# Technological Change & Energy Efficiency

## Recorded Session #6

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# Energy Efficiency is important, and policies are popular

- ***Global energy consumption* is on a path to grow 50% over the next 25 years**
    - *Increased* $CO_2$ emissions, air pollution, oil consumption, and energy prices
- **Energy efficiency improvements are *mechanism for decreasing* energy use**
- **Energy-efficiency policies are *politically popular***

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

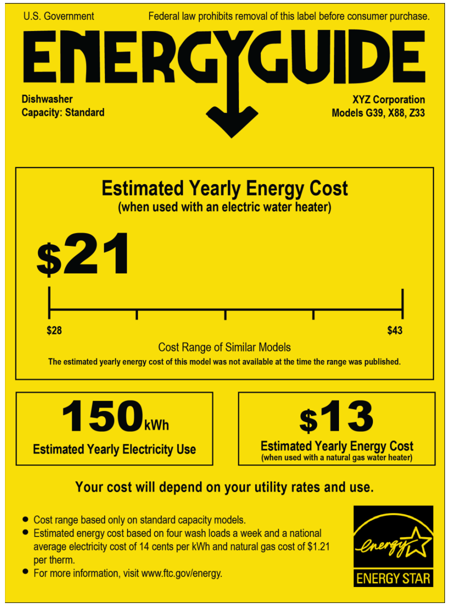
December 19, 2022

*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.

# Energy Efficiency Policies are *Very* Popular

- **Policies have taken the form of Standards, Pricing, and Information**




| 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)

# Why are energy efficiency policies so popular?

- **People (including politicians) generally believe it's a "win-win" proposition**
- **Hypothetical Win #1: Energy generation and use is associated with *many well-known externalities***
  - This seems pretty *clear*
- **Hypothetical Win #2: Consumers *fail* to take up *privately optimal* energy-efficiency investments**
  - Perhaps because they *lack* information
  - Correcting this mistake might *save* them money
  - This is much *less clear*, and merits careful analysis

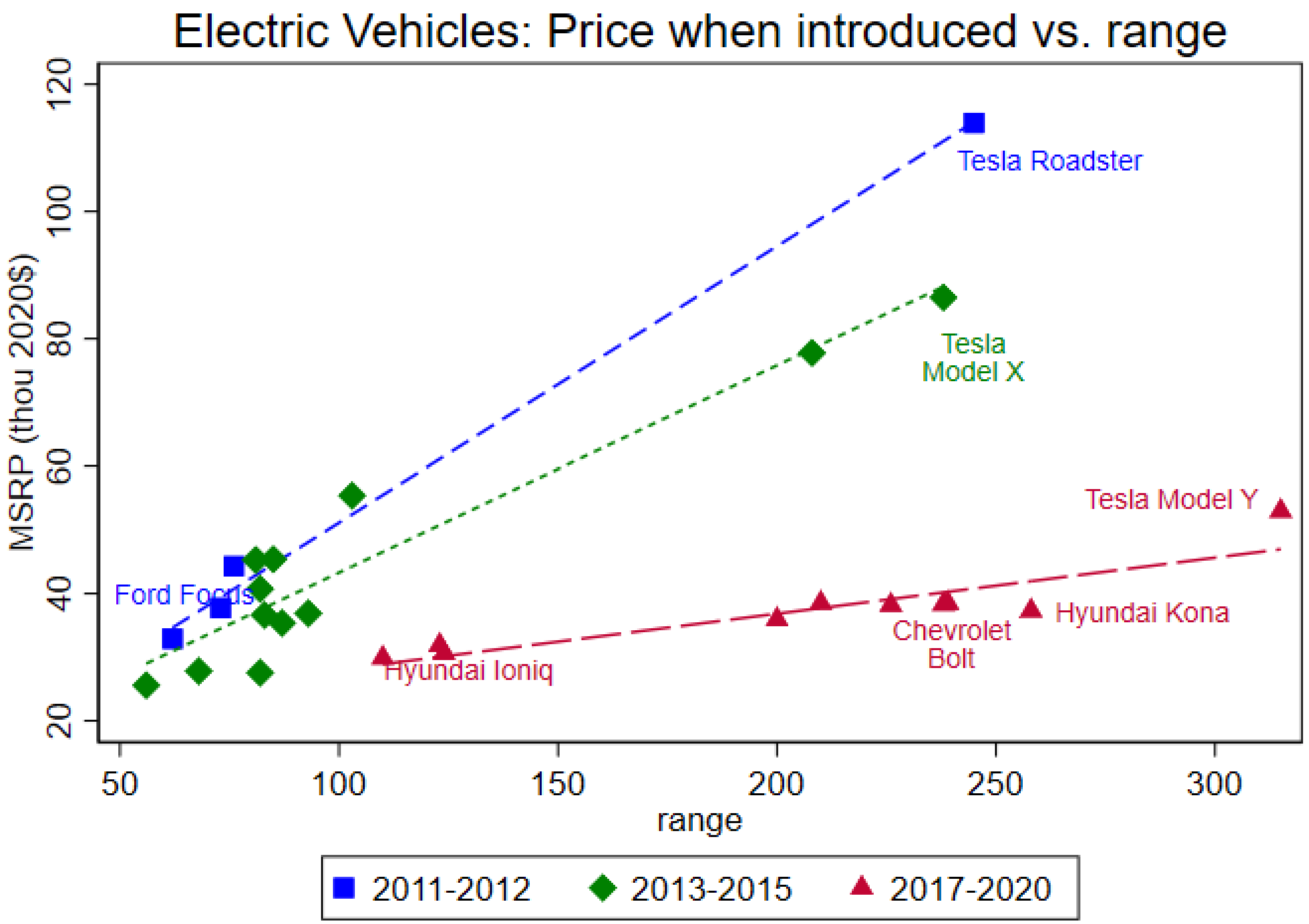
# Analysis of Energy Efficiency Leads to a Paradox

