Energy Efficiency

Economics & Policy

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Intro

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.

Roadmap

- Discuss what energy efficiency means and why it's popular
- Go through Allcott & Greenstone model of EE
- Discuss energy evidence for the energy efficiency gap
- Empirical theme: field experiments
  - next class: social comparisons; appliances
  - next week: weatherization

Kaya Identity

$$F = P \times \frac{G}{P} \times \frac{E}{G} \times \frac{F}{E}$$

where:

- F is global CO2 emissions from human sources
- P is global population
- G is world GDP
- E is global energy consumption

How can we reduce emissions?

- Curb growth (P or G/P)
- Innovate/ regulate (reduce F/E)
- Become more energy efficient (reduce E/G)

Energy efficiency vs. energy taxes

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 #2: Consumers fail to take up **privately** optimal EE investments

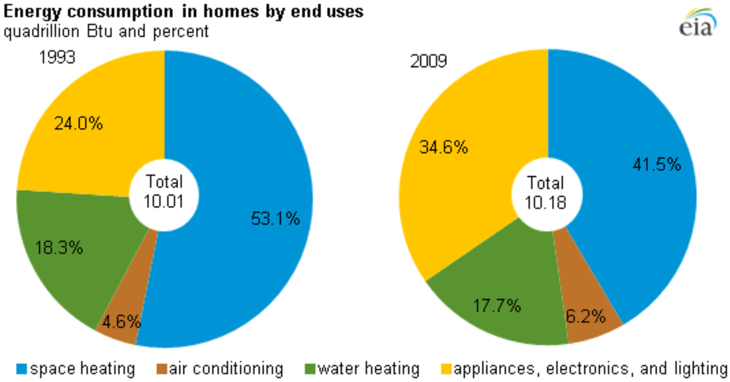
- for example because they do not have correct information
- correcting this mistake saves them money
- much less obvious

Americans spend a lot of money on energy

In 2014, US households spent:

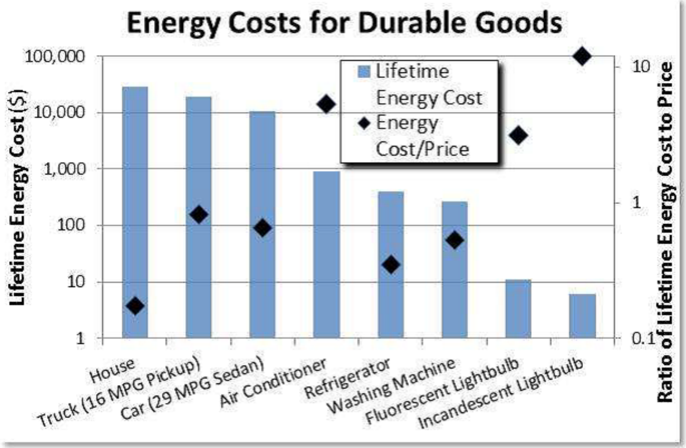
- $2,468 on gasoline
- $1,484 on electricity
- $439 on natural gas
- $152 on fuel oil

We don't derive utility from these goods directly, but from the services they generate *when combined with other capital*



Source: EIA RECS

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)

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

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- p is the price of energy
- e= energy efficiency (energy use / unit m)

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- 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.

Toyota RAV4 vs. RAV4 Hybrid: Which Should You Buy?

Find out how the two Toyota SUVs stack up.

Motor Trend Staff - Photos; Kelly Lin - Words | May 4, 2020

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

A model of energy efficiency

Total cost (TC) of energy using capital:

$$TC_j = \underbrace{c_j}_{\text{capital cost}} + \underbrace{e_j pm/(1+r)}_{\text{energy cost}}$$

- c_j =up front cost (purchase price of product j)
- m= is the amount the good is used (ie hours of air conditioning)
- p= price of energy
- e_j= energy efficiency (energy use / unit m)
- r is the discount rate

Two goods: inefficient ($j = I$); efficient ($j = E$)

- Efficient good cost more today: $c_E - c_I > 0$
- But saves on energy tomorrow: $e_E - e_I < 0$

