Whole System Perspective on Energy Optimization Program Strategy

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16 July 2013

Whole System Perspective

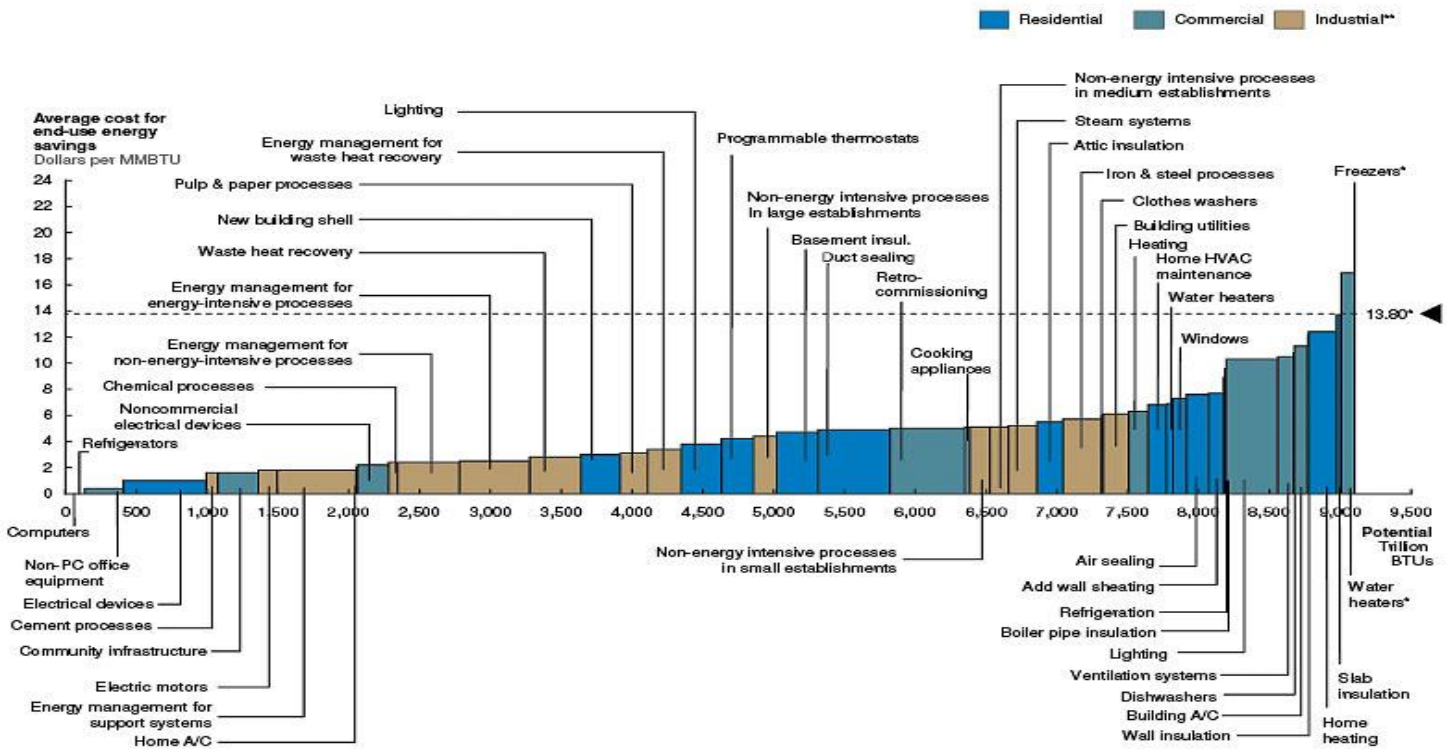
- In contrast to our usual discussions of Energy Optimization Programs from measures up, I will focus on analyzing whole utility data and decomposition to whole customer data.
- Case study data are for Consumers Energy (electricity) in 2007.
- Data analysis shouldn't be quantitatively relied upon as I haven't repeated the calculations not have they been peer-reviewed.

Energy Optimization Program Strategy

- What measures will be offered or emphasized to which customers?
- For convenience, I will use McKinsey & Company's 2009 report "Unlocking Energy Efficiency in the US Economy" as a frequent point of reference.

McKinsey's Energy Efficiency Supply Curve

Exhibit 7: U.S. energy efficiency supply curve – 2020

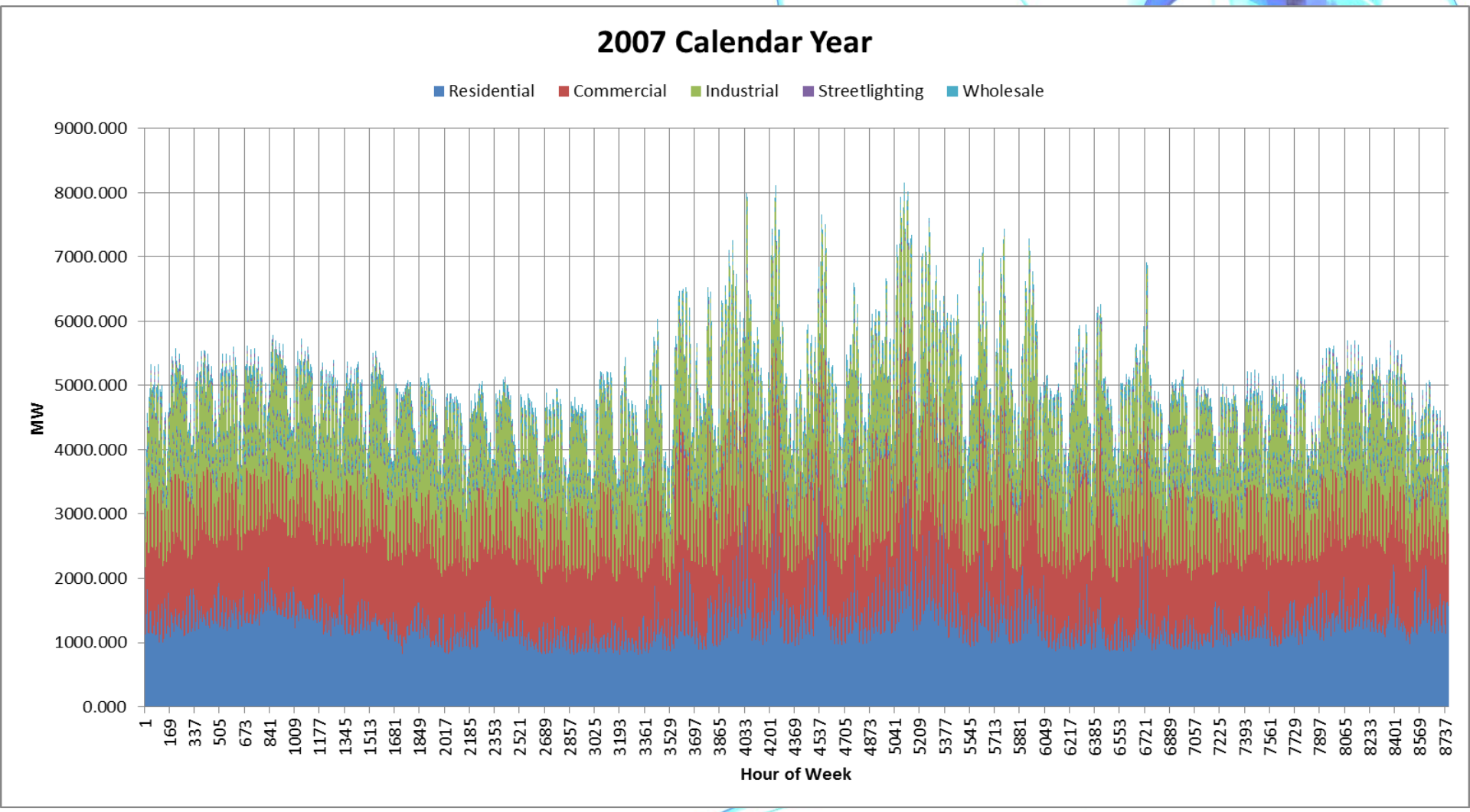


* Average price of avoided energy consumption at the industrial price; $35.60/MMBTU represents the highest regional electricity price used; new build cost based on AEO 2008 future construction costs

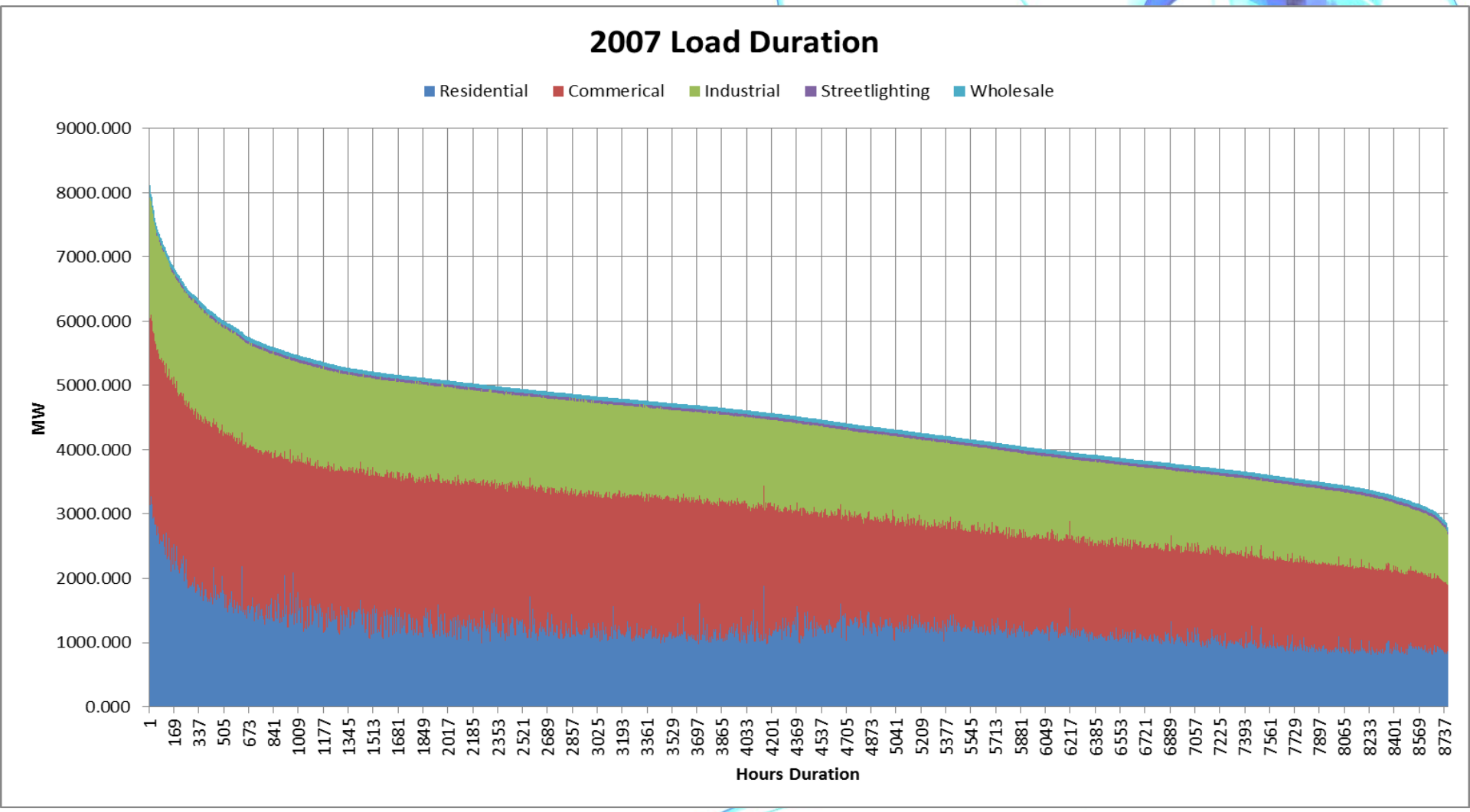
** Our 49th source of savings, refining processes, offers no NPV-positive savings

