Advanced Energy Data Analytics

NC Association of Energy Engineers

February 12th, 2019

Energy Analysis Topics

- Utility Billing and Basic Energy Metrics
- Portfolio Analysis
- Load Shape Analysis and Indices
- Surface Plot Interpretation
- Weather Modelling
- Energy Savings Measurement
- Cumulative Sum “CUSUM”
- Demand Response Measurement
- Anomaly Detection
- Energy Usage Disaggregation
- Sources of Energy Waste
- Demonstration

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About Enpira

Utilities

- Energy Savings and Demand Response Analysis
- Customer Engagement
- Custom Analytics & Services

Buildings

- Energy Management Information System
- Recommissioning Support
- Advanced Analytics

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Empirical vs. Theoretical Energy Analysis

Theoretical	Empirical
As designed	As operated
What aught to happen	What actually happened
Based on simulation	Based on observation
Models govern	Data govern
Commissioning	Recommissioning

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Utility Billing Cost Components

Charge	Value	Description
Customer Charge	$/month	Connection charge per facility May include minimum bill
Commodity Charge	$/kWh $/therm	Cost of delivered energy, note fixed & variable costs, distribution, seasonal or time of use rates
Demand Charge	$/kW	Dependent on maximum of metered demand and minimum billing demand, seasonal adjustment
Fuel Cost Adjustment	$/kWh	Variable charge to compensate utility for variable input fuel costs
Service Charges & Riders	$/month	Collected fees for public projects
Secondary Services	$/kWh $/kW	Usually for higher voltages or three-phase service
Load Management Rebates	- $/kW	Payment to reduce load during peak demand

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Basic Energy Metrics

Metric	Value	Application
Electricity Cost	$/kWh	Review tariff or energy procurement contract
Gas and Fuel Cost	$/therm	Determine benefits of fuel switching options
Energy Use Index, EUI	kBtu/sqft	Benchmark against similar building types
On/Off Peak Cost	$/kWh	Shift loads to off-peak e.g. thermal storage
Demand Charge Pct.	%	Find excess billed demand
Load Factor	avg/max	Avoid setting peaks (low) or unnecessary use (high)
Power Factor Charges	$/kW	Investigate sources of kVA, budget for correction

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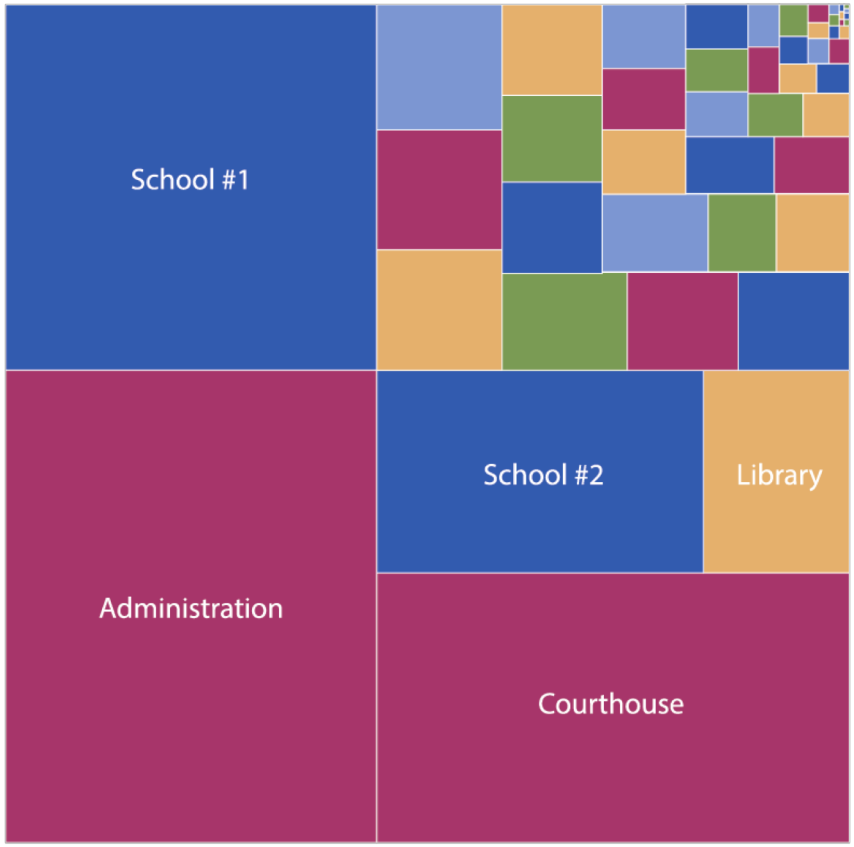
Portfolio Analysis



Within Portfolio

- $, kBtu,kWh, kW, therms
- Annual usage or per sqft
- Weather model metrics
  e.g. marginal kWh/^{O}F-day

External Benchmarking

- Energy Star Portfolio Manager
- Building Performance Database
- Commercial Buildings Energy Consumption Survey