For otherwise identical products, consumers should minimize total costs

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- Consumers vary in terms of p,r, and m. For each consumer, can use these to determine "reservation prices" $C_E - C_I$ [Graph]

EE gap

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

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  - ie p should be p_{social}

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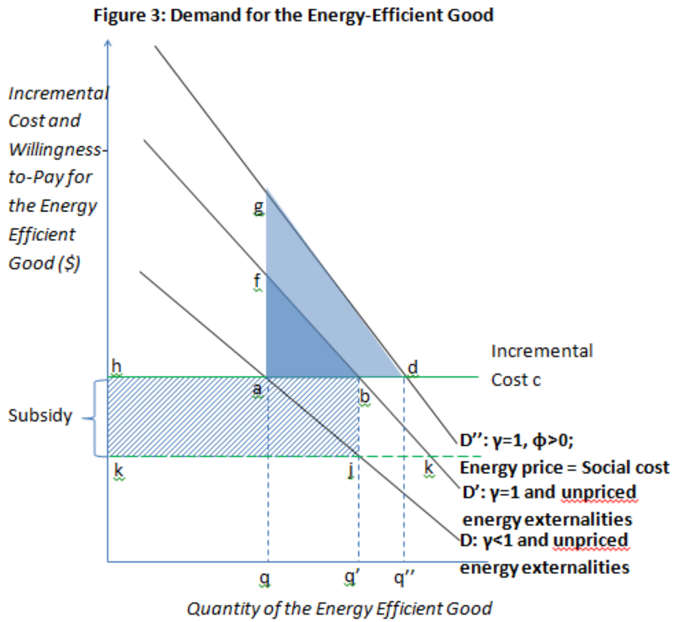
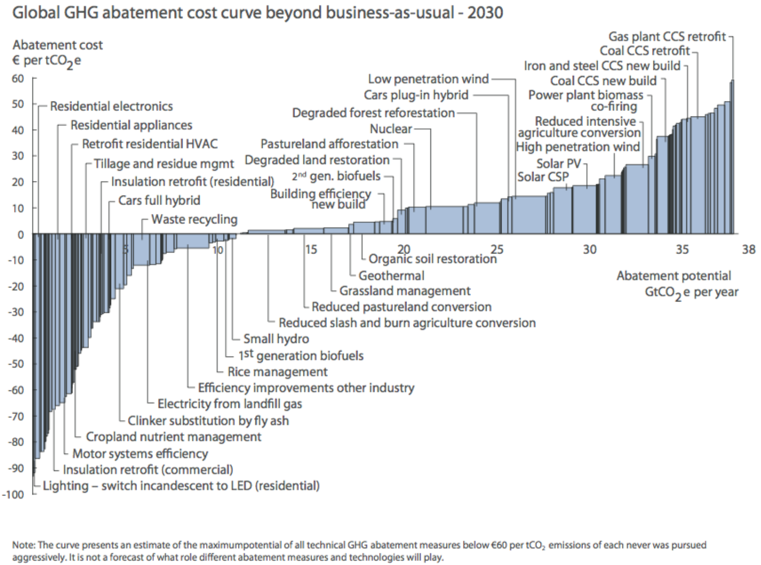
  - ie $TC_E < TC_I$, but consumers still chose I
- Ie what if consumers value a future (discounted) dollar saved at $\gamma < 1$?

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

Demand for efficient option



Energy Efficiency: Is there a free lunch?



Source: McKinsey & Company (2009)

Demand curve recap

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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Consider Two goods: inefficient ($j = I$); efficient ($j = E$)

- Efficient good cost more today: $c_E - c_I > 0$
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Who *should* buy the efficient good?

- Individual energy savings:

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

- This traces out a demand curve for E

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- Individual energy savings:

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

- This traces out a demand curve for E
- Rational to buy E that savings exceeds the up front cost difference $(c_E - c_I)$
- McKinsey famously looked at this and concluded there were many actors out there whose saving exceeded the capital cost, but nevertheless bought the inefficient capital good.

