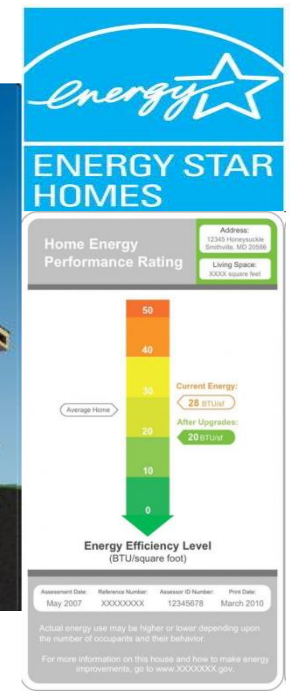
NEMS Modeling:
Making Homes Part of the Climate Solution

Georgia Institute of Technology & Oak Ridge National Laboratory

March 24, 2011



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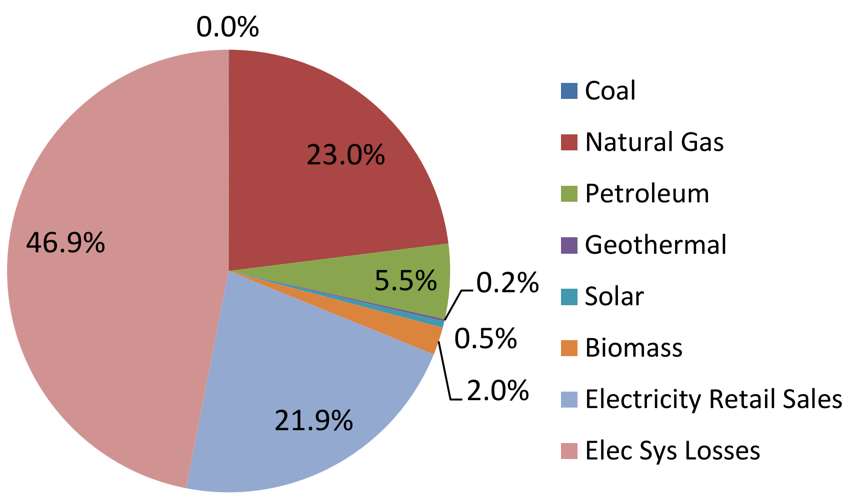
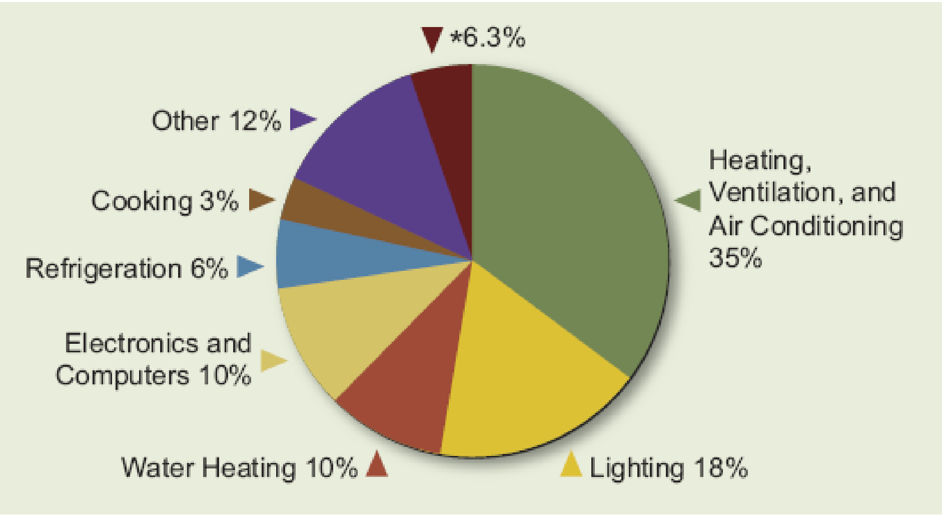
Energy Use in U.S. Buildings by Source and End-Use

Residential Energy Consumption, 2009



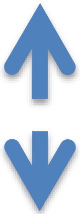
Residential Buildings, 2006



Residential Energy Consumption, 2035

Electricity: 24%

Natural gas: 21%
Petroleum: 4%

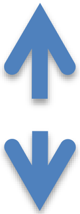


Source: U.S. EIA, *Annual Energy Review 2010*

Residential Buildings, 2035

Other Uses: 26%

Lighting: 10%



Source: U.S. EIA, *Annual Energy Outlook 2010*

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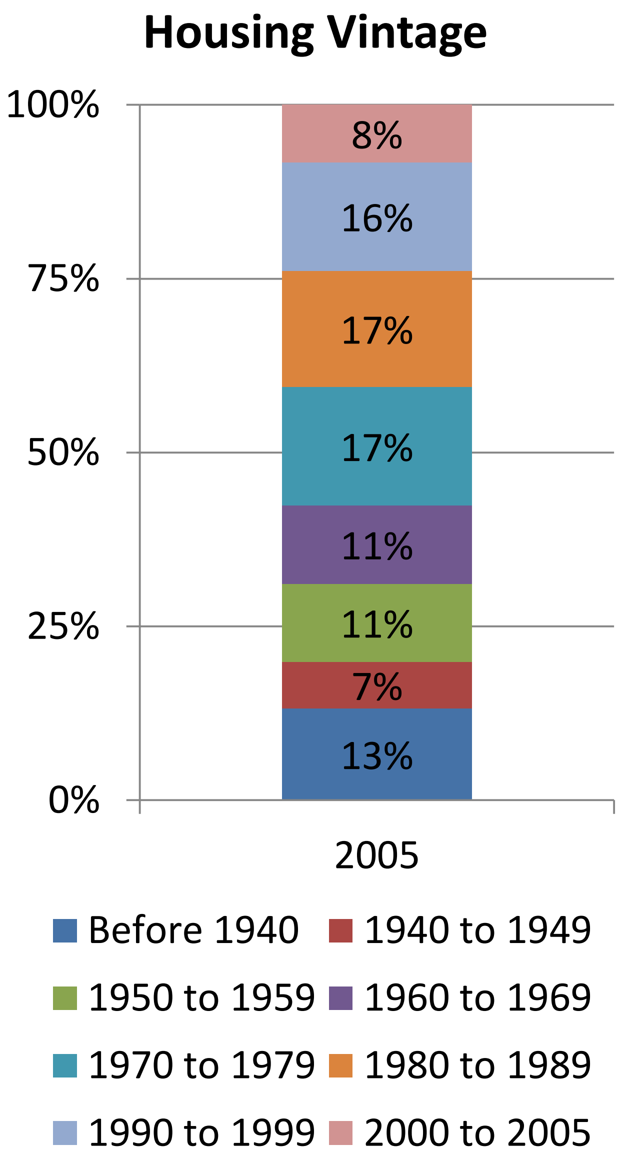
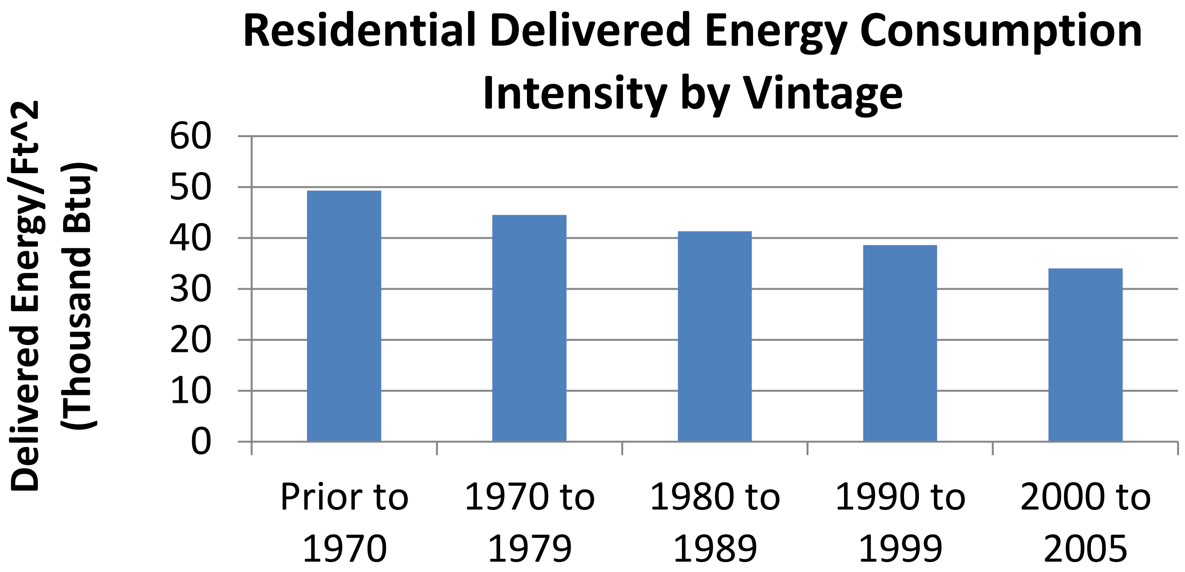
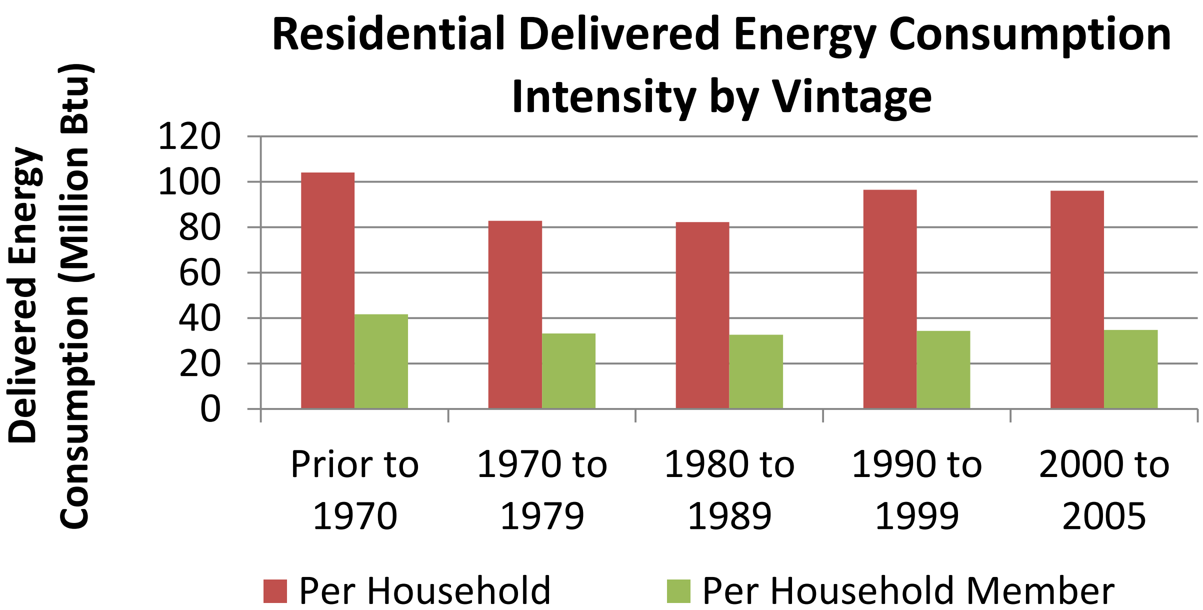
Residential Housing Vintage and Energy Use, 2005







Source: 2009 Buildings Energy Data Book, Table 2.2.4 and 2.2.5

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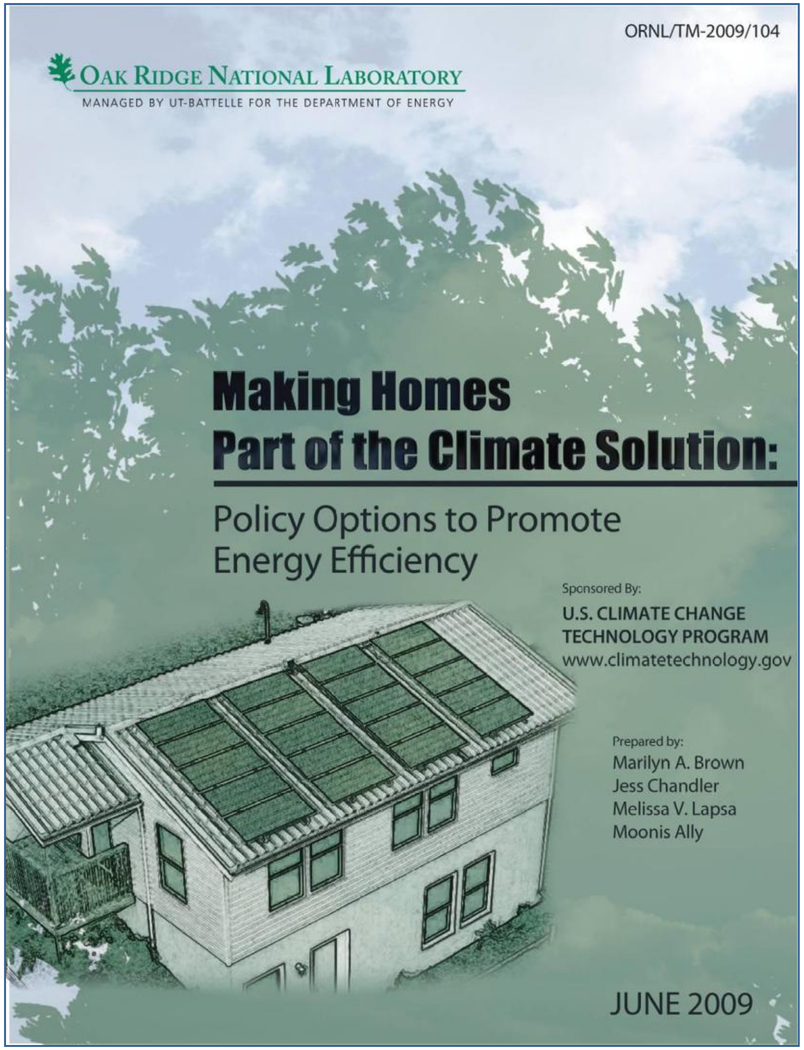
QUESTION BEING RESEARCHED

What are the estimated benefits and costs of four federal policies promoting residential energy efficiency?



Research Approach

- Further assess federal policy options outlined in *Making Homes Part of the Climate Solution*
- Adjust policy options to reflect current behavioral research
- Simulate the policy options in the National Energy Modeling System (NEMS) and conduct spreadsheet analysis
- Estimate the potential benefits and cost-effectiveness with regard to energy savings and avoided carbon and criteria air pollutants emissions
- Consider risk and uncertainty through policy sensitivities

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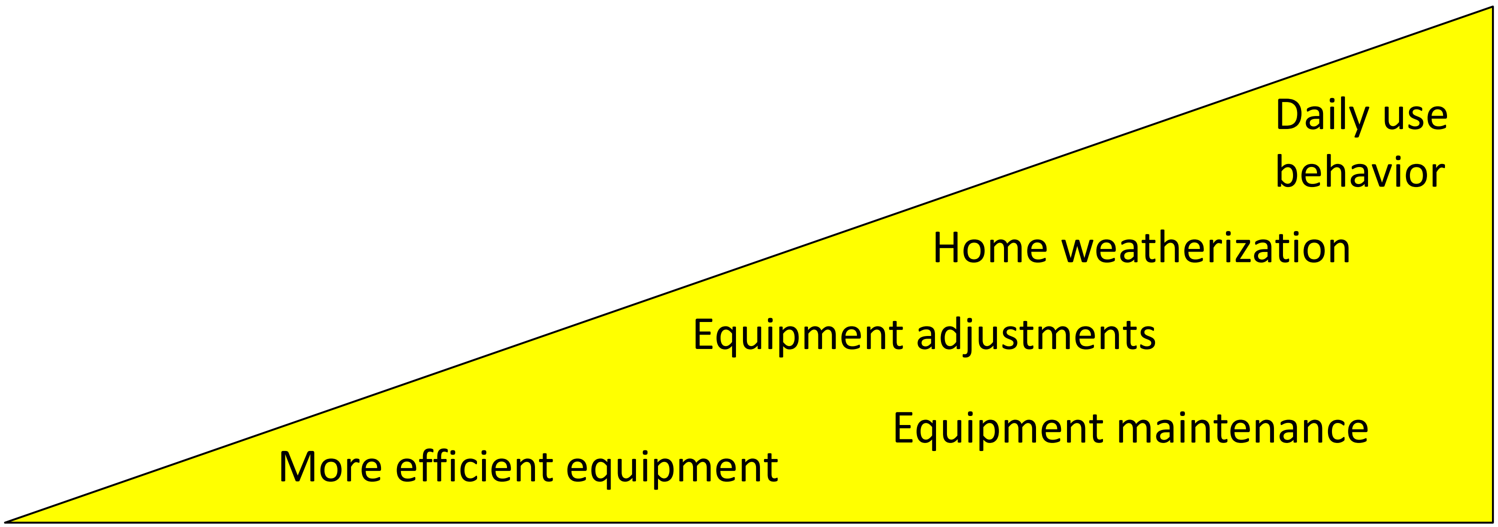
The Behavioral Wedge

Household Actions Can Provide a Behavioral Wedge to Rapidly Reduce U.S. Carbon Emissions



"17 types of household actions that can reduce energy consumption with available technology, low cost, and without appreciable lifestyle changes."

Source: Dietz, T., G. T. Gardner, J. Gilligan, P. C. Stern, and M. P. Vandenbergh. 2009. *Proceedings of the National Academy of Sciences*. http://www.pnas.org/content/106/44/18452.

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Four Residential Energy Efficiency Policies Analyzed

- National Building Codes with Complete Enforcement
  - Examines the effect of building code enforcement – a behavioral issue
- On-Bill Financing
  - Incentivizes consumer choices for energy efficient options through financing
- Smart Meters with Dynamic Pricing
  - Provides greater consumer information for day-to-day household energy consumption
- Mandated Disclosure with Home Energy Performance Ratings
  - Provides greater consumer information at point of sale or lease

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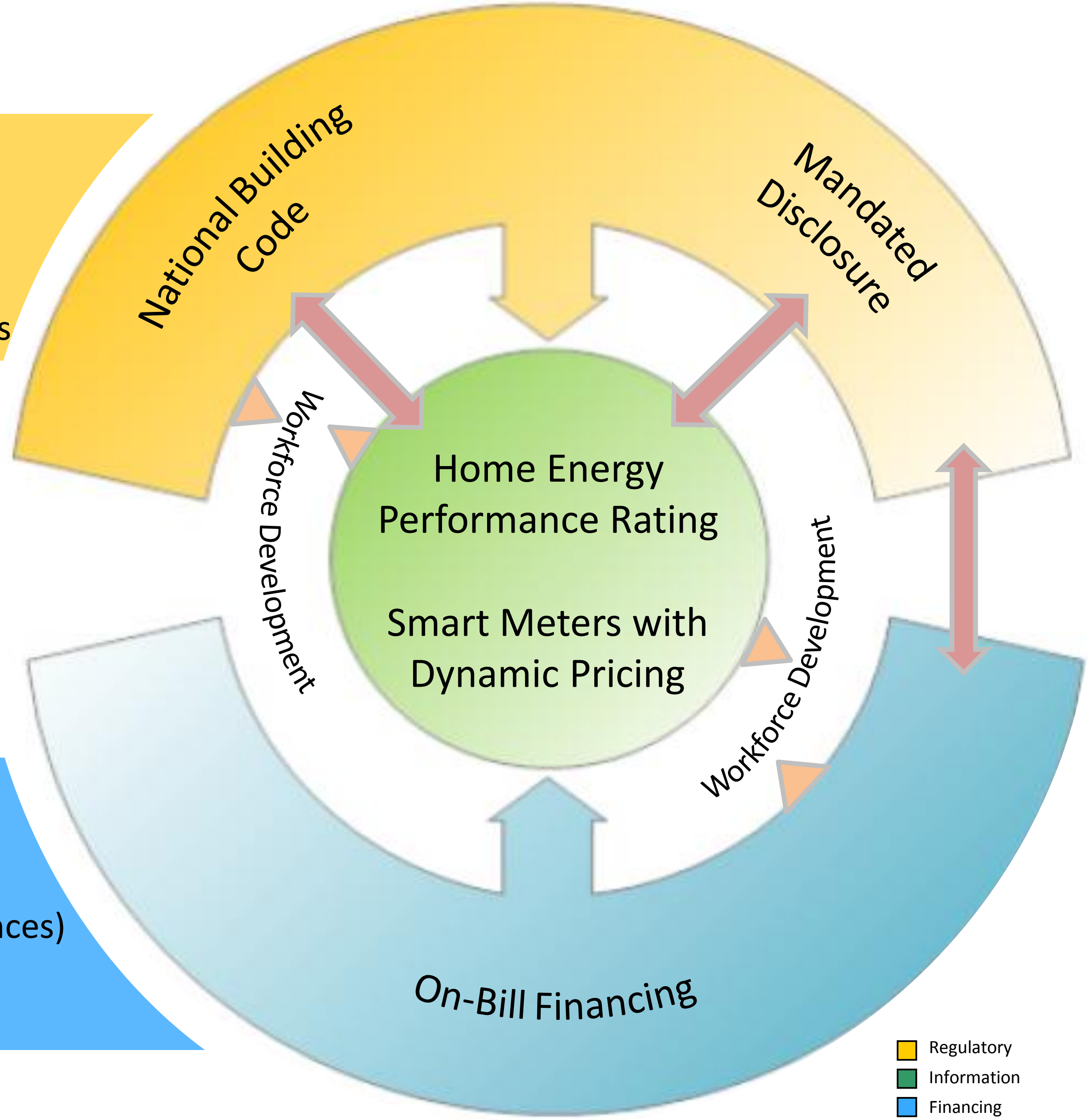
The Policy Options are Synergistic

Current Federal Policies

Overcoming Inadequate Regulations
- Building Codes (i.e. 2006 IECC)
- Building Codes Assistance Project
- Electric & Natural Gas Decoupling
- Energy Efficient Resources Standards

Overcoming Information Barriers
- DOE's Home Energy Score
- Information Campaigns by Utilities and Governments
- Energy Star Labeling
- Energy Efficiency Fund-Raisers by School Children

Overcoming Financial Barriers
- Utility Loan & Rebate Programs
- Sales Tax Holidays
- Stimulus Programs (Cash for Appliances)
- Better Buildings
- Federal Tax Rebates



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Nine Potential Levers in NEMS for Behavioral Policies

Policies	National Building Codes with Complete Enforcement	On-Bill Financing with Decoupling	Smart Meters and Dynamic Pricing	Mandated Disclosure with Home Energy Performance Rating*
Remove Less Efficient Building Codes	✓			
Add More Stringent Building Codes	✓			
Vary Time Horizon of Capital Loan		✓		
Decrease Interest Rate for Capital Loan		✓		
Loan Option for Appliance Capital Cost		✓		
Decrease Rebound Effect			✓	
Increase Price Elasticity of Demand			✓	
Increase Time Horizon for Operating Cost				✓
Decrease Discount Rate for Operating Cost				✓

*Spreadsheet analysis was used for Mandated Disclosure.

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Methodology and General Assumptions

- Assumptions
  - 3% discount rate for societal cost benefit analysis
  - 7% discount rate sensitivity analysis
  - Sensitivity analysis of policy design, participation rates, and investment costs
  - Administration costs are estimated for each policy
  - 5% annual decrease in energy savings after 2035
  - Carbon price schedule and air pollutant assumptions are based on NRC and EIA reports

	NO_x	SO_2	PM_{10}	$PM_{2.5}$	Total (Equally weighted across plants)	Total (Weighted by net generation of plants)
Natural gas for electricity (¢/kWh)	0.239	0.019	0.009	0.176	0.447	0.166
Coal for electricity (¢/kWh)	0.353	3.946	0.018	0.312	4.569	3.323
Natural gas for residential heat (¢/MCF)	27.04	0.385	N/A	0.832	36.4	N/A

Source: National Research Council (2009), Tables 2-9, 2-15, and 4-2 (inflated to $2008)

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Mandated National Building Energy Codes Policy

Recommended Federal Action: Expand technical assistance to States to accelerate their adoption of advanced building energy codes. Subject to available funds, provide financial assistance to establish and expand training and certification programs focused on third-party verification of building energy code compliance.

