Energy Efficiency

Economics & Policy

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Intro

Roadmap

- Discuss what energy efficiency means in economic terms, and why it's so popular in policy circles
- Today: Go through Allcott & Greenstone model of EE and explanations for the energy efficiency gap
- Next class: Nudges
- Next week: Weatherization
- Empirical theme: field experiments

Americans spend a lot of money on energy

In 2023, BLS Consumer Expenditure Survey reports that the average US household spent:

- $2,694 on gasoline
- $1,762 on electricity
- $540 on natural gas
- $140 on fuel oil

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In 2023, BLS Consumer Expenditure Survey reports that the average US household spent:

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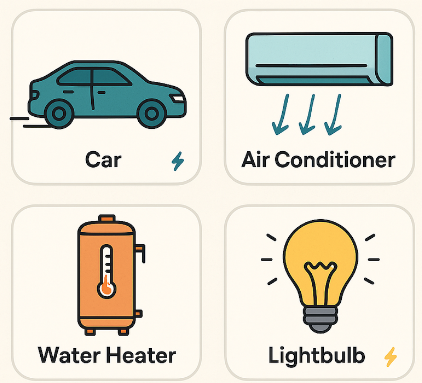
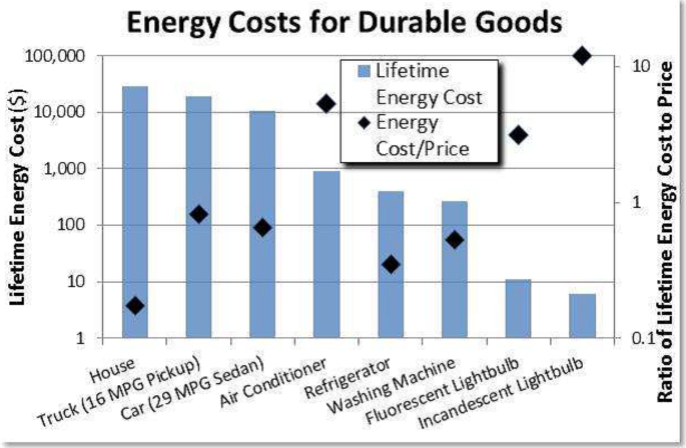
Important: We don't get any utility from energy directly.

Actual utility comes from energy "services" generated *when combined with other capital*



What matters for utility is the *total* cost of energy services: capital costs + energy costs

The ratio of energy costs to capital costs varies a lot



Source: Allcott & Greenstone (2012)

Many policies in place to encourage the adoption of more efficient energy-using capital

Policy	Years	Magnitude
	Standards	
Appliance efficiency standards	1988-	$2.9 billion annual cost
Building codes	1978-	
CAFE standards	1978-	$10 billion annual cost
	Prices	
Federal Hybrid Vehicle Tax Credit	2006-2010	$426 million annual credit
Gas guzzler tax	1980-	$200 million annual revenues
Weatherization Assistance Program	1976-	$250 million annual cost
Demand-Side Management	1978-	$3.6 billion annual cost
2009 Economic Stimulus	2009-	$17 billion total
	Information and Marketing	
Fuel economy labels	mid-1970s	
Appliance “yellow tags”	1980	
Energy Star program	1992	$50 million annual cost

Source: Allcott (2015)

Energy efficiency vs. energy taxes

- Consider the market for oil.
- CO2 emissions contribute to climate change.
- Two ways to reduce oil consumption:
  - Tax oil (increase price p)
  - Encourage energy efficiency (fuel economy)

One of the reasons EE is so popular is that people believe it's a "win-win" proposition

This sentiment has been popular for four decades now (Lovins 1979, McKinsey & Co. 2009)

Win #1: Energy consumption is associated with many externalities

- reducing energy use brings us closer to the social optimum
- this seems pretty clear

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Win #1: Energy consumption is associated with many externalities

- reducing energy use brings us closer to the social optimum
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Win #2: Consumers fail to take up **privately** optimal EE investments

- for example because they do not have correct information
- correcting this mistake saves them money
- much less obvious (to economists)

JOSEPH R. BIDEN

46th President of the United States: 2021 - present

FACT SHEET: Biden-Harris Administration Takes More Than 100 Actions in 2022 to Strengthen Energy Efficiency Standards and Save Families Money

December 19, 2022

Department of Energy Proposes New Lightbulb Efficiency Rule

Today, the White House and the Department of Energy (DOE) announced that the Biden-Harris Administration has surpassed its goal to take 100 actions in 2022 to strengthen energy efficiency standards for a range of appliances and equipment to lower costs for American families. These new standards advanced by the Biden-Harris Administration will help save the average family at least $100 annually through lower energy bills.

Model

A model of energy efficiency

Total cost (TC) of energy using capital:

$$\underbrace{TC}_{\text{total cost}} = \underbrace{c}_{\text{capital cost}} + \underbrace{epm/(1+r)}_{\text{energy cost}}$$

- c is the up-front cost of capital

A model of energy efficiency

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- m is the amount the good is used (ie miles driven)
- p is the price of energy
- e= energy efficiency (energy use / unit m)

A model of energy efficiency

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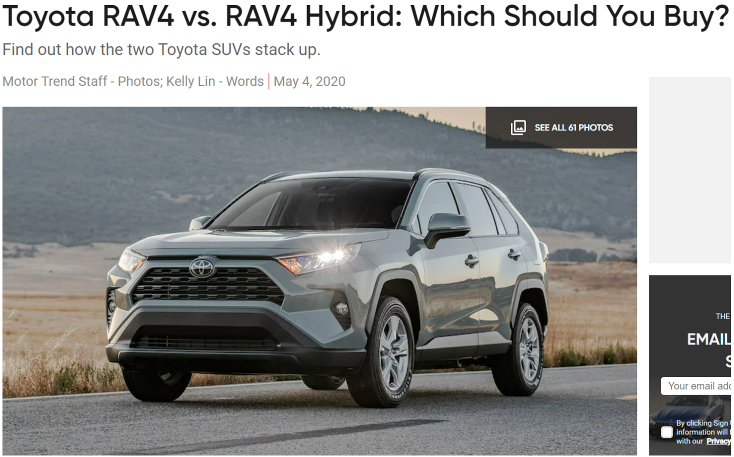
- c is the up-front cost of capital
- m is the amount the good is used (ie miles driven)
- p is the price of energy
- e= energy efficiency (energy use / unit m)
- r is the discount rate
  - For simplicity, assume all energy expenditure occurs in a single future period t. r is the rate of time preference between utility now and t years from now.

Example: 2022 Toyota RAV4

Imagine two identical goods, that differ only on energy use and up-front cost.



- Fuel economy (e): 27 vs 41 MPG (city)
- Up front cost (c): \$26,975 vs \$29,575

For otherwise identical products, consumers should minimize total costs

- Two goods: inefficient ($j = I$); efficient ($j = E$)
  - Efficient good cost more today: $c_E - c_I > 0$
  - But saves on energy tomorrow: $e_E - e_I < 0$
- Total cost of good j

$$TC_j = c_j + e_j pm/(1+r)$$

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$$TC_j = c_j + e_j pm/(1 + r)$$

- purchase E if $TC_E < TC_I$
- implies:

$$c_E - c_I < \frac{(e_I - e_E)p}{(1 + r)} * m$$

Who should buy the efficient good?

