Did Federal Incentives Boost Sales of Hybrid Electric Vehicles?

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Abstract

Transportation represents a significant contribution to anthropogenic greenhouse gas emissions. The promotion of adoption of new, more efficient vehicle technologies through incentives can help as a climate change mitigation strategy. This study assesses the overall effectiveness of several of these incentives using econometric methods. Our primary model employs a novel lagged dependent variable of sales to represent natural growth from technological diffusion using a generalized method of moments estimator with both fixed effects and first differences. Our primary results indicate that when natural growth is accounted for, the Tax Relief Act of 2004 is not statistically significant but the Energy Policy Act of 2005 resulted in significant increases in sales for hybrids ranging from 3% to 20% depending on the vehicle model.

Background and Data

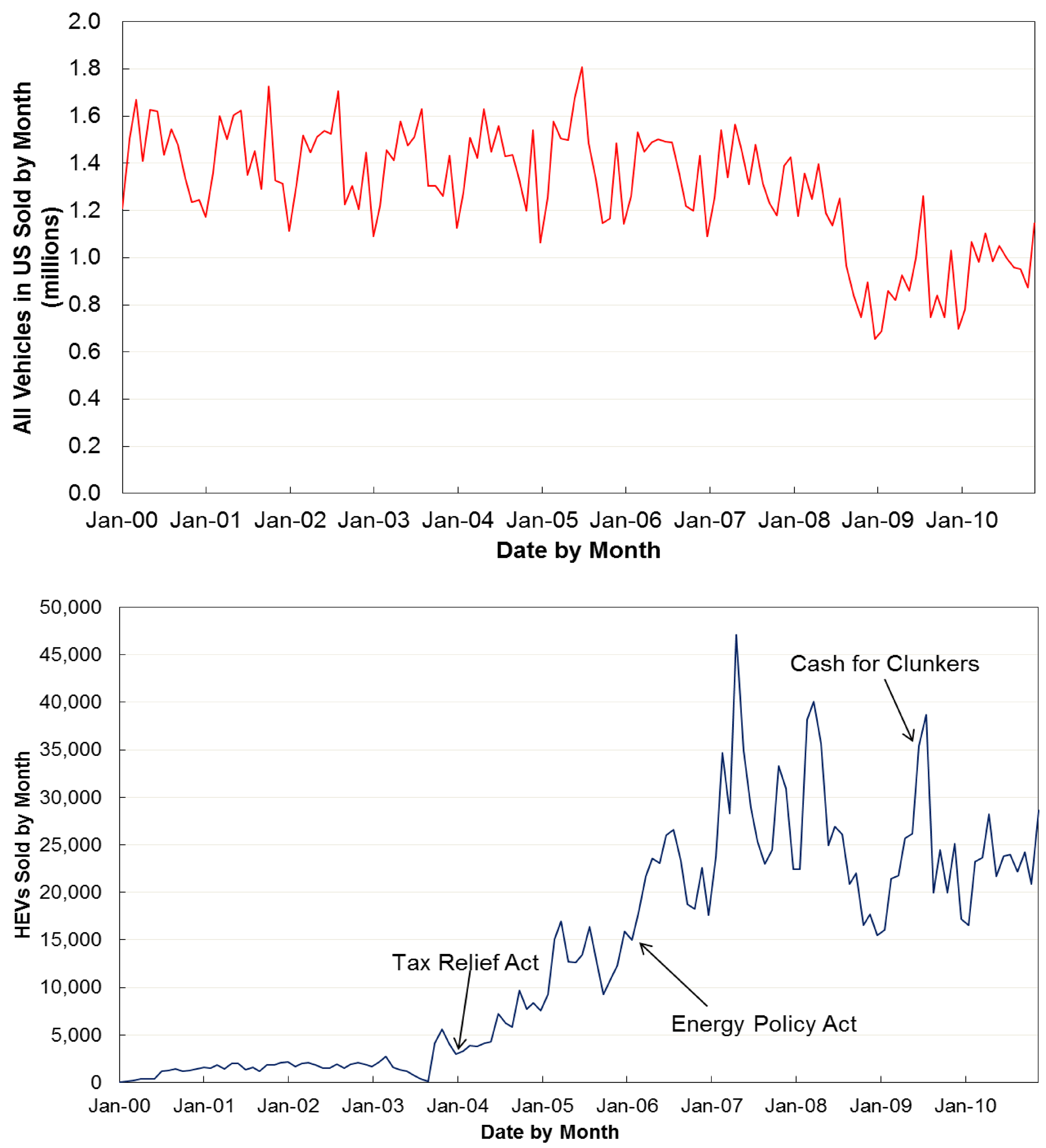

Figure 1: Total Monthly Sales of Vehicles in the US and the Total Monthly Sales of Hybrid Vehicles in the US. Data collected from Autonews Data Archives and Hybridcars Dashboard.

Methodology

Our unique approach to the regression involved the inclusion of a lagged dependent variable to simulate an S-shaped adoption curve. The structural form of the regression was constructed from the simplest specification, adding controls until the following form was obtained:

$$S_{i,t} = \alpha + \pi(S_{i,t-1}) + \beta(Policy_{i,t}) + \gamma(x_{i,t}) + \delta(x_{i,t} \cdot HybridDummy) + u_{i,t} + \varepsilon_{i,t}$$

- *i* is an indicator for vehicle model
- *t* is an indicator for time period (month)
- *S* represents monthly sales
- *Policy* represents incentive variables of interest
- *x* represent control variables
- *HybridDummy* is a dummy variable for whether *i* is an HEV

Incentive variables are the Tax Relief Act of 2004 and the Energy Policy Act of 2005. Control variables include Cash for Clunkers, production stoppage, unemployment, disposable income, interest rates, and gas prices.

Our regression models are estimated using generalized method of moments with fixed effects and first differences estimators. The GMM is employed to address bias issues with the use of the lagged dependent variable and the FE/FD approach helps to account for omitted variable bias.

Results

Table 1: Generalized Method of Moments, Fixed Effect Regression Results

VARIABLES	Coefficients (Robust Standard Errors)					
L.ln(sales)	0.914***	0.911***	0.910***	0.911***	0.914***	0.910***
	(0.00832)	(0.00845)	(0.00851)	(0.00845)	(0.00837)	(0.00852)
L.ln(sales)*hybrids	-0.0335	-0.0250	-0.0410	-0.0253	-0.0392	-0.0353
	(0.0273)	(0.0286)	(0.0278)	(0.0283)	(0.0278)	(0.0287)
TaxReliefAct	**-0.0678**	**-0.0373**	**-0.0417**	**-0.0432**	**-0.0589**	**-0.0258**
	(0.0802)	**(0.0835)**	**(0.0805)**	**(0.0818)**	**(0.0806)**	**(0.0837)**
TaxReliefAct*nonhybrids	**-0.0354*** **	**-0.0393*** **	**0.0280**	**-0.0382*** **	**-0.0431*** **	**-0.0409*** **
	(0.0101)	**(0.0102)**	**(0.0173)**	**(0.0101)**	**(0.0112)**	**(0.0112)**
EnergyPolicyAct	**4.80e-05** **	**6.95e-05*** **	**4.10e-05** **	**6.83e-05*** **	**3.66e-05** **	**5.57e-05** **
	(1.91e-05)	**(2.69e-05)**	**(1.93e-05)**	**(2.56e-05)**	**(1.84e-05)**	**(2.70e-05)**
EnergyPolicyAct*nonhybrids	**-0.0840*** **	**-0.0796*** **	**0.0547***	**-0.0824*** **	**-0.104*** **	**-0.0831*** **
	(0.0115)	**(0.0114)**	**(0.0306)**	**(0.0114)**	**(0.0176)**	**(0.0177)**
CashForClunkers	0.0350	0.0667**	0.0340	0.0641**	0.0558*	0.0757***
	(0.0261)	(0.0274)	(0.0261)	(0.0272)	(0.0287)	(0.0293)
ProductionStoppage	-0.660***	-0.668***	-0.669***	-0.668***	-0.661***	-0.675***
	(0.0578)	(0.0582)	(0.0585)	(0.0583)	(0.0582)	(0.0586)
PriusAdvertise	0.257	0.263	0.185	0.264	0.242	0.252
	(0.167)	(0.168)	(0.166)	(0.168)	(0.164)	(0.164)
Ln(Unemployment)		-0.0999***				-0.101***
		(0.0206)				(0.0212)
Ln(Unemployment)*hybrids		0.196**				0.198**
		(0.0941)				(0.0925)
Ln(Income)			-0.668***			
			(0.138)			
Ln(Income)*hybrid			1.170***			
			(0.284)			
Ln(Interest)				0.0200***		
				(0.00415)		
Ln(Interest)*hybrid				-0.0394**		
				(0.0186)		
$Ln(GasPrice)_{t-6}$					0.0868	0.00574
					(0.0671)	(0.0691)
$Ln(GasPrice)_{t-6}$*hybrid					0.505**	0.606***
					(0.201)	(0.198)
Observations	19,962	19,962	19,962	19,962	19,962	19,962
R^2	0.912	0.913	0.913	0.912	0.912	0.913
# of Groups	326	326	326	326	326	326
Hansen J Stat	0.00333	0.00379	0.00489	0.00394	0.00546	0.00566

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Results Continued

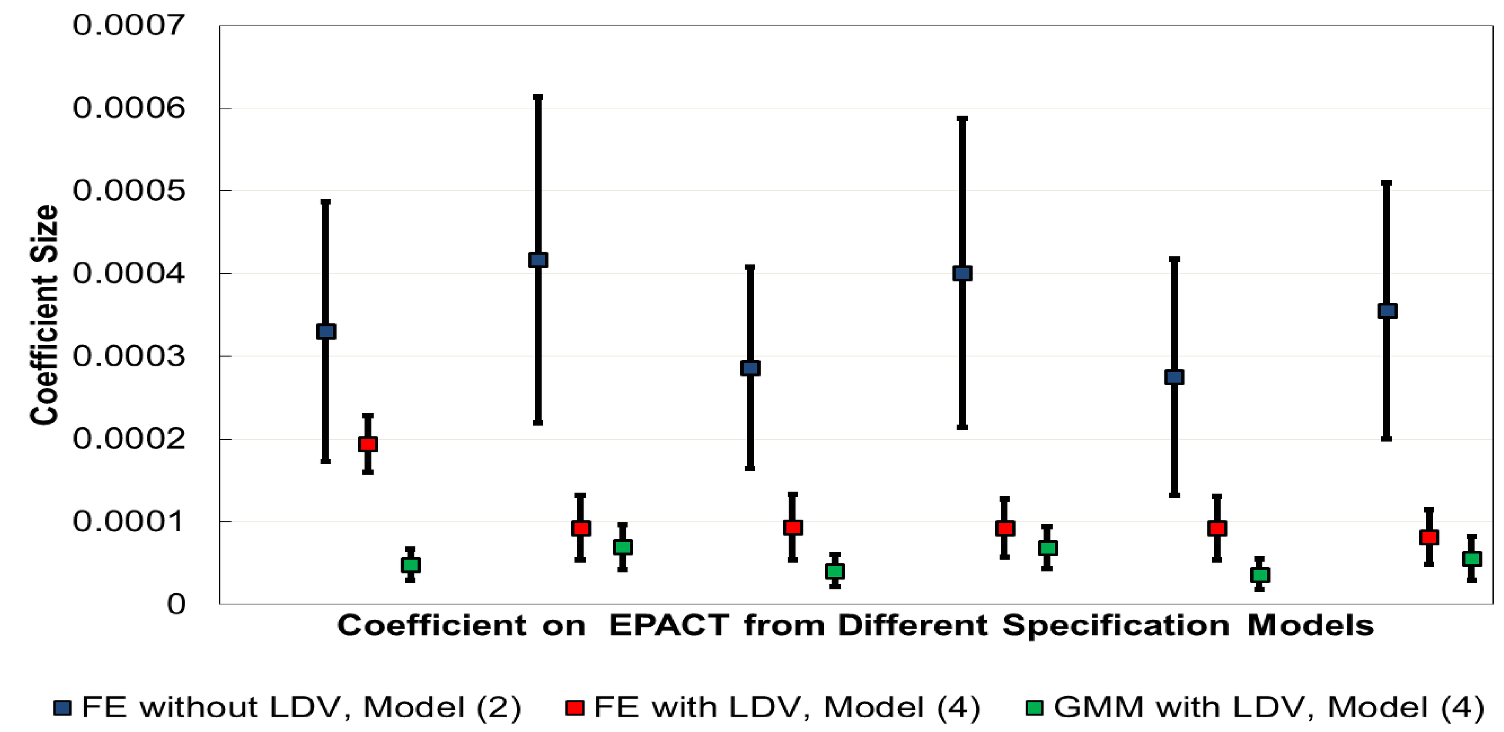

Figure 2: Demonstrating overestimation bias in coefficients when not accounting for natural growth of technology