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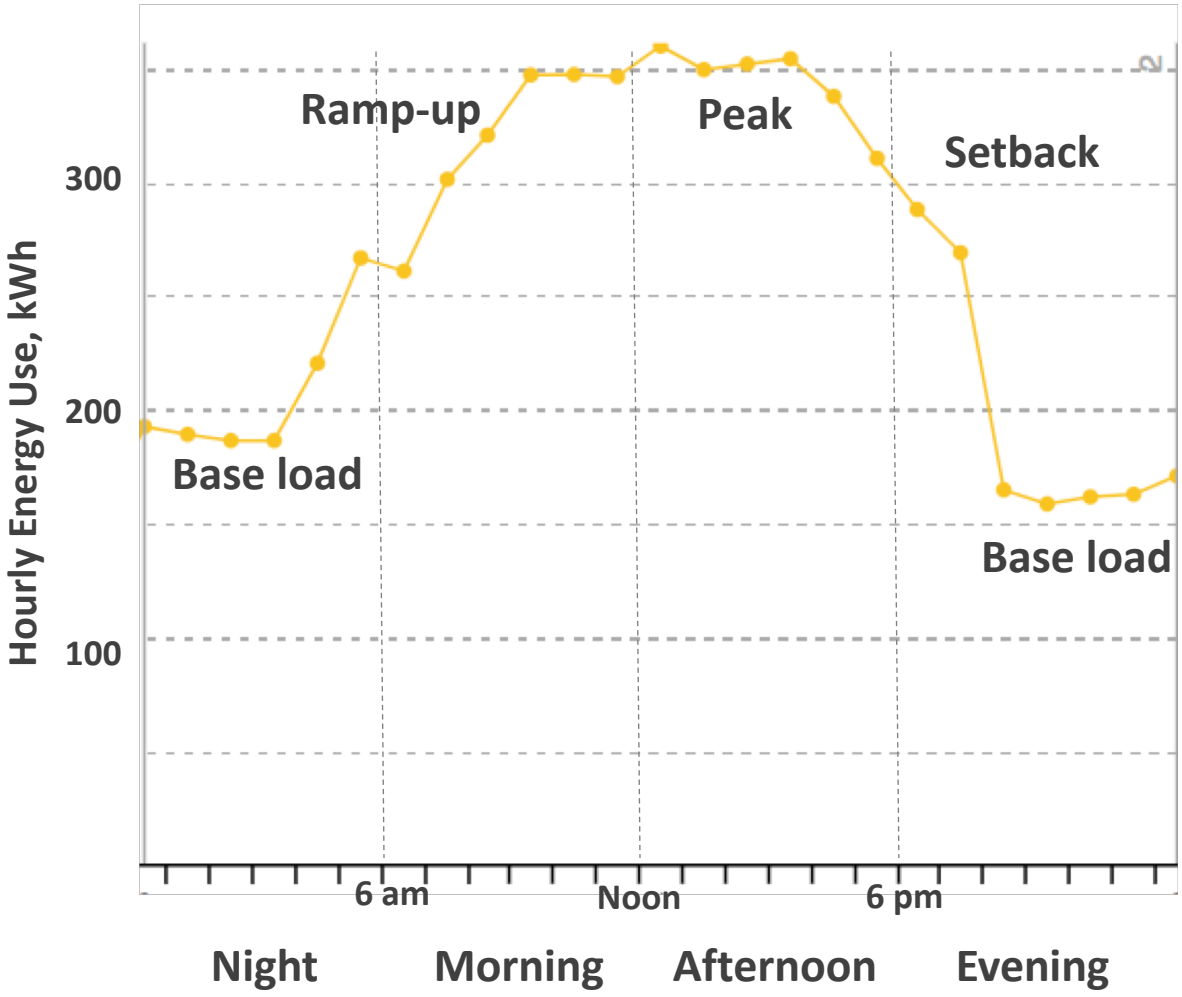
Understanding Daily Building Energy Use



Load Shape Indices

Load Factor (daily) *average/max*	.74
Base-to-Peak *min/max*	.44
Baseload Modulation *min/average*	.59
Day Load Factor *day average/day max*	.94
Day Baseload Modulation *day min/ day average*	.79
Baseload Uniformity *min/day min*	.59
Night Impact *night average/average*	.80

Note: Day is 8am to 6pm

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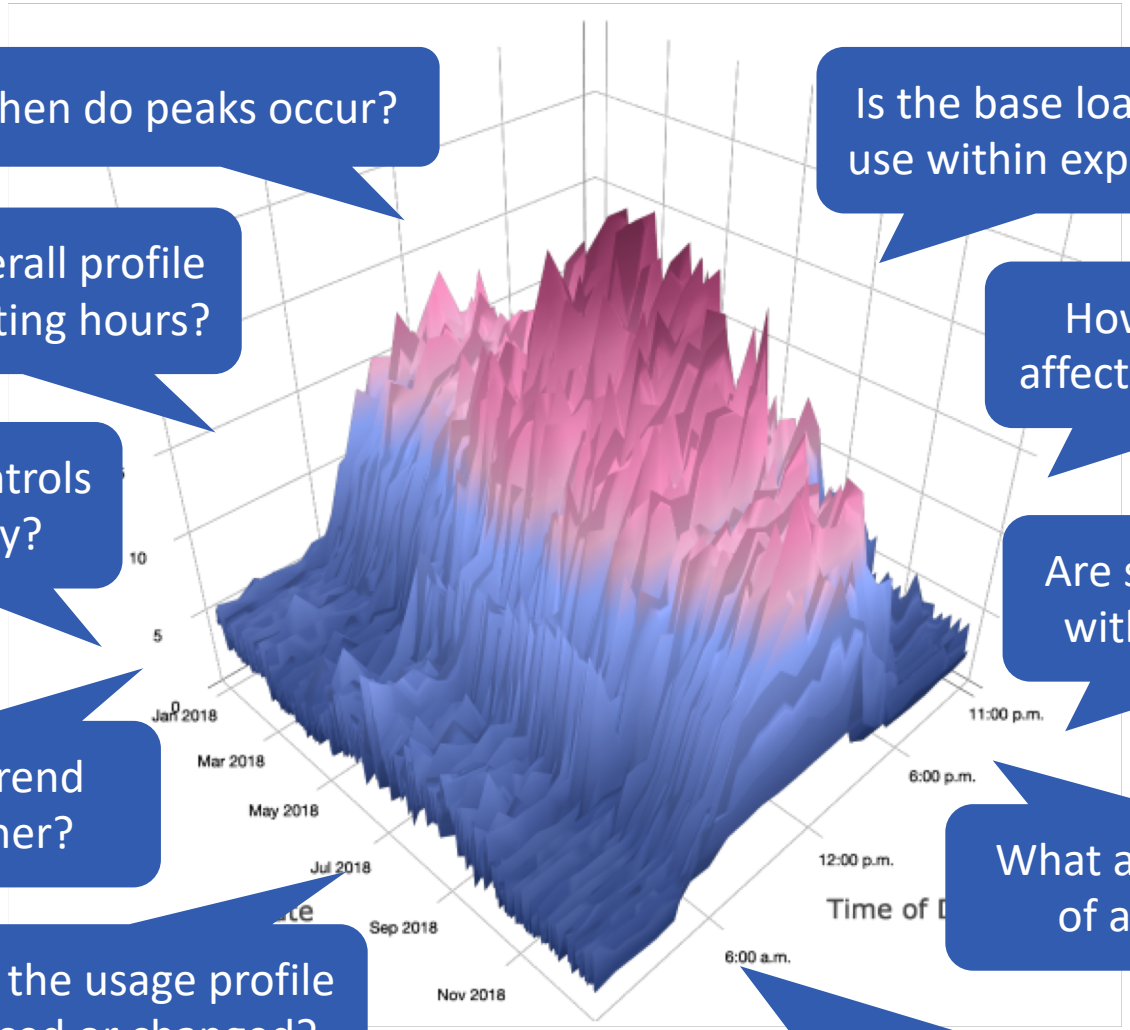
Meter Data Interpretation



When do peaks occur?

