

# CLOSING THE LOOP

IMPROVING HOME ENERGY AUDITS BY INCORPORATING BEHAVIOR

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# PROBLEM: EXPECTATIONS & DISAPPOINTMENTS OF HOME ENERGY AUDITS

- **Utilities & government**
  - Long list of promised benefits
  - Echoed by media
- **People**
  - Long history of low uptake, low renovation rate
  - Questions about accuracy, relevance
- **All**
  - What should we expect?
  - What energy savings are we getting?
  - What other benefits and costs?
  - Can home energy audits be seen, done differently?

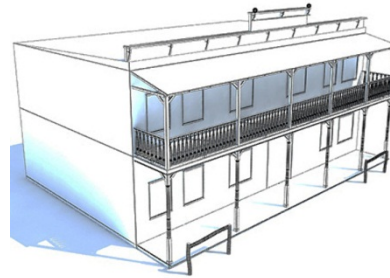
"The best \$75 a homeowner can  
spend"

"Learn about how much energy your  
home is using"

"Save money, save the earth"

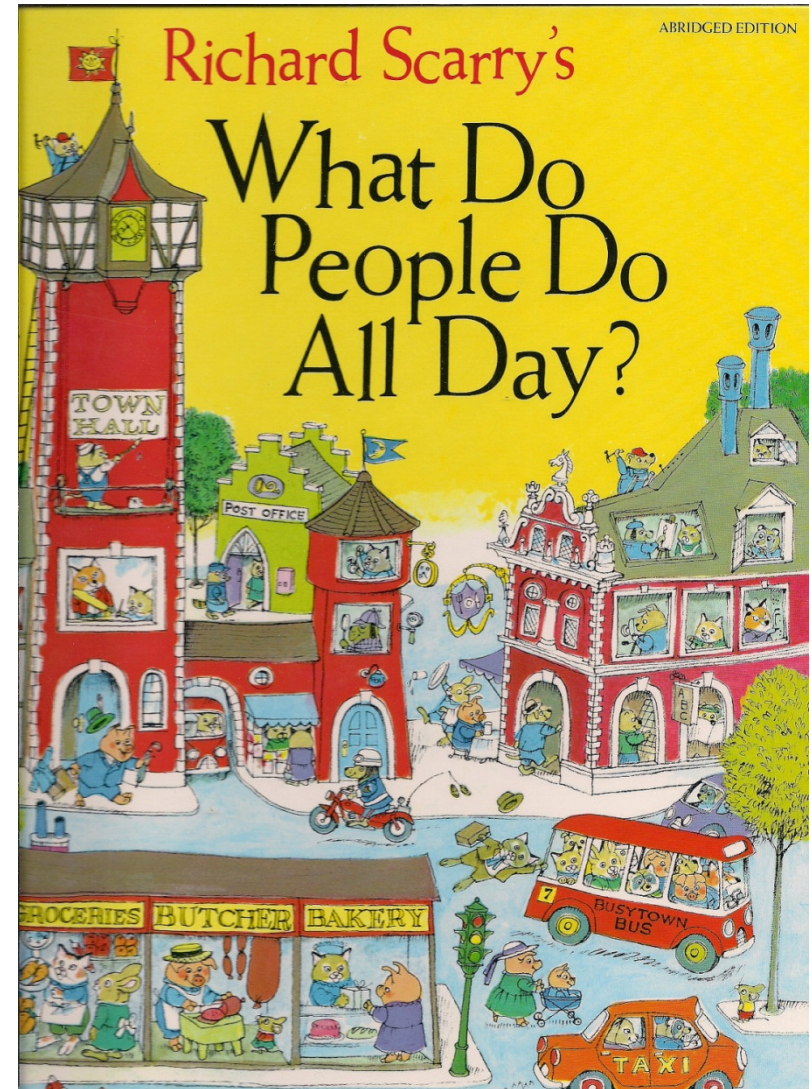
# WHAT'S CURRENTLY ON OFFER

- **Energy modeling + trained auditors**
  - From lite to comprehensive
- **Asset orientation**
  - HERS, Home Energy Score, labels ...
  - Focus on durable systems
  - Devised for “average” homeowners
  - Improving building stock, Negawatts
- **What homeowners typically get**
  - Subsidized participation
  - Advice on how to invest in *efficiency*
  - Co-benefits, perhaps
  - Info on various financial incentives
  - Swag
  - Connections to contractors



