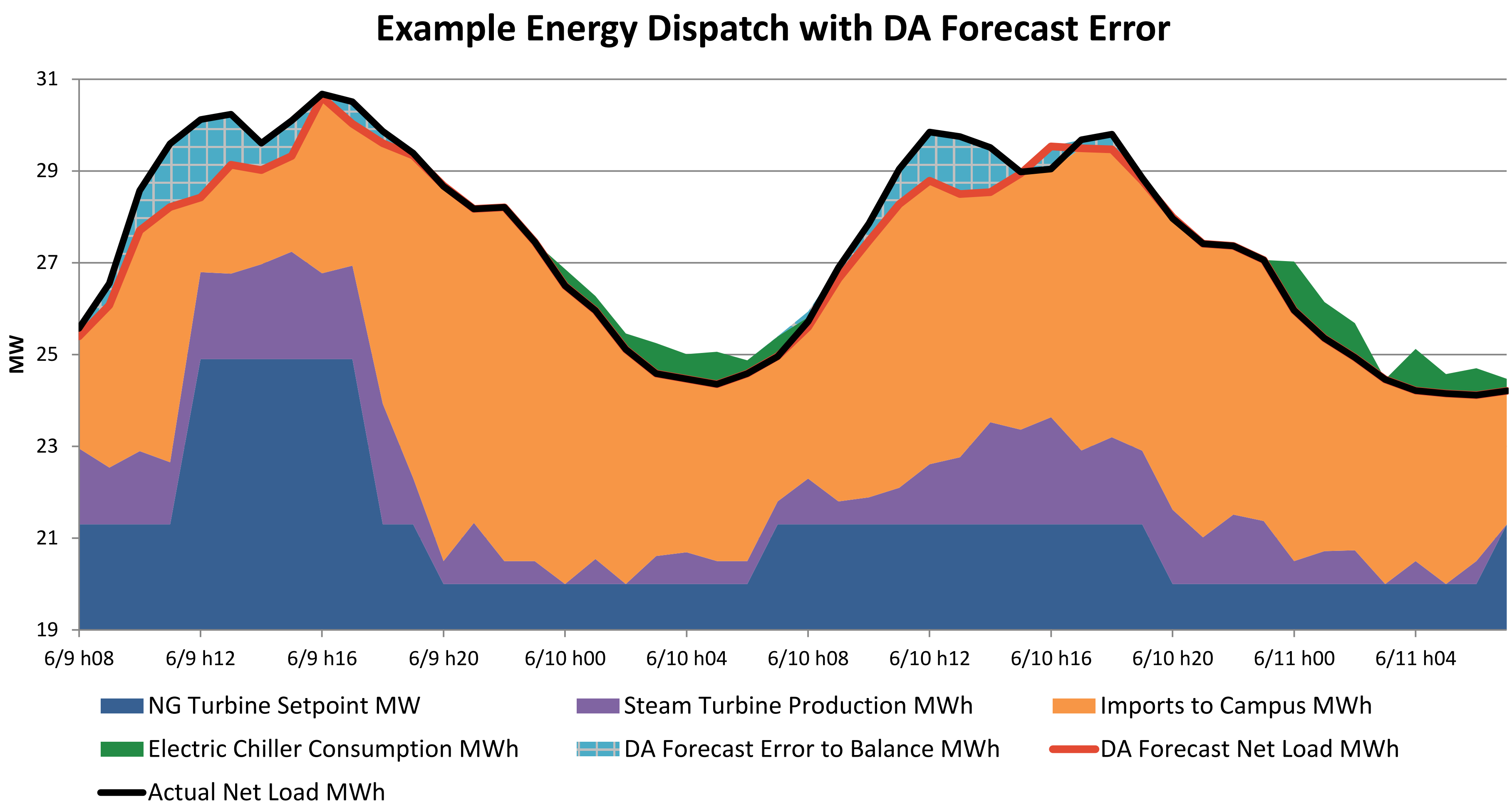
Additional Resources

- **http://calsolarresearch.ca.gov/Funded-Projects/second-solicitation-funded-projects.html**
  - Tasks 6-8 report: Strategies and incentives for integration of renewable generation using distributed energy resources
  - Additional reports found on the website
- **https://solarhighpen.energy.gov/2013_doe_cpuc_high_penetration_solar_forum**
- **Later in 2013**
  - E3 update to NEM cost-effectiveness report
  - E3 update to technical potential of high penetration distributed generation report