Energy expenditure on service:

$$\text{Expense} = \left(\frac{\text{energy}}{\text{usage}}\right)(\text{usage})\,(\text{energy price})\,(\text{discount factor})$$

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Last three terms are random variables that vary across individuals (i)

$$\text{Expense}_i = (e)\,(m_i)\,(p_i)\left(\frac{1}{1+r_i}\right)$$

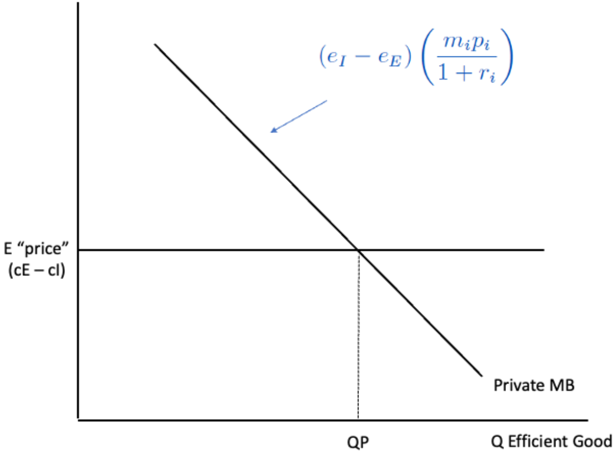
Tracing out a demand curve for the efficient good

- Individual energy savings from buying E:

$$(e_I - e_E)\left(\frac{m_i p_i}{1+r_i}\right)$$

- If we arrange everyone in descending order of this value, this traces out a demand curve for E (draw this)
- Assume everyone faces the same upfront costs. Then the difference in these costs $(c_E - c_I)$ represents the "price" of E.
- Everyone who saves more than this amount should buy E. Everyone who saves less should not.

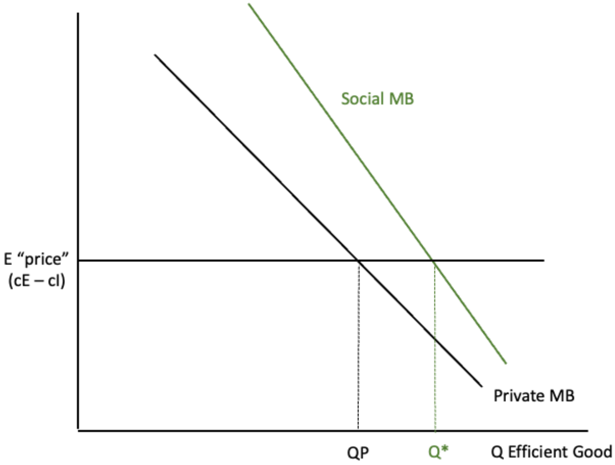
Rational private demand for energy efficiency



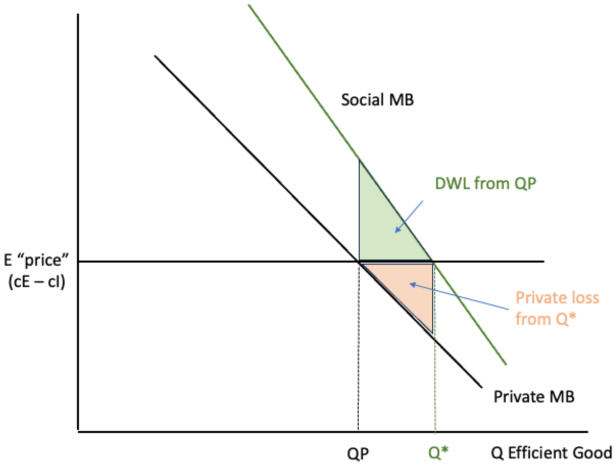
EE gap

We know that people use too much energy because of unpriced externalities

In the model, p should be $p_{social} = p + \phi$, where ϕ is the marginal external cost of energy use



In the rational model, consumers would lose money if they were more efficient. But society would gain.



The energy efficiency "gap" (or "energy paradox")

- Energy paradox is the observation that energy-efficiency technologies that would *privately* pay off for adopters (in terms of energy cost savings) . . . are nevertheless not adopted
  - ie $TC_E < TC_I$, but consumers still chose I

The energy efficiency "gap" (or "energy paradox")

- Energy paradox is the observation that energy-efficiency technologies that would *privately* pay off for adopters (in terms of energy cost savings) ... are nevertheless not adopted
  - ie $TC_E < TC_I$, but consumers still chose I
- What are some possible reasons for this? Why might consumers choose I even if the energy savings outweigh the upfont cost?

$$c_E - c_I < \frac{(e_I - e_E)p}{(1+r)} * m$$

Behavioral economics: humans vs "econs"

Economics historically assumed that agents were infallible, computationally limitless and rational.

- implies people must be cost minimizing

In the real world, human beings:

- make mistakes (misoptimize)
- don't like thinking hard about things (there is a cost to optimization)
- are inattentive
- experience regret/ loss aversion
- care about peer effects
- are easily swayed by default options
- overly discount the future (present bias)

This is important for energy efficiency because it can

- explain the gap
- suggest ways to correct it that don't involve taxes/ regulation
    - (and cost much less)

Innattention

Sometimes information is presented correctly, but consumers are just not attentive to it (or it isn't salient enough)

Example: Online shipping (Hossain & Morgan 2006)

- total cost of buying a something online = price of the good + shipping costs
- consumers should only care about the total cost.
- Experiment: on eBay, randomly vary good prices and shipping costs of Xbox games, keeping the total cost fixed
- Result: using a lower price leads to more bidders and higher revenue
- Interpretation: shoppers forget to think about shipping costs when bidding
- EE Implication: Energy costs are less salient than up front costs, so people might underweight them

Which choice leads to greater fuel savings?

(A) a 15 mpg Cadillac Escalade instead of a 12 mpg Chevrolet Suburban
(B) a 50 mpg Toyota Prius instead of a 29 mpg Toyota Corolla?

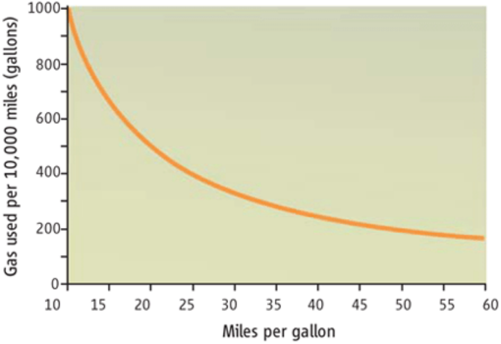
Source: Wolfram blog post (2013)

Assume you would drive the same distance and speed in each car.

The MPG Illusion

Assume you're going to drive 100 miles,

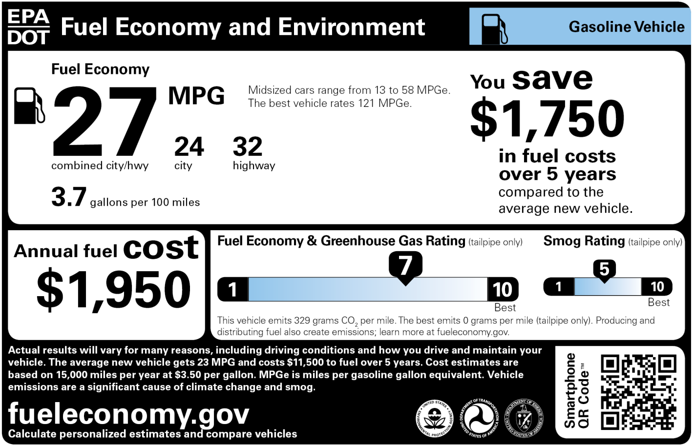
- (A) 8.3 gal in the Suburban vs 6.7 gal in the Escalade → save 1.6
- (B) 2 gal in the Prius vs 3.4 in the → save 1.4
- So the correct answer is A. Why?



