While waiting for the workshop to start…

Get ready to participate!

- Turn on your camera
- Find the unmute button and say "Hi" to check your audio

- Find the "raise hand" button

Answer our opening question!

What are you hoping to get from today's session?

Answer in chat or raise hand and unmute

SEPTEMBER 9TH, 2025

Advanced Option C M&V: Hourly Data Modeling Techniques

From Monthly Bills to Hourly Insights –

Statistical Methods for Enhanced Savings Verification

Craig Sinnamon
PowerTakeOff - Director of Analytics and Data Management
Lucas Born
PowerTakeOff - Manager, Program EM&V

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Welcoming our guest speaker

Power TakeOff

Presented By: Craig Sinnamon & Lucas Born, CEM, CMVP

With help from: Hannah Whipple, PMVA & Jordanka Marčeta-Thayer, PMVA

Introduction - why hourly data?

Moving Beyond Monthly Aggregation

- Traditional Option C uses monthly utility bills - but we're missing operational patterns
- Hourly data reveals load shapes, occupancy patterns, and weather interactions
- Better captures savings from controls, scheduling, and operational improvements
- Enables detection of persistence issues and load shifting effects
- Critical for projects with time-varying impacts (demand response, peak shaving)

Key Point: Hourly data provides the granularity to model what's actually happening.

Hourly data sources & considerations

Consumption Data

- Interval meter data (15-min, hourly)
- Quality checks: missing data, anomalies, meter changes
- Time zone consistency and daylight-saving transitions

Weather Data

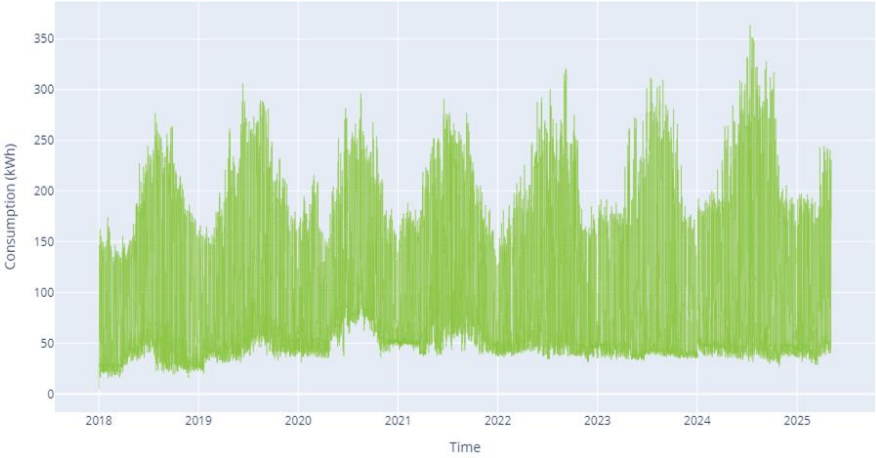
- Local weather stations vs. airport data
  - Informed by building location
- Hourly temperature, humidity, solar radiation
- Data gaps and interpolation strategies

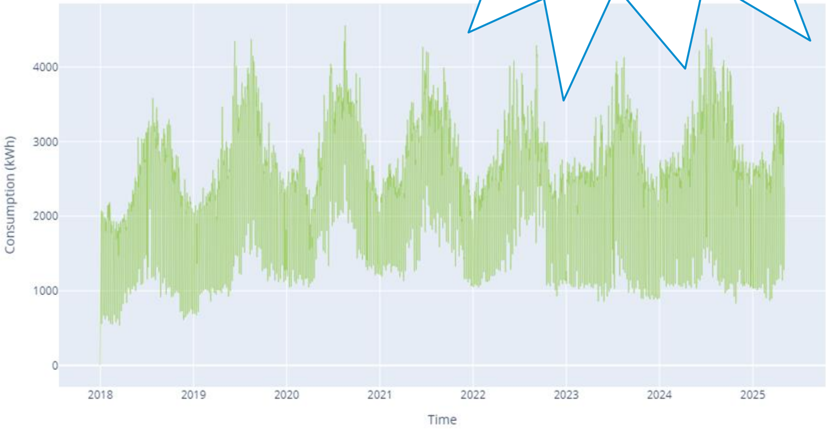
The foundation of good modeling starts with quality data.