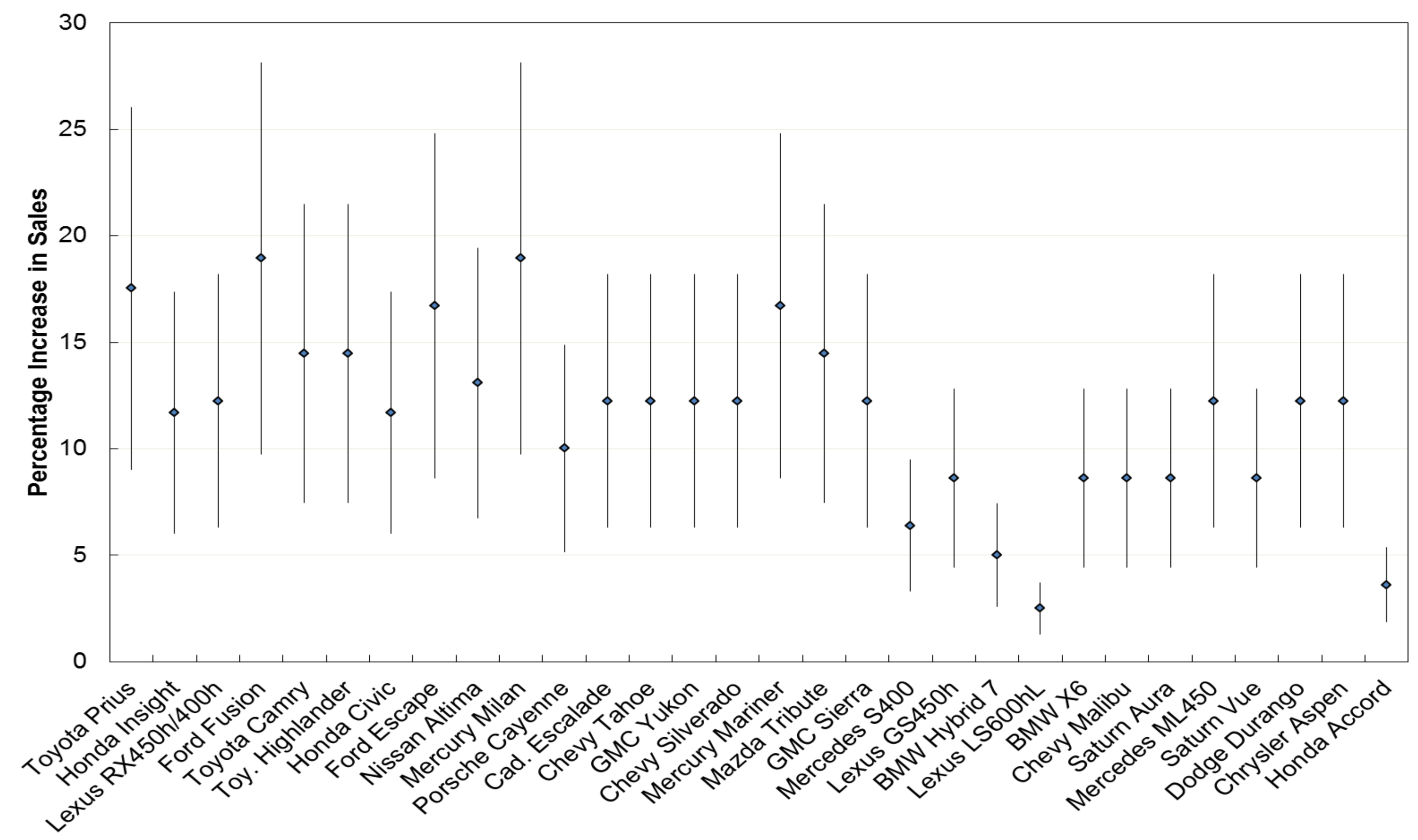

Figure 3: Percentage increase in sales of hybrid vehicles by model, attributable to the Energy Policy Act of 2005

Conclusions

We found that our general methodology is an important contribution to the body of existing work, especially to incorporate natural growth characteristics. The Energy Policy Act of 2005 was found to be statistically significant in increasing sales of hybrid electric vehicles. As a climate mitigation strategy, a future study can be conducted to measure the effectiveness of these policies by estimating the savings in greenhouse gas emissions. In addition, our regression models suggest that raising gas prices could potentially be an alternative strategy that would have the dual effect of decreasing emissions and generating substantial revenue, independent of other effects.

Acknowledgements

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Energy Labels Increase Demand for Compact Fluorescent Bulbs:♣

Analyzing Consumer Preferences for Lighting Technologies Using Discrete Choice Analysis

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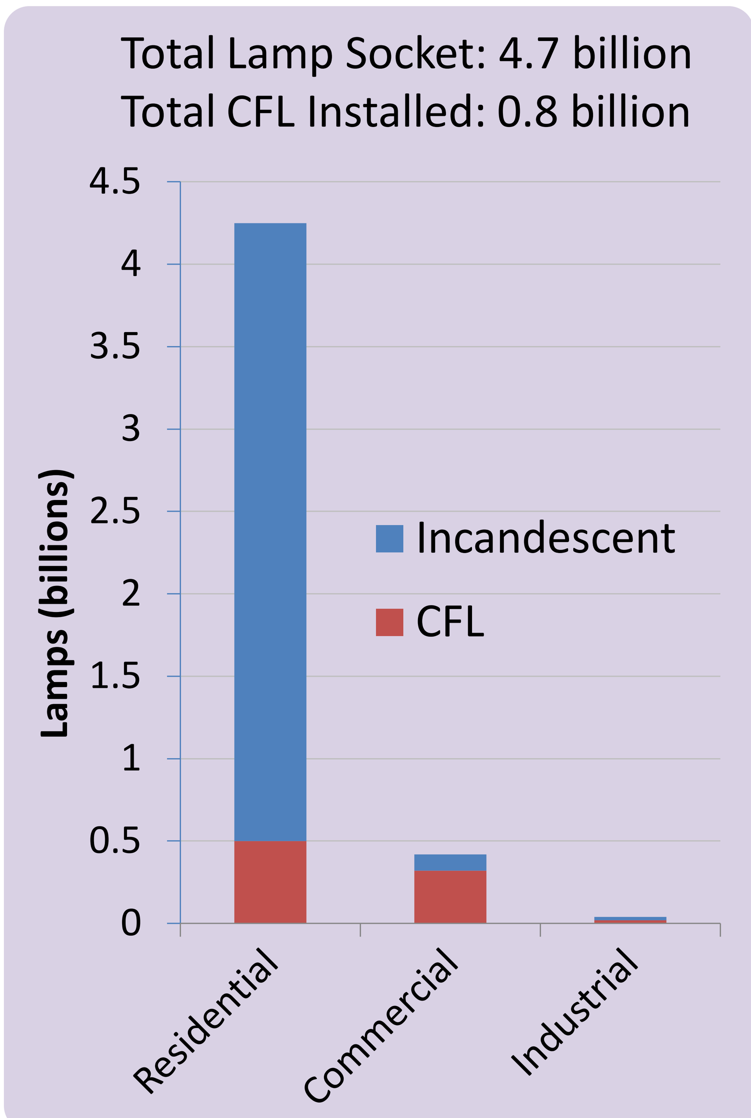
Introduction

We observe slow transition to CFLs, especially in residential sector, which suggest that there are barriers that keep consumers from buying CFLs. This study investigates how we can explain differences in consumers' preferences for lighting technology and how the preferences are influenced by the recently-mandated FTC label containing estimated annual operating cost information.



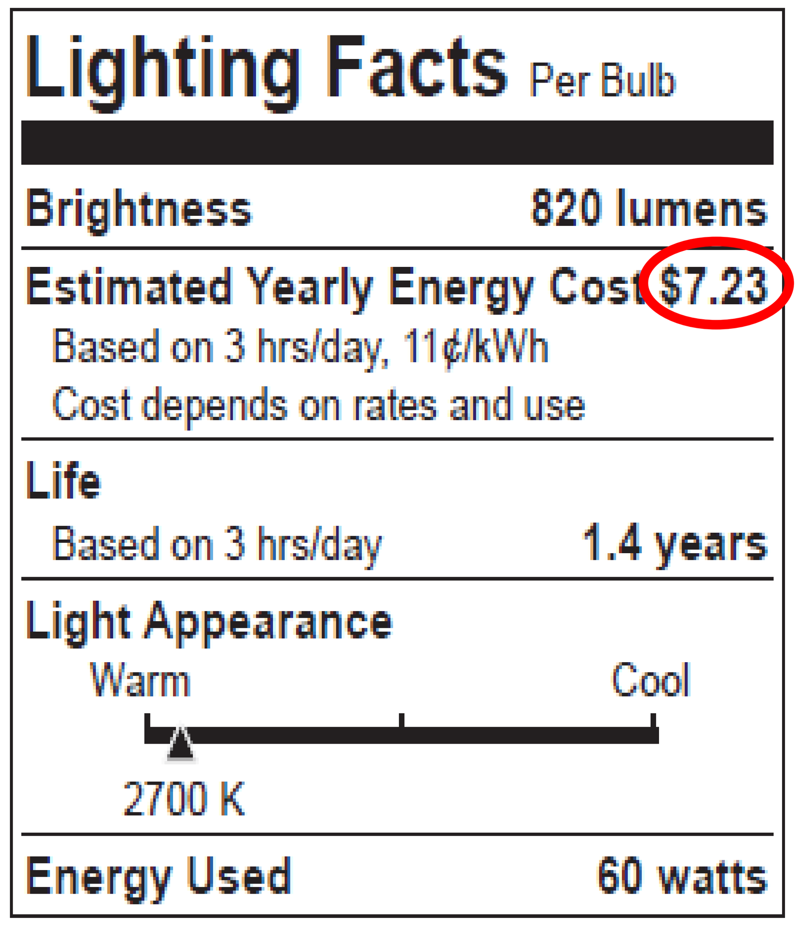


Figure 1. U.S. national socket saturation and the new front label for light bulbs
(Source: D&R International, 2009; FTC, 2010)