Source: EIA AEO 2008, McKinsey analysis

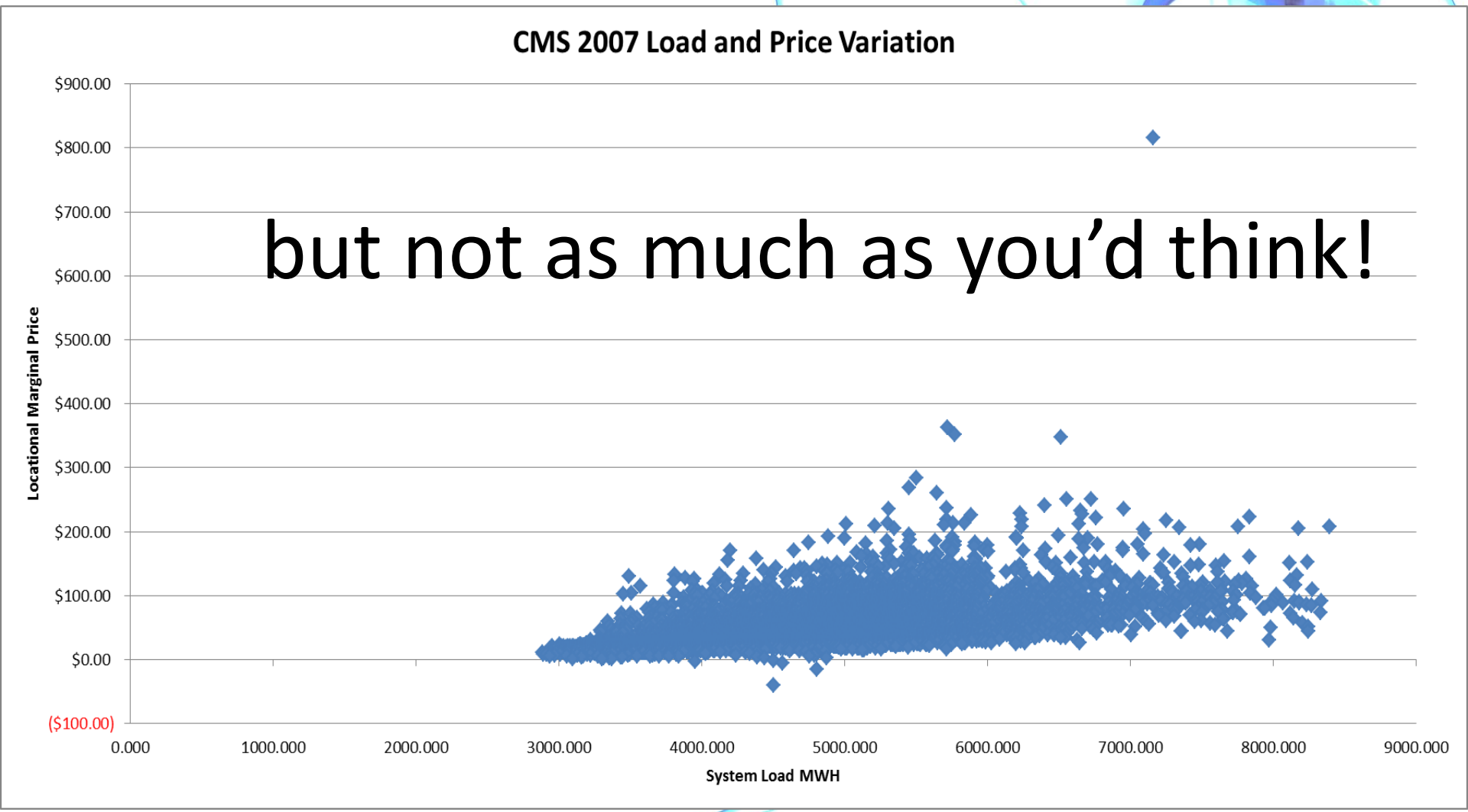
Consumer Energy Hourly Customer Load



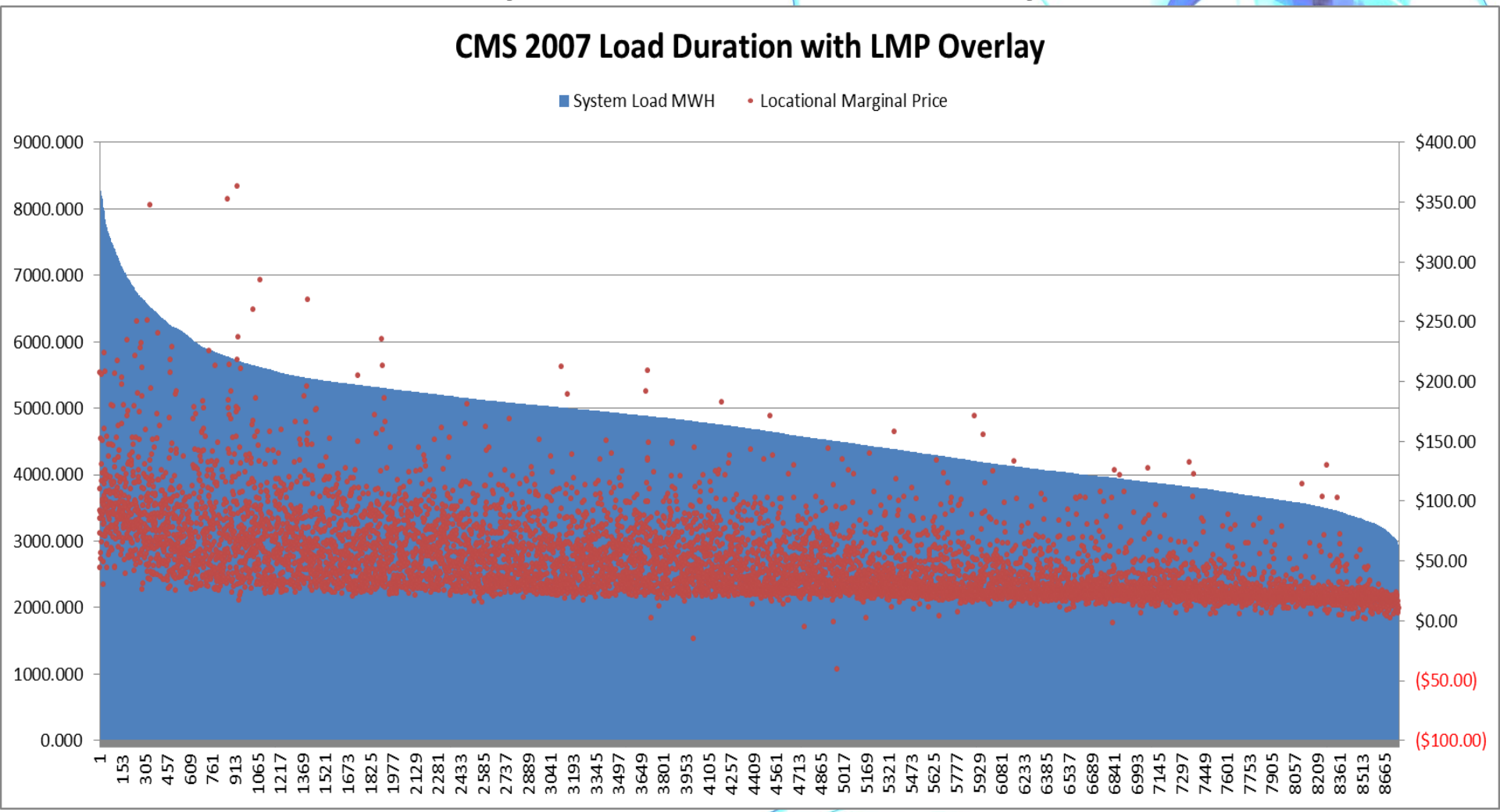
Consumers Energy Hourly Customer Load



Cost of Generation is Related to Load



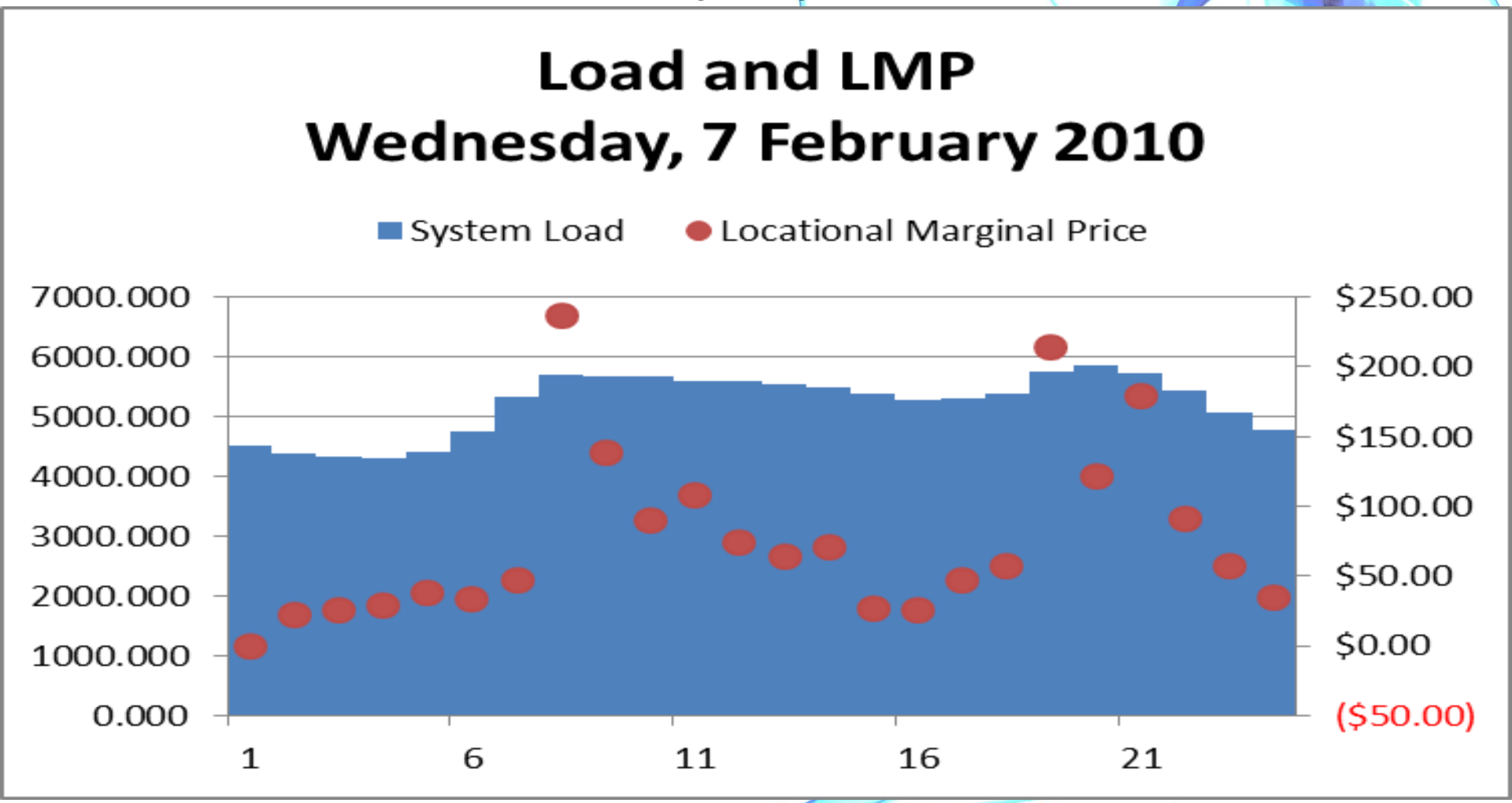
And here's another way to see that load and price are loosely related



Variation in Marginal Energy Cost is Considerable

and needs to be considered in EO program targeting and evaluation

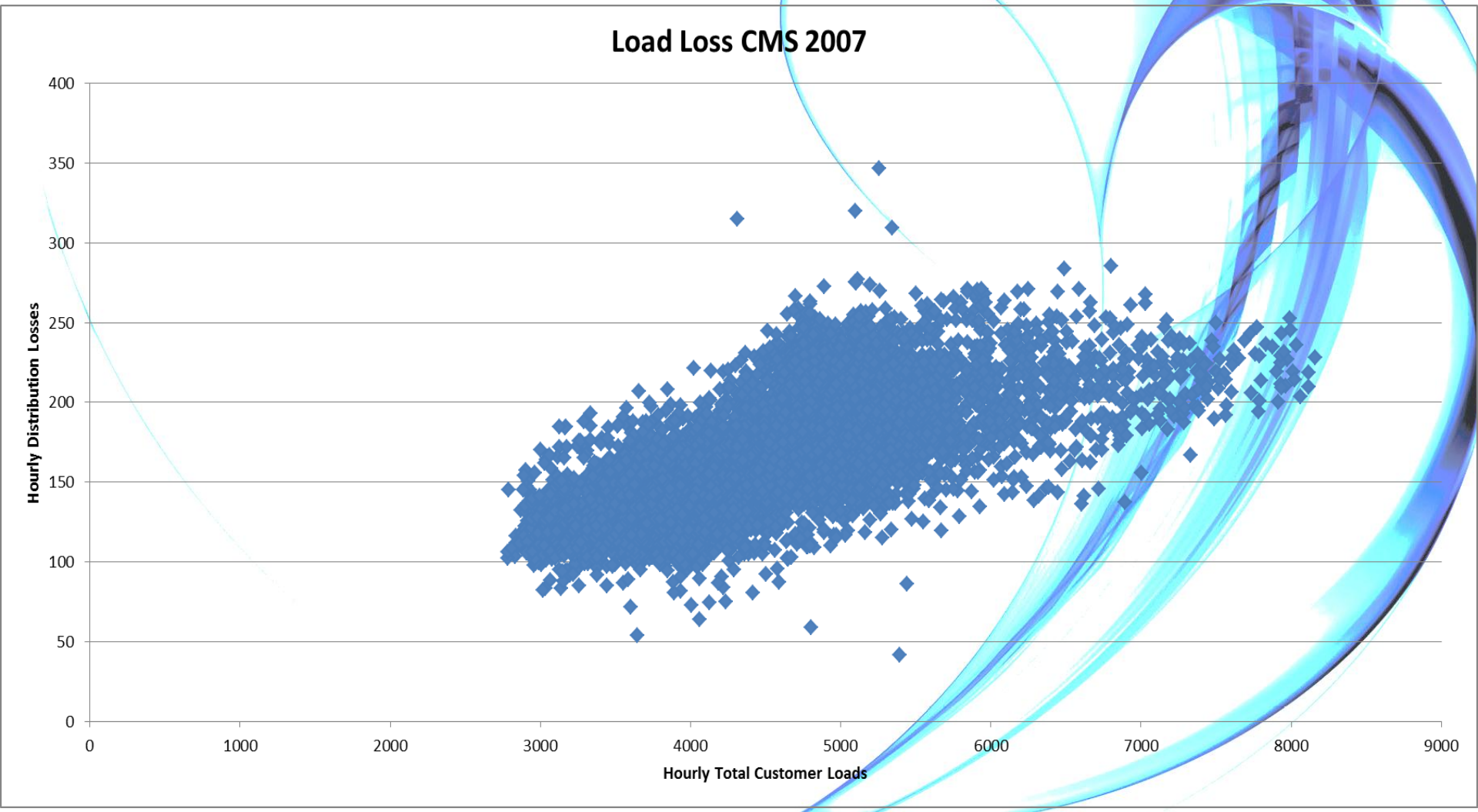
Cost Variation at Intermediate Loads is Driven Primarily by Load Variation



Plan of Presentation

- Examine what drives electricity use and costs
  - Distribution Losses
  - Public Lighting
  - Residential
  - Commercial
  - Industrial
  - Managing Load Variation
- In each case we'll reflect on what this implies for EO Program Strategy
- Then we'll sum up with suggested priorities

Distribution Losses



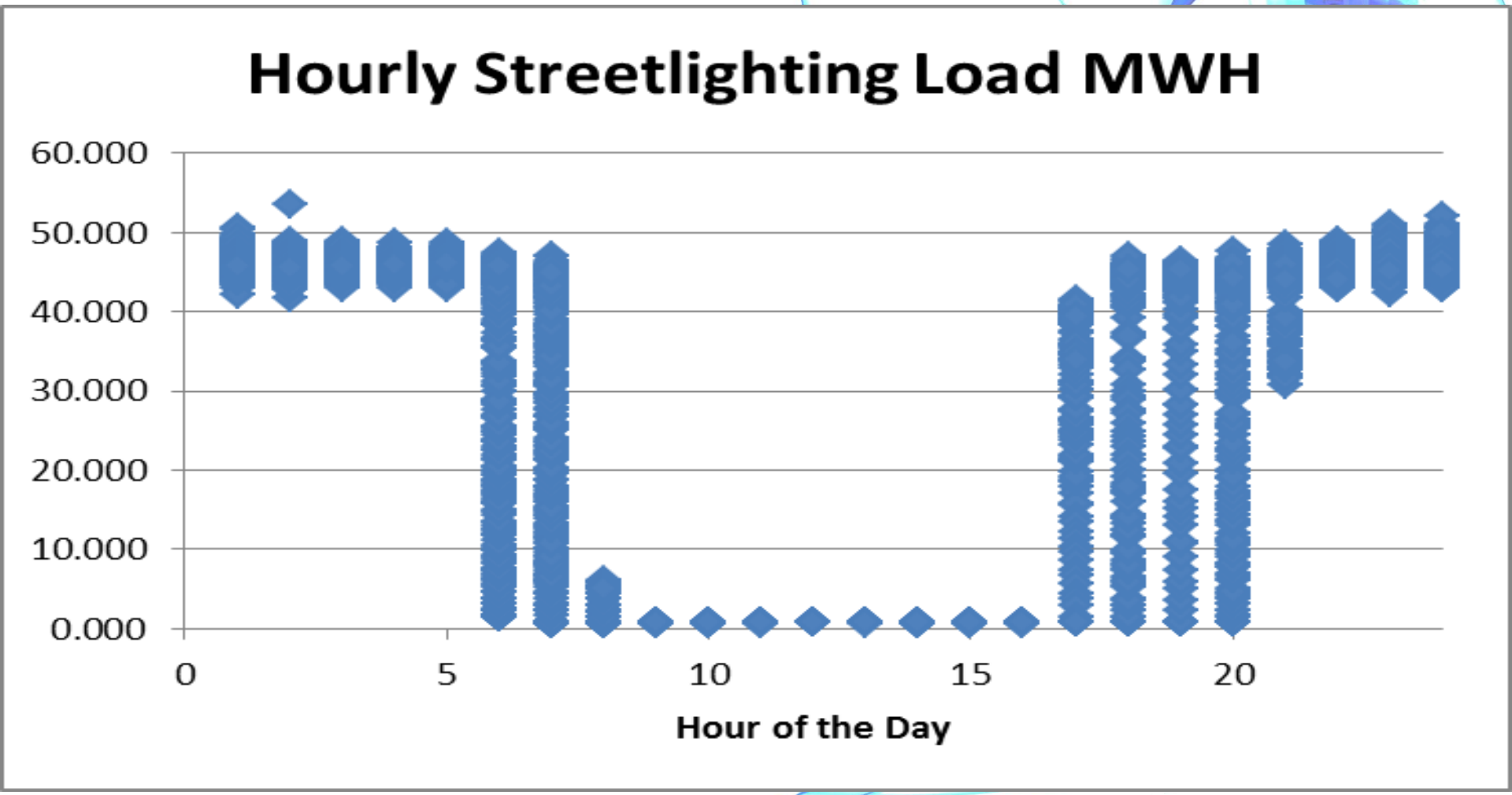
Distribution Losses

- Base Losses – 57MW
- Average Marginal Loss of Load
  - Industrial – 2.2%
  - Commercial – 5.6%
  - Residential – 4.9%
- Maximum Hourly Marginal Loss of Load
  - Industrial – 3.8%
  - Commercial – 11.4%
  - Residential – 8.6%
- Average Loss of Load – 3.7% or 1.5 million MWH/yr

Reducing Distribution Losses

- Dynamic Volt-VAR Control
  - has significant other benefits
- More Efficient Transformers
  - but solid state is coming
- Reconductoring
- But these do not qualify for EO programs!