# RE-DIRECTION

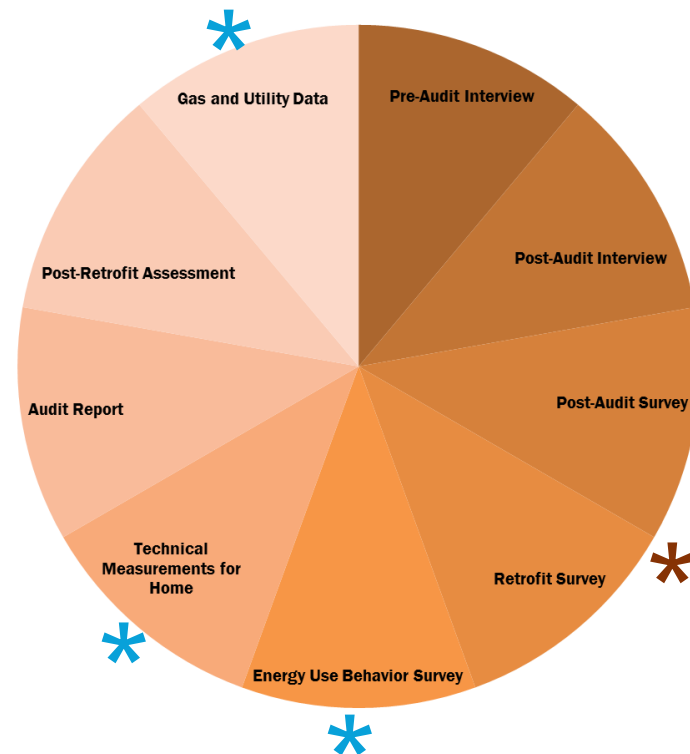
- Do homeowners seek asset efficiency, or something else?
- From “asset” to more operational perspective
  - House → home
  - Technology → technology + behavior/practice
  - Investment-orientation → user-orientation
  - Efficiency → energy + performance
  - “Average” life → own circumstances
- By adding in behavior can we get:
  - Better technical recommendations?
  - Compelling behavioral recommendations?
  - People who better understand energy use and comfort in their homes?
  - Stronger connection between what audits offer and what people want?



*Experiment with behavior*

# WHAT WE DID: EXPERIMENT USING AN UNUSUAL DATA COLLECTION

- **Seattle Audits, 2009-2011**
  - Asset focused
  - Typical results for a well-executed program
  - 1000+ audits, 300+ surveys
  - n=101 with tech, behavior, and utility data
- **Data collection**
- **Home energy modeling**
  - EnergyPlus, Home Energy Saver
  - With and without behavior \*
- **Comparison to bills**
- **Comparison of recommendations**
- **Survey results \***



# WHAT WE FOUND: PREVIEW

- Adding behavior improves accuracy of total bill estimate and probably cost-effectiveness calculations
  - Changes technology recommendations
  - Simple behavioral recommendations
- Could do even better
- Receptivity of homeowners
  - Interested in learning how to better use energy in their homes
  - Not so interested in asset efficiency or ratings *per se*
  - *Need art here too*

# FINDING 1: MODELING WITH BEHAVIOR

- Process
  - Modeled using “standard” default behavior versus survey-reported behavior
- Moderate improvement in how well modeled estimates match energy bills
  - Reduces overestimation
  - Reduces probability of being way off

Coupon #:

Household Energy Use Survey

Throughout this survey, please select the answers that best reflect your household's practices overall, rather than for any individual. Please follow the [skip instructions](#) throughout the survey so you only answer the items and sections that are applicable to your household.