Objectives

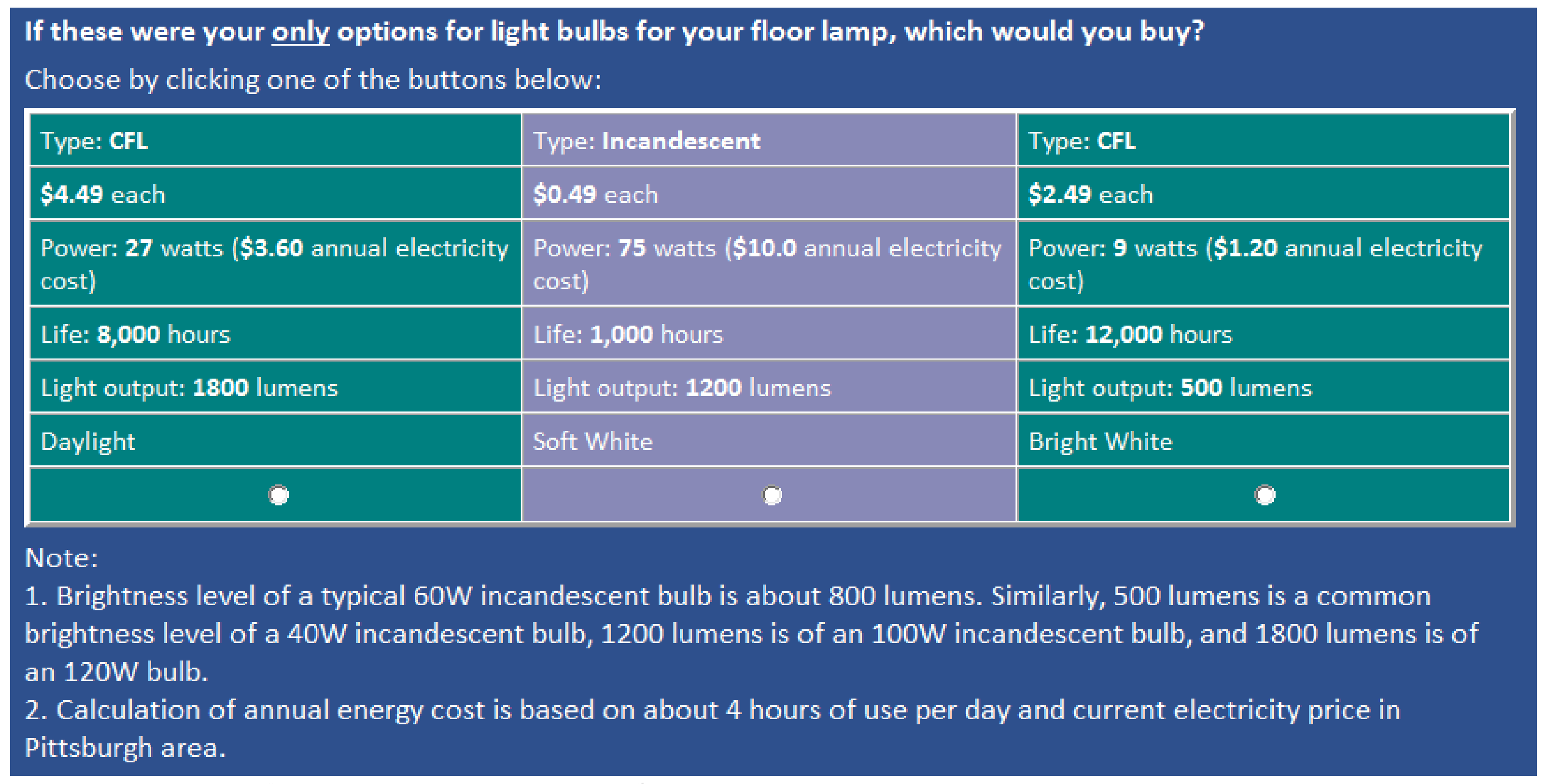
- Analyze differences in consumer preferences for lighting technologies
- Quantify the size of individual impact from different factors affecting consumer choices through discrete choice analysis,
- Understand how disclosing information on operating costs affects technology choices, and
- Measure implicit discount rates specific to lighting choices.

Methodology

Choice-based Conjoint Experiment:
Each participant answered 12 randomized choice tasks and three fixed choice tasks on a laptop (Fig. 2). The annual operating cost was shown only to a half of the participants. The attribute values in the table vary in each choice task following our randomized design. **183** participants were recruited and **168** of them were used for analysis.

Discrete Choice Analysis: The discrete choice model statistically relates observed choices to the attributes of the participant and/or of the alternatives available to him/her. From the choices made, we can estimate a quantitative model of consumer i's utility U_{ij} from their choice of alternative j. (Equation 1)

Estimating Implicit Discount Rate: we estimate the implicit discount rate explicitly in the estimation procedure using annualized cost. (Equation 2)



If these were your only options for light bulbs for your floor lamp, which would you buy?
Choose by clicking one of the buttons below:

Type: **CFL**	Type: **Incandescent**	Type: **CFL**
$4.49 each	**$0.49** each	**$2.49** each
Power: **27 watts** (**$3.60** annual electricity cost)	Power: **75 watts** (**$10.0** annual electricity cost)	Power: **9 watts** (**$1.20** annual electricity cost)
Life: **8,000** hours	Life: **1,000** hours	Life: **12,000** hours
Light output: **1800** lumens	Light output: **1200** lumens	Light output: **500** lumens
Daylight	Soft White	Bright White

Note:
1. Brightness level of a typical 60W incandescent bulb is about 800 lumens. Similarly, 500 lumens is a common brightness level of a 40W incandescent bulb, 1200 lumens is of an 100W incandescent bulb, and 1800 lumens is of an 120W bulb.
2. Calculation of annual energy cost is based on about 4 hours of use per day and current electricity price in Pittsburgh area.

Figure 2. Example of a choice task seen by participants

Estimate

$$U_{ij}^{M1} = (\beta_1 + \sigma_1 v_{1i}) \cdot type_{ij} - \exp(\beta_2 + \sigma_2 v_{2i}) \cdot price_{ij} + \beta_3 \cdot life_{ij} + \beta_4 \cdot bght_{ij} + \beta_5 \cdot bght_{ij}^2 + \beta_6 \cdot watt_{ij} + \sum_{m=1}^{2} \beta_{7,n} \cdot color_{mij}$$
$$+ D_{ocost,i}\left(\beta_{1c} \cdot type_{ij} + \beta_{2c} \cdot price_{ij} + \beta_{3c} \cdot life_{ij} + \beta_{4c} \cdot bght_{ij} + \beta_{5c} \cdot bght_{ij}^2 + \beta_{6c} \cdot watt_{ij} + \sum_{m=1}^{2} (\beta_{7c,n} \cdot color_{mij})\right) + \epsilon_{ij} \quad (1)$$

and

$$U_{ij} = \beta_0 \left(\frac{\beta_1}{1 - \frac{1}{(1+\beta_1)^{life_{ij}}}} \cdot price_{ij} + Ocost_{ij} \right) + \beta_2 \cdot type_{ij} + \beta_3 \cdot color_{1ij} + \beta_4 \cdot color_{2ij} + \beta_5 \cdot bght_{ij} + \beta_6 \cdot bght_{ij}^2 + \epsilon_{ij} \quad (2)$$

Experiment Procedure

1. Participants finish the choice tasks shown on the laptops. (Fig. 2)
2. They choose one that they are most likely to buy among five real bulb packages displayed on a table. (Fig.3 : Physical choice task)

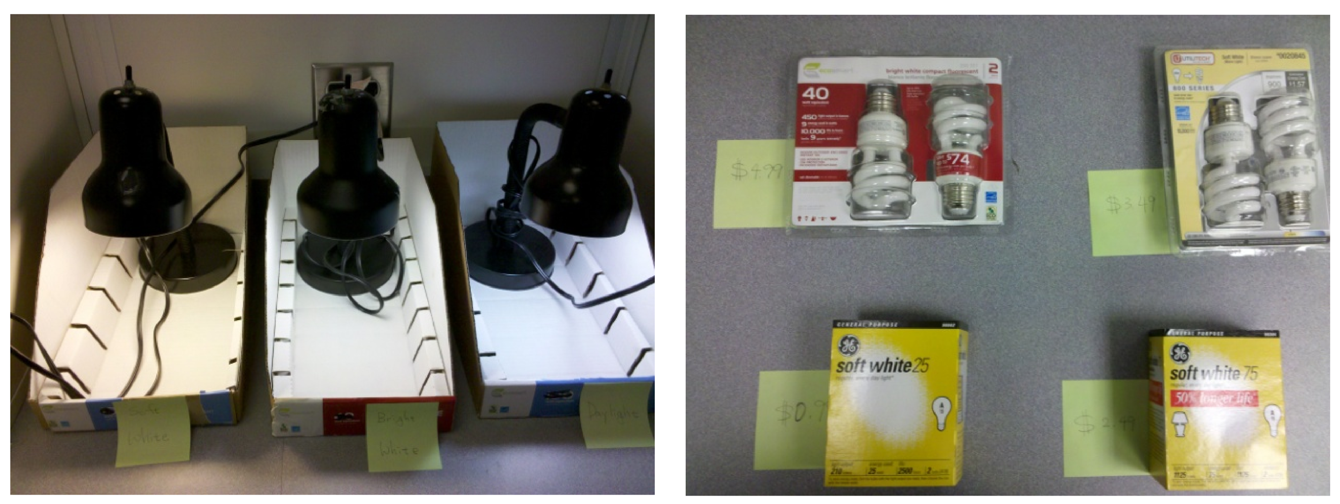


Figure 3. Experimental setup

3. They finish answering the remaining survey questions on demographics, experience, knowledge, and attitudes.

Results

Implicit discount rates drop five fold when operating cost information is provided.

Table 1. Estimates of implicit discount rates depending on the availability of operation cost information. Three columns represent the three nonlinear models we tested.

	Model type	
	Basic	**Basic+Attitude**
Operating cost shown	119% (22%)	96% (22%)
Operating cost not shown	553% (67%)	576% (75%)

Choices shift toward longer lifetime and lower power when the information is given. Bulb features and cost drive choice more than consumer demographics or awareness. Environmental awareness and political leanings affect bulb preferences.

Table 2. Significant variables observed from two main models

Variables	**Basic**		**Basic+Attitude**	
color=bright white	-0.165*	(0.0889)	-0.165*	(0.0890)
color=daylight	0.0368	(0.0862)	0.0419	(0.0862)
watt	-0.00271**	(0.00131)	0.00345	(0.00565)
watt*D_{ocost}	-0.00738***	(0.00188)	-0.00757***	(0.00191)
lifetime ($x10^3$ hours)	0.0972***	(0.00799)	0.0972***	(0.00799)
lifetime*D_{ocost}	0.0273**	(0.0113)	0.0274**	(0.0113)
brightness ($x10^3$ lumens)	1.621***	(0.417)	1.604***	(0.417)
brightness^2	-0.560***	(0.178)	-0.551***	(0.178)
(type=CFL)*NEP score			0.0478**	(0.0238)
watt*liberal			-0.00570***	(0.00207)
type=CFL	0.528***	(0.136)	-0.352	(0.497)
std. dev.	1.024***	(0.0987)	0.960***	(0.0982)
price	-2.222***	(0.278)	-2.199***	(0.274)
std. dev.	1.219***	(0.189)	1.178***	(0.177)
Log likelihood	-2306		-2292	
Observations	7,560		7,560	

The basic model was used to predict choice probabilities for the five physical samples presented in the second part of our experiment. The average share prediction error provides one metric for summarizing aggregate prediction accuracy. The model predicts share with an average of 3% error in the hold-out conjoint task and 6% error in the physical choice task, which involves unobserved attributes, compared to 10% error for a random model.

Table 3. Distribution of actual choices by subjects and of predicted choice probabilities for physical sample choices

	CFL #2	CFL #1	CFL #3	Incand. #1	Incand. #2	Total
Observed # of Choices	74 (44.1%)	33 (19.6%)	32 (19.0%)	23 (13.7%)	6 (3.6%)	168
Predicted % of Choices	30%	28%	18%	14%	10%	100%

Table 4. Average share prediction errors

	Estimation data		**Hold-out task**		**Physical choice**	
	Model	Random	Model	Random	Model	Random
Log-likelihood	-2306	-2768	-170.8	-184.6	-245.8	-270.4
Avg. share pred.error			3%	10%	6%	10%
N	2520=168*15		168		168	

Conclusion

Displaying annual operating cost information will increase the adoption of efficient light bulbs by leading consumers to choose bulbs with longer lifetime and lower energy use and to use substantially lower implicit discount rates. The new FTC label that includes operation costs will be a good improvement over the old labeling.