- **Think about Two Important Economic Questions:**
  - How do people & businesses make energy efficiency decisions?
  - What are the effects, costs, and benefits of energy-efficiency policies?
- **A key issue:** the "energy paradox" or "energy efficiency gap"
  - **The energy paradox:** the apparent reality that energy-efficiency technologies that would pay off for adopters (in terms of energy cost savings) are *nevertheless not adopted*
  - **The energy-efficiency gap**: apparent reality that some energy-efficiency technologies that would be socially efficient are *not* adopted (not a paradox – externalities)

# Let’s be clear about the “energy paradox”

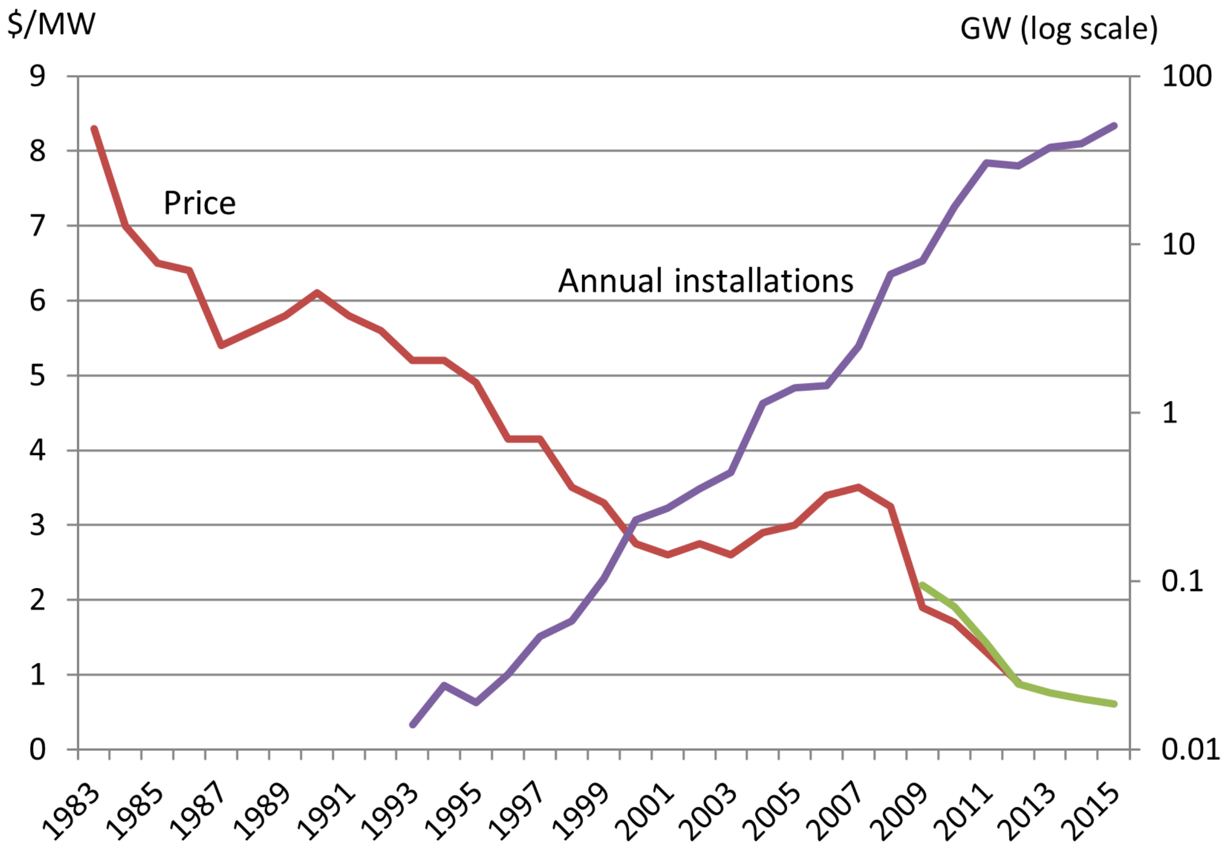
- **The *apparent* reality that energy-efficiency technologies that would pay off for adopters (in terms of energy cost savings) … are nevertheless *not* adopted**
  - Seminal studies by Hausman 1979, and Dubin & McFadden 1984
- **Let’s be clear about what *adoption* means …**
- **Three stages of technological change (Schumpeter 1939)**
  - *Invention* – creation of new equipment (in the laboratory)
  - *Innovation* – commercialization, i.e. taking it from the laboratory to the showroom floor
  - *Diffusion* – gradual process of *adoption* (purchase) of product
  - [And, of course, *utilization* – use of the adopted product]
- **Energy paradox is mainly about *diffusion,* but let’s take a quick look at recent *innovation* in climate-friendly technologies …**

# Innovation in Electric Vehicles, 2011-2020




- **Shift downward of slopes** (decreased tradeoff of cost for range) is consistent with **16% annual decrease in EV battery costs**. (Source: Gillingham and Stock 2018)

