M&V 2.0 Some Notes

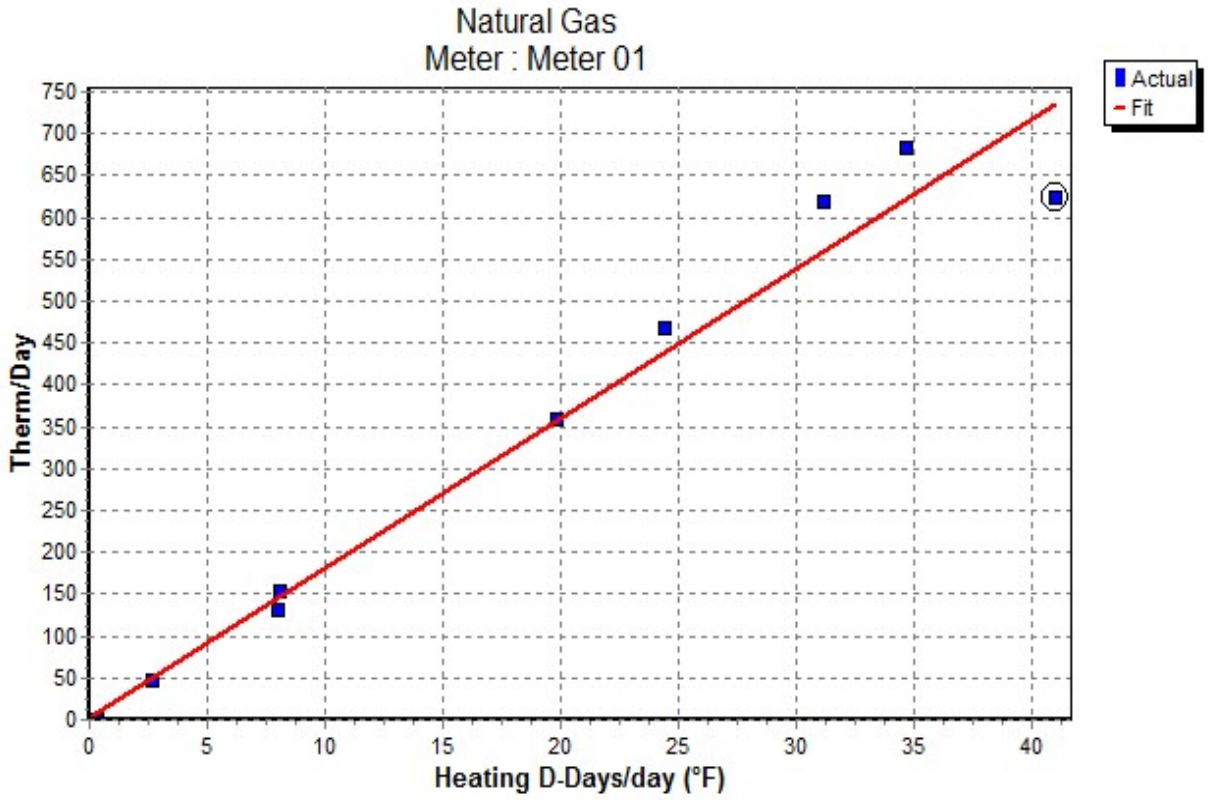
John Avina CEM, CEA, CMVP, CxA
President
Abraxas Energy Consulting

NAESCO National Association of Energy Service Companies

Topics

- Non-routine adjustments or baseline modifications
- A look at interval vs. daily vs. weekly vs. monthly data
- Determining what Data Interval is Best
- Uncertainty and Statistics
- Advice for ESCOs