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Assessing the effect of EISA and EPA regulations on mercury inventory from residential lighting

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Background Information

Lighting constitutes a large share of electricity consumption, and many current lighting technologies are highly inefficient. Improved technology for lighting holds great potential for energy, emissions and cost savings.

- Fluorescent technologies are seen as promising alternatives to incandescent lamps, since they last longer, have higher efficacy and are more efficient.
- Fluorescent replacements lead to reduced mercury emissions from power plants during the use of the bulb. However, concerns exist that the net mercury emission throughout the lifetime of the bulb may increase as the result of the mercury content in the bulb.

The present analysis examines the impact of recent U.S. mercury-related regulations on residential lighting demand growth over the next ten years, in terms of electricity consumption and mercury inventory.

Recent mercury-related regulations

Recent lighting energy efficiency-related regulations and utility emission standards both impact mercury mass through the use of lamps.

- The Energy Independence and Security Act of 2007 (EISA) has established requirements for the maximum wattages at different four ranges of lumen output. This indirectly translates into a "phase-out" of incandescent lamps.

Light Output Range (Lumens)	Future Maximum Rated Wattage (Watts)	Effective Date
1,490-2,600	72	January 1, 2012
1,050-1,489	53	January 1, 2013
750-1,049	43	January 1, 2014
310-749	29	January 1, 2014

- In 2011, EPA issued the "maximum achievable control technology" (MACT) standards for mercury pollution from power plants. The standards establish mercury emission limits for both existing and new coal-fired or oil-fired power plants.

Subcategory of power plant	Mercury emission limit for new sources (lb/GWh)	Mercury emission limit for existing sources (lb/GWh)
Coal-fired unit not low rank virgin coal	1.3E−2	1.3E−2
Coal-fired unit low rank virgin coal	4.0E−2	4.0E−2
Liquid oil-fired unit	1.0E−4	2.0E−3

Data

Data is obtained from EPA eGRID 2007, 2010 U.S. Lighting Market Characterization, and EIA Annual Energy Outlook 2012. eGRID 2007 provides nationwide power plant-specific electricity generation and emissions rates for mercury. 2010 U.S. Lighting Market Characterization provides average number of lamps, average daily operating hours, and average wattage and efficacy by lamp type in the residential sector. Annual Energy Outlook 2012 provides U.S. household units, average house square footage and electricity grid mix.

Assumptions

The power plant stock is assumed to be static over the next ten years. The mercury intensity of coal and efficiency of mercury control technology are assumed to remain the same throughout 2022. The inventory of residential incandescent lamps is assumed to be composed of equal number of lamps in 40W, 60W, 75W, and 100W, 95% of which burn out at end of their lifetime (~1,000 hours) while the remaining 5% are replaced prior to their burn-out dates due to retrofits. The stock of incandescent lamps as of the base year is assumed to be composed of equal amount of brand-new, half-year old, and one-year old lamps. All the incandescent lamps subject to EISA maximum wattage requirements are assumed to replaced by CFLs, though they can possibly be replaced by LEDs as the technology evolves. A 20% national CFL recycling rate is applied to calculate the total mercury mass from CFLs, assuming 25% out of the 5mg mercury contained in each non-recycled CFL would be released to the environment.

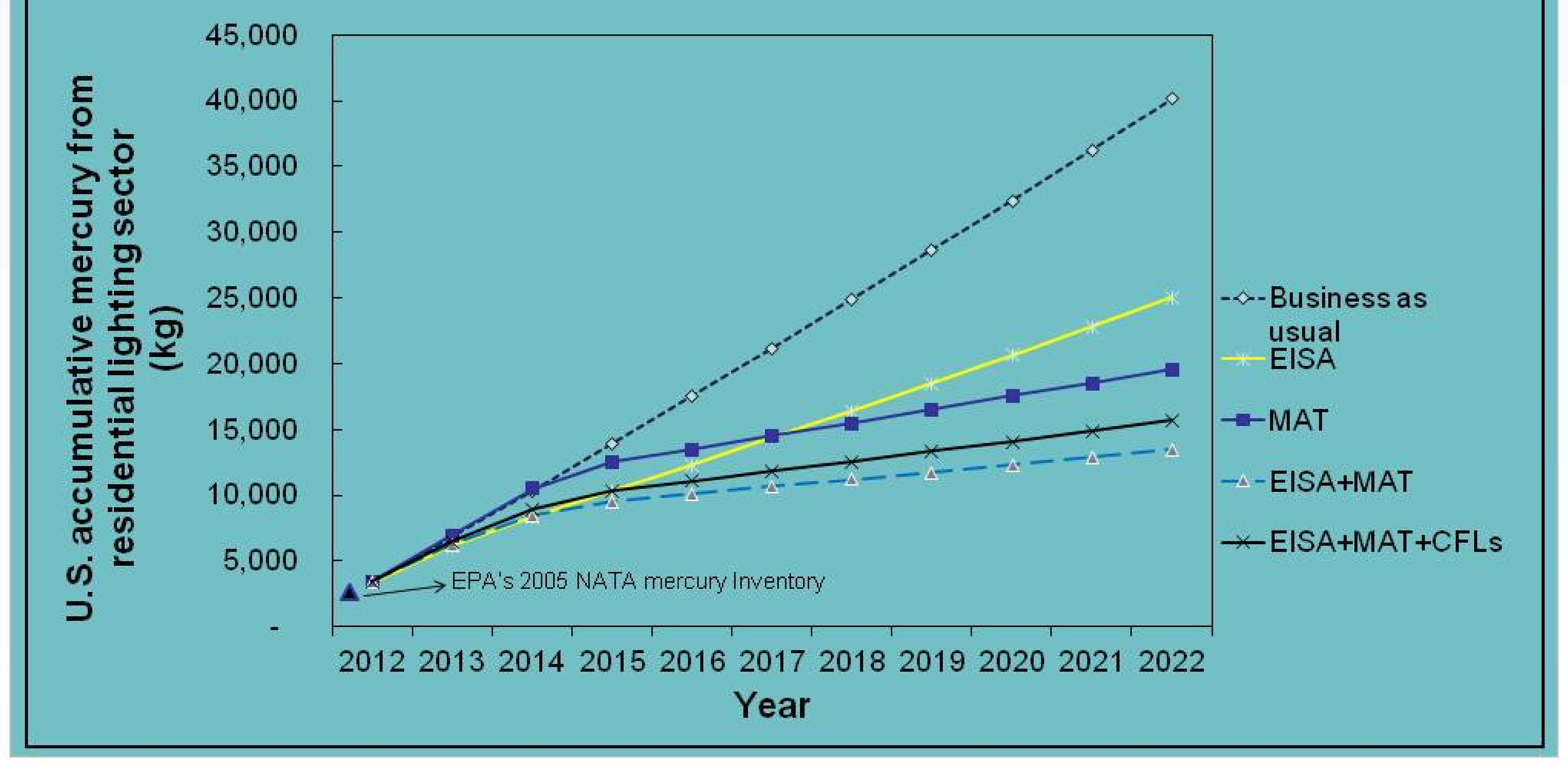
Policy scenarios

The analysis examines the influence of EISA and MACT on mercury mass from lighting under four policy scenarios over the period of 2013 to 2022:

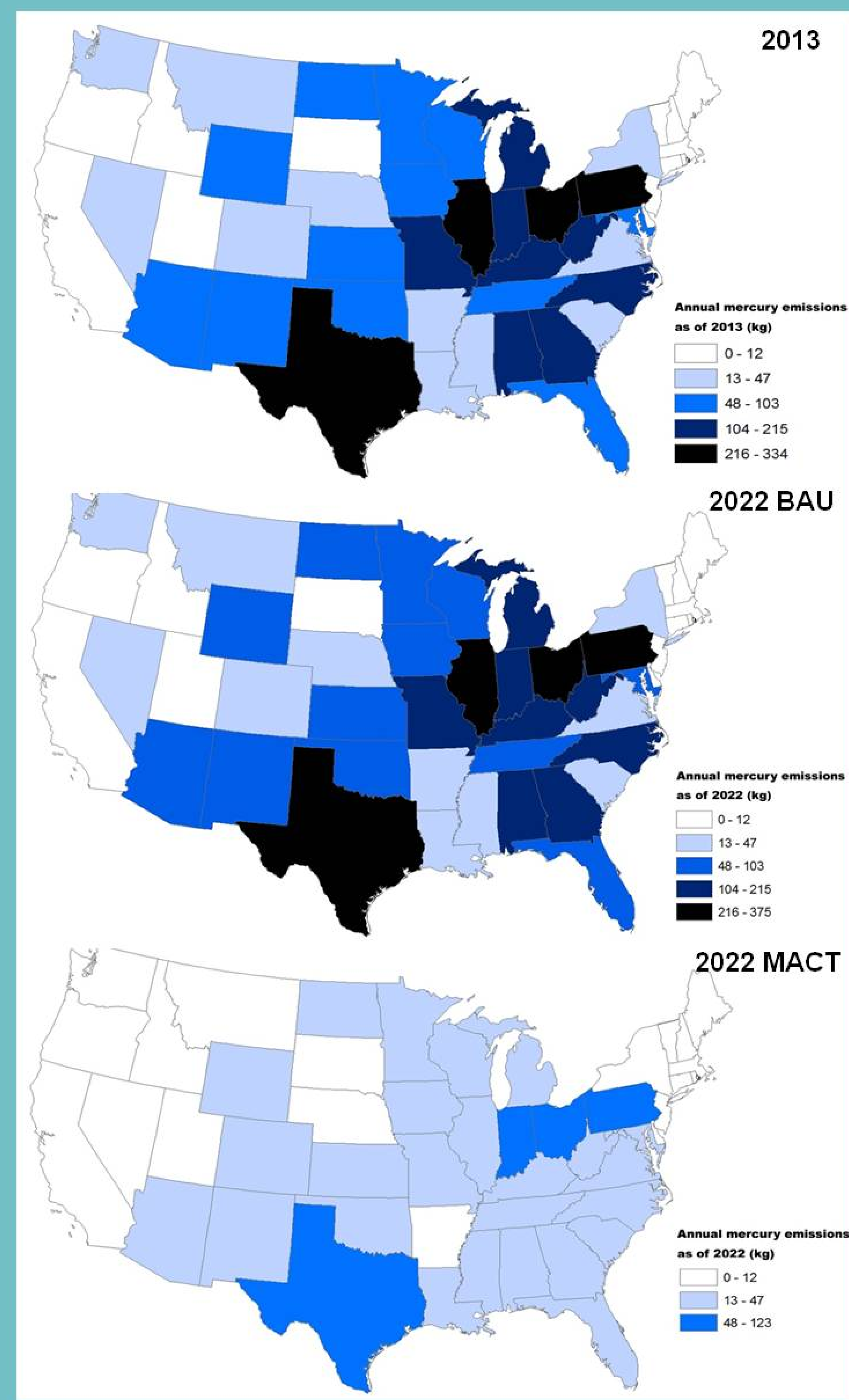
Business-as-usual scenario	Projected mercury emissions inventory of residential lighting (in particular, incandescent lamps), based on the growth of residential households and lighting demand.
EISA scenario	Projected mercury emissions from residential lighting, accounting for change in lamp stock composition as the lamp maximum wattage requirements set by EISA 2007 takes into effect in 2013.
MACT scenario	Projected mercury emissions from residential lighting, accounting for the mercury emission limits for existing coal-fired power plants set by MACT that will take into effect in 2015. This scenario is generated through a bounding analysis, assuming lighting is entirely powered by oil-fired generators or coal-fired generators.
EISA + MACT scenario	Projected mercury emissions from residential lighting, accounting for both the maximum wattage requirement and mercury emission limits.