- Residential building energy code is a set of standards specifying the minimum acceptable energy efficiency level for new houses.
- The International Energy Conservation Code (IECC), developed by the International Code Council (ICC), is a model code available for state to choose to adopt/adapt or not.
- The 2009 IECC code the latest version for residential building energy code.
- State compliance measurement activities
  - state energy code compliance evaluation pilot studies
  - State level technical assistance
- Third party verification is needed

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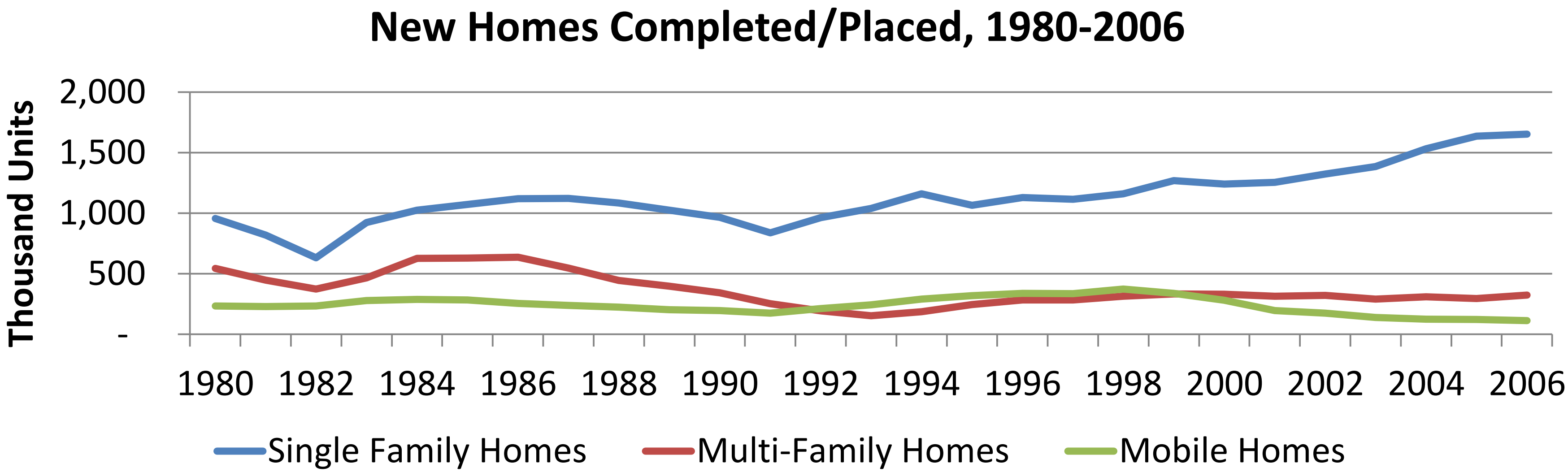
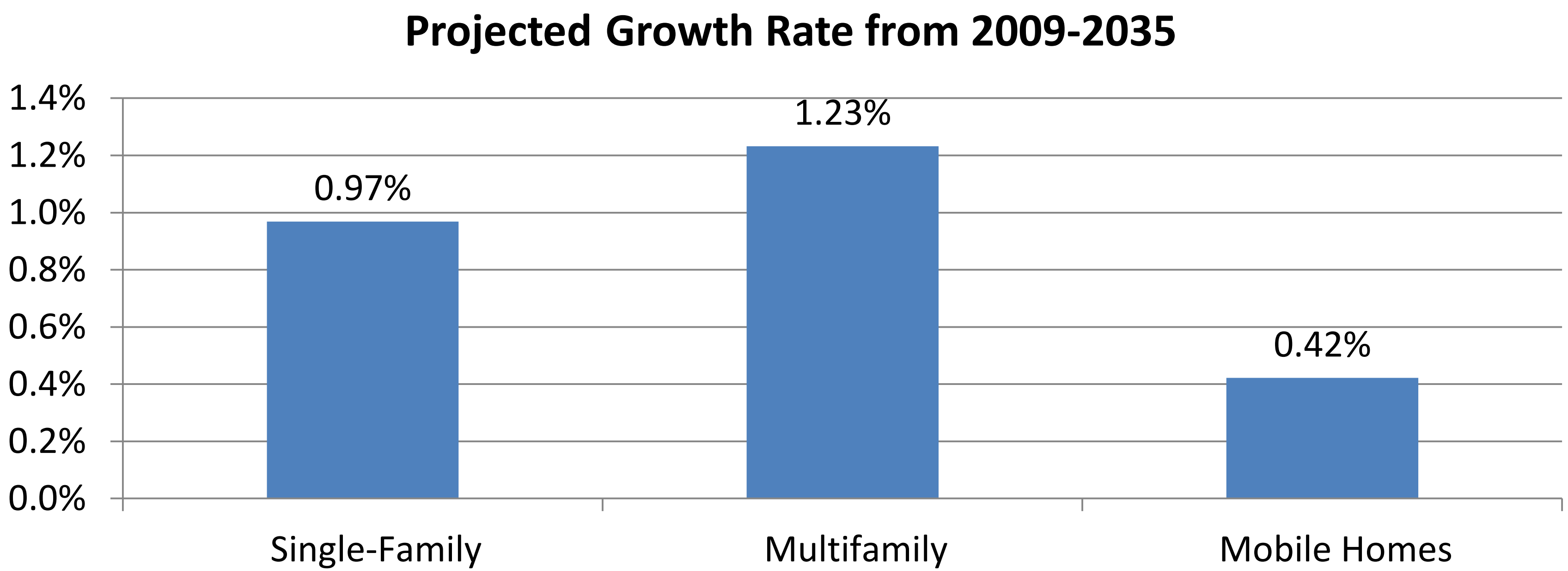
Residential New Construction and Square Footage





Source: 2009 Building Energy Data Book, Table 2.2.6,

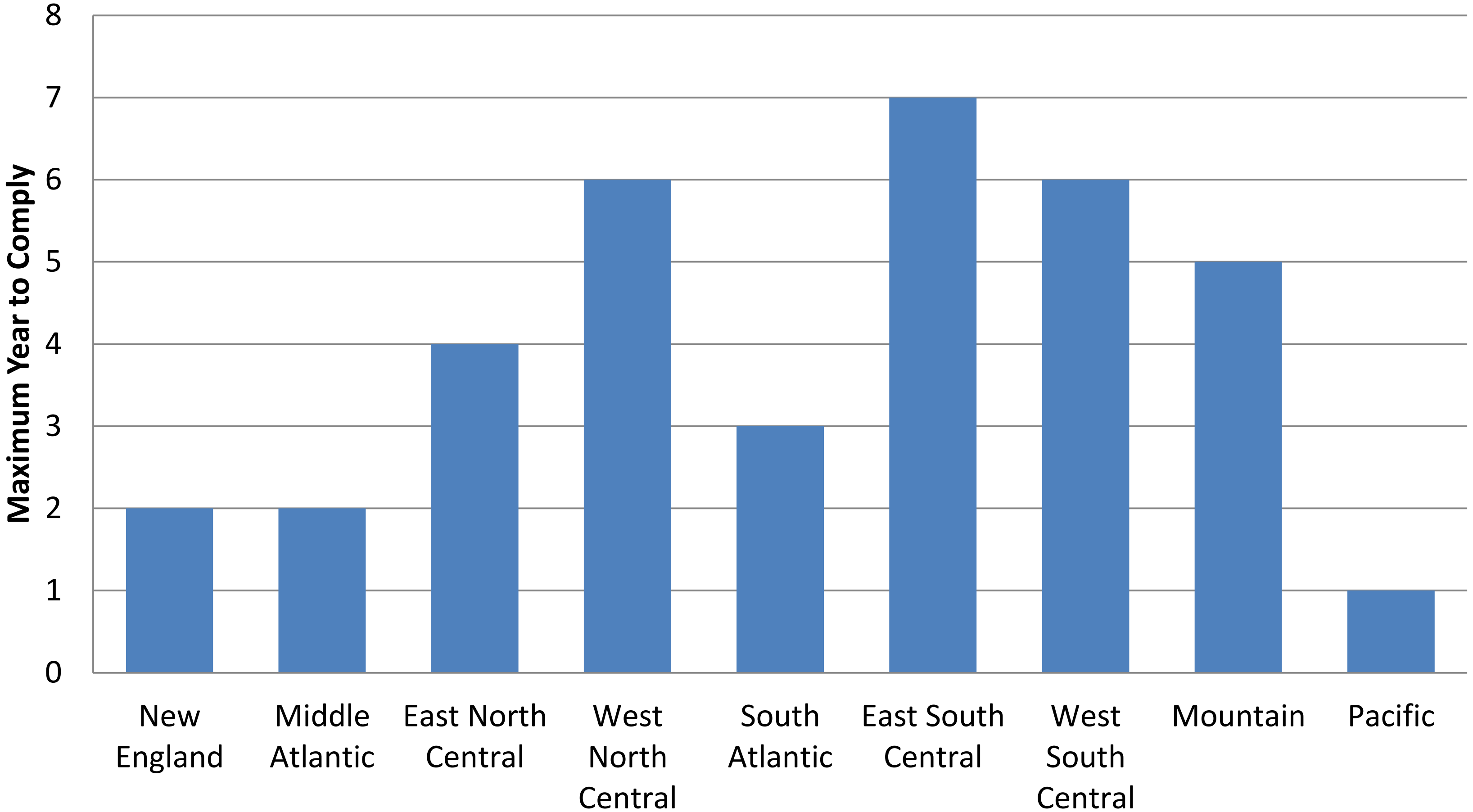
Building codes do save energy and third party verification is important

- With subsequent updates, building energy codes have 1-2% savings per year[1].
- Third party verification, training and education efforts for code compliance need to be strengthened.
  - The effectiveness of energy code is the product of:

    Strong Model Code * State Adoption * Verified Compliance * Performance Assurance[2]
  - Median compliance of the IECC code (40-60%)[3]

1. Harris, et al., 2010; Tolkin, **et a**l., 2010; HMG,2005
2. Harris, et al., 2010;
3. Young, 2005

NEMS Reference Case Models Variable Code Enforcement



Source: ACEEE: The 2010 State Energy Efficiency Scorecard, Oct 2010

Modeling Methodology and Assumptions

- Accelerate advanced building energy code adoption by forcing retirement of the least stringent code every three years
- Provide assistance to establish and expand programs for third-party verification of code compliance.
  - Public administration of the program requires maintaining a certification program for third-party verifiers.
- Sensitivities Conducted
  - A slow phasing-out (every five years) building code scenario was tested against the main policy scenario (retires the least stringent code every three years).

Lever	Reason	Location
Removing Less Efficient Building Codes	As building codes are advanced and enforced, less efficient codes will be removed faster.	rtektyc.txt
Adding new, more stringent building codes	More efficient building codes will be implemented by 2035 than NEMS currently allows (Only 5 building code types).	Residential source code and rtektyc.txt

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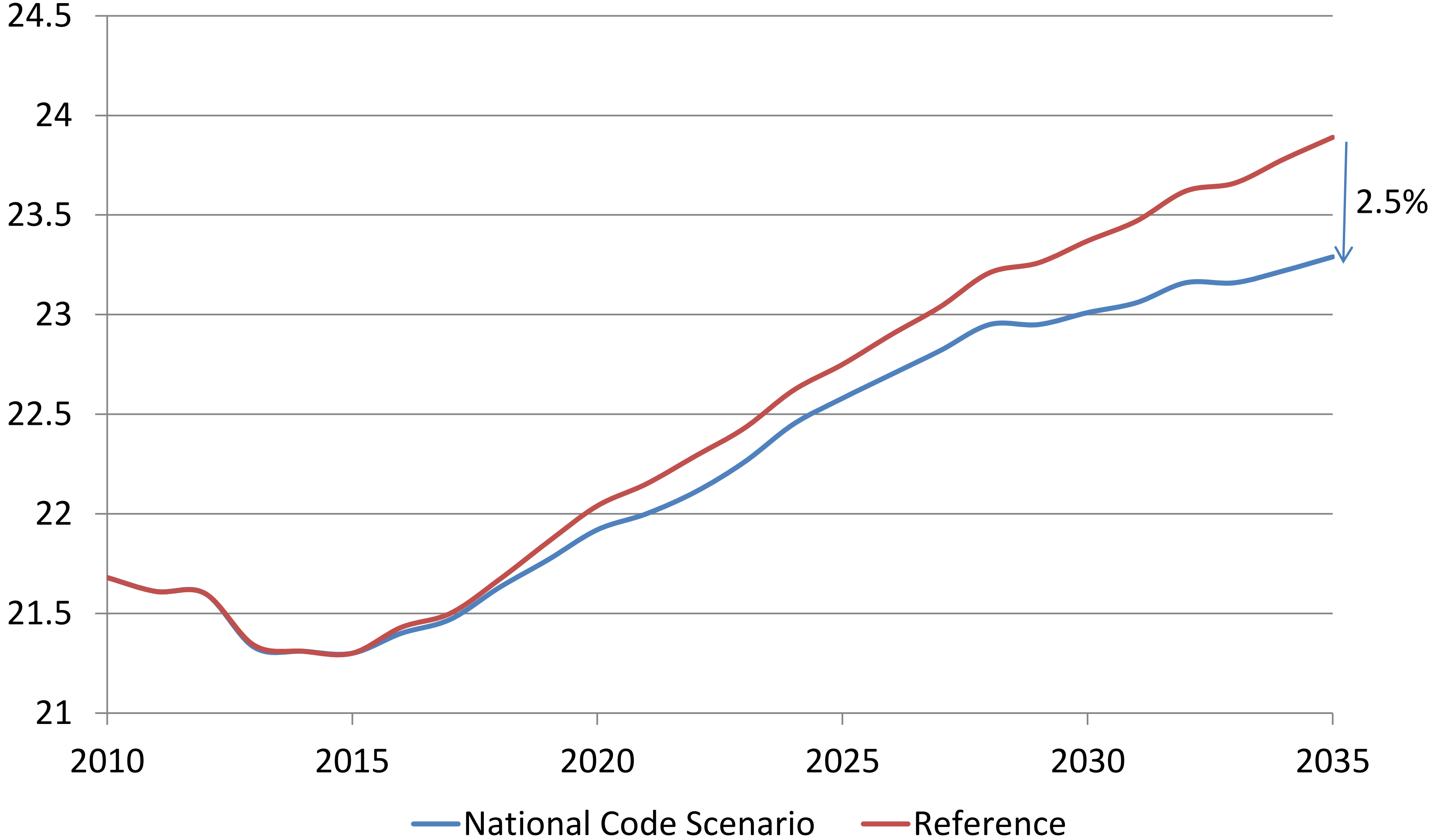
Modeling Methodology and Assumptions, cont'd

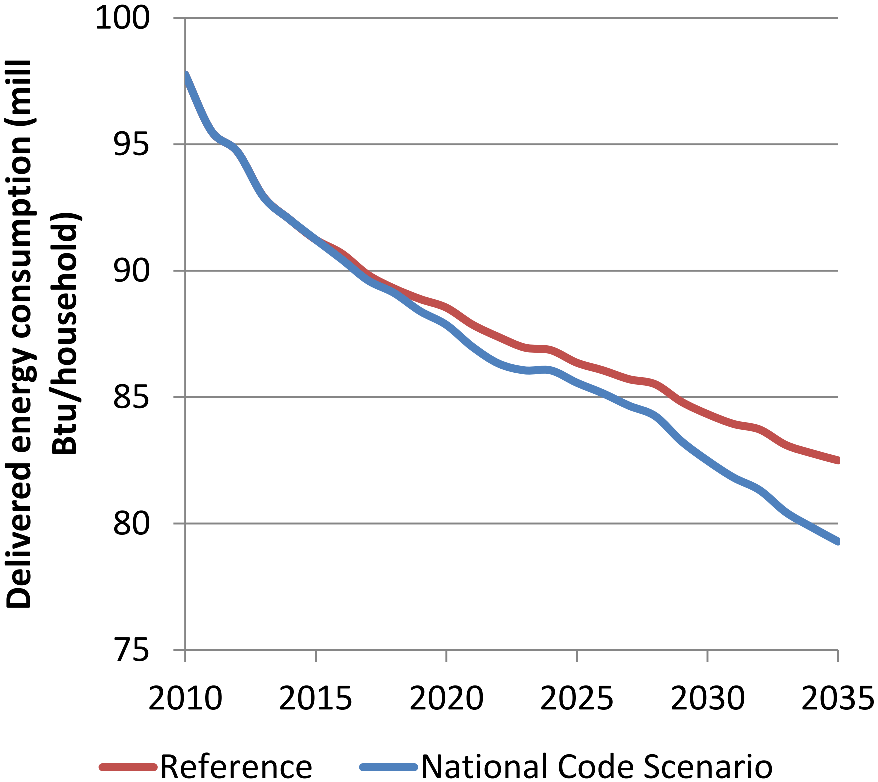
- Complete code compliance is obtained by forcing the retirement of the less stringent building codes.
- New codes were added to simulate the gradual efficiency improvements of the energy codes (see highlighted rows below).
- The least stringent code was phased out every three years.
- The most efficient code, the PATH code, is available all the time.

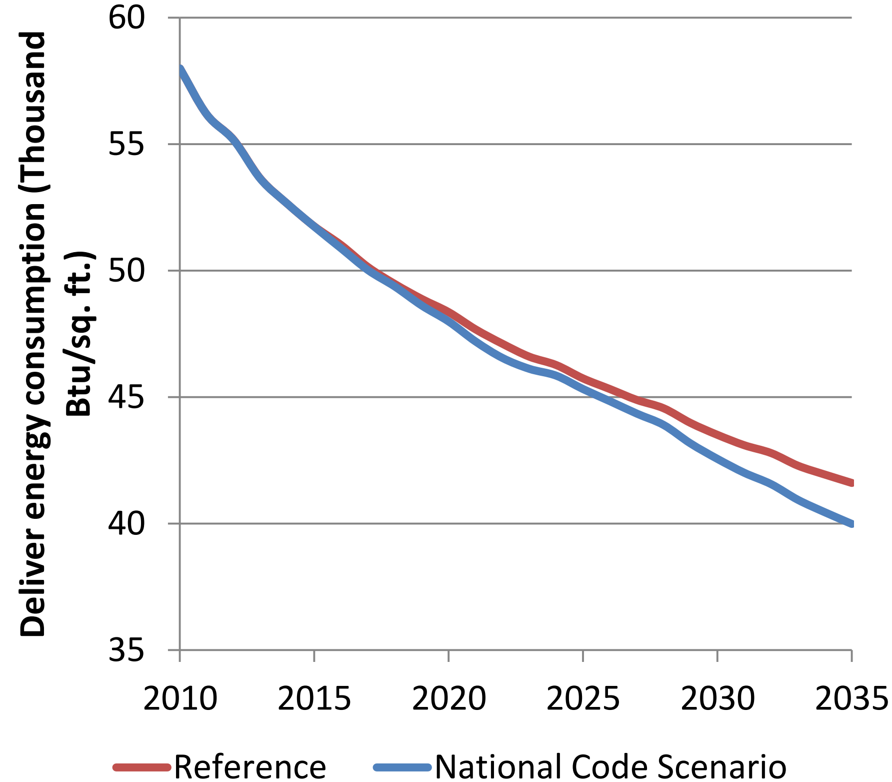
Energy Code	Efficiency Level	Available Years	
		Reference	National Code Scenario
No IECC		2006 – 2050/2010	2006 – 2012/2010
IECC 2006		2006 - 2050	2006 – 2015
Energy Star	~30% above IECC 2006	2006 - 2050	2006 – 2018
2012 code	~35% above IECC 2006	N/A	2012 – 2021
2015 code	~38% above IECC 2006	N/A	2015 – 2024
FORTY	~40% above IECC 2006	2006 – 2050	2006 – 2027
2021 code	~45% above IECC 2006	N/A	2021 - 2030
PATH	~50% above IECC 2006	2006 - 2050	2006 - 2050