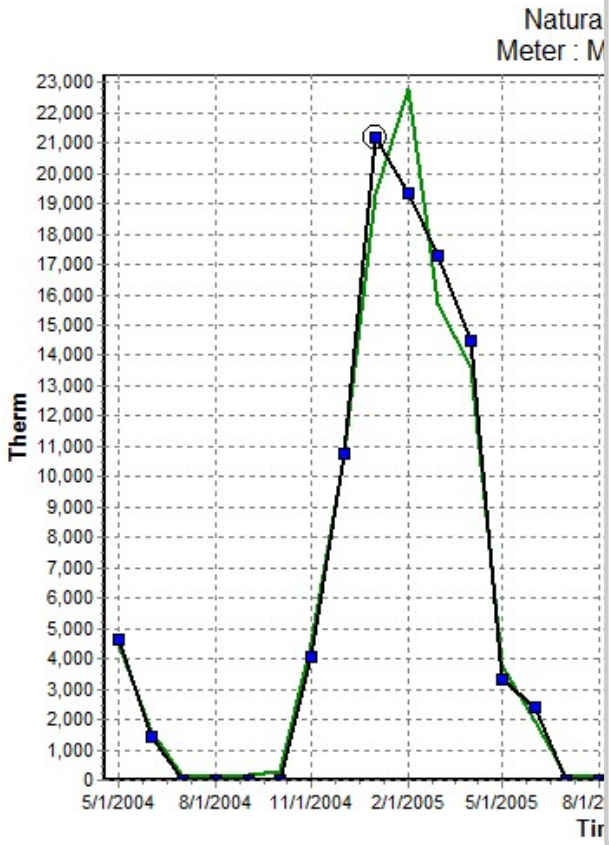
Retail in Minnesota



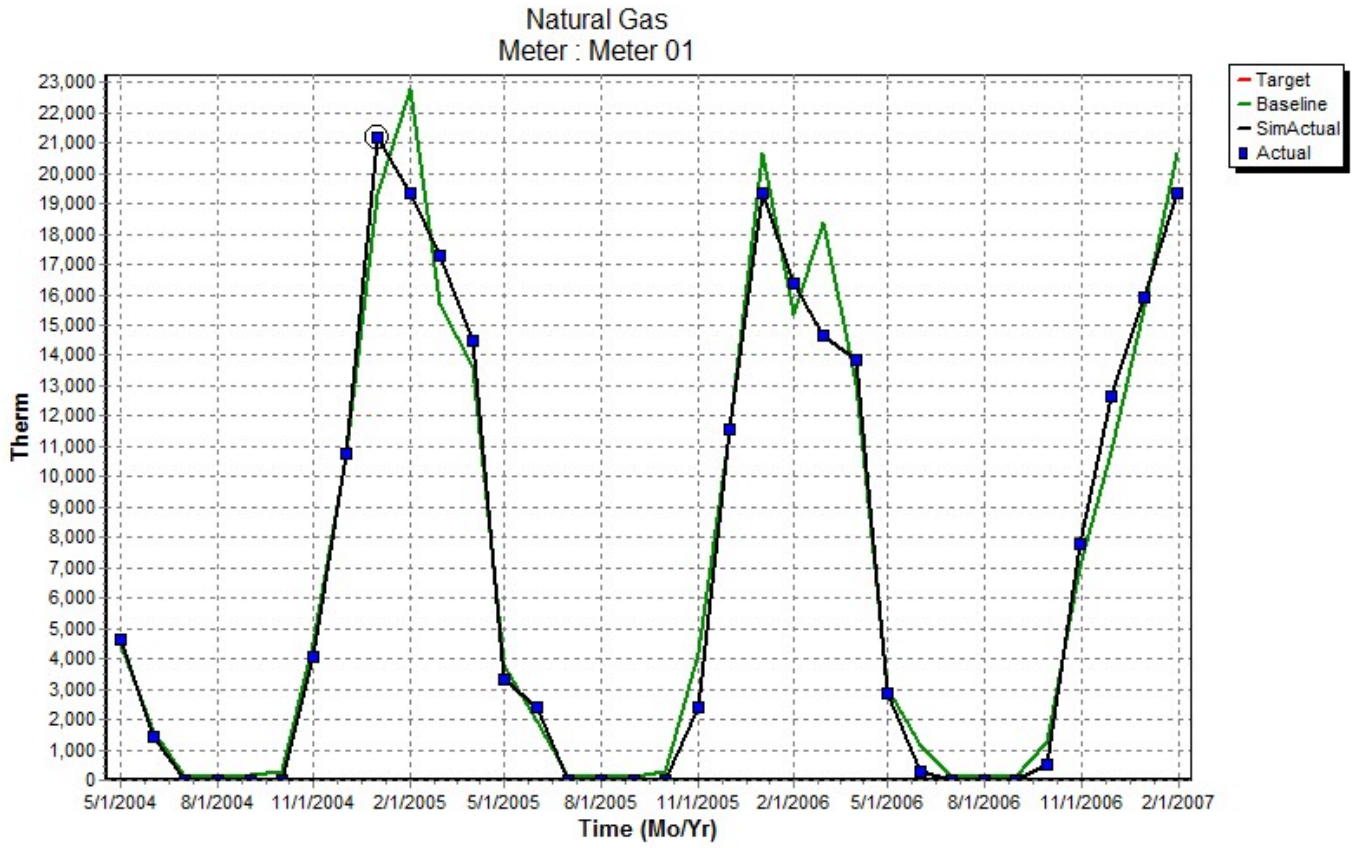
Therm= (3.6 * #Days) + (17.84 * HDD)

