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# Influence of Occupancy on Building Energy Use and Use of an Occupancy-Adjusted Performance Metric

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# Study Objectives

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- To further develop the concept, DOE-FEMP sponsored PNNL to conduct an exploratory study to:
  - Assess the influence of occupancy on building energy use and EUI in a "typical" office building, where occupancy is based on concept of full time equivalent occupancy (FTEO)

$$FTEO = \frac{Total\ Annual\ Occupied\ Person\ Hours}{1645\ Hours}$$

  - If warranted, provide a factor for accounting for the influence of changes in occupant density in planning decisions

# Study Approach (1)



- Literature review on occupancy impact on building energy use
- Review of simulation and benchmarking tools
- Identified two GSA buildings to explore occupancy-EUI correlation
  - GSA Headquarters, 1800 F St NW, Washington, DC
  - Byron Rogers Federal Building and U.S. Courthouse, Denver, CO
- Data collection and processing
  - 15-minute electric demand data was converted to hourly and daily energy use
  - Hourly steam and 15-minute natural gas data were converted to daily energy use
  - Occupancy data using prox card swipe-in logs (and swipe-out in one building)
  - 1-hour interval weather data from NOAA

# Study Approach (2)

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- Data analysis
  - Correlated building energy use to average daily outdoor temperature
  - Correlated building energy use to estimated daily FTEO
  - Created a multivariate regression model to assess the impact of both independent variables (weather and person-hours) on the dependent variable (energy use)
  - Studied sensitivity of traditional EUI, occupancy-based EUI and energy consumption for various occupancy levels
- Validation
  - DOE Building Performance Database to correlate occupant density with EUI
  - Bottom-up estimate of energy use from non-weather related occupant loads

# Building Data Limitations

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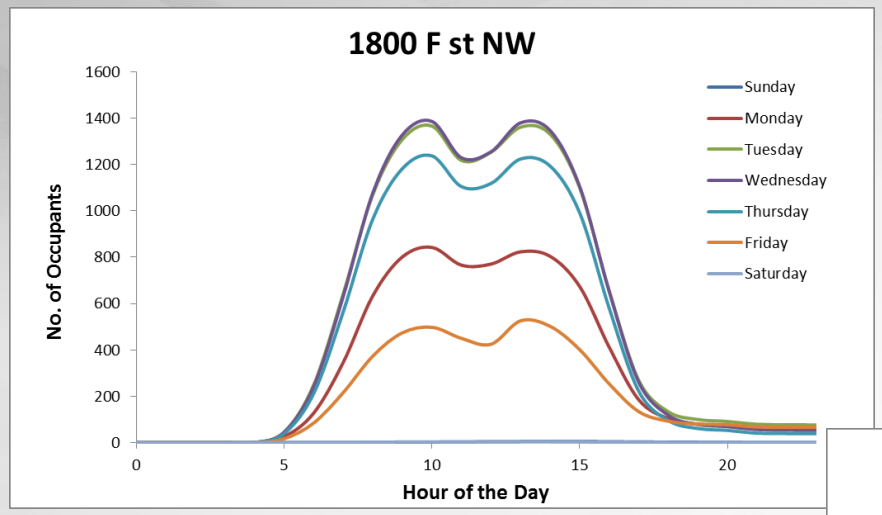
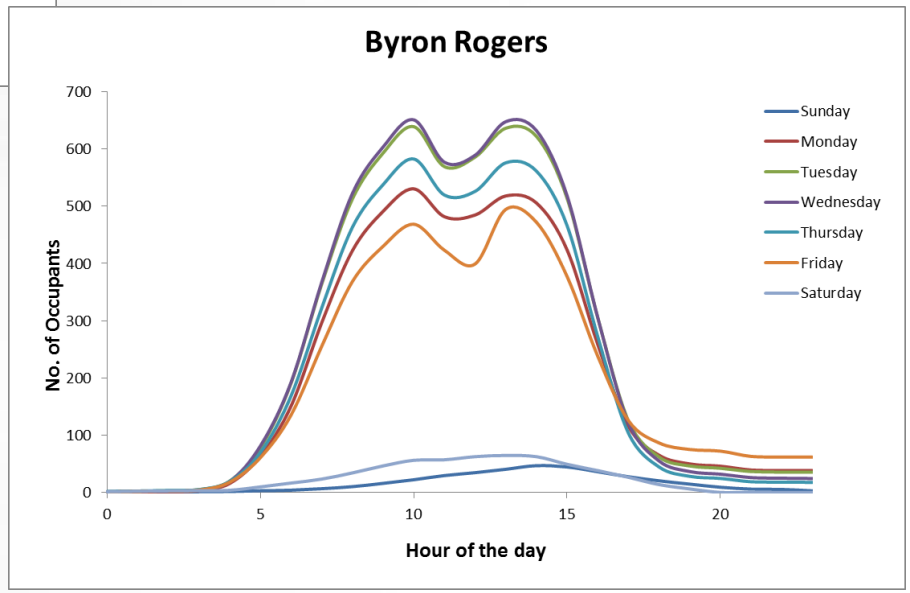
- GSA Headquarters
  - Electricity interval data could only be acquired for a portion of the building (accounted for 20-25% of the billed monthly consumption)
  - Developed adjustment factor based on ratio of metered to billed energy use for each month and prorated daily kWhs using factors to fill in missing data
  - Disclaimer: Missing data could pertain to loads influenced by occupancy (e.g. plug loads) and the effects would not be captured accurately in this analysis