Exploratory Analysis

Visualize Data

- Graphs and scatter plots reveal patterns and anomalies to explore



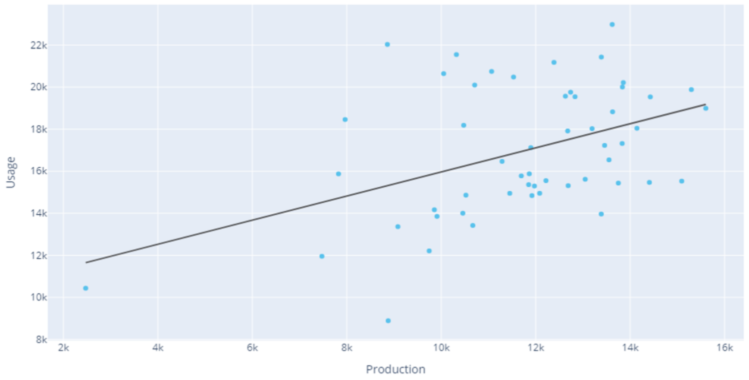


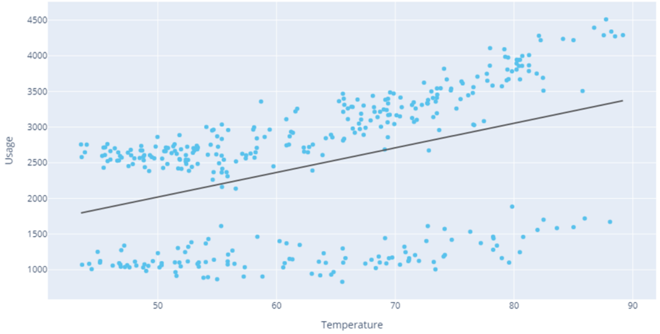
Different seasonal usage patterns starting in 2023

Exploratory Analysis

Compare Data

- Look for similar patterns in energy consumption and independent variables
- Plot against both time and other variables to look for correlations





Usage is positively correlated with both temperature and production

Starting Simple - Basic Regression with HDD/CDD

HDD (Heating Degree Days): Measure of heating needs. Calculated by summing the degrees below 18°C.

CDD (Cooling Degree Days): Measure of cooling needs. Calculated by summing the degrees above 18°C.

Your First Hourly Model

$$\text{Energy} = \beta_0 + \beta_1(\text{HDD}) + \beta_2(\text{CDD}) + \varepsilon$$

Key Steps:

- Calculate hourly HDD/CDD from temperature data
- Start with standard 18°C balance points
- Examine scatter plots for linearity assumptions
- Check residuals for patterns

What to Look For:

- "Passing" statistical fitness metrics
  - Industry standard recommendations (next slide) or,
  - As agreed on by all stakeholders
- Coefficients that make sense

Evaluating the Model: Statistical Fitness and Reasonability

Passing Statistical Fitness Metrics

- Adjusted R^2 (Coefficient of Determination) >0.7 : Proportion of variance explained
- CV(RMSE) < 25% : Coefficient of variation of root mean square error
- FSU < 50% : Fractional Savings Uncertainty
- NMBE < 0.005% : Normalized mean bias error

Understand the Model:

- Evaluating if the regression model and it's variables are reasonable
- Significance of variables
  - p-values: < 0.1 for statistical significance
  - t-statistics: Absolute value > 2 (rule of thumb)
- Coefficients: Should be reasonable

Informed by ASHRAE Guideline 14, IPMVP, LBNL

Optimizing Balance Points

Grid Search Approach

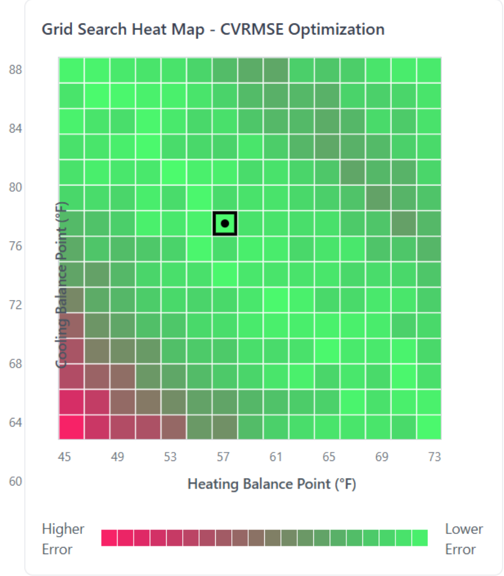
- Test balance point combinations (e.g., 15-21°C for heating, 15-24°C for cooling)
- Evaluate each combination using R^2 or CV(RMSE)
- Optional: Plot results as heat map or contour plot