### SECTION 1. HEATING YOUR HOME

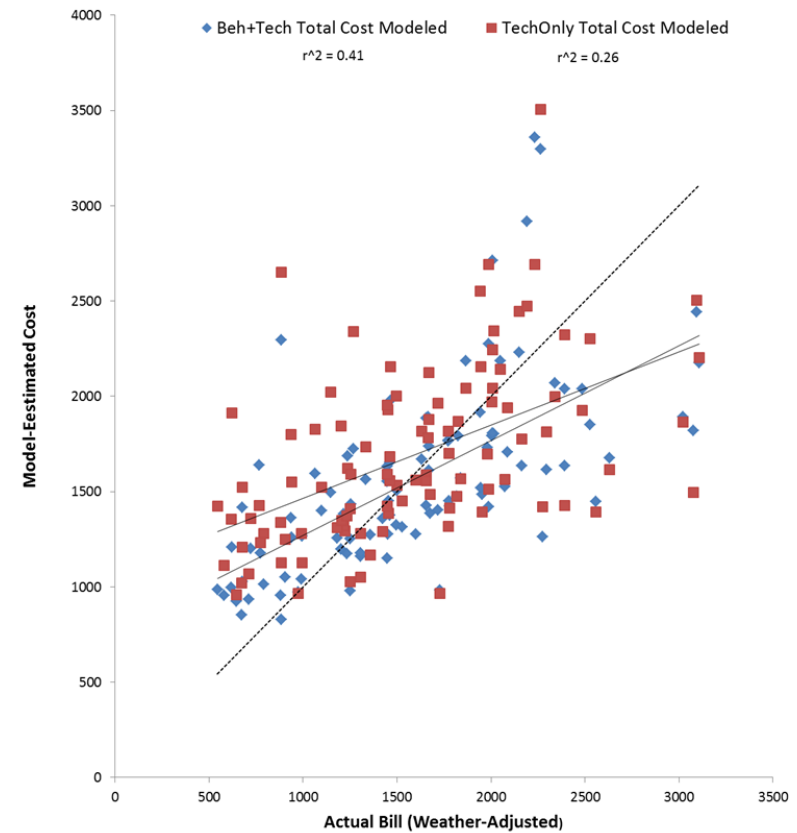
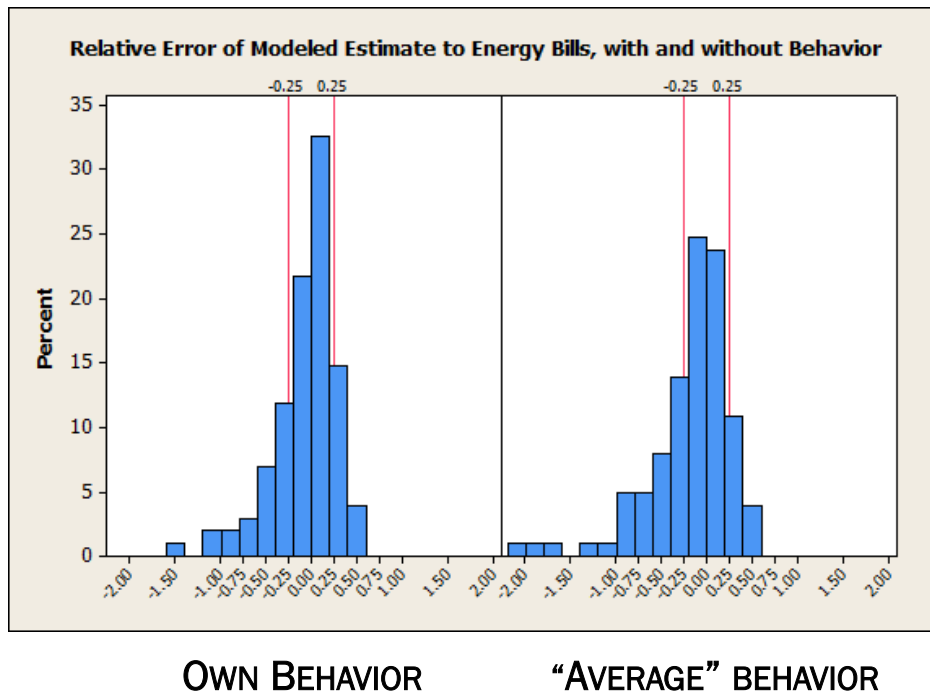
- In what months do you usually *start* and *stop* heating your home? [Please select only one start and one stop]