Results

Projected mercury mass from **power plants** under different policy scenario:



Mercury mass from coal-fired power plants will substantially decrease over the next ten years, as a result of MACT:



- The mercury mass profiles look different by state, depending on the electricity grid mix of each state. TX and OH remain one of the biggest contributors to mercury emissions from power plants, despite of MACT.
- Mercury mass can be reduced by 44% by 2022 in EISA scenario and 73% in MACT scenario. EISA+MACT scenario will generate the most mercury mass reductions, 85% by 2022.
- Mercury mass from power plants are about 20 times as many as that released from CFLs.

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Utility Demand-Side Efficiency Spending

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Abstract:
This work examines energy savings and variation in the cost-effectiveness of utility demand-side energy efficiency (DSEE) expenditures. Self-reported utility-level data, made available by EIA from 1990, will be used to develop and estimate of the cost-effectiveness of reduced electricity demand. I hypothesize that this data will include significant geographic (and temporal) variation, reflecting differences in utility program design, state policy objectives, and regional climatic conditions. The existing literature on the subject of demand-side efficiency programs neglects this heterogeneity.

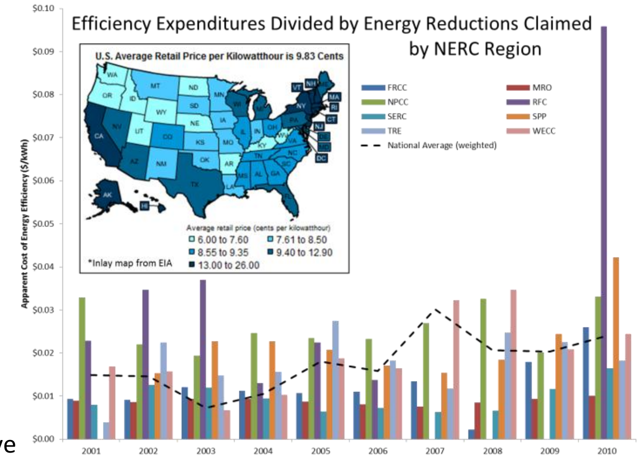
These data will be subsequently combined with data which captures the variation in emission factors associated with marginal generation. This will enable the development of an assessment of the social cost-effectiveness of the DSEE spending which will incorporate the geographic variation of both efficiency efficacy and emissions intensity.

Primary Research Questions:

1) What regions have benefited most from DSEE?
2) Has efficiency spending been cost-effective? Where? Where it has not been; why?
3) What have been the external costs/benefits and how does this vary geographically?

Initial Hypotheses:

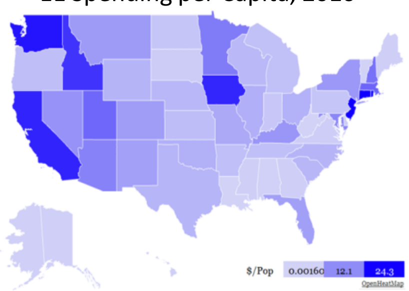
1) Traditionally structured states, that have a guaranteed rate of return, will have less cost-effective EE programs.
2) Cost-effectiveness will vary between climate zones (in what direction?), but have some consistency within them.
3) States with greater cumulative EE spending will have higher costs for new spending (higher on the MCC).



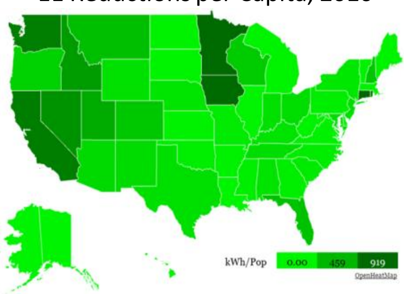
Data:

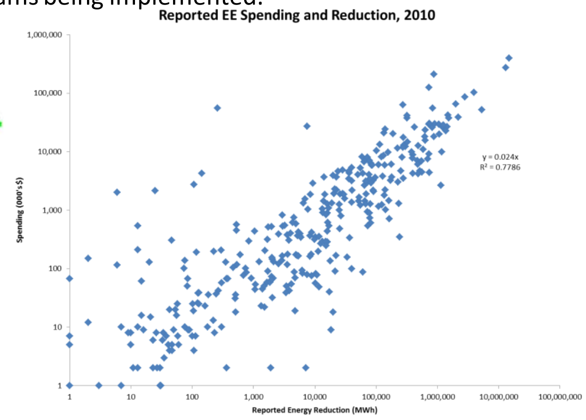
EIA Form 861 provides utility-reported DSEE activities as well as other utility characteristics. This will be combined with data gleaned from reports to state-level PUCs for a sample of utilities to develop a characterization of the types of programs being implemented.

EE Spending per Capita, 2010



EE Reductions per Capita, 2010





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The electricity consumption and energy savings potential of video game consoles in the United States

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Background

Over 100 million current-generation video game consoles have been sold in the US. In addition to increased sales, game consoles are consuming more energy as they become more powerful computing machines. For example, the launch models of the Microsoft Xbox 360 and Sony PlayStation 3 both consume over 175 W when in active use, while the previous models of these consoles consumed less than 100 W at launch. In addition to playing video games (historically their only function), consoles can play physical media, stream digital media from local or Internet sources, and provide access to a host of media and online services, causing the usage of game consoles to increase. The power consumption of video game consoles is increasing, the quantity of game consoles in US homes is increasing, and it is likely that the amount of time they are being used is increasing, resulting in a rapid increase in overall electricity consumption.

Figure 1: *Active power consumption of the three PlayStation console generations over time. The color of the circle corresponds to the console generation that model falls under, and area of the circle represents worldwide sales of the model (from redesign date forward). The figure shows both the trend of increasing power consumption between models, due to increased computational capabilities, and decreasing power consumption within a model, due to improved design under fixed performance.*

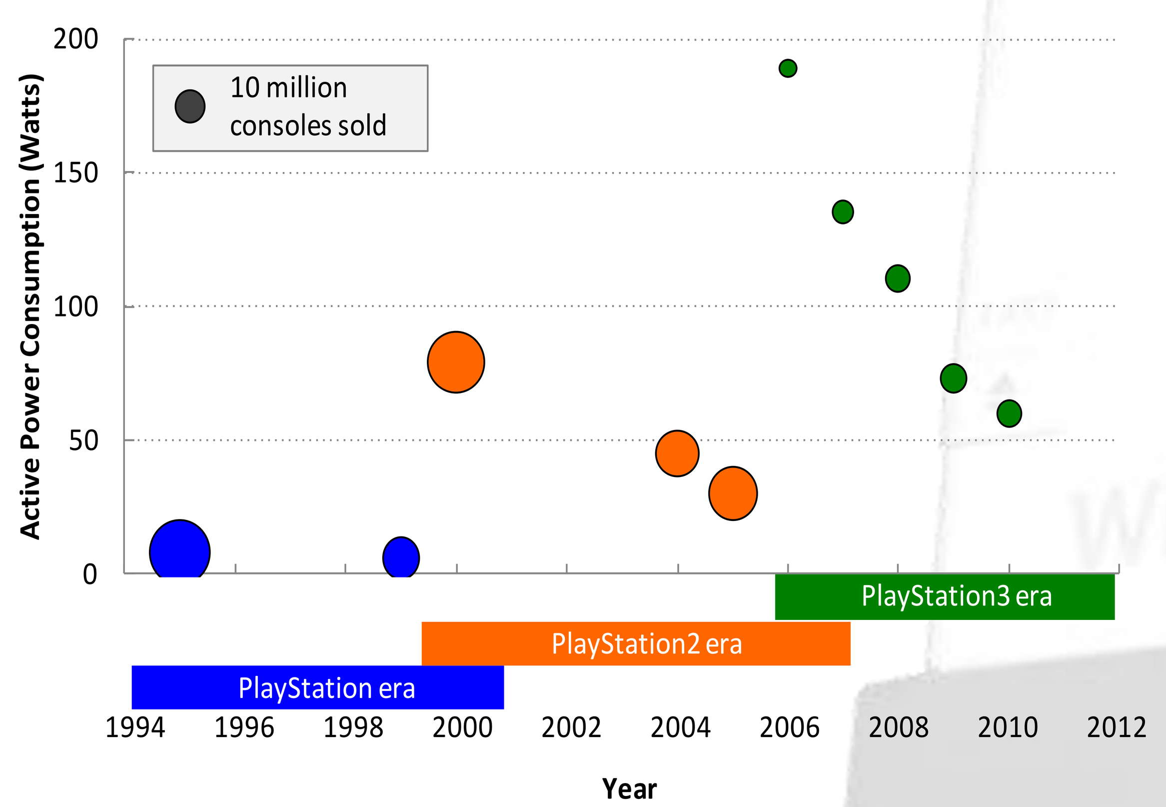
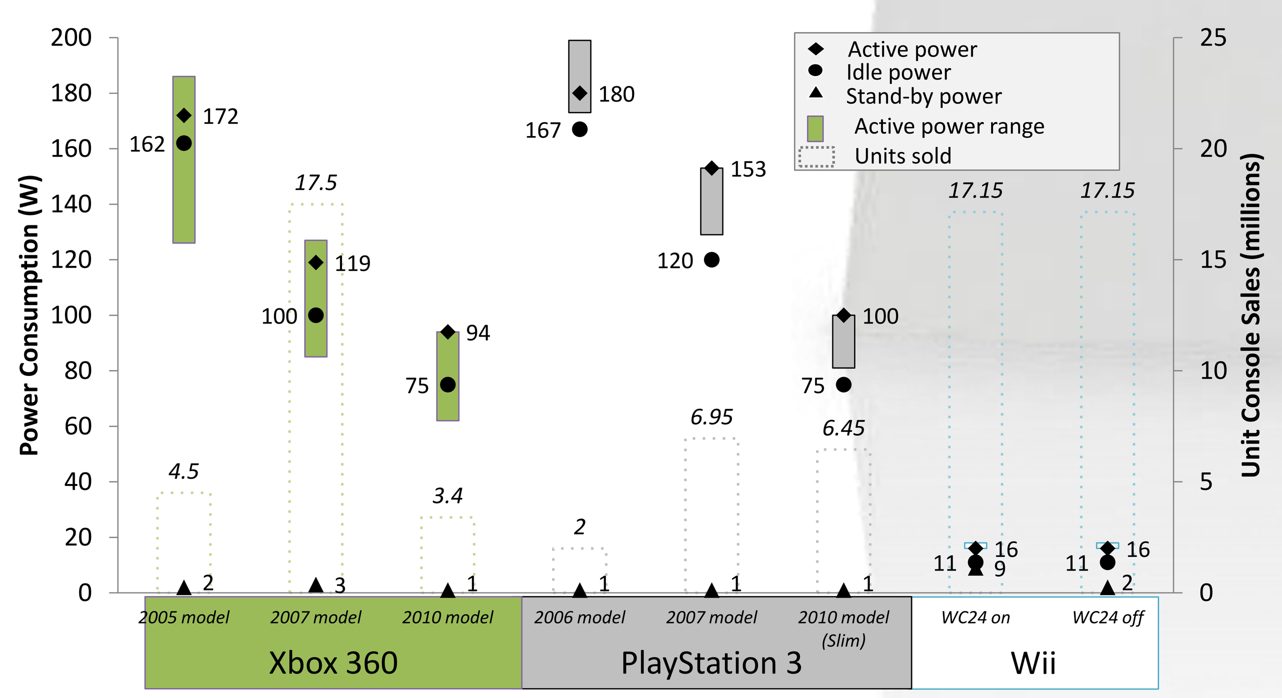


Figure 2: *Power consumption and sales figures of current-generation video game consoles. Ranges are provided for the active power.*



Estimated Console Electricity Consumption

Using the data for power consumption, number of consoles in American homes, and time the consoles are operational in each of the three modes (active, idle, and stand-by), we estimate that total console electricity consumption in the US was 16 TWh in 2010. This is roughly 1% of annual US residential electricity consumption and is double the annual electricity consumption of the state of Rhode Island. 16 TWh is approximately 330 kWh per game console per year, though actual consumption depends strongly on which console is being discussed and how it is used.