- Byron Rogers Federal Building
  - Prox access system logs entry swipe-ins and not exits
  - Hourly occupancy was estimated based on occupancy trends from GSA HQ building

# Occupancy Profiles

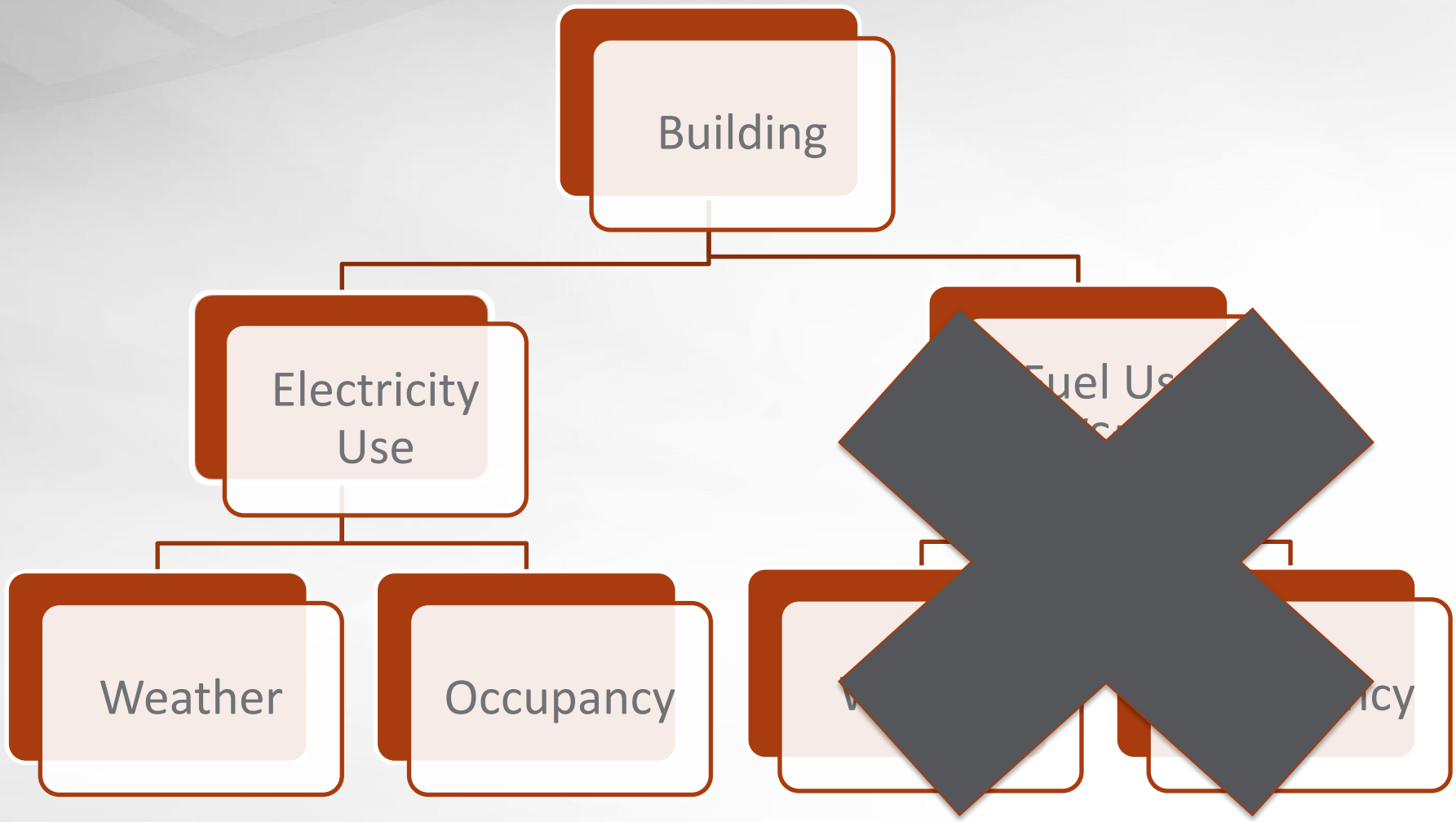




# Analysis Approach





# Findings:
## *Analysis for Weather