Energy Management Technology: Motivate, Enable, and Engage Homeowners to Reduce Energy Usage

by Kat A. Donnelly, PE, President, EMpower Devices and Associates
with substantial input from Carrie Armel, Ph.D., Precourt Institute of Energy Efficiency, Stanford University

for

Advancing Energy Efficiency and Conservation in Our Homes:
A Public Policy Information Event Organized by the Clean Energy and Energy Efficiency Subcommittee of the Energy & Technology Committee, CT PUC,
March 5, 2009.

EMpower Devices:
EM = Energy Management
EMpower = consumer ownership and control
Devices (Noun) = Technology
Devices (Verb) = Methods

Presentation Outline

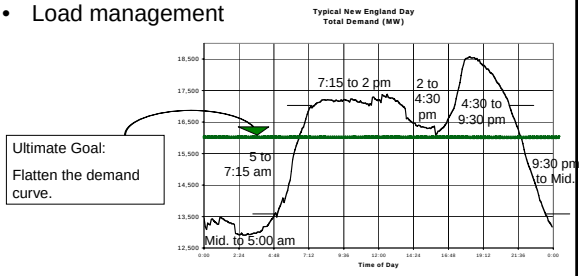
- Presentation Motivation
- Home Area Networking (HAN) Technology
- Consumer Behavior Approaches
- Pushing the Envelope using Technology

Graphic by Carrie Armel, PIEE, Stanford University

Just a tiny snapshot of the companies focused on the residential consumer.

Presentation Motivation: Measurement and Feedback Goals and Results

- Residential Consumer Demand Management
- Load management



Ultimate Goal:
Flatten the demand curve.

Presentation Motivation: Measurement and Feedback Goals and Results

- Residential Consumer Demand Management
- Load management
- Monetize Energy Efficiency
  - Measurement and Verification
  - Collect White Tags, rebates, incentives, etc.
- Evaluate and refine policies and procedures
- Create Target Marketing
- Improve utility customer service/satisfaction

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Home Area Networking Technology: Quick Overview

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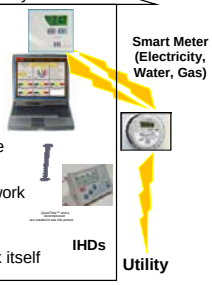
- In-Home Networks
  - Stand-Alone Feedback Devices
  - Simple Automation Products
  - Mesh Network/Software Automation Services
- Smart Meter ("Outside" the home. Utility Controlled.)
- The Future: The Marriage of Smart Meters, Home Automation Networks, Distributed Generation, & Storage

Home Automation Network: Electricity, Gas, and Water

Multiple components interact to provide a wide range of capability.

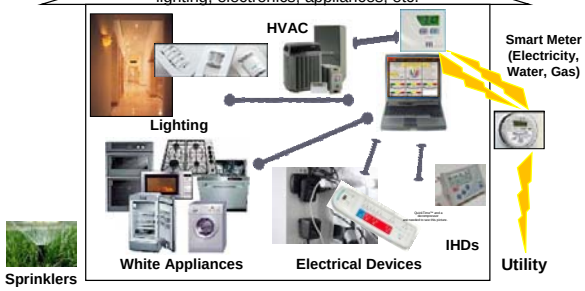


Basic components of HAN:

1. Network connects 1 or more outside information services to HAN
2. Network operating system and network management software
3. Access point or network nodes that form the wired or wireless network itself

Home Automation Network: Electricity, Gas, and Water

4. End-Points such as thermostats, in-home displays, lighting, electronics, appliances, etc.



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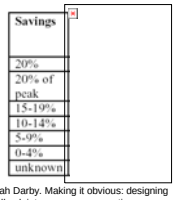
Today's Feedback Technologies: Feedback Levels and Effectiveness

Consumer Effectiveness	Frequency	Level of Detail
-Little to No Effect	-Monthly (Utility Bill)	-Household
-Some Response	-Next Day (CA Smart meters)	-Circuit Level
-Most Effective	-Real-Time Display, Website, or HAN*	-Appliance Level
		-Completely disambiguated

*HAN-Home Area (Automation) Network

Simple Feedback Devices: Behavioral Research Findings



Sarah Darby. Making it obvious: designing feedback into energy consumption.

Residential Electricity Use Feedback: A Research Synthesis and Economic Framework. EPRI, Palo Alto, CA December 2008. 1016844.