Considerations:

- Balance points should reflect actual building operation
- Consider different balance points for different seasons
- Document assumptions and reasoning

Optimal Balance Points

Heating BP:	57°F
Cooling BP:	72°F
CV-RMSE:	15.0%



Non-Linear Weather Relationships

Beyond Linear HDD/CDD: When linear relationships don't capture operational realities

Temperature Bins:

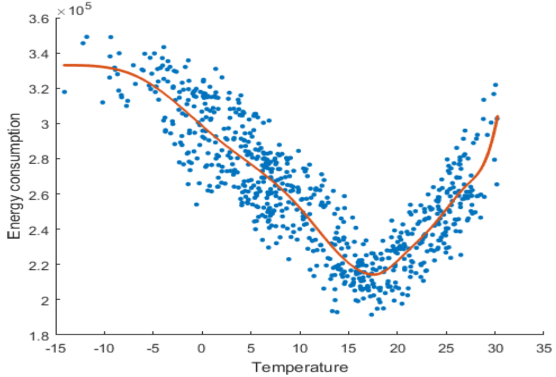
- Divide temperature into ranges (ie. 5°C bins)
- Each bin variable is represented by the hourly temperature variance between the actual and the floor (cooling) or ceiling (heating) of the bin
- Captures equipment staging and efficiency curves

Piecewise Linear Models:

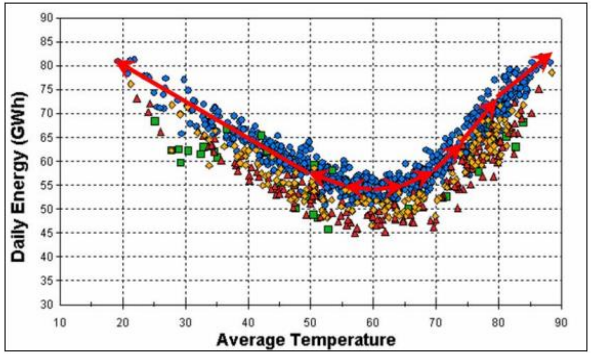
- Different slopes for different temperature ranges
- Reflects equipment operation characteristics

Polynomial Terms:

- Quadratic temperature terms for curved relationships
- Use sparingly - can lead to overfitting



Javier Hidalgo, Testing nonparametric shape restrictions



J. Stuart McMenamin, Defining Normal Weather for Energy and Peak Normalization

Time-of-Week and Time-of-Year Variables

Hour-of-Day Patterns

- 24 hourly indicator variables
- Captures operational schedules across a day

Hour-of-Week Patterns (TOWT Model)

- 168 hourly indicator variables
- Captures operational schedules throughout a week

Day-of-Week Effects

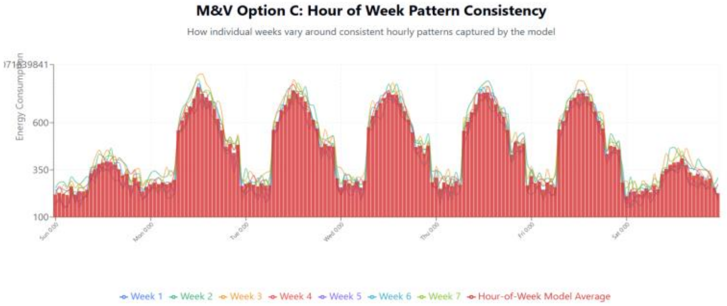
Monday, Tuesday, ..., Sunday indicator variables

- Captures occupancy patterns without occupancy data
- Accounts for different weekday/weekend operations

Monthly Indicators

Jan, Feb, ..., Dec variables

- Seasonal equipment efficiency changes
- Occupancy variations (schools, retail)
- Solar heat gain differences