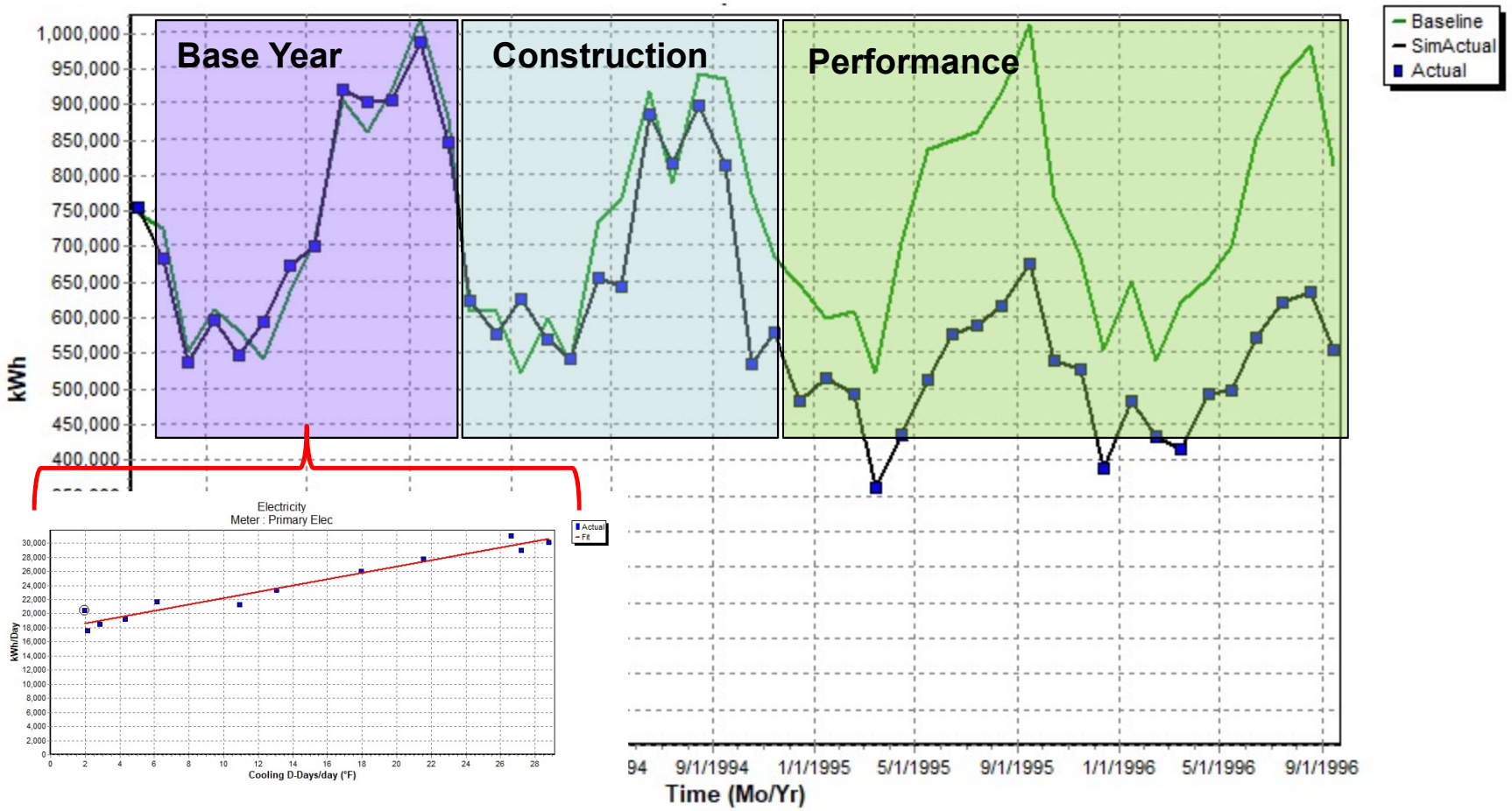
R2 = 0.975 ♦ CVRMSE = 17.06

Retail in Minnesota



Retail in Minnesota

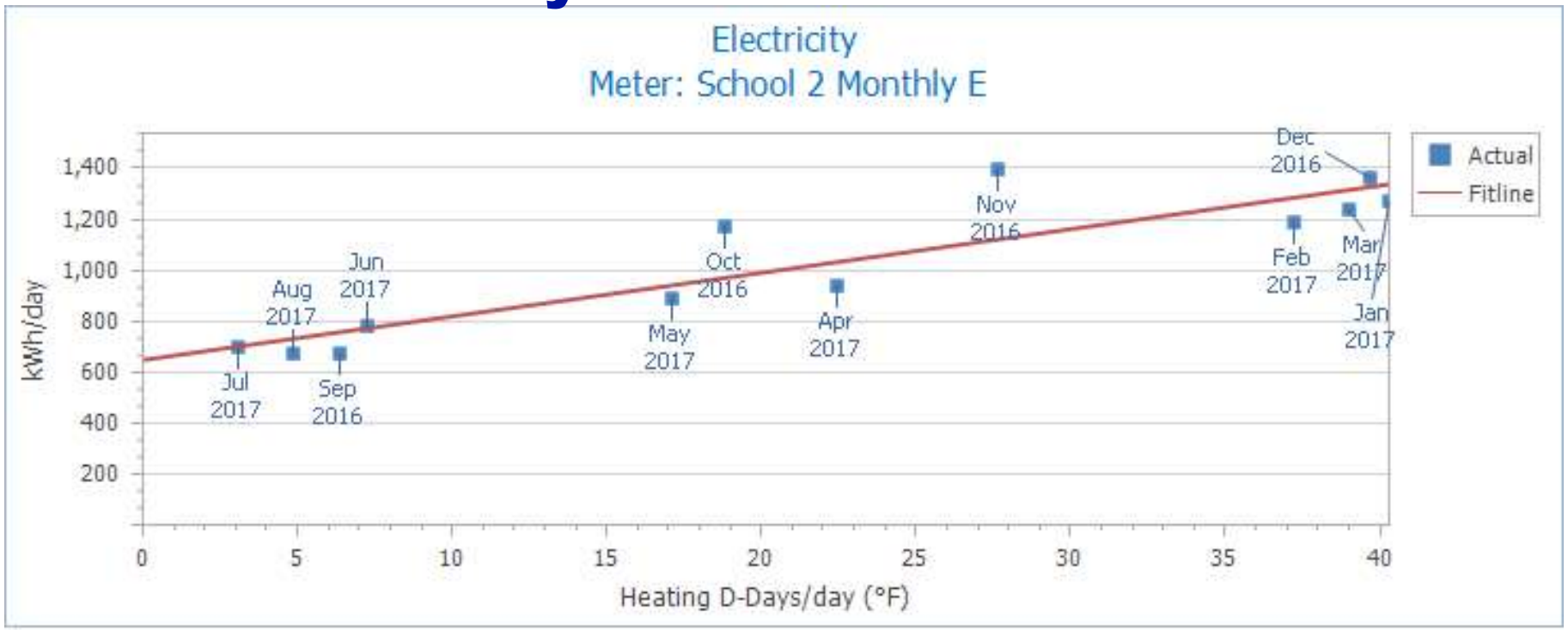




kWh= (17757.941 * #Days) + (445.787 * CDD)

