Measuring Savings From Behavioral Programs

ACEEE – Energy Efficiency as a Resource

Robert Luneski, Technical Manager Industrial & Agricultural Sector

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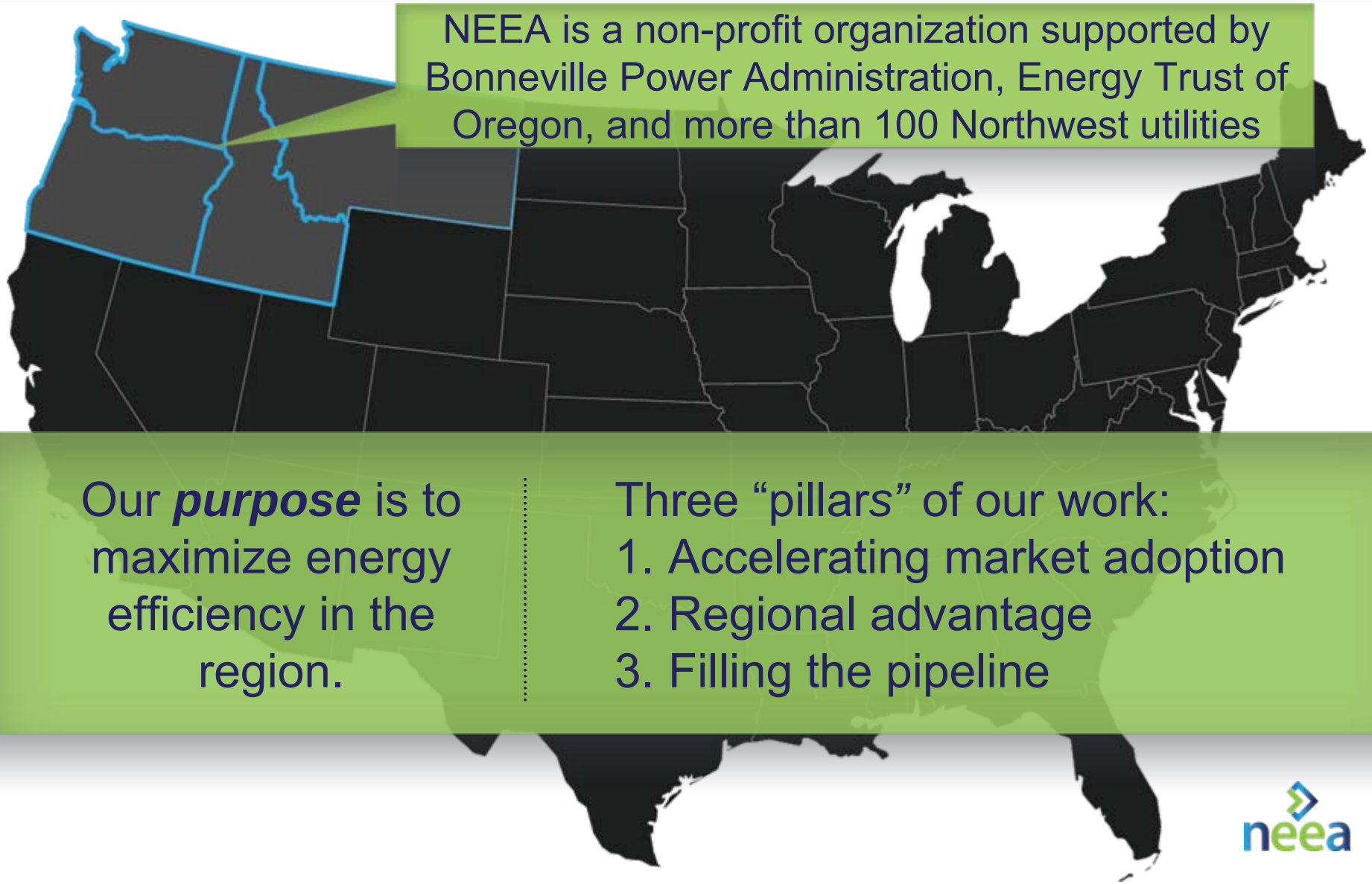
Northwest Energy Efficiency Alliance (NEEA)



NEEA is a non-profit organization supported by Bonneville Power Administration, Energy Trust of Oregon, and more than 100 Northwest utilities

Our ***purpose*** is to maximize energy efficiency in the region.