Energy Savings from Mandated National Building Codes



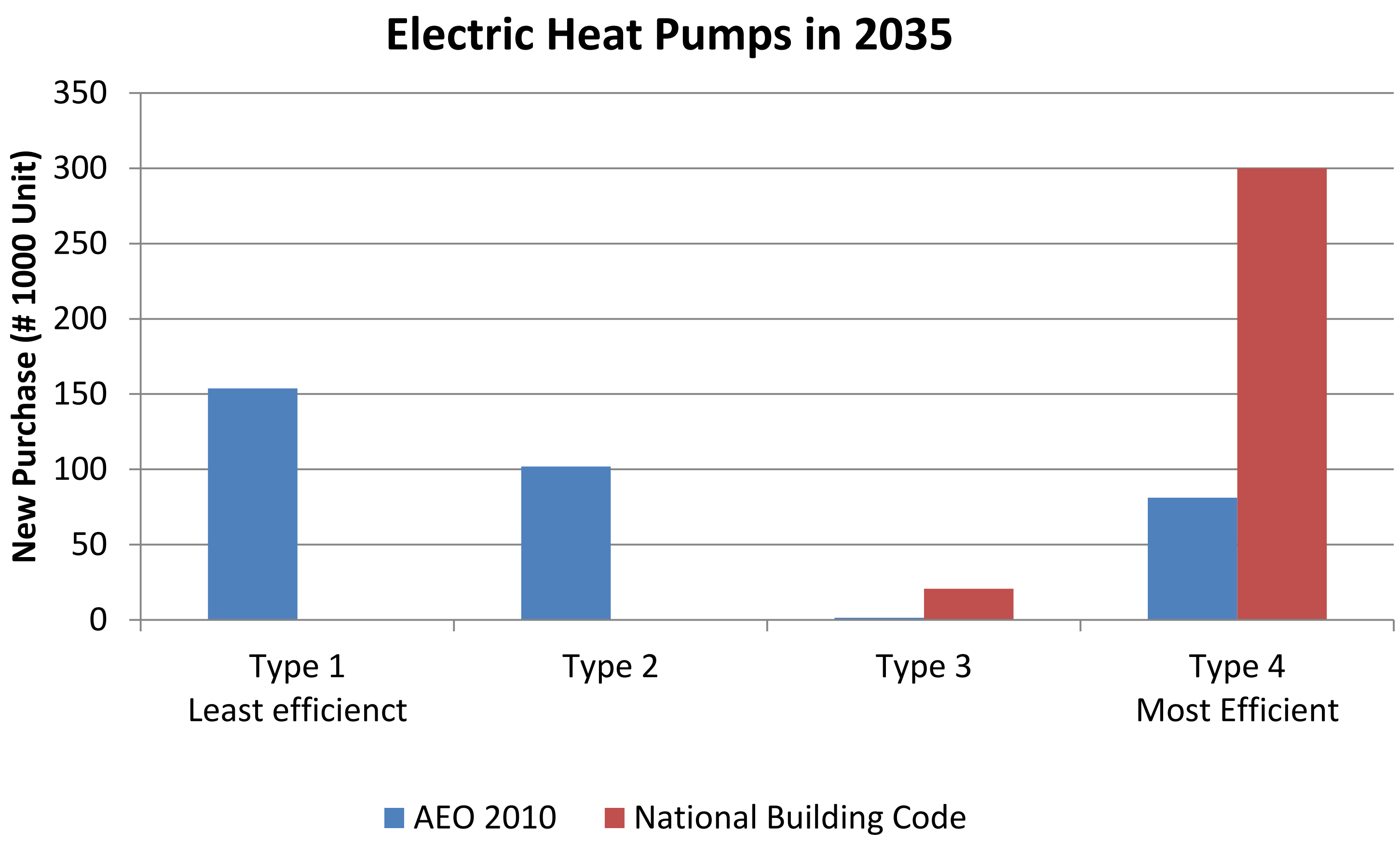
Average Energy Intensity Decreases





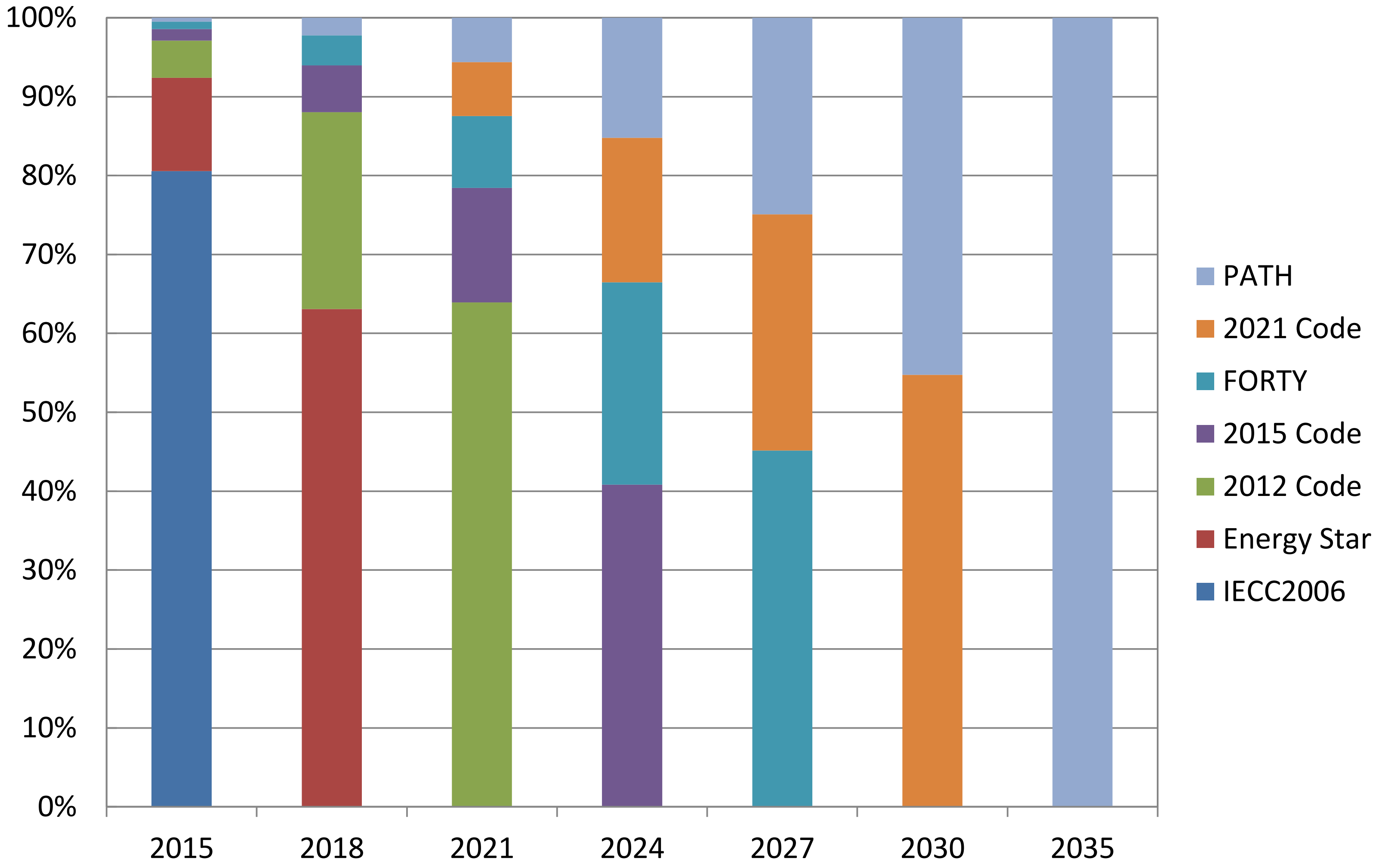
- The per household energy consumption and per sq. ft. energy consumption both decrease faster with the mandatory national code.

Evidence of Technology Shift with Stricter Codes



- Consumers' choices over heating equipments are affected by the national building code. For example, home builders switch from type 1 & 2 electric heat pumps to type 4 in the policy case.

New Homes Built to Each Building Code*



*Based on HVAC System Data

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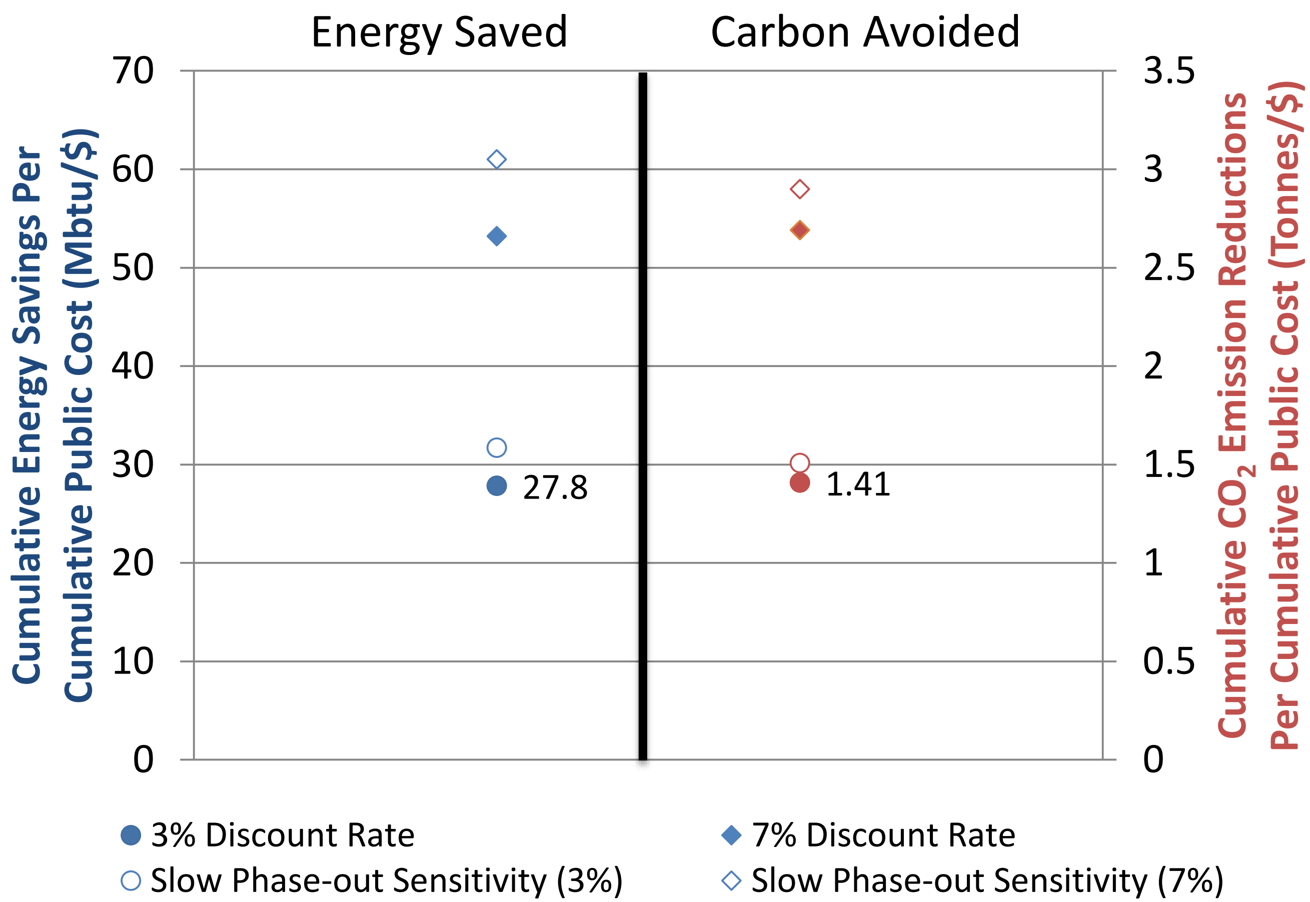
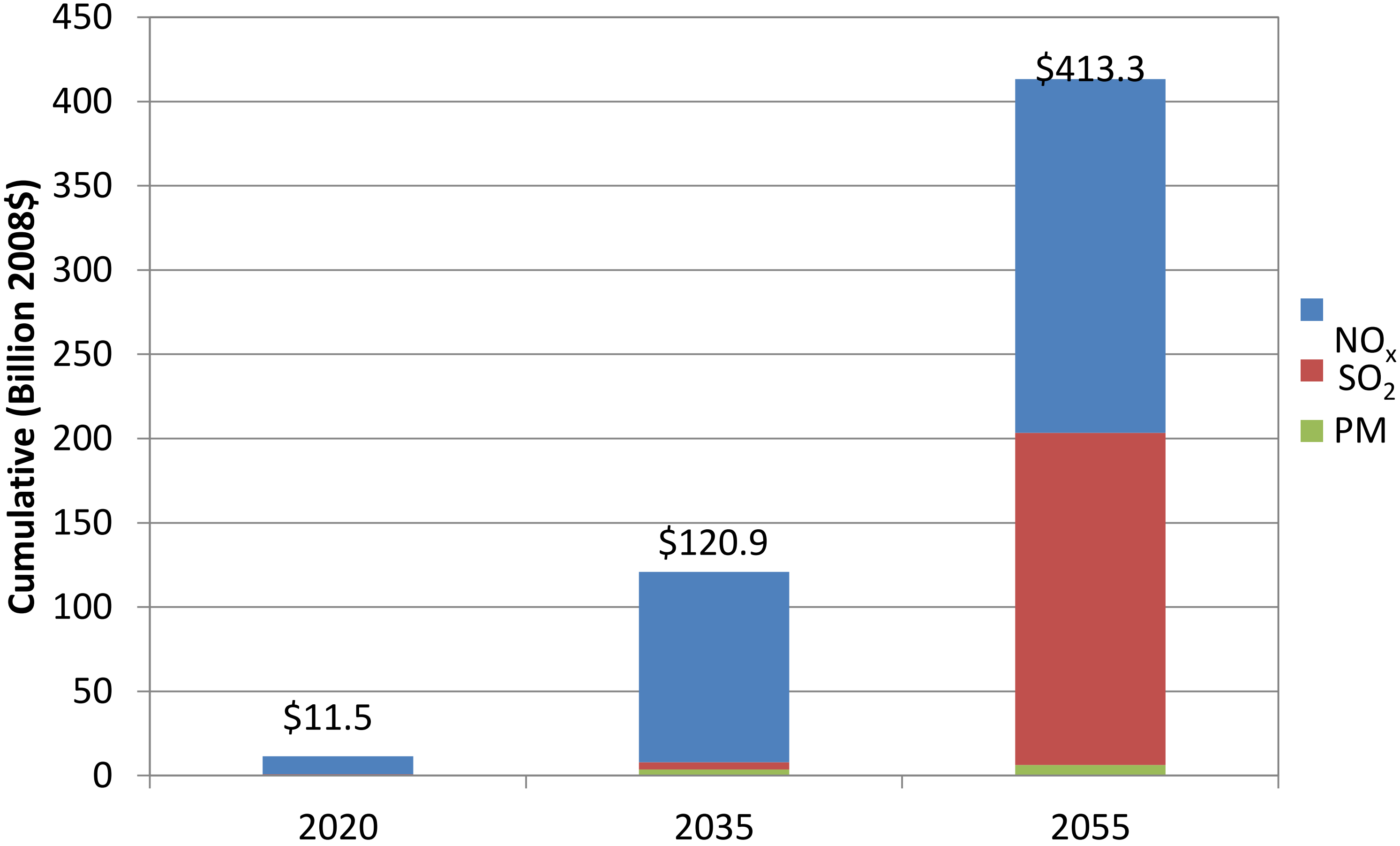
Mandated National Building Code from the Homeowners' Perspective

Year	BAU Energy Consumption*	Annual Energy Savings			Cumulative Energy Savings		Annual Private Cost	Cumulative Private Cost
	Trillion Btu	Trillion Btu	$M (2008)	%	Trillion Btu	$M (2008)	$M (2008)	$M (2008)
2011	21,610							
2020	22,040	116	1366	0.52	318	4,436	1,146	10,633
2035	23,890	598	2737	2.50	5,024	36,813	512	24,216
2055	--	--	--	--	10,705	53,751		24,216

Leveraging Ratios for a Mandated National Building Code



Value of Avoided Damages from Criteria Pollutant Emissions (Billions $2008)



* Assumes no new environmental regulations, but does include the Clean Air Interstate Rule limiting No_x and SO_2 in 28 states.

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Benefit/Cost Results are Highly Favorable*

	Cumulative Social Benefits** (Billions $2008)				Cumulative Social Costs** (Billions $2008)				
Year	Energy Savings	Value of Avoided CO_2	Value of Avoided Criteria Pollutants	Total Social Benefits***	Public Costs	Private Costs	Total Social Costs***	Social B/C Ratio	Net Societal Benefits (Billion $2008)
2020	5.9	0.35	15.9	22.1	0.0	13.4	13.5		
2035	70.4	4.91	242	317	0.4	38.4	38.8		
2055	124	9.77	522	655	0.4	38.4	38.8	16.9	616

* Sensitivities are forthcoming

** Present value of costs and benefits were calculated using a 3% discount rate.

*** Total costs and benefits do not include various non-monetized values (e.g. mercury pollution reduction, increased productivity, water quality impacts, etc.).

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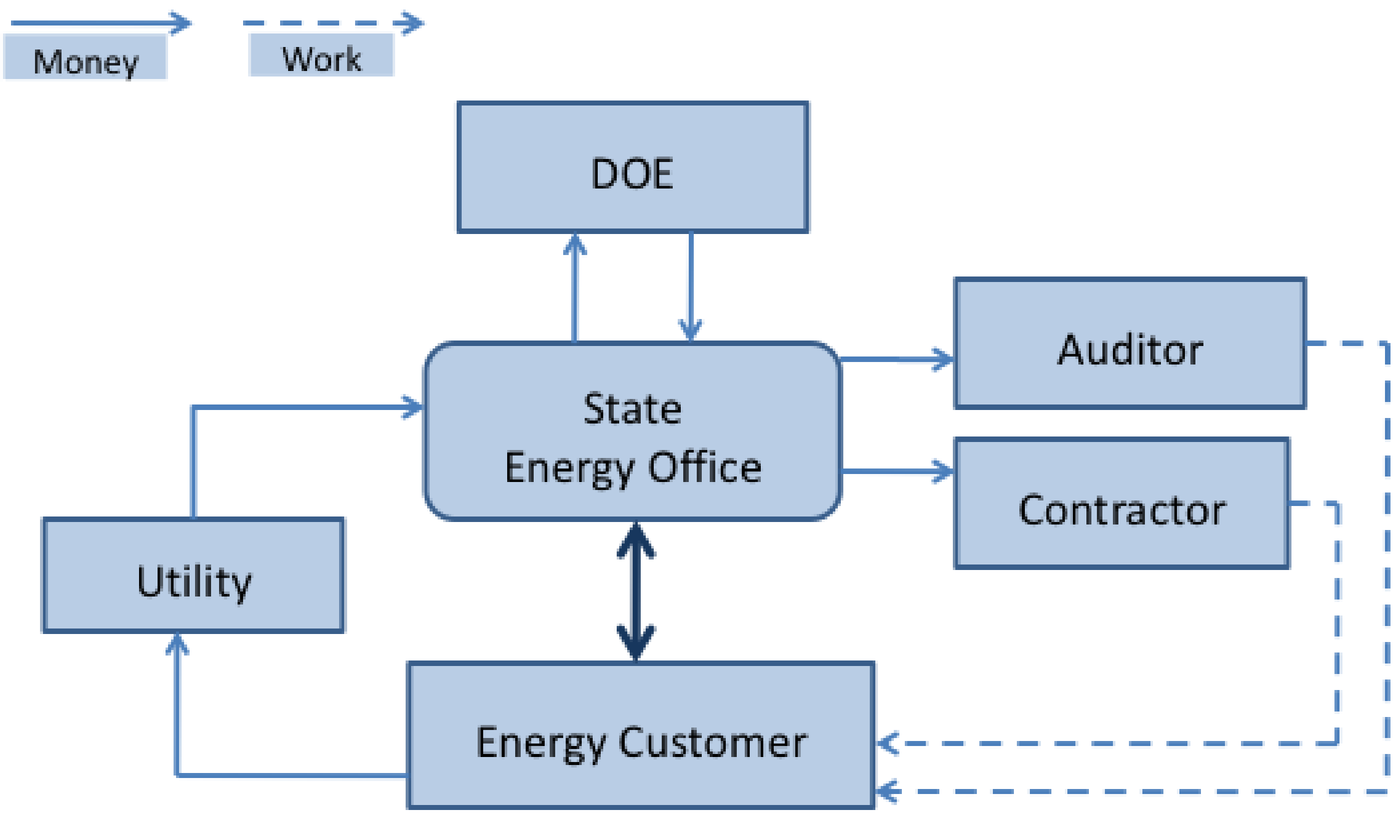
On-Bill Financing

Recommended Federal Action: Provide financial assistance to State Energy Offices to establish revolving loan funds to enable on-bill utility financing of energy-efficiency improvements without up-front capital costs to the building owner.

- Addresses risk aversion by “mainstreaming” retrofit financing
- Overcomes the cash-flow barrier confronted by many homeowners and small businesses
- Loans are made by the utility company and are repaid by adding a charge to the utility bill
- A revolving loan fund could extend the positive impact of the Stimulus Bill by many years

Decision to Renovate

On-bill financing
- reduces the up front cost to the consumer
- returns funds to the system for re-use



On-Bill Financing Programs

- On-bill financing programs have two mechanisms: customer obligation and meter obligation
- More on-bill financing programs are available for small businesses than for residential customers
- On-bill financing programs usually offer zero interest loans to small businesses
- The interest rates of on-bill financing programs range from 0-7%
- The payback time ranges from 2 – 10 years

NEMS Modeling Methodology

Lever	Method	Location
Adding loan option for appliance capital costs	The current NEMS capital costs for appliances are up-front costs. By changes the lifecycle cost equation, the option for loans will be available for efficient equipment.	Residential source code
Adjusting interest rates and payback time for loan options	Three levels of interest rates were tested: 0%, 5% and 7%; three levels of payback time were tested: 5 year, 7 year and 10 year.	Residential input file: rtekty

- Sensitivities Conducted
  - Various options for interest rate and payback periods were tested for on-bill financing policy
  - The effects of offering Energy Star equipment through on-bill financing were examined
    - Expands the coverage of on-bill financing from the most efficient appliances to Energy Star appliances which satisfy the current Energy Star efficiency requirements
    - See additional slide for Energy Star efficiency criteria and the qualifying equipment types modeled in NEMS

Policy Specific Assumptions & Methodology

- The source code equation for calculating the lifecycle costs for appliances was modified to allow loan options.
- Administration cost assumed to be $0.13/MBtu saved
- Public investment is the cost for providing the seed money for low interest loans
- The avoided damages of criteria air pollutants associated with on-bill financing policy is calculated based on the estimated damages of NO_x, SO_2, PMs from electricity generation and natural gas for spacing heating in the residential sector.

Projected Energy Savings in 2035 (Trillion Btu)

- On-bill financing option available for the most efficient appliances.
- Highest energy savings are associated with zero interest and 10-year payback time.

Interest rate	Total Energy Savings (Trillion Btu)		
	Payback time 5 years	Payback time 7 years	Payback time 10 years
0%	70 (0.3%)	240 (1.0%)	420 (1.8%)
5%	30 (0.1%)	140 (0.6%)	290 (1.2%)
7%	20 (0.1%)	100 (0.4%)	240 (1.0%)

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On Bill Financing from the Residents' Perspective: Savings Exceed Costs

Year	BAU Energy Consumption*	Annual Energy Savings			Cumulative Energy Savings		Annual Private Cost	Cumulative Private Cost
	Trillion Btu	Trillion Btu	$M (2008)	%	Trillion Btu	$M (2008)	$M (2008)	$M (2008)
2011	21,610							
2020	22,040	50	743	0.23	330	5,053	452	4,114
2035	23,890	140	661	0.59	1,800	16,166	239	9,114
2055	--	--	--	--	3,130	20,256		9,114

On-Bill Financing(interest rate = 5%, payback time = 7 year)

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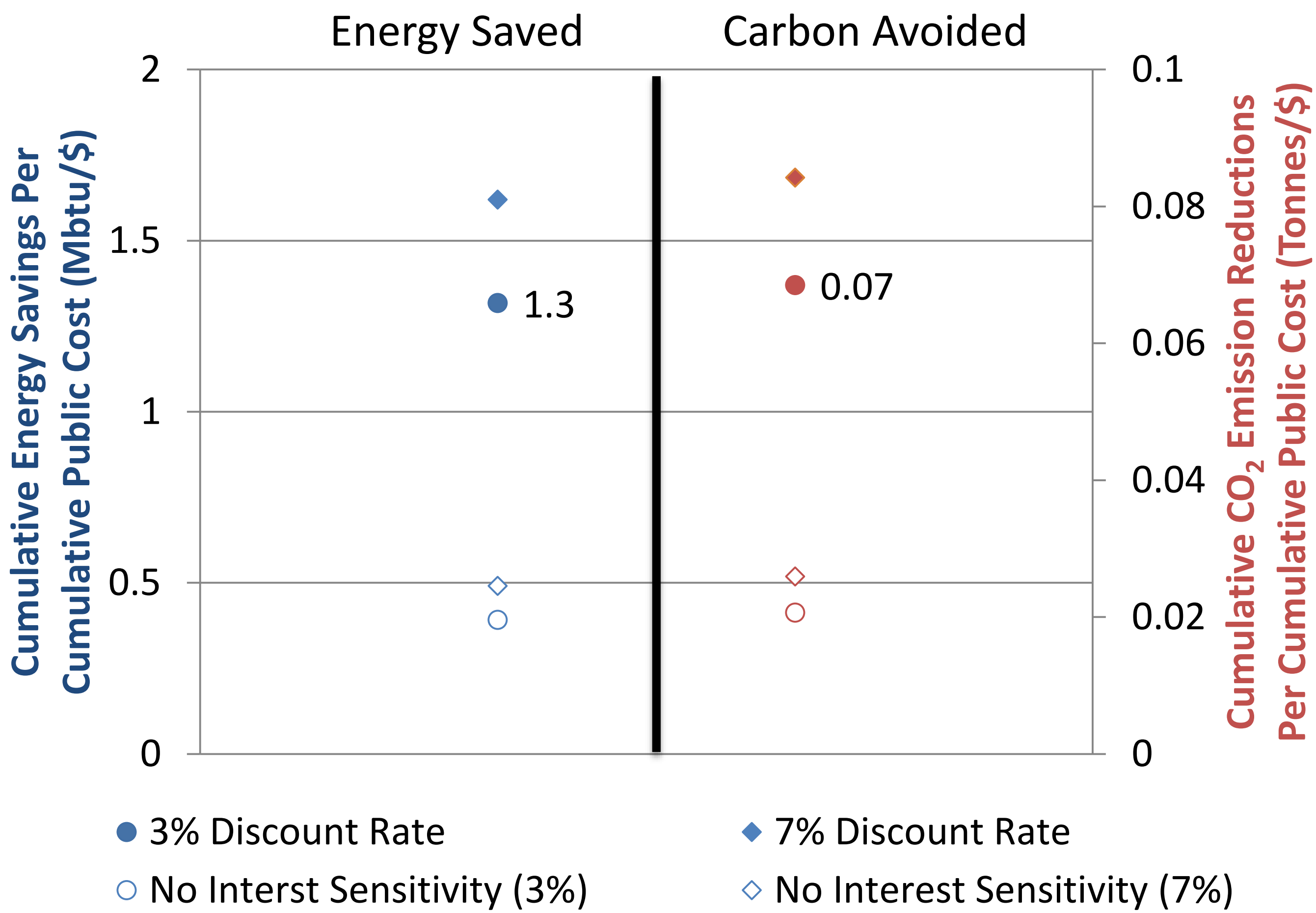
Leveraging Ratios for a Mandated National Building Code