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
a. <b>START</b> heating	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
b. <b>STOP</b> heating	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

- Thinking about the months that you heat your home, which of the following best describes how you heat your home? [Please select only one]
  - ☐ We only use the main heating equipment (e.g., central furnace, boiler)
  - ☐ We mostly use the main heating equipment, and sometimes use supplemental heating  
(Supplemental heating equipment can be portable heaters, baseboard heaters, or a fireplace/stove)
  - ☐ We mostly use supplemental heating, and sometimes use the main heating equipment
  - ☐ We only use supplemental heating equipment [Skip to #6 on next page](#)
- Is the thermostat that controls your main heating equipment programmable? In other words, can you set it so that the temperature setting automatically changes at different times of the day and different days of the week?
  - ☐ Yes ☐ No
- If you use your home's main heating equipment at all, do you *primarily*...
  - ☐ Set the thermostat to a specific temperature and let the heat **turn itself on and off**
  - ☐ Use the thermostat as a **switch**, and manually **turn the heat on and off**
  - ☐ Use **programmed settings** so that desired temperatures automatically change at different times
  - ☐ Other [please specify]: \_\_\_\_\_
- Do various household members use your household's main heating equipment differently?
  - ☐ Yes ☐ No
- During the months you heat your home, please indicate your typical thermostat settings.

	Weekdays				Weekends			
	Morning (6 am - 9 am)	Day (9 am - 4 pm)	Evening (4 pm - 10 pm)	Overnight (10 pm - 6 am)	Morning (6 am - 9 am)	Day (9 am - 4 pm)	Evening (4 pm - 10 pm)	Overnight (10 pm - 6 am)
Off	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
59° or less	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
60° - 65°	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
66° - 67°	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
68° - 69°	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
70° - 71°	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
72° - 73°	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
74° - 79°	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
80° or more	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Don't Know	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

# MODEST IMPROVEMENTS



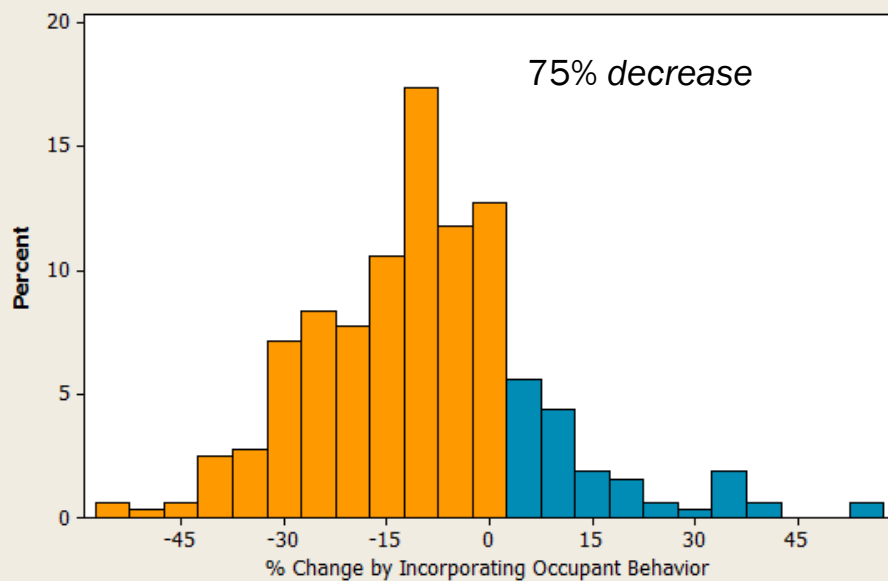


...