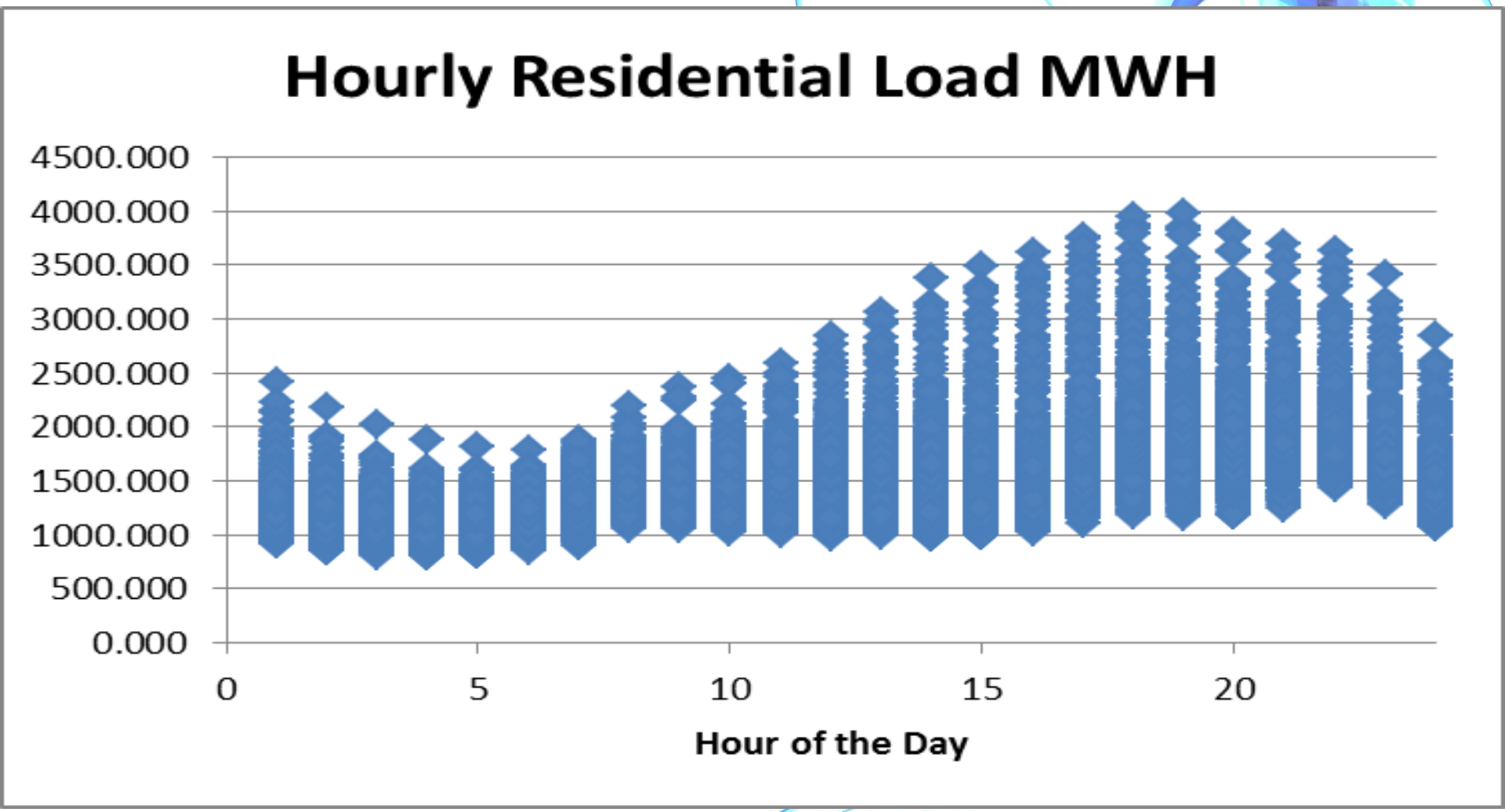
Streetlights Use Electricity When Its Dark



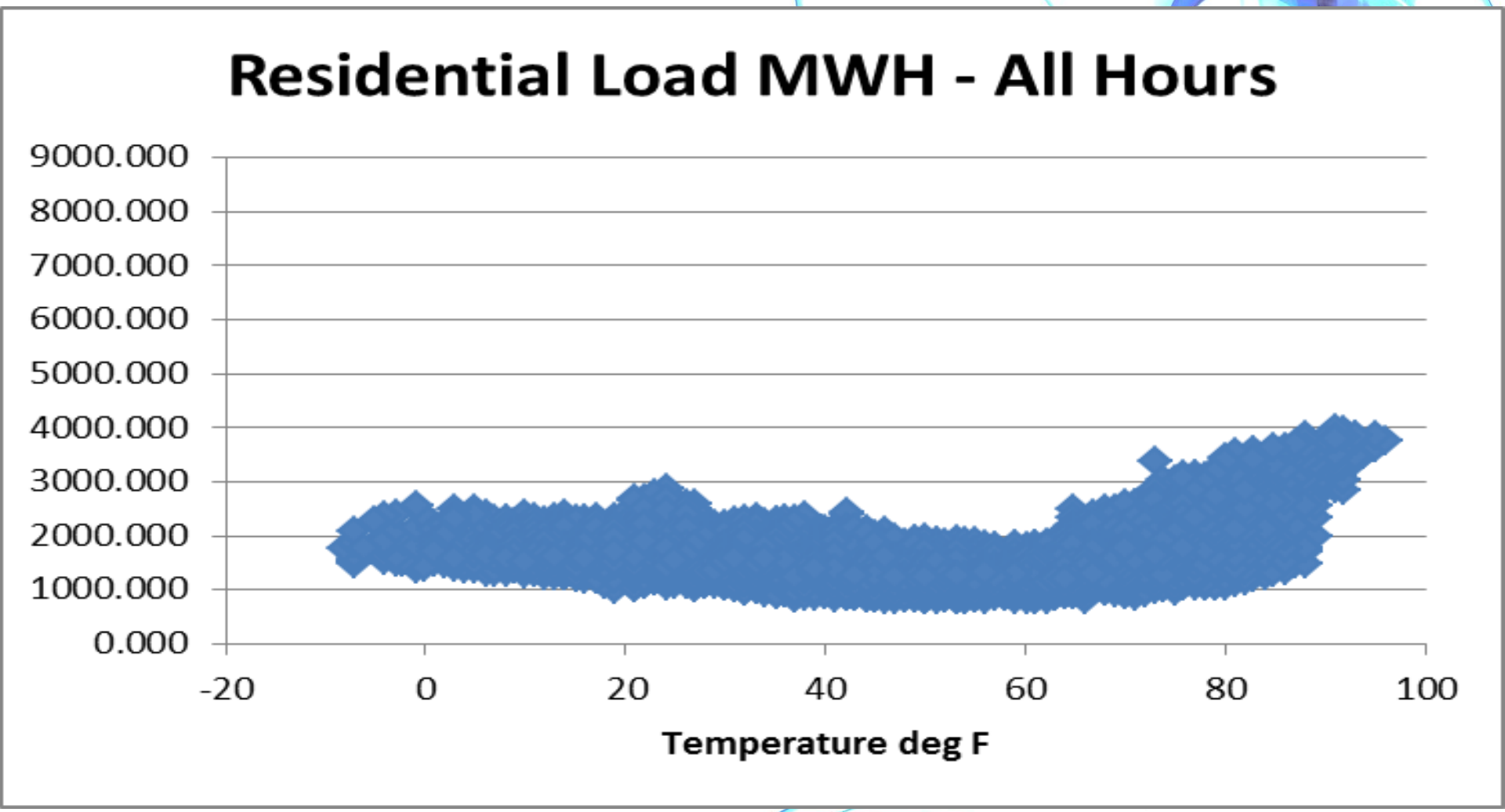
Community Infrastructure

- Public Lighting is reported separately by utilities but McKinsey includes water and sewer, telecommunications infrastructure, traffic controls and public buildings.
- Energy efficiency in each of these has high benefit-cost performance and (except public buildings) has a very finite list of participants.
- Government buildings are about 20% of commercial loads.
- Community infrastructure should be a primary program focus.

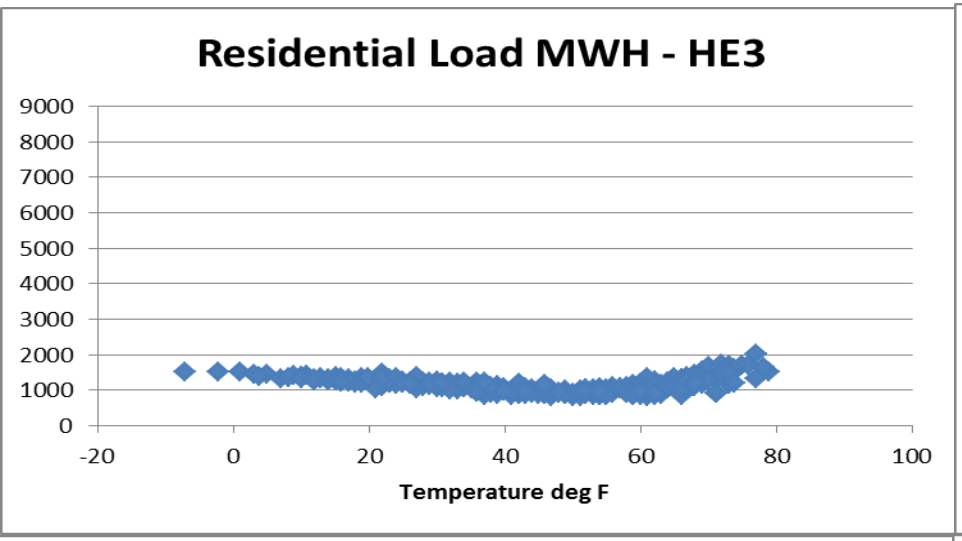
Residential Load Varies with Time of Day