Influence*

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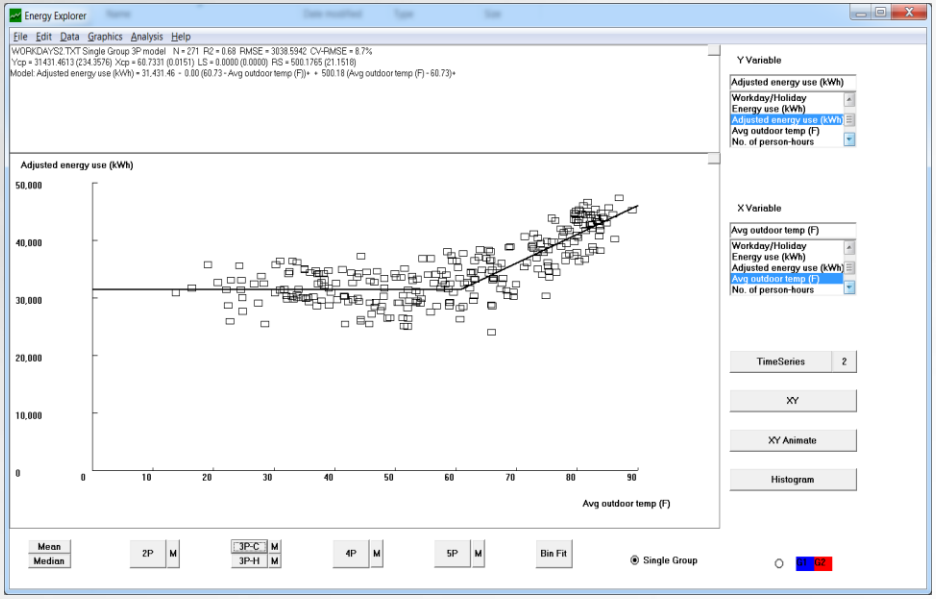
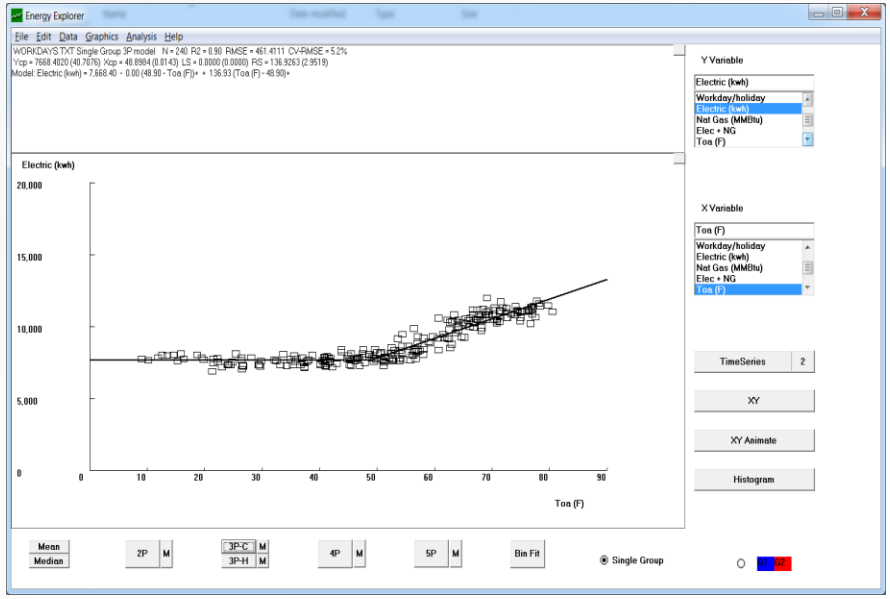
- Weekday Daily Electricity Use vs. Daily Average Temperature
  - GSA HQ: Strong Correlation R2=0.68
  - Byron Rogers: Strong Correlation R2=0.90