Three "pillars" of our work:

1. Accelerating market adoption
2. Regional advantage
3. Filling the pipeline

Measuring Behavioral Energy Savings

Savings from behavioral or business practice change programs occur from:

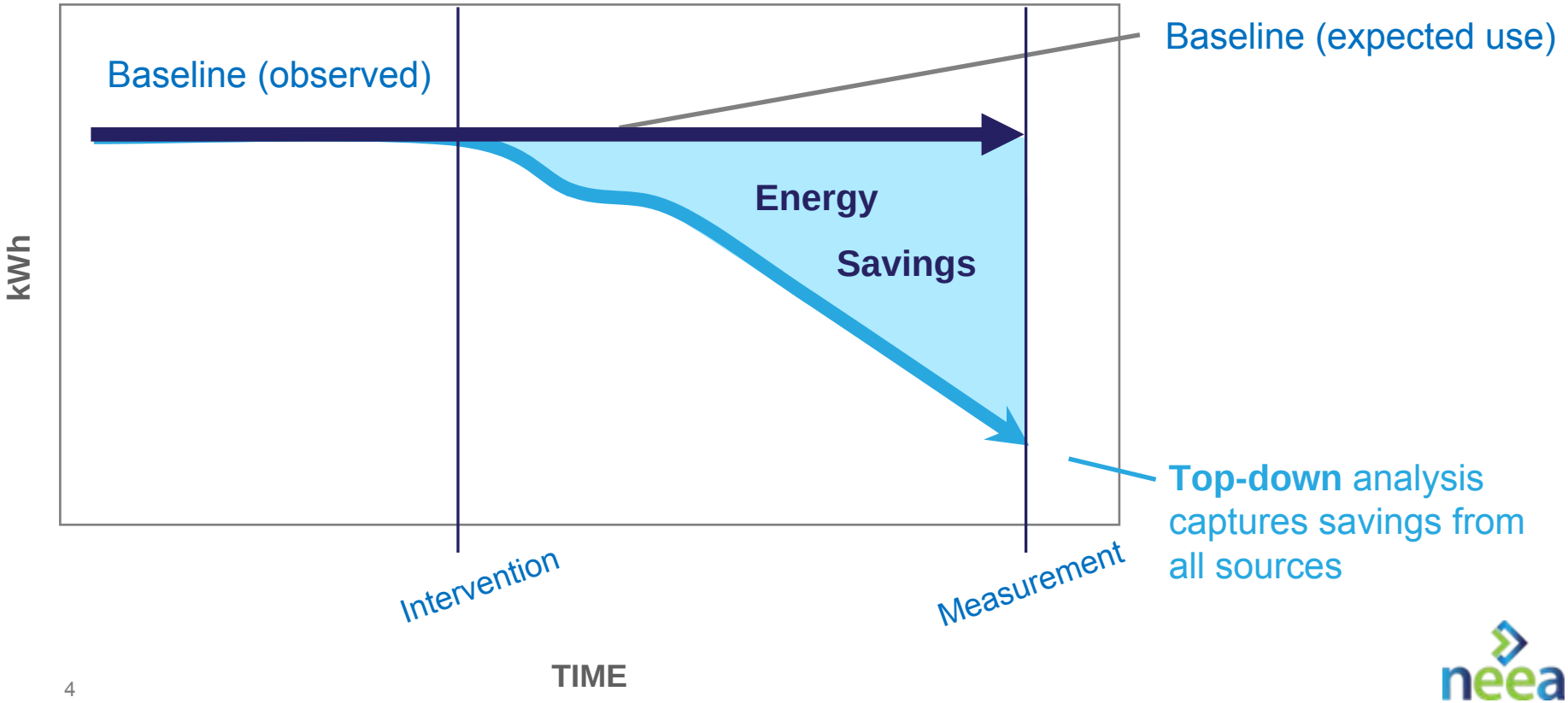
- increased awareness
- modified work procedures
- executive sponsorship
- goal setting
- management review
- active energy team
- acceleration of projects

Challenge:

Measure (in kWh) an impact that you can not see or observe?