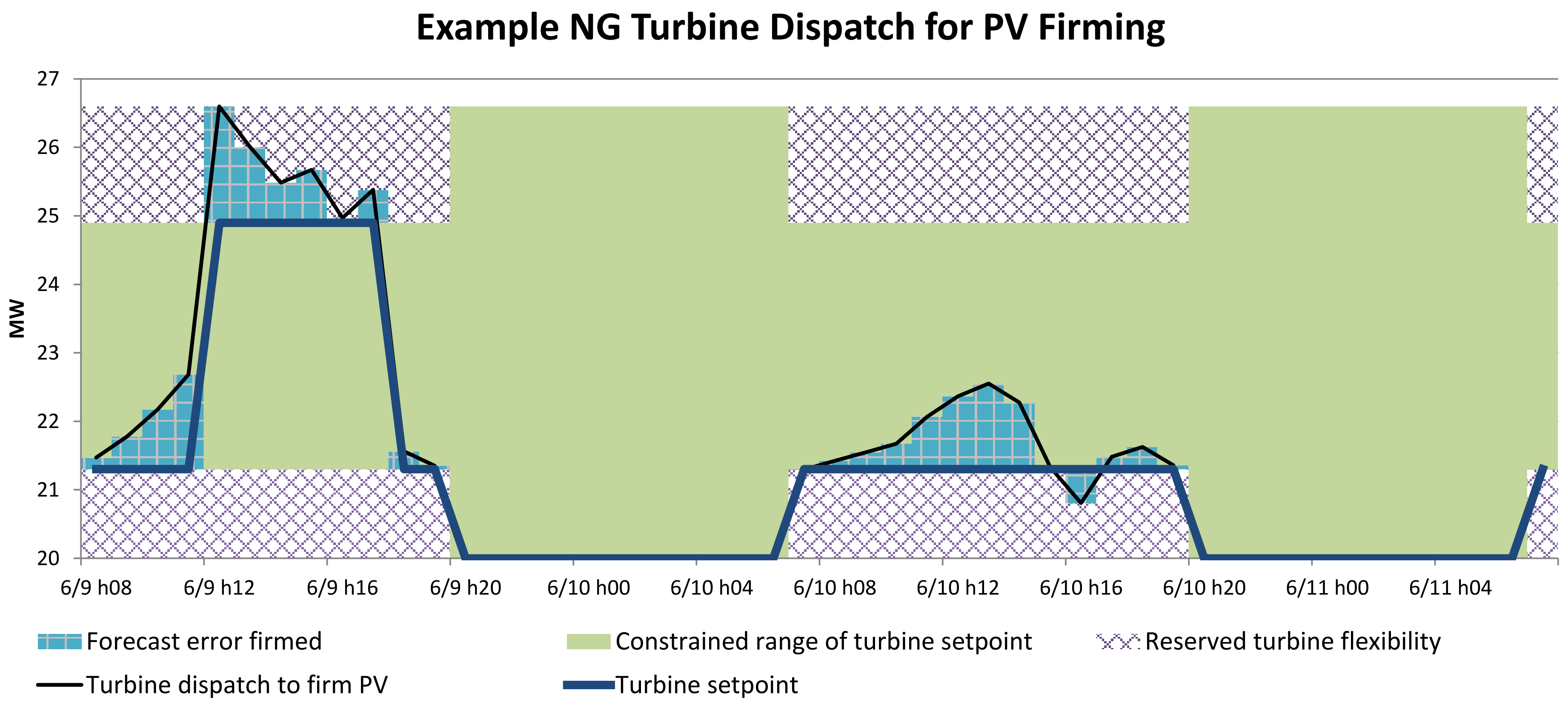
PV Firming – Levels of PV, Magnitude of Forecast Error