On-Bill Financing(interest rate = 5%, payback time = 7 year)

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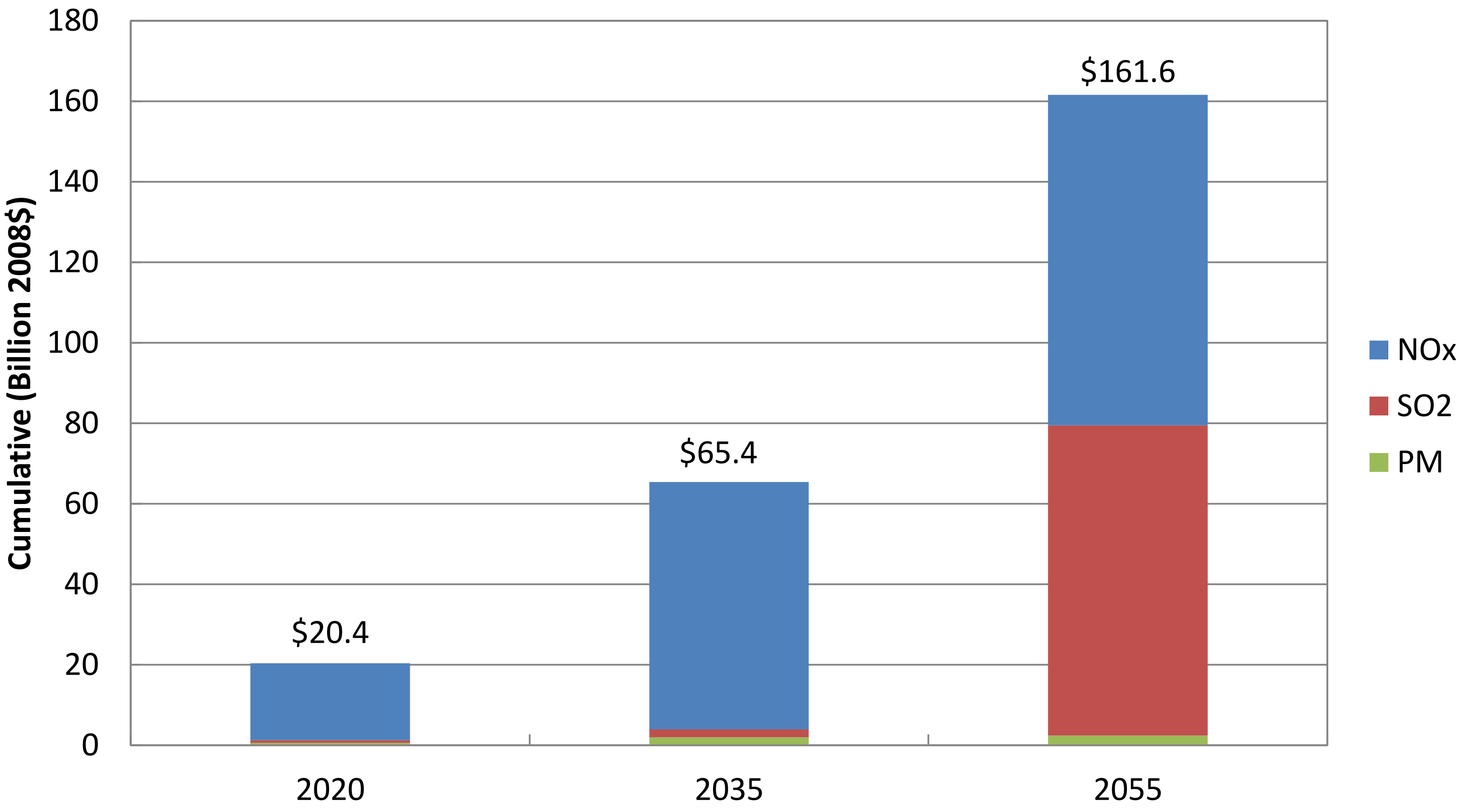
Value of Avoided Damages from Criteria Pollutant Emissions* (Billions $2008)



* Assumes no new environmental regulations, but does include the Clean Air Interstate Rule limiting No_x and SO_2 in 28 states.

On-Bill Financing(interest rate = 5%, payback time = 7 year)

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Benefit/Cost Results are Highly Favorable

	Cumulative Social Benefits* (Billions $2008)				Cumulative Social Costs* (Billions $2008)				
Year	Energy Savings	Value of Avoided CO_2	Value of Avoided Criteria Pollutants	Total Social Benefits**	Public Costs	Private Costs	Total Social Costs**	Social B/C Ratio	Net Societal Benefits (Billions $2008)
2020	6.3	0.38	25.4	32.0	1.8	5.0	6.8		
2035	27.7	1.91	112	142	2.4	14.4	16.8		
2055	40.5	3.03	164	208	2.4	14.4	16.8	12.4	191

* Present value of costs and benefits were calculated using a 3% discount rate.

** Total costs and benefits do not include various non-monetized values (e.g. mercury pollution reduction, increased productivity, water quality impacts, etc.).

On-Bill Financing(interest rate = 5%, payback time = 7 year)

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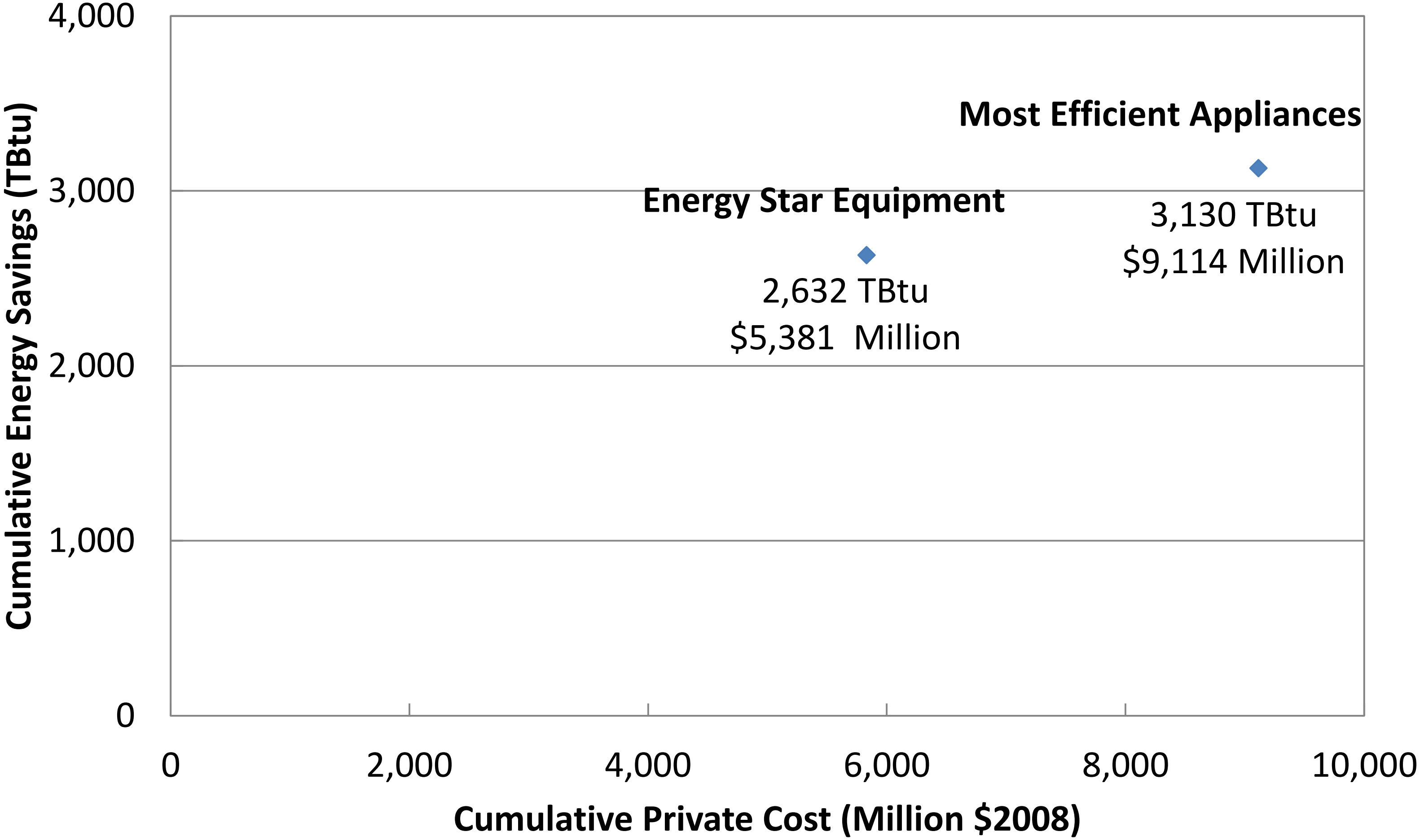
On-Bill Financing for Energy Star Equipment: Lower Cost, Lower Energy Savings



On-Bill Financing(interest rate = 5%, payback time = 7 year)

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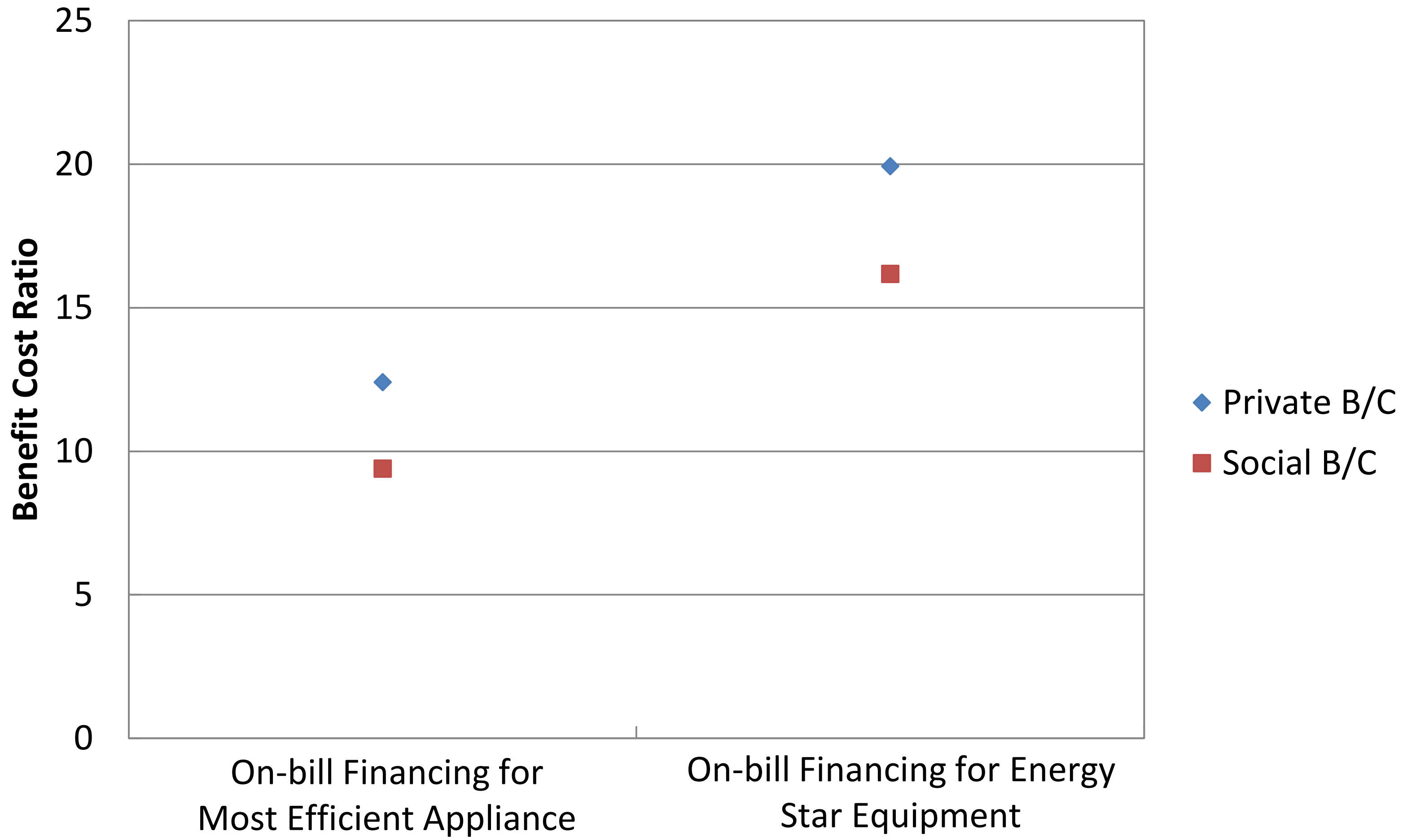
On-Bill Financing for Energy Star Equipment: Higher B/C Ratios



On-Bill Financing(interest rate = 5%, payback time = 7 year)

Smart Meters with Dynamic Pricing

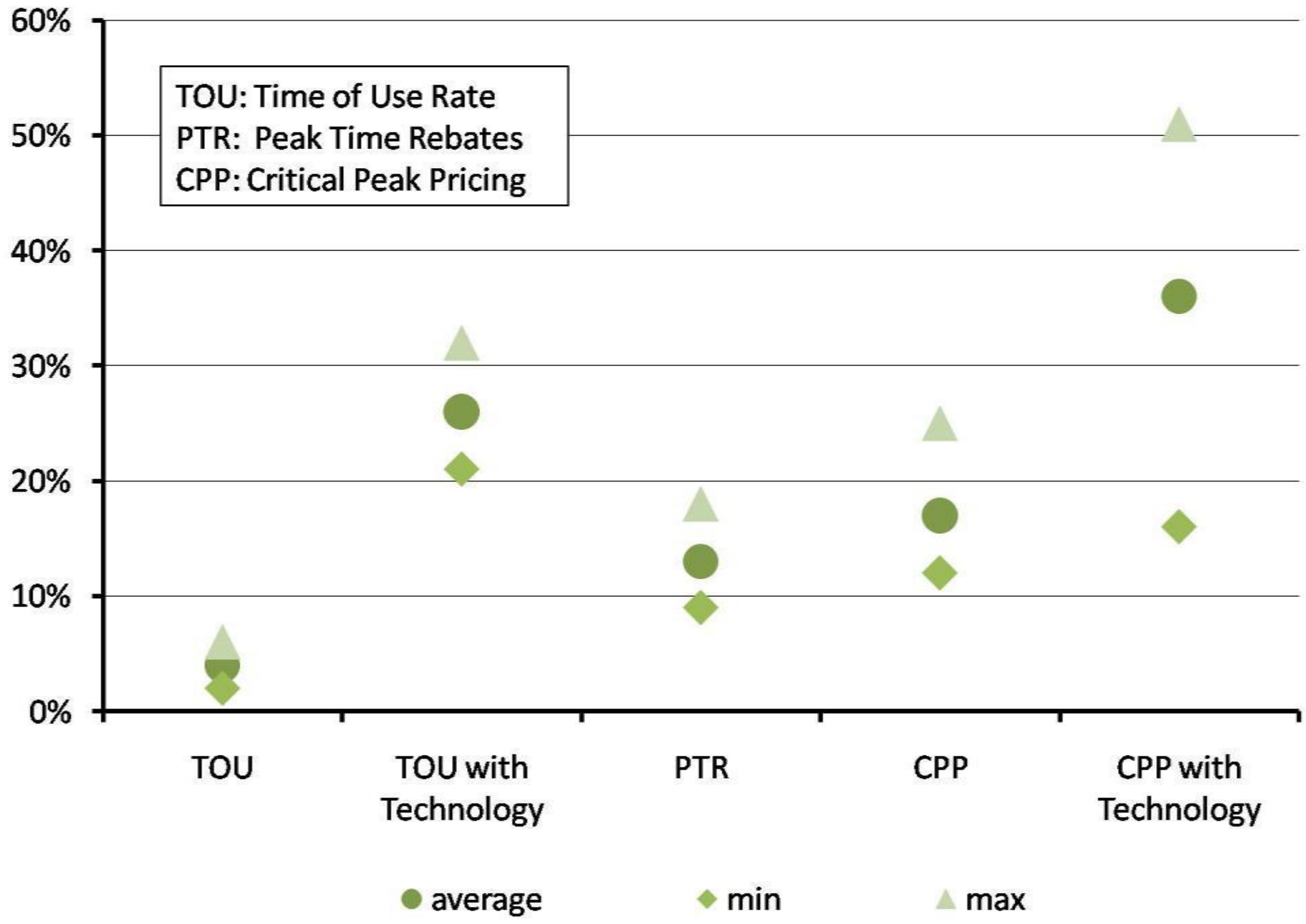
Recommended Federal Action: Provide technical and financial assistance to States and utilities to provide for expanded demand response of residential electric loads through smart metering technologies and dynamic pricing schemes.

- Relates actions to energy use and cost by providing real-time feedback to consumers.
- Creates savings immediately following implementation.
- Reduces peak load – avoiding the construction of new plants.

Picture from: http://www.ecobee.com/product/smart-overview/

Everyday Decisions

- Policy to Link Actions with Outcomes: Smart Meters with Dynamic Pricing



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Information Can Reduce Energy Consumption and Rebound Effect

- Information has been shown to reduce energy consumption
  - Experiments: Savings range from 3.5 - 22% [1]
- Information framing affects energy use [2]
  - Consumption information
    - Decreases energy consumption, generally
    - If average consumption provided →lowest consumers may increase use.[3]
  - Social Norms
    - Removes "boomerang effect" [3]
    - Consumer believes norms are least influential in their decisions, but actually influential in achieving energy conservation[4]

- Experimental results with information and smart meters suggest:
  - Rebound effect already occurred
    - Information provided only, no new equipment added
  - Consumers unaware of it or its magnitude
- Suggests energy consumption information can decrease rebound effect

1. Sudarshan, 2010; Peterson, 2010; Houde, 2010; Hodge, 2010; Frader, 2010; Hodge, 2010; Amann, 2010
2. Lindenberg & Steg, 2007
3. Schultz, et al. 2007
4. Nolan, et al., 2008

Two Levers were Pursued in NEMS.

Lever	Reason	Location
Increase price elasticity of demand	Consumer price elasticity increases with greater price information (Gaudin, 2006).	Residential source code
Decrease rebound effect	Instant feed-back on energy use will likely moderate the rebound effect.	Residential source code

- Sensitivity Analysis
  - Three different rebound effects were tested
    - 75%, 50%, and 25% of reference case rebound effect
  - Three difference price elasticities were tested
    - Added -0.15, -0.25, and -0.35 to base price elasticity values of -0.15 and -0.30
  - All 9 combinations tested with reference case prices and 10% electricity price escalation
  - Total combination of 18 different sensitivity runs for price elasticity and rebound effect variations
  - Rates of full smart meter uptake by households varied from 5 years to 10 years

Policy Specific Methodology

- NEMS source code changed to accommodate both levers
  - Price elasticity source code changes
    - New equation: $ALPHA_{new} = ALPHA_{old} + RTPALPHA$
      - Where RTPALPHA = user defined value for price elasticity increase in rtekcl file
    - Retains increase in price elasticity included in AEO 2010 (-0.15 to -0.30 for some end-uses given stimulus)
  - New Rebound Effect Equation for $RB_{y,eg,b,r}$ >1:

$$Revised\ RB_{y,eg,b,r} = \left(RB_{y,eg,b,r} - 1\right) * \beta + 1$$

where

- $Revised\ RB_{y,eg,b,r}$ is the scenario rebound effect
- $RB_{y,eg,b,r}$ is the reference case rebound effect
- β is the scaling factor (<1)
  - Ex. β = 0.25 → new rebound effect is 75% less than original

Policy Specific Assumptions

- Households are the single family (SFH) and multi-family households (MFH) projected by AEO 2010.
- After 5 years, all SFH and MFH have installed smart meters.
- Only new households each year require smart meters to be installed thereafter.
- Private cost for smart meter implementation is $500 per meter per home.
  - Can be paid over 10 years with 7% discount rate.
  - 5% cost reduction each year in cost
- No administration cost
- Public costs of $10 million investment per year into the Regulatory Assistance Project for the first 10 years.

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Smart Meters and Dynamic Pricing from the Residents' Perspective*

Year	BAU Energy Consumption **	Annual Energy Savings			Cumulative Energy Savings***		Annual Private Cost	Cumulative Private Cost
	Trillion Btu	Trillion Btu	$M (2008)	%	Trillion Btu	$M (2008)	$M (2008)	$M (2008)
2012	21,611							
2020	22,032	-36.9	1,556	-0.17	-759	1,884	64.6	43,735
2035	23,915	285	8,305	1.19	963	23,062	42.2	60,973
2055	--	--	--	--	3,672	33,904		60,973

* Present value of costs and benefits were calculated using a 7% discount rate.

** Reference case residential energy consumption

***Investments stimulated from the policy occur through 2035. Energy savings are then modeled to degrade at a rate of 5% after 2035, such that all benefits from the policy have ended by 2055.

Note: For sensitivity with 50% rebound effect reduction and -0.25 added price elasticity.