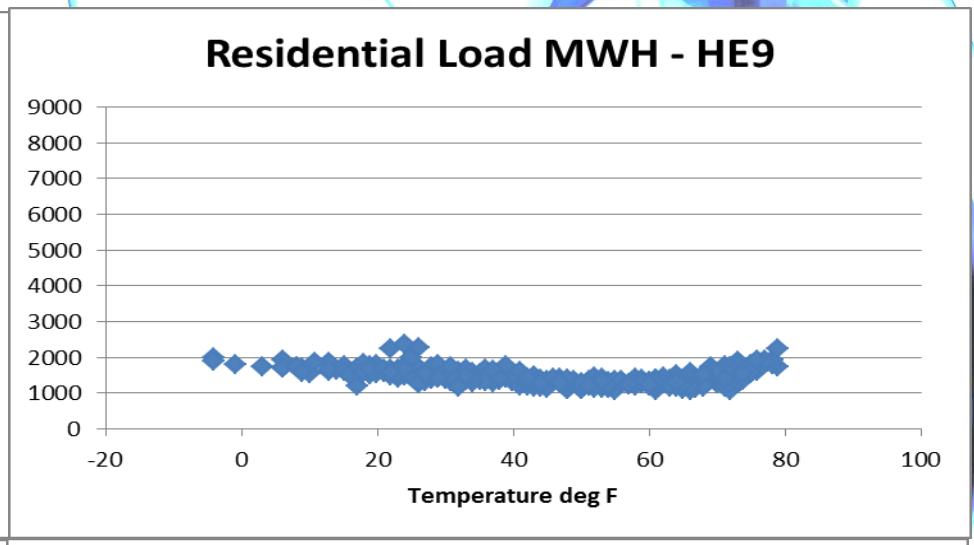


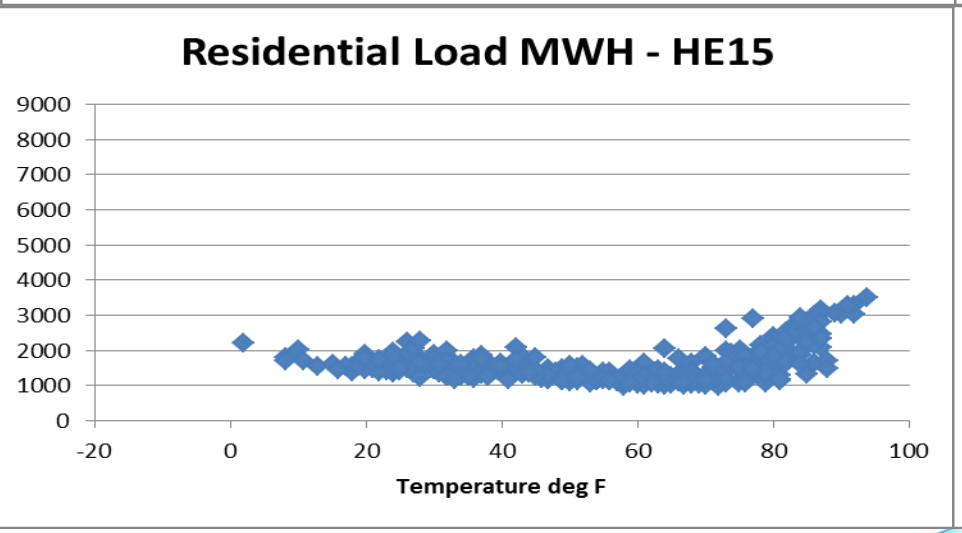
And Also with Weather

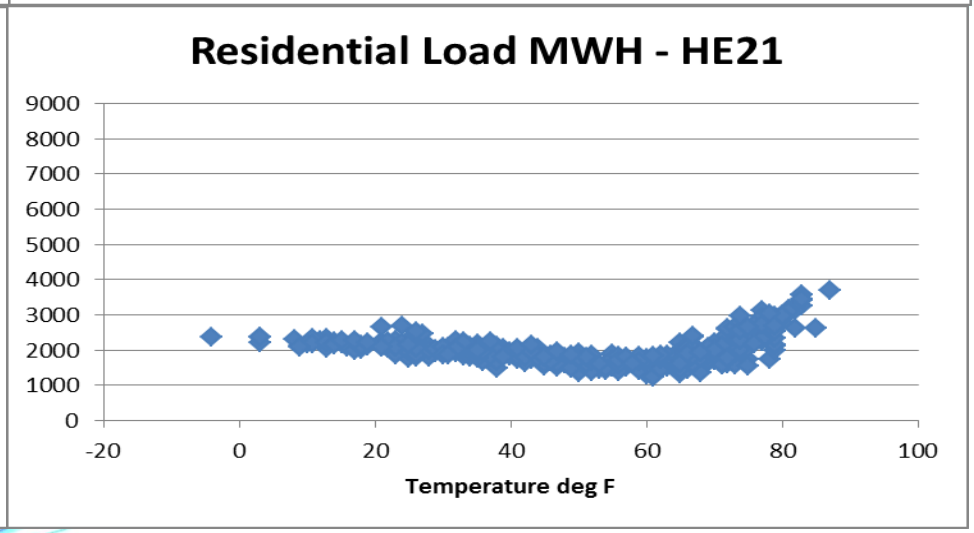


Most residential load variation is explained by hour and weather

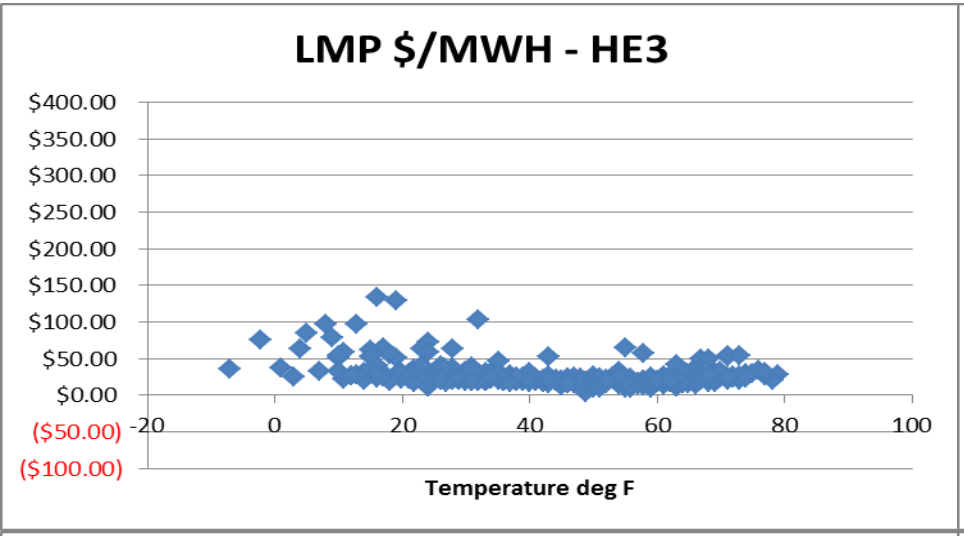


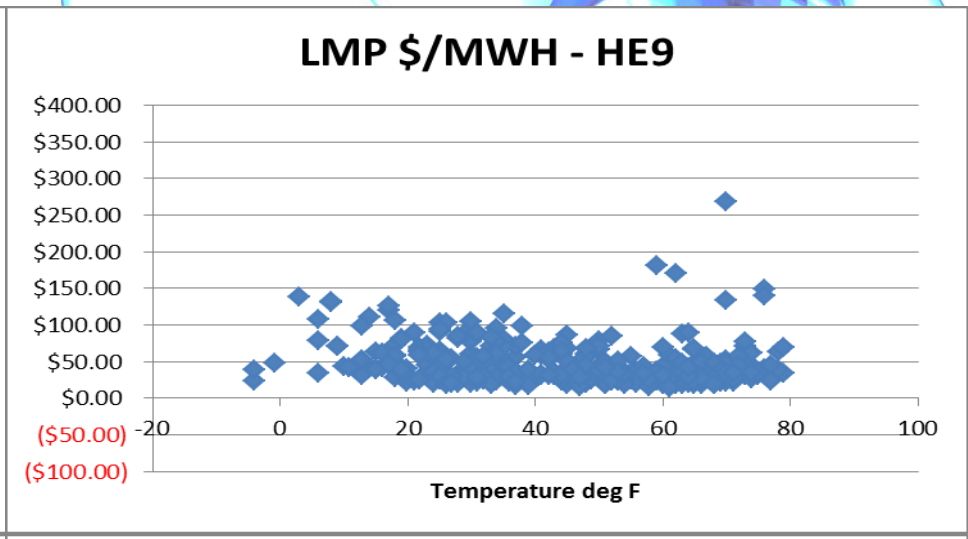


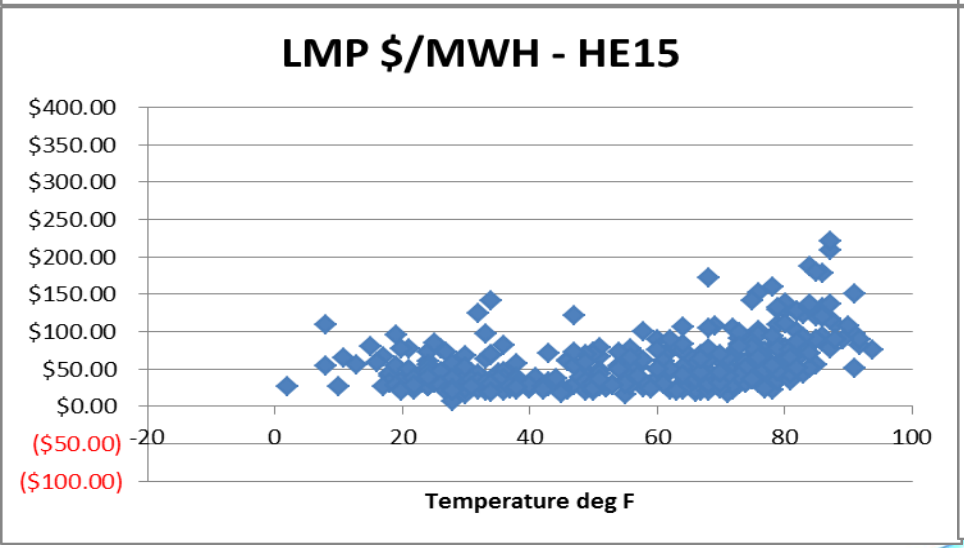


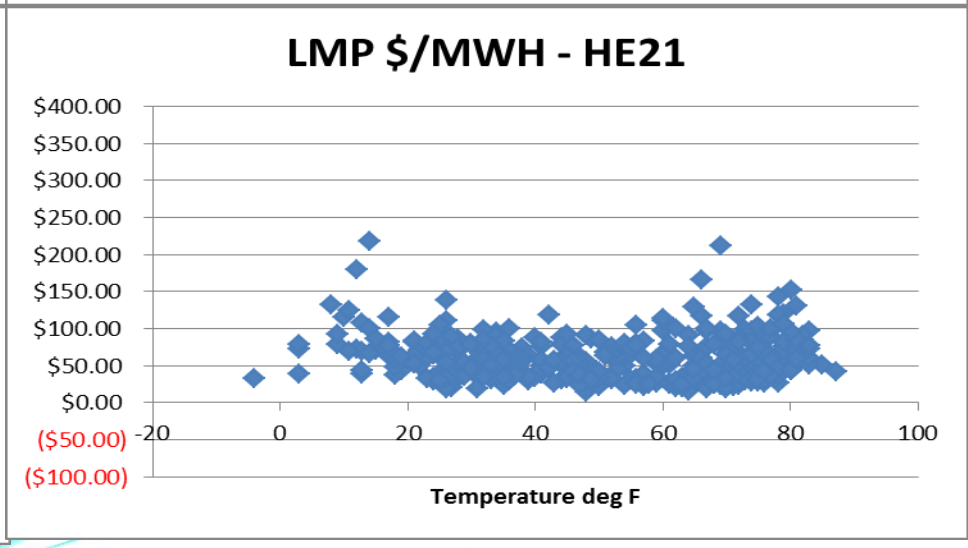


Weather and hour similarly explain some generation cost variations

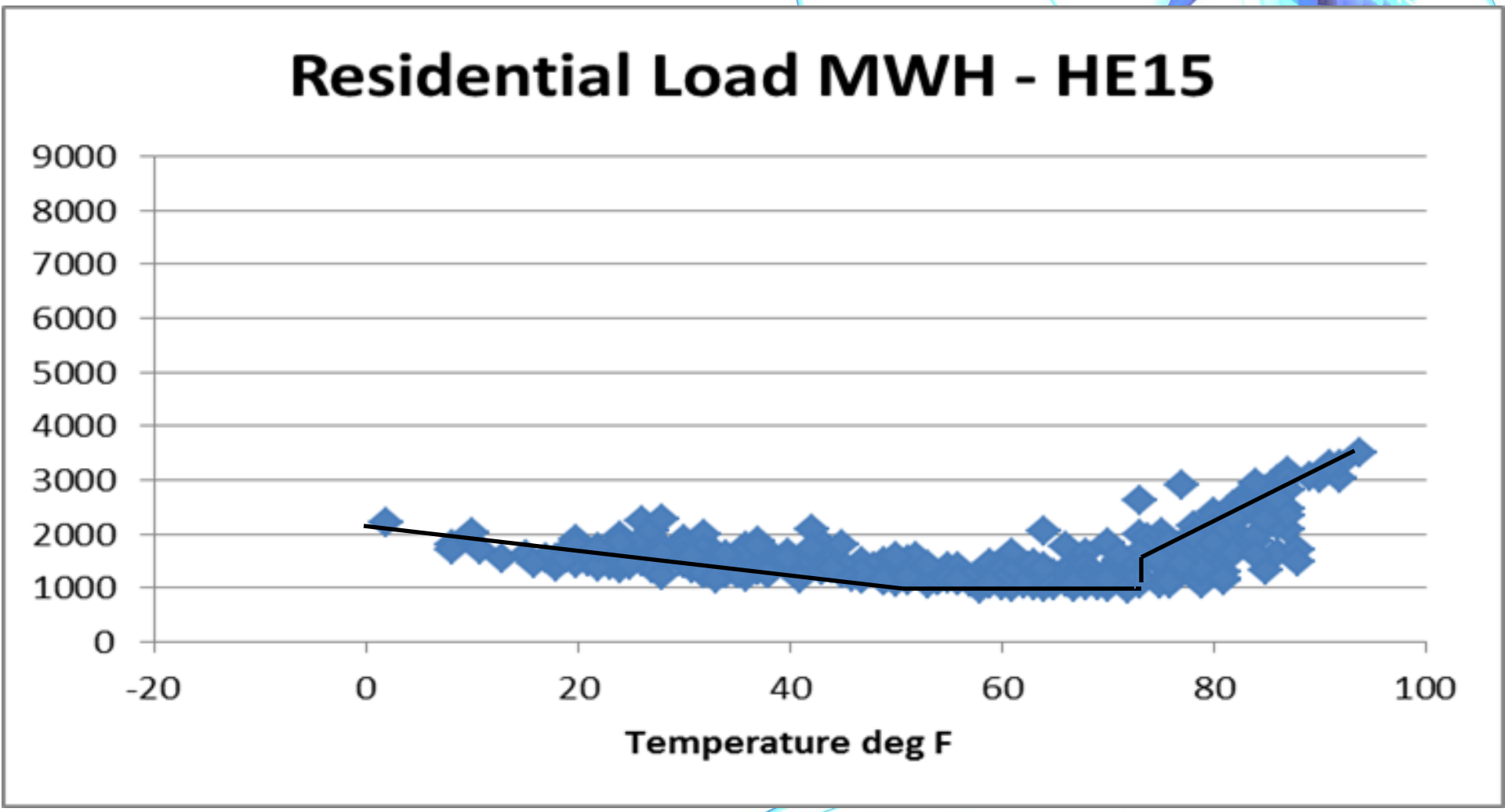




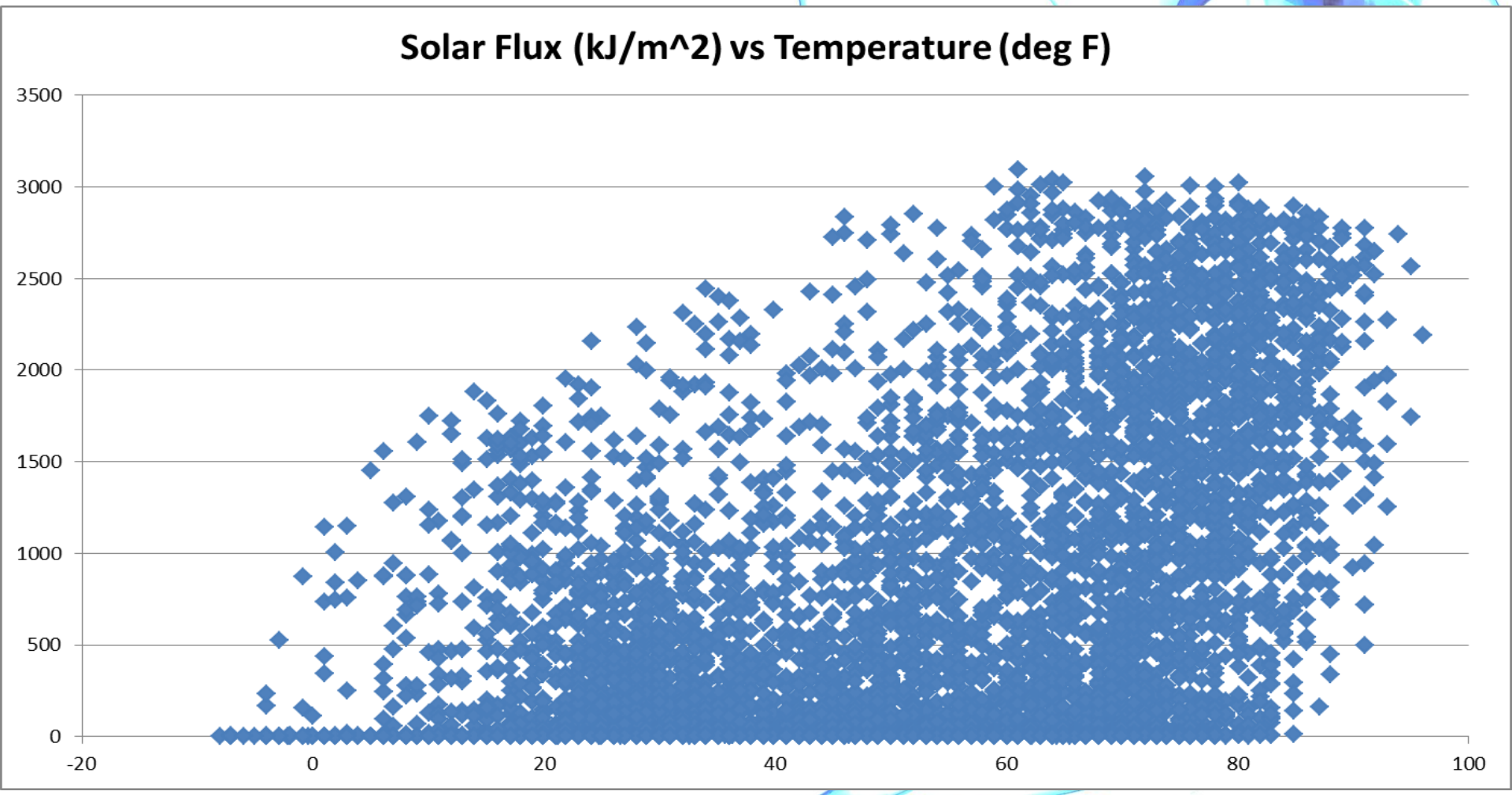




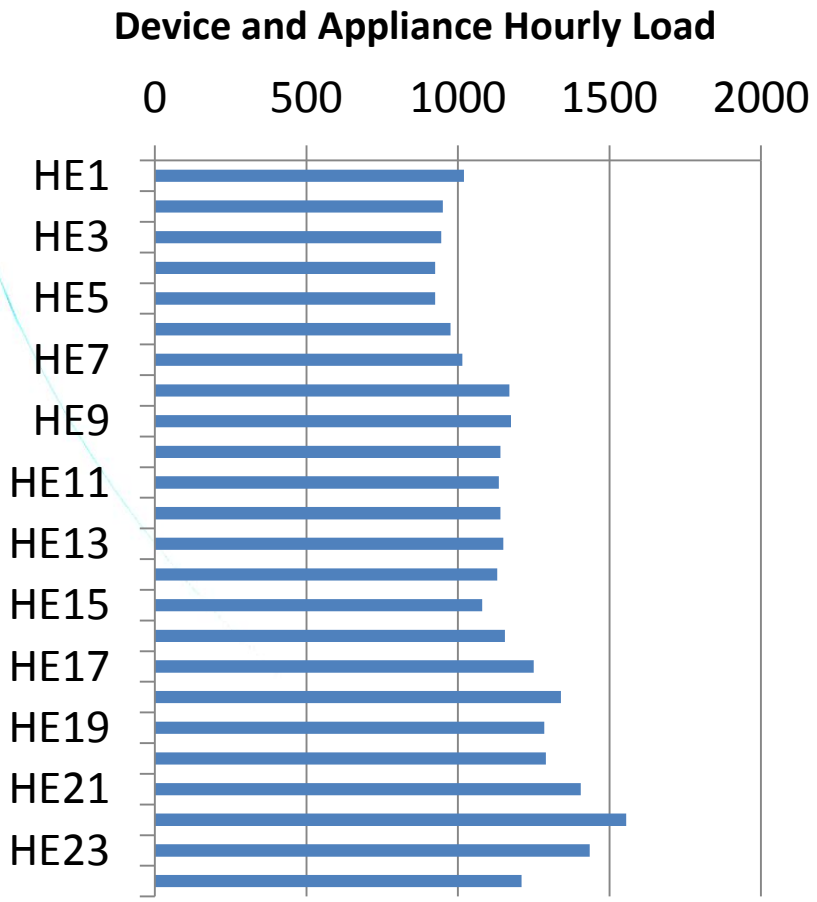
Residential Load Model Development



Solar effects are often confounded with temperature



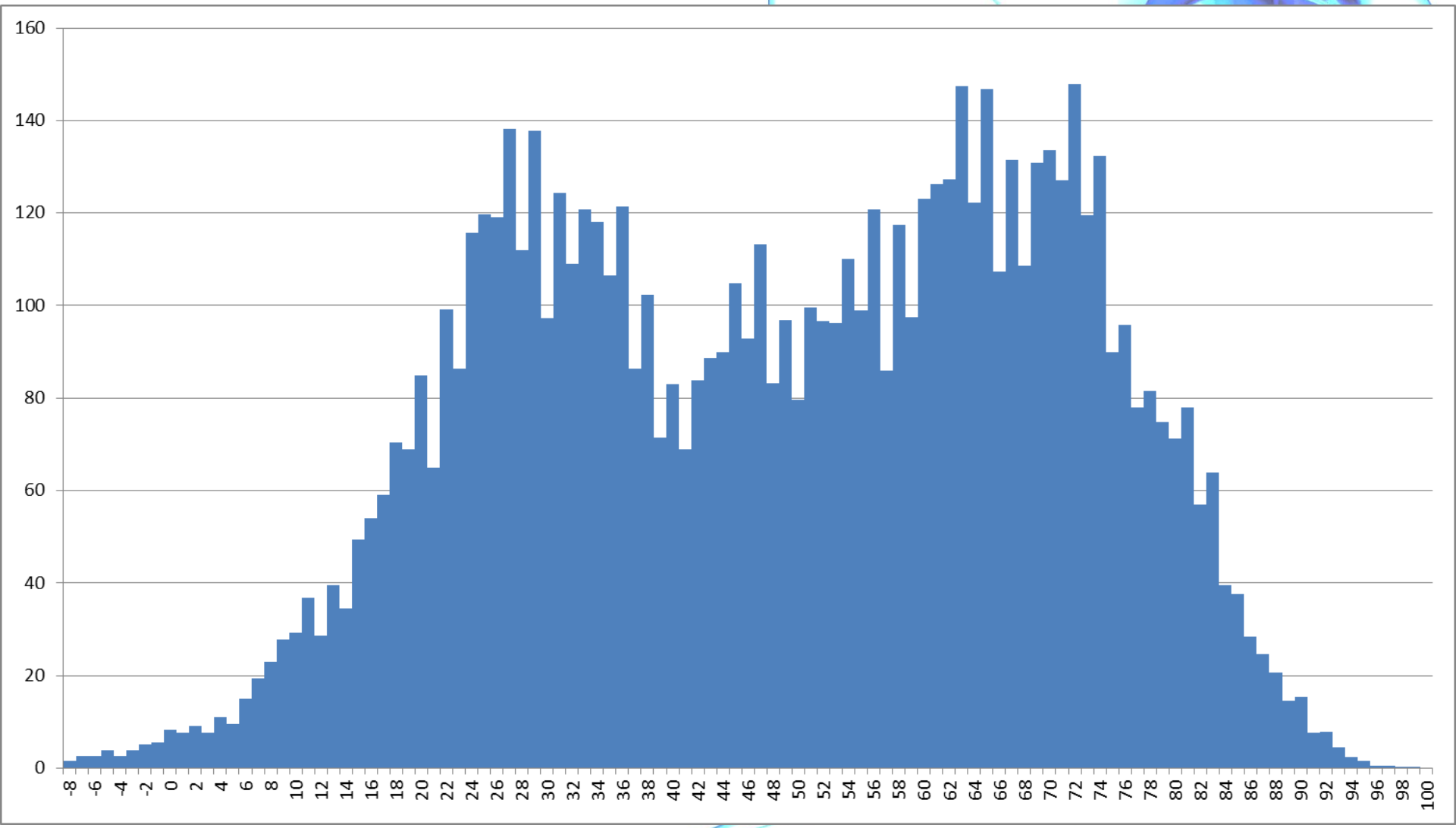
Residential Load Model Development



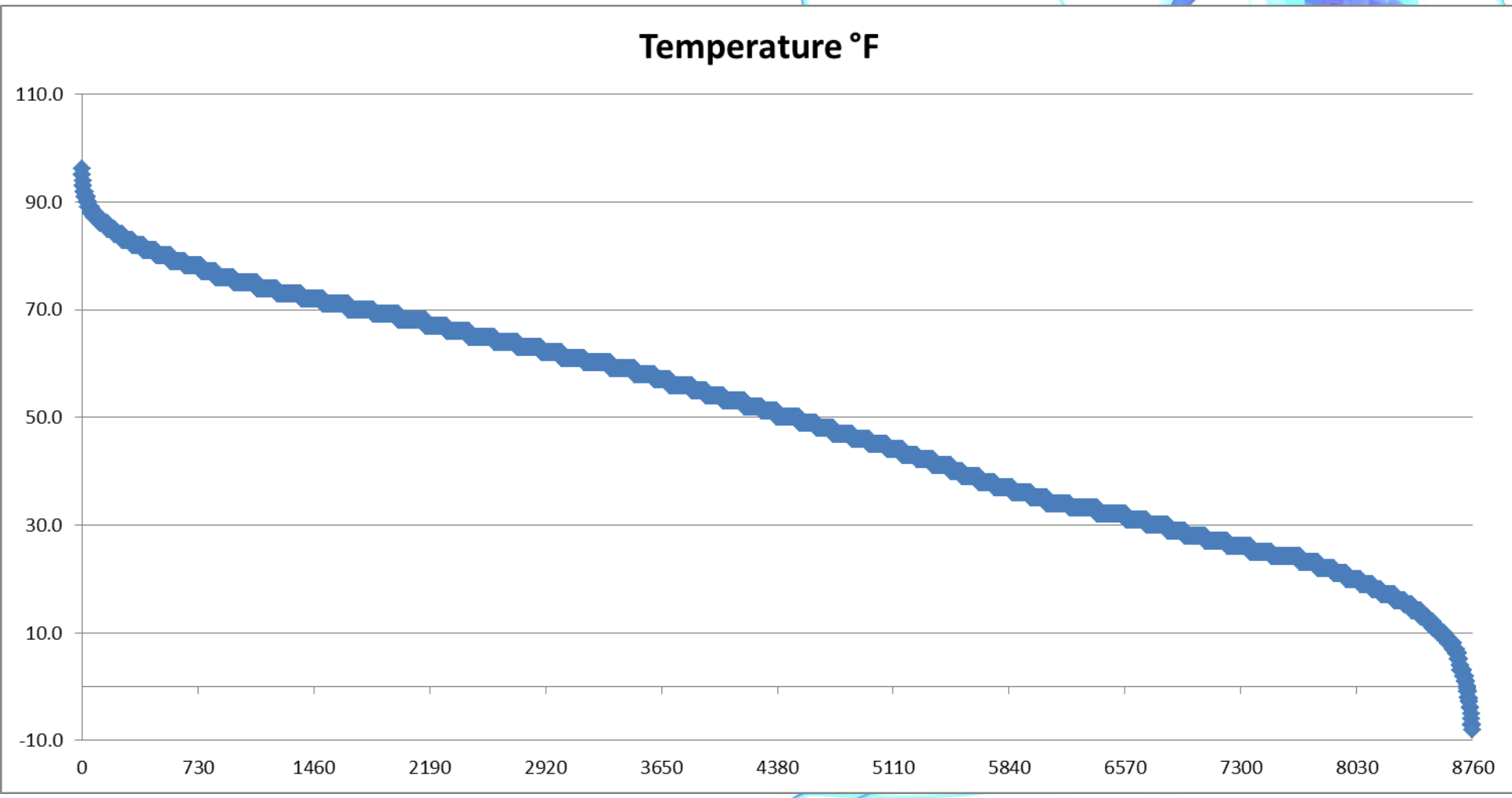
Additional Hourly Loads

- Morning/Evening Lighting – 190 MWH
- Weekend Daytime – 65MWH
- Heat Load – Flux of 1 degree F difference per 65MWH Device and Appliance Load
- Heating – 20MWH per heating degree F
- Cooling – 100MWH per cooling degree F
- Cooling – 0.4MWH per MWH Device and Appliance Load
- Cooling – 300MWH per MJ/m^2 insolation

2007 Temperature Frequency – Rural Clinton County



2007 Temperature Duration – Rural Clinton County



Some Annual Calculations of Residential Loads

- Total Residential Load – 13,571,640 MWH
- Total HVAC Load – 4,190,600 MWH (31%)
- Electricity Load for Heating – 2,122,260 MWH
- Electricity Load for Cooling – 2,068,341 MWH
  - Shell Heat Flux – 961,340 MWH
  - Internal Heat Loads – 552,800 MWH
  - Heating from Sunlight – 554,200 MWH