PV Firming – Addressing Day Ahead Forecast Error

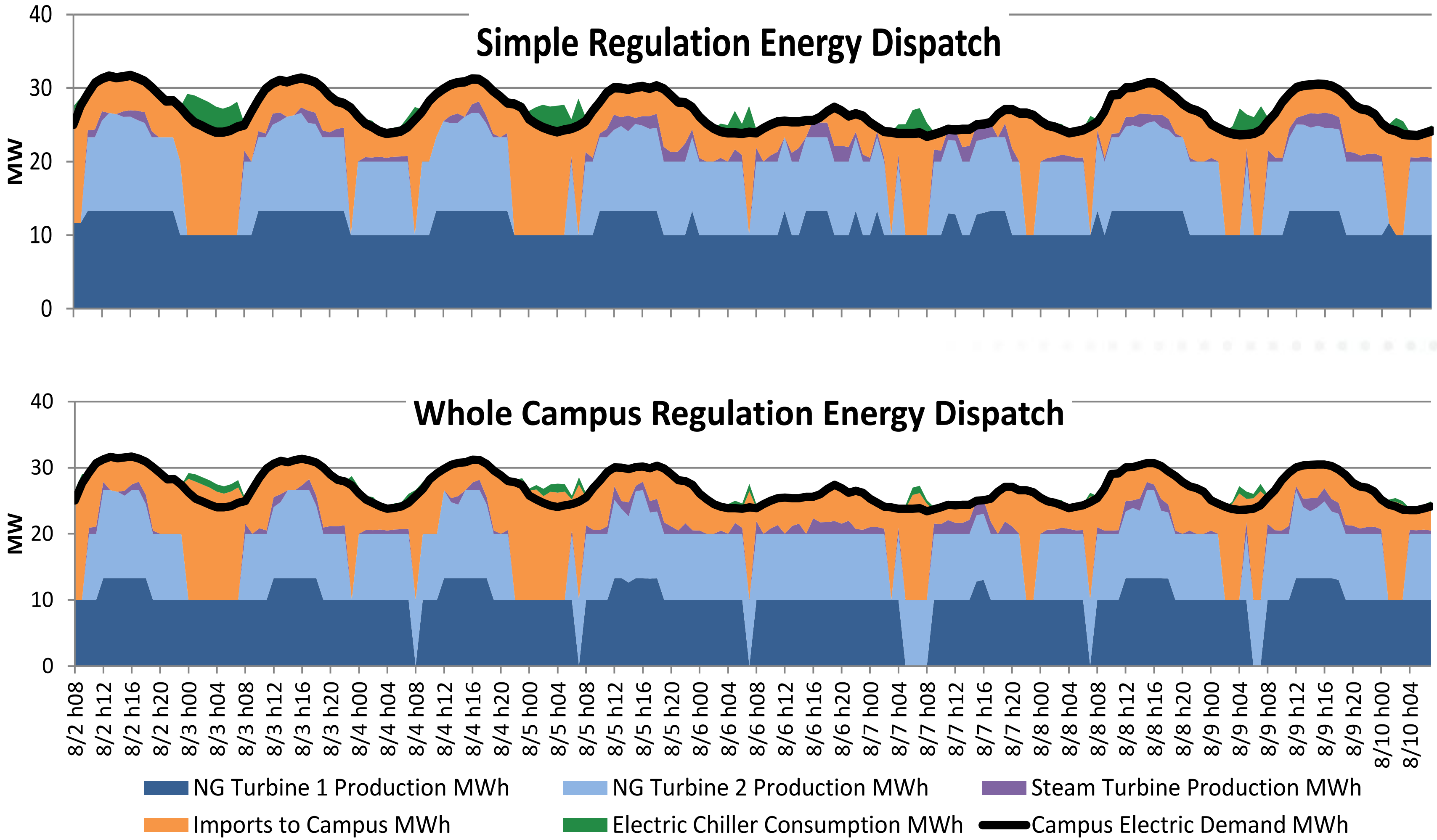


PV Firming – NG Turbine Firming Explained