Energy Savings and Cost by Households

Description	2012	2020	2035
Annual number of new homes served (million)	23.49	1.41	1.07
% of Total SFH and MFH Housing stock	20.00%	1.10%	0.73%
Annual average energy savings per home (MBtu/home)	-5.19	-4.60	32.44
Annual private cost per home ($/home)	$74	$1,232	$39
Annual public cost per added home ($/home)	$0.43	$7.09	$0

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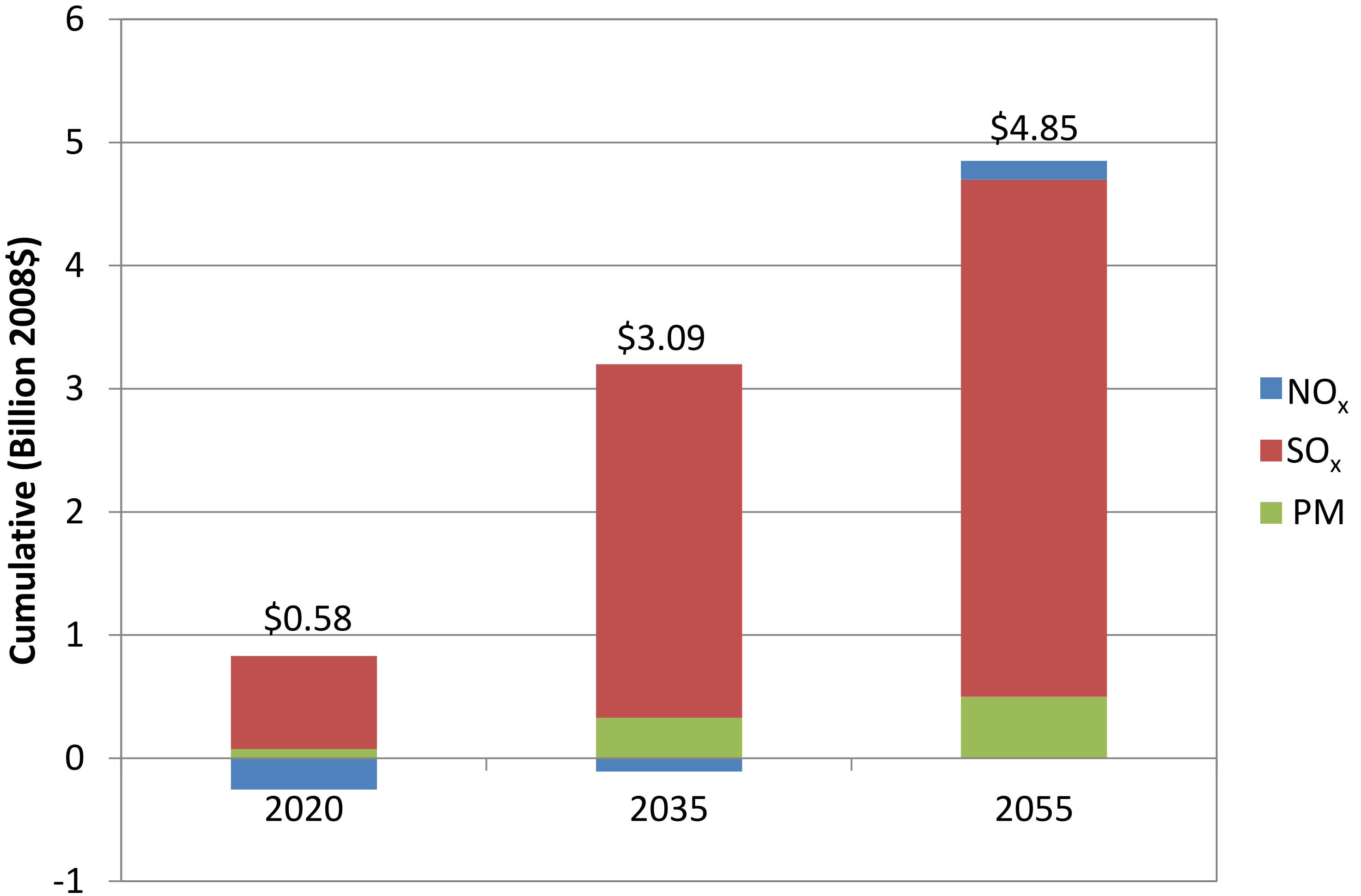
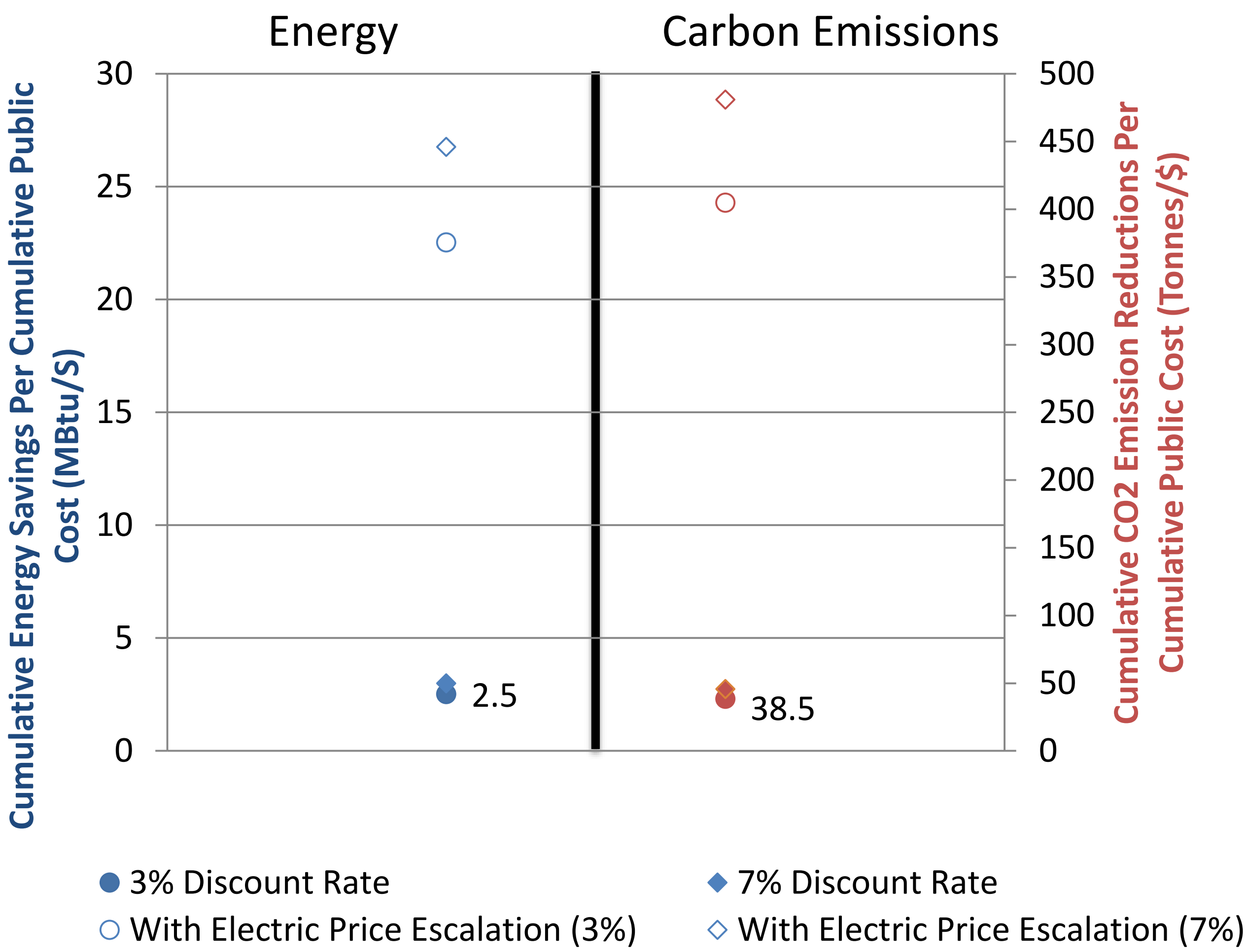
Value of Avoided Damages from Criteria Pollutant Emissions*



Note: For sensitivity with 50% rebound effect reduction and -0.25 added price elasticity.

* Assumes no new environmental regulations, but does include the Clean Air Interstate Rule limiting No_x and SO_2 in 28 states.

Leverage Ratios Change Substantially with 10% Electric Price Escalation.



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Benefit/Cost Results are Favorable

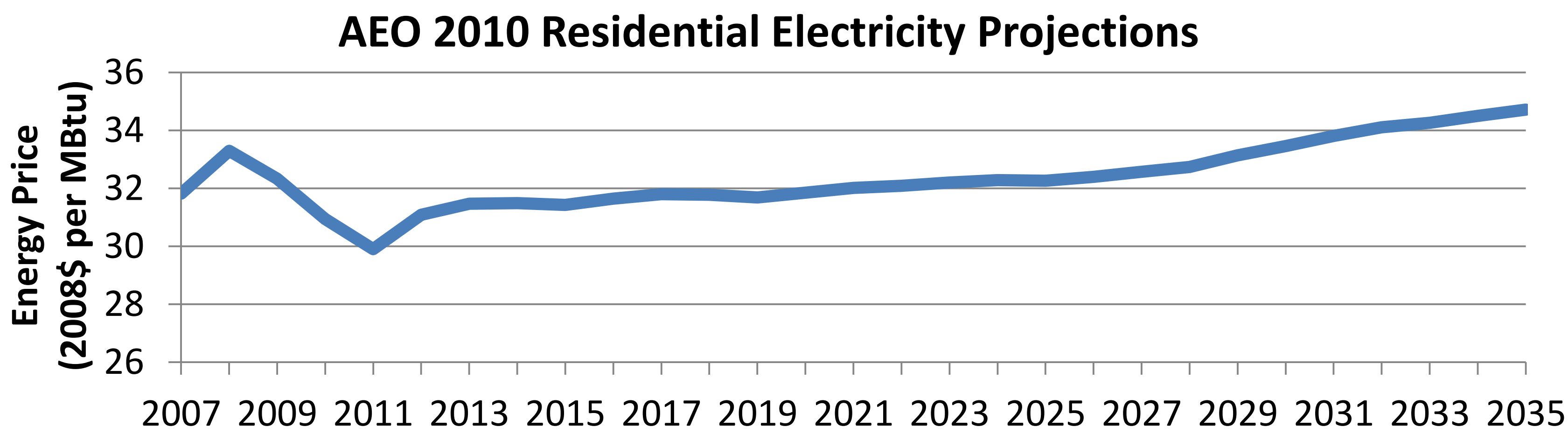
	Cumulative Social Benefits* (Billions $2008)				Cumulative Social Costs* (Billions $2008)			Benefit/Cost Analysis	
Year	Energy Savings	Value of Avoided CO_2	Value of Avoided Criteria Pollutants	Total Social Benefits**	Public Costs	Private Costs	Total Social Costs**	Social B/C Ratio	Net Societal Benefits (Billions $2008)
2020	2.76	-0.77	0.57	2.56	0.08	52.35	52.43		
2035	43.5	1.46	3.09	48.10	0.10	78.80	78.90		
2055	76.3	4.25	4.85	85.44	0.10	78.80	78.90	1.1	6.5

* Present value of costs and benefits were calculated using a 3% discount rate.

***Total costs and benefits do not include various non-monetized values (e.g. mercury pollution reduction, increased productivity, water quality impacts, etc.)*

Variable Impact of Price Elasticity and Rebound Effect

Percentage of Total Energy Savings of Baseline - No Price Escalation							
		2020			**2035**		
		Price Elasticity Change			**Price Elasticity Change**		
		-0.15	**-0.25**	**-0.35**	**-0.15**	**-0.25**	**-0.35**
% RE Used	**75%**	-0.27%	-0.59%	-0.90%	0.54%	0.71%	0.92%
	50%	0.05%	-0.18%	-0.45%	0.96%	1.21%	1.50%
	25%	0.36%	0.23%	0.05%	1.33%	1.71%	2.08%



Uncertain Future of Electricity Price

- EIA does not usually include policies until promulgated.
- Therefore, a future with higher electricity prices due to potential legislation is not considered.
- A sensitivity with a 10% electricity price escalation was conducted.
  - Predicted savings significantly increase with higher electricity prices.

Percentage of Total Energy Savings of Baseline - 10% Electricity Price Escalation							
		2020			2035		
		Price Elasticity Change			Price Elasticity Change		
		-0.15	-0.25	-0.35	-0.15	-0.25	-0.35
% RE Used	75%	3.80%	3.89%	3.93%	5.00%	5.54%	6.08%
	50%	4.11%	4.29%	4.43%	5.42%	6.04%	6.67%
	25%	4.43%	4.66%	4.88%	5.79%	6.54%	7.25%

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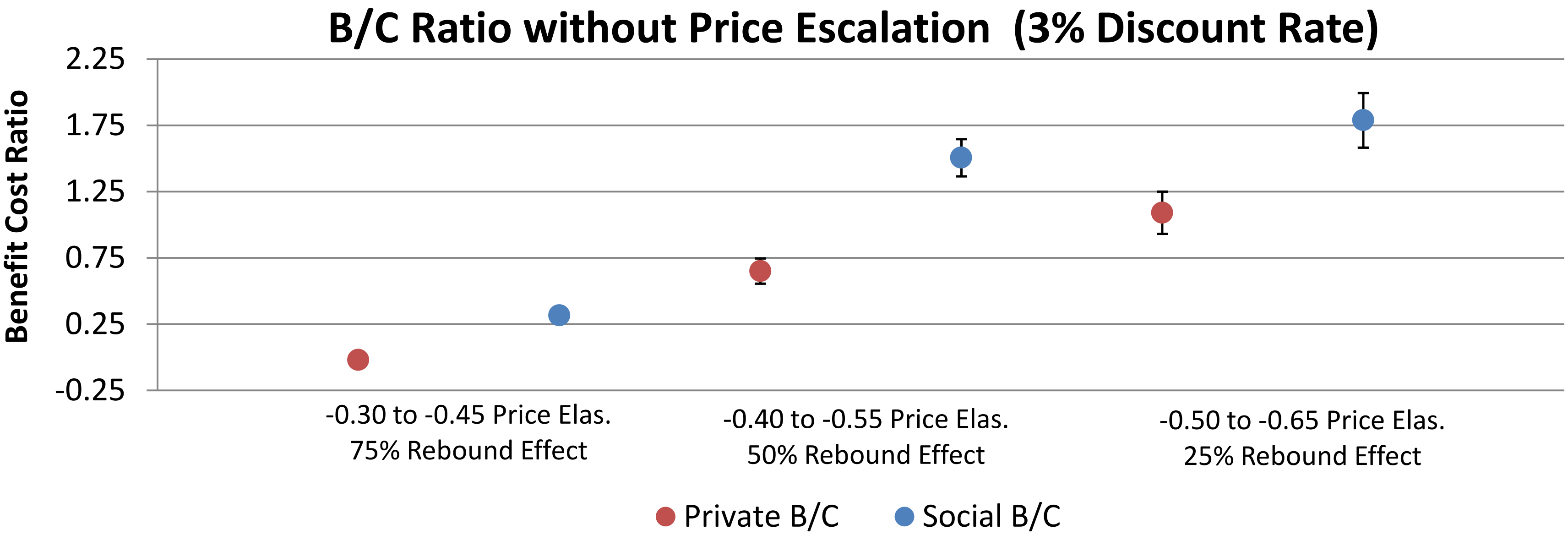
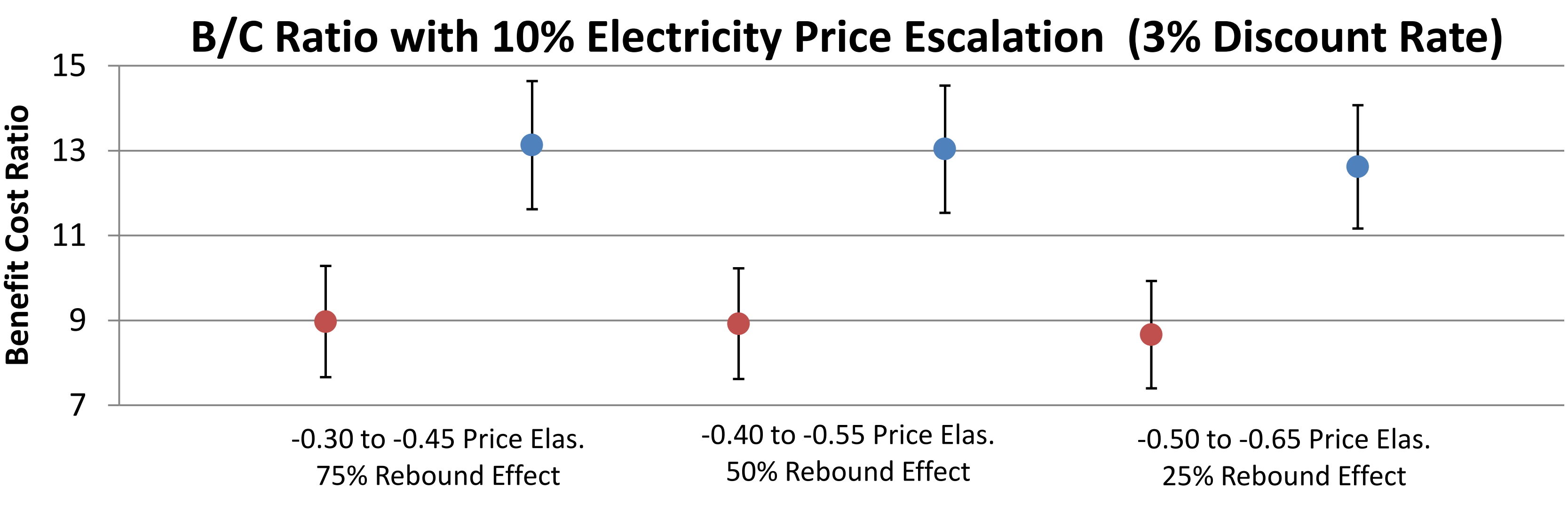
A 10% Price Escalation Significantly Affects the Realized Benefit-Cost Ratios





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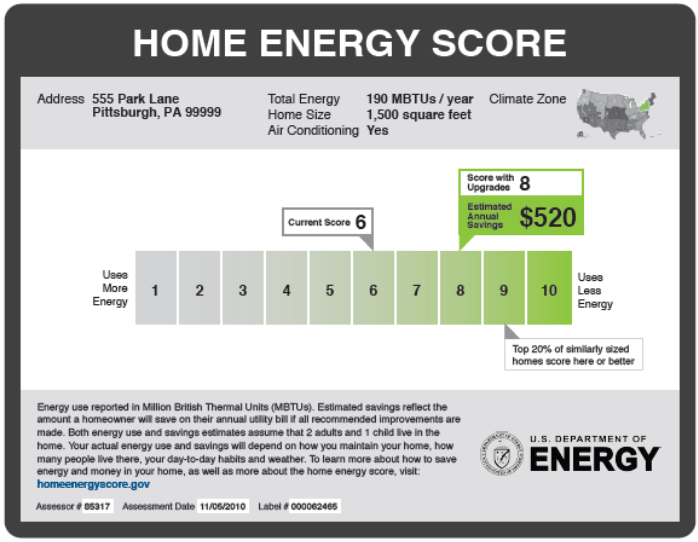
Mandated Disclosure with Building Energy Performance Ratings

Recommended Federal Action: Require disclosure of home energy consumption or home energy performance at the point of sale or lease of a residential unit.

- Promotes accounting of energy efficiency of a residential unit in selling or rental price
  - A premium is realized at time of sale for energy efficient homes.
    - In the ACT, every star improvement in home rating increased expected sales price by ~3% (NFEE, 2008).
    - For every dollar saved in fuel costs, an additional $10-$25 of added home value occurs at time of sale (Nevin & Watson, 1998).
  - Though little on residential rental units, rental and sales prices for energy efficient commercial buildings are higher than traditional buildings (Cooperman et al., 2010).



Picture from: http://www.eere.energy.gov/pdfs/homeenergyscore.pdf

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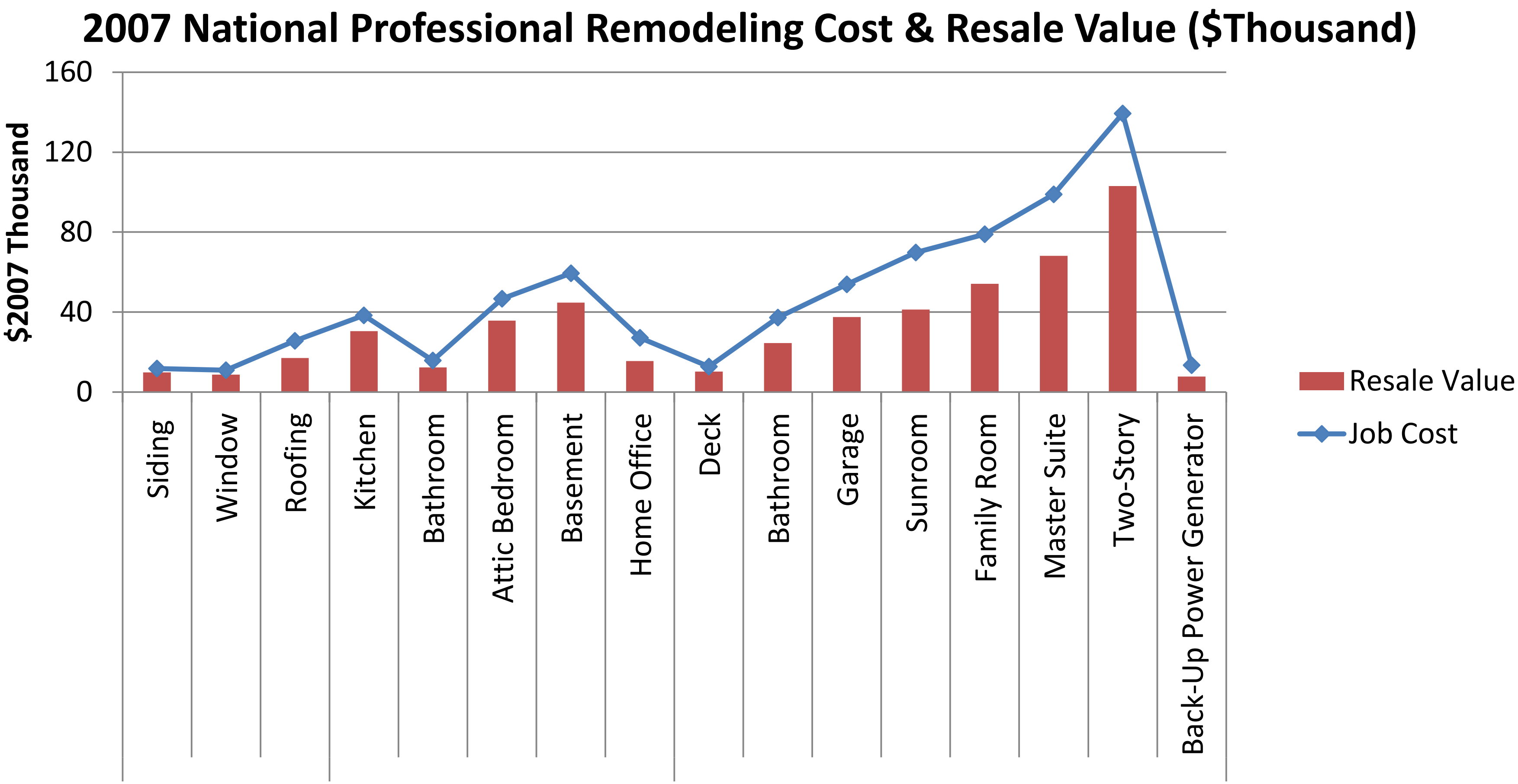
Home Equity Improvement with Remodeling and Energy Retrofits

- 71.4% of the renovation and retrofit costs can be recouped in resale value.



Mandated Disclosure with Building Energy Performance Ratings

Source: U.S. DOE Buildings Technologies Program, October 2009. 2009 Buildings Energy Data Book, Table 2.6.4

Policy Specific Assumptions & Methodology

- NEMS levers of lower discount rate and longer times horizons for operating costs did not increase EE investments as expected.
- Spreadsheet assumptions:
  - Energy savings from Weatherization Assistance Program (WAP) for insulation and infiltration measures
    - Electric heated : 10.5% of pre-weatherized energy saved (Berry & Schweitzer, 2003)
    - Natural gas heated : 22.9% of pre-weatherized energy saved (Schweitzer, 2005)
  - WAP upper estimate for weatherization cost per home of $3,000 assumed (Schweitzer, 2005).
  - America's Energy Future cost curves used for equipment installation
    - Dishwasher, refrigeration, furnace fans, space cooling/heating, and water heating (AEF, 2009)
    - Only 50% energy savings assumed to be available due to overlap with WAP
  - Turnover rate for homes (US Census Bureau, 2011)
    - Single family: 4.25% for sale or rent per year, average from 2000-2010
    - Multi-family: 10.7% average vacancy rate for rentals with units > 5 from 2000-2010

Policy Specific Assumptions & Methodology

- Assumptions continued:
  - Diffusion curve assumed for implementation
    - 10 years for full adoption
    - Market penetration saturated at 50% of all eligible homes (WAP)/energy savings (AEF)
    - 5% of market penetration initially participate
  - 2 year lag between when energy efficiency measures installed and home sells for an equity premium
  - $10 equity premium for every $1 annual energy savings (NFEE, 2008; Nevin & Watson, 1998)
  - Administration cost of $0.065/MBtu energy saved
- Sensitivity conducted for:
  - Penetration (50% to 25%)
  - Weatherization cost per home ($3,000/home to $6,000/home)
  - Home equity premium ($10 to $1 home equity per $1 energy savings)

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Mandated Disclosure with Building Energy Performance Ratings from the Residents' Perspective*

Year	BAU Energy Consumption **	Annual Energy Savings			Cumulative Energy Savings***		Annual Home Equity Premium	Cumulative Savings & Benefit	Annual Private Cost Million $2008		Cumulative Private Cost
	Trillion Btu	Trillion Btu	$M (2008)	%	Trillion Btu	$M (2008)	$M (2008)	$M (2008)	Implementation Costs	Energy Rating Cost	$M (2008)
2012	21,611										
2020	22,032	373.9	3,837	1.70	1,432	16,719	12,368	49,414	8,293	809	37,054
2035	23,915	822.3	3,504	3.44	11,546	79,978	15,975	186,464	9,897	967	89,731
2055	--	--	--	--	16,828	95,957		208,688			89,731

* Present value of costs and benefits were calculated using a 7% discount rate.

** Reference case residential energy consumption

***Annual energy savings modeled to degrade at a rate of 5% for a 20 year life. All benefits from the policy end by 2055.