Slide by: Carrie Armel, Stanford University

- 5-15% reductions in electricity use
- Greater reductions with more specific feedback
- Good persistence

Precourt Institute For Energy Efficiency

Stanford University

Behavioral Aspects of Successful Feedback: Motivate, Enable, and Engage

- **Motivate**:
  - Set challenging, but achievable goals
  - Comparisons among like groups (Social Norms and Peer Pressure)
- **Enable** (through feedback technologies):
  - Computerized, interactive, custom presentation
  - Clear and Appealing interface (Keep it SIMPLE!)
  - Supplemental Automation
  - Data
    - Both whole house and appliance specific
    - Real-time (<2 s)
    - Given over a long period of time (historical)
- **Engage**:
  - Wide variety of approaches: "Not one size fits all"
  - Social Communities and Competitions
  - Personalized feedback loop

Behaviors, barriers, & benefits

- Target different behaviors and personalities
  - purchase behaviors,
  - one time behaviors (e.g., thermostat programming),
  - or habits.
- Establish behavior change goals
- Identify and Overcome barriers
- Recognize other benefits
  - Social approval
  - Environmental
  - Convenience
  - Health

Based on slide by:
Carrie Armel, Stanford University

Precourt Institute For Energy Efficiency

Stanford University

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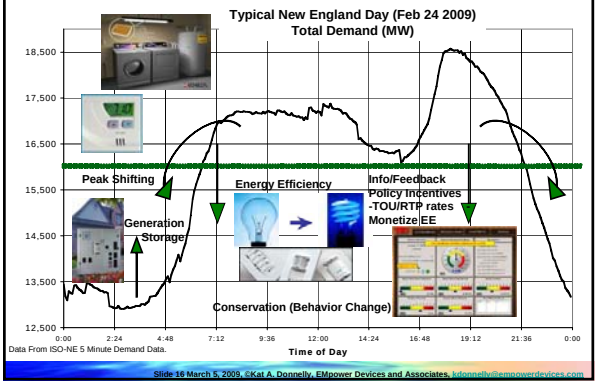
Managing Load with the HAN



Data From ISO-NE 5 Minute Demand Data.

Energy Efficiency Reality T.V.: "Energy Smackdown"

Home energy use gets a 'smackdown' on reality TV, Caitlin Carpenter, The Christian Science Monitor, Jan 9, 2008

Contestant Findings
Ultra-environmentalist Thought had low hanging fruit done. Tightened the belt: house at 56 degrees, extra blankets, cooler showers.
Moderate Env. Paying 25% less for electricity, loves the reduced plastic bags
Highly Consumptive Concentrated on a few, smaller changes

- Three local MA families compete to reduce carbon emissions
- Three different lifestyles so viewers could relate
- Encourage community awareness, peer pressure, social incentives

- Findings--All three families
  - Made lifestyle changes
  - Through friendly competition, found making changes in their homes and lifestyles wasn't as hard as they thought.
  - "Social incentives often more effective than economic incentives to spur behavior change" (Karen Erhardt-Martinez, ACEE)

Energy Efficiency Reality T.V.: "Energy Smackdown"

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Contestant Findings	Start CO_2/ person/yr
Ultra-environmentalist Thought had low hanging fruit done. Tightened the belt: house at 56 degrees, extra blankets, cooler showers.	10,216
Moderate Env. Paying 25% less for electricity, loves the reduced plastic bags	18,692
Highly Consumptive Concentrated on a few, smaller changes	26,733

- Average American emits 15,000 pounds CO_2/person/year
- Aired on local cable TV station August & Sept, 2008.

•Another Finding for all three families
- Some of the old habits die hard

Question: Who was "the biggest loser"?

(Reduced the largest percentage of CO_2?)

Energy Efficiency Reality T.V.: "Energy Smackdown"

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Contestant Findings	Start CO_2/ person/yr	End CO_2/ person/yr	% Saved
Ultra-environmentalist Thought had low hanging fruit done. Tightened the belt: house at 56 degrees, extra blankets, cooler showers.	10,216	5,204	49%
Moderate Env. Paying 25% less for electricity, loves the reduced plastic bags	18,692	6,850	63%
Highly Consumptive Concentrated on a few, smaller changes	26,733	~18,500 (?)	~30% (?)