# Findings:
## *Analysis for Occupancy Influence*

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### Initial Approach

- Does occupancy influence a building's energy consumption?
  - All data points were plotted together and occupancy correlation was evaluated
  - A distinct clustering pattern was noticed in the data for Byron Rogers, which warranted a modified approach

### Modified Approach

- Does occupancy have different levels of influence on plug load- and HVAC-related energy use?
  - Dataset divided into 2 groups based on the temperature change point on the electricity vs. outdoor air temperature correlation graph
  - Occupancy correlation (slope) was calculated for each dataset
  - Slopes were weighted based on the number of data points analyzed

- Approach did impact results for Byron Rogers building

# Findings:
## *Analysis for Occupancy Influence*

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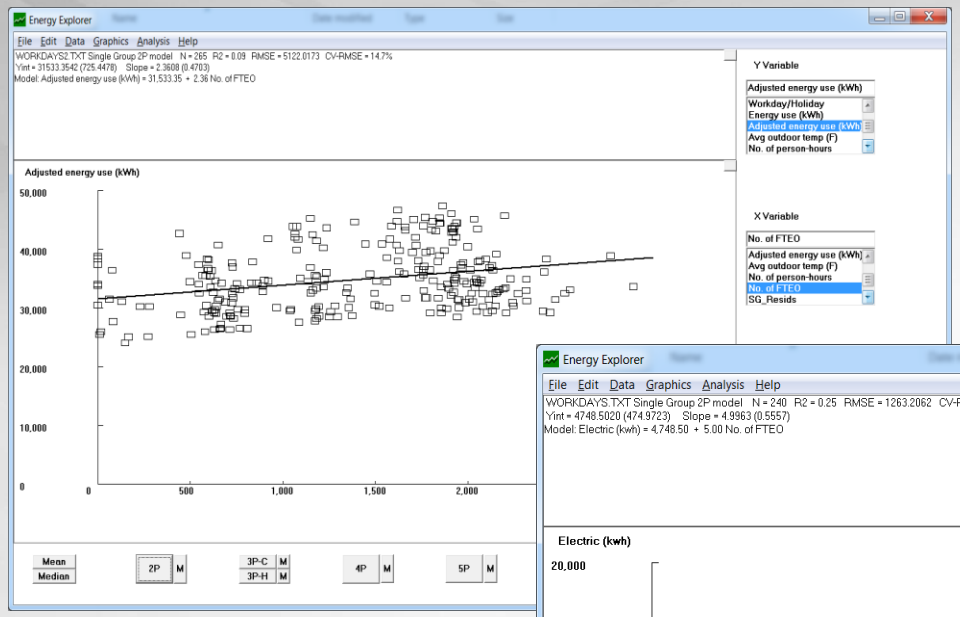