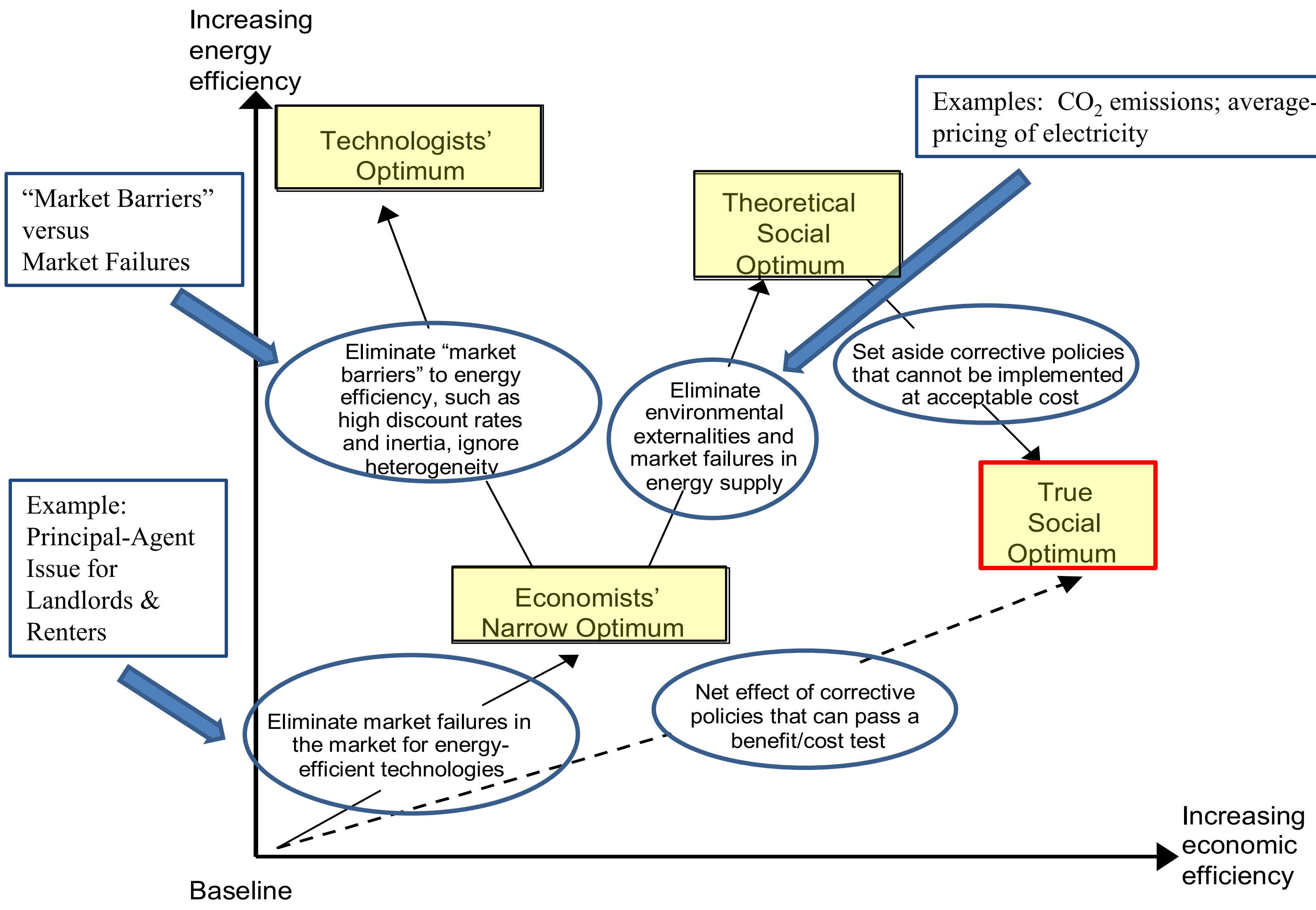
# Innovation in Solar Panels, 1983-2015




Source: International Energy Agency (2017), Navigant Consulting (2009), Gerarden (2017)

- Note that price index excludes subsidies. (Source: Gillingham and Stock 2018)

# Energy paradox is mainly about *diffusion*, but there are multiple interpretations of the "gap" …



# Deconstructing the Energy Efficiency Paradox/Gap

- **Basic definition (energy *paradox*):** the *apparent* reality that some energy-efficiency technologies that would pay off for adopters … are *not* adopted

- **Broader definition (energy-efficiency *gap*):** apparent reality that some energy-efficiency technologies that would be *socially efficient* are not adopted

- ***Why*** are such technologies **not adopted**? What explains the paradox/gap?

- Answers have very important policy implications.

- Let's sort potential explanations into 3 categories – Chapter 32 in *Economics of the Environment* …

Deconstructing the Energy-Efficiency Gap:
Conceptual Frameworks and Evidence

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Energy-efficient (EE) technologies offer considerable promise for reducing the financial costs and environmental damages associated with energy use, but these technologies appear not to be adopted to the degree that appears justified, even on a purely private basis.

We present two complementary frameworks for understanding the EE gap. First, we build upon previous literature (Jaffe and Stavins 1994; Gillingham, Newell, and Palmer 2009) by dividing potential explanations for the gap into three categories: market failures, behavioral explanations, and model and measurement errors. Second, we examine the elements of cost-minimizing EE decisions, the typical benchmark used in assessing the gap's magnitude.