Is the base load energy use within expectation?

Does the overall profile match operating hours?

How does weather affect total energy use?

Are HVAC controls set properly?

Are seasonal variances within expectations?

Is the data trend drifting higher?

What are the causes of anomalies?

How can the usage profile be reduced or changed?

How does the profile compare with similar buildings?

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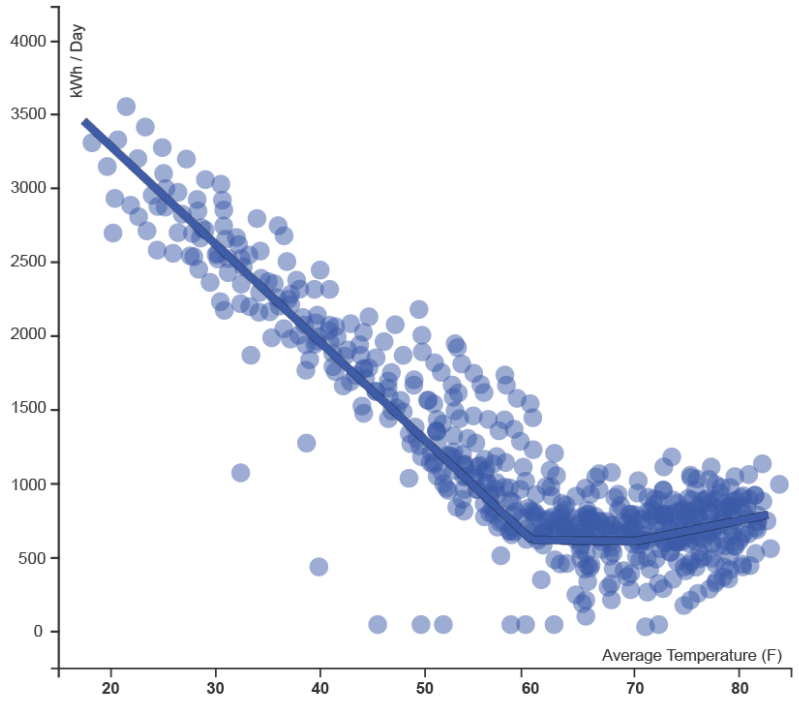
Whole Building Energy Use Modelling

$$E = C - B_1(DD_{TH}) + B_2(DD_{TC})^*$$



E	Average daily usage
C	Average daily non-weather dependent usage
B_1	Marginal energy use per degree day for heating (below heating BPT_H)
DD_{TH}	Heating Degree Days, based on BPT_H
B_2	Marginal energy use per degree day for cooling (above cooling BPT_C
DD_{TC}	Cooling Degree Days, based on BPT_C

BPT: Balance Point Temperature – outdoor temperature at which building heat gains equal heat loses

* Natural Gas models exclude B_2 and DD_{TC}

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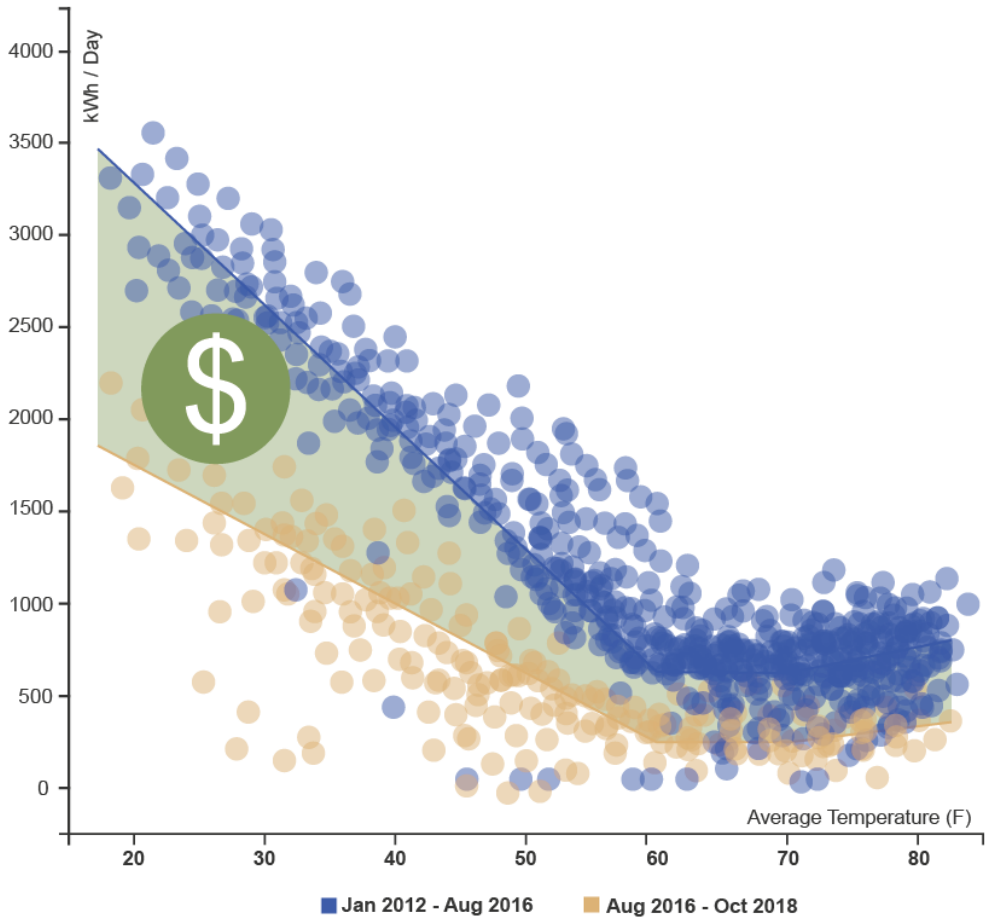
Measuring Energy Savings



NREL Uniform Methods Project

1. Compute Whole Building Energy Use Models for pre- and post-improvement periods
2. Compute pre- and post-improvement Normalized Annual Consumption (NAC) by applying one year of weather normals to the two models
3. Savings = Pre-NAC – Post-NAC