- Surprised?
- Findings
  - All three families reduced by over 30%

Energy Efficiency Reality T.V.: "Energy Smackdown"

Home energy use gets a 'smackdown' on reality TV, Caitlin Carpenter, The Christian Science Monitor, Jan 9, 2008

Contestant Findings	Start CO_2/ person/yr	End CO_2/ person/yr	% Saved	Method	Savings From
Ultra-environmentalist Thought had low hanging fruit done. Tightened the belt: house at 56 degrees, extra blankets, cooler showers.	10,216	5,204	49%	-Audit (utility provided) -Measurement & Feedback device -List of small changes -Walk around when above threshold	-Small, simple things that add up to a big diff, -Aha Moment: Close fireplace flue, -Sharing ideas with social network
Moderate Env. Paying 25% less for electricity, loves the reduced plastic bags	18,692	6,850	63%	-Audit (utility provided) -Rest Unknown	-Got rid of old upright freezer (30% of household usage) -Insulation ($2000 net cost ($12,000 utility rebate)) -Got rid of plastic bags
Highly Consumptive Concentrated on a few, smaller changes	26,733	~18,500 (?)	~30% (?)	-Audit (utility provided) -Rest Unknown	-composting, -CFLs, -powerstrips for phantom load, -cloth napkins -carpooling

Energy Efficiency Reality T.V.: Beyond the "Energy Smackdown"

- Network TV
- Community Competitions
- Tie into some of the Deep Energy Reduction Projects going on
  - Affordable Comfort's Thousand Home Challenge
  - Cambridge Energy Alliance work
  - California Net Zero energy homes

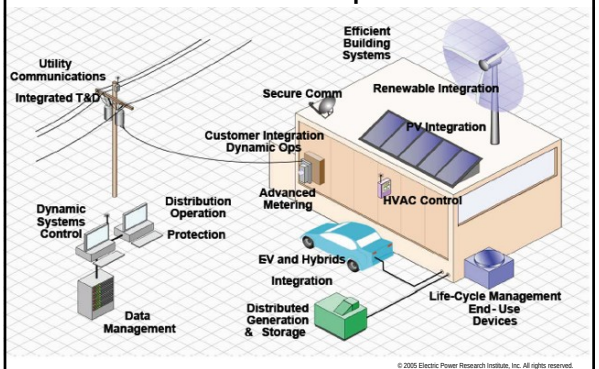
The Future of HAN…The Complete Home Network

http://www.z-wave.com/modules/AboutZ-Wave/

Other communication types:

- Power Line Communication
- ZigBee, Etc.

The Future of HAN…The Complete Home Network



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Acknowledgments and References

- Coordination with Carrie Armel (Stanford University, Precourt Institute for Energy Efficiency)
- Fischer, C. (2008). Feedback on household electricity consumption: a tool for saving energy? *Energy Efficiency, 1*(DOI 10.1007/s12053-008-9009-7), 78-104.
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- Midden, C. J. H. (2007). Florian G. Kaiser, and L. Teddy McCalley, Technology's Four Roles in Understanding Individuals' Conservation of Natural Resources, Eindhoven University of Technology. *Journal of Social Issues, 63*(1), 155-174.
- Feel free to contact me to discuss further: Kdonnelly@empowerdevices.com

Colorado "Smart Home" Cuts 30 Percent Of Energy Use (VIDEO)

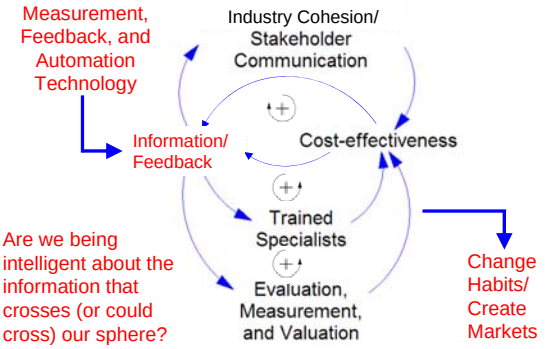
Getting a grip on the smart grid

Feb. 17: A Colorado experiment may become the model for plans to create a national power grid, NBC's Anne Thompson reports. http://www.msnbc.msn.com/id/21134540/vp/29245307#29245307

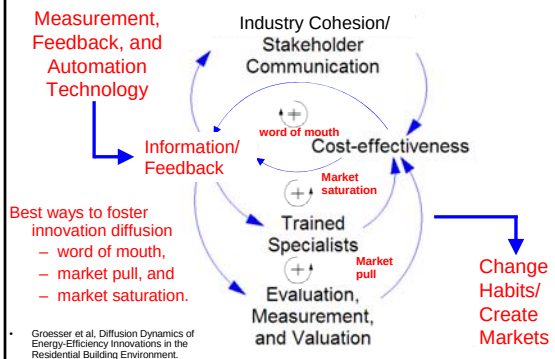
"Smart grids" and "smart homes" are new discussions nationally -- and exciting ones, at that -- but some towns have been speaking that language for a long time.

Boulder, Colo., for example, passed the nation's first municipal carbon tax, and now it's the site of a very interesting smart home that communicates with the utility company to more intelligently use energy.

Use Technology to Drive Behaviors and Markets



Use Technology to Drive Behaviors and Markets



Best ways to foster innovation diffusion
- word of mouth,
- market pull, and
- market saturation.