I. Potential Explanations

First, potential market-failure explanations for the EE gap include information asymmetries and imperfections in markets for energy, capital, and innovation.

Second, potential behavioral explanations include myopia, cognitive limitations, inattentiveness, loss aversion and reference dependence, and systematically biased beliefs.

Third, there are potential model and measurement explanations. These feature reasons why the adoption rate of EE technology may not be as paradoxical as it first appears. Potential sources of model and measurement error include unobserved costs or overstated energy savings from adoption, ignored product attributes, heterogeneity across potential adopters, use of inappropriate discount rates, and uncertainty.

Determining the validity of candidate explanations—and the degree to which each contributes to the EE gap—are crucial for crafting sensible public policy responses.

# An Economic Perspective:
# Potential Explanations of the Paradox/Gap

- ***Market-Failure*** Explanations

- ***Behavioral*** Explanations

- ***Model and Measurement*** Explanations

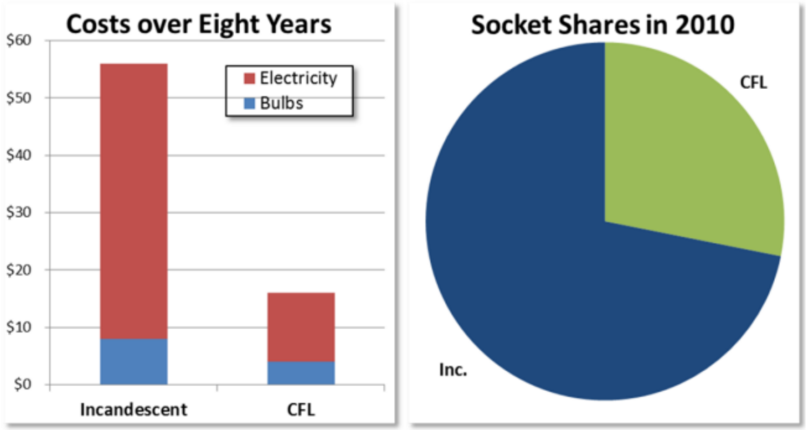
# Potential Explanations of the Paradox/Gap: *Market-Failure Explanations*

- **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)
- **Energy Market Failures**
  - Externalities – environmental, security (Krupnick, *et al.* 2010)
  - Average-cost electricity pricing – cost-of-service regulation (Joskow 1976)
- **Capital Market Failures**
  - Liquidity constraints
  - Particularly relevant in developing countries
- **Innovation Market Failures**
  - R&D spillovers due to public-good nature of information (evidence from patent studies by Griliches 1992; Jaffe 1998; Popp; & others)

# Potential Explanations of the Paradox/Gap: *Behavioral Explanations*

- **If people are rational and computationally limitless, then they may cost minimize**
- **But in the real world, people:**
  - Make mistakes
  - Don't like thinking hard about things
  - Are inattentive
  - Care about peer effects
  - Are swayed by default options
  - Overly discount the future
- **This is very important for energy efficiency, because it can help explain the apparent energy paradox, …**
  - … and suggest ways to correct it that don't involve taxes/regulation (and cost much less)
- ***What about firms?* [RS car, 12 mi/day -- Fed Exp truck, 50-300 mi/day]**