Source: Larrick and Soll (2008)

Gas demand = miles driven * (gas/mile)
What we care about is GPM, not MPG!

Solution: New Fuel Economy Labels

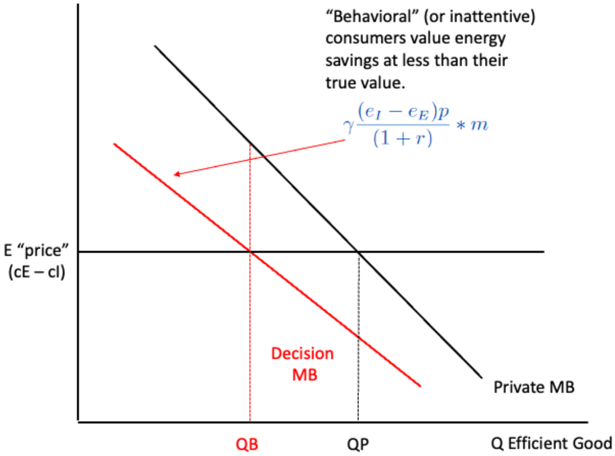


Consumers can still choose gas guzzlers if they want, but now they have better information to make their decision.

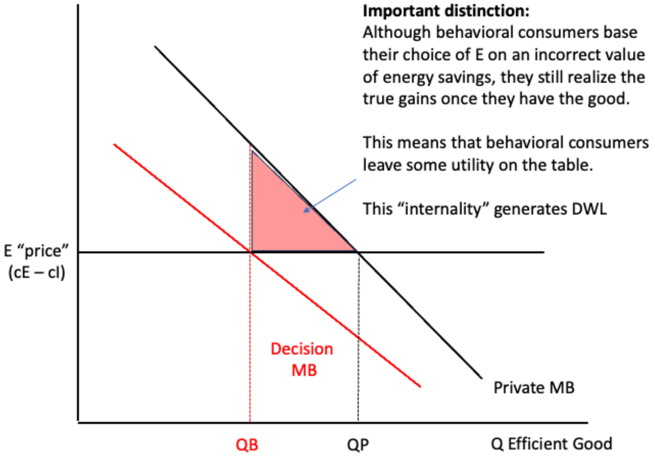
Updating the model to account for consumers undervaluing energy savings

Consumers value a future (discounted) dollar saved at $\gamma < 1$

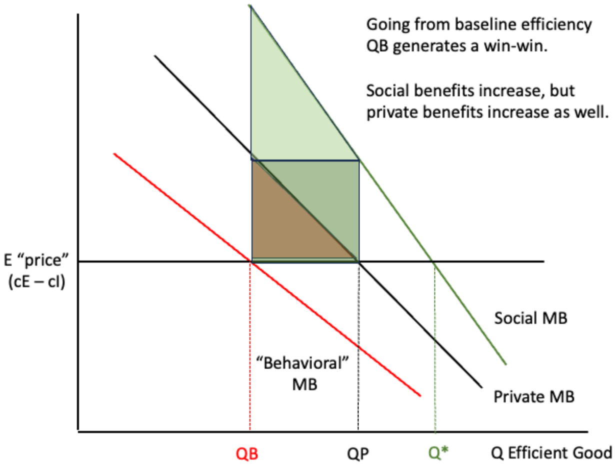
Adopt if: $c_E - c_I < \gamma \frac{(e_I - e_E)p}{(1+r)} * m$



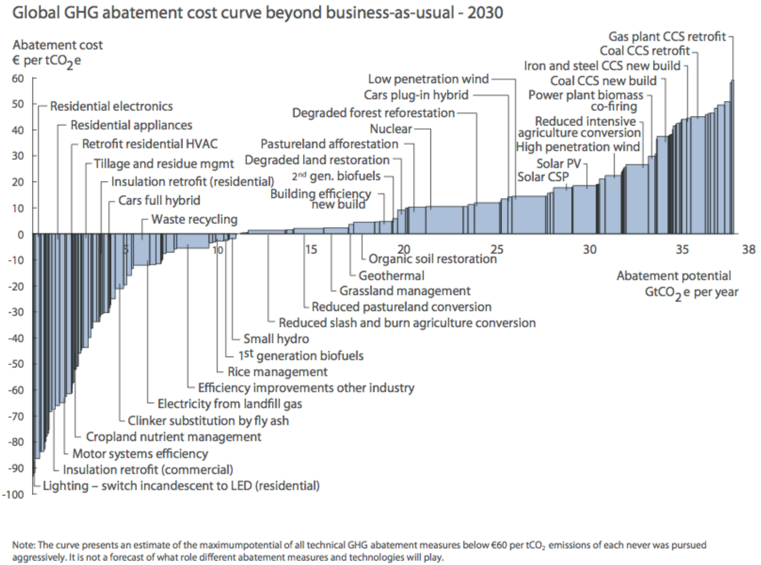
Now increasing energy efficiency can actually increase private benefits



Now increasing energy efficiency can actually reduce both externalities and internalities



Energy Efficiency: Is there a free lunch?



Source: McKinsey & Company (2009)

How do we really know people are making mistakes?

$$c_E - c_I < \frac{(e_I - e_E)p}{(1+r)} * m$$

- Need to know:
  - True energy savings
  - True usage m and energy prices p
  - Real discount rate r
- If we mis-measure any of these, we might incorrectly conclude that people are making mistakes
- What are some other "rational" explanations for low takeup?

Some "rational" explanations for low takeup

Information Problems

- Principal-agent issues (e.g., renters/landlords – Davis 2011)
- Lack of information, asymmetric information (research on residential construction, Jaffe & Stavins 1995; Palmer et al. 2011)

Capital Market Failures

- Liquidity constraints
- Particularly relevant in developing countries

Measurement error

- Uncertainty over benefits, energy prices

EE experiments

Measuring the energy efficiency gap

- Can make assumptions about discount rates (r), usage (m), and energy prices (p), and see if observed takeup matches predicted "rational" takeup. (What McKinsey does)
- But any thing we get wrong there will be attributed to innattention/mistakes (low γ)
- what we'd like to do is find situations where we "know" $\gamma = 1$, and compare what people buy in the baseline.
- the way economists typically do this is to run an experiment
  - pick consumers
  - randomly give them perfect information about energy savings
  - compare to consumers in control group

Example: Water Heaters

The Role of Sales Agents in Information Disclosure: Evidence from a Field Experiment

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With a large nationwide retailer, we run a natural field experiment to measure the effects of energy use information disclosure, customer rebates, and sales agent incentives on demand for energy-efficient durable goods. Although a combination of large rebates plus sales incentives substantially increases market share, information and sales incentives alone each have zero statistical effect and explain at most a small fraction of the low baseline market share. Sales agents strategically comply only partially with the experiment, targeting information to more interested consumers but not discussing energy efficiency with the disinterested majority. These results suggest that seller-provided information is not a major barrier to energy-efficiency investments at current prices in this context.

Data, as supplemental material, are available at http://dx.doi.org/10.1287/mnsc.2015.2327.

Keywords: energy efficiency; energy-using durables; information disclosure; randomized field experiments

History: Received March 16, 2015; accepted July 17, 2015, by John List, behavioral economics. Published online in *Articles in Advance*.