- Groesser et al, Diffusion Dynamics of Energy-Efficiency Innovations in the Residential Building Environment.

Will Smart Meters Ripen or Rot? Five First Principles for Embracing Customers as co-Creators of Value

1. Embrace customer-centered design
2. Blend rational and emotional experiences
3. Engage customers in small, observable steps of adoption
4. Segment by observable customer actions
5. Use action research to drive emergence and evolution of solutions

Honebein, PH, Cammarano, RF, and Donnelly, K (2009). *Will Smart Meters Ripen or Rot? Five First Principles for Embracing Customers as Co-creators of Value*. Customer Performance Group LLC White Paper.

Feedback Issues

- **Resolution:** Frequency and Level of Detail about usage
- **Presentation/Visualization**: Need better approach incorporating consumer behavior and social networking principles
- **Networking and Automation:** Need partnerships, collaboration, and leadership. It's about much more than Energy!
- **Data Management:** Large-scale, complex systems needed.
- **Mode of display**: Targeted display, internet, mobile access, others?
- **Target population:** Need to segment customers
- **Target behaviors:**
  - Segmented customers/unique approaches for maximum impact
  - Need to walk people through change over time as they are ready
- **Security and Privacy:** We need to address specific security and privacy issues that individuals may have with such a system. How do we address these?

Feedback Technologies

Feature	Utility Bill	Smart Meters	Simple Stand Alones	Home Area Networks	Disambiguation Algorithms
Frequency	Monthly				
Level of Detail: Whole House or Appliance-Specific	Whole home				
Additional Capabilities	Some tips, rebates				
Cost to Consumer	N/A				

Carrie Armel (Stanford University Precourt Institute for Energy Efficiency) and Kat A. Donnelly (EMpower Devices & Assoc.)

EMpower Devices

Feedback Technologies

Feature	Utility Bill	Smart Meters	Simple Stand Alones	Home Area Networks	Disambiguation Algorithms
Frequency	Monthly	10 s, 15 min, 1x/day			
Level of Detail: Whole House or Appliance-Specific	Whole home	Whole home (some large appliance recognition is possible with analysis)			
Additional Capabilities	Some tips, rebates	Control or automation w/additional technology			
Cost to Consumer	N/A	Recovered in rates			

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Feedback Technologies

Feature	Utility Bill	Smart Meters	Simple Stand Alones	Home Area Networks	Disambiguation Algorithms
Frequency	Monthly	10 s, 15 min, 1x/day	Real-time (~2s)		
Level of Detail: Whole House or Appliance-Specific	Whole home	Whole home (some large appliance recognition is possible with analysis)	Whole home OR appliance-specific with displays on individual appliances		
Additional Capabilities	Some tips, rebates	Control or automation w/additional technology	Most display instant usage only, some have cumulative data & future proj-ections		
Cost to Consumer	N/A	Recovered in rates	$20 - 250 per unit		

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Frequency	Monthly	10 s, 15 min, 1x/day	Real-time (~2s)	Real-time (~2s)	
Level of Detail: Whole House or Appliance-Specific	Whole home	Whole home (some large appliance recognition is possible with analysis)	Whole home OR appliance-specific with displays on individual appliances	Appliance-specific shown at a common display (some show overall home as well)	
Additional Capabilities	Some tips, rebates	Control or automation w/additional technology	Most display instant usage only, some have cumulative data & future proj-ections	Control and automation is possible, including on entertainment & security systems	
Cost to Consumer	N/A	Recovered in rates	$20 - 250 per unit	$20-300 per sensor/transmitter → $1,500-10,000 for whole house	

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Frequency	Monthly	10 s, 15 min, 1x/day	Real-time (~2s)	Real-time (~2s)	Real-time (~2s)
Level of Detail: Whole House or Appliance-Specific	Whole home	Whole home (some large appliance recognition is possible with analysis)	Whole home OR appliance-specific with displays on individual appliances	Appliance-specific shown at a common display (some show overall home as well)	Appliance-specific & overall home shown at a common display
Additional Capabilities	Some tips, rebates	Control or automation w/additional technology	Most display instant usage only, some have cumulative data & future proj-ections	Control and automation is possible, including on entertainment & security systems	- Limitation is 75-85% accuracy - Control and automation is probably not possible
Cost to Consumer	N/A	Recovered in rates	$20 - 250 per unit	$20-300 per sensor/transmitter → $1,500-10,000 for whole house	• Little cost to add to existing technology • $100-$200 as stand-alone device

Carrie Armel (Stanford University Precourt Institute for Energy Efficiency) and Kat A. Donnelly (EMpower Devices & Assoc.)