What are some explanations for this?

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

Behavioral

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

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)

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?

Compare Side-by-Side

Fuel Economy | Energy and Environment | Safety | Specs

Personalize	2013 Toyota Prius	2013 Toyota Corolla
	Hybrid Vehicle 	
	1.8 L, 4 cyl, Automatic (variable gear ratios)	1.8 L, 4 cyl, Automatic 4-spd
	MSRP: $24,200 - $30,005	MSRP: $16,230 - $20,550
EPA Fuel Economy		
Miles per Gallon	REGULAR GASOLINE **50** Combined **51** City **48** Highway	REGULAR GASOLINE **29** Combined **26** City **34** Highway

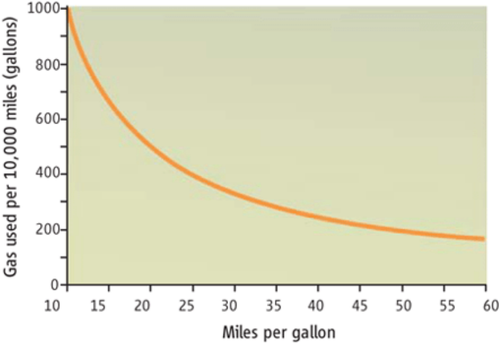
Source: Wolfram blog post (2013)

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

The MPG Illusion

Assume you're going to drive 100 miles,

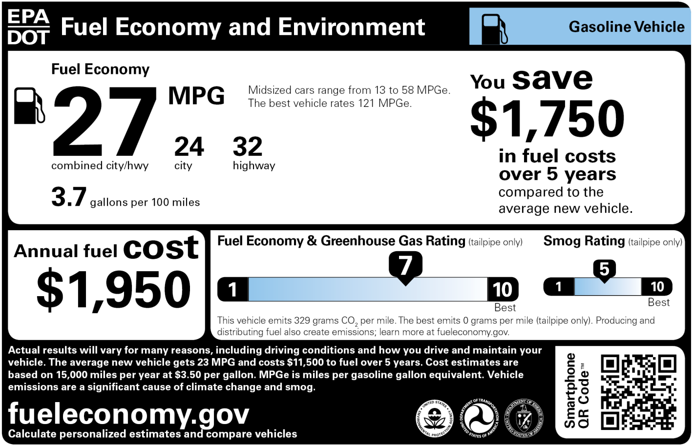
- (A) 8.3 gal in the Suburban vs 6.7 gal in the Escalade $\rightarrow$ save 1.6
- (B) 2 gal in the Prius vs 3.4 in the $\rightarrow$ save 1.4
- So the correct answer is A. Why?



Source: Larrick and Soll (2008)

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

Solution: New Fuel Economy Labels



Innattention

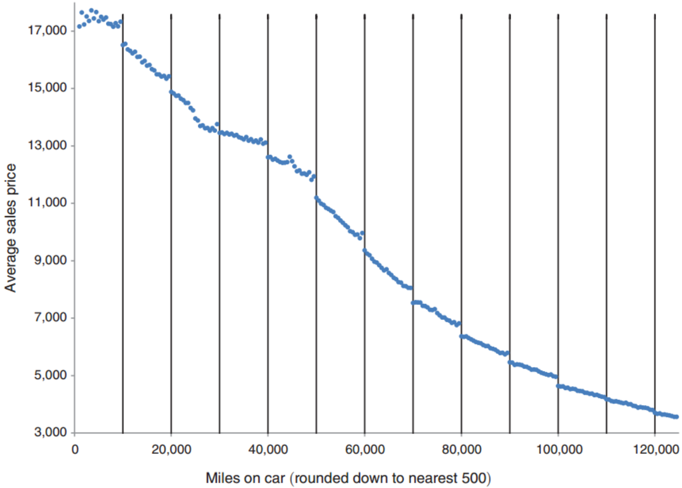
Sometimes information is presented correctly, but consumers are just not attentive to it (or it isn't salient enough)