Table 1*: Base case total US console electricity use by operational mode and by console type. Energy units are GWh in 2010.*

(GWh in 2010)	Xbox 360	PS3	Wii	All
Stand-by	370	90	1,100	1,600
Active	1,600	890	80	2,600
Idle	6,800	4,100	1,000	11,800
Total	8,700	5,100	2,200	**16,000**

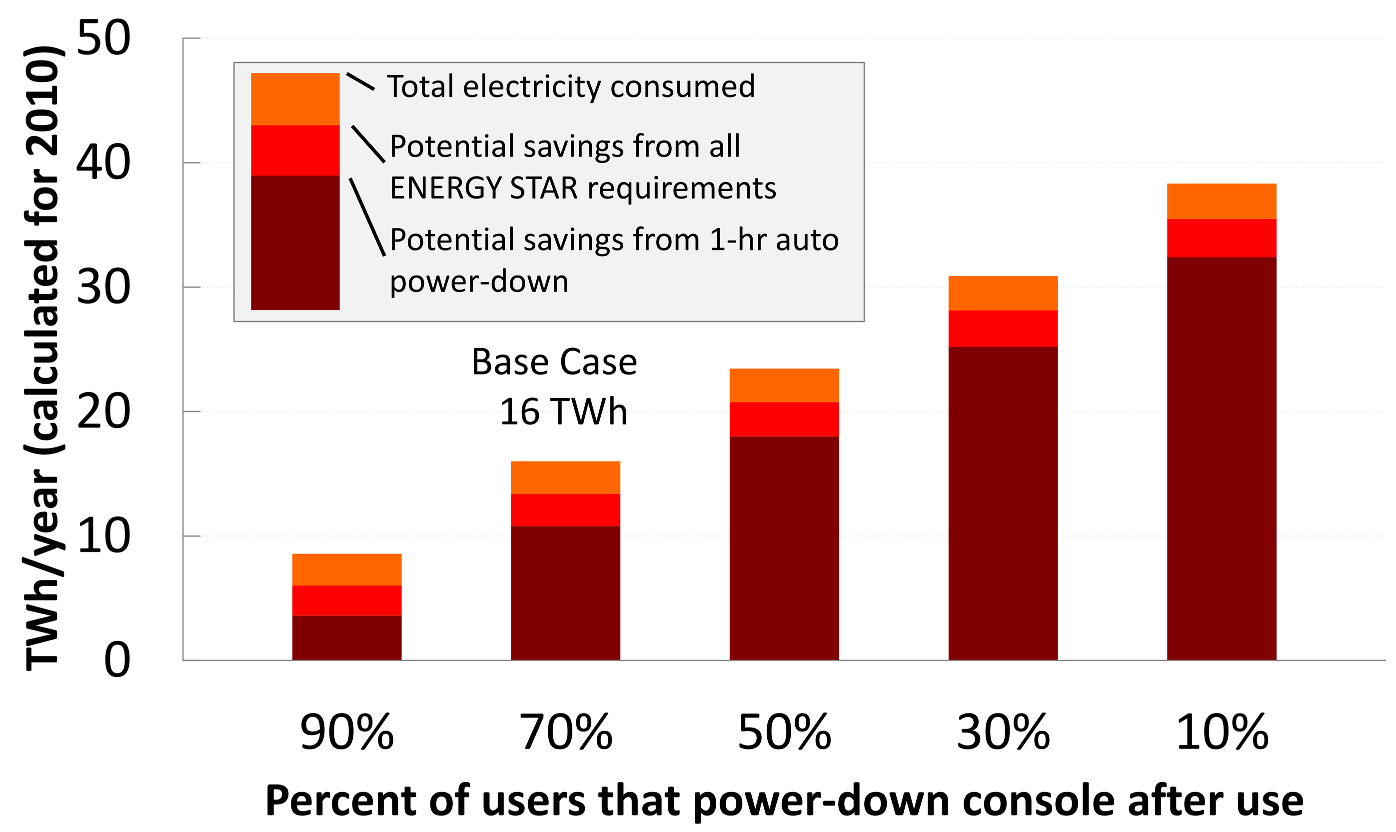
Value of Energy-saving Improvements

There are several technical options for reducing overall electricity consumption of video game consoles. Overall consumption can be decreased by reducing the power consumption in any or all of the modes of operation (stand-by, idle, or active use), or by increasing hardware flexibility so that less computationally-intensive tasks can be performed with some of the processing resources disabled. Proposed ENERGY STAR requirements target energy use in two distinct ways. The first specifies limits on how much power the console can use while operating in each state. The second specifies how long the console can be left in various states, increasing the likelihood that the console will be in its lowest power state. We find that the auto-power down requirement would save more energy that all other ENERGY STAR requirements combined, as long as more than 7% of users leave their consoles idle when not in use (Figure 3).

Table 2*. ENERGY STAR Game Console Requirement (version 5.1) summary.*

	Phase One	*Phase Two*	*Phase Three*
Operational Mode Power Requirements			
Sleep	2 W	1 W	1 W
System idle	--	45 W	25 W
Media playback	--	--	35 W
Power Management Requirements			
Sleep mode engaged after 1 hour inactivity	✓	✓	✓
Console must power down immediately after auto-wake event		✓	✓
Power management settings enabled by default	✓	✓	✓

Figure 3*: Total electricity consumed by video game consoles and potential savings of auto power-down and all ENERGY STAR Tier 3 requirements, as a function of the percent of users that manually power-down the console after use.*



Conclusions

We estimate that the total electricity consumption of video game consoles in the US was around 11 TWh in 2007 and 16 TWh in 2010, an increase of almost 50% in three years. Assuming that 30% of consoles are left idle, the savings from a 1-hour auto power-down, which could be enabled on most of the 75 million existing current-generation consoles by a firmware update, could have reduced residential energy consumption by about 1% in 2010. While the energy savings from a 1-hour auto power-down amounts to 1% of residential electricity, it is perhaps more important to note that it could be achieved with almost no upfront cost, no change in the quality and level of service provided to consumers, would have no adoption/implementation delay, and does not rely on any action or decision on the part of consumers.

Acknowledgements

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Low-hanging fruit? Reducing fuel burn and emissions from taxiing aircraft

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Background

- In 2005, aviation was responsible for 3.5% of total anthropogenic radiative forcing. By 2050, its share is expected to rise to 4.0-4.7% (Lee et al. 2009).
- At the same time, as energy prices have risen, airlines have struggled to maintain profitability.
- The industry is under pressure to reduce its operating expenses, as well as its environmental footprint (e.g., under the auspices of the European Union's Emissions Trading Scheme).

In this context, it is important to understand the costs associated with different measures to reduce the industry's environmental footprint.

This research contributes to an existing body of work (e.g., Deonandan & Balakrishnan 2010) by estimating both the benefits (lower fuel burn, emissions) and costs (capital, maintenance, labor, fuel) associated with switching from main-engine taxiing to alternative methods of taxi.

Data and Methods

- The analysis is based on 2006 (BTS 2011) data on the taxi times of domestic passenger flights: just over 80% of all US departures (8 million flights) are included.
- It is assumed that engines are operated at the idle (7% of maximum) setting while taxiing, and emissions and fuel are estimated using an ICAO (2010) database. Data on auxiliary power unit (APU) fuel burn was obtained from a number of industry sources (Fleuti & Hofmann 2005, EEA, Inc. 1995).
- In the base case, it is assumed that the aircraft taxies with either one or two main engines running. This base case is compared to two alternatives.
  - The aircraft is towed by a tug powered by diesel, gasoline, or electricity from an on-board battery.
  - The aircraft is propelled on the ground by an APU-powered electric motor embedded in its nose wheel.

Future work

- Refine and validate assumptions based on interviews with airline and airport executives, regulators.
- Quantify non-GHG emissions reductions (e.g., NO_X, VOCs)
- Build a detailed understanding of the operational issues that their use might raise: for example, whether the current layout of airports allows for their movement without compromising safety.
- For the electric motor-in-nose-wheel system, quantify the impact of the increase in aircraft weight.

P R E L I M I N A R Y Results

- In the best case, the alternatives studied would reduce CO_2 emissions from domestic civil aviation in the US by about 2%, while reducing costs.
- If we assume that aircraft always taxi with one engine, the additional emissions reductions from using a tug are very expensive
- Using an embedded electric motor to propel the aircraft during taxi reduces emissions at negative cost in all considered cases

Figure 1: Switching to petroleum-fuelled tugs would cut emissions at negative cost if we assume that in the base case aircraft taxi with two main engines (figure on left), but not if we assume that they taxi with only one (figure on right)

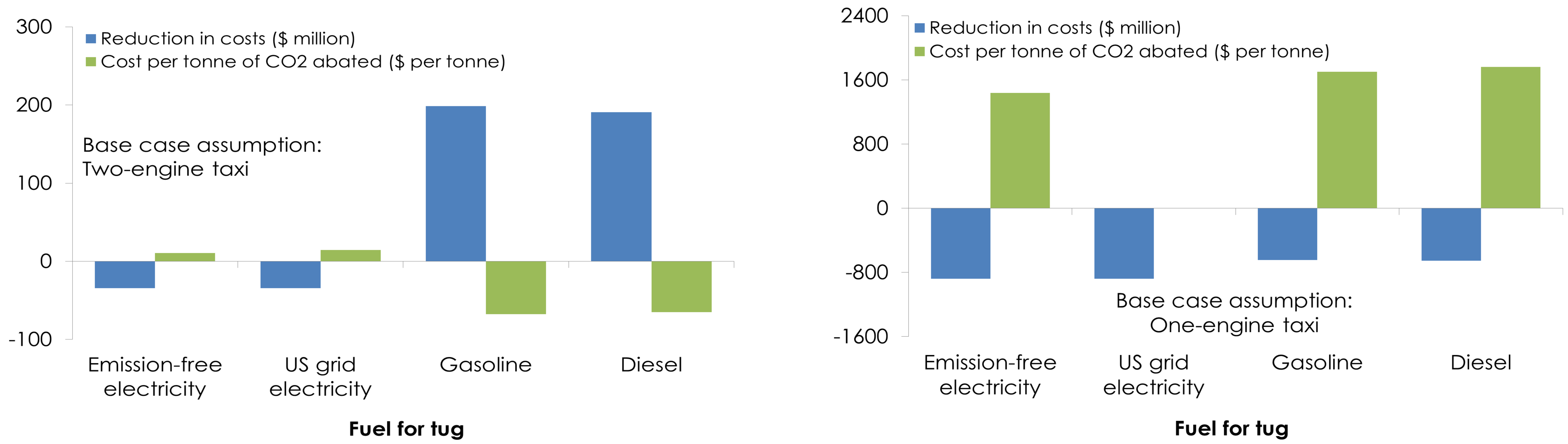


Figure 2: Electric tugs, though uneconomical on average, could be reduce both costs and emissions at some airports