ASHRAE-14 Method

1. Compute a Whole Building Energy Use Models for the pre-improvement period
2. Saving = pre-improvement model with post-improvement weather – post-improvement usage

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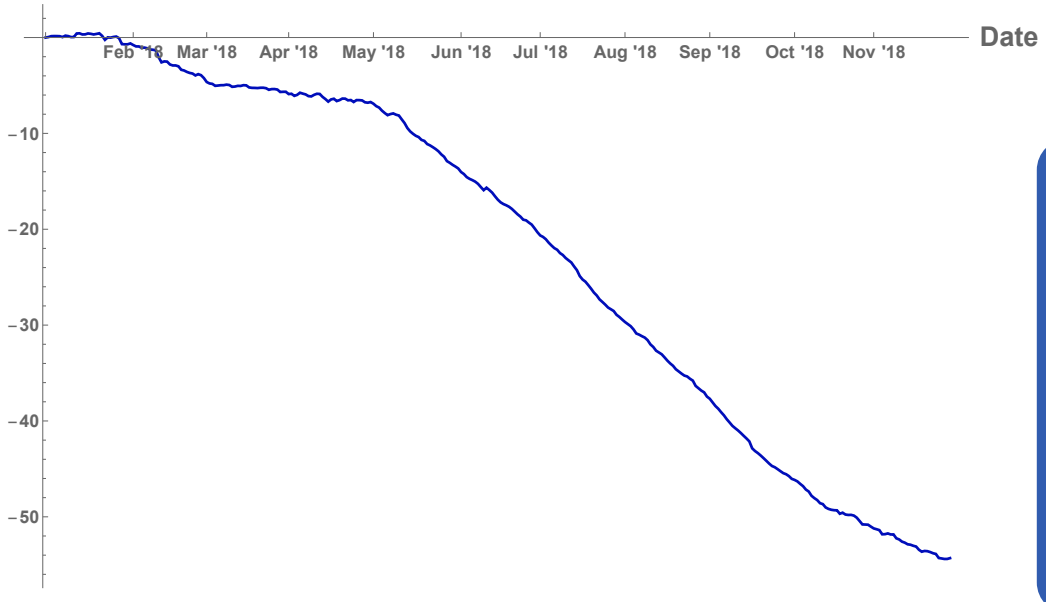
Cumulative Sum “CUSUM”



Cumulative Sum of Savings

- Cumulative difference between metered consumption and predicted consumption based on a pre-improvement model
- Quantifies total energy savings (or losses) over time
- Detects performance changes
- Electricity or Natural Gas

Use Cases

- Verification of energy efficiency measures
- Ensuring persistence in savings
- Detecting waste

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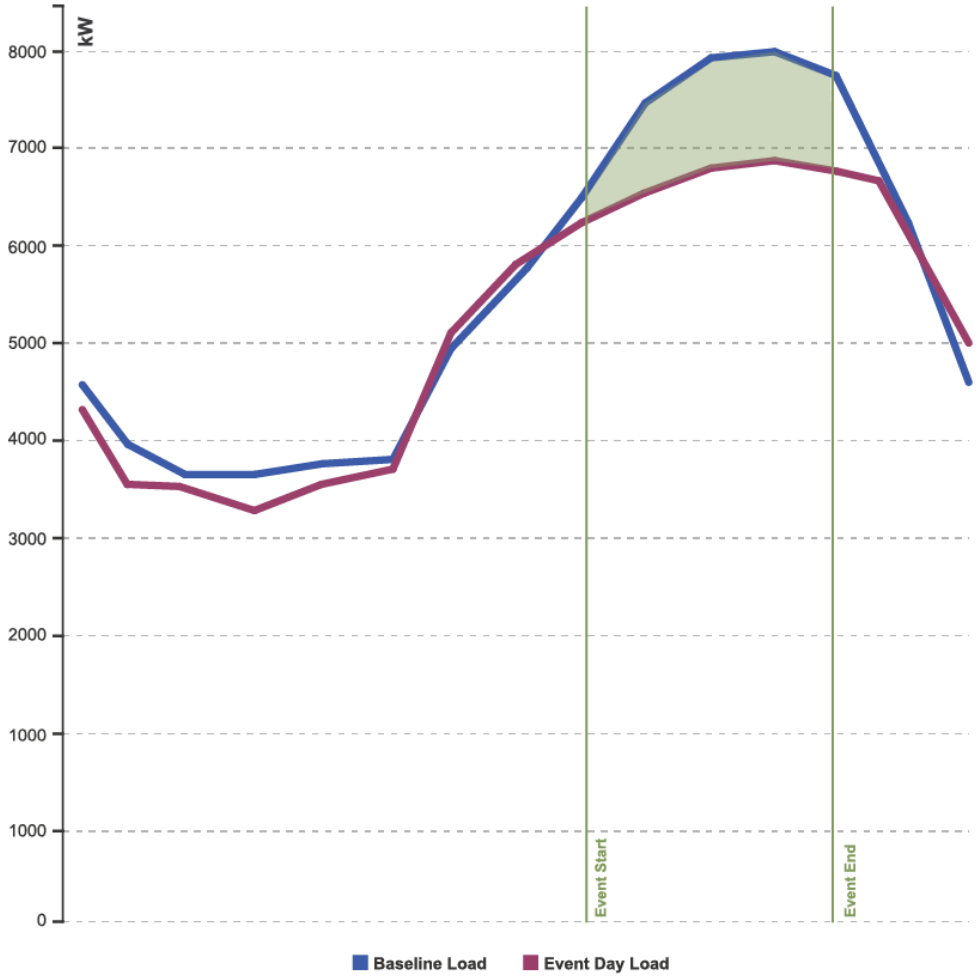
Demand Response Measurement

How much load is shed by a building during a demand response event?