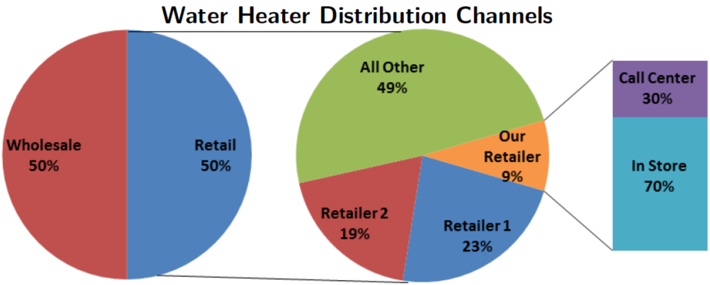
Setup

What we do:

- Focus on water heaters: Second largest home energy use: Energy cost = 29 billion/year
- Lifetime energy cost > upfront price
- Mundane product → conceptually interesting
- Randomized control trial (RCT) with large nationwide retailer
- At call center: vary Energy Star info, rebates, and sales incentives
- Measure effects on demand
- Extensive surveys and audits of sales agents and consumers

Market overview

- Approx one water heater per US household
- Half fueled by natural gas

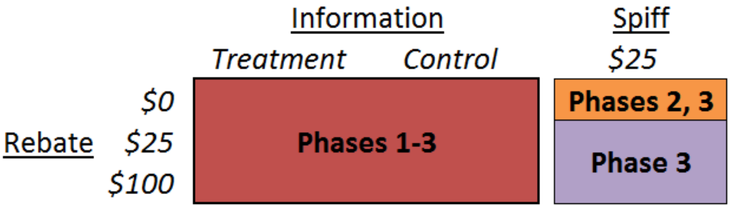


- 96% of production from three manufacturers

Product overview

- 6-year warranty: $\$ \approx 220$ incremental price, $\$ \approx 40$/year savings
  - 13-18% IRR
- But Energy Star market share $\approx 1/30$.
- 12-year warranty: Energy Star bundled with premium features

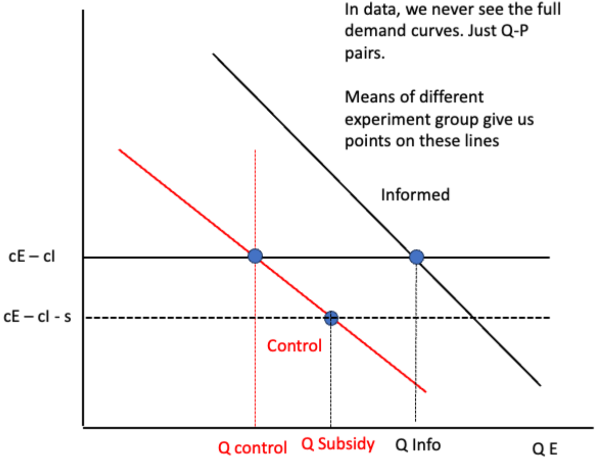
Experimental design



1/3 of agents randomly assigned to only Info Control

Phase	Dates	Sales
1	Nov 21-April 6	8875
2	April 7 -June 13	3658
3	June 14-July 7	1038

Mapping experiment to the model



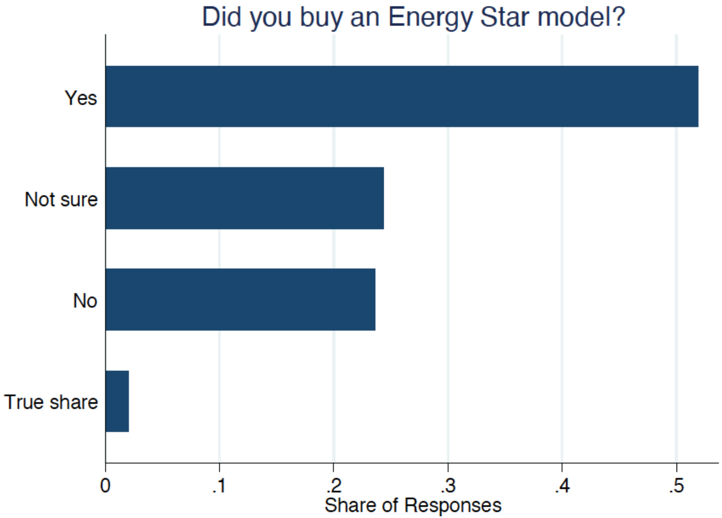
Info script

Let me take a moment to tell you about our Energy Star models. Energy Star water heaters cost about $220 more than a standard model, but they save a typical household $40 each year, so you would make up that price difference in about six years. Over 12 years, which is the normal life of a water heater, you would save $480 in energy bills. Energy Star models may not be available for every home. If possible, would an Energy Star water heater be of interest to you?

Effect of treatments on Energy Star takeup

1(100 Rebate)	0.006	0.012	0.037
	(0.003)**	(0.005)**	(0.013)***
1(25 Rebate)	0.001	0.002	0.003
	(0.001)	(0.003)	(0.005)
1(Information)	0.000	0.000	0.004
	(0.002)	(0.004)	(0.007)
1(Spiff)	-0.002		0.001
	(0.002)		(0.007)
1(Spiff and 25 Rebate)	-0.004		-0.007
	(0.002)**		(0.005)
1(Spiff and 100 Rebate)	0.040		0.219
	(0.022)*		(0.118)*
R^2	0.01	0.01	0.01
N	23,347	20,240	23,347
Regression Type:	ITT	Self-Report IV	Scaled ITT

Consumers are confused about Energy Star



But they do not underestimate energy savings

How much money do you think the natural gas for the water heater will cost each year?				
10th	**50th**	**90th**	**Mean**	**Yellow Tag**
50	200	600	305	Approx 300
How much less money do you think the natural gas would cost each year for an Energy Star water heater compared to a similarly-sized non-Energy Star water heater?				
10th	**50th**	**90th**	**Mean**	**Yellow Tag**
0	50	300	129	Approx 30
Implied percent savings from Energy Star				
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Punchline: They are just not interested in the value proposition.

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What are some reasons for this?

Nudges and Libertarian Paternalism

Paternalism in public policy

- Governments frequently intervene to protect us from:
  - Imperfect information
  - Failure to maximize long-run welfare
- Many times the "solution" is to outright ban the activity in question. Examples:
  - Drug, alcohol, and cigarette taxes and bans
  - Food and consumer product safety standards
  - Helmet and seat belt laws
  - Usury laws and other financial services regulation

Biden administration puts the final nail in the coffin for incandescent light bulbs

PUBLISHED WED, AUG 2 2023•1:46 PM EDT

Catherine Clifford
@IN/CATCLIFFORD/
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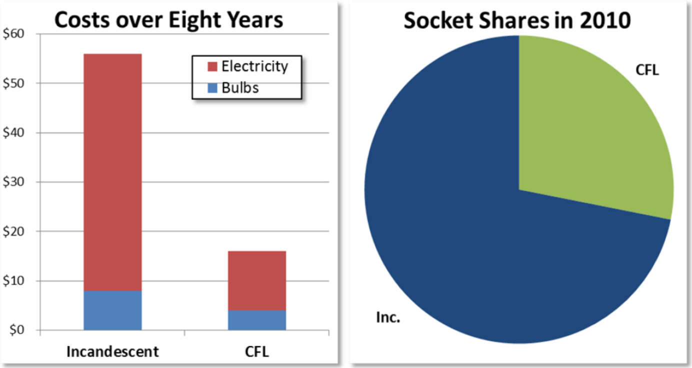
WATCH LIVE

KEY POINTS

- On Tuesday, the Biden administration put the final nail in the coffin for incandescent light bulbs, the result of a decade-plus-long legislative path. The first step in the journey began in 2007 when the Energy Independence and Security Act passed.
- The phase-out of light bulbs that have energy efficiency standards of more than 45 lumens per watt has been gradual. On Tuesday, the last stage of that gradual roll-out ended.