R2 = 0.953 ♦ CVRMSE = 4.30

School 2 Monthly

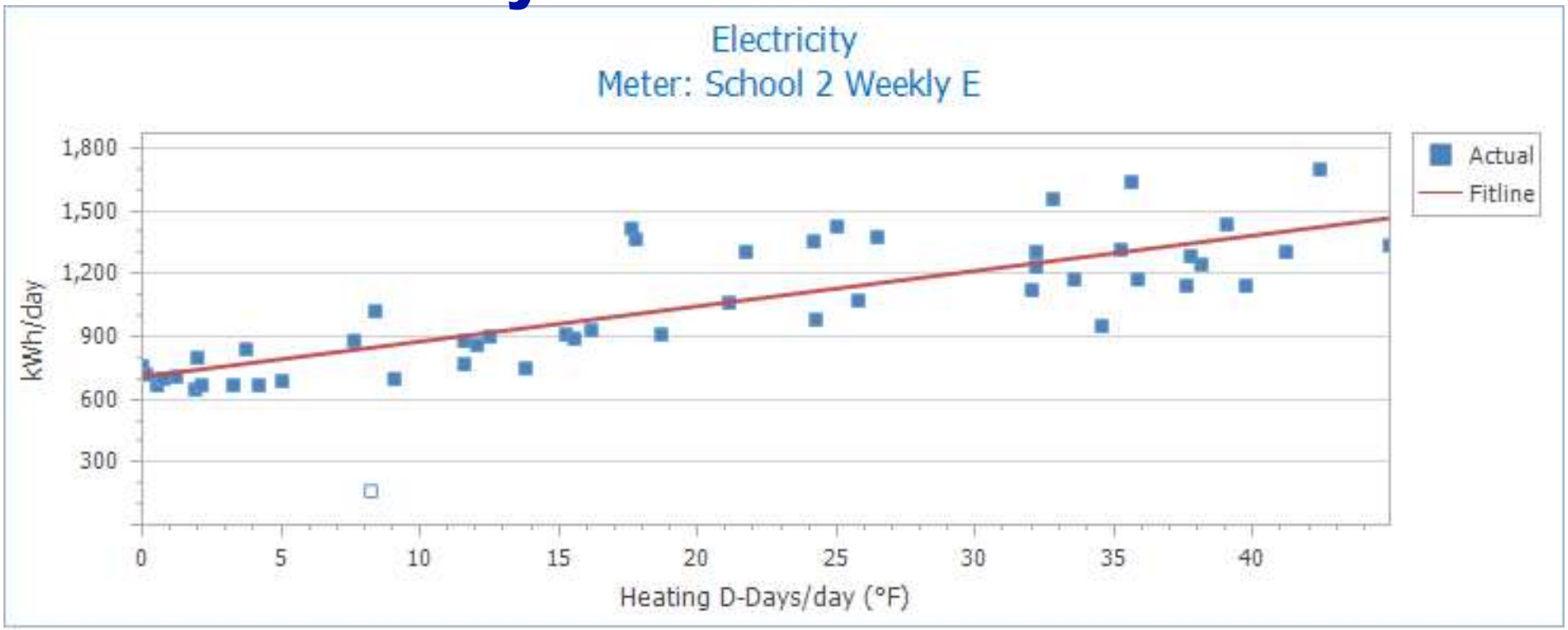


kWh = 647.602×#Days + 17.105×HDD

R2 = 0.813

CVRMSE = 11.64%

School 2 Weekly

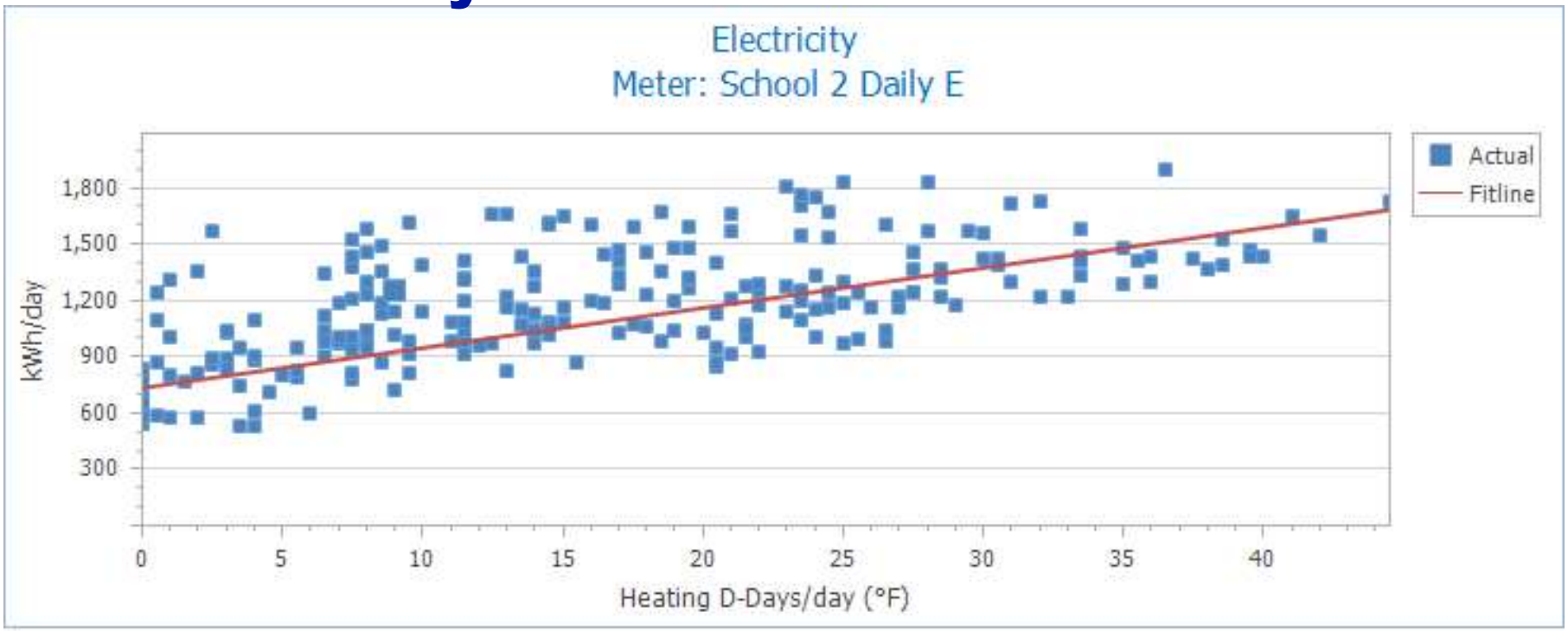


kWh = 702.287×#Days + 17.048×HDD

R2 = 0.688

CVRMSE = 15.78%

School 2 Daily



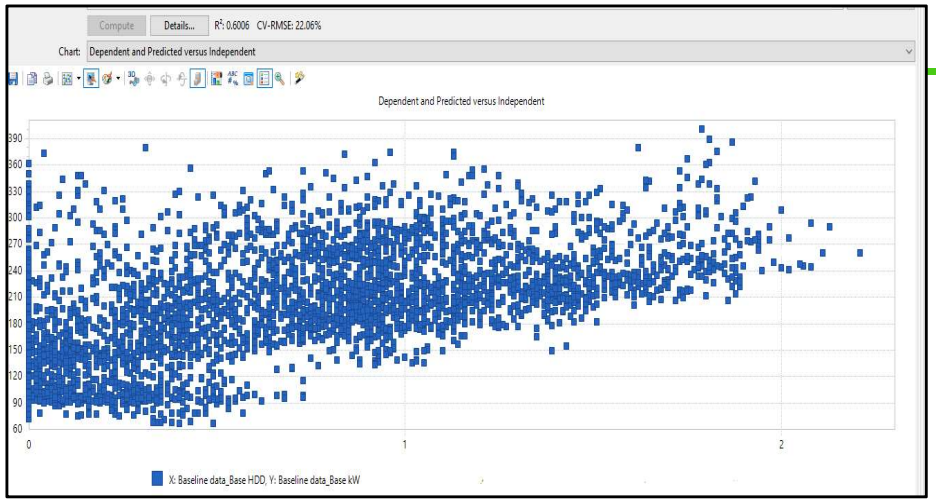
kWh = 732.127×#Days + 21.242×HDD + 113.890×Weekdays (without Holidays)