- Load for Lighting – 416,100 MWH
- Device and Plug Loads – 8,964,900 MWH

Reducing Device and Plug Load by 1 MWH does what?

- Assume uniform distribution across the hours of the year (e.g., refrigerator efficiency)
- Net Electric Effects:
  - 1.00 MWH direct savings
  - +.06 MWH reduced cooling
  - -.13 MWH increased electricity for heating
  - =.93 MWH metered net savings
  - =.97 MWH including marginal line losses
- Increased natural gas consumption – 1.4 MCF
  - – which could generate 0.18 MWH electricity

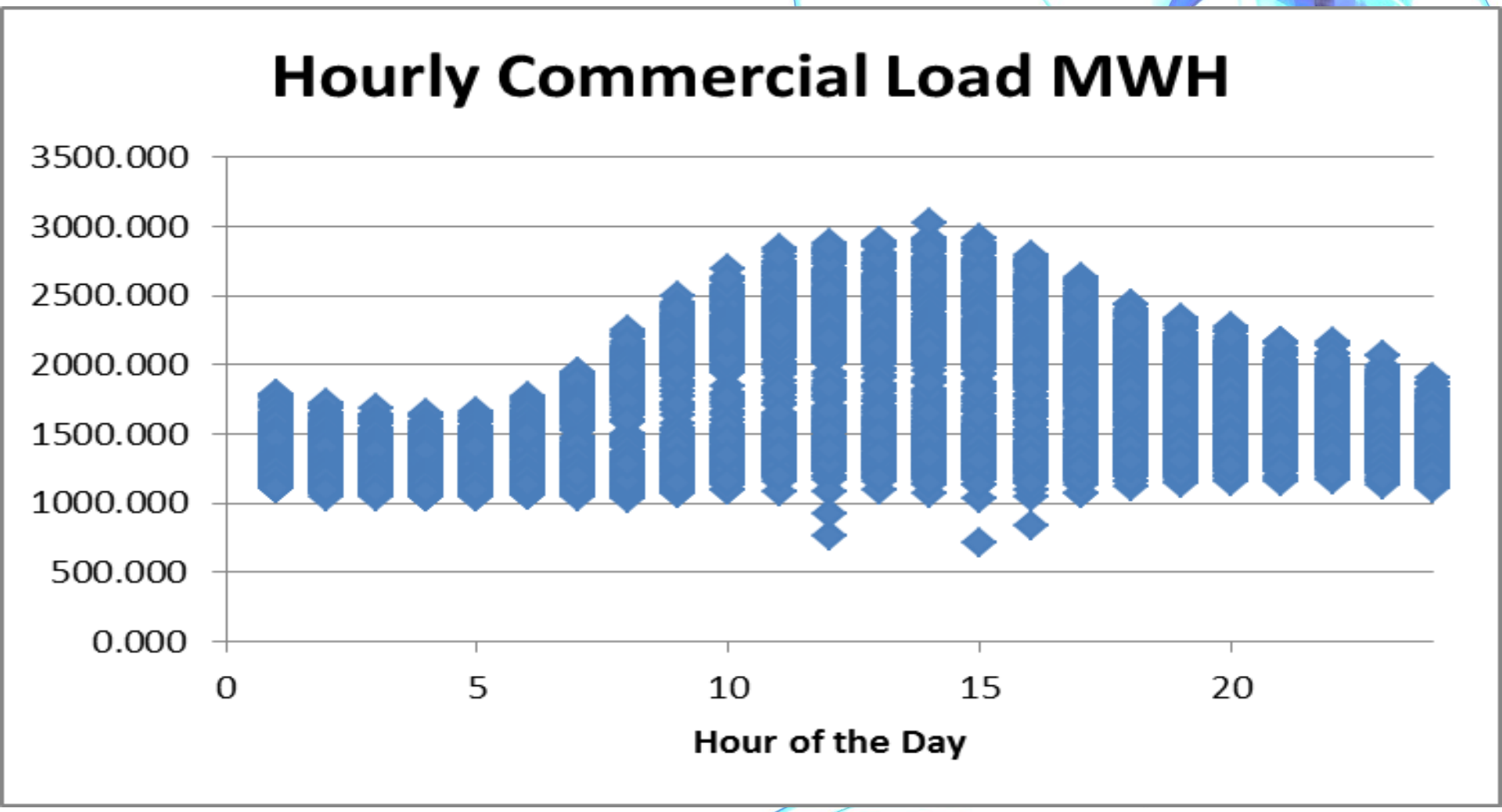
Average LMPs (2007)

- Annual - $47.75/MWH
- Cooling - $74.01/MWH
- Solar Load Cooling - $79.87/MWH
- Heating - $44.56/MWH

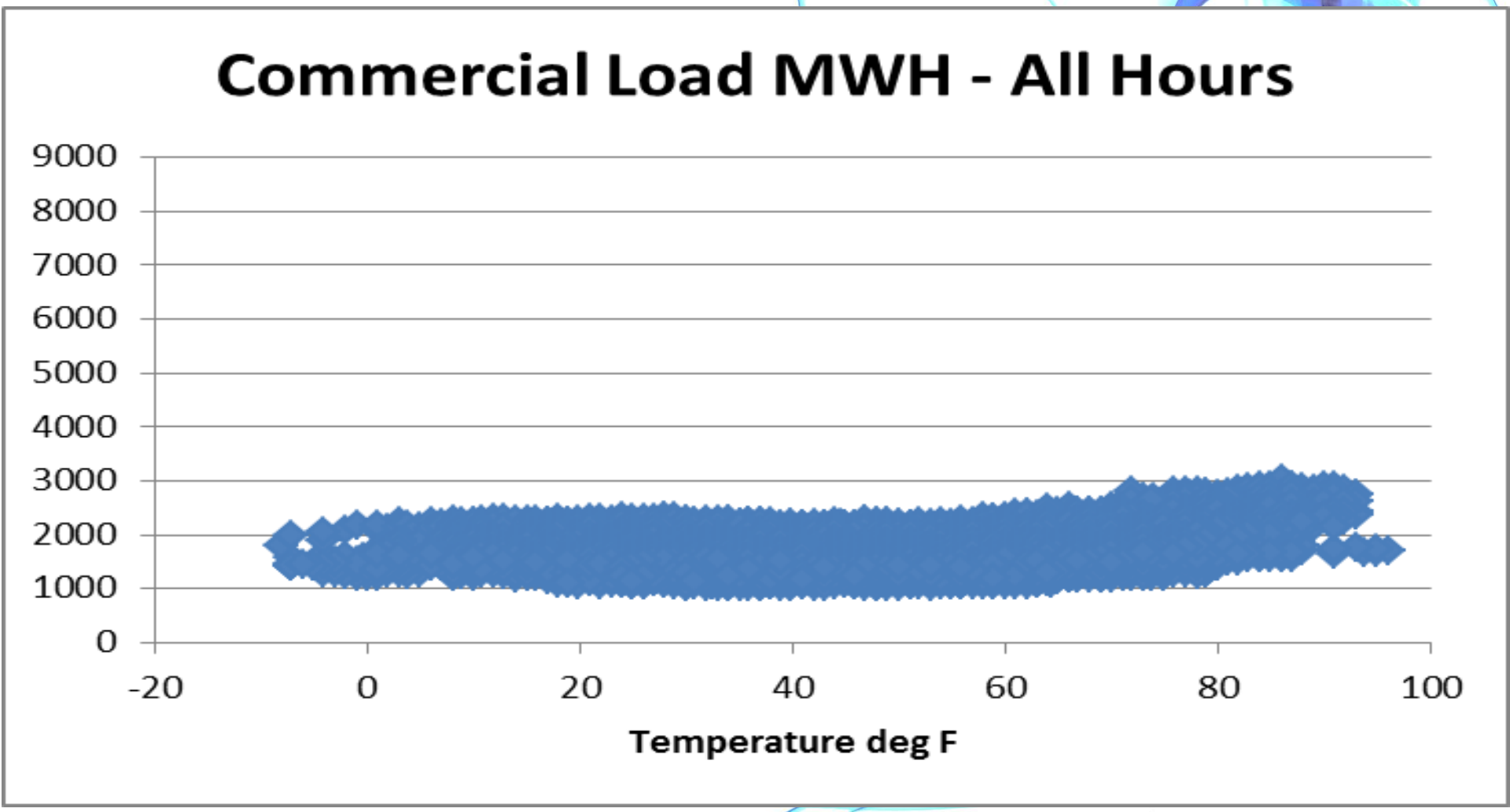
Residential Program Strategy Recommendations

- Improve modeling by incorporating automated end-use monitoring into sample metering program to track end-use loads in relation to weather and HVAC.
- Base home rating on annual heating and cooling costs based on modeling like that shown and use both for customer information and make available for real estate transactions..
- Mass deployment of occupancy-aware and learning automated thermostats (700 MW potential capacity reduction, 700 GWH annual energy savings).
- Coordinated electricity and natural gas programs for heating COP improvements and shell improvements
- Emphasize basement insulation and duct sealing.
- Evaluate as potential measures awnings or thermo-chromic film on southern and western facing windows, solar attic fans, white or green roofs to reduce solar heat loads.