Are we sure *everyone* is making a mistake?

"The Lightbulb Paradox"



Source: Allcott & Taubinsky (2015)

- Incandescents cost less ($1 vs $4), but don't last as long
- What explains low takeup here?
  - **Irrational**: People uninformed, energy savings not salient
  - What are some **Rational?** explanations?

Appealing alternative: policy "nudges"

- Insights from behavioral economics has lead to interest in a softer form of paternalism, known as "Libertarian Paternalism"
  - *Nudge*, by Sunstein and Thaler (highly recommended summer reading)
- Not an oxymoron
  - Idea is to design policy in that can correct behavioral failures, but still allows people to make whatever choice they want

How does this paper answer this question?

Evaluating Behaviorally Motivated Policy: Experimental Evidence from the Lightbulb Market†

By Hunt Allcott and Dmitry Taubinsky*

Imperfect information and inattention to energy costs are important potential motivations for energy efficiency standards and subsidies. We evaluate these motivations in the lightbulb market using a theoretical model and two randomized experiments. We derive welfare effects as functions of reduced-form sufficient statistics capturing economic and psychological parameters, which we estimate using a novel within-subject information disclosure experiment. The main results suggest that moderate subsidies for energy-efficient lightbulbs may increase welfare, but informational and attentional biases alone do not justify a ban on incandescent lightbulbs. Our results and techniques generate broader methodological insights into welfare analysis with misoptimizing consumers. (*JEL* D12, D83, H21, H31, L67, Q41, Q48)

Allcott and Taubinsky (2015) experiment

"The Lightbulb Paradox"

We have given you a $10 shopping budget to purchase a package of light bulbs. Your first 15 purchase decisions will concern the two packages of light bulbs shown below.

Choice A	Choice B
Philips 60-Watt-Equivalent Compact Fluorescent Light Bulb, 1-Pack	**Philips 60-Watt Incandescent Light Bulbs, 4-Pack**
	

Click for detailed product information

Between the 15 decisions, the only thing that varies is the price. Each of these decisions has a chance of being the one choice (out of 30) that will become your official purchase, so you should think about each purchase carefully. Whatever money you do not spend on the light bulbs, you get to keep: any remaining money will be provided to you as cash-equivalent bonus points. Please think about each decision carefully.

Here is an example of how this might work. After you make all your decisions, suppose that Decision Number 6 from the set below were selected as your official purchase.

CFLs last longer than incandescents. At average usage:

- Incandescents burn out and have to be replaced every year.
- CFLs burn out and have to be replaced every eight years.

If one incandescent bulb costs $1 and one CFL costs $4, this means that the total purchase prices for eight years of light are:

- $8 for incandescents
- $4 for CFLs

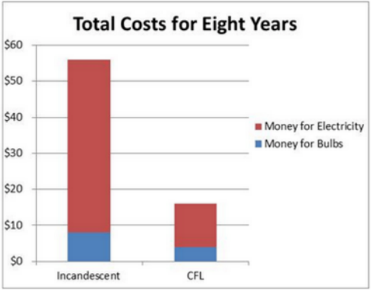
Also, CFLs use less electricity than incandescents. At national average usage and electricity prices:

- A standard (60-Watt) incandescent uses $6 in electricity each year.
- An equivalent CFL uses $1.50 in electricity each year.

Thus, for eight years of light, the total costs to purchase bulbs and electricity would be:

- $56 for incandescents: $8 for the bulbs plus $48 for electricity
- $16 for a CFL: $4 for the bulbs plus $12 for electricity

The graph below illustrates this:

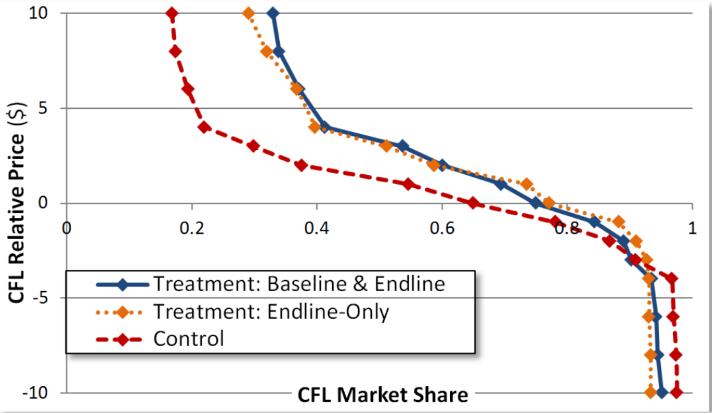


AT ask people to make 15 choices with different relative prices. Why?

Now please make your decisions for each of the 15 choices below.

Decision Number	Choice A 60-Watt-Equivalent Compact Fluorescent Light Bulb, 1-Pack	Choice B 60-Watt Incandescent Light Bulbs, 4-Pack
	Purchase Choice A for free	Purchase Choice B for $10
1)	○	○
	Purchase Choice A for free	Purchase Choice B for $8
2)	○	○
	Purchase Choice A for free	Purchase Choice B for $6
3)	○	○
	Purchase Choice A for free	Purchase Choice B for $4
4)	○	○
	Purchase Choice A for $1	Purchase Choice B for $4
5)	○	○
	Purchase Choice A for $2	Purchase Choice B for $4

Results



Source: Allcott & Taubinsky (2015)

- For many consumers, $\gamma < 1$
- But some consumers *really* do not like CFLs

Maybe banning incandescants isn't a good idea?

Policy results

Welfare Analysis Under Alternative Assumptions

	Scenario	Optimal Subsidy ($/pack)	Ban Welfare Effect ($/package)	Ban Welfare Effect (% of surplus)
1	Base	3	-0.44	-41

- A subsidy of $3 would maximize (private) welfare
- But a ban would not increase welfare (based on internalities alone)

Updating the model

- I and E may differ on non-energy dimensions (ie light quality)
  - if goods aren't perfect substitutes, and people value them based on non-energy dimensions, we need to account for this.
- let ξ represent the incremental utility "cost" of I.
- now the decision rule is adopt E if:

$$\gamma pm(e_I - e_E)/(1 + r) > (c_E - c_I) + \xi$$

Updating the model

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- An energy efficiency "gap" will exist whenever $\gamma < 1$
    - ie consumers are inattentive to or uninformed about energy costs
- but simply observing that people are not buying the efficient good based solely on energy and up front costs is not enough to conclude this.

Measuring energy savings

What if we're not sure how efficient a good is?

- In our simple model of energy efficiency, an investment E is worth making if energy savings are worth more than the up front cost (and any difference in preference for the good)

$$\gamma pm(e_I - e_E)/(1+r) > (c_E - c_I) + \xi$$

- A key assumption is that we *know* the energy rating e.
- In reality, this is more complicated for many goods
  - Cars may perform one way in ideal track conditions, and another in the real world
  - Energy lost via heat from an incandescent depends on how long it's on and ambient temperature
- What matters to consumers is *realized* energy savings
- This is also what matters for policymakers who might use taxpayer money to subsidize these investments

Case Study: Weatherization Assistance Program

- Largest residential energy efficiency program in the US
  - Benefited over 7 million homes since 1976
- Provides free home improvements to low income households
- The 2009 ARRA (stimulus) dramatically increased WP funding
  - $450 million in 2009
  - $5 billion 2011-2012

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- The 2009 ARRA (stimulus) dramatically increased WP funding
  - $450 million in 2009
  - $5 billion 2011-2012
- How large are the savings from this program? Was all this taxpayer spending worth it?
  - DOE says it was a huge success
  - Some economists question these results
  - Comparing the two approaches provides a good introduction to the challenges involved in measuring energy savings

Measuring the gains from weatherization

- Participants first receive a free audit to identify needs
  - insulation, new windows, furnace upgrades, etc.
- Auditor predicts the savings from each measure and makes recommendations.
- This audit data and information on local weather, etc are fed into a model, the National Energy Audit Tool (NEAT).
- These estimates are just guesses, so we want to *measure* the savings using billing data.