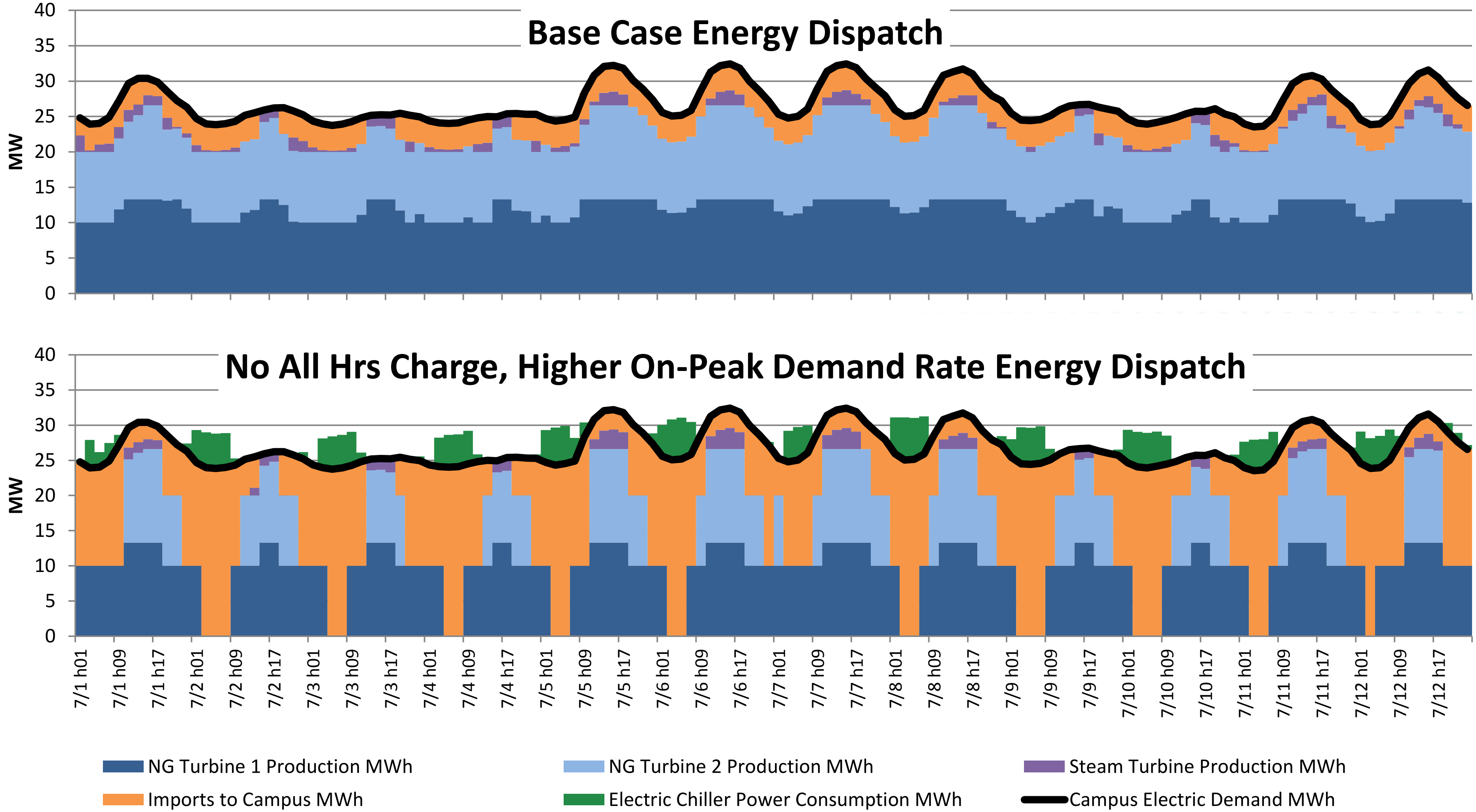


NG & Steam Turbine Firming is the same concept, where total flexible reserve is made up of both NG and steam turbine capacity