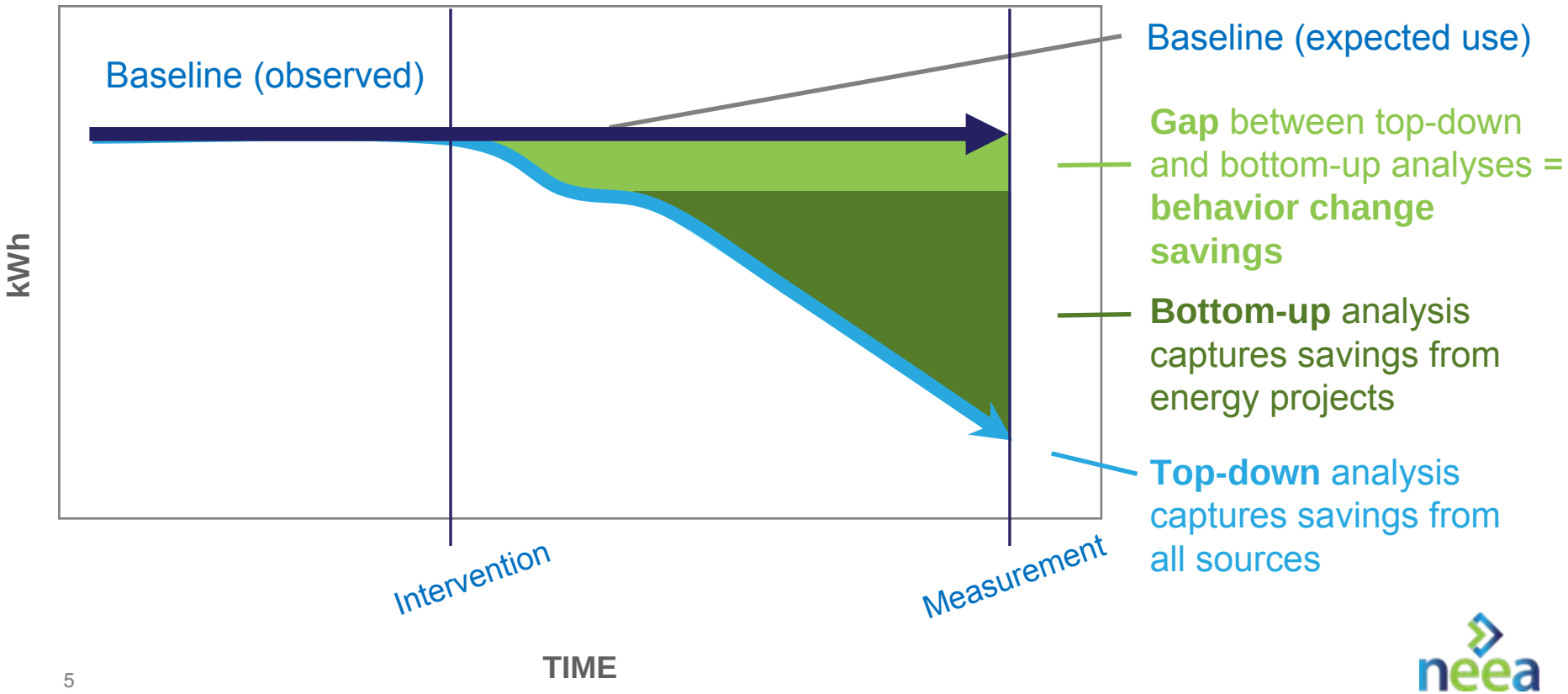
Measuring Behavioral Energy Savings

- Measure energy savings from all sources.
  - Model total energy consumption using generalized linear regression to account for primary energy drivers. "Top-down analysis"
  - Estimate energy savings using an intervention parameter



Measuring Behavioral Energy Savings

- Measure energy savings from all sources.
- Subtract energy savings from projects. “Bottom-up analysis”
- The balance is energy savings from behavior change.