Baselining Methodologies

- Day Matching
- Weather Modeling
- Machine Learning

Event Day Load

- As metered

Load Drop

- Drop = Event Day Load – Baseline Load
- At each meter read interval or averaged across the event

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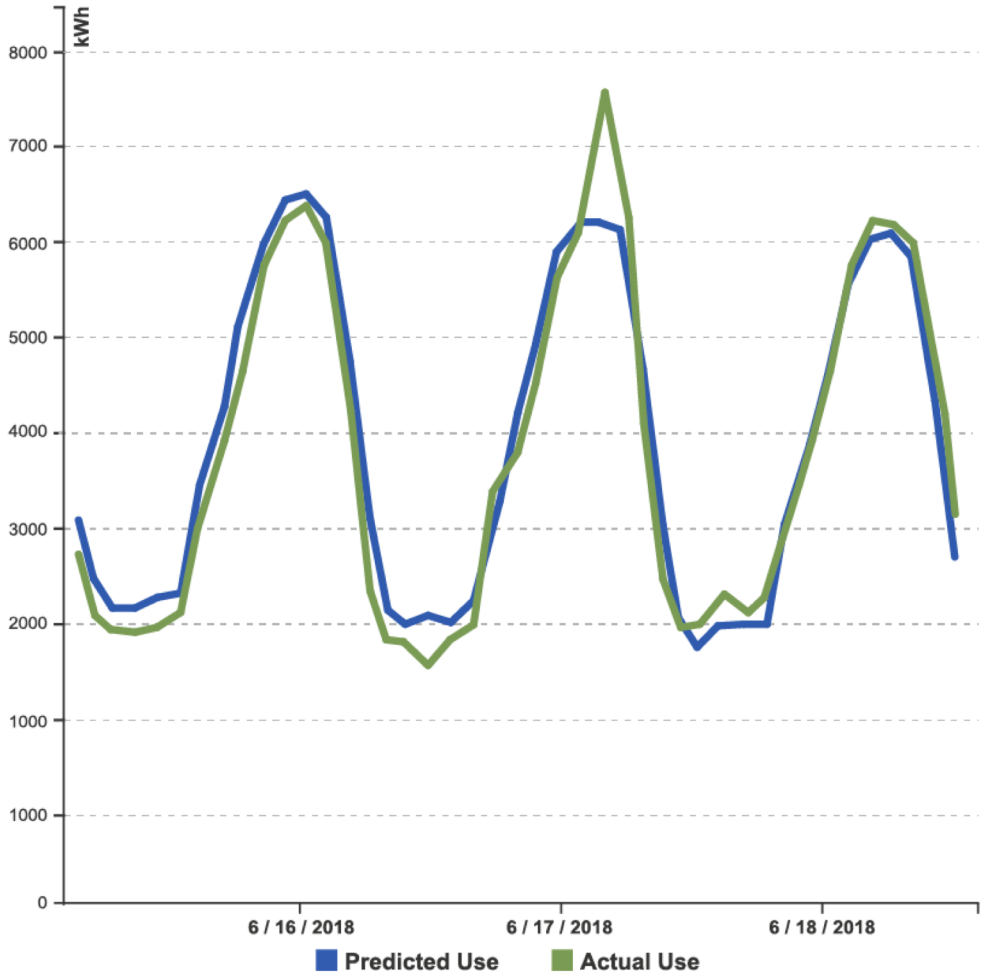
Anomaly Detection



Predicted Use

- Based on historic usage and weather data, and forecast weather

Actual Use

- As metered
- Excess use (~10%+) identifies anomalies

Use Cases

- Identifying abnormal operations
- Avoiding excessive peak demand charges
- Identifying after-hours system overrides

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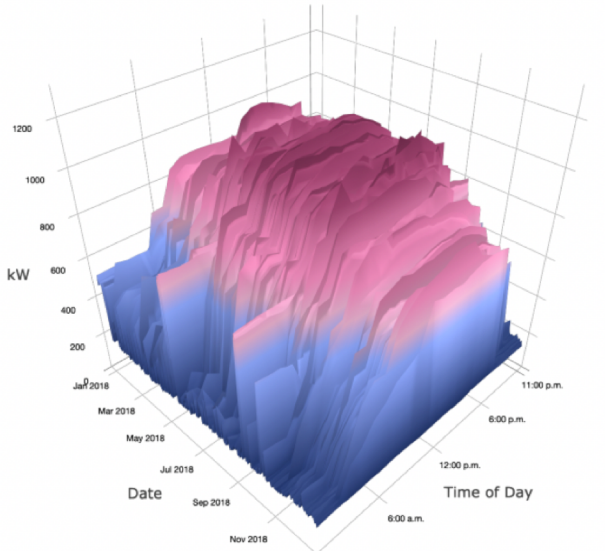
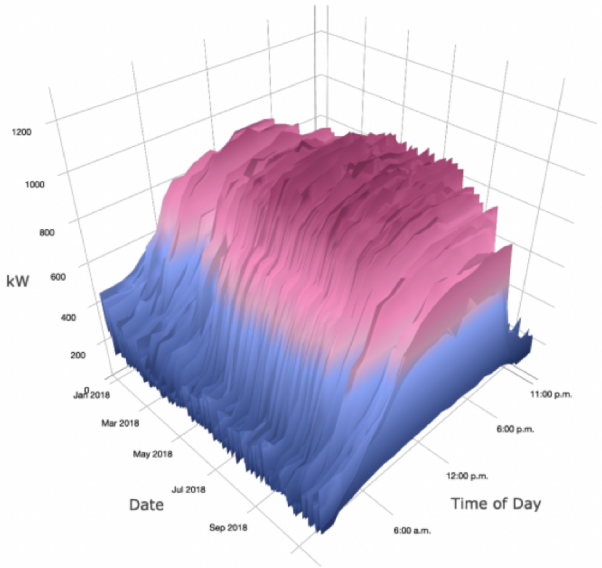
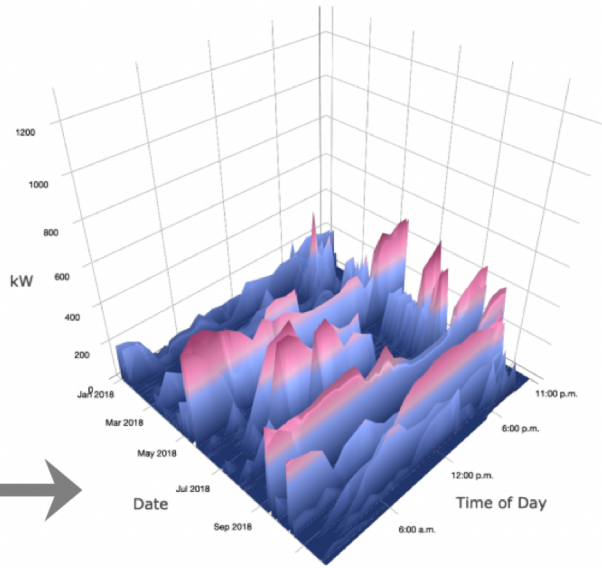
Anomaly Detection In Practice