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

People take shortcuts when making decisions

Average car auction price vs. miles on the car



Source: Lacetera, Pope, and Sydnor (2012)

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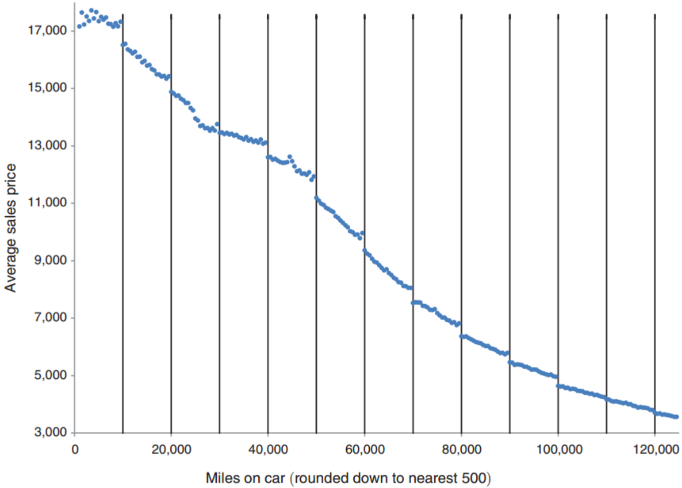

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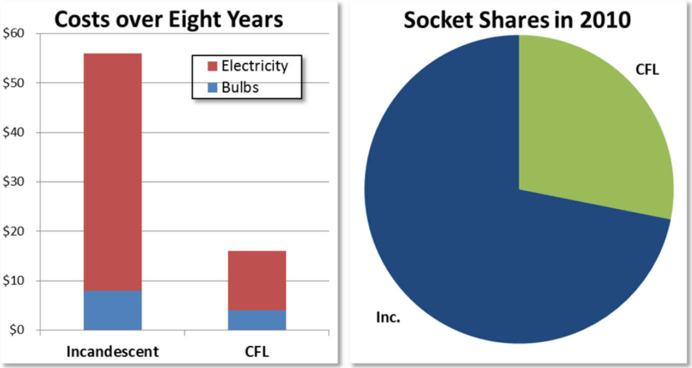
Why do prices end in .99? People tend to focus on the first digit

How can we tell if people are making mistakes?

"The Lightbulb Paradox"



Source: Allcott & Taubinsky (2015)

- Incandescents cost less ($1 vs $4), but don't last as long
- What explains low takeup here?
  - People uninformed, energy savings not salient, costs up front vs benefits later

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
Philips 60-Watt-Equivalent Compact Fluorescent Light Bulb, 1-Pack

Choice B
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

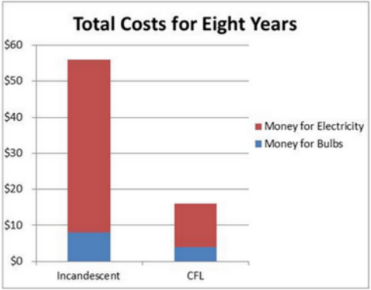
Also, CFLs use less electricity than incandescents. At national average usage and electricity prices:

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

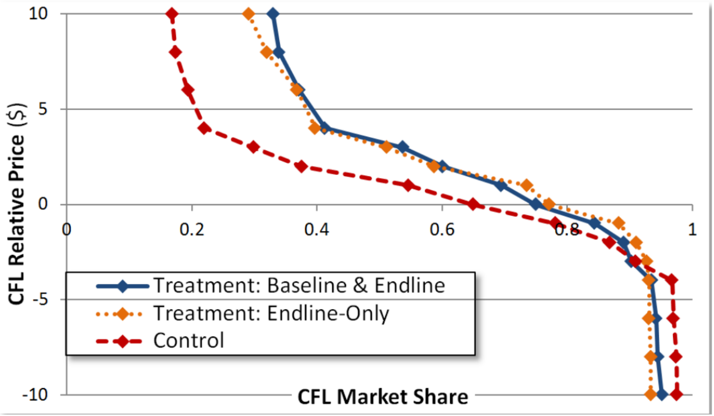
Thus, for eight years of light, the total costs to purchase bulbs and electricity would be:

- $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:



Some people appear to really dislike CFLs



Source: Allcott & Taubinsky (2015)

- CFLs have a different light quality
- CFLs take longer to heat up
- CFLs have to be disposed off carefully

Maybe banning incandescants isn't a good idea?