**Example: "The Lightbulb Paradox"**

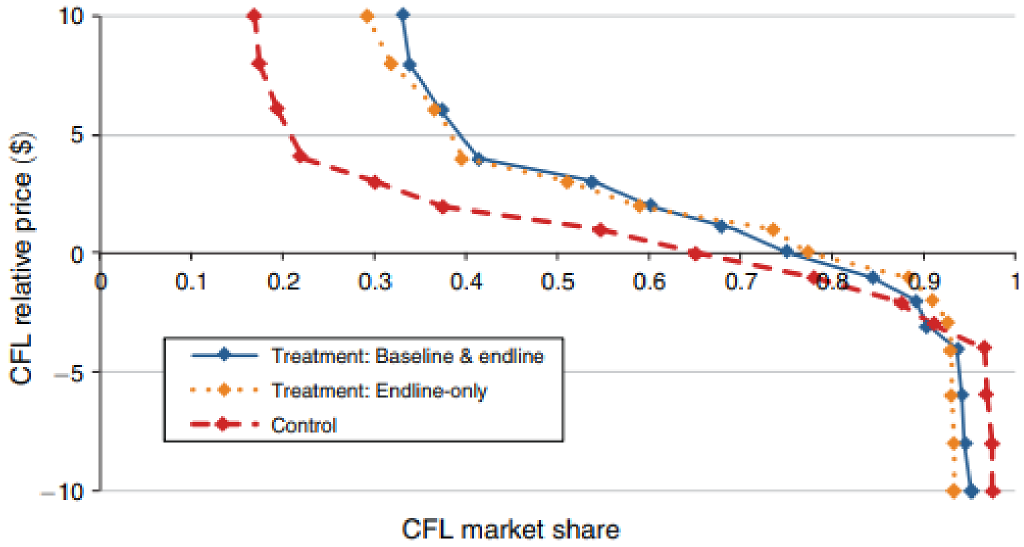



Source: Allcott & Taubinsky (2015)

- Incandescents cost much less, but compact flourescents (CFLs) last longer
- What explains low adoption?
  - People uninformed, energy savings not salient, costs up front vs benefits later
- Or they just don't like CFLs …

# Experimental Evidence on the Lightbulb Paradox

- Allcott and Taubinsky ran an experiment to see how willingness-to-pay for CFLs responds to information about their superior energy efficiency.
- They found that additional information increases willingness to pay for some people, but others still strongly prefer incandescent lightbulbs.
- Other factors also matter!