The TOWT Model Framework

Time-of-Week and Temperature (TOWT)

$$Energy = \beta_0 + \Sigma(\beta_j \times Hour_j) + Weather\_Terms$$

Why TOWT Works:

Includes Hour-of-Week indicator variables (ie. 168 hours each week)

Accounts for different occupancy patterns without occupancy data

Alternatives: Simpler to implement and explain

- Daily TOWT: Day-of-Week indicator variables
    - Typically 6 and an intercept
- Weekday vs. Weekend variables
- Occupied vs. Unoccupied as a binary variable
    - If available

Advanced Variable Selection

Industrial Facilities - Production Variables

- Production schedules as indicator variables
- Production volume as continuous variable
- Equipment-specific run hours

Other Potential Variables:

- Humidity levels (facilities with process loads)
- Solar radiation (buildings with large glazing)
- Occupancy counts (if available)
- Equipment status indicators

Challenge: Correlation between variables - use variance inflation factors (VIF)

Model Selection Statistics in Practice

When to Add Variables:

- Significant improvement in Adjusted R^2 (> 0.01 increase)
- p-value < 0.1 for new variable
- Physical justification exists

When to Change Approach:

- CV(RMSE) > 25% with simple models
- Residual plots show clear patterns
- Autocorrelation in residuals

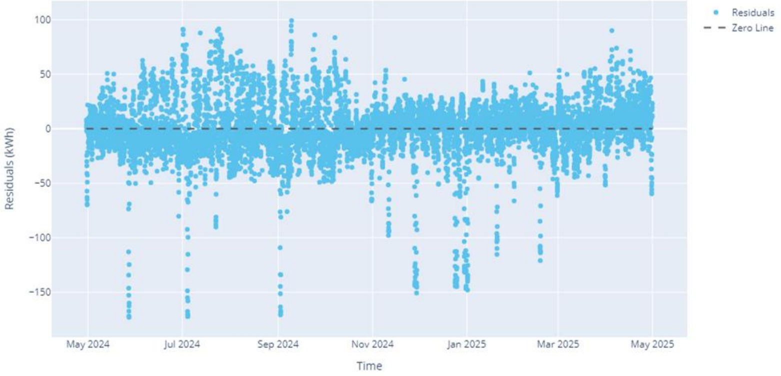
Red Flags:

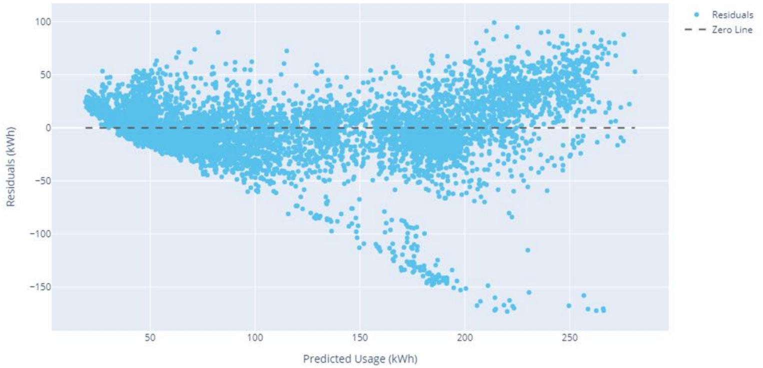
- Coefficients with wrong sign
- VIF > 5 (multicollinearity)
- Overfitting (too many variables for data available)

Residual Analysis & Model Diagnostics

What Residual Plots Tell You:

- **vs. Fitted Values**: Check for heteroscedasticity
- **vs. Temperature**: Missed weather relationships
- **vs. Time**: Seasonal patterns or equipment changes
- **Autocorrelation**: Time-series patterns





Diagnostic Actions:

- Transform variables if non-linear patterns
- Add indicator variables for anomalous periods
- Consider equipment change dates
- Check for data quality issues

Uncertainty and Savings Significance

Prediction Intervals

- 68% confidence intervals for individual predictions
- Wider intervals for extrapolation beyond baseline range

Savings Significance Testing

- t-test for savings estimates
- Consider measurement period length
- Account for model uncertainty in savings calculations