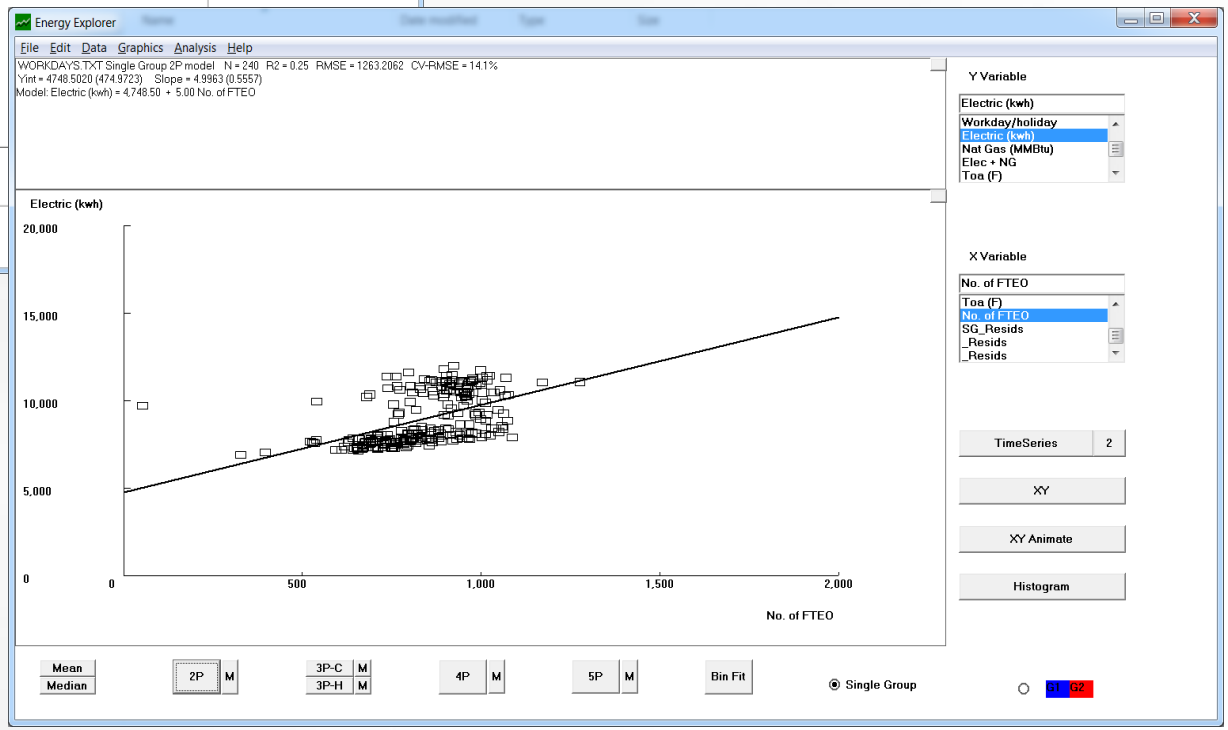

# Findings: GSA HQ Building
## *Electricity Use Analysis using Modified Approach*

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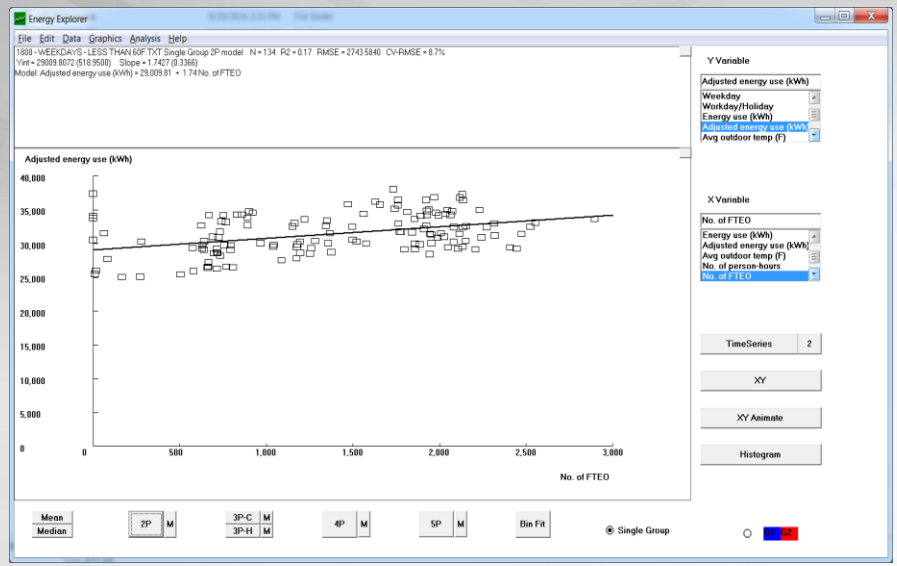