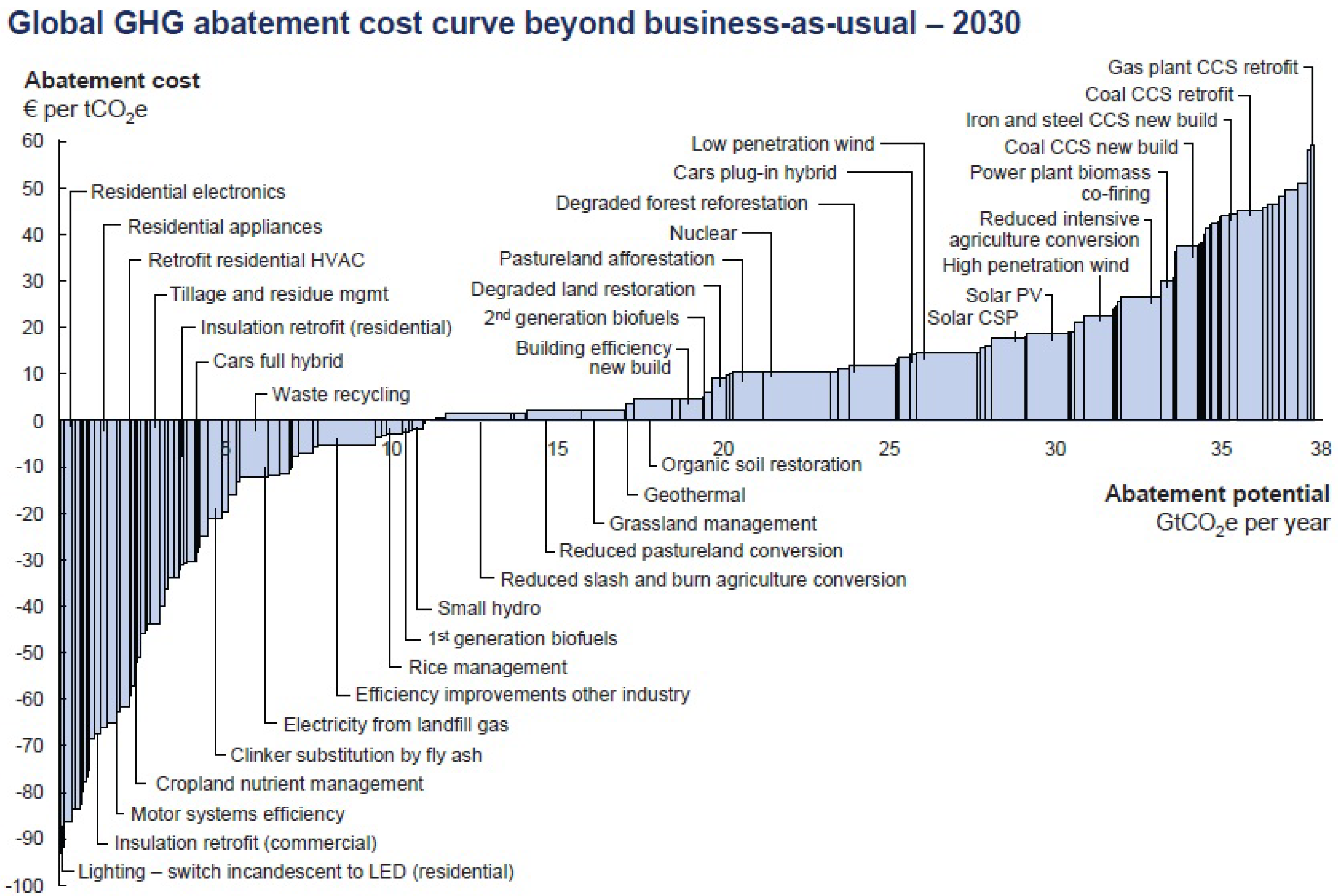



*Source:* Allcott, Hunt, and Dmitry Taubinsky. 2015. "Evaluating Behaviorally Motivated Policy: Experimental Evidence from the Lightbulb Market."