- **Could be further improved**
  - More refined behavioral data collection
  - Integrating consumption data: monthly or AMI
  - More refined modeling
- **Bill estimation is a clue, not a goal**

## FINDING 2: UPGRADE RECOMMENDATIONS SHIFT WITH END USE ESTIMATES

Change in Heating Cost Estimate  
Reported Behavior vs. Model Default Behavior



- Most say they heat less than model defaults – which are already quite conserving for this tool. Using behavior:
  - Median 10% heating estimate decrease
  - 25% are more than 21% lower
  - And these guys are pretty conservative ...
- Changes in technical recommendations
  - For ~ 2/3 measures, adding behavior increased payback time
  - Does not often “invalidate” the recommendation
- Does this matter?

87% report LOWER settings in morning than assumed  
84% report “” settings overnight than assumed  
67% report “” settings during the day than assumed  
39% report “” settings during the evening than assumed

# MODEST PROPOSAL FOR BEHAVIOR CHANGE

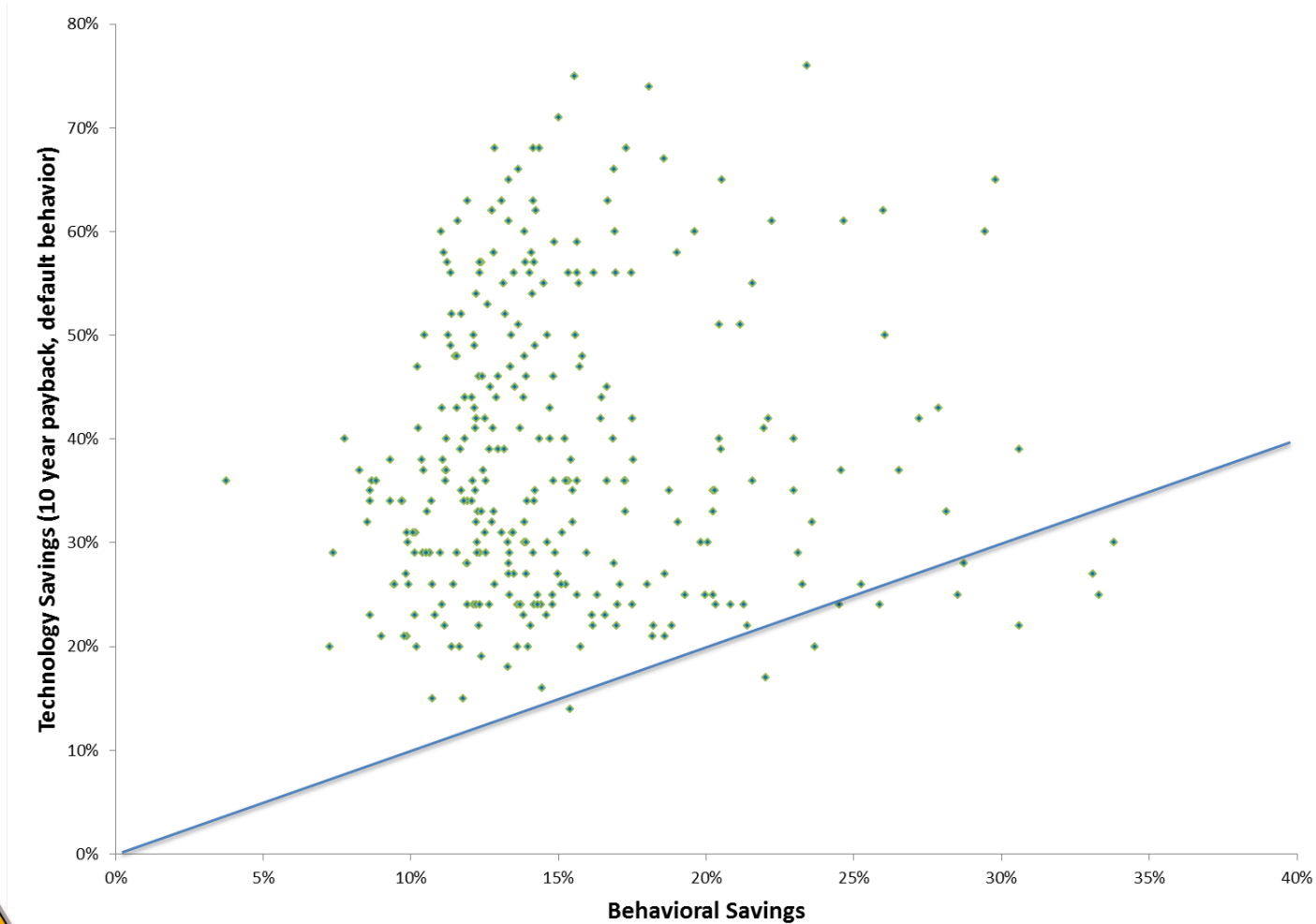


Georg Pedersen <http://ytorf.com/2008/10/a-modest-proposal/>

## FINDING 3: BEHAVIORAL CHANGES MAKE A DIFFERENCE

Behavioral Change	Average \$ Savings,	Median \$ Savings	% of Cases Rec.
	where recommended		
1. No clothes drying (loads = 0)	\$47	\$41	96%
2. Do not use air conditioning	25	20	9%
3. Set water heater temp to 120F	43	33	32%
4. Wash all clothing loads with cold wash/cold-rinse settings	20	11	56%
<i>During heating season:</i>			
5. Turn thermostat down 2 degrees below current settings, all hours all days	144	129	100%
6. Overnight, set thermostat to 60 deg	72	50	32%
7. Overnight and during weekday working hours, set thermostat to 60 deg	99	73	31%