Actual Use



Predicted Use



Anomalies

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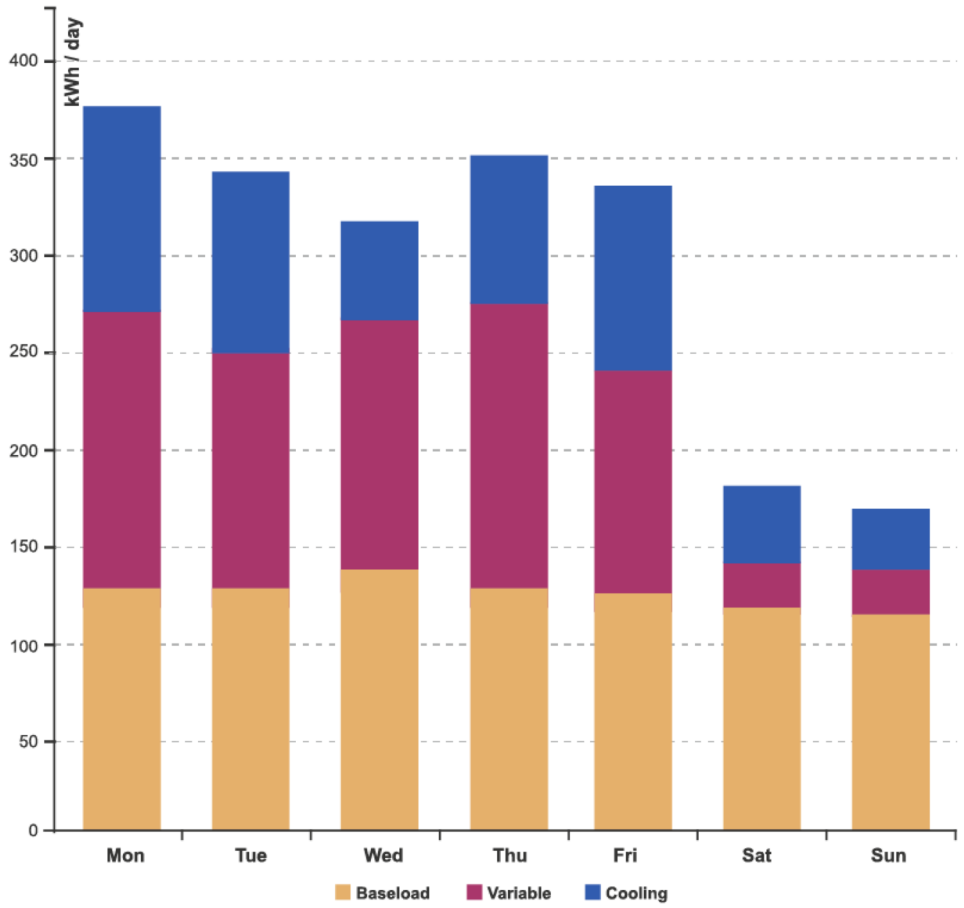
Energy Usage Disaggregation



Heating & Cooling Load

- Dependent on weather
- HVAC system & thermal envelope

Variable Load

- Usage that tracks occupancy
- Lighting, computers, office equipment

Base Load

- Similar pattern each day
- Security lighting, ventilation, plug loads

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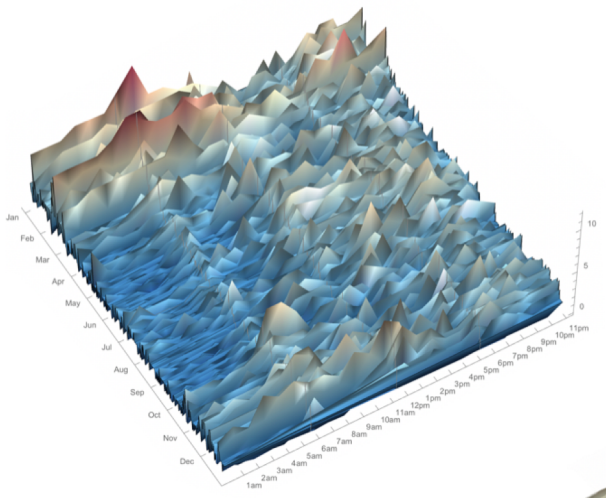
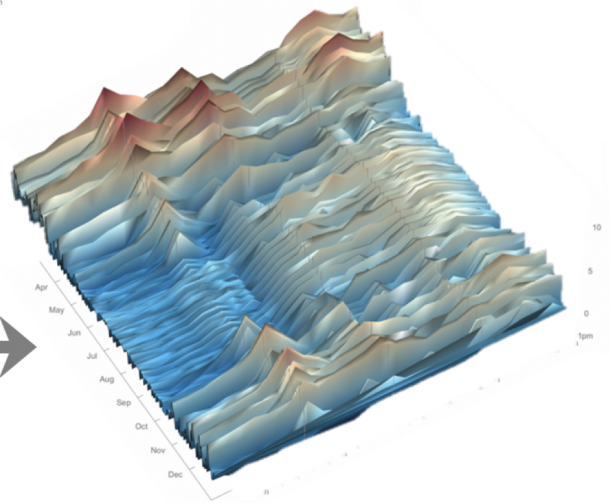
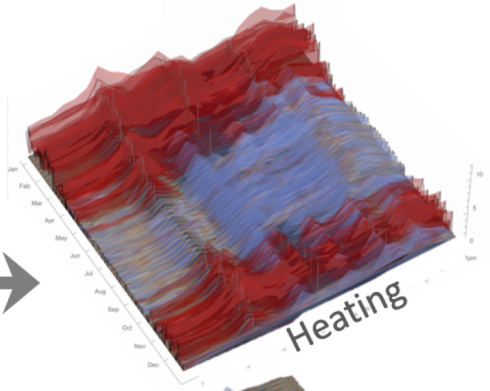
Disaggregating In Practice