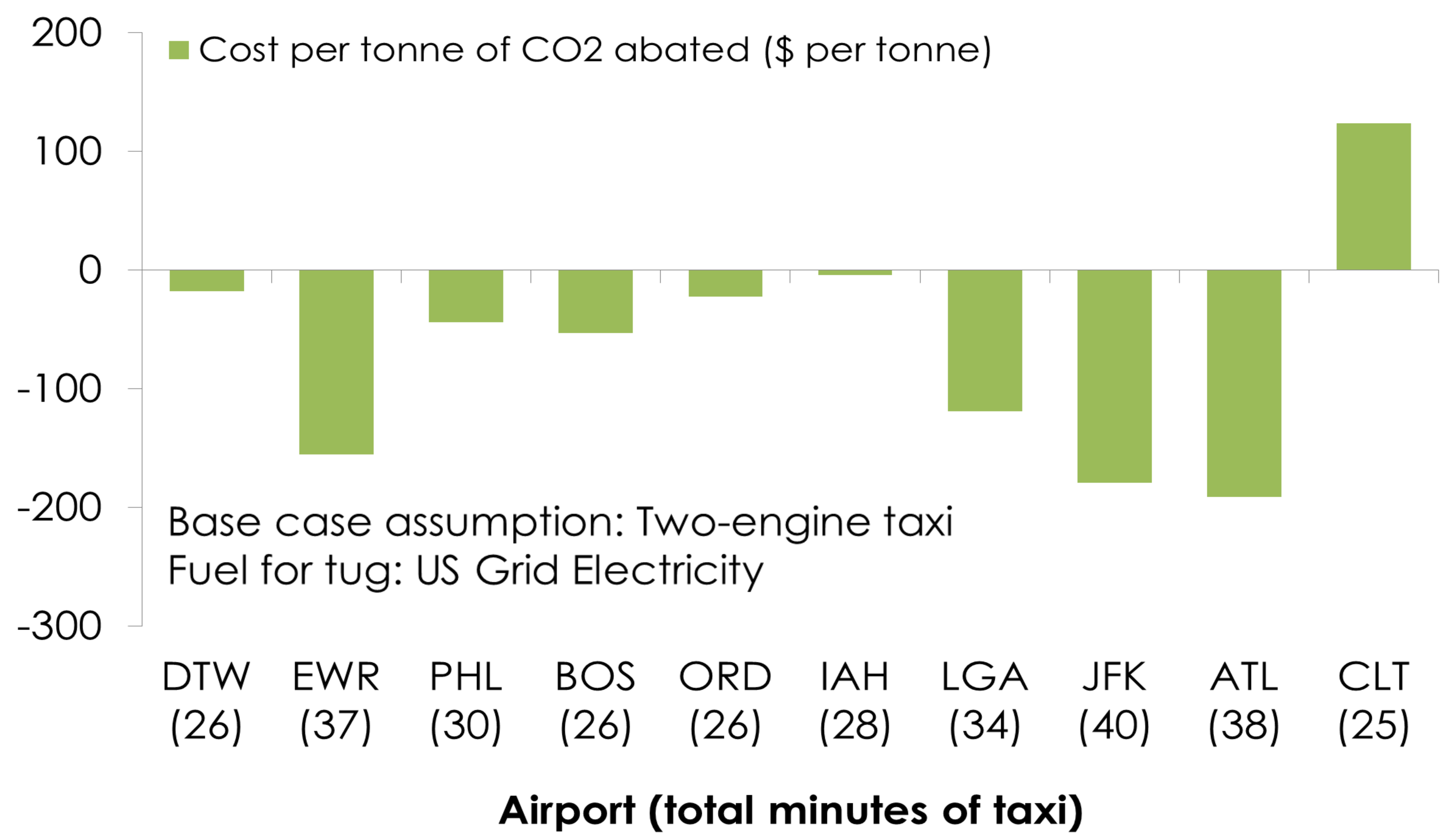
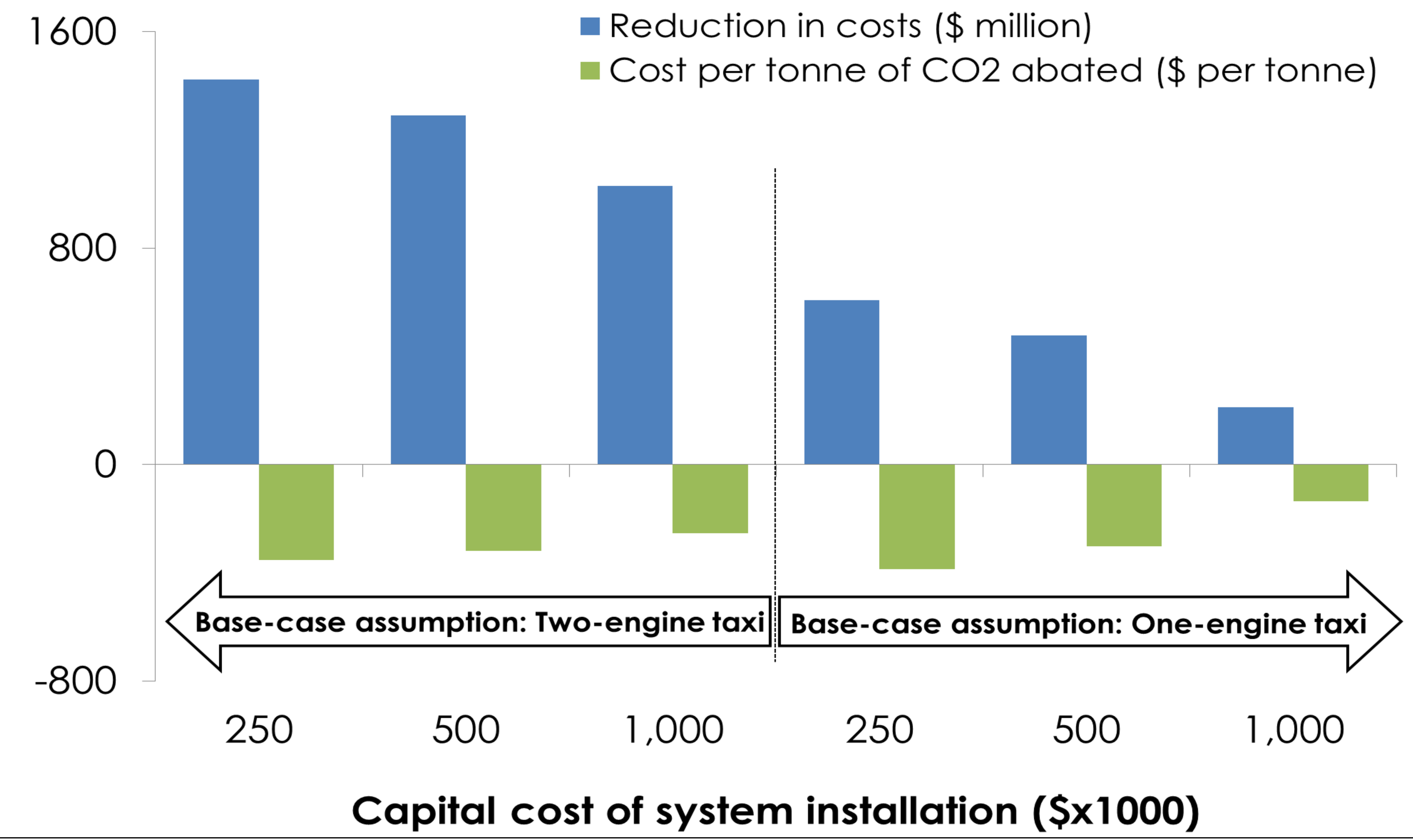


Figure 3: Embedding an APU-powered electric motor in the nose-wheel would cut emissions at negative cost



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Advertising Energy Saving Programs:
The Potential Environmental Cost of Emphasizing Monetary Savings

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We studied the effect of highlighting financial or environmental benefits of saving electricity. We presented participants with descriptions of residential energy programs, emphasizing either (a) monetary savings, (b) environmental impact reduction, or (c) both. We found that highlighting monetary savings, whether alone or in addition to environmental savings, reduced respondents' willingness to enroll in energy-savings programs. In addition, fewer participants provided environmental reasons for their enrollment decisions when programs emphasized monetary savings, even when environmental savings were also emphasized.

Introduction

- Some energy programs have both financial and environmental benefits. Companies tend to use the former to entice customers.
- According to standard economics, emphasizing the financial benefits of saving energy should increase customers' motivation to use less. However, offering financial rewards, especially small ones, might undermine intrinsic motivation for actions that people would take anyway.
- We tested whether emphasizing financial savings undermines the intrinsic motivation of environmental protection.

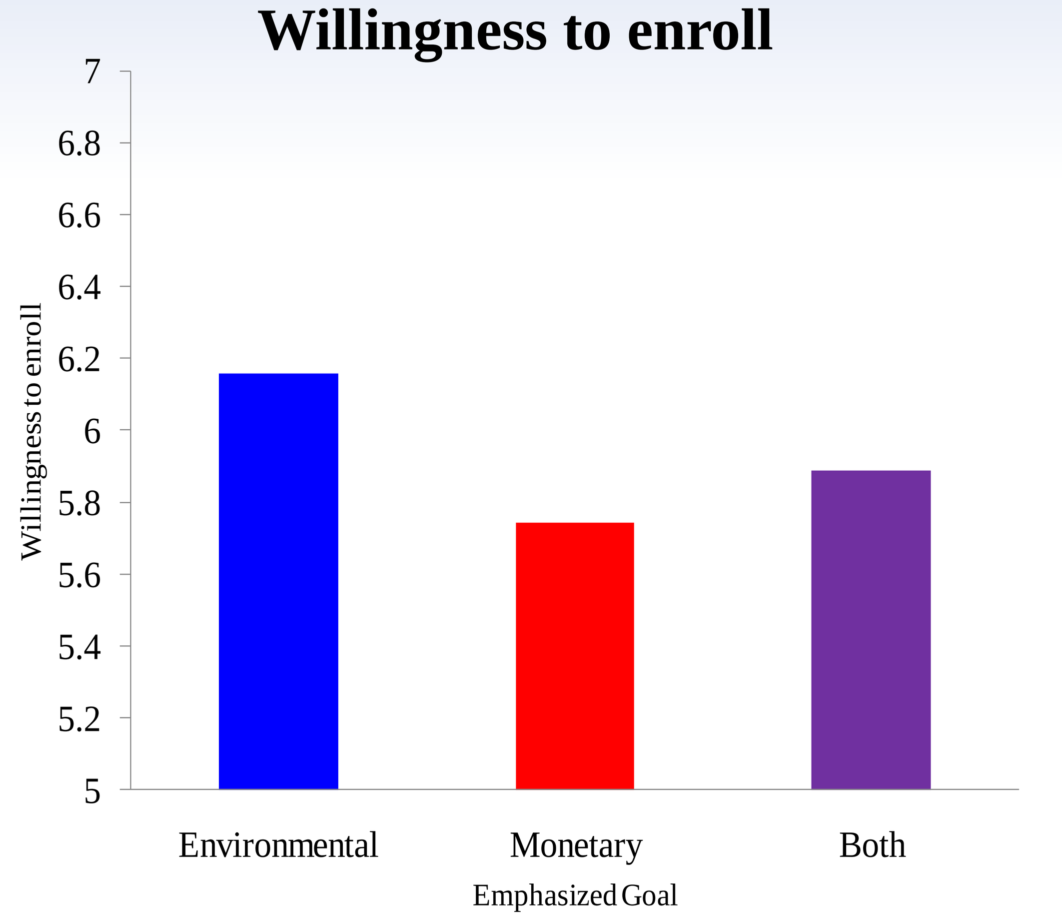
Participants

- We recruited 1,172 participants through Amazon's mTurk and Craigslist. All reported paying their own electricity bill (M_{age} = 33.2; SD_{age} = 11.9).

Procedure

- We described two programs modeled on those currently offered by electric utility companies: one targeting overall *energy conservation* and one targeting *peak shaving*, designed to reduce consumption when demand might overload the grid.
- The program descriptions emphasized either reduced environmental impacts, reduced electricity bills, or both.
- Participants rated their willingness to enroll, and explained their answers.
- They reported their environment-related attitudes on the revised New Ecological Paradigm (NEP) scale.