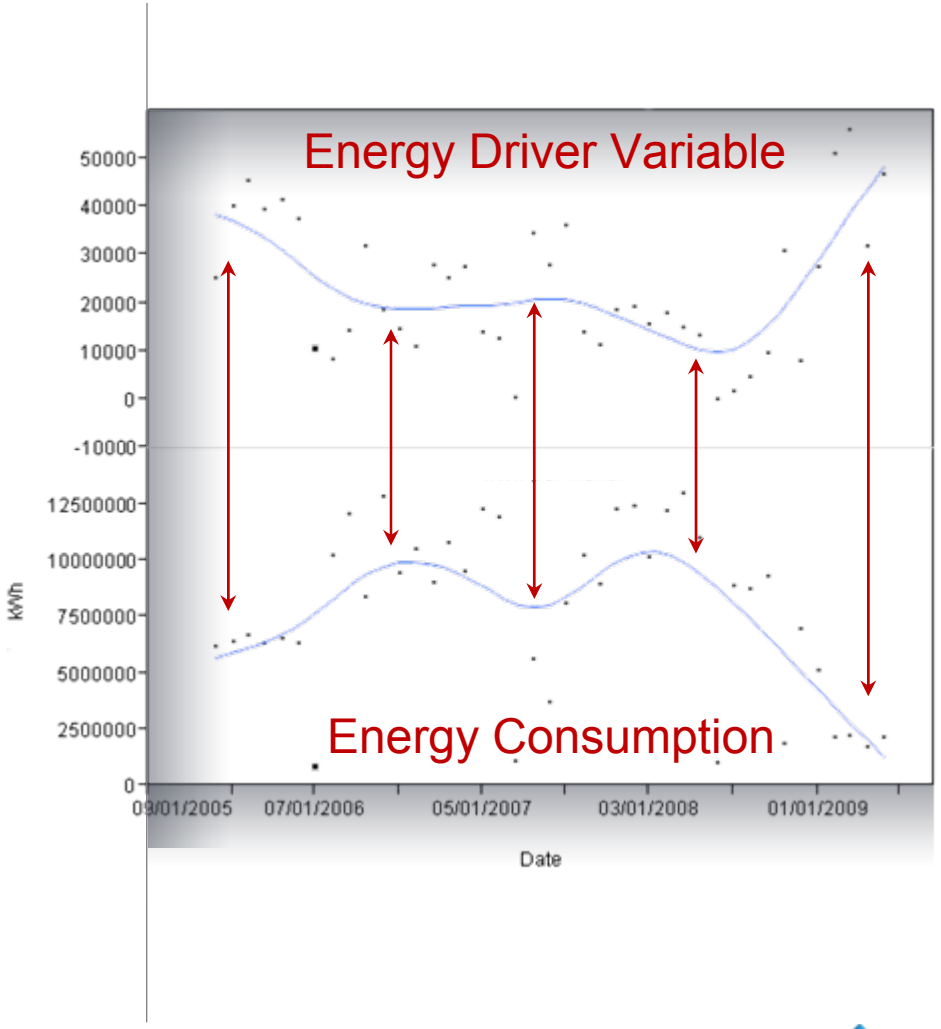


Modeling Industrial Energy Consumption

An ***energy driver*** is any variable whose change in value results in a change in energy consumption.

Common energy drivers are:

- Production output
- Weather
- Raw material quality
- Maintenance events
- Process yield
- …