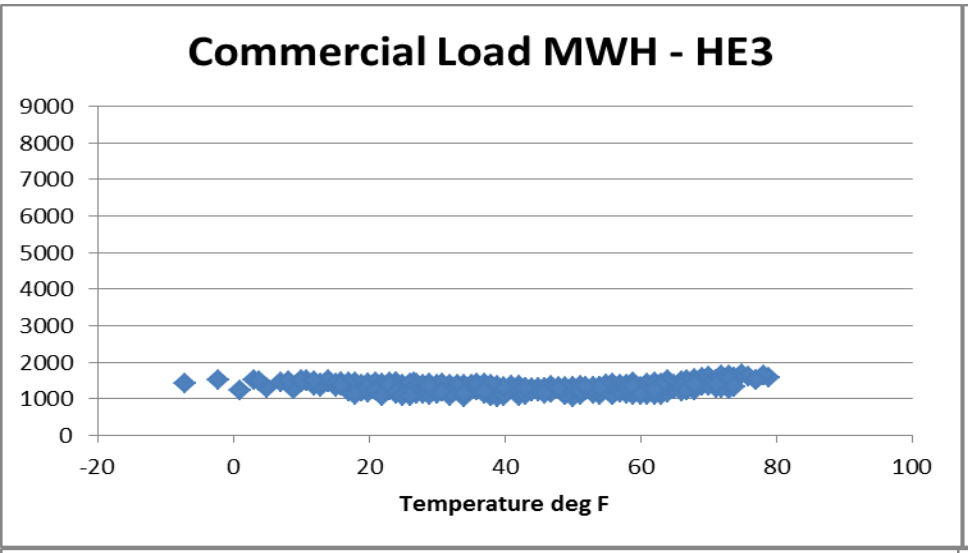
Commercial Load Variation is Unsurprising

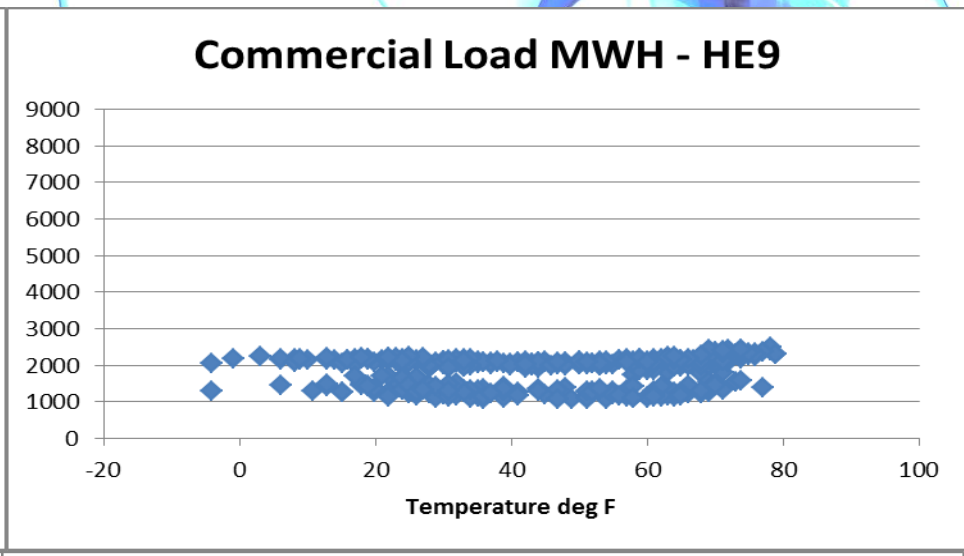


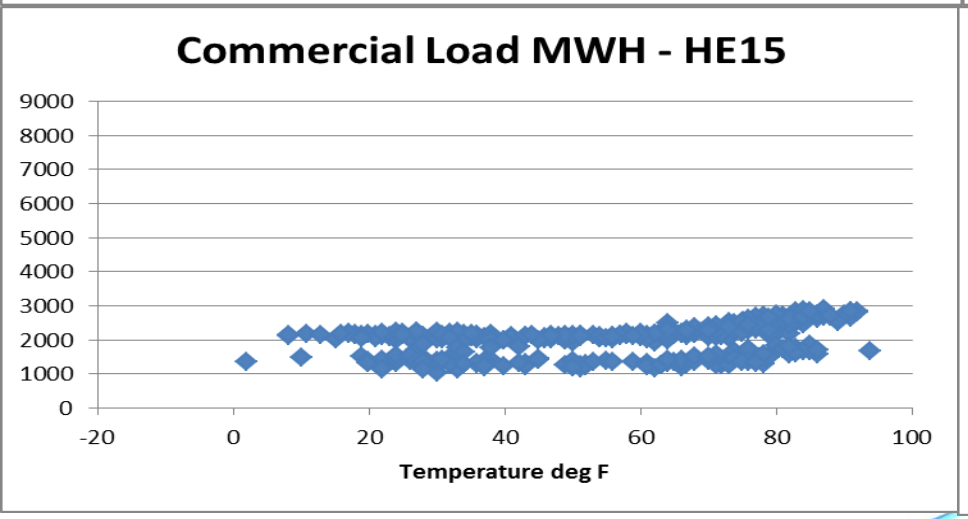
And is significantly less weather-affected than residential

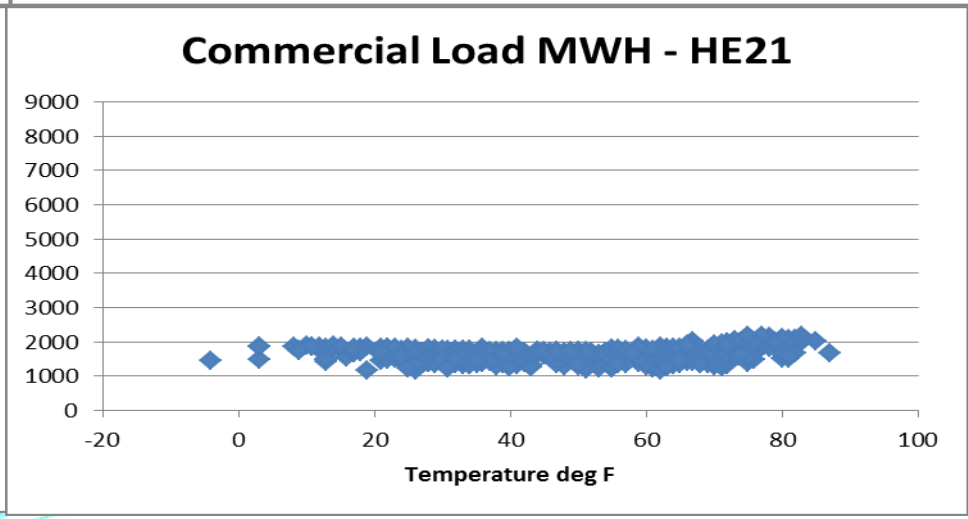


Weekend daytime load isn't much higher than night-time load









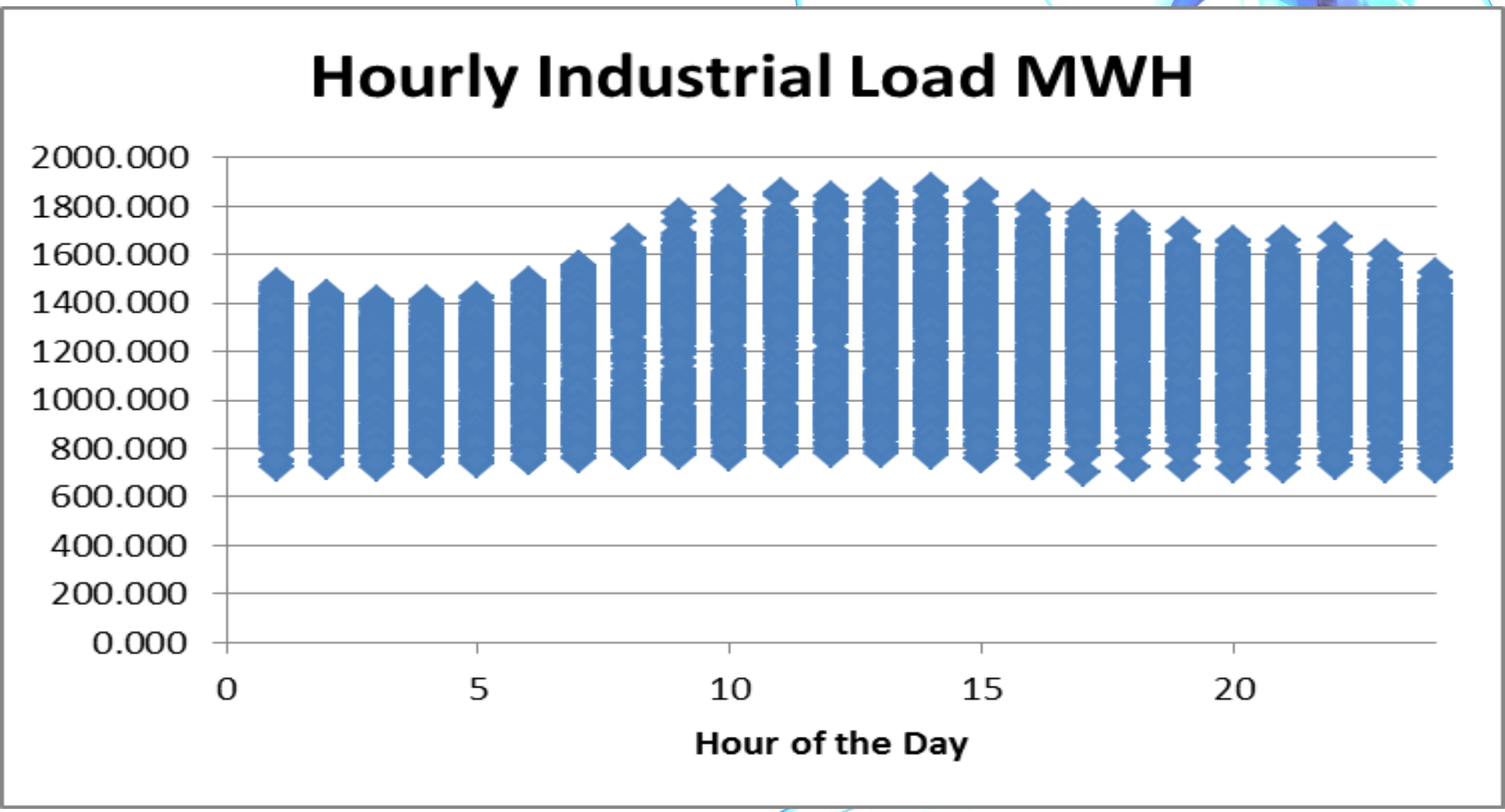
Some Observations

- Weekday-weekend daytime gap suggests that offices have a significant activity-related load.
- Limited difference between night-time and weekend daytime load suggests that retail has limited activity-related load.
- Regression analysis suggests that much of the upturn in load at high temperatures is associated with solar insolation rather than temperature per se.
- Regression analysis suggests that internal loads cause commercial buildings to be in cooling mode far more hours of the year than in residential buildings.

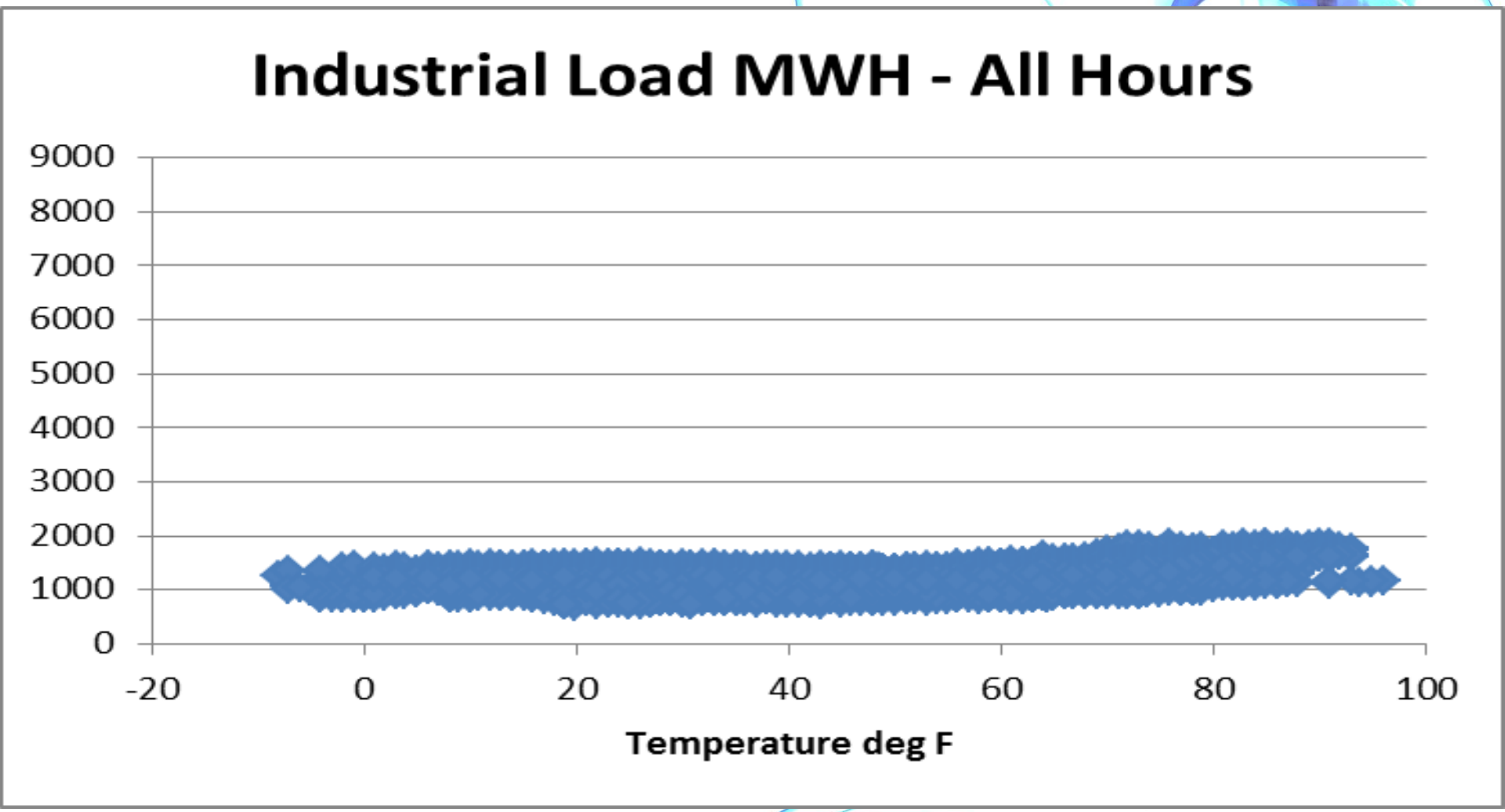
Commercial Program Strategy Recommendations

- Focus on sales channel programs to promote energy-efficient office equipment.
- Offer routinely scheduled retro-commissioning services to all commercial customers
- Promote use of automated building management systems with an emphasis on occupancy-based lighting controls.
- Promote electro-chromic windows that can reduce solar heat loads when the building is not in heating mode.
- Since a large fraction of building-internal heat load from lighting is from AC to DC conversion, promote change in lighting to DC.
- Promote retrofitting of air-side economizers for cooling when external air temperatures are below internal target.
- Promote geothermal HVAC in new commercial buildings.