DOE's evaluation found the WP to be a resounding success

According to the , DOE press release:

- For every dollar invested in weatherization, $4.50 was generated in energy and non-energy benefits.
- Approximately 8,500 jobs were created or retained.
- Single-family homes saved an average of $283 annually on energy costs.
- Carbon reduction of 2.2 million metric tons.

Conclusion: "The results demonstrate that weatherization provides cost-effective energy savings and health and safety benefits to American families."

Here is the full report and summary of results.

How did the DOE arrive at these findings?

- Fowlie, Greenstone and Wolfram looked under the hood of the 4,500 page (!) DOE study
    - Our judgment is that many of the DOE's conclusions are based on dubious assumptions, invalid extrapolations, the invention of a new formula to measure benefits that does not produce meaningful results, and no effort to evaluate statistical significance
- Found numerous mistakes/ inconsistencies
- DOE had no control group for health and well being measures

DOE energy calculations involve two comparisons

- Observed the treated population before and after, and a control group after only.
- Can't do difference-in-differences, so they average the differences between these groups...

  To the best of our knowledge, this approach has never been used in any textbook or research paper previously.....The approach to estimating nonenergy benefits is unrecognizable, and we believe the resulting estimates have no meaningful interpretation

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  - What does this mean? What are some stories here?

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- More importantly: FGW argue that weatherization is a "purposeful" decision.
  - What does this mean? What are some stories here?
- DOE implicitly assumes no selection

Who opts into weatherization?

- Consumers have beliefs about how much energy they will use with and without weatherization
  - Note these could be biased or just plain wrong
- There could also be other things they do / don't like about weatherization
  - Maybe it's a hassle to install
- Adopt if:

$$\text{Expected savings } + \text{non-energy benefits} > \text{weatherization cost}$$

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- Who adopts? What type of households?
- Do you think these households would use more or less energy than average without weatherization?

Estimating the Causal Effect of Weatherization

Each individual (i) has two potential outcomes Y (energy use)

- one where they have weatherization (Y_{i1})
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Fundamental Problem of Causal Inference:
We only every observe one state of the world for each individual.

To make progress, we are forced to compare households that got the treatment to those that didn't. How bad is this?

Selection Bias

Want to learn about the true population average treatment effect (average savings from weatherization)

$$\beta^{ATE} = E[Y_{i1} - Y_{i0}]$$

What if we compare WP and no-WP homes:

$$\begin{aligned} \hat{\beta} &= E[Y_{i1}|WP_i = 1] - E[Y_{i0}|WP_i = 0] \\ &= E[Y_{i1}|WP_i = 1] - E[Y_{i0}|WP_i = 1] \qquad \text{(Causal Effect)} \\ &\quad + E[Y_{i0}|WP_i = 1] - E[Y_{i0}|WP_i = 0] \qquad \text{(Selection bias)} \end{aligned}$$

Our estimate of the energy saved is biased by "selection" – the difference in the untreated state of the world, across households who do and don't get WP.

What if we run an experiment?

- Imagine we could randomly assign households to weatherization.
- Since we assign WP_i randomly, our selection bias term $E[Y_{i0}|WP_i = 1] - E[Y_{i0}|WP_i = 0]$ equals zero.

What if we run an experiment?

- Imagine we could randomly assign households to weatherization.
- Since we assign WP_i randomly, our selection bias term $E[Y_{i0}|WP_i = 1] - E[Y_{i0}|WP_i = 0]$ equals zero.
- Unfortunately, in the real world we can't force people to participate in this program.
- We can however, *encourage* them.
    - this could be a monetary incentive, advertising, persuasion, etc
- This is what Fowlie, Greenstone and Wolfram did

Fowlie, Greenstone and Wolfram (2015)

- 30,000 WP-eligible households in Michigan
- Randomized encouragement design:
  - 25% of households put in treatment group
  - received extensive outreach and assistance signing up for WP
  - but control households *still eligible* for WP under own volition

FGW encouragement activities

Encouraged group (households)	8,648
Initial home visits	6,694
Robo-calls	23,500
Personal calls	9,171
Follow up appointments	2,720
Average cost/encouraged hh	$55.00

Note: The table summarizes efforts to encourage a group of Michigan households to take up weatherization assistance. These households were selected randomly from a sub-population of households who were located in the service territory of our partner utility and presumptively eligible based on ex ante available income information.

Result 1: People do not seem to want to weatherize

- Average WP household received $5,150 worth of home improvements **totally free**
- Yet in the control group, only 1% opt into the program
- In the treatment group, only 6% opt in despite extensive encouragement
- What do people make of this?

Result 1: People do not seem to want to weatherize

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- Yet in the control group, only 1% opt into the program
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- What do people make of this?
- Takeway: there must be large hassle costs associated with this program.
    - What might those be?

The authors estimate two models of energy savings

$$ln(y_{imt}) = \beta \mathbf{1}\{WP\}_{imt} + \alpha_{im} + \alpha_{mt} + \epsilon_{imt}$$

- Quasi-experimental approach: Difference in differences
  - Estimates average treatment effect on treated (ATET)
- Experimental approach: Instrumental variables
  - Typically we think of an RCT as randomly assigning $\mathbf{1}\{WP\}$
  - But in this case it just increased the probability of assignment
  - Can use IV to predict probability of $\mathbf{1}\{WP\}$, ie use treatment group assignment as an instrument
  - If treatment effects differ across households, this will recover the local average treatment effect (LATE)
    - Or the treatment effect of "compliers"

Result 2: Energy savings were 10-20%

Panel A: Dependent variable is monthly energy consumption (in logs)

	Total Energy		Gas	Electricity
	(1) OLS-FE	(2) IV-FE	(3) IV-FE	(4) IV-FE
WAP	-0.10**	-0.20*	-0.21**	-0.10
	(0.01)	(0.08)	(0.08)	(0.10)
Imputed baseline consumption MMbtu/month	7.52		6.38	2.19
F-statistic	.	267.41**	260.10**	266.78**
Households	27,990	27,229	26,054	27,115
Observations	1662781	1653583	1528526	1638337

- IV $<$ OLS. Suggests selection bias term $E[Y_{i0}|WP_i = 1] - E[Y_{i0}|WP_i = 0]$ is greater than zero.
- ie households selecting into WP would have had higher than average non-WP usage