R2 = 0.581

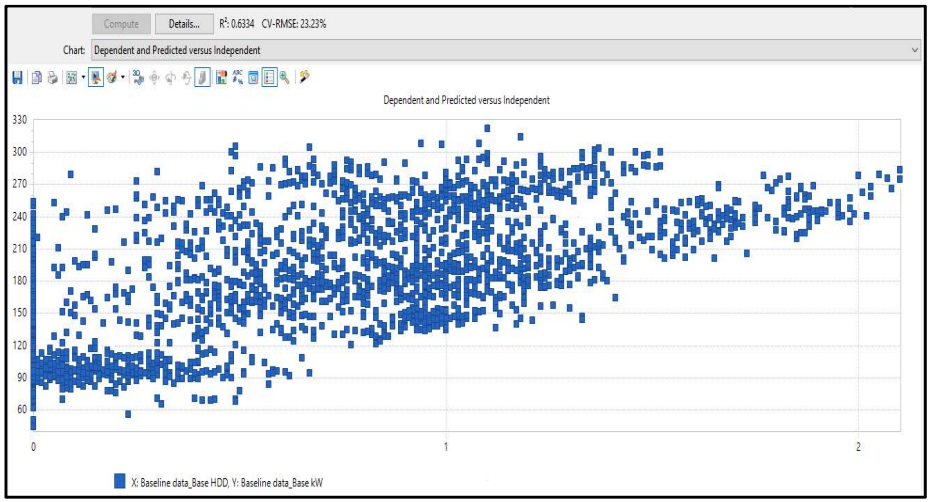
CVRMSE = 20.64%

School 2 Hourly

Baseline Weekday kW vs. Hourly

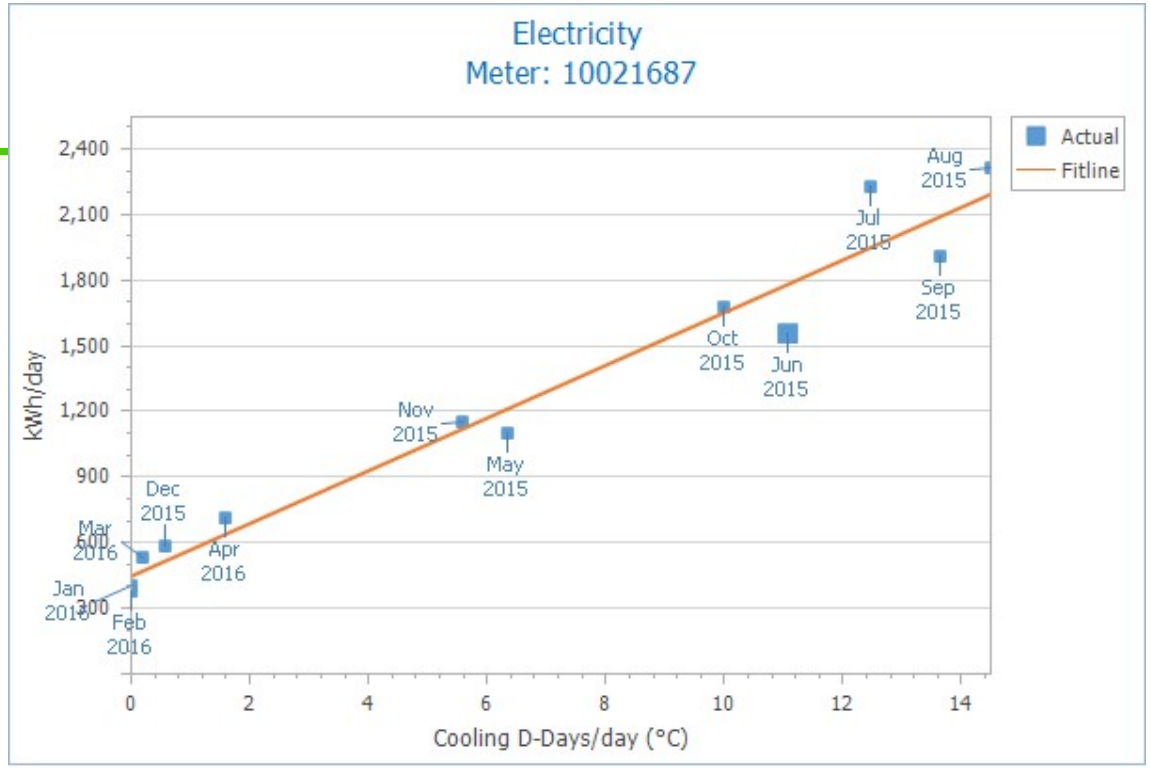


Baseline Weekend Holiday kW vs. Hourly HDD



Statistics 101

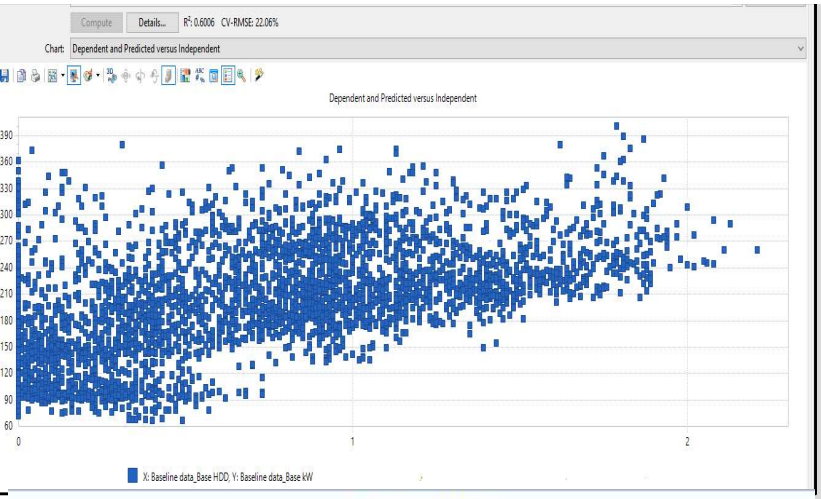
- R2 is the “goodness of fit”
  - Or, to what extent does the independent variable (CDD) predict the dependent variable (kWh)
  - The variation of the dependent variable determined by the independent variable
  - The IPMVP suggests an R2 > 0.75