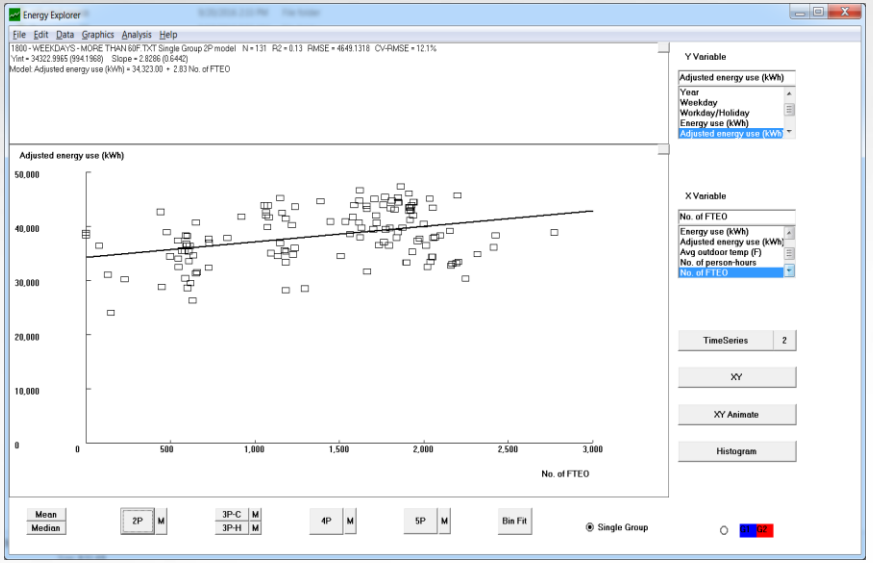


| Outdoor Temperature Change Point | R2 | # Datapoints | kWh/day/FTEO |
|---|---|---|---|
| Less than 60F | 0.17 | 134 | 1.74 |
| Greater Than 60 F | 0.13 | 131 | 2.83 |

- Weighted slope = 2.28 kWh/day/FTEO

# Findings: Byron Rogers Building
## *Electricity Use Analysis using Modified Approach*

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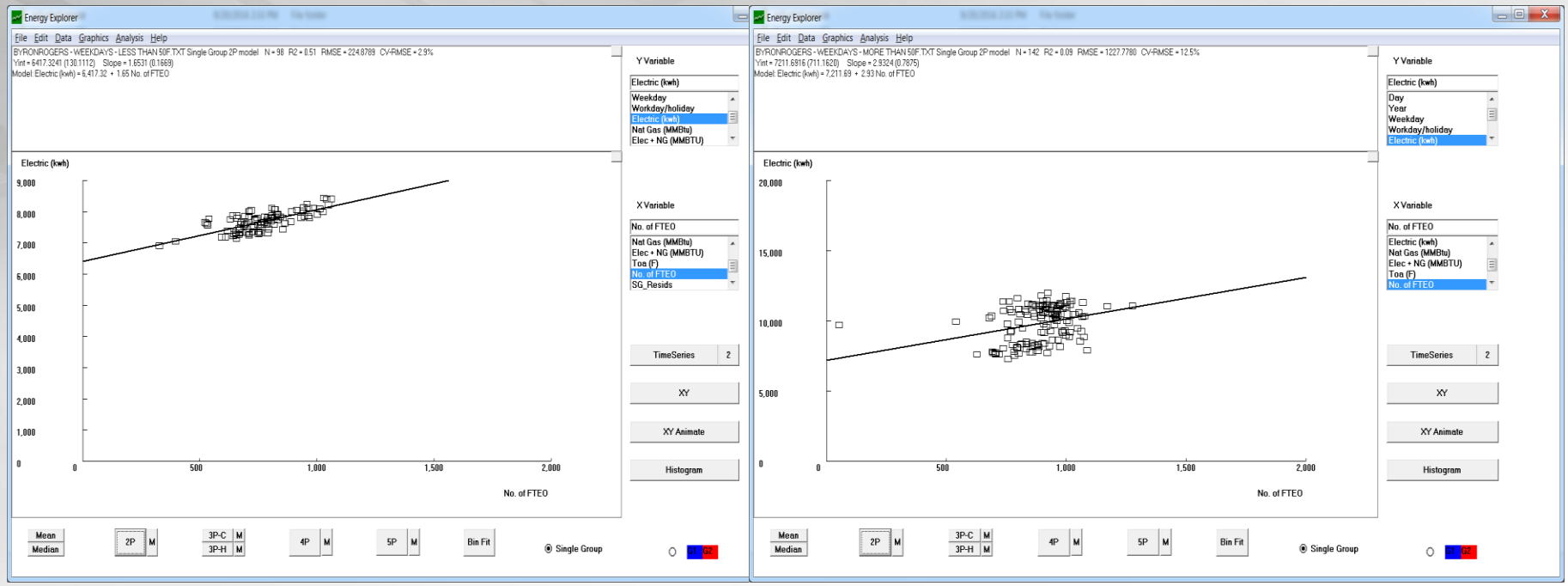



| Outdoor Temperature Change Point | R2 | # Datapoints | kWh/day/FTEO |
|---|---|---|---|
| Less than 50F | 0.51 | 98 | 1.65 |
| Greater than 50F | 0.09 | 142 | 2.93 |

