Using Smart Devices to Achieve Intelligent Efficiency
February 6, 2013

Nick Lange
Ethan Goldman
Jeff Hullstrung
Efficiency Vermont
Learning Objectives

• Learn what new technologies are available to measure and manage energy performance in residential and commercial buildings.

• Learn how data from internet-connected devices can be used to identify and quantify efficiency opportunities.

• Lean about the services available from Efficiency Vermont to assist in selecting, purchasing, and analyzing data from internet-connected building monitoring and control devices.

• Learn about industry trends in building automation and data analytics.
Next Generation Thermostats:
What we know, What we’re learning, What’s Next (and why it matters)

Nick Lange
Emerging Savings Opportunities
What’s a next generation thermostat?

$ Expensive
• $200+ – (Recurring Service Fees?)

@ Internet Connection
• Remote Control – (Website, Phone, Service)
• Sophisticated controls – (automaticity, sensors, “smarts”)

? Savings Potential
• 5% to 25% Heating & Cooling – ($50 to $250+/yr)
Worth it?

nest $249

• Auto-Schedule!
  • 10-12% heating savings
  • 15% cooling savings
  • Average of $131-$145/yr

• Seasonal Savings™
  • Even More Savings

Programs itself. Then pays for itself.
Worth it?

Lyric $279 $249
- Geofencing!
  - Phone GPS integration
- Fine Tune™ & Smart Cues™
  - Avg $186/yr savings
Worth it?

**ecobee3**  $249
- Remote sensors
  - For homes with more than one room
- “Smart, really smart”
  - Average 23% savings!
Worth it?

Wi-Fi only $100

3rd Party Services (Free*)

- Comverge
- Ecofactor (xfinity)
- Weatherbug
- Opower
The big question:

Can a $250 product bring GEICO* results to 50% of Vermonter’s home energy usage?

*save up to 15% or more?
The easy answer:

It depends*

*on housing types and heating systems compatibility, sensor accuracy, heat load, multiple zones, measure life, baselines, ventilation & electrical & behavioral savings, data-driven diagnostics, add-on services, demand response, heat pump aux loads, and so many many many many more?
A Brief History of Time Thermostat Savings

Mr. Peabody’s Wayback Machine

Two Questions:

#1: Why Review The History of Thermostats?

#2: Why Rocky & Bullwinkle?

The Rocky & Bullwinkle Show (1959-1964)
A Brief History of Time Thermostat Savings

Mr. Peabody’s Wayback Machine

Honeywell “T87 Round”

- Semi-Automatic “wind-up” day/night setbacks

The Rocky & Bullwinkle Show (1959-1964)

1960 – present

Efficiency Vermont
A Brief History of Time Thermostat Savings

ca. 1990

Digital Programmables!

1990 – Present
A Brief History of Time Thermostat Savings

Dudley Do-Right

The Rocky & Bullwinkle Show (1959-1964)

Programmable Thermostat Specifications

<table>
<thead>
<tr>
<th>Setting</th>
<th>Setpoint Temperature (Heat)</th>
<th>Setpoint Temperature (Cool)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wake</td>
<td>≤70°F</td>
<td>≥78°F</td>
</tr>
<tr>
<td>Day</td>
<td>setback at least 8°F</td>
<td>setup at least 7°F</td>
</tr>
<tr>
<td>Evening</td>
<td>≤70°F</td>
<td>≥78°F</td>
</tr>
<tr>
<td>Sleep</td>
<td>setback at least 8°F</td>
<td>setup at least 4°F</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Setting</th>
<th>Time</th>
<th>Setpoint Temperature (Heat)</th>
<th>Setpoint Temperature (Cool)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wake</td>
<td>6 a.m.</td>
<td>70°F</td>
<td>78°F</td>
</tr>
<tr>
<td>Day</td>
<td>8 a.m.</td>
<td>62°F</td>
<td>85°F</td>
</tr>
<tr>
<td>Evening</td>
<td>6 p.m.</td>
<td>70°F</td>
<td>78°F</td>
</tr>
<tr>
<td>Sleep</td>
<td>10 p.m.</td>
<td>62°F</td>
<td>82°F</td>
</tr>
</tbody>
</table>
A Brief History of Time Thermostat Savings

ENERGY STAR Programmables

- 10-30% Savings
- Default Program
- HOLD Button
A Brief History of Time Thermostat Savings

Dudley Do-Right? Not so much…

Heating Savings: ~3% to 7%

Cooling Savings: -1% to 1%
A Brief History of Time Thermostat Savings

Programmable ENERGY STAR

1995 – 2009
Rest in Peace
A Brief History of Time Thermostat Savings

Nest
- The iPod of Tstats
- “Easy-to-use”
- “Learning”
- “Attractive”

#1 Selling “Smart” Thermostat
A Brief History of Time Thermostat Savings

Currently “under” revision…
- Usability
- Demand Response-ability
- Auditability:

- REAL WORLD DATA
- ANALYTICS
How Much Smarter?