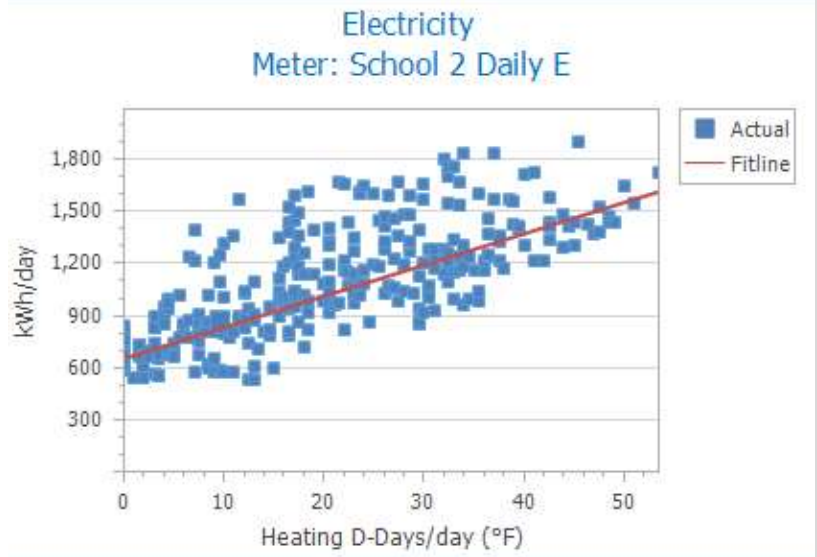
kWh = 451.061×#Days + 120.242×CDD

R2 = 0.962

CVRMSE = 11.19%

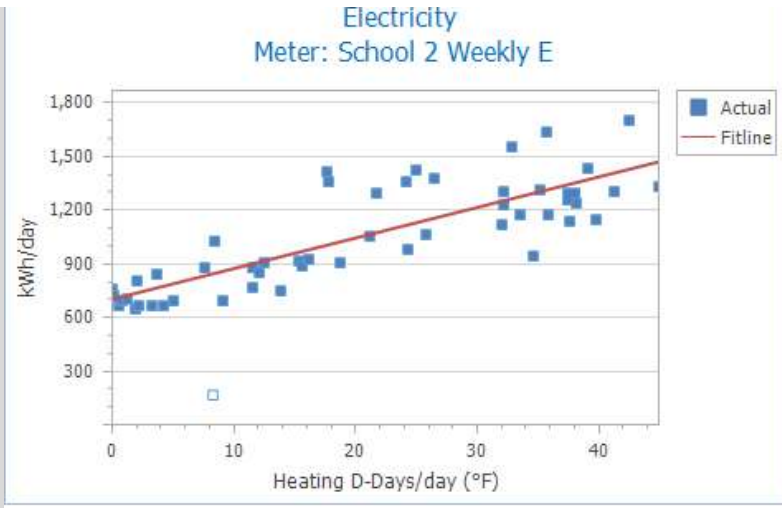


- R2 is the "goodness of fit"
- Finer detailed data drops the R2
- Larger intervals smooth the randomness of human activities

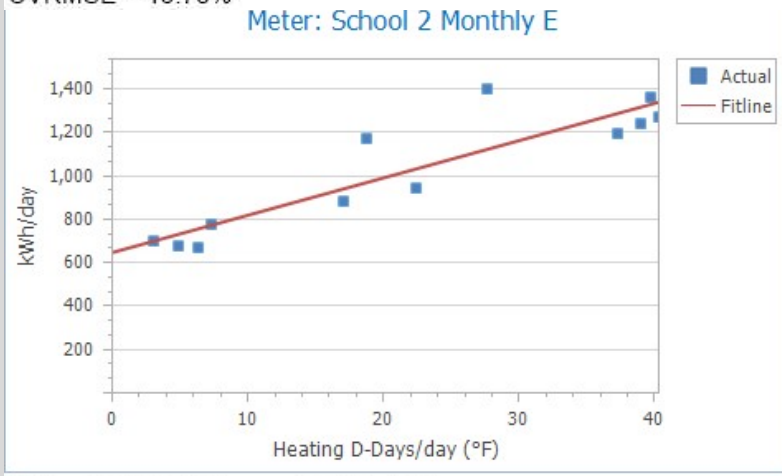


kWh=648.425×#Days + 17.937×HDD + 121.269×Weekdays (
R2 = 0.626
CVRMSE = 19.50%

School 2	R2
Monthly	0.81
Weekly	0.69
Daily	0.63
Interval Weekday	0.60
Interval Weekend	0.63



kWh = 702.287×#Days + 17.048×HDD
R2 = 0.688
CVRMSE = 15.78%

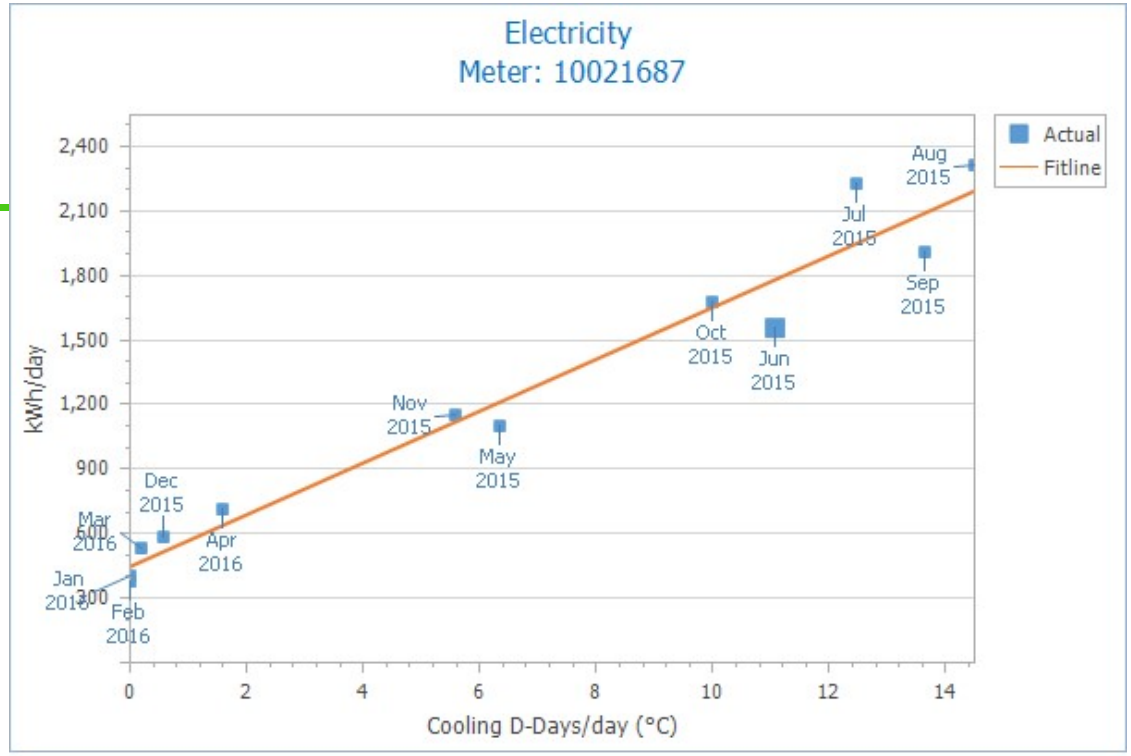


kWh = 647.602×#Days + 17.105×HDD
R2 = 0.813
CVRMSE = 11.64%

Statistics 101

- CV(RMSE) is a measure of scatter
  - Or, what percent from the fit line is the average bill
  - The variation in the dependent variable NOT determined by the independent variable
  - ASHRAE 14 suggests