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Energy Savings and Costs by Households

Description	2012	2020	2035
Annual number of new homes served (million)	0.12	2.70	3.22
Total number of homes with energy savings(million)	0.12	15.63	57.43
% of Total SFH and MFH housing stock	0.11%	2.22%	2.31%
Average energy savings per home (MBtu/home)	29.13	23.92	14.32
Private cost per home (2008$/home)	$3,380	$3,376	$3,371
Public cost per home (2008$/home)	$1.89	$1.77	$1.65

Source: Spreadsheet calculations based from AEO 2010 Reference case projections for residential population, delivered energy consumption, and electricity related losses.

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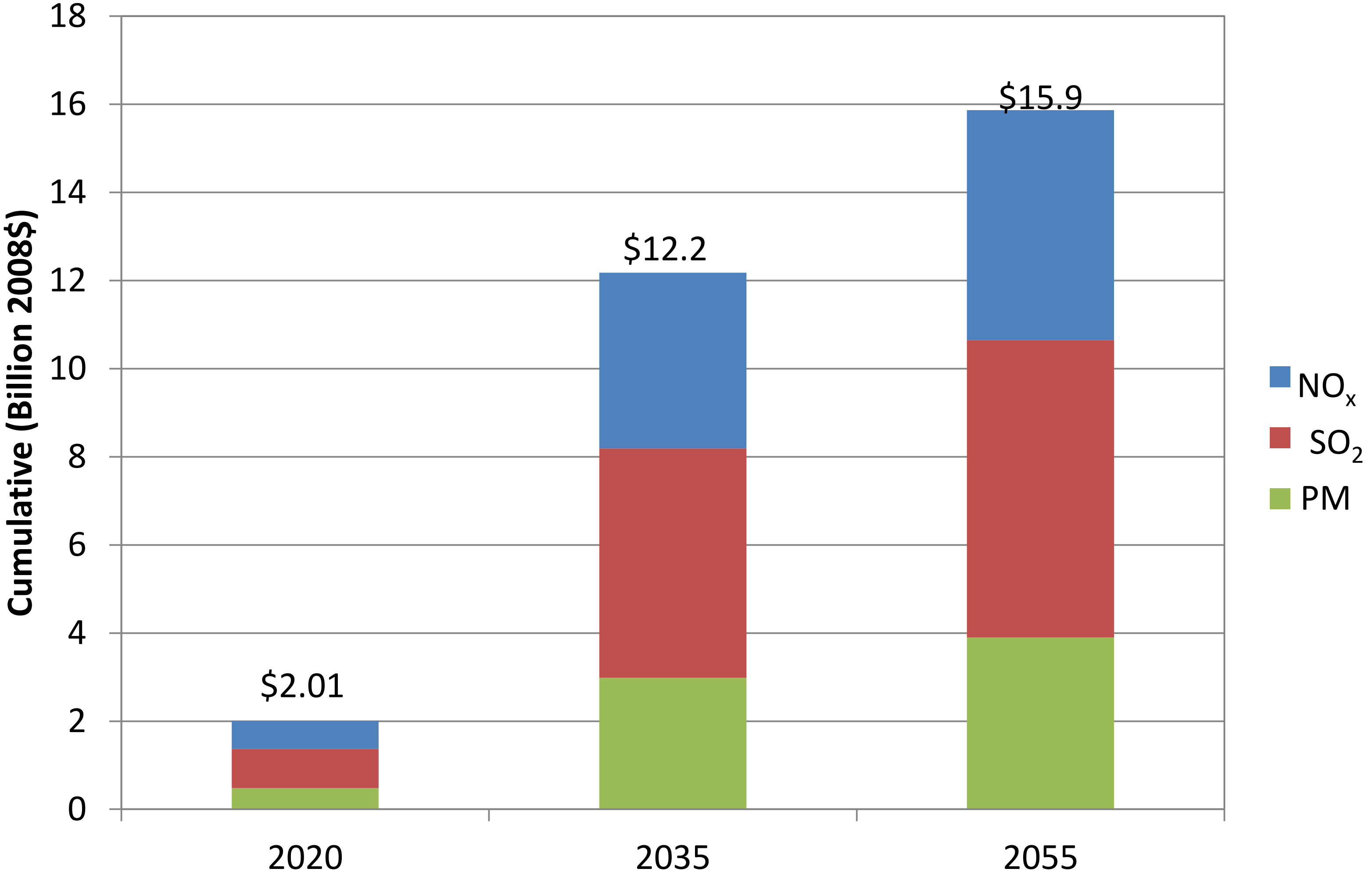
Value of Avoided Damages from Criteria Pollutant Emissions*



* Assumes no new environmental regulations, but does include the Clean Air Interstate Rule limiting No_x and SO_2 in 28 states.

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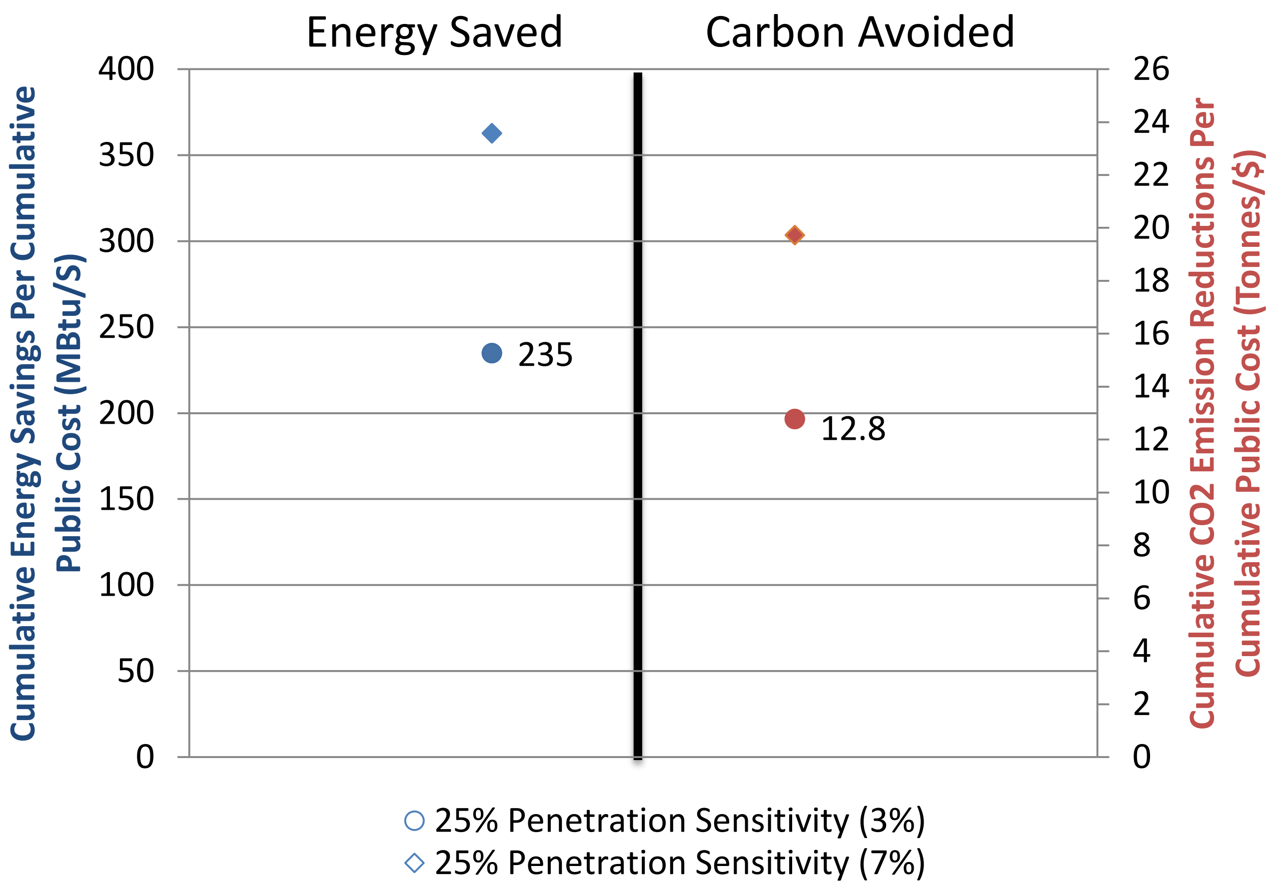
Public Costs Leverage Significant Energy Savings and Carbon Mitigation



	Policy (50% penetration)		Sensitivity (25% penetration)	
	3%	7%	3%	7%
Cumulative energy savings per dollar (MBtu/$)	234.92	362.78	234.90	362.71
Cumulative CO_2 emission reduction per dollar (tonnes/$)	12.77	19.732	12.77	19.729

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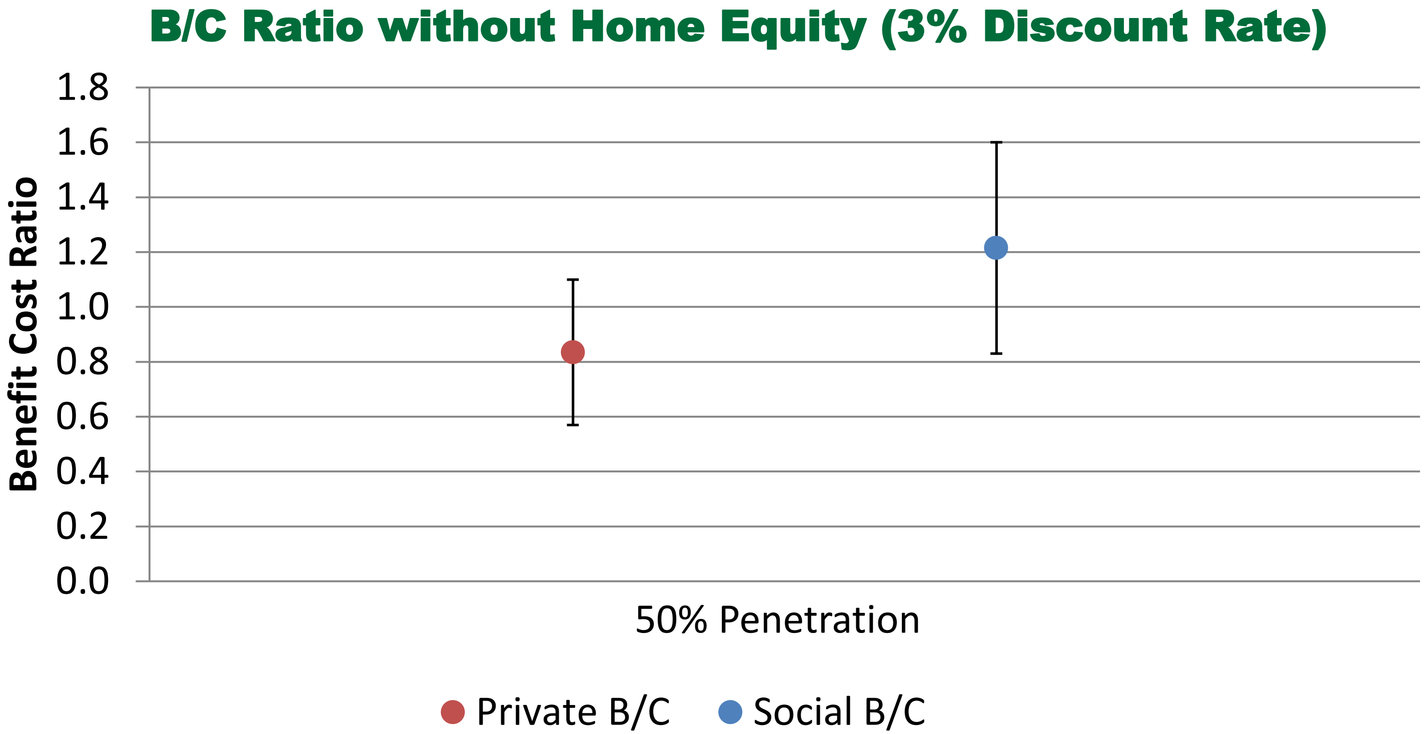
Benefit/Cost Results are Favorable

	Cumulative Social Benefits* (Billions $2008)					Cumulative Social Costs* (Billions $2008)			Benefit/Cost Analysis	
Year	Energy Savings	Value of Avoided CO_2	Value of Avoided Criteria Pollutants	Home Equity Benefits	Social Benefits**	Public Costs	Private Costs	Total Social Costs**	Social B/C Ratio	Net Societal Benefits (Billions $2008)
2020	21.0	1.71	2.01	41	66	0.024	45.12	45		
2035	138	12.8	12.2	174	337	0.072	140	140		
2055	184	17.9	15.9	190	408	0.072	140	140	2.9	268

* Present value of costs and benefits were calculated using a 3% discount rate.
**Total costs and benefits do not include various non-monetized values (e.g. mercury pollution reduction, increased productivity, water quality impacts, etc.)

NOTE: Social B/C ratio is 1.56 when not including home equity benefits.
Social B/C ratio is 1.7 when home equity benefits are included, but the equity premium is assumed to be $1 per $1 energy savings instead of $10 per $1 energy savings.

Cost Effectiveness of Mandated Disclosure Impacted by Assumed Cost to Weatherize Homes



- Error bars show estimates of B/C ratio at different weatherization costs per home
  - Low estimate: $6,000 per home to weatherize
  - High estimate: $3,000 per home to weatherize

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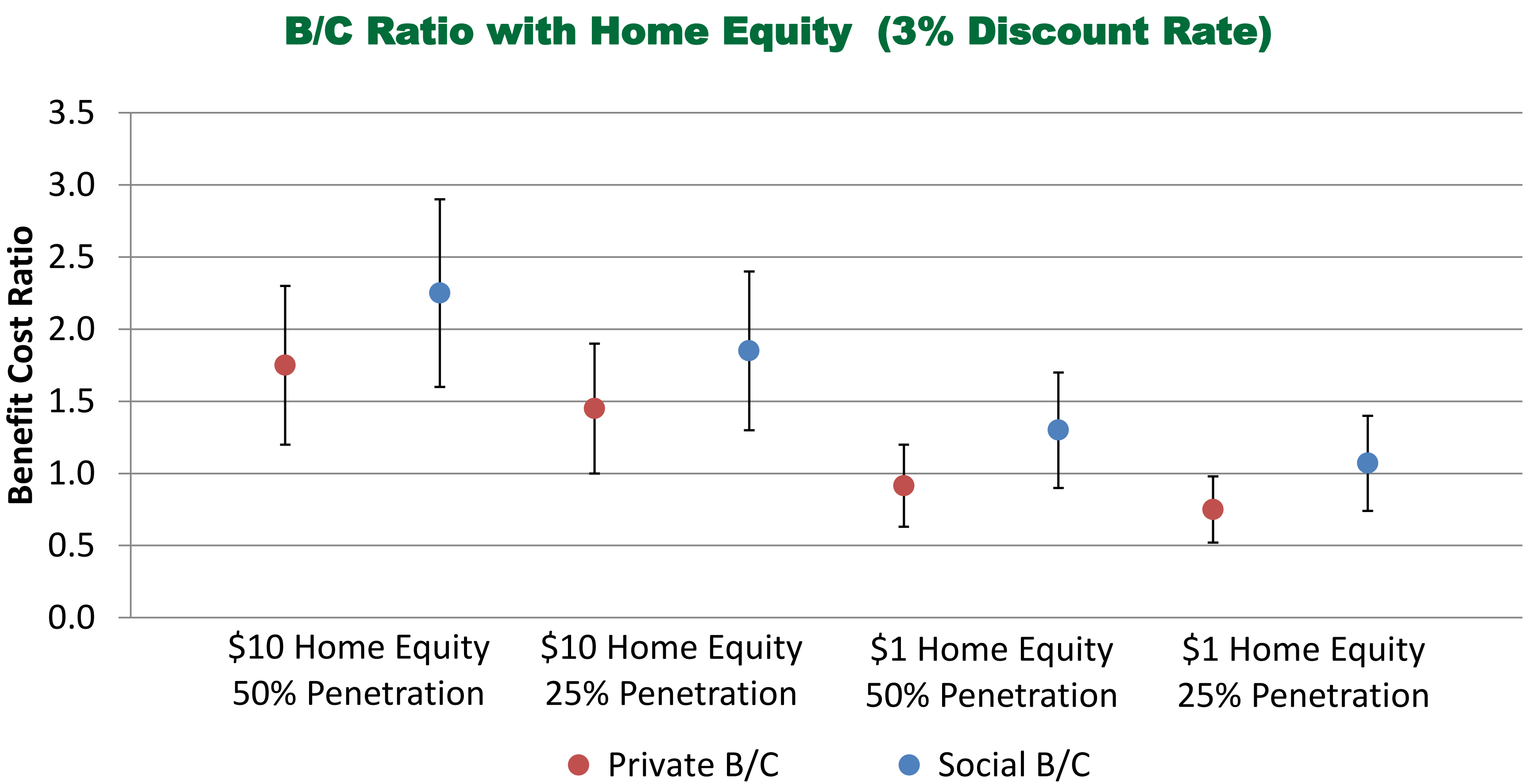
Mandated Disclosure is Cost Effective with a $10 Home Equity Premium



- Error bars show estimates of B/C ratio at different weatherization costs per home
  - Low estimate: $6,000 per home
  - High estimate: $3,000 per home

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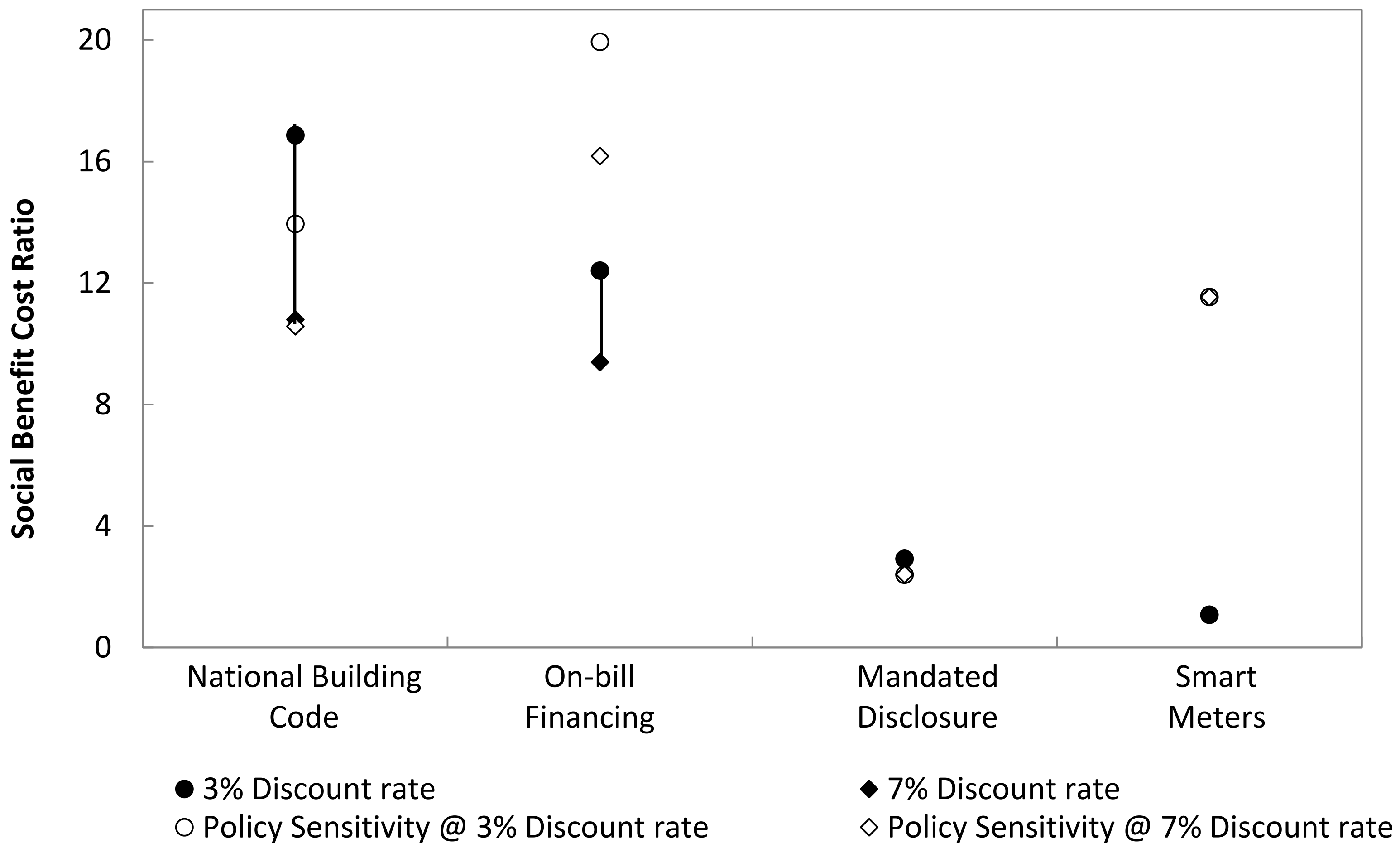
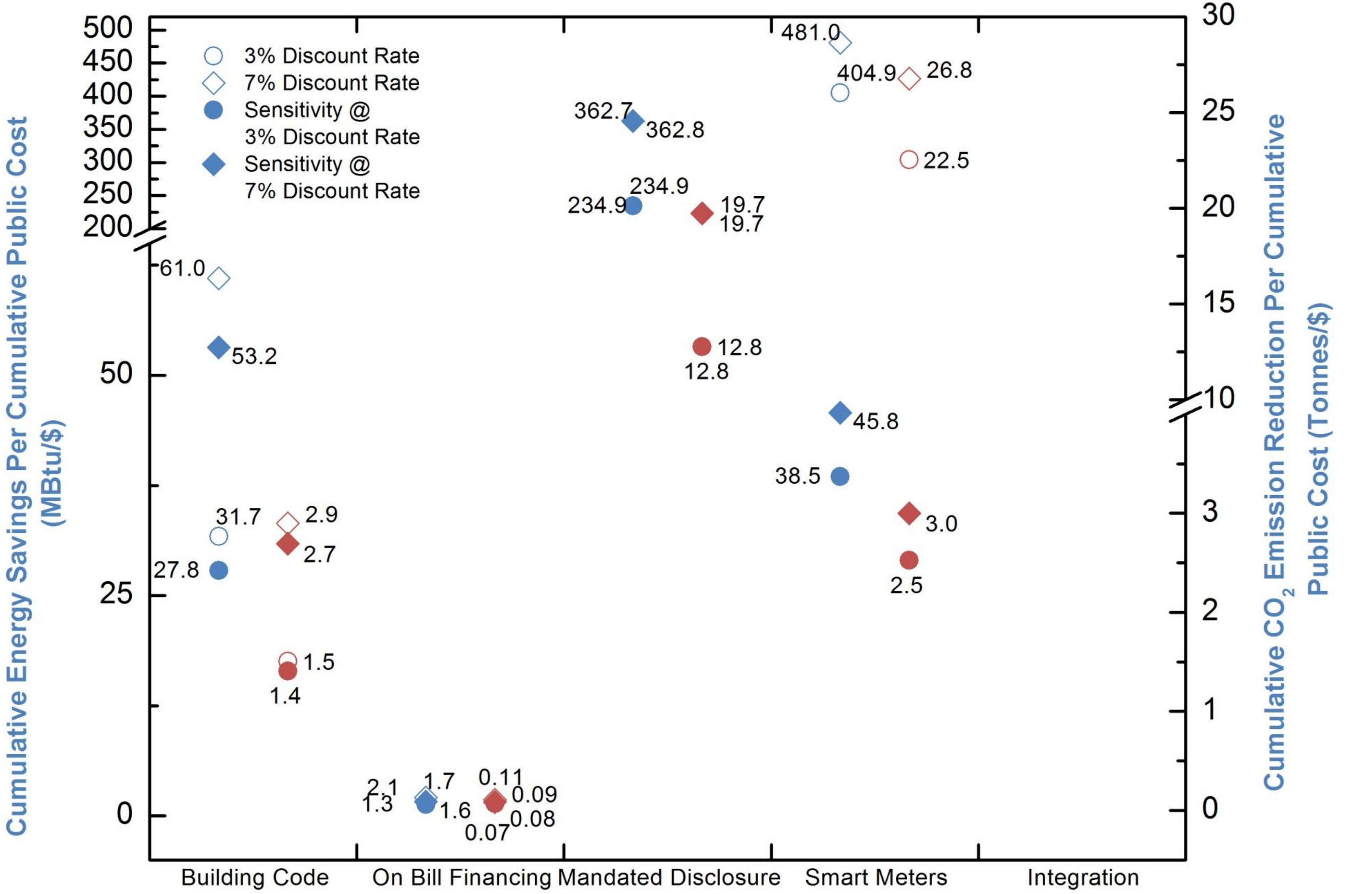
Social Benefit/Cost Ratios