Less Heating or Cooling
• Optimize setpoints
  • Coarse Adjustments
  • Micro-Adjustments

Lower Costs
• Optimize Loads
  • Pre-cooling/heating
  • Staggered runtimes

Data Sources: People* Building* Weather* System*
2012 R&D Study

Data → Indirect Savings potential
(2014) Thermostat Study Goals

Primary Goal

Direct Savings
Characterization for Residential Market
*Single and LI Multi-Family*

Secondary Goals

Indirect Savings
Program Design
*Analytics and Tools*

Industry Impact
Promote Savings
*Demonstrate & Coordinate*

Build on R&D Success:
Thermostat-based performance metric proof-of-concept

Scale study:
Bring robust understanding to program benefits
2014 Thermostat Study Design

Direct Savings

End of Summer 2014 → 2015

Nest 2\textsuperscript{nd} Gen w/ Seasonal Savings

>500 Single-Family Homes

~500 units in Multi-Family Buildings

Fuel Dealer Installers

Housing Authority

Detailed Site Characteristics

Fuel Consumption (Pre /Post 2 yrs)

Matched Control & Treatment Groups

Primary Goal

Secondary Goals

Indirect Savings

Customer pays (installation)

EVT pays

Analytics on 1000+ Units/Homes

Calibrated Metric & Benchmarking

Data Specification

Promote Savings Potential

Team & Partner

Efficiency Vermont
Participant Screening & Recruitment

- Housing Vermont:
  - Property Managers across the state

- Fuel Dealer Partners:
  - Bourne’s Energy
  - Cota & Cota Inc.
  - Energy Coop of Vermont
  - Vermont Gas Systems
Study Dashboard (small data)

- Recruitment
  - Marketing/Outreach
- Geo-Location
- Installing Partner
Who Cares?

Ratepayers & “Customers”

Industry Partners

*800lb Gorilla… May wag the dog
Why Thermostats, Why Now?

Large Savings Potential

Market Readiness

High Quality Data

To go (boldly?) into the final frontier* … of savings

*Intelligent Efficiency

Efficiency Vermont
A glimpse of what’s to come…

“And Nest Thermostats get better over time. Thanks to automatic software updates, the Nest Thermostat you buy actually gets better at saving energy the longer you own it.

Over the past three years, we’ve updated the thermostat more than 30 times, and added new features to help people save even more.”
Finding the Information Hiding In Your Data

Ethan Goldman
Efficiency Vermont
Once, there was darkness
Then, came data
And it is (pretty) good
Bring your own data

41% Appliances

Do you have any of the following appliances?

- Washing machine
- Dryer
- 2nd refrigerator
- Mini-fridge
- Standalone freezer

The percentages shown here are estimates.
VIPER Tool (AMI data)
Look for patterns

Time of Day

Date (1 yr)

Maintenance shutdown?

Christmas shutdown?

Summer

Winter

High KW

Low KW

Production hours

Efficiency Vermont
Look for events

Expensive spike!
Look for trends

Off-hours

On-hours

Long “tail” = Savings

Efficiency Vermont
Live demo!

(Drum roll, please…)

Efficiency Vermont
Getting live data from smart meters
Getting live data from smart meters
Getting live data from smart meters
Remote energy analysis

Summary for time-period shown in graph
- Energy Used: 7.36 MWh (approx. $956.69 used)
- Energy Generated: 0.00 Wh (approx. $0.00 saved)
- Net: 7.36 MWh bought (approx. $956.69 spent)

Summary over last 30 days
- Energy Used: 8.62 MWh (approx. $1,120.06 used)
- Energy Generated: 0.00 Wh (approx. $0.00 saved)
- Net: 8.62 MWh bought (approx. $1,120.06 spent)
Remote energy analysis
Light-level analysis
Light-level analysis

Hourly-Daily Light Use Profile (% on-time in 1-hour chunks for each day)

Jan 10, 2013 (Thu)
Jan 03, 2013 (Thu)
Dec 27, 2012 (Thu)
Dec 20, 2012 (Thu)

Total Percent On-Time: 63.93%
Projected Annual Operating Hours: 5600.00 Hrs
Projected On-Time During Summer Peak: 16.92%
(1-5 PM, Mon-Fri, Jun - Aug, excluding federal holidays)
Projected On-Time During Winter Peak: 100.00%
(5-7 PM, Mon-Fri, Dec & Jan, excluding federal holidays)
Annual projection based on 20.96 metered days
FCM projection based on 13 metered business days
Now we will measure everything! (Yeah, right!)