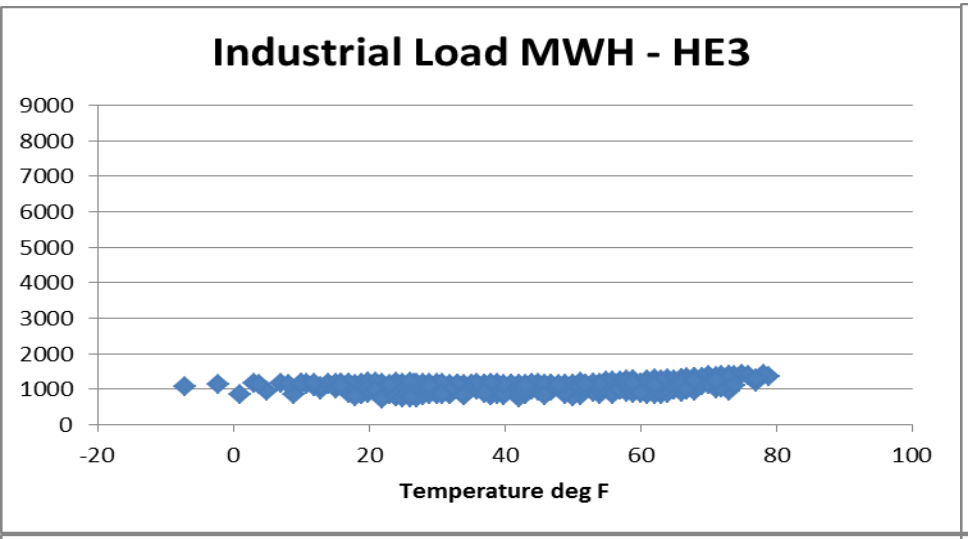
Industrial Loads are more variable across days than I expected

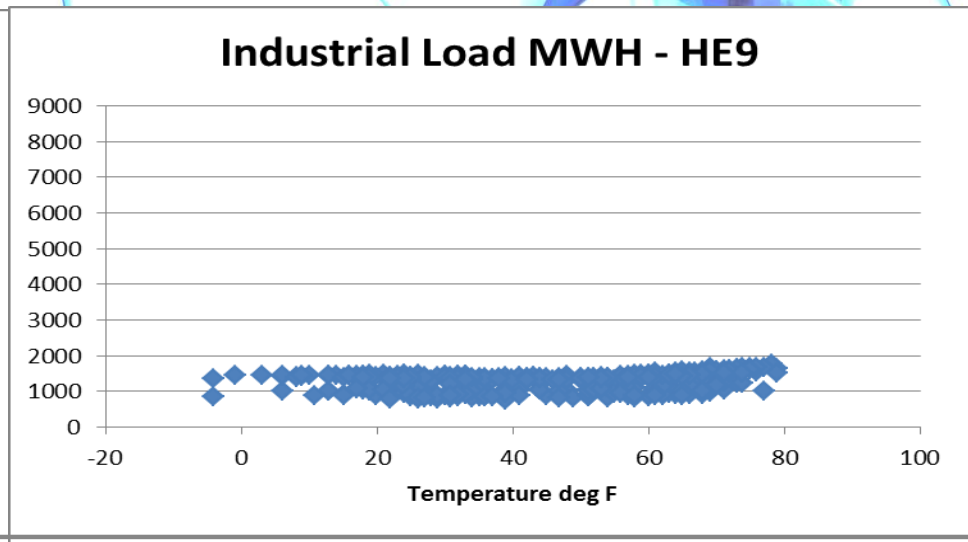


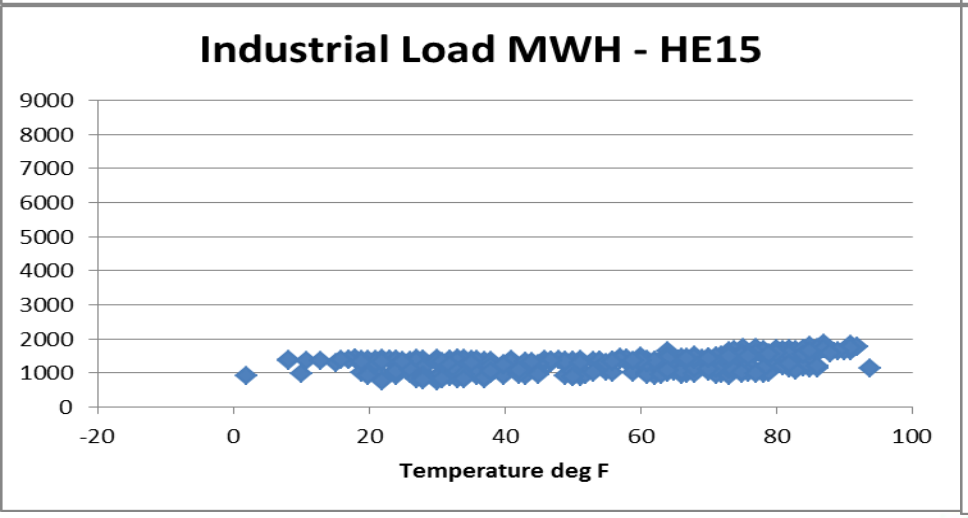
Significant Industrial Load Variation is Related to Weather

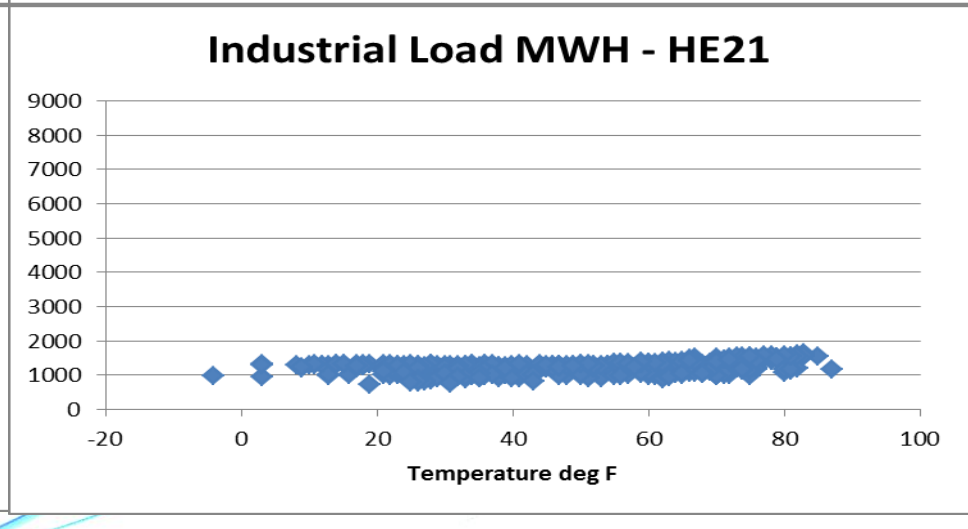


As well as time of day and weekend vs weekday…









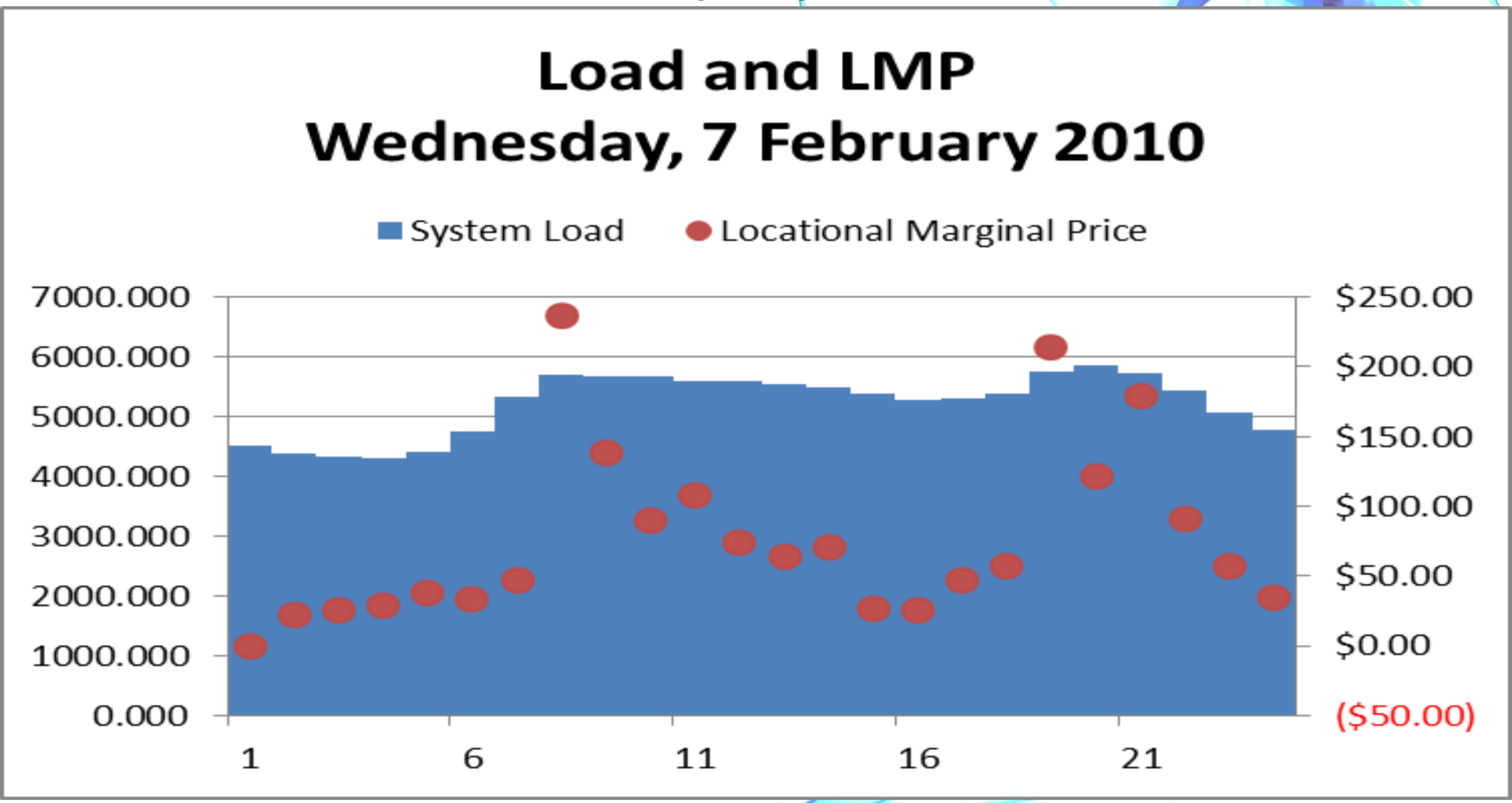
Observations concerning Industrial Loads

- Increase in industrial loads at high temperatures are likely due to:
  - Plant cooling for worker comfort
  - Increased energy for process cooling and refrigeration
  - Decreased efficiency of chillers
- A large share of industrial electricity consumption is from 24x365 operations in energy-intensive process industries.
- But almost as much is consumed in time-varying industrial activities. Optimal scheduling of bulk energy operations in time (process heating and cooling) has proven to reduce energy consumption by 10% - 15%.

Industrial Program Strategy Recommendations

- Primary focus for now should be on energy management systems and energy-aware process management systems.
- Secondary focus should be on managing heat, particularly waste heat isolation, waste heat recovery, combined heat and power, and industrial ecology in which waste heat and materials are transferred between enterprises.
- Third focus should be on motor efficiency.
- A long-term economic development strategy for Michigan can be built on capacity for energy-efficient process engineering, particularly including advanced manufacturing.

Cost Variation at Intermediate Loads is Driven Primarily by Load Variation



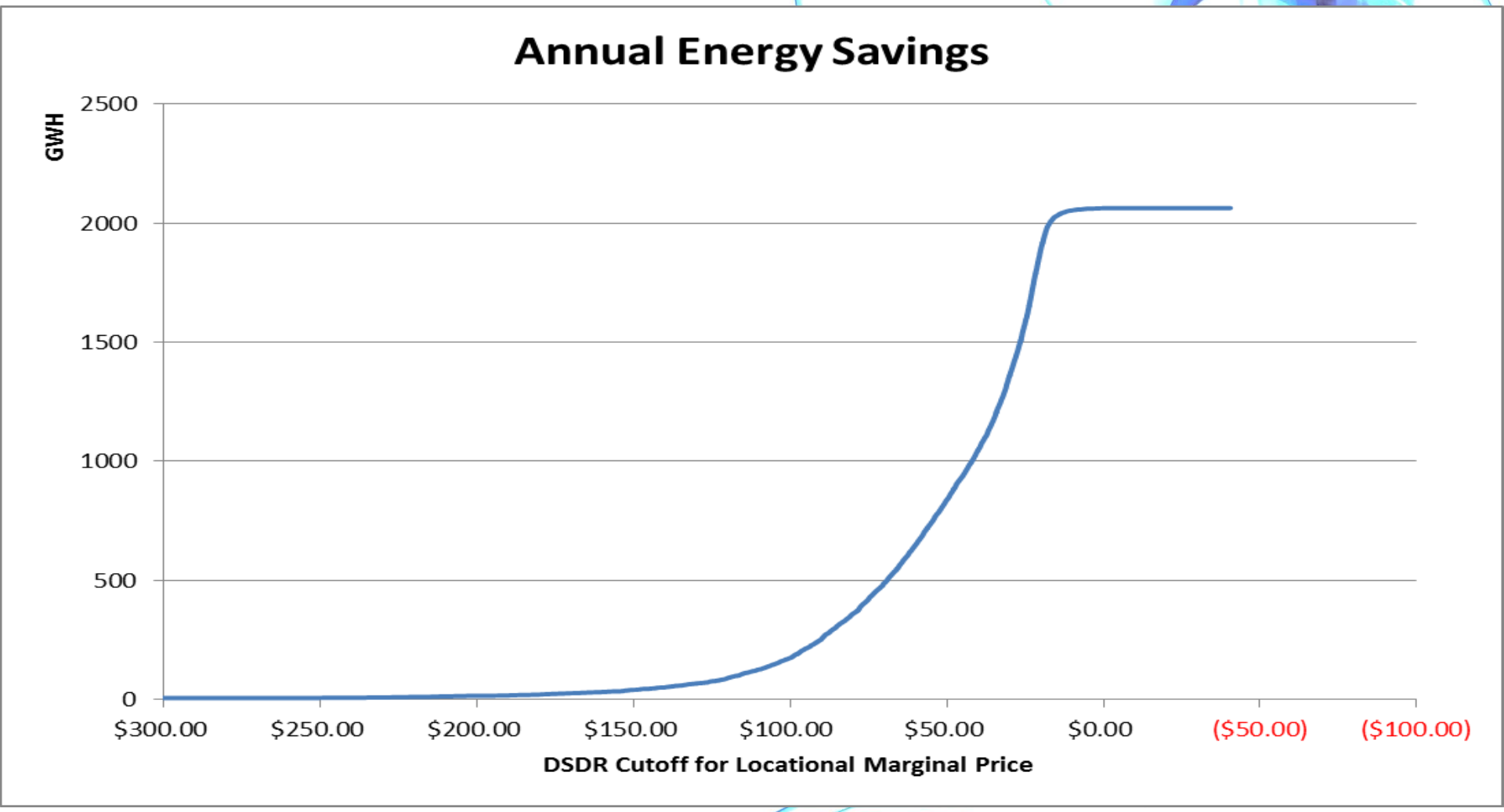
Costly Load Variation Reduction and Energy Efficiency Can Be Joint Products

- Dynamic Rate Design – exposing customers to hourly or shorter-term changes in wholesale prices
- Demand Response – asking customers to respond to explicit calls for load reduction at high-cost times
- Distribution System Demand Response (Conservation Voltage Reduction) – reducing distribution system voltage, hence energy delivery, at high cost times.