Willingness to enroll



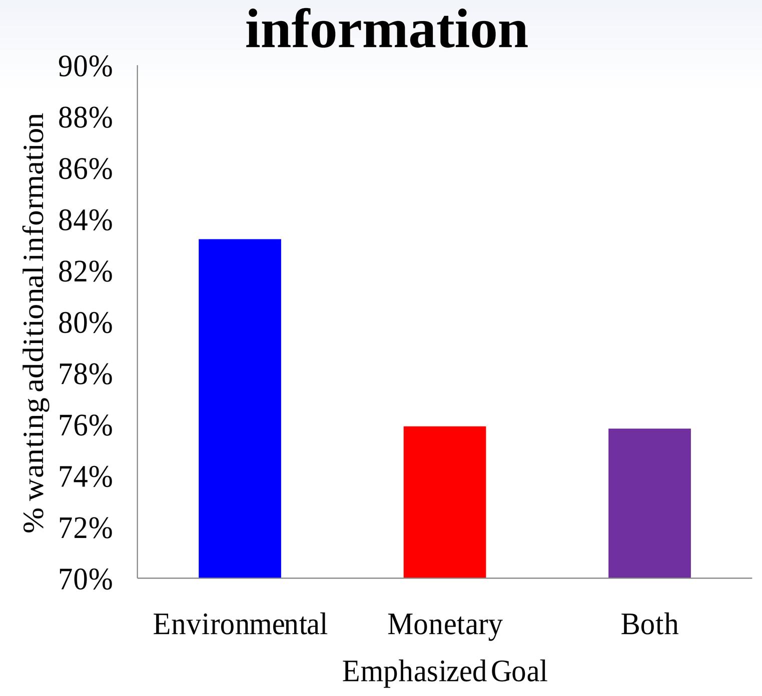
Significant main effect of emphasized goals, $F(2, 1168) = 6.87$, $p < .01$, with pair-wise comparisons indicating greater willingness when emphasizing environmental savings (M = 6.16, SD = 1.46), compared to monetary savings (M = 5.74, SD = 1.57), $F(1, 1168) = 13.55$, $p < .01$, or both (M = 5.89, SD = 1.63), $F(1, 1168) = 5.85$, $p < .05$, with no significant difference between the latter two, $F(1, 1168) = 1.63$, $p > .10$.

Reasons about enrolling (coded)

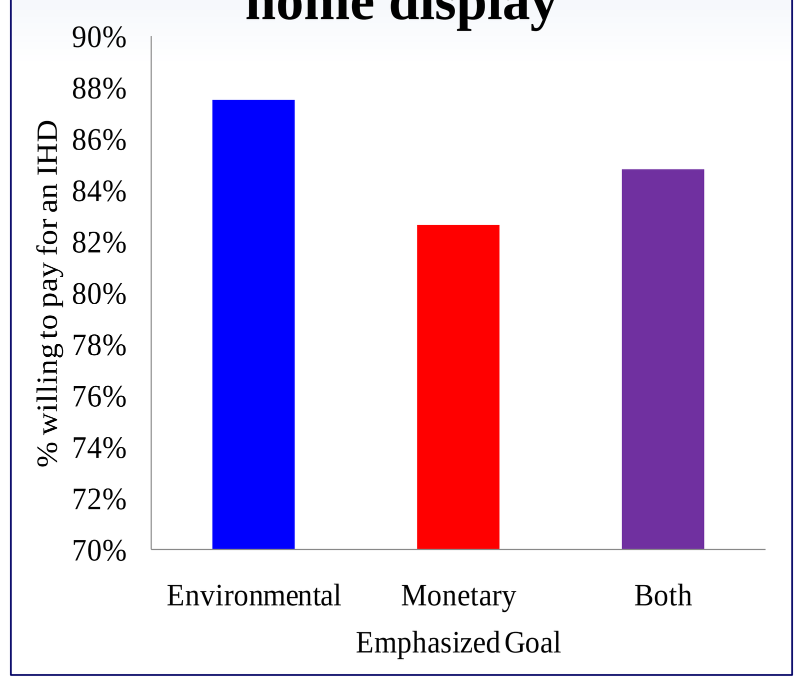
Reason \ Goal	Environmental	Monetary	Both
Monetary reasons	41.3%	43.1%	43.5%
Environmental reasons	24.2%	12.2%	16.7%
Feedback and control	14.5%	14.0%	14.9%
Need more time/information	10.6%	12.0%	11.4%
Save energy	15.1%	7.4%	10.6%

Environmental reasons for enrollment decisions were significantly more common when emphasizing environmental savings rather than financial savings, $p < .01$, or both, $p < 0.05$, with a marginally significant difference between the latter two, p = 0.08. Emphasizing financial savings did not increase mention of monetary reasons (all $ps > .10$).

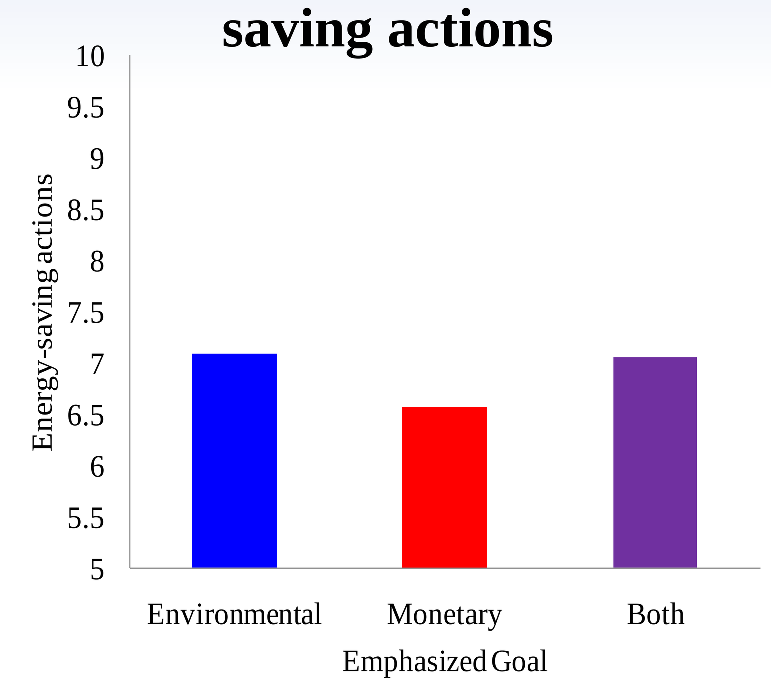
Want to receive additional information



Willingness to pay for an in-home display



Willingness to take energy-saving actions



Programs emphasizing environmental savings lead more participants to want additional information, to be willing to pay for an in-home energy display, and to select more energy-saving actions, compared to programs emphasizing monetary savings or both ($ps < .06$). However, the latter two variables showed no significant differences between emphasizing environmental vs. both goals (p > .10). Only for energy saving actions was emphasizing both goals better than emphasizing just financial ones, $F(1, 1168) = 10.97$, $p < .01$.

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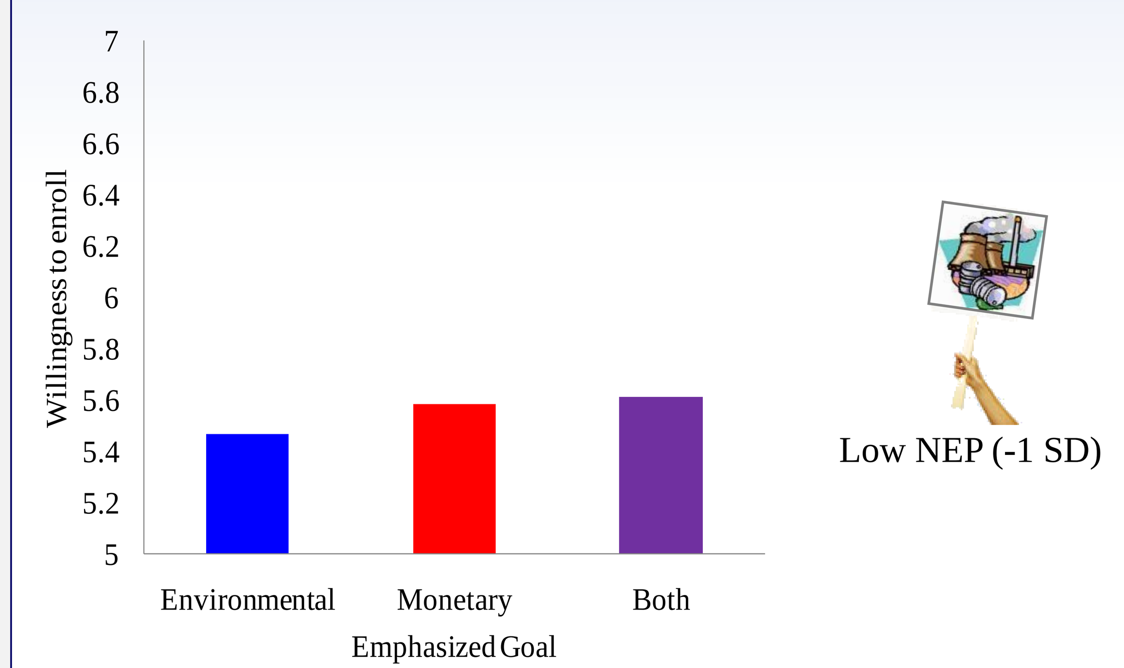
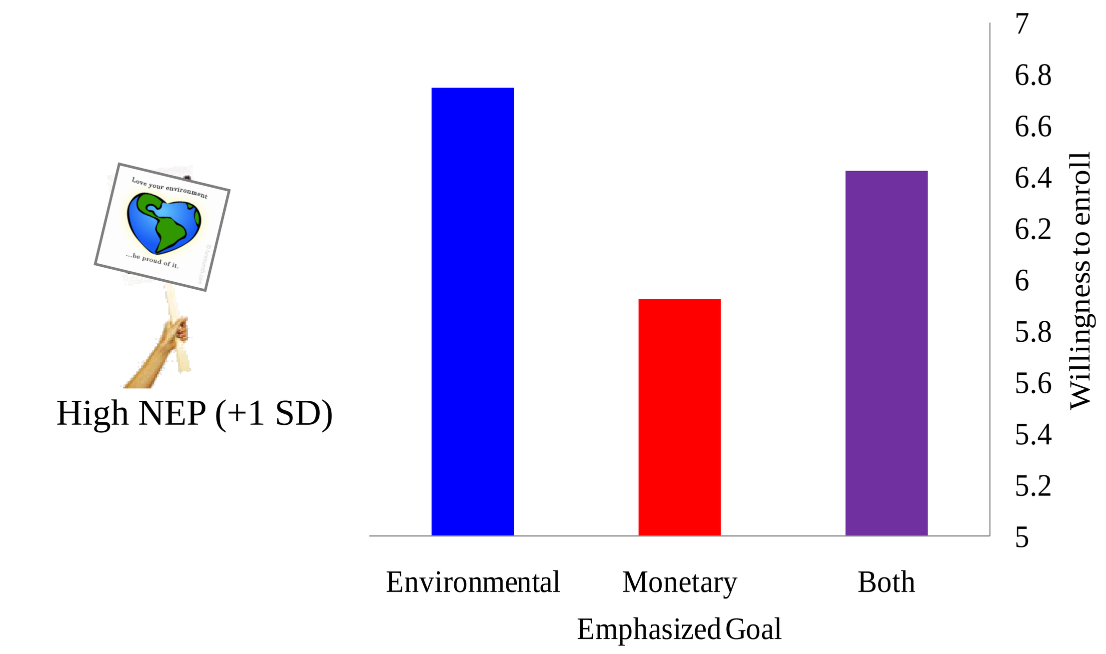
Conclusions

- Emphasizing the monetary benefits of residential energy savings programs, either alone or in addition to environmental benefits, reduced reported willingness to enroll in them.
- Participants spontaneously provided monetary reasons for their enrollment decisions, whether or not the program description mentioned monetary benefits.
- Participants were half as likely to offer environmental reasons when the program descriptions emphasized monetary benefits, even if the environmental ones were jointly highlighted as well.

Willingness to enroll and attitudes toward the environment





NEP scores (M = 3.65 SD = 0.65) were significantly above the scale-midpoint (= 3.00) (t (1171) = 29.37, $p < 0.01$). Comparing low-NEP and high-NEP participants (1 SD below or above the sample mean) revealed a marginal interaction between NEP and emphasized goals, (F(2, 328) = 2.62, p = .07).

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