Adopting Energy Efficiency in Connected Homes

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Smart Stuff is the New Hotness...

...but there are definitely still a lot of kinks to work out
<table>
<thead>
<tr>
<th>Functionality Category</th>
<th>Short Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control-based</td>
<td></td>
</tr>
<tr>
<td>Smart Lighting</td>
<td>Lighting bulbs, controls, and fixtures that have automated control functionality</td>
</tr>
<tr>
<td>Smart Plug</td>
<td>Single communicating piece of hardware that controls or provides feedback about connected energy consuming devices</td>
</tr>
<tr>
<td>Smart Hub</td>
<td>Device that enables and manages interaction between existing smart hardware within a single home</td>
</tr>
<tr>
<td>Smart Hub and Smart Switch</td>
<td>Dual function wall mounted smart switch that also enables and manages interaction between existing smart hardware within a single home</td>
</tr>
<tr>
<td>Smart Switch</td>
<td>Wi-Fi enabled wall switch that controls or provides feedback about connected energy consuming devices</td>
</tr>
<tr>
<td>Smart Appliance</td>
<td>Communicating appliance which can be controlled remotely via various interfaces</td>
</tr>
<tr>
<td>Smart Thermostat</td>
<td>HVAC Wi-Fi enabled control utilizing remote or rule based mechanisms</td>
</tr>
<tr>
<td>Smart Home Platform</td>
<td>Software platform that enables multiple different hardware devices to operate as a home automation system</td>
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<tr>
<td>Information-based</td>
<td></td>
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<tr>
<td>Energy Portal</td>
<td>Online dashboard that is consumer or program administrator facing</td>
</tr>
<tr>
<td>Data Analytics Platform</td>
<td>Cloud based analytics platform that analyzes large volumes of data collected from existing smart hardware</td>
</tr>
<tr>
<td>In-Home Display</td>
<td>Physical display that collects data from existing hardware and provides real time feedback and/or prompts</td>
</tr>
<tr>
<td>Load Monitor</td>
<td>Single non communicating piece of hardware that displays energy consumption data of the connected appliance or devices</td>
</tr>
<tr>
<td>Web Service Platform</td>
<td>Cloud-based platform that focuses on more than just energy</td>
</tr>
</tbody>
</table>
# A Note on Smart Thermostats

<table>
<thead>
<tr>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Programmable thermostats</strong></td>
</tr>
<tr>
<td>Retains basic thermostat capability, regardless of link status</td>
</tr>
<tr>
<td>Can collect temperatures, HVAC run-times and HVAC performance information from field systems</td>
</tr>
<tr>
<td>Temperature stability</td>
</tr>
<tr>
<td>Programmable for schedules and setbacks</td>
</tr>
</tbody>
</table>

| **Wi-Fi thermostats**                                 |
| Wi-Fi-enabled                                        |
| Online dashboard and/or mobile app connected to the user account |
| Intuitive user interface (UI) that may include touchscreen or buttons |

| **Smart thermostats**                                |
| Proximity sensing allows a user to accept and act upon external data (like the location of a smart phone). |
| Occupancy sensing directly detects and acts upon internal sensors (inside the thermostat). |
| “Learning,” optimization, or adaptive control; algorithms that learn user behavior or track usage to improve performance |
| Basic demand response capabilities: allows remote connection with utilities, who, with authorization, can adjust thermostat settings during peak demand periods (optional). |
Smart controls for DHPs

Cielo
Breezi

Sensibo

Tado

Momit
Smart Outlets

- GE Smart Switch
- iDevices Switch
- Belkin Insight Switch
- Cielo Control Switch
Smart home platforms

Lowe’s Iris

Apple HomeKit

Alexa?

Kirio

Samsung SmartThings
How much energy can connected devices save?

### In-home displays
- Electric savings range: 5–22%
- Gas savings range: 5–22%

### Energy portals
- Electric savings range: 5.7–7.4%
- Gas savings range: 5.7–13%

### Smart thermostats
- Electric savings range: 2–16%
- Gas savings range: 8–12.5%
- Can save energy in oil- and propane-heated homes, too

### Smart plugs and strips
- Demand savings range: 0.5–1.0 kW per customer
- Energy savings range: 1–4.58%

In the most heating dominated climates in the U.S., this type of product could save an average of 10 Million BTUs per year (that’s about 3000 kWh or 100 therms).
Smart Home Ecosystem: Example
Benefits of Smart Technology

- Convenience
- Security and safety
- Health and comfort
- Energy Savings
- Planning for renewables
- Energy Balance - Path to net zero energy
- Resilience

Good for Homeowners
Good for Everyone

Production + Consumption = Return on investment

Good for Homeowners
Good for Everyone

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Benefits now:
Energy Savings