  CV(RMSE) < 25 for energy



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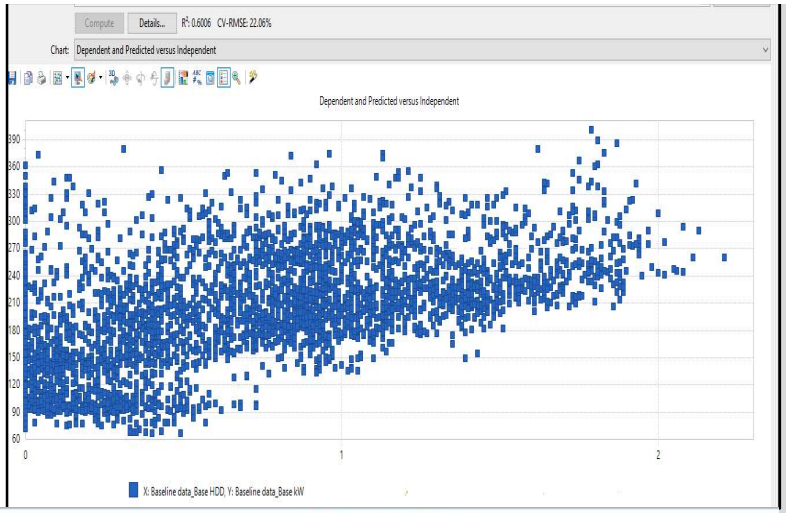
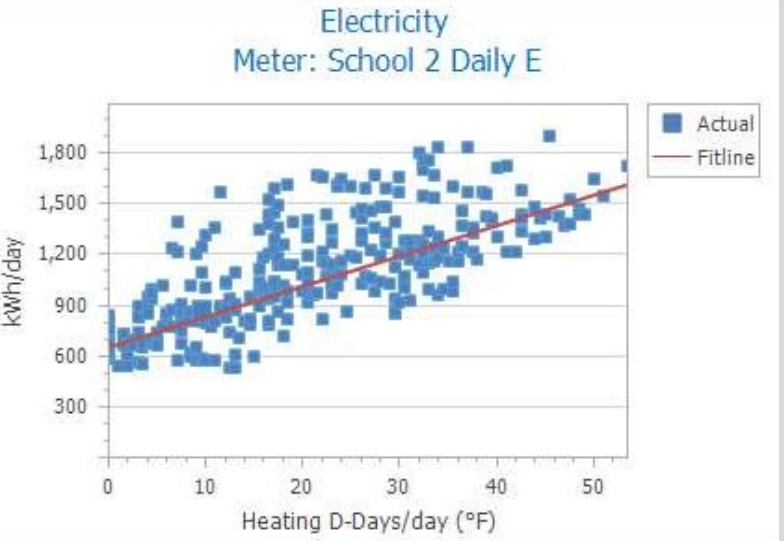


- CVRMSE is a measure of scatter
- Finer detailed data increases scatter
- Larger intervals smooth the randomness of human activities



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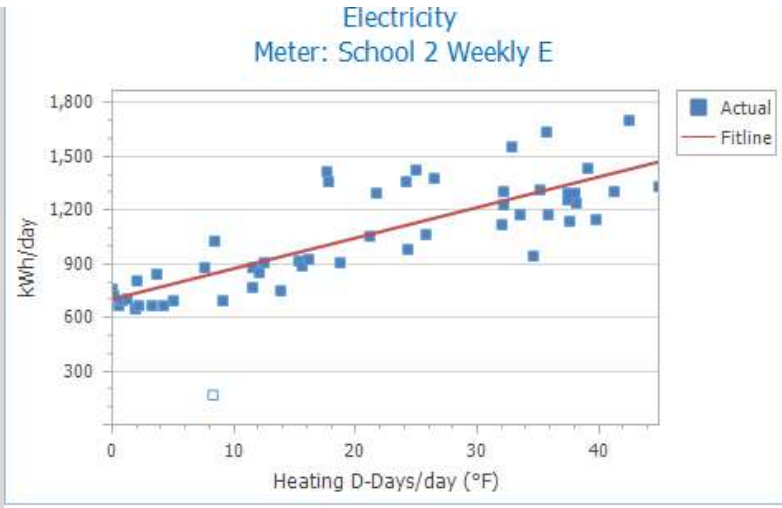

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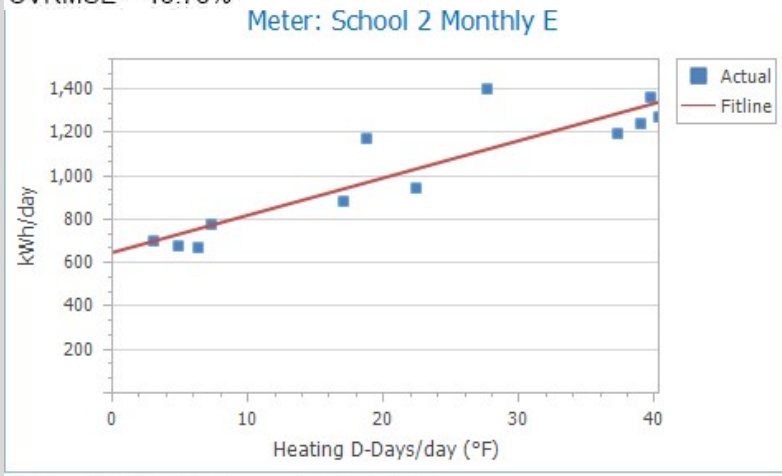

kWh = 647.602×#Days + 17.105×HDD

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CVRMSE = 11.64%

School 2

	R2	CVRMSE
Monthly	0.81	12%
Weekly	0.69	16%
Daily	0.63	20%
Interval Weekday	0.60	20%
Interval Weekend	0.63	23%

Uncertainty

- So how do you determine which model is best?
- What is the right answer?
  - Best R2 ?
  - Lowest CVRMSE ?
  - Fractional Savings Uncertainty ?

Uncertainty Models

$$\frac{\Delta E_{save,m}}{E_{save,m}} = t \times \frac{1.26 \cdot CV\left[\frac{n}{n'}\left(1+\frac{2}{n'}\right)\frac{1}{m}\right]^{1/2}}{F}$$

$$\frac{\Delta E_{save,m}}{E_{save,m}} = t \cdot \frac{(aM^2+bM+c) \cdot CV\left[\frac{n}{n'}\left(1+\frac{2}{n'}\right)\frac{1}{m}\right]^{1/2}}{F}$$

$$se(\hat{y}) = \frac{s \times m_{post}}{\sqrt{n_{base}}} \times \left(1 + \frac{\left(\bar{x}_{base} - \bar{x}_{post}\right)^2}{\mathrm{Var}(x_{base})}\right)^{1/2}$$

- ASHRAE 14
- Improved ASHRAE 14 (Sun and Baltazar)
- Rushton's Exact Formula for OLS Regression

School 1

	R2	CVRMSE	Savings %	Uncertainty
Monthly	0.98	6%	45%	17%
Weekly	0.94	11%	44%	15%
Daily	0.85	19%	42%	8%
Interval Weekday	0.71	26%	39%	
Interval Weekend	0.80	26%		

School 2

	R2	CVRMSE	Savings %	Uncertainty
Monthly	0.81	12%	78%	19%
Weekly	0.69	16%	77%	12%
Daily	0.63	20%	75%	5%
Interval Weekday	0.60	20%	81%	
Interval Weekend	0.63	23%		

So which fit is best?