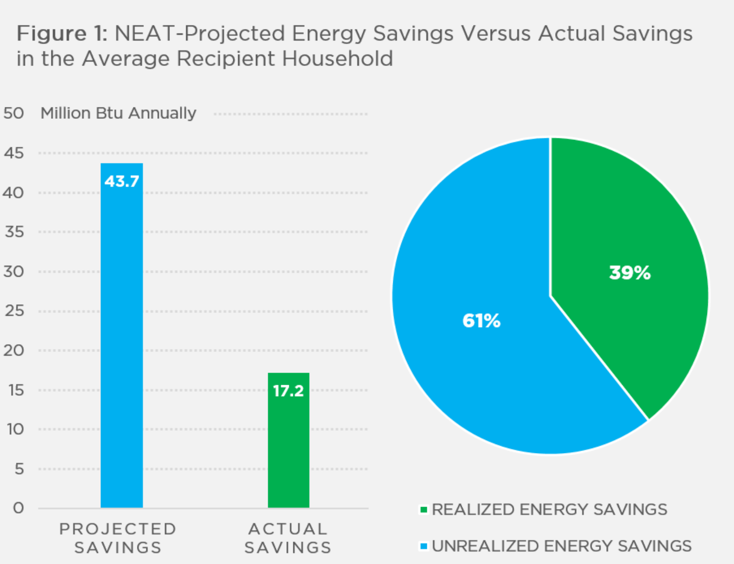
While these savings are substantial, they are significantly less than the up front costs

Panel B: Present value of (discounted) savings

Time Horizon	Discount rate		
	3 percent	6 percent	10 percent
10 years	\$2,003	\$1,728	\$1,443
16 years	\$2,949	\$2,373	\$1,837
20 years	\$3,493	\$2,693	\$1,999

- Average WP household received \$5,150

Engineering model projected savings were 2.5 times larger



Source:Fowlie (2015)

Even accounting for environmental externalities, the program still has negative costs

Ex Ante (NEAT) vs Ex post (FGW) benefit estimates

Panel C: Social internal rate of return		
10 years	-1.0%	-20.0%
16 years	5.4%	-9.5%
20 years	7.0%	-6.1%
Panel D: CO_2 abatement cost - 3 percent discount (\$/ton CO_2)		
10 years	\$29	\$552
16 years	-\$19	\$329
20 years	-\$35	\$255

Could low savings be due to a rebound effect?

- What is the rebound effect?
- Do you think it would be large here?

Could low savings be due to a rebound effect?

- What is the rebound effect?
- Do you think it would be large here?
- Why does it matter if there's a rebound effect?

We don't have much evidence on rebound effects

- Typically hard to measure
- FGW randomly contacted a subset of treated and non-treated households
- Went to 1,658 households on cold days
  - Asked what the thermostat was set to
- 899 people let them in the house (688 let them close the door)
  - Moved to the center of the room and waved two thermometers around

Result 3: No evidence of a rebound effect

	Thermometer (1)	Thermometer (2)	Thermostat (3)	Thermostat (4)
Base temperature	72.36**	72.17**	69.26**	68.91**
	(0.95)	(1.24)	(0.96)	(1.29)
Weatherized home	0.57	0.65	-0.57	-0.56
	(0.41)	(0.44)	(0.29)	(0.33)
Heating Degree Days	-0.16**	-0.15**	0.04	0.05
	(0.03)	(0.04)	(0.03)	(0.04)
Propensity Score Weights?	N	Y	N	Y
R-squared	0.02	0.02	0.01	0.01
Observations	1359	1359	899	899

Note: The table reports measured indoor temperature differentials across weatherized (WAP) and unweatherizedhouseholds. Columns (1) and (2) have the indoor thermometer temperature reading as a dependent variable while columns (3) and (4) use the survey thermostat readings. Columns (2) and (4) are weighted so that surveyed population better represents total quasi-experimental sample. Standard errors clustered at the household level.

Call in the auditors?

- What did people learn from this debate?

Call in the auditors?

- What did people learn from this debate?
- I personally think it's unfair lump ORNL together with polluters in India
- But selective attention affects all of us, and ORNLs response shows clear signs of this.
- Highlights the benefits of independent evaluators

Weatherization Summary

- Energy efficiency
  - engineering models over-estimate
  - people really can't be bothered
  - rebound effect small
- Broader
  - importance of transparent and independent evaluation
  - RCTs in energy able to deal with selection

Energy Efficiency Wrapup

Energy Efficiency Gap Summary

- Long-standing interest in energy efficiency due to externalities.
- More popular than Pigouvian taxes because it seems like a "win-win"
- We describe this claim in a simple economic model that simply says that the net gains to consumers are the energy savings less the up-front cost difference.

$$\text{Net Savings} = pm(e_I - e_E)/(1+r) - \xi - (c_E - c_I)$$

- failure to adopt when net gains are positive is a mistake (and correcting that mistake makes people better off)
- model clarifies what we need to know to conclude people are making mistakes

Quantifying the energy efficiency gap is challenging

- people are heterogeneous
  - particularly wrt to usage m
  - what is the right r ? credit card rate?
  - even if you know those values on average, you would get it wrong for half the population
- goods involve many attributes, not just energy:
  - ξ probably not zero (as in light bulbs)
- we actually don't know $(e_I - e_C)$ with certainty
  - engineering estimates can differ in the real world for lots of reasons (weatherization an extreme example)

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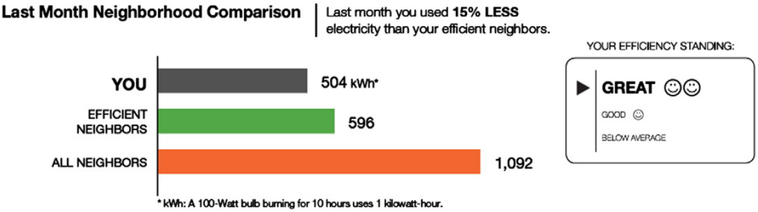
For all these reasons, many simple calculations of the energy efficiency gap (ie McKinsey) are probably misleading.

- Many careful studies have tried to measure the gap using field experiments.
- While people surely make mistakes, the tl;dr from nearly two decades of evidence suggests people aren't making massive mistakes.

Unused this year

Social Norms: The OPOWER experiments



- OPOWER provides information energy efficiency to electriciy consumers
  - social comparison (above)
  - action items (next slide)
- Allcott (2011) randomly varied which households got the information
  - used billing data to estimate the impact on electricity use.

OPOWER information

Action Steps | **Personalized tips chosen for you based on your energy use and housing profile**

Quick Fixes
Things you can do right now

☐ **Adjust the display on your TV**
New televisions are originally configured to look best on the showroom floor—at a setting that's generally unnecessary for your home.

Changing your TV's display settings can reduce its power use by up to 50% without compromising picture quality. Use the "display" or "picture" menus on your TV: adjusting the "contrast" and "brightness" settings have the most impact on energy use.

Dimming the display can also extend the life of your television.

SAVE UP TO
$40 PER TV PER YEAR

Smart Purchases
Save a lot by spending a little

☐ **Install occupancy sensors**
Have trouble remembering to turn the lights off? Occupancy sensors automatically switch them off once you leave a room—saving you worry and money.

Sensors are ideal for rooms people enter and leave frequently (such as a family room) and also areas where a light would not be seen (such as a storage area).

Wall-mounted models replace standard light switches and they are available at most hardware stores.

SAVE UP TO
$30 PER YEAR

Great Investments
Big ideas for big savings

☐ **Save money with a new clothes washer**
Washing your clothes in a machine uses significant energy, especially if you use warm or hot water cycles.

In fact, when using warm or hot cycles, up to 90% of the total energy used for washing clothes goes towards water heating.

Some premium-efficiency clothes washers use about half the water of older models, which means you save money. SMUD offers a rebate on certain washers—visit our website for more details.