- Weighted slope = 2.41 kWh/day/FTEO

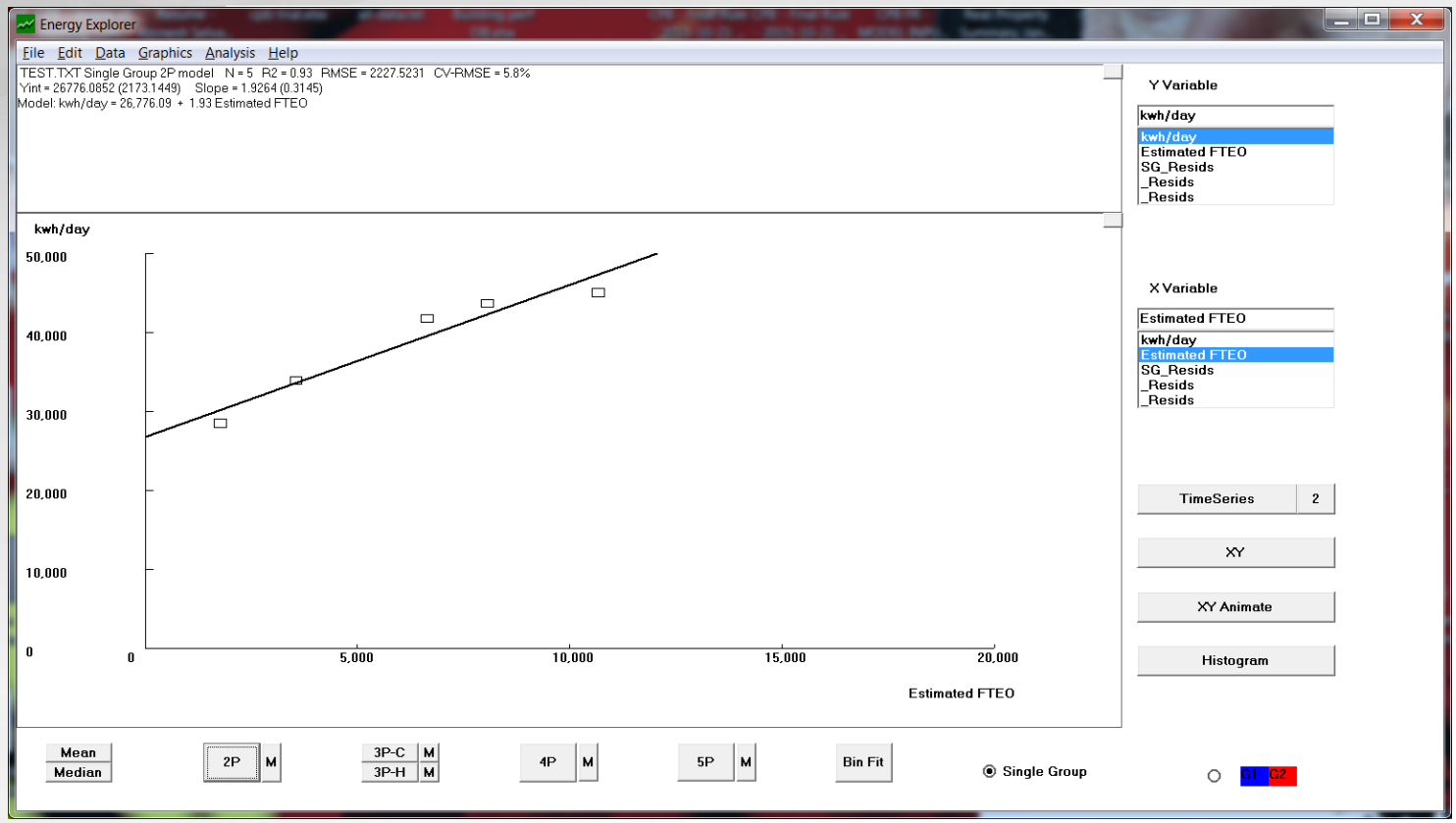
# Validation: Buildings Performance Database