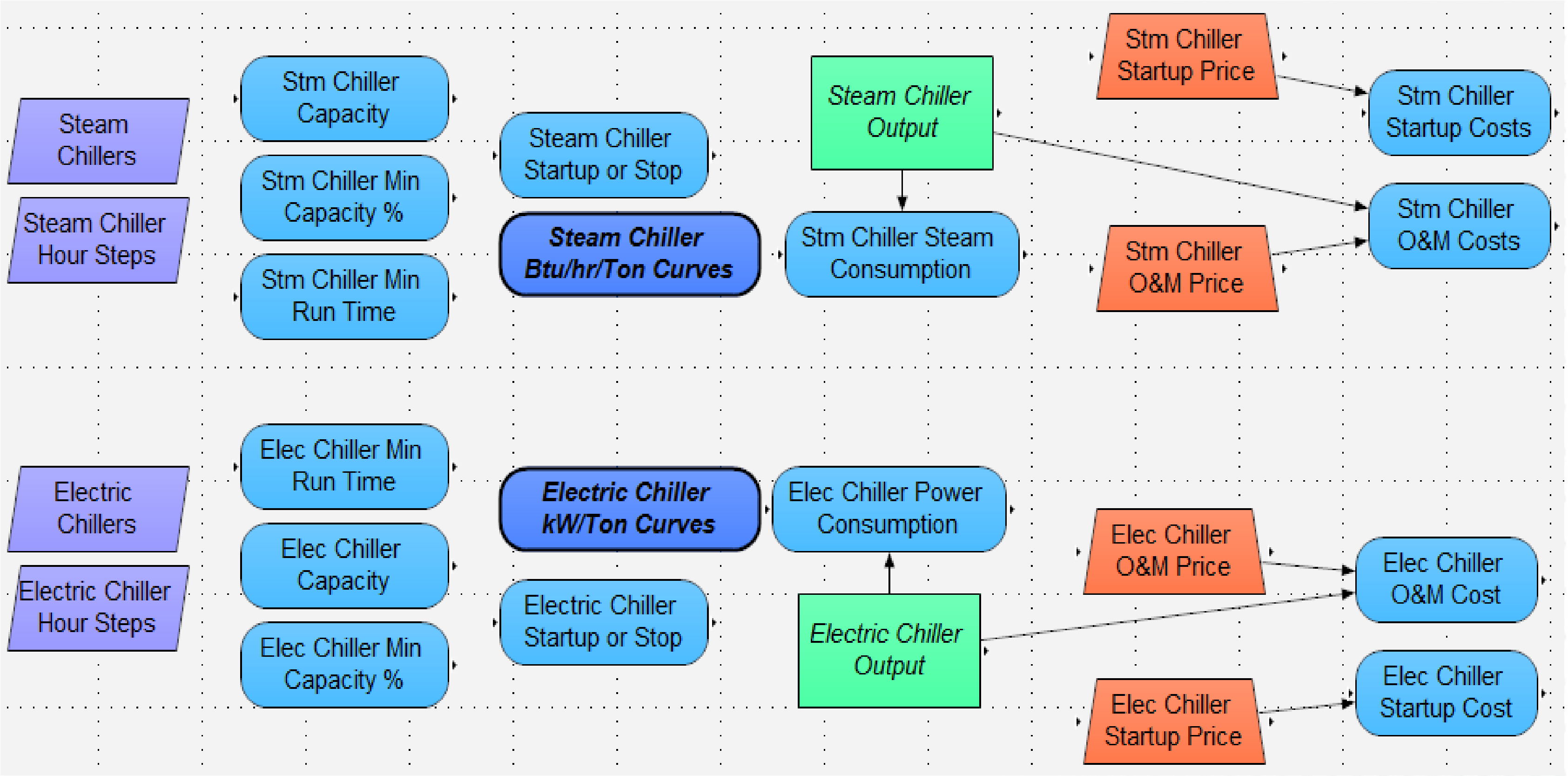
Regulation Dispatch



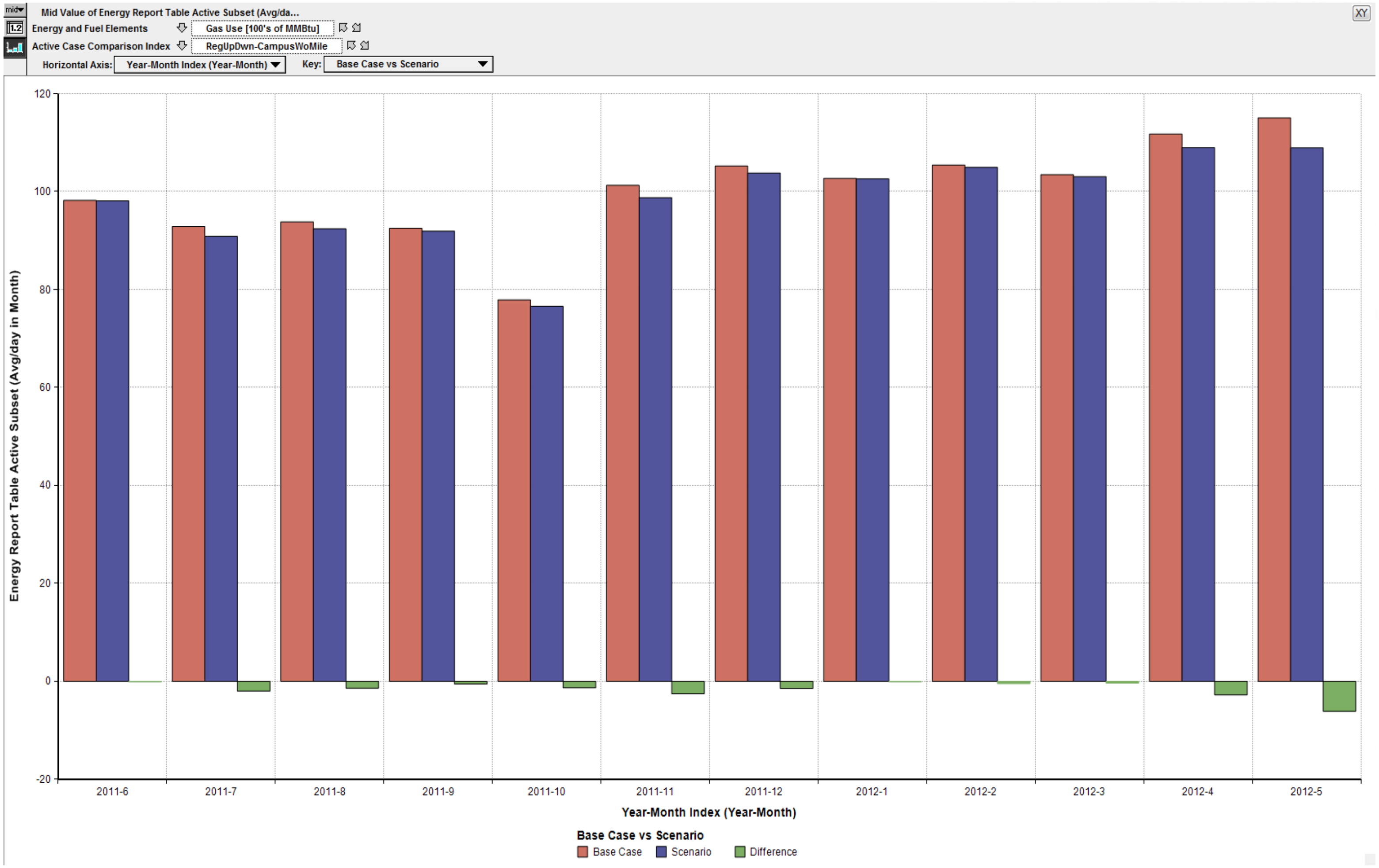
Peak Load Shifting: Change in Dispatch



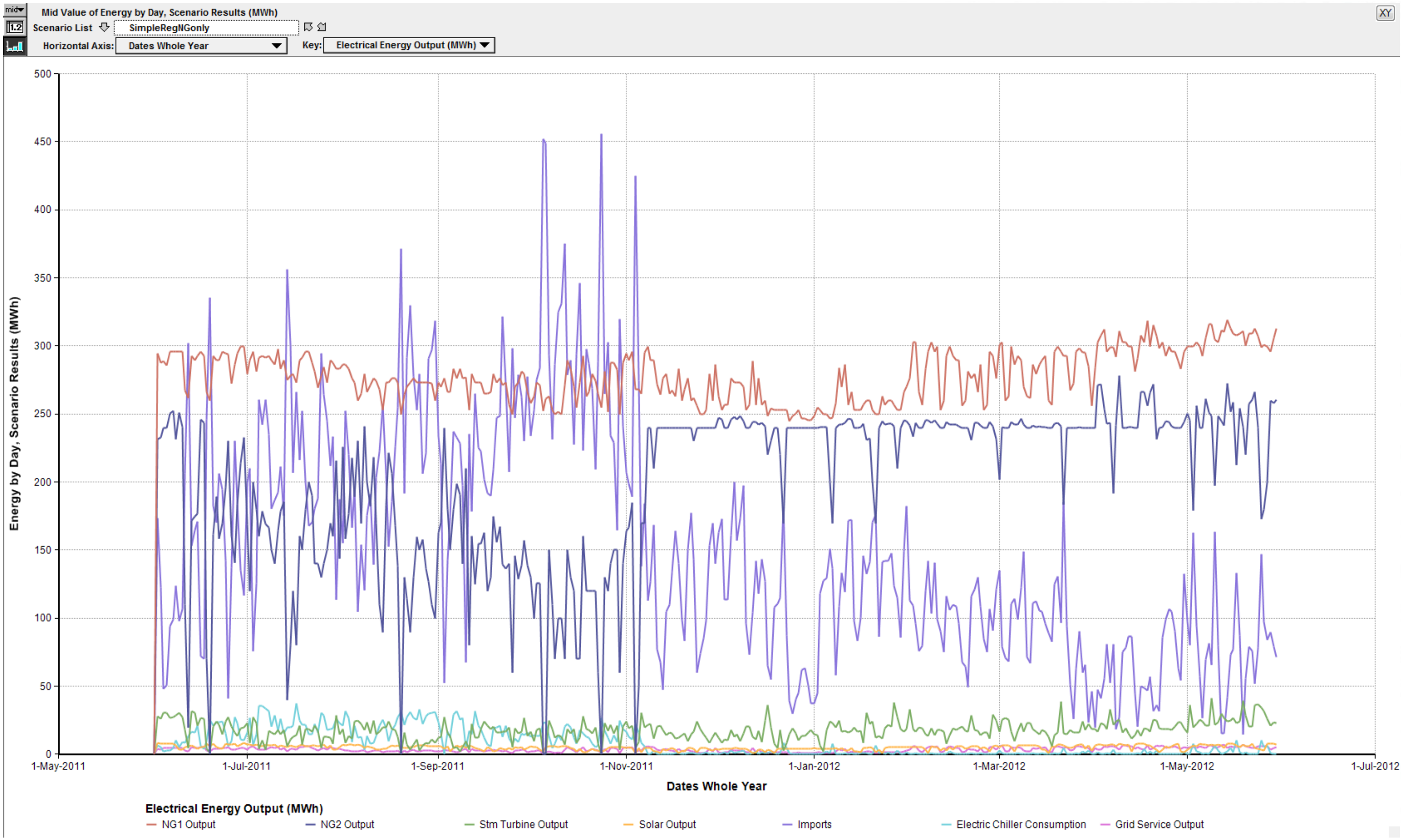
Chiller Optimization



Change in Energy Imports for Full Year



Daily Output by Resource for Full Year



Cost-effectiveness: TRC Costs

- **UCSD energy costs are a mix of wholesale costs and retail rates**
- **Retail rates are (almost) always higher than wholesale (TRC) costs**
  - We assume that the actual TRC cost will be less than or equal to the UCSD costs of implementing strategies
- **Capital cost of the existing resources are considered sunk**
  - Only the variable operating costs are included as TRC cost