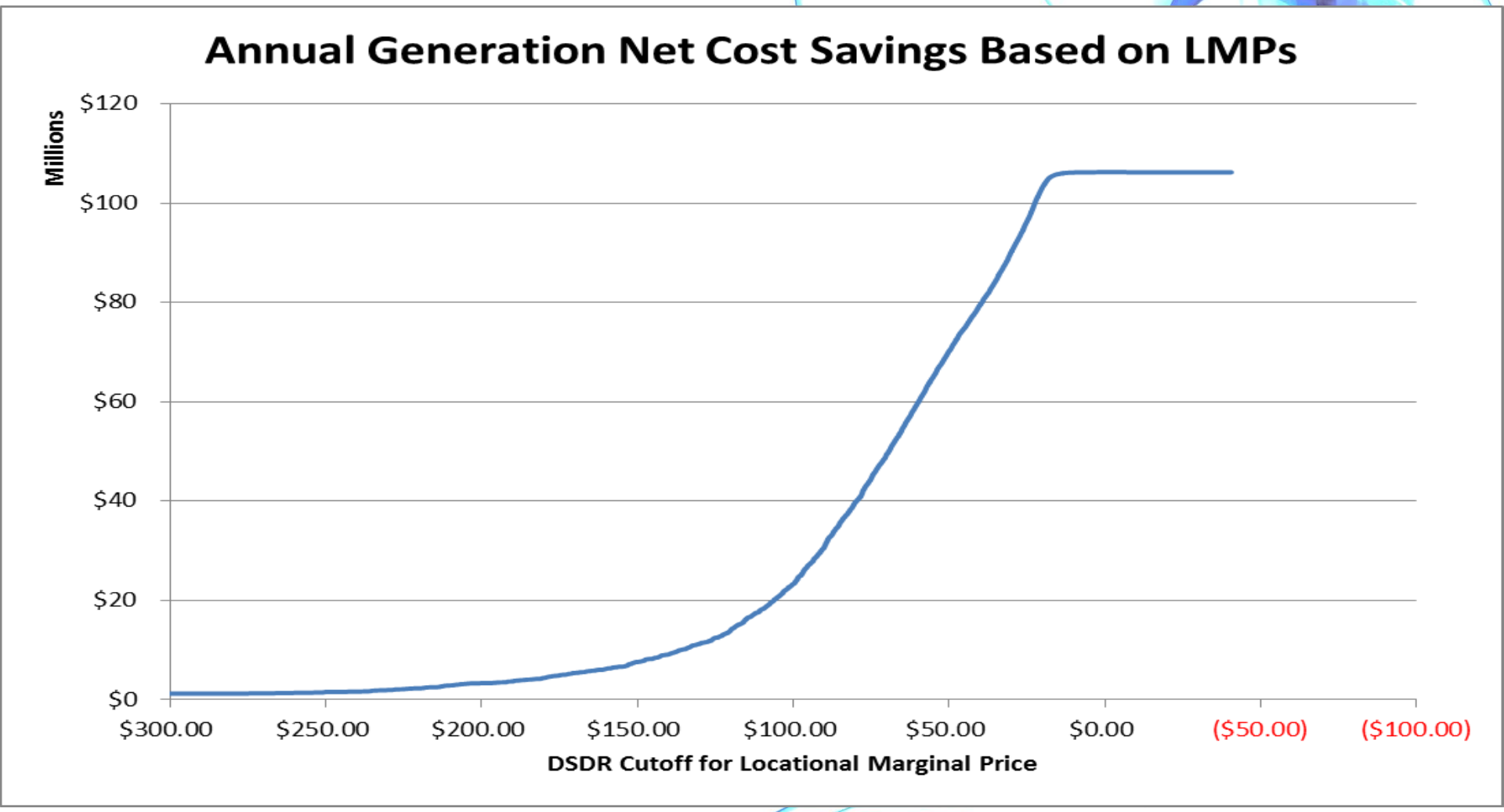
Variation in Marginal Energy Cost is Considerable

and needs to be considered in EO program targeting and evaluation

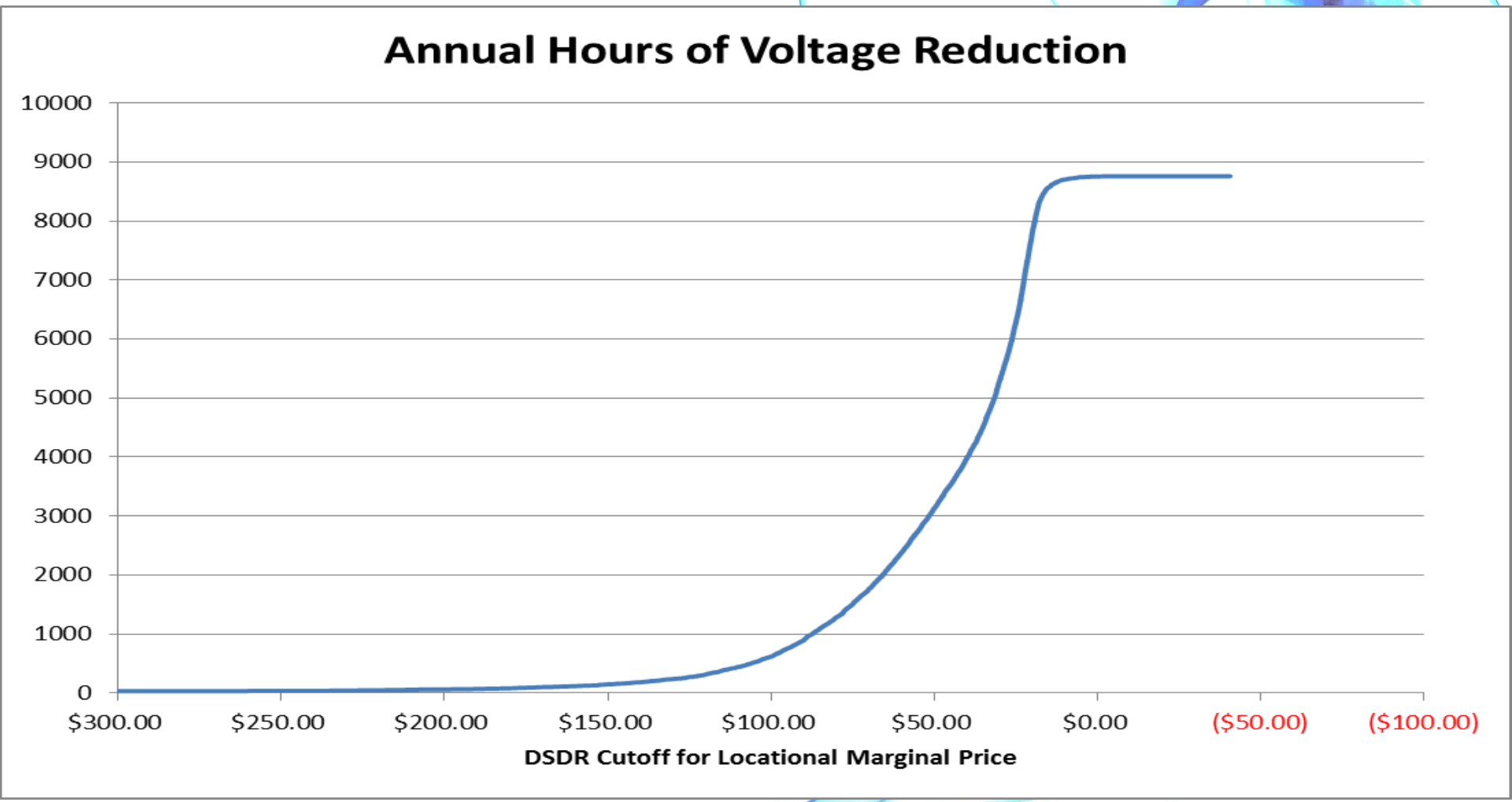
DSDR Voltage Reduction EO Benefits



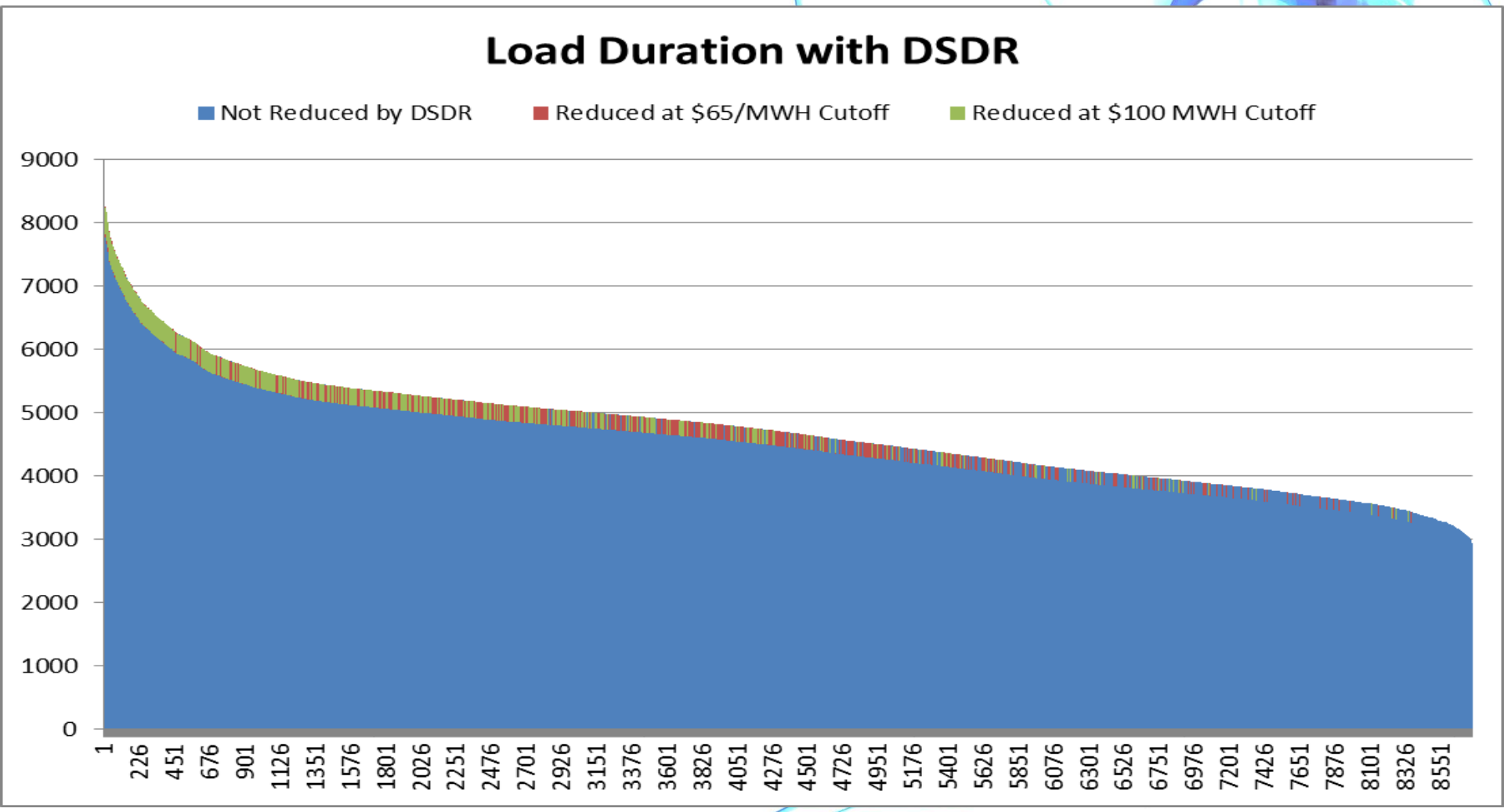
with considerable generation savings



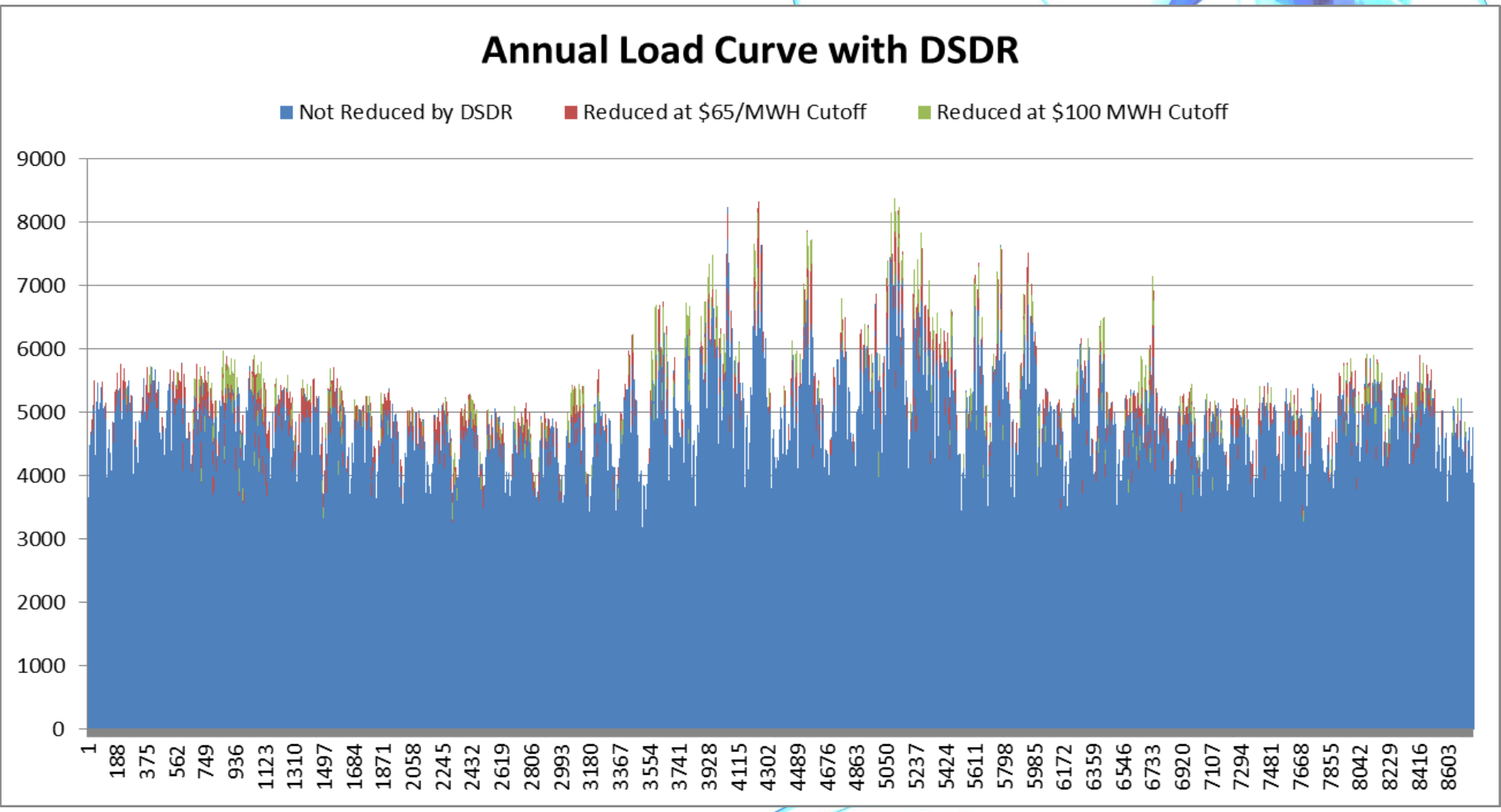
With controllable levels of customer effects



considerable load factor improvement



and considerable load stabilization



Summing Up

- Consideration and analysis of system load data and energy efficiency supply curves provides a useful perspective on EO program strategy.
  - New measure ideas
  - Increased benefits from expenditures
- Not shown today, but possible to analyze individual customer load data in this way and identify target customers for particular measures.
  - e.g., residences with strong vs weak relationship between load and temperature can be targeted for shell or HVAC improvements
  - e.g., drift in energy usage patterns can be used to target customers for retro-commissioning