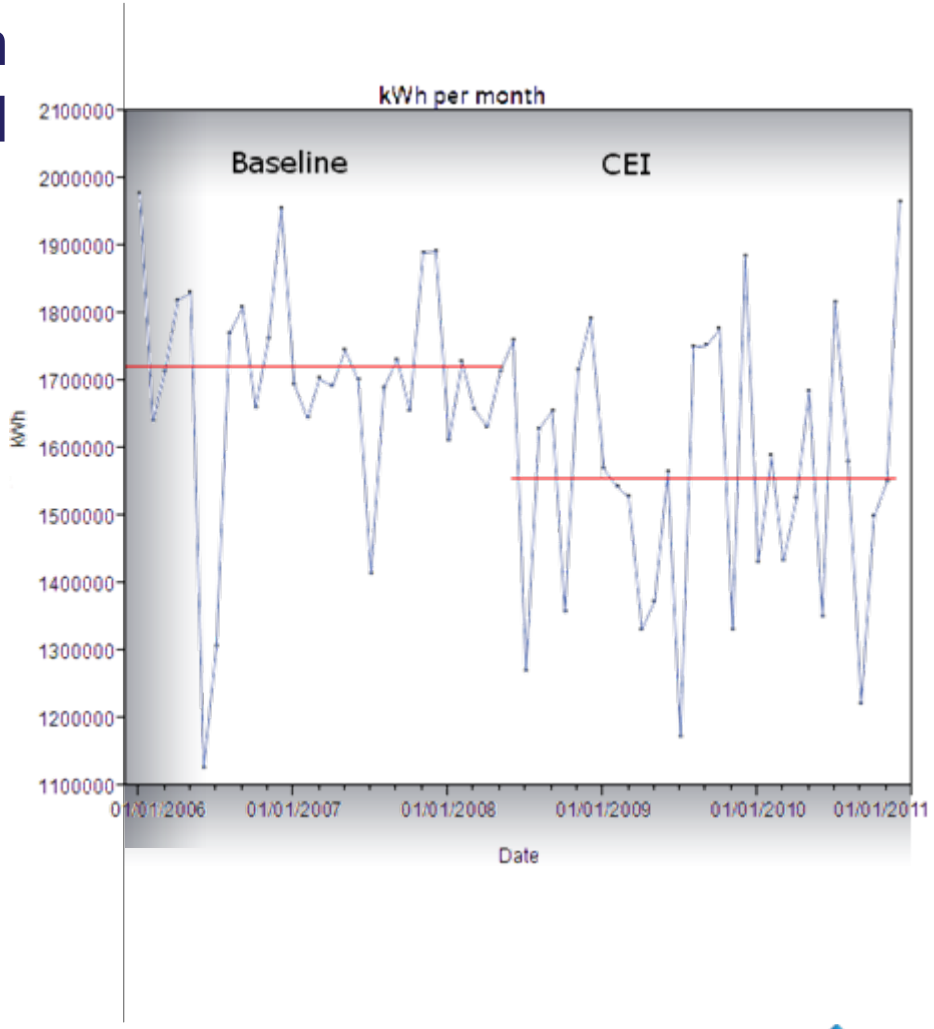


Modeling Industrial Energy Consumption

Industrial energy consumption patterns are widely varied and typically industry dependent.

The impact of an energy program can be observed as:

- Step Change



Modeling Industrial Energy Consumption

Industrial energy consumption patterns are widely varied and typically industry dependent.

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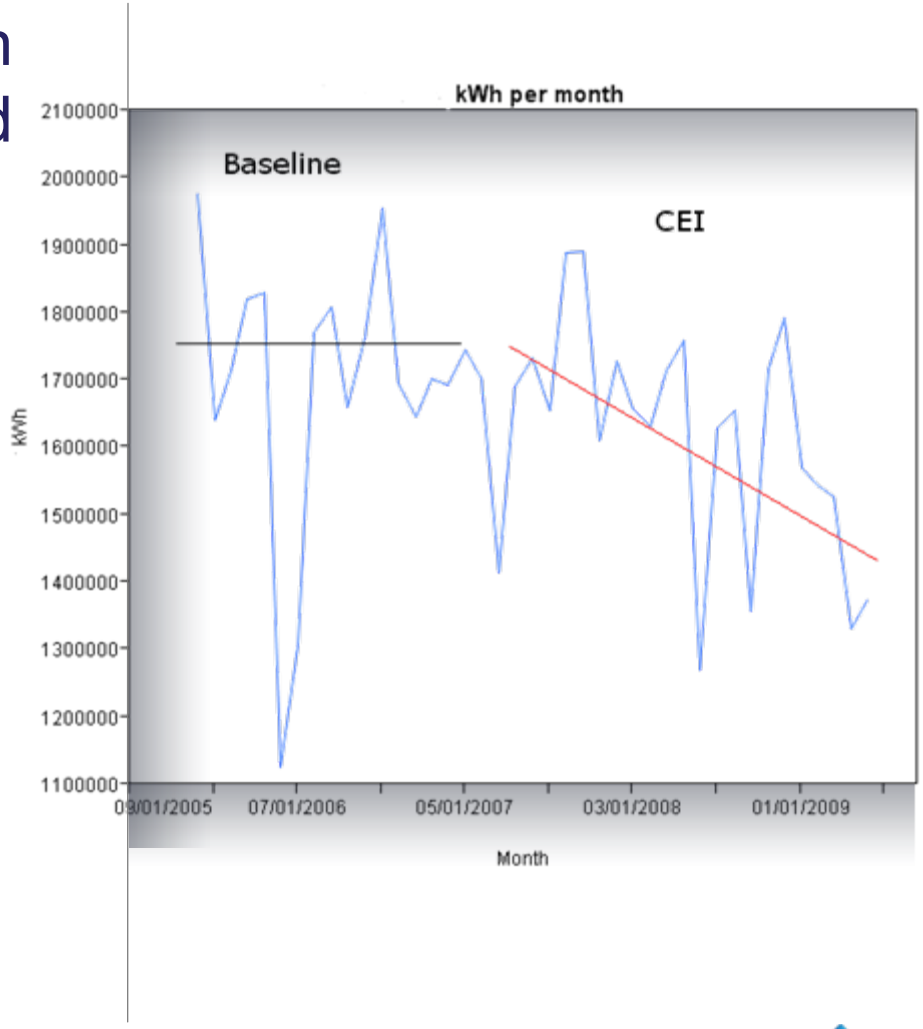
- Step Change
- Change in trend