Cost-effectiveness: TRC benefits

- **TRC benefits for each strategy are quantified based on alternative resources or established avoided costs**
  - PLS: resource adequacy or residual capacity value
  - PV Firming: estimates of grid integration costs
  - Frequency regulation: CAISO AS prices
- **PV Firming: not quite cost-effective based on grid level integration costs**
- **Frequency regulation cost-effective, but small percentage of total campus energy costs**

Peak Load Shifting TRC Details

- **"Cost" of increased peak load shifting is:**
  - Increase in electricity imports: $8/kW shifted
  - Decrease in natural gas consumption $9/kW shifted
  - In our illustrative case SDG&E demand charge revenue remains unchanged
- **Benefits (for month of August)**
  - Energy costs alone: $38/kW shifted
  - E3 avoided costs: $85/kW shifted
    - Includes system and T&D capacity value
- **TRC benefits much greater than cost**
  - RIM benefits also greater (for Direct Access customer)

Research for Policy Makers

- **What additional steps needed to access technical potential of existing DER**
  - 500 MW of college campus load
  - 2,000 MW of flexible industrial load
  - 8,500 MW of CHP at 1,200 sites in California
- **Overcoming ‘soft’ barriers for DER**
  - Data quality and management
  - Operational costs, risks and uncertainty
- **Beyond dynamic pricing – what else is needed**
  - Sub-metering, flexible capacity payments, two-part rates