# **Potential Explanations of the Paradox/Gap:**
# ***Model and Measurement Explanations***

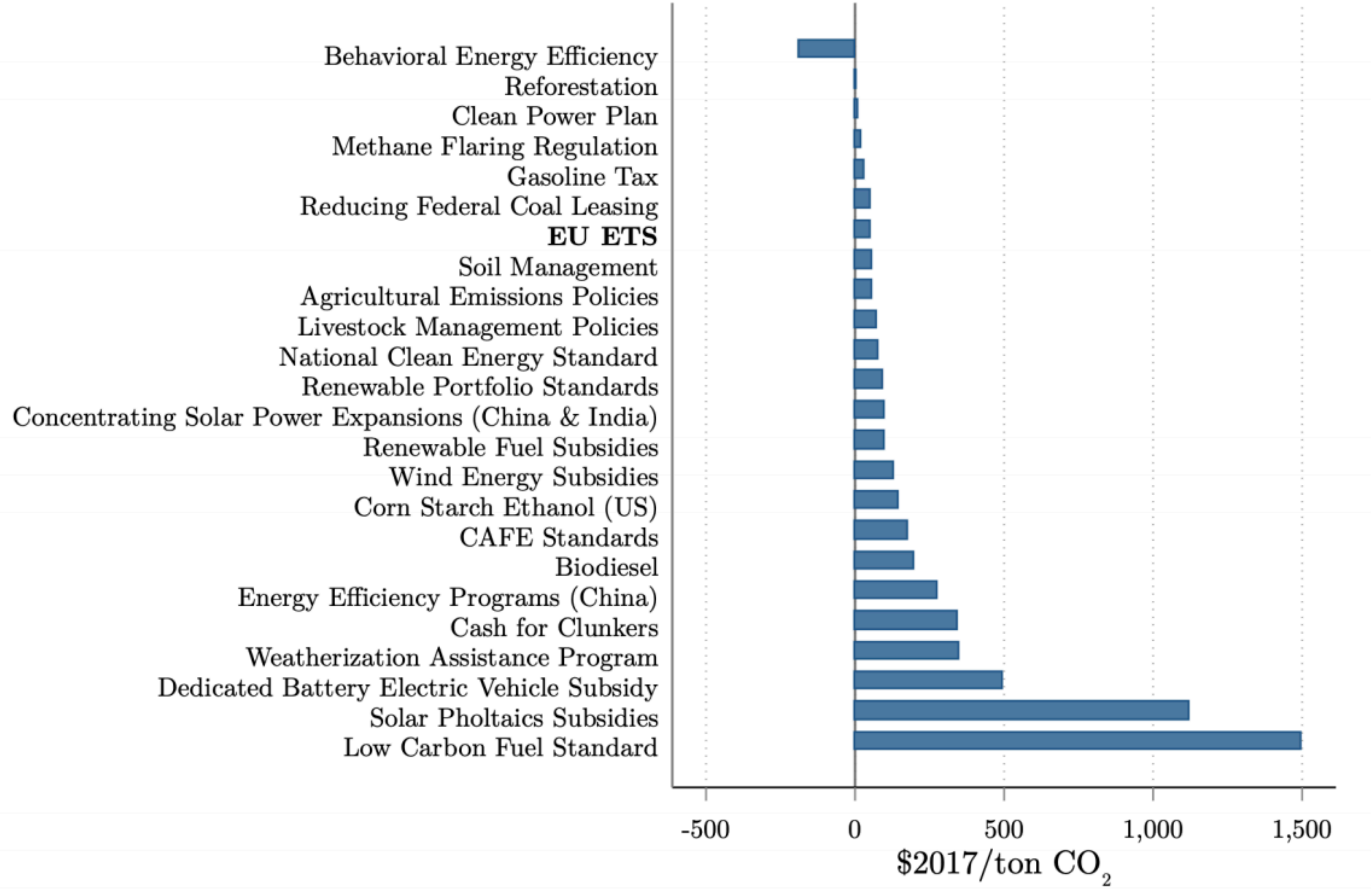
- Analytical Error:  unobserved costs of adoption
  - An explanation of some “negative costs” in McKinsey cost curve …