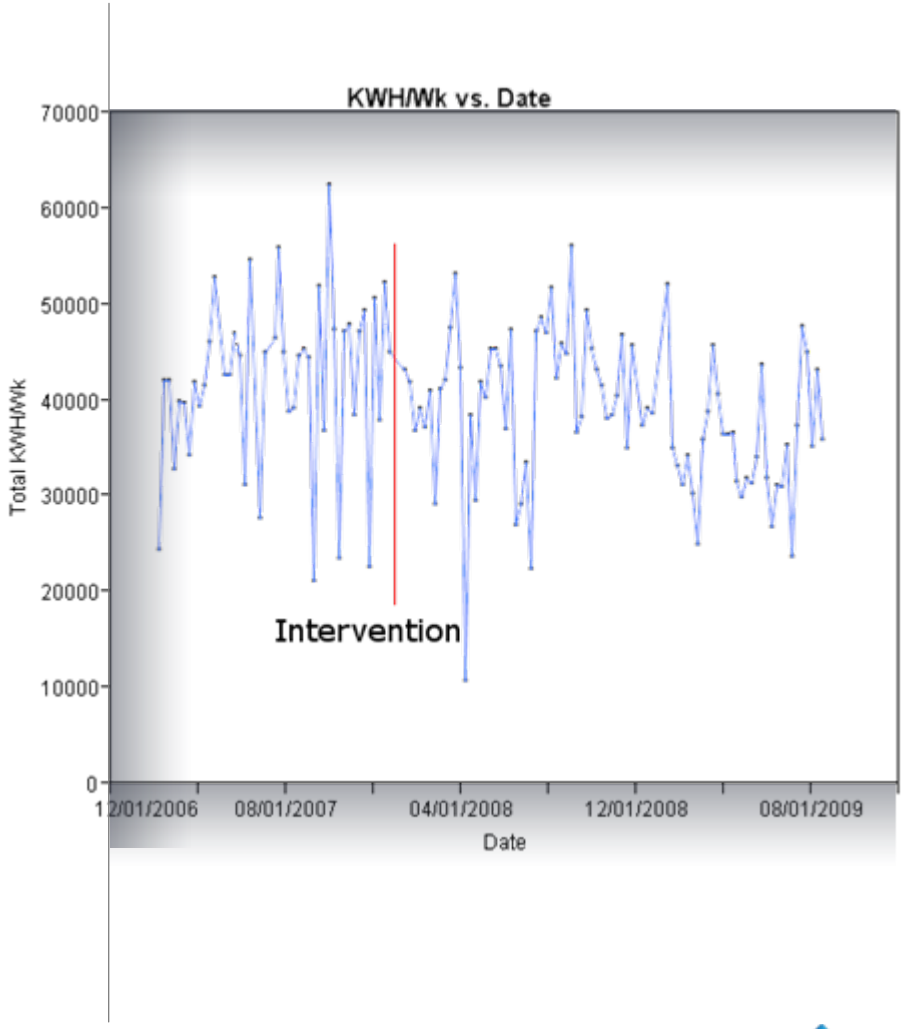


Modeling Industrial Energy Consumption

Industrial energy consumption patterns are widely varied and typically industry dependent.

The impact of an energy program can be observed as:

- Step Change
- Change in trend
- No real or apparent change



Warning: Scary Slides Ahead

MODEL SPECIFICATION

Generalized Energy Consumption Model

- Intervention Step form

$$kWh_i = \beta_0 + \beta_1 Intervention_i + \sum \beta_j EnergyDriver_{ji} + \varepsilon_i$$

- Intervention Trend form

$$kWh_i = \beta_0 + \beta_1 TrendBaseline_i + \beta_2 TrendIntervention_i + \sum \beta_j EnergyDriver_{ji} + \varepsilon_i$$

Where : kWh_i = Total Electricity use per period i

Intervention = Step Indicator variable (0 before, 1 after)

Trend(B)(I) = Scaled trend variable

$EnergyDriver_j$ = Any variable that significantly impacts energy consumption

β_1 = Estimated impact of intervention per time period

β_1 β_2 = Estimated change in energy consumption per time period (Trend Model)

β_j = Coefficient for $EnergyDriver_j$

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Calculating Energy Savings

- Intervention Step form
  - If β_1 is significantly different from zero AND negative then

$$TotalSavings = n * \beta_1$$ where n = # of periods post intervention

- Intervention Trend form
  - Perform trend hypothesis test

H_0: Trend Baseline = Trend Intervention (Intervention had no effect on energy consumption)
H_1: Trend Baseline ≠ Trend Intervention (Intervention had an effect on energy consumption)

$$t = \frac{\beta_{Baseline} - \beta_{Intervention}}{\sqrt{Var(\beta_{Baseline}) + Var(\beta_{Intervention})}}$$

  - If Trend Intervention is statistically significant different from AND less than Trend Baseline then