- Built-in sensors
- Calibrated and documented
- Communicating continuously
- Calculating automatically

Standards?
Mystery data!
Networks?
Subjectivity!

Efficiency Vermont
Energy Models: Industrial and Commercial

• Efficiency Vermont has been working with customers at large industrial and commercial facilities to develop energy models
  • Enables prediction of energy usage in future periods
  • Takes into account external and internal variables
    • Weather normalization is the most basic (external)
      • Dry bulb or wet bulb temperature
    • Internal variables are numerous
      • Production levels – can be multiple products
      • Occupancy or schedule
Energy Models: Industrial and Commercial

- Linear models typically used
  - Energy usage is modeled as a function of multiple variables

\[
\text{Energy} = f(\text{baseload, heating load, cooling load, schedule, production}_n)
\]

\[
E = B + C_1 \times \text{HDD} + C_2 \times \text{CDD} + C_3 \times \text{S} + C_4 \times P_1 + C_5 \times P_2 + \ldots + C_N \times P_N
\]

- Linear models are easiest to understand

Caution: Math Ahead
Energy Models: Industrial and Commercial

- Example linear model
  - A simple model for a facility with one main product and a process-related cooling load, no production on holidays

Energy = 50,000 + 600 * CDD – 20,000 * Holiday + 50 * Widgets

- The baseload is 50,000 kWh per day
- 600 kWh are required for each cooling degree day
- Facility energy usage drops by 20,000 kWh on holidays
- 50 kWh are required for each widget that the facility produces

(Total annual usage 22 million kWh)
Energy Models: Industrial and Commercial

Facility Energy Model

- Facility Monthly Energy Usage (kWh)
  - Model kWh
  - Actual kWh
  - CuSum

- Cumulative Sum of Energy Savings (kWh)
  - 0 to 2,500,000
  - 1,200,000 to 1,000,000
  - 800,000 to 600,000
  - 400,000 to 200,000
  - 0 to -200,000

- January to December

Source: Efficiency Vermont
Energy Models: Industrial and Commercial

- Initial models based on monthly data
  - Production data were available with monthly resolution
  - Showed general trends
    - Large time delay lacked usefulness as a diagnostic tool

- Daily data provides faster feedback
  - Ability to dispatch team to investigate changes
    - Good: What are we doing better?
    - Bad: What slipped out of control?
Energy Models: Industrial and Commercial
Energy Models: Industrial and Commercial

• What does it tell us?
  • Are we making long-term progress?
    • Is the overall trend in the right direction?
Energy Models: Industrial and Commercial

![Facility Energy Model Graph]

- Good trend
Energy Models: Industrial and Commercial

• What does it tell us?
  • Are we experiencing short-term challenges?
    • Is backsliding evident?
Energy Models: Industrial and Commercial

Facility Energy Model

- Backsliding
- Leveling off
Energy Models: Industrial and Commercial

• What does it tell us?
  • Do we see evidence of the specific energy efficiency efforts?
    • Is the slope changing?
Energy Models: Industrial and Commercial

Facility Energy Model

Steeper slope

Efficiency Vermont
Energy Models: Industrial and Commercial

- What does it tell us?
  - What is the magnitude of energy savings?
    - Does it match our expectations?
Energy Models: Industrial and Commercial

Facility Energy Model

Yearly energy savings

0 10,000 20,000 30,000 40,000 50,000 60,000 70,000 80,000 90,000
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

0 100,000 200,000 300,000 400,000 500,000 600,000 700,000 800,000 900,000 1,000,000 1,200,000
Cumulative Sum of Energy Savings [kWh]

- Energy Model  Actual  CuSum
Energy Models: Industrial and Commercial

Third-party tools are available
Energy Models: Industrial and Commercial

What’s next?
• Hourly models
  • Moving towards real-time data display
• Energy dashboards
  • Whole facility
  • Individual production line
Thank you for staying until the bitter end!