Theory wrapup

Updating the model

I and E may differ on non-energy dimensions

- example: lightbulbs
- let ξ represent the incremental utility cost of I

Consumers may be innatentive to or uninformed about energy costs

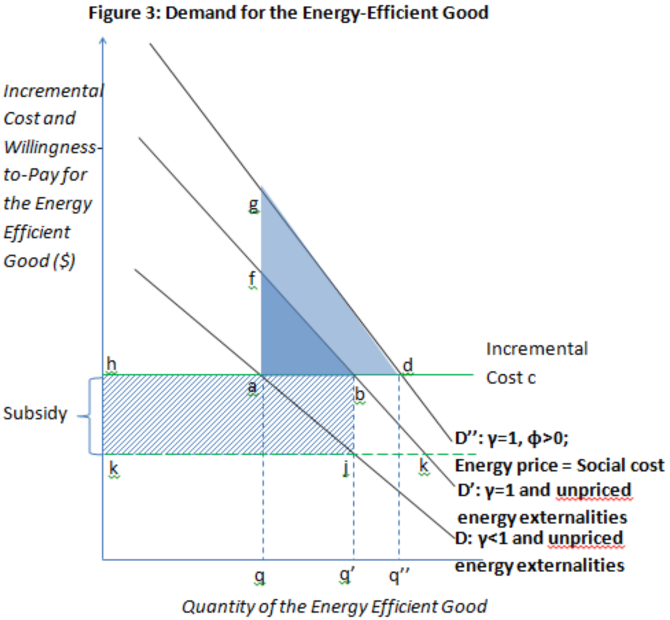
- let $\gamma > 1$ represent overweighting
- $\gamma < 1$ represent underweigthing

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

Saying there is an energy efficiency "paradox" is equivalent to $\gamma < 1$

- ie $TC_E < TC_I$, but consumers still chose I

Correcting these market failures



Lessons from the model

2 forces driving observed EE takeup away from the social optimum:

- externalities
- investment inefficiencies

General econ principle: 2 failures $\rightarrow$ 2 policy instruments.

- a Pigouvian tax on the externalitiy (ie gasoline)
- and policy to correct the investment inefficiencies

Using investment measures alone does not yield the efficient outcome:

- people buy more efficient cars, but still drive them too much.
- note that blanket subsidies can be very costly if consumers are heterogenous

To design optimal policy: need to know if the values of γ, ξ and r

Problems with the "engineering" EE gap literature

- we don't know key parameters:
  - ξ probably not zero
  - what is the right r ? credit card rate?
  - how long with the durable last?
- we actually don't know $(e_I - e_C)$ with certainty
  - engineering estimates can differ in the real world for lots of reasons
- people are heterogeneous
  - particularly wrt to m and r
  - even if you know those values on average, you would get it wrong for half the population

Summary

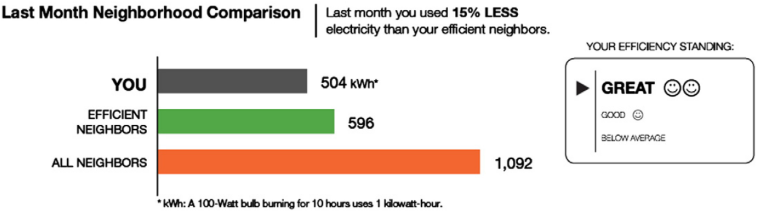
- Long standing interest in energy efficiency
- Seems like a "win-win"
- Can place this claim within a simple economic model to evaluate policy
  - highlights what has to be true for private gains
- Taking the model to data is challenging
- Many positive results in this literature either came from settings with questionable identification or untested assumptions
- Many "deep" parameters we don't know
- Next few classes will look at good empirical papers in this literature

OPOWER

How much of the energy efficiency gap is behavioral?