SAVE UP TO
$30 PER YEAR

Source: Allcott (2011)

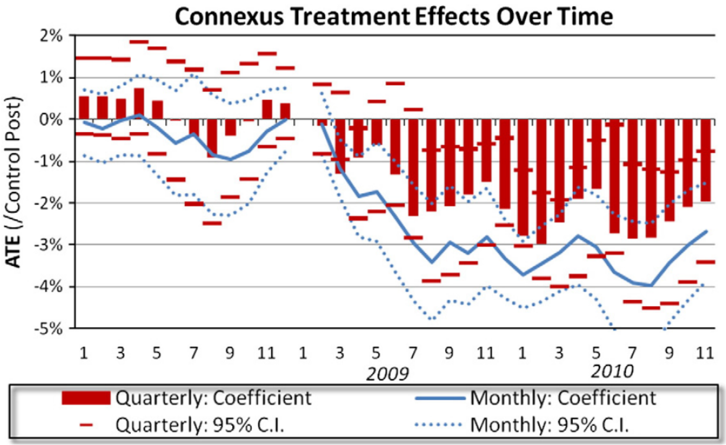
OPOWER Sample

Overview of OPOWER projects.

Experiment			N		
Number	Region	Start date	Households	Treatment	Observations
1	Rural Midwest	February, 2009	8175	8175	343,729
2	Urban Midwest	July, 2009	37,484	18,790	1,264,375
3	Urban Midwest	July, 2009	56,187	28,027	1,873,482
4	Rural Midwest	January, 2009	78,273	39,024	3,421,306
5	Suburban Mountain	October, 2009	11,612	7,254	394,525
6	Suburban Mountain	October, 2009	27,237	16,947	914,344
7	West Coast	October, 2009	24,940	23,906	570,386
8	Rural Midwest	April, 2009	17,889	9,861	794,457
9	Urban Northeast	September, 2009	49,671	24,808	1,712,530
10	Rural Midwest	February, 2009	8429	8,390	360,577
11	West Coast	October, 2008	79,229	34,893	3,121,879
12	West Coast	January, 2009	25,211	5,570	985,148
13	West Coast	January, 2009	17,849	3,852	672,629
14	West Coast	January, 2009	22,965	22,846	893,322
15	West Coast	September, 2009	39,336	19,663	671,990
16	West Coast	March, 2008	59,666	24,761	2,543,372
17	West Coast	April, 2008	24,293	9903	1,036,768
Combined		March, 2008	588,446	306,670	21,574,819

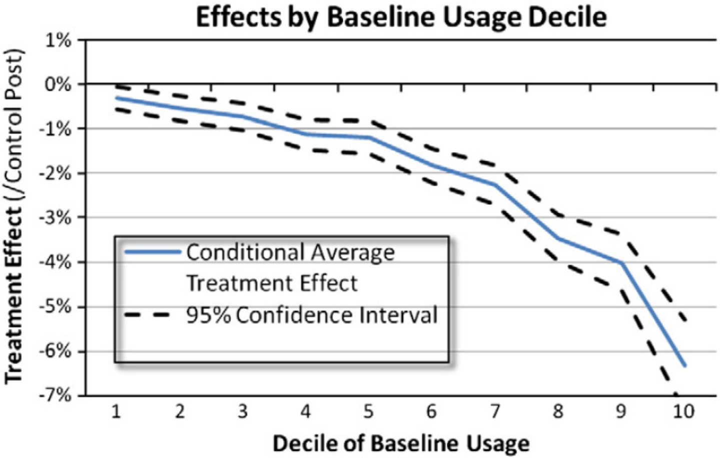
Source: Allcott (2011)

OPOWER results



Source: Allcott (2011)

OPOWER: No "boomerang" effect



Source: Allcott (2011)

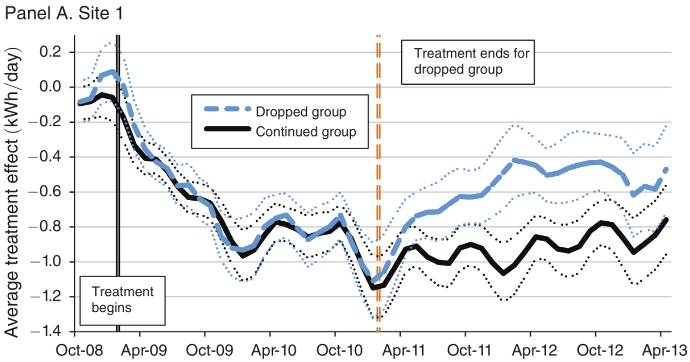
Cost effectiveness

Allcott & Mullainathan (2010)

- OPOWER cost: 2.5 cents per kWh saved
- Long run marginal cost of electricity: 8 cents per kWh
- Net savings: 5.5 cents per kWh
- Marginal carbon intensity: .34 tons CO2 pe kWh
- OPOWER carbon abatement cost: -$165 per ton CO2
- Approximate cost of wind $20 per ton of CO2

Conclusion: Nudges should be an important part of any cost-effective climate policy

OPOWER: Long-run backsliding?



Source: Allcott & Rogers (2014)

Effects decay, but slowly ~ 10-20% per year

What do we take away from OPOWER Results

What do we take away from OPOWER Results

- Something atypical going on
- Possible explanations
  - New information (good)
  - Attention (good)
  - Guilt (bad)

Causal estimation under random *encouragement*

Define (Z_i) as whether or not you're encouraged. Taxonomy of household types (t)

- **Always takers ($t = A$):** take WP without encouragement ($WP_i = 1$ if $Z_i = 1$ or if $Z_i = 0$)
- **Never takers ($t = N$):** don't take WP even if encouraged ($WP_i = 0$ if $Z_i = 1$ or if $Z_i = 0$)
- **Compliers ($t = C$):** only take WP if encouraged ($WP_i = 1$ if $Z_i = 1$; $WP_i = 0$ if $Z_i = 0$)

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Who do we observe take WP in each arm of the experiment?

	Encouraged	Control
WP	Always takers + Compliers	Always takers
No WP	Never takers	Never takers + Compliers

If we compute the average electricity consumption in each group, what do we get?

	Encouraged	Control
WP	Always takers + Compliers	Always takers
No WP	Never takers	Never takers + Compliers

- Let $Pr(t)$ be the probability of each compliance type in the population
- let Y_1^t and Y_0^t be the average electricity use of each type with and without WP.

$$E[Y|Control] = E[Y_{i0}^N]Pr(N) + E[Y_{i0}^C]Pr(C) + E[Y_{i1}^A]Pr(A)$$

$$E[Y|Encouraged] = E[Y_{i0}^N]Pr(N) + E[Y_{i1}^C]Pr(C) + E[Y_{i1}^A]Pr(A)$$

If we difference these two equations, it's clear that they **only** group we learn about from this experiment is the compliers.

Intent to treat & LATE

- If we simply difference the raw average of the treatment and control groups, we get:

$$E[Y|Encouraged] - E[Y|Control] = (E[Y_{i1}^C] - E[Y_{i0}^C])Pr(c)$$

- This is referred to as the Intent to treat effect (ITT)
- The ITT is the average savings for compliers ($E[Y_{i1}^C] - E[Y_{i0}^C]$) times the share of compliers in the population.
- Define the average savings for compliers as the Local Average Treatment Effect (LATE).
- We can estimate the share of compliers by simply comparing the probability of WP in the treatment and control group (in FGW, 6% - 1% = 5%)
- We can then recover the LATE by dividing the ITT by this probability.

Better LATE then never?

This tells us that even with an experiment (or a good instrumental variable), we can *never* learn about the true average savings for the entire population.

The best we can do is to learn the average (causal) effect for housholds that would get WP if encouraged, but otherwise would not.

What do people think of this?