- Plotted site Electricity EUI vs. Occupant Density
- Data not accessible to run a true regression, so cluster means were visually identified to run a quasi-regression

| Occ density (Ppl/1000SF) Bin-Low | Occ density (Ppl/1000SF) Bin-High | Occ density (Ppl/1000SF) Cluster Mean | Mean Electric EUI (kBtu/SF/year) |
|---|---|---|---|
| 0 | 2 | 1.5 | 47.36 |
| 2 | 4 | 3 | 56.39 |
| 4 | 6 | 5.6 | 69.39 |
| 6 | 8 | 6.8 | 72.54 |
| 8 | 10 | 9 | 74.84 |

# Findings: Buildings Performance Database




**Slope = 1.93 kWh/day-FTEO**

# Findings: Bottom-up Estimate Typical Personal Loads

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| Typical Personal Loads | % of occupants using equipment daily | Watt-hrs / occupant-day |
|---|---|---|
| Desktop Computer (EStar) | 50% | 181 |
| Laptop computer (EStar) | 50% | 24 |
| LCD Monitor (EStar) | 100% | 73 |
| Computer speakers (Estar) | 50% | 3 |
| Mobile phone charger | 50% | 19 |
| Phone: analog | 75% | 20 |
| Phone: VOIP (EStar) | 25% | 12 |
| Task lighting | 25% | 16 |
| Personal printer: laser | 13% | 13 |
| Personal printer: inkjet | 13% | 11 |
| Coffee maker | 6% | 22 |
| Space heater | 2% | 2 |
| Compact refrigerator (2.3 cu.ft Estar) | 5% | 34 |
| | **All loads** | **0.43 kWh/occ-day** |

***With less conservative assumptions, use from all loads approached 1 kWh/occ-day***

# Summary: Impact of Occupancy



- Occupancy appears to have relatively minor impact on energy use based on regression analyses in these two office buildings
- Estimates of per occupant impact were within the same general range

| Analysis | Estimated Impact on Building Energy Use |
|---|---|
| GSA HQ building data | 2.28 kWh/day-FTEO |
| Byron Rogers building data | 2.41 kWh/day-FTEO |
| DOE Building Performance Database | 1.93 kWh/day-FTEO |
| Bottom-up analysis | 0.43 to 0.94 kWh/day-occupant (plug loads only) |

# Sensitivity of EUI to Occupancy Changes

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| | Peak Occupancy Increase | FTEO Adjustment Factor (actual hrs logged/FTEO hrs) | Difference in Predicted Electric EUIs (kWh/SF-yr) | Occupant-adjusted Electric EUI (kWh/FTEO-yr) |
|---|---|---|---|---|
| GSA HQ 1800 F St NW, Washington, DC | 76% (2500 to 4400 heads) | 0.55 | +7% | -39% |
| Byron Rogers, Denver, CO | 50% (1000 to 1500 heads) | 0.78 | +14% | -24% |

*Note: Predicted changes in electric EUI are based on building-specific regression curves. It would not be appropriate to apply these to other buildings.*

# Conclusions

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- Based on a limited analysis of occupancy influence on building energy using daily-scale data in two office buildings, and estimated impacts using less granular data:
  - Each FTEO appears to contribute ***~2kWh/day*** to building loads
  - Influence was small compared to weather but statistically significant

- Occupancy-adjusted EUI could be tracked as a supplemental metric to help understand
  - Actual energy use per occupant
  - Impact of adding shifts or changes in telework use
  - How building consolidation efforts affect energy use
  - How facility utilization is influencing whole building energy use

# Conclusions

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- Calculating occupancy-adjusted EUI requires accurate occupancy logs and the level of data processing is non-trivial

- The estimated electricity use/FTEO-day documented in this study could be used to assess general impacts of occupancy changes, *however*
  - Actual impact will depend on building specific operations; the methodology established in this study could be replicated to estimate impacts of building consolidation efforts in a specific building

# Further Research



- We recommend expanding this study to larger number and type of buildings to see if results are similar
  - Use modified analysis approach, separating energy use data into two bins based on outdoor air temperatures / HVAC change point.
  - The analysis has the potential to differentiate between occupancy-based non-weather-dependent loads (plug loads, common lighting) and occupancy-based weather-dependent loads (HVAC loads), which has been a challenging problem to solve by itself.
  - This could be useful in the case of high performance buildings with tight building envelopes and very high HVAC component to the occupancy-based energy use.

- Use of updated Portfolio Manager regression curve to develop an adjustment factor to the traditional EUI based on occupancy change, for buildings without access to occupancy data