- Lots of common behavioral econ "failures" seem to apply to energy.
- Can think of salient anecdotes / examples where we can easily fool people once.
- Big leap between that and a scalable policy intervention.
- Allcott (2011) was the first paper to really to this.
- How did he do it?

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)

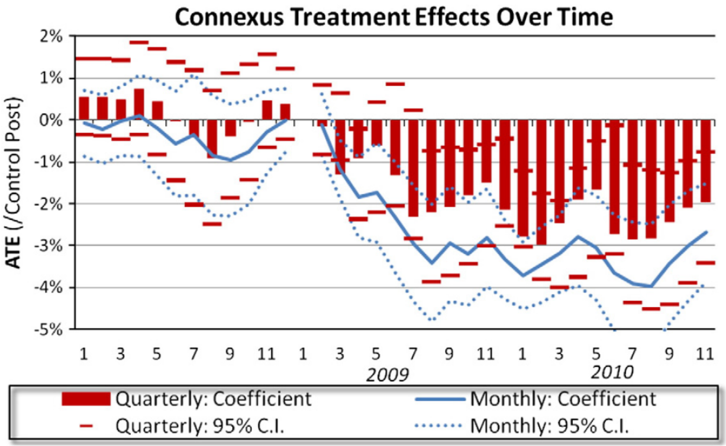
OPOWER Sample

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

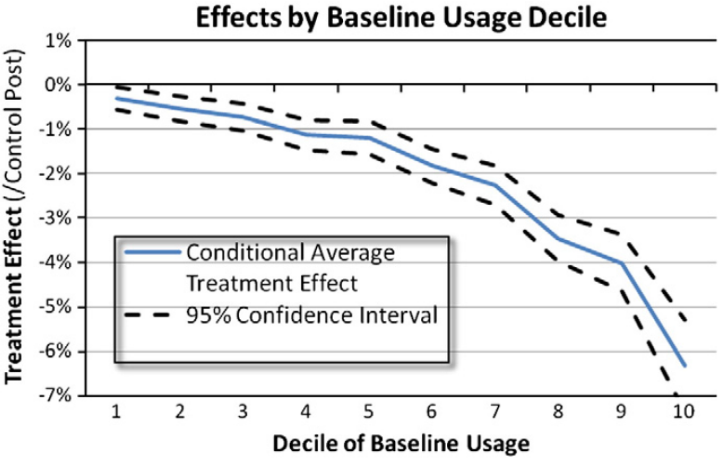
Source: Allcott (2011)

OPOWER results



Source: Allcott (2011)

OPOWER: No “boomerang” effect



Source: Allcott (2011)

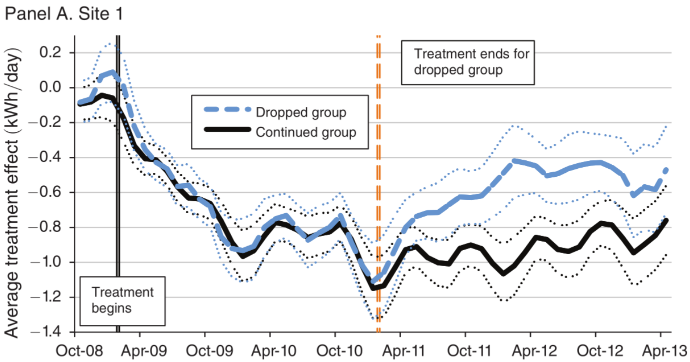
Cost effectiveness

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)

Appliance Experiments

Allcott & Sweeney (2017)

Allcott & Sweeney (2017)

Extras

Paternalism in public policy

- Governments frequently intervene to protect us from:
  - Imperfect information
  - Failure to maximize long-run welfare
- 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

Rise of the "nudge"

- 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
- Examples:
  - ordering of food in a lunch line
  - make retirement contributions the default
- Today we discussed using social forces to shape behavior
  - What do people think about nudges?