8. Set thermostat to 66 morning, day, and evening, and 60 overnight	162	122	34%
9. Set thermostat to 66 morning & eve; 60 weekday work and overnight	187	163	35%
10. Set thermostat to 63 morning, day, and evening, and turn OFF overnight	319	262	50%
11. Set thermostat to 63 morning and eve, and turn OFF weekday work and overnight	361	300	46%
Overall (1-4 and max of heating changes 5-11)		17% of household level consumption	

## FINDING 4: TECHNOLOGY CHANGE VS. BEHAVIOR CHANGE

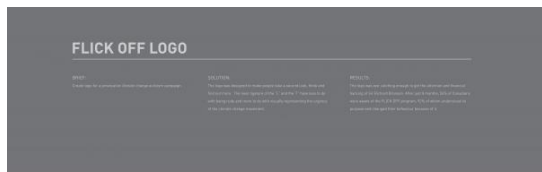
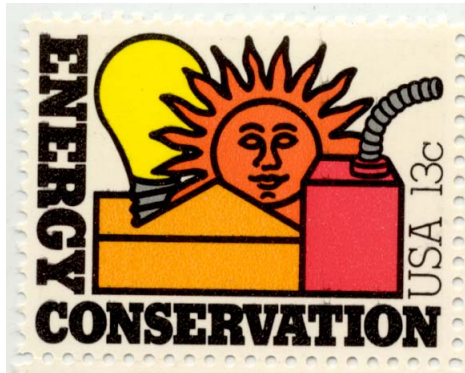




## FINDING 5: TOWARD IMPROVING BEHAVIORAL ADVICE



# IMAGES FOR EFFICIENCY



FLICK  FF





# USING EXISTING STRENGTHS





# SURVEY SAYS: A NEW STORY ABOUT ENERGY?

Liked/Interested	Not So Much
<u>Diagnostic testing</u>	Energy and carbon scores
<u>Auditor's enthusiasm &amp; time</u>	No tie-in to contractors, incentives
Range of things to do, especially DIY	Too few recommendations or TMI
The modeling	Imprecision of results
Hearing about operational changes	Difficulty of actually completing some measures
Safety checks	Appliances & non-standard equipment given short shrift
Individualization of advice	Standardization of advice

# WHAT SURVEY RESPONDENTS SAID ABOUT BEHAVIORAL CHANGE

## Example comments about why they changed behavior

“We became more aware of how to save energy without struggle”

“Now see the general loss of energy and making changes where we could”

“If I’m going to pay to repair my home, then it means I am more committed and aware”

“It confirmed for us that it really needed to be done if we wanted our house to be a more livable space. Also, there wasn't anything else that could have a significant impact.”