Leveraging Ratios are Significant



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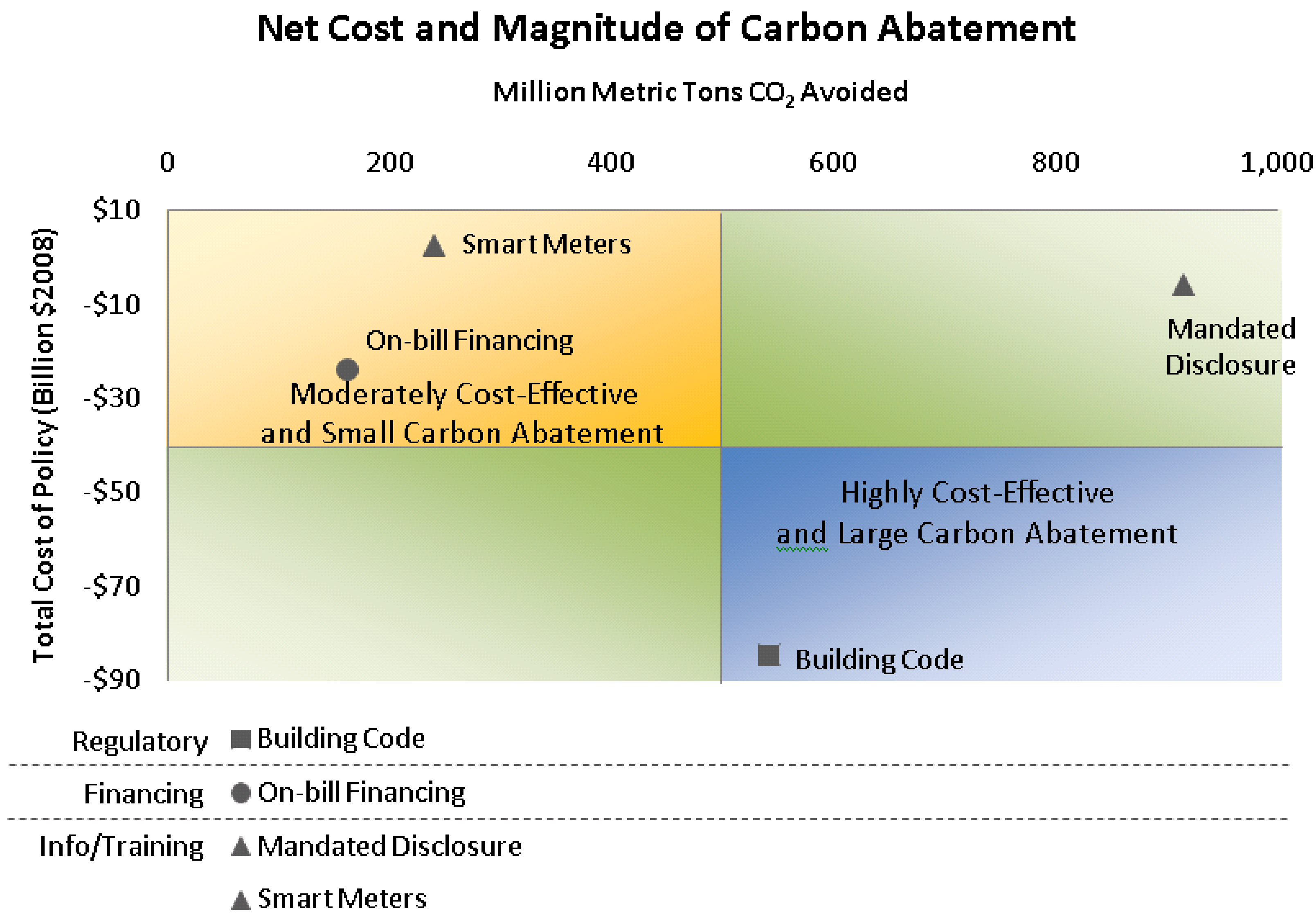
Building Codes and Mandated Disclosure Offer Cost Effectiveness and Largest Carbon Abatement



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Conclusions

- All four policies have favorable social benefit cost ratios.
- From the households' perspective, energy savings generally exceed private costs
- Plausible alternative assumptions about participation rates, costs, electricity prices, discount rates, home equity premium, and alternative program and policy designs can alter benefit-cost ratios significantly.

<u>Note regarding alternative assumptions:</u>

- Participation Rates: Households served
- Costs: Cost to weatherize a home
- Electricity Prices: 10% electricity price escalation
- Discount Rates: at 3% and 7% for benefit cost analysis
- Home Equity Premium: $10 or $1 premium for every $1 energy savings
- Program Design: On-bill financing programs vary interest rate and payback periods.
- Policy Design: Slow retiring of building codes

Next Steps

- Integrated NEMS analysis (March 31)
- Final PowerPoint presentation to DOE (April 30)

- Questions:
  - Is the PowerPoint sufficient or should we prepare a revised report?
  - Which journals and conferences should we target for dissemination?
  - Should we announce the PPT in an email?
  - Where should the PPT be posted?
  - Should we do a webinar?

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Acknowledgements

- Climate Change Policy and Technology Office
- Youngsun Baek, Georgia Institute of Technology
- Jess Chandler, Georgia Institute of Technology
- John Cymbalsky, U.S. Department of Energy
- Melissa Lapsa, Oak Ridge National Laboratory
- Narendra Parihar, Georgia Institute of Technology
- Richa Sharma, Georgia Institute of Technology

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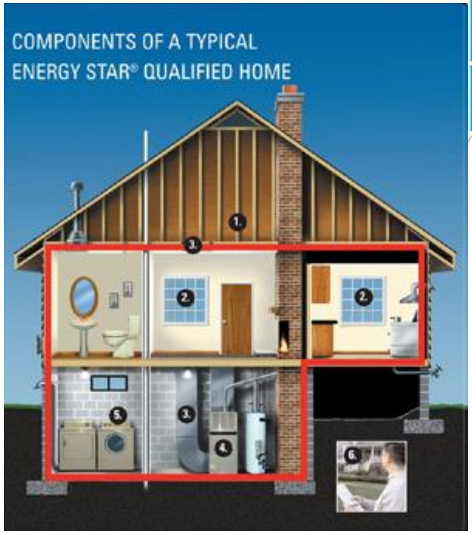
NEMS Modeling: Making Homes Part of the Climate Solution -- National Building Codes

Georgia Institute of Technology & Oak Ridge National Laboratory

April 5, 2011



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Mandated National Building Energy Codes Policy

Recommended Federal Action: Expand technical assistance to States to accelerate their adoption of advanced building energy codes. Subject to available funds, provide financial assistance to establish and expand training and certification programs focused on third-party verification of building energy code compliance.

- Residential building energy code is a set of standards specifying the minimum acceptable energy efficiency level for new houses.
- The International Energy Conservation Code (IECC), developed by the International Code Council (ICC), is a model code available for state to choose to adopt/adapt or not.
- The 2009 IECC code the latest version for residential building energy code.
- State compliance measurement activities
  - state energy code compliance evaluation pilot studies
  - State level technical assistance
- Third party verification is needed

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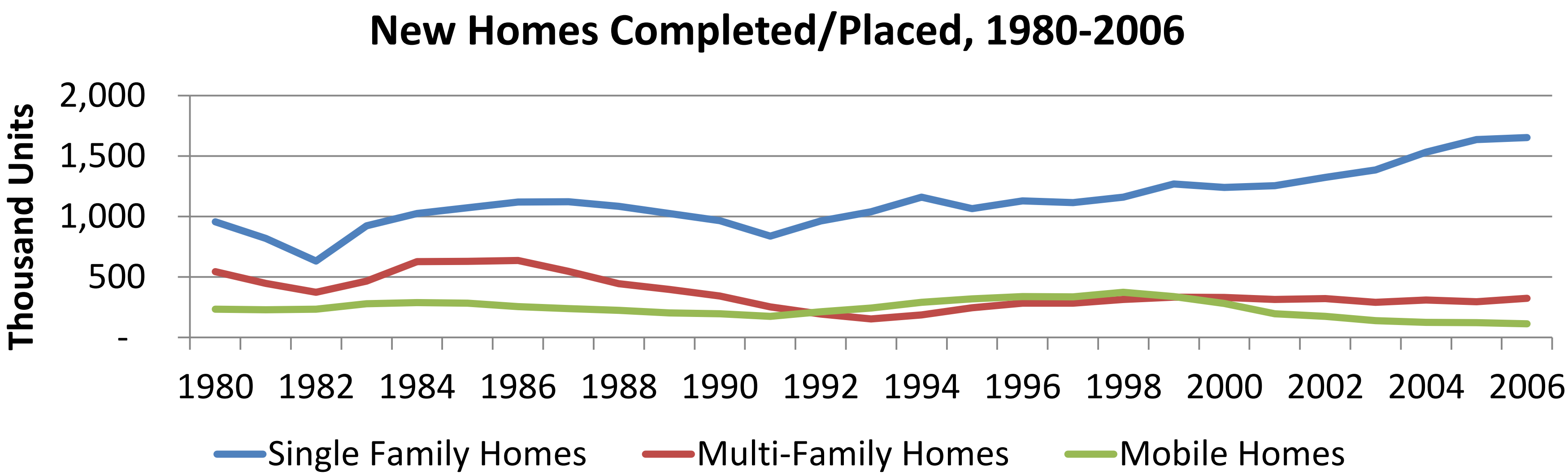
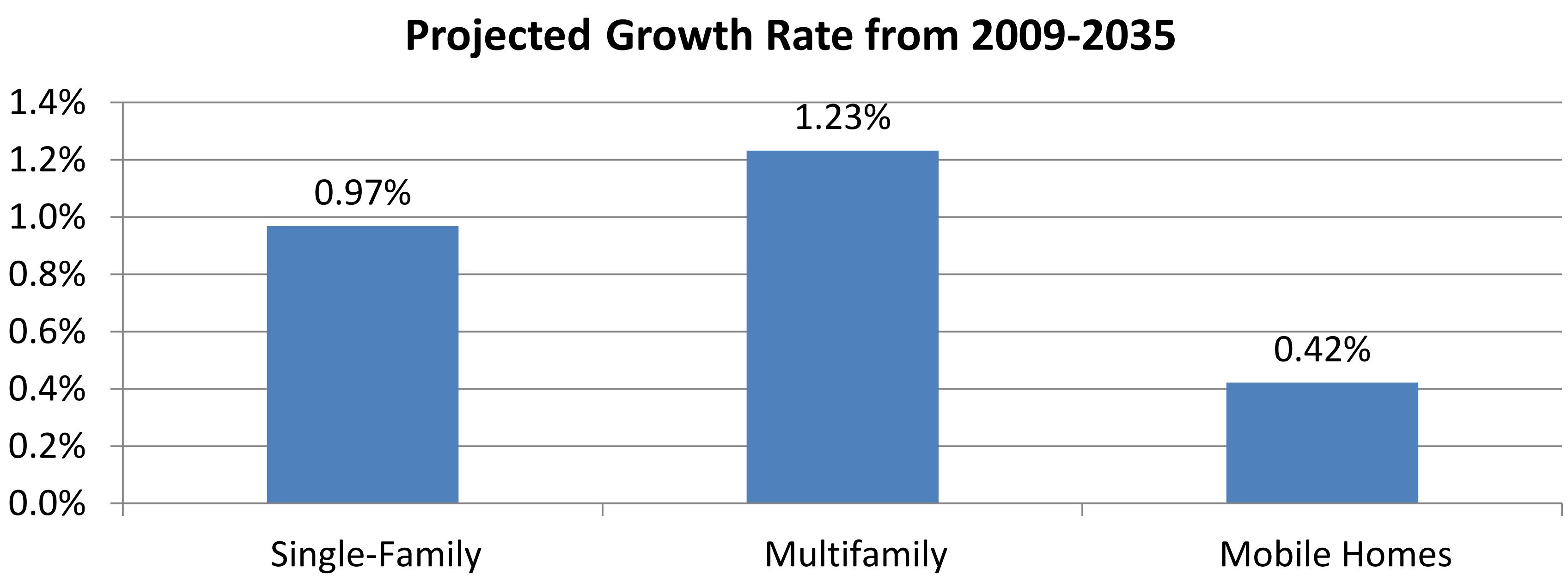
Residential New Construction and Square Footage





Source: 2009 Building Energy Data Book, Table 2.2.6,

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Building codes do save energy and third party verification is important

- With subsequent updates, building energy codes have 1-2% savings per year[1].
- Third party verification, training and education efforts for code compliance need to be strengthened.
  - The effectiveness of energy code is the product of:

    Strong Model Code * State Adoption * Verified Compliance * Performance Assurance[2]
  - Median compliance of the IECC code (40-60%)[3]

1. Harris, et al., 2010; Tolkin, **et a**l., 2010; HMG,2005
2. Harris, et al., 2010;
3. Young, 2005

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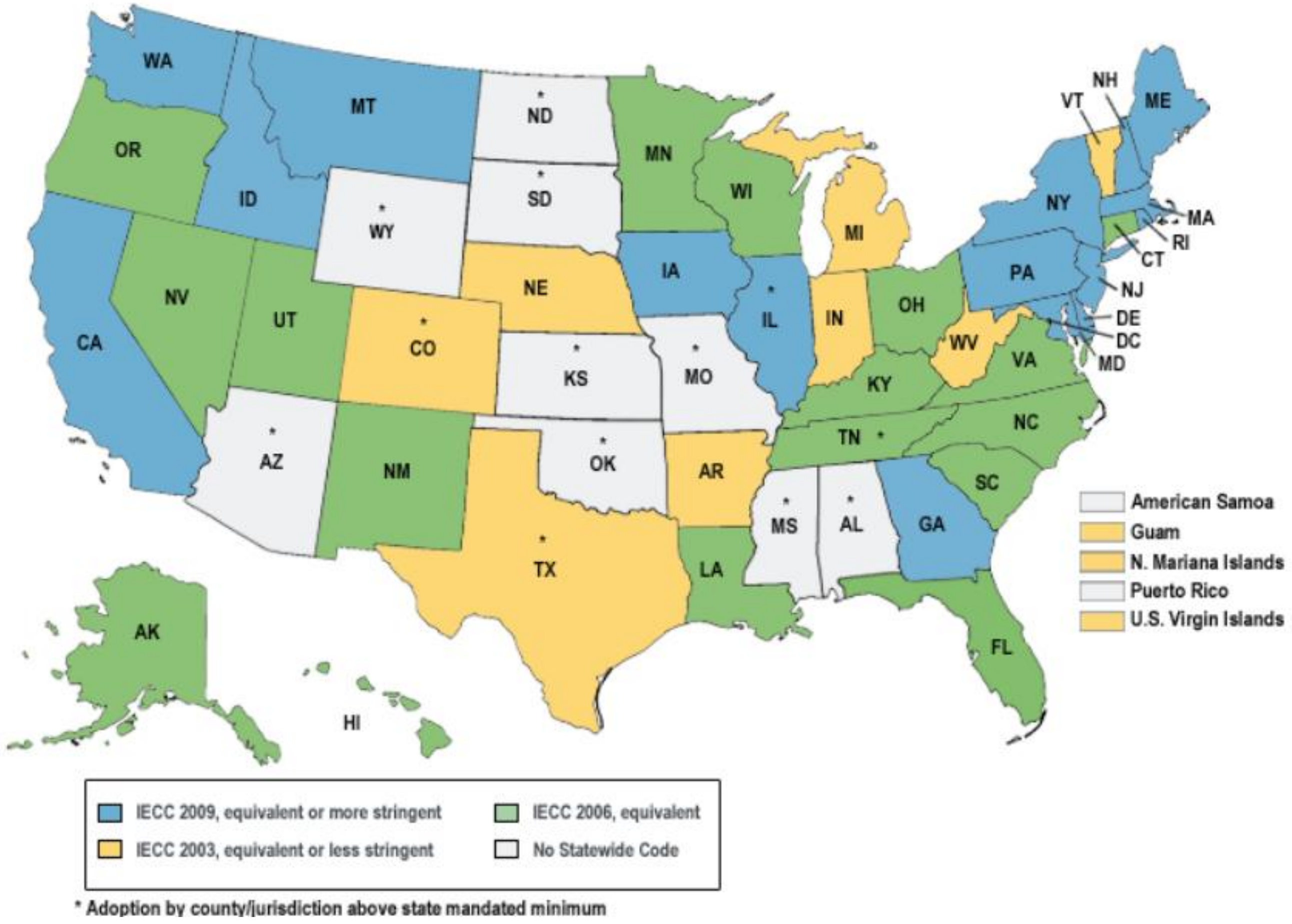
Status of energy code adoption: residential
as of Jan 5, 2011



Source: DOE EERE Building Energy codes Program (http://www.energycodes.gov/states/)

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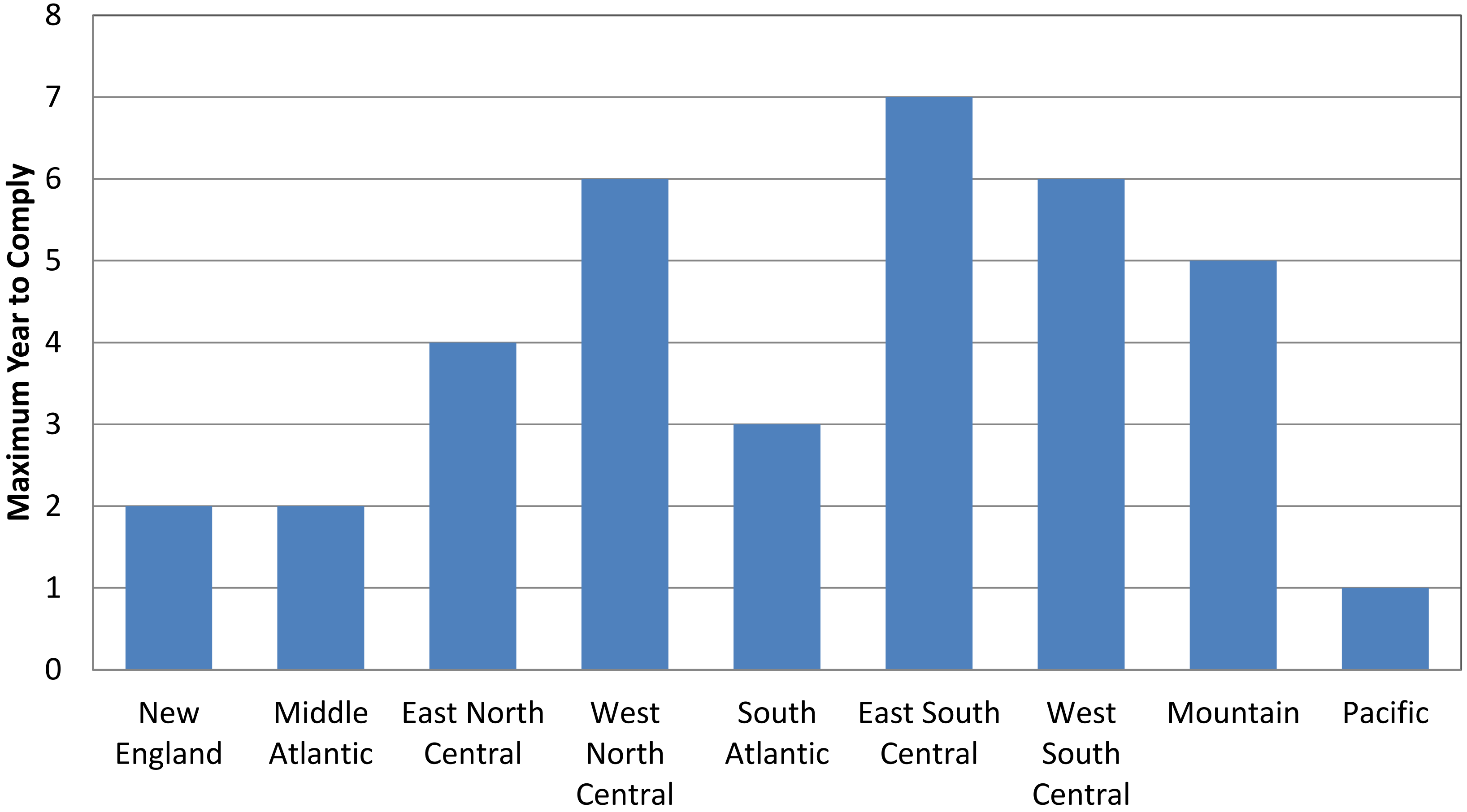
NEMS Reference Case Models Variable Code Enforcement



Source: ACEEE: The 2010 State Energy Efficiency Scorecard, Oct 2010

Modeling Methodology and Assumptions

- Accelerate advanced building energy code adoption by forcing retirement of the least stringent code every three years
- Provide assistance to establish and expand programs for third-party verification of code compliance.
  - Public administration of the program requires maintaining a certification program for third-party verifiers.
- Sensitivities Conducted
  - A slow phasing-out (every five years) building code scenario was tested against the main policy scenario (retires the least stringent code every three years).