Fractional Savings Uncertainty:

$$FSU = \sqrt{(Model\_Uncertainty^2 + Metering\_Uncertainty^2)}$$

2019 Uncertainty Assessment for IPMVP Application Guide

Common Pitfalls & Best Practices

Best Practices:

Plot everything - data and residuals

Document all modeling decisions

Add new variables, only when it makes sense

Review model fit across different periods

Avoid These Mistakes:

Using airport weather for urban buildings

Ignoring daylight saving time transitions

Overfitting models

Data used in baseline model unavailable in the reporting period

Implementation Workflow Summary

Step-by-Step Process:

1. Data Quality: Clean and validate consumption and weather data
2. Exploratory Analysis: Scatter plots, correlation matrices
3. Base Model: Simple HDD/CDD regression
4. Balance Point Optimization: Grid search approach
5. Variable Addition: Time-of-week, then other variables
6. Model Validation: Residual analysis and diagnostics
7. Uncertainty Analysis: Prediction intervals and significance testing

Decision Points: Use statistics alongside knowledge of the change and facility, to guide each step

Key Takeaways

Hourly Modeling Advantages:

- Captures operational patterns missed by monthly models
- Better savings accuracy for controls and scheduling projects
- Enables detection of persistence and load shifting

Critical Success Factors:

- Quality data is everything
- Let statistics guide your modeling decisions
- Physical understanding trump's statistical fit
- Document your approach and assumptions

Remember: The goal is an accurate, defensible savings estimate - not the most complex model

Questions & Discussion

Stay connected with tools and resources

- Virtual one-on-one coaching: post-webinar support intake form for tailored support for organizations to manage energy resources effectively
- Monthly bulletin: sign up to receive monthly training updates on all Save on Energy training and support new tools and resources
- Live training calendar: visit this page to easily register for upcoming events and workshops
- Training and support webpage: visit this page to access all training and support materials

Post-Webinar Support

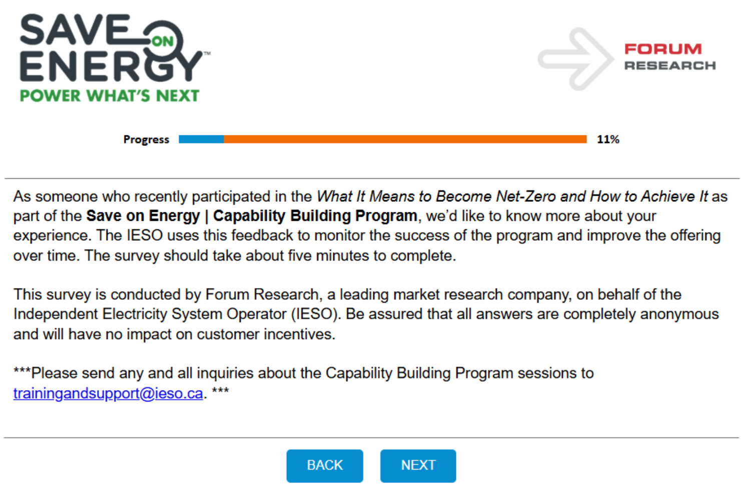
One-on-one coaching: tailored support for managing energy resources effectively

Post-webinar support intake form

Coaching sessions conducted virtually: phone, video calls, and email

Designed for organizations, new or old, seeking guidance.

Upcoming survey: We want your feedback!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FORUM RESEARCH

Progress 11%

As someone who recently participated in the *What It Means to Become Net-Zero and How to Achieve It* as part of the **Save on Energy | Capability Building Program**, we'd like to know more about your experience. The IESO uses this feedback to monitor the success of the program and improve the offering over time. The survey should take about five minutes to complete.

This survey is conducted by Forum Research, a leading market research company, on behalf of the Independent Electricity System Operator (IESO). Be assured that all answers are completely anonymous and will have no impact on customer incentives.

***Please send any and all inquiries about the Capability Building Program sessions to trainingandsupport@ieso.ca. ***

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- Check your email! A survey is coming your way soon.
- Why? Help us improve our training programs.
- Who? Conducted by Forum Research on behalf of the IESO.
- Time? Takes only 5 minutes to complete.
- Confidentiality: Your responses are anonymous and won't impact participation or incentives.

The survey will be sent from:
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Thank you!

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