Smart Thermostat
$249.99
1191-1237 kWh
50 Therms

Smart Plug
$49.99
~28 kWh

Smart Lighting
$14.97
~72 kWh

Smart Power Strip
$59.99
~216 kWh

Home Energy Monitor
$219.99
2-8% savings overall

Smart Water Heater Controls
$150.00
~330 kWh
30 Therms

Smart Home Bundle
estimated savings:
~1760 – 2150 kWh
~80 Therms

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Benefits in the future: Home as energy management system

Energy Storage → Smart Thermostat → Health & Safety

EV Charging → Smart Water Heater Controls

Distributed Generation (PV) → Home Energy Monitor

Smart Plug

Smart Lighting

Convenience
Thank you!
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Home Energy Management Systems (HEMS) Product Demonstration in NYC

- NYSERDA-sponsored project to create stakeholder engagement and consumer education strategy to accelerate broad-market adoption of HEMS across NY State.
- Smart Home Product demonstration targeting HVAC, lighting, and plug loads
- 24 homes (12 single-family, 12 multi-family)
- Pre/post energy M&V and homeowner surveys
- HEMS installation begins November/December 2017.
ANSI/CTA-2045 Modular Communication Interface Standard

Grid Control via CTA-2045 Interface

- A/C Control Signal
- Pump Control Signal
- EVSE Control Signal
- Inverter Control Signal
- PVH Control Signal

- Thermostat and Air Conditioner
- Pool pump
- Water Heater
- PV Inverter
- EVSE and Electric Vehicle
Emerging Research: Unifying Home Automation Services

Unique, user-centric Home Energy Management System for Energy Efficiency and Demand Response

Cybersecure foresee
Home Energy Management

Smart/Green Home Energy Automation Schematic (conceptual)

Wi-Fi/Ecobee API
CTA-2045
Wi-Fi/HomeConnect API

Utility or Aggregator

HVAC
Water Htr
Refrigerator
Dishwasher
Laundry
Other Loads

AC Panel

AC Inverters

Solar PV
Wind
Fuel Cell
Battery


Example Use Case: Solar Self-Consumption

Preliminary Laboratory Results

- PV power
- Whole home power
- Battery power
- Baseline whole home power

Backfeed reduction started
Backfeed reduction ended
Example Use Case: Demand Response

Preliminary Laboratory Results
Example Use Case: Demand Response

Comparison of whole home power consumption

- Baseline Mode
- Energy Efficiency Mode

Preliminary Laboratory Results

NATIONAL RENEWABLE ENERGY LABORATORY
Example Use Case: Demand Response

Comparison of whole home power consumption

Load shed DR event from 14:30 to 16:30

Incoming DR event notified at 12:30
Example Use Case: Demand Response

Comparison of whole home power consumption

Load shed DR event from 14:30 to 16:30

Incoming DR event notified at 12:30
Example Use Case: Demand Response

Comparison of whole home power consumption

- DR Time Period
- Demand Response Mode
- Baseline Mode
- Energy Efficiency Mode

Load shed DR event from 14:30 to 16:30

Occasional loads for maintaining thermal comfort in DR mode

Recovery from the DR event

Incoming DR event notified at 12:30

foresee shifted loads (charged the battery, pre-cooled the home, and pre-heated the water heater) in DR mode

foresee minimized power backfeeding in EE mode

foresee reduced building loads during the DR event

Preliminary Laboratory Results
### Daily Energy Savings Breakdown by Source

#### EE vs. baseline

<table>
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<tr>
<th>Season</th>
<th>RBSA Home</th>
<th>Heating</th>
<th>Cooling</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Tenino</td>
<td>Eugene</td>
<td>Seattle</td>
</tr>
<tr>
<td>Daily Energy Savings (kWh)</td>
<td>5.28</td>
<td>6.90</td>
<td>8.01</td>
</tr>
<tr>
<td>Daily Cost Savings ($)</td>
<td>0.58</td>
<td>0.76</td>
<td>0.88</td>
</tr>
<tr>
<td>Daily CO2 Reduction (lbs)</td>
<td>1.90</td>
<td>3.15</td>
<td>2.89</td>
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#### DR vs. baseline

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<tr>
<td>Daily CO2 Reduction (lbs)</td>
<td>0.82</td>
<td>2.09</td>
<td>0.55</td>
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### Graph

- **Daily energy savings in EE mode, vs RBSA**
- **Daily energy savings in DR mode, vs RBSA**
- **Energy takeback/cost when DR is called**

(Simulated INC Event: 4-hour load-shed DR)
Batteries were fully utilized except one low-load home

Significant contributions from reduction of controllable loads

(Simulated INC Event: 4-hour load-shed DR)
Summary of Findings... so far:

- Interoperability is maturing across the smart buildings market very quickly
- Unified operation of multiple devices has numerous benefits
- Win-win solutions can exist for homeowners, utilities, and society to mutually benefit
- Rate structures have strong influence on how the equipment will be operated under automation
- Cybersecurity is an emergent barrier:
  - Protect consumers & utilities
  - Manage aggregated devices as Critical Infrastructure
Thank you!

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