NOT Calculating Uncertainty with Interval Data

- It takes Ambient heat hours to penetrate through the building envelope.
- As a result, cooling at 5 pm is affected by weather at 4 pm, 3 pm, 2 pm, or even 1 pm.
- So kWh at 5 pm may NOT be independent of kWh at 4 pm. They may be related.
- This is called Auto-correlation or Serial correlation.
- For linear regressions, statisticians assume ALL dependent values are independent of each other. For interval data, that may not be true.
- 5 pm's kWh may be correlated to 4 pm's kWh or 3 pm's etc.
- Nobody really knows (yet) how to calculate uncertainty for interval models with auto-correlation.
- So, how do we know if these interval data models are better? We don't.

UNCERTAINTY APPROACHES AND ANALYSES FOR REGRESSION MODELS AND ECAM

Prepared for: BONNEVILLE POWER ADMINISTRATION
Carrie Cobb

Prepared by: SBW CONSULTING, INC.
2820 Northup Way, Suite 230
Bellevue, WA 98004

August 11, 2017

Regression for M&V: Reference Guide

Version 1.1

May 2012

Prepared for

Bonneville Power Administration

A Comparison of Approaches to Estimating the Time-Aggregated Uncertainty of Savings Estimated from Meter Data

Bill Koran, SBW Consulting, West Linn, OR
Erik Boyer, Bonneville Power Administration, Spokane, WA
M. Sami Khawaja, Ph.D., The Cadmus Group, Portland, OR
Josh Rushton, Ph.D., Rushton Analytics, Portland, OR
Jim Stewart, Ph.D., The Cadmus Group, Portland, OR

ABSTRACT

An increasing number of utility programs use savings estimates based on changes at the utility meter, using regressions or other data-driven approaches. The program types include pay-for performance, strategic energy management, some of the behavior-based programs, and programs

NAESCO National Association of Energy Service Companies

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INTERNATIONAL PERFORMANCE MEASUREMENT AND VERIFICATION PROTOCOL®

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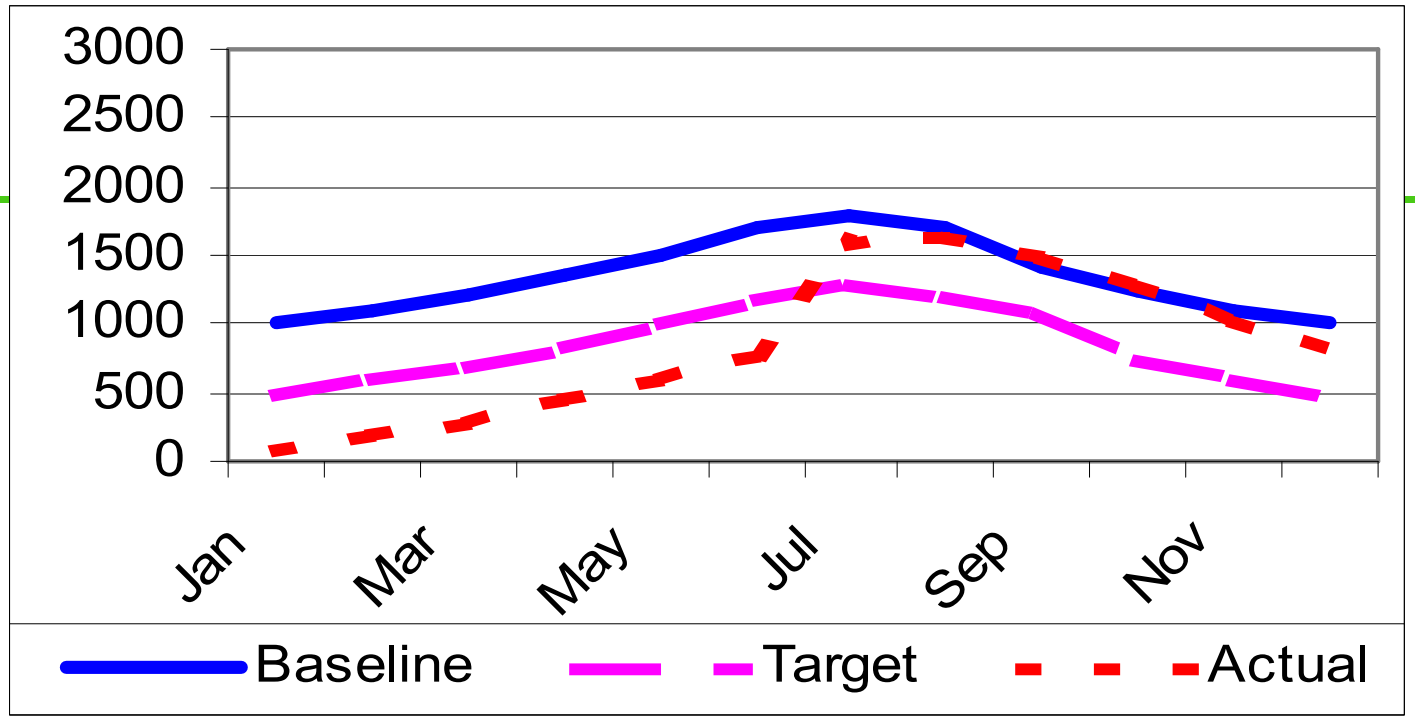
Brief History of M&V in PC

Risk



A great performance contract until the customer increase operating hours and adds some new equipment and the bills increased. Savings disappear.

Interval Data may be better (certainly faster) for identifying changes in usage patterns.

Thanks

John Avina CEM, CMVP, CxA

President

Abraxas Energy Consulting

San Luis Obispo, CA Pittsburgh, PA

Lewisville, CO Charleston, SC

P: 805.547.2050

johnavina@abraxasenergy.com

www.abraxasenergy.com