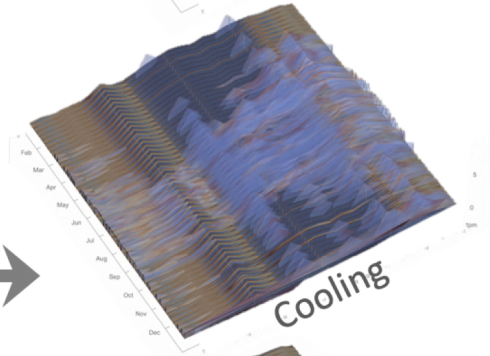


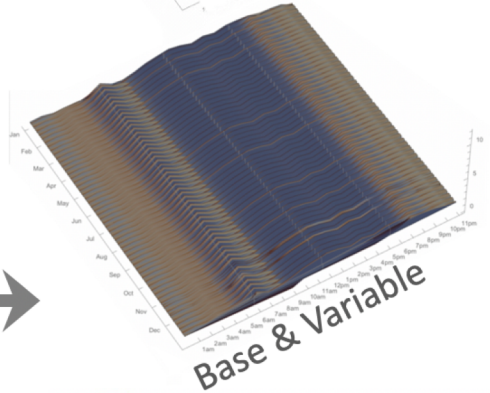
Actual Use



Predicted Use







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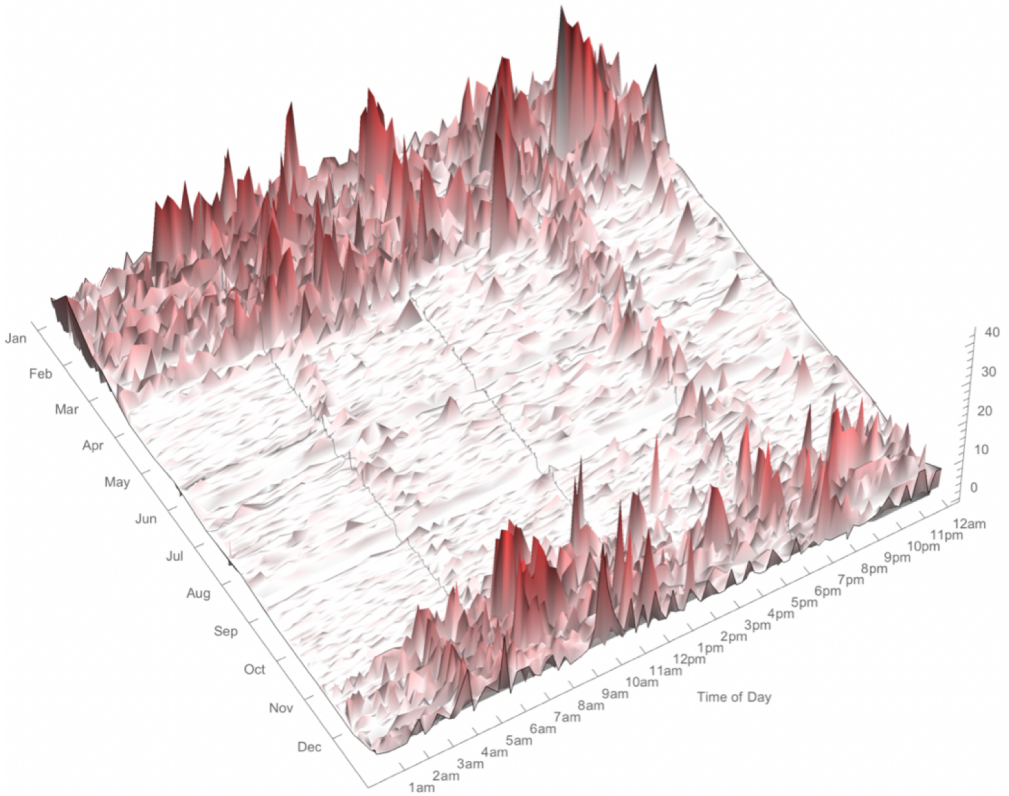
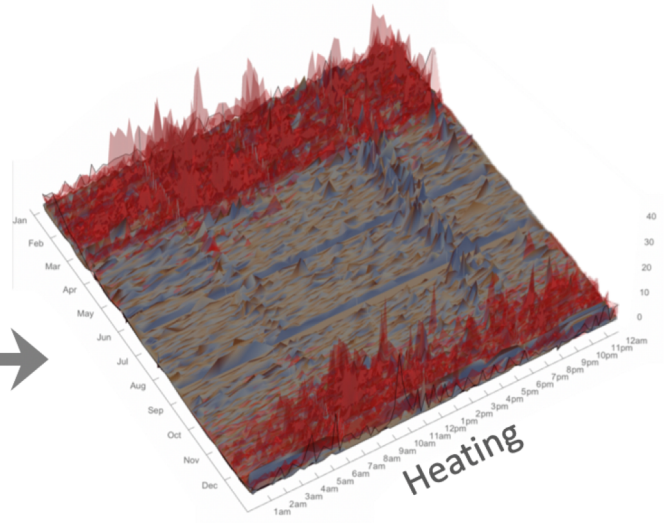
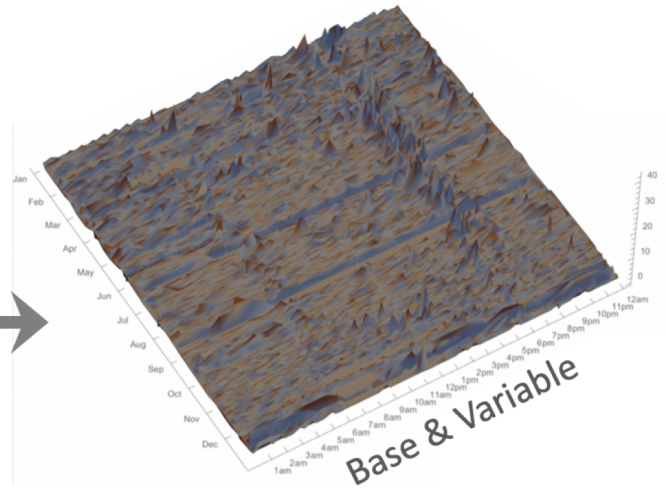
Disaggregating Natural Gas Meter Data



Actual Usage





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Waste = Saving Opportunity

Source of Waste	How Waste is Detected
System Overrides	Anomalies = Actual – Predicted Usage
Excess Demand	High peak load events, anomalies
Operational Inefficiencies	Inefficiencies = Predicted – Ideal Usage
Simultaneous Heating & Cooling	Overlapping Balance Point Temperatures
Billing Errors	Abnormal meter reads, wrong tariffs etc.
HVAC Equipment Degradation	Year-on-year weather model parameter changes