Lever	Reason	Location
Removing Less Efficient Building Codes	As building codes are advanced and enforced, less efficient codes will be removed faster.	rtektyc.txt
Adding new, more stringent building codes	More efficient building codes will be implemented by 2035 than NEMS currently allows (Only 5 building code types).	Residential source code and rtektyc.txt

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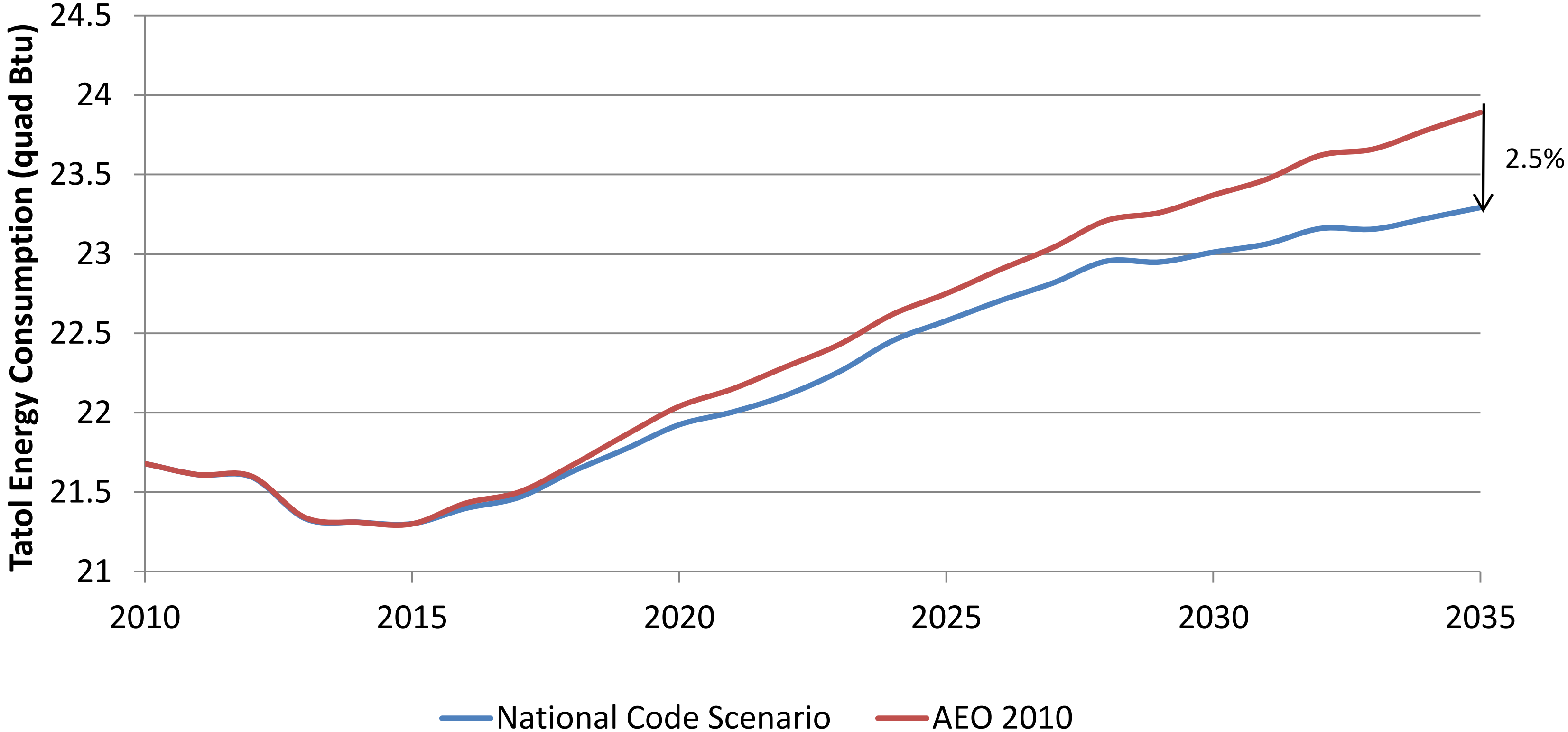
Modeling Methodology and Assumptions, cont'd

- Complete code compliance is obtained by forcing the retirement of the less stringent building codes.
- New codes were added to simulate the gradual efficiency improvements of the energy codes (see **highlighted** rows below).
- The least stringent code was phased out every three years.
- The most efficient code, the PATH code, is available all the time.

Energy Code	Efficiency Level	Available Years	
		Reference	National Code Scenario
No IECC		2006 – 2050/2010	2006 – 2012/2010
IECC 2006		2006 - 2050	2006 – 2015
Energy Star	~30% above IECC 2006	2006 - 2050	2006 – 2018
2012 code	~35% above IECC 2006	N/A	2012 – 2021
2015 code	~38% above IECC 2006	N/A	2015 – 2024
FORTY	~40% above IECC 2006	2006 – 2050	2006 – 2027
2021 code	~45% above IECC 2006	N/A	2021 - 2030
PATH	~50% above IECC 2006	2006 - 2050	2006 - 2050

Energy Savings from Mandated National Building Codes



- In 2035, the residential sector consumes 598 TBtu (2.5%) less energy in the national building code scenario than in the reference scenario.
- In total, national building codes save about 5 quad Btu energy, while 54% of the savings comes from space heating, and 46% comes from space cooling.

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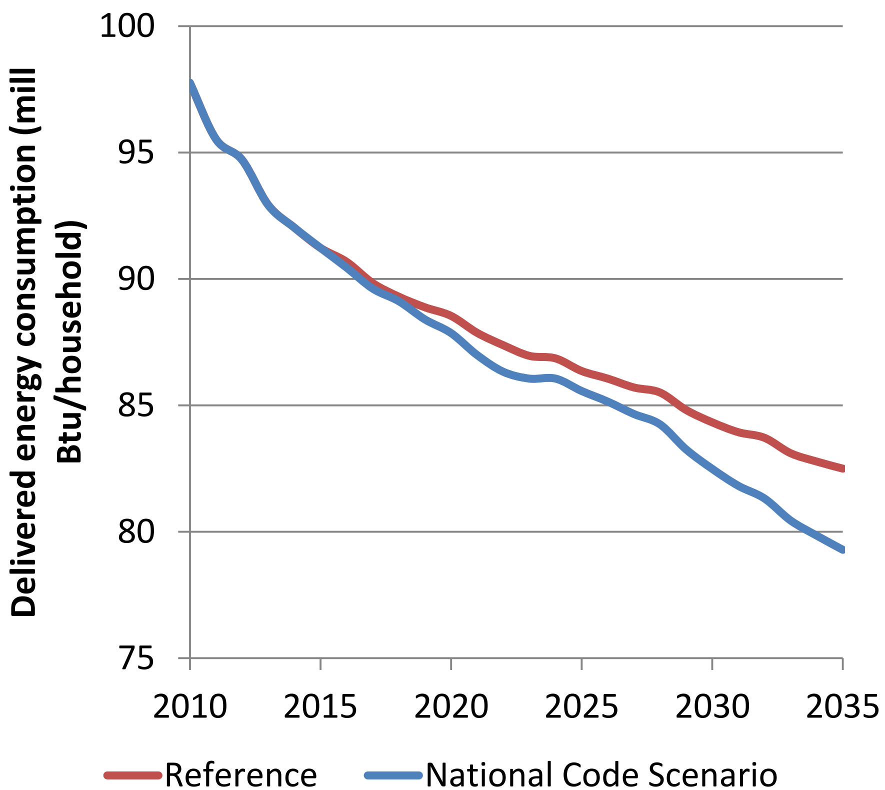
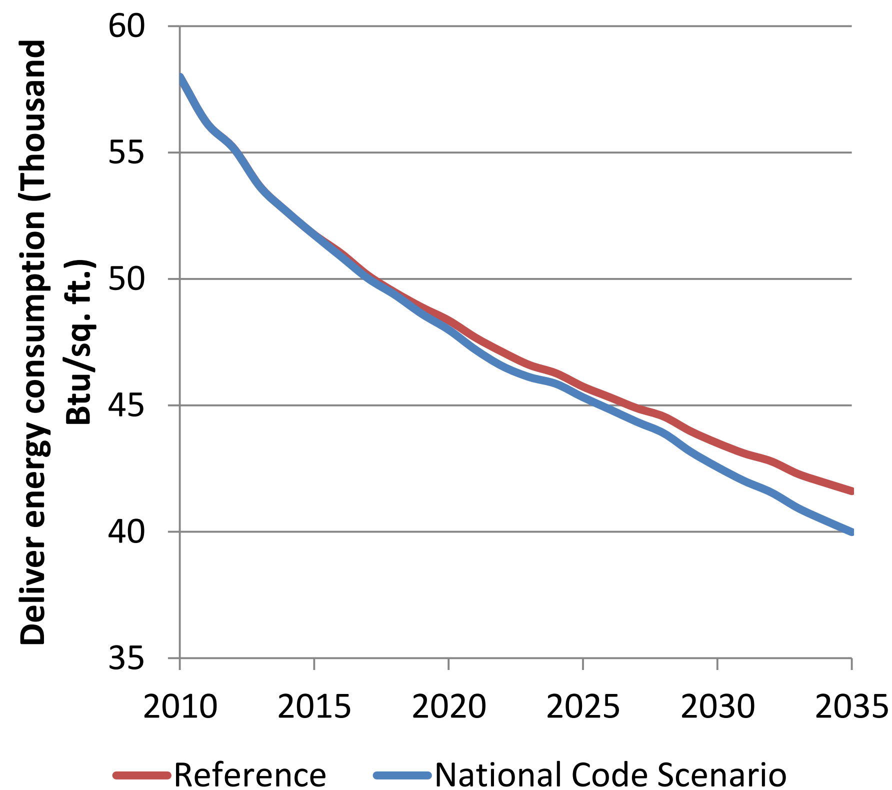
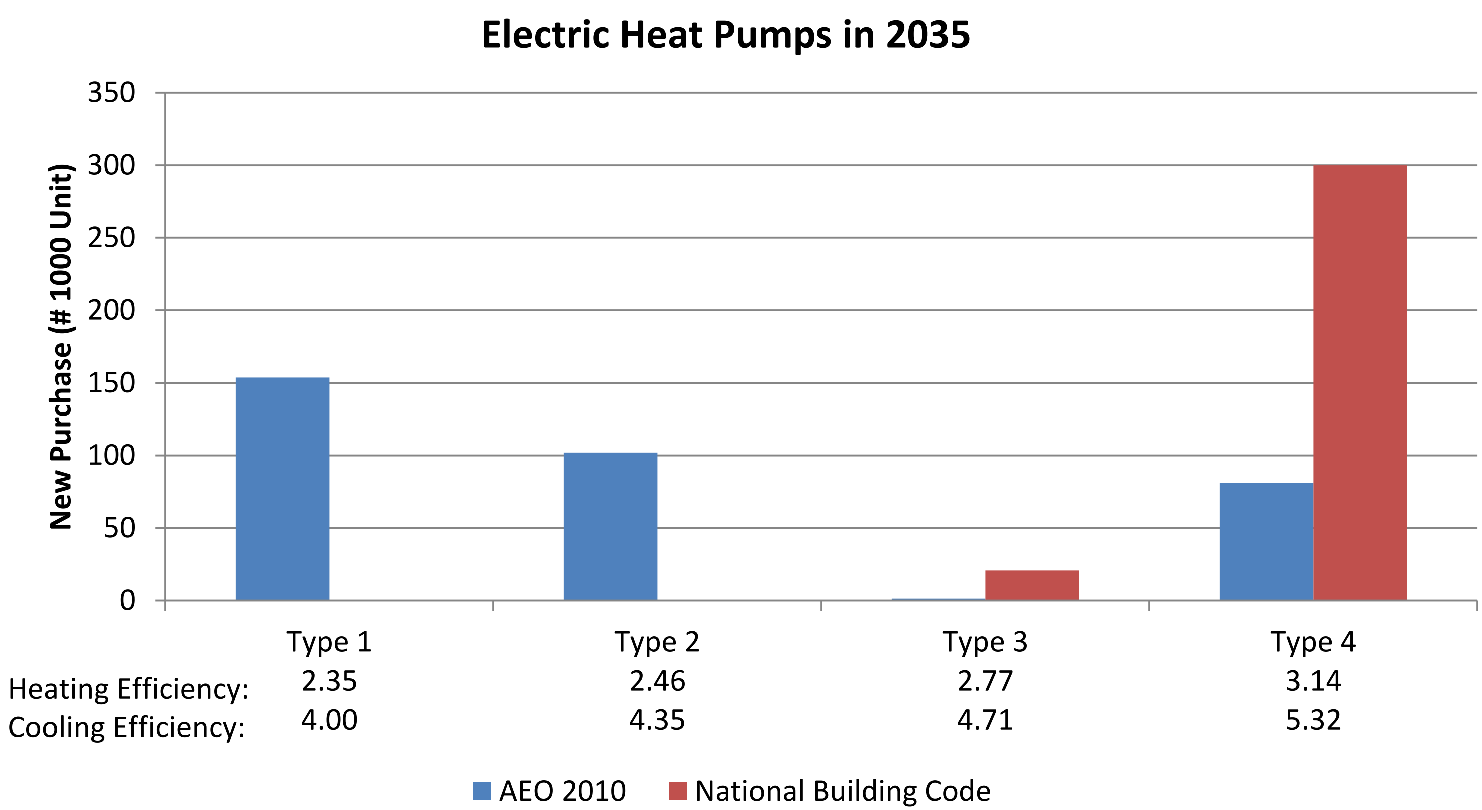
Average Energy Intensity Decreases





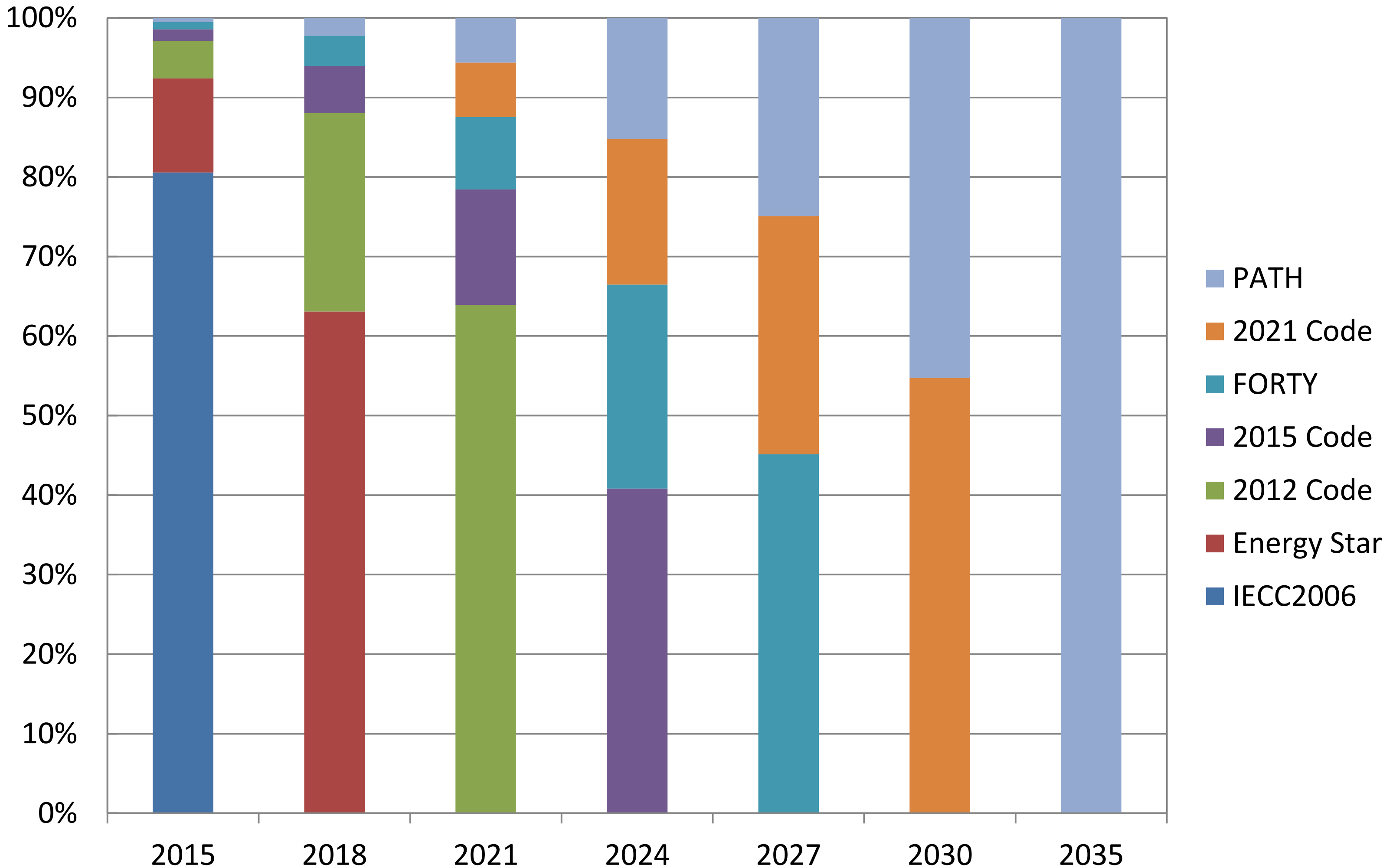
- The per household energy consumption and per sq. ft. energy consumption both decrease faster with the mandatory national code.

Evidence of Technology Shift with Stricter Codes



- Consumers' choices over heating equipments are affected by the national building code. For example, home builders switch from type 1 & 2 electric heat pumps to type 4 in the policy case.

New Homes Built to Each Building Code*



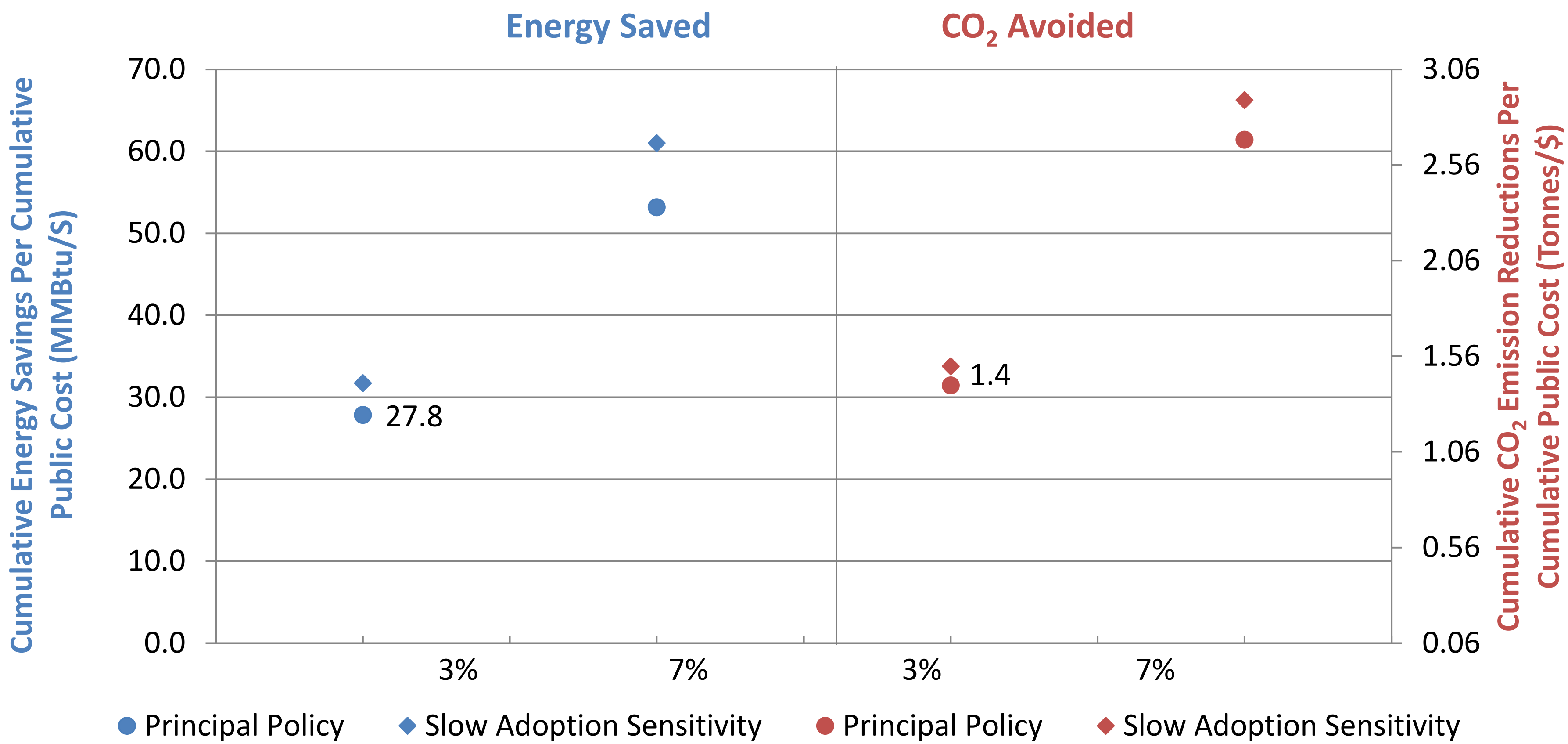
*Based on HVAC System Data

Mandated National Building Code from the Homeowners' Perspective

Year	BAU Energy Consumption*	Annual Energy Savings			Cumulative Energy Savings		Annual Private Cost	Cumulative Private Cost
	Trillion Btu	Trillion Btu	$M (2008)	%	Trillion Btu	$M (2008)	$M (2008)	$M (2008)
2011	21,610							
2020	22,040	115.5	1366	0.52	318	4,436	1,146	10,633
2035	23,890	598.0	2737	2.50	5,024	36,813	512	24,216
2055	--	--	--	--	10,705	53,751		24,216

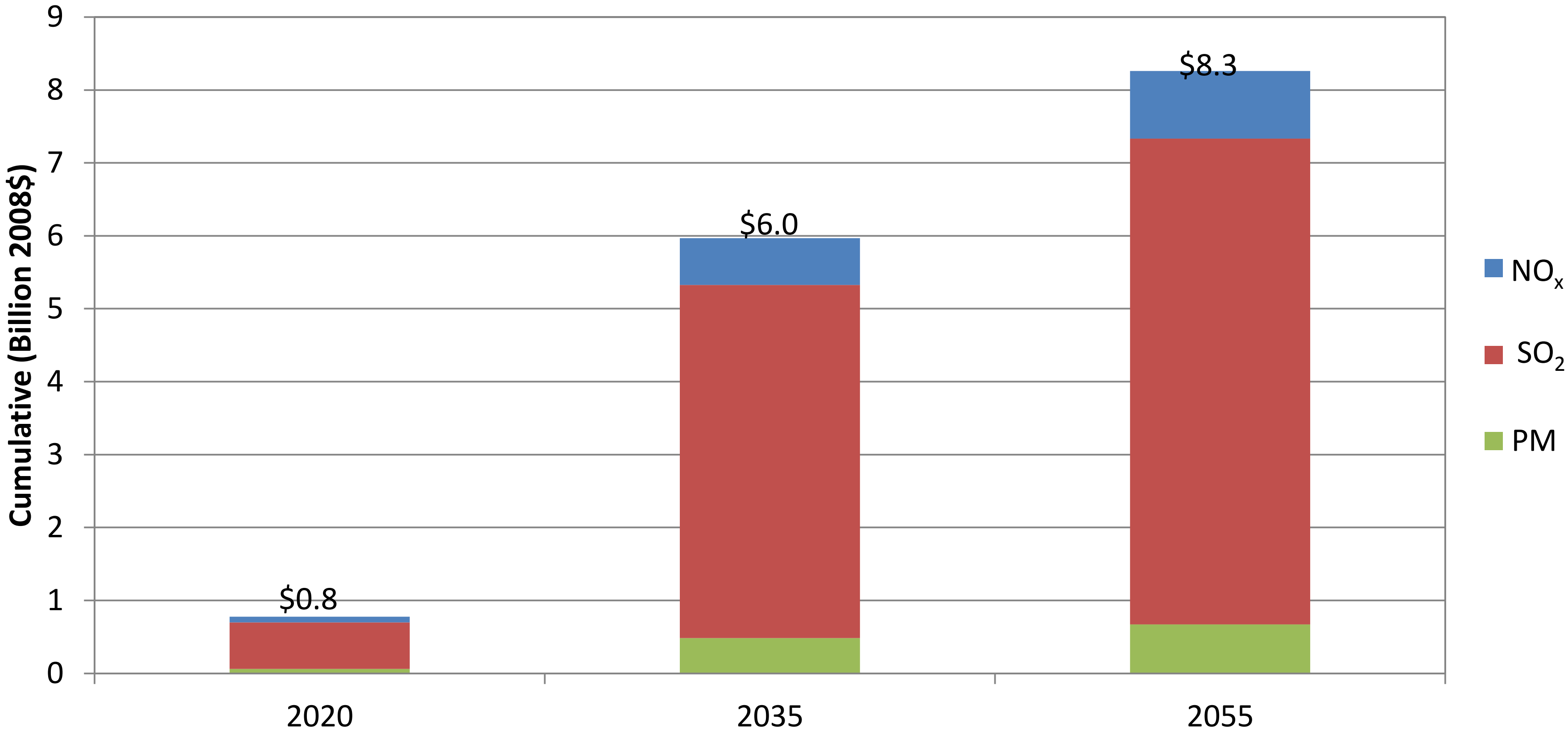
* Present value of costs and benefits were calculated using a 7% discount rate.
** Reference case residential energy consumption
***Investments stimulated from the policy occur through 2035. Energy savings are then modeled to degrade at a rate of 5% after 2035, such that all benefits from the policy have ended by 2055.

Leveraging Ratios for a Mandated National Building Code



Note: It costs the public $0.04 for each MMBtu energy saved from the National Building Code policy. The cost effectiveness for the National Building Code policy for carbon abatement is $0.71/ton. Comparatively, the estimated damages from CO