# The (In)Famous McKinsey Cost Curve




Note: The curve presents an estimate of the maximum potential of all technical GHG abatement measures below €60 per $tCO_2e$ if each lever was pursued aggressively. It is not a forecast of what role different abatement measures and technologies will play.
Source: Global GHG Abatement Cost Curve v2.0

# An Economic View of GHG Abatement Costs




- From Gillingham and Stock 2018.

# Potential Explanations of the Paradox/Gap:
## *Model and Measurement Explanations* (continued)

- **Product characteristics/attributes**
  - Hedonics: products as a bundle of attributes
  - First-generation compact fluorescent light bulbs: color & noise
  - CFLs: size, shape, dimmers, etc.
- **Heterogeneity in demand across potential adopters**
  - Griliches (hybrid corn, 1957; Hausman and Joskow 1982)
  - Ubiquitous phenomenon with virtually all new technologies
- **Uncertainty (real, not informational)**
  - Future energy prices (theory – Dixit & Pindyck 1994) – option value for waiting
  - Empirical analysis (home improvements, Hassett and Metcalf 1994)

# General Policy Implications

- **Cause of paradox/gap implies whether & how policy should address it**
- **What about *conventional*, command-and-control regulations?**
  - Major effect -- *remove* some products from market (energy-efficiency standards)
- **What about *subsidies* as a diffusion (adoption) policy?**
  - Can provide perverse incentive to *increase* energy use (rebound effect:  effect of cheaper insulation versus energy tax)
  - Require large public *expenditures* per unit of effect (infra-marginal units)
- **Multiple market failures – in climate change context, environmental *externality* and *public-good* nature of information generated by R&D**
  - Pricing of externality is *necessary, but not sufficient*
  - Direct technology policy is *necessary, but not sufficient*
- **Major Implications:**
  - Innovation & diffusion respond to market incentives (price signals)
  - But existence of multiple market failures clarifies case for combining pricing policies with technology policies

# Key Take-Aways

1. **Three key stages of technological change**: invention, innovation, & diffusion

2. **Critical issue is the "energy paradox"**

   - Identification of **appropriate policies depends on understanding correct explanations** of the paradox/gap:
   - Market-Failure Explanations; Behavioral Explanations, and Model & Measurement Explanations

3. **Conventional technology policies, including subsidies, bring significant problems**

4. **Multiple market failures necessitates multiple policies: both pricing policies and technology policies may be necessary, but neither is sufficient!**