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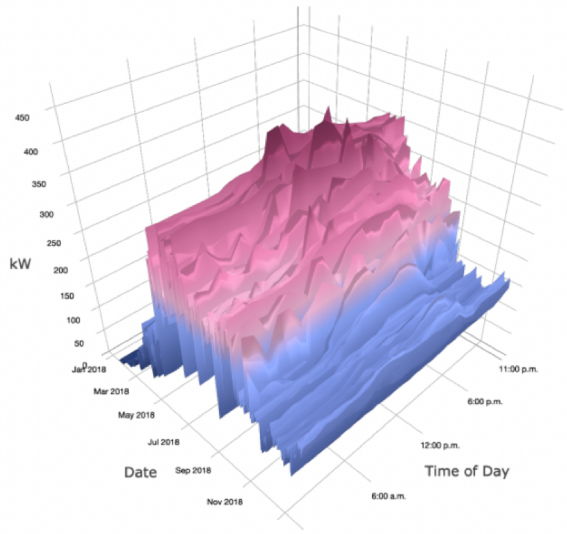
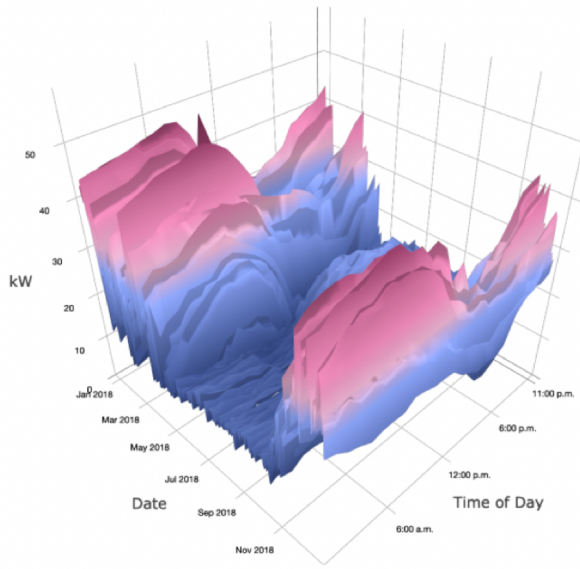
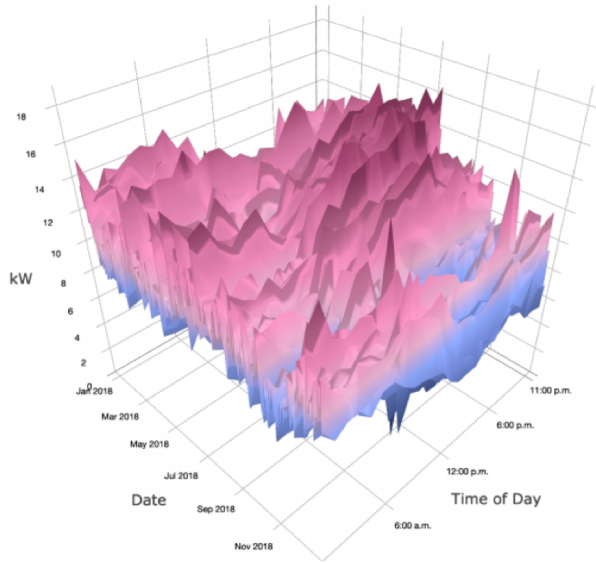
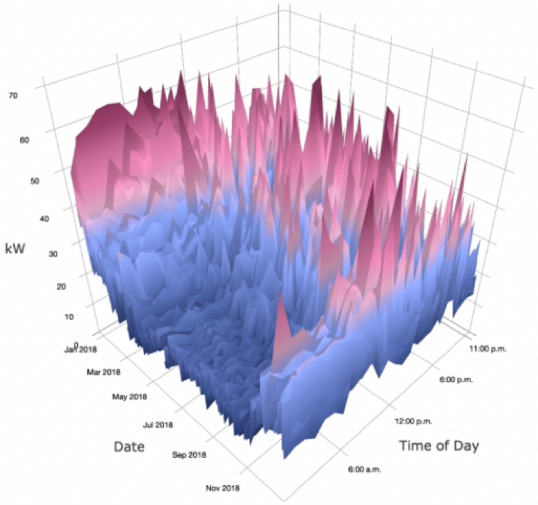
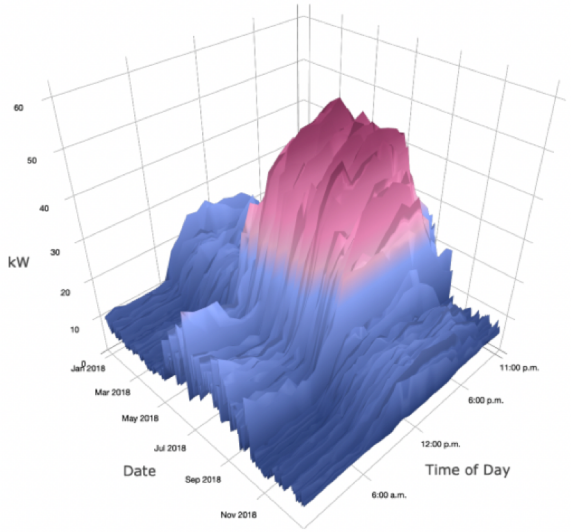
How is your building doing?

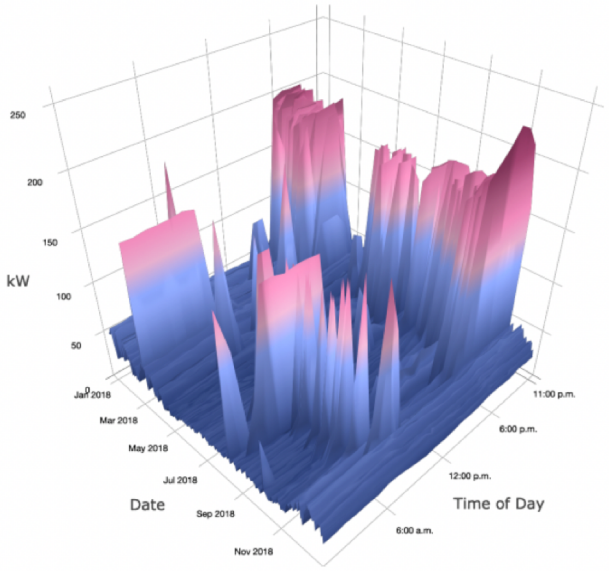












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