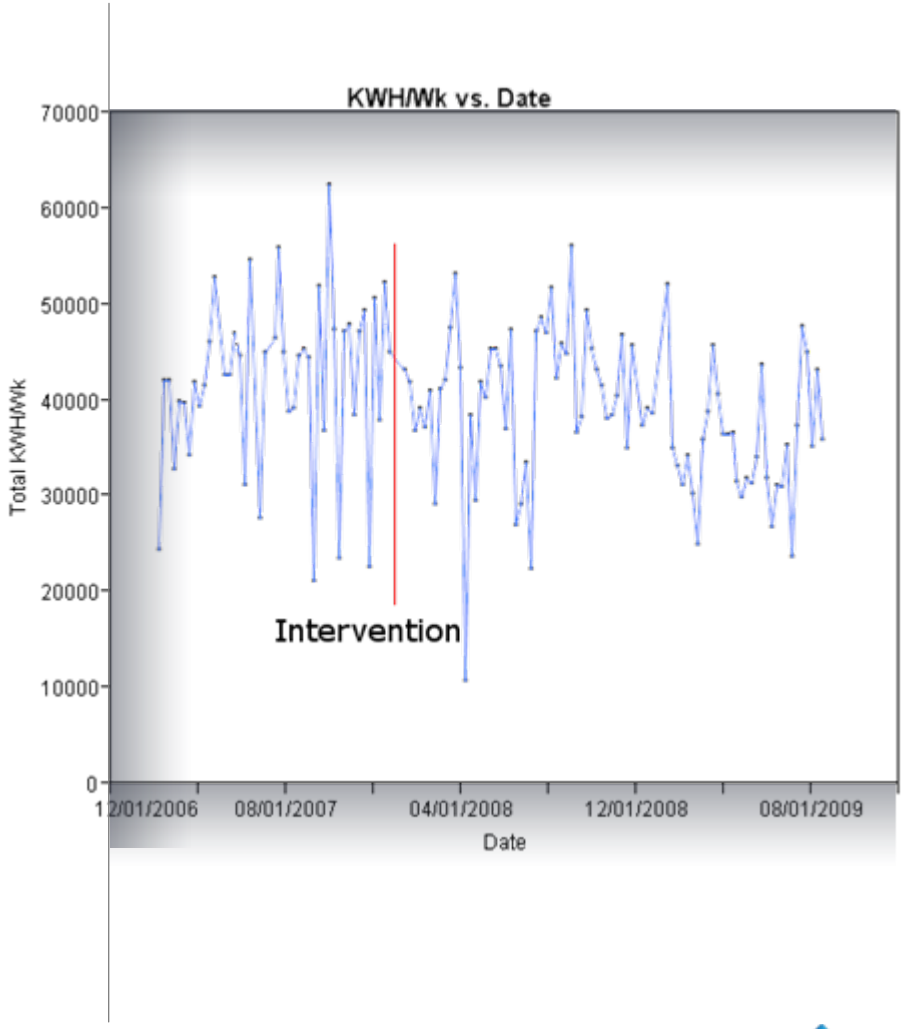
$$TotalSavings = \sum_{i=1}^{n} i * (\beta_{Baseline} - \beta_{Intervention})$$

where n = # of periods post intervention

APPLICATION EXAMPLE

Modeling Application

- Step model using total production showed no energy savings.
- Facility was convinced the SEM program was saving significant energy.