## Types of changes

*Behavioral change not emphasized, but 25% said they made some*

“Now we keep doors closed where the drafts were and put up a wool blanket where one of the other drafts was”

“Used a heating pad instead of turning on the central heat”

“We turn off lights more” / “We turn off lights less” (1)

“We found we were only reducing comfort by unplugging things”

1977



Jimmy Carter

2012



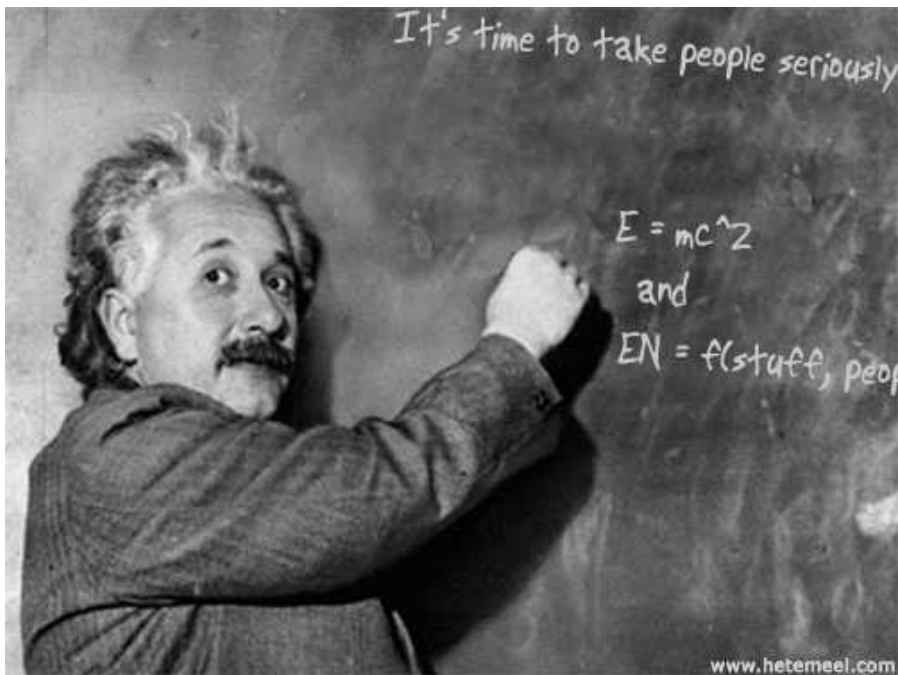
Lands' End

- Better hybrid recommendations
  - *Closing doors, envelope management, portable heating, targeted air sealing, not wasting time with things that barely make a difference, doing something interesting ...*
- Scale and compare savings

# CONCLUSIONS

1. Adding in behavior improved bill estimates
2. This should improve technical recommendations as well
3. Behavioral recommendations can yield appreciable savings that compare favorably to technology upgrades
4. People are interested in good behavioral recommendations and better understanding of energy use in their home
  - But not the same old stuff
  - A new vision backed by convincing technical theory

# ADVANCING THE ART



## 1. Improve methods for incorporating behavior

- More sophisticated integration of usage data, whether annual, monthly, or AMI
- Experiment with methods of behavioral data collection
- Models or sub-models that help expose compelling changes
- Extend to renter-occupied and multi-family situations (48% of dwellings!)

## 2. Improve behavioral recommendations

- To better match what people want to know
- Rather than standard/average stories
- Provide supporting products

## 3. Home energy audits don't have to be only about selling technical efficiency

- Could be about better use and understanding options



# END



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