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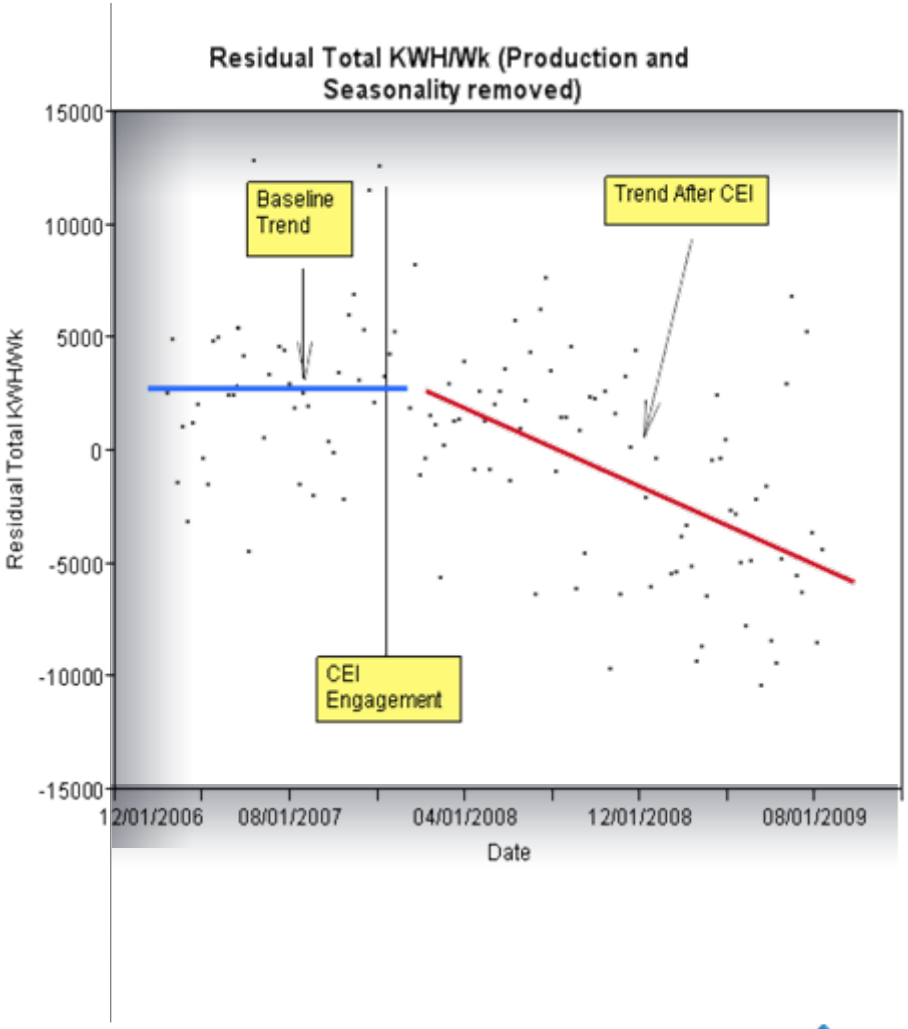
- Investigation revealed facility produced 3 products each of which required a different amount of energy.

Modeling Application

- Step model using total production showed no energy savings.
- Facility was convinced the SEM program was saving significant energy.
- Investigation revealed facility produced 3 products each of which required a different amount of energy.
- Refit model with production volume for each product. Residuals showed distinct downward trend.



Model Diagnostics

H_0: Trend Baseline = Trend CEI (CEI had no effect on energy consumption)

H_1: Trend Baseline ≠ TrendCEI (CEI did have an effect on energy consumption

$$t = \frac{TrendBaseline - TrendCEI}{\sqrt{Var(TrendBaseline) + Var(TrendCEI)}} = \frac{39.5 - (-74.8)}{\sqrt{34.8^2 + 16.9^2}} = -2.95 \quad \text{Prob>|t|} < .001$$

- Energy savings have been demonstrated because TrendCEI is statistically significantly less than TrendBaseline

Estimated Savings (kWh) through 86 weeks of intervention
$\sum_{i=1}^{86} i * (39.5 - (-74.8))$ = 427,596 kWh
90% Confidence Interval (189,521 < kWh Savings < 665,671)

CEI Validated Program Results (2006–2010)*

The long story

- 15 CEI implementations from 2006-9
- Cadmus validated data, models, and physical site validation of capital projects.
- Validated top down analysis resulted in significantly more savings than could be accounted for by capital projects.
- The "Net top down" are savings attributed to business practice/behavior change and are ***50%*** of the total savings
- Savings by source proportional to consumption by source

Validated Electric Savings

O&M + Capital (aMW)	Net Top-Down (aMW)	Total Electric Savings (aMW)
8.053	2.961	11.013

1 aMw = 8760 MWh = 8,760,000 kWh

Validated Natural Gas Savings

O&M (therms)	Net Top-Down (therms)	Total Gas Savings (therms)
2,289,164	4,710,318	6,999,482

1 therm = 100,000 BTU = 29.3 kWh

The short story

Implementation of Strategic Energy Management Systems result in ~ 3% per year reduction in energy costs for all sources of energy.

Total savings equivalent to powering more than 15,000 homes for a year

3% of electric and natural gas consumption per year

* NEEA Market Progress Evaluation Report #6: Evaluation of NEEA's Industrial Initiative (E11-220)

Questions?

For complete details of the modeling methodology see the technical paper *"A generalized method for estimation of industrial energy savings from capital and behavioral programs"* in the proceedings of the 2011 Industrial Energy Technology Conference (IETC)

The validation of the modeling methodology and energy savings resulting from the Industrial Initiative can be found in *"NEEA Market Progress Evaluation Report #6: Evaluation of NEEA's Industrial Initiative (E11-220)"* prepared by the Cadmus Group, Inc. and released on 2/08/11. The document can be found at:

http://neea.org/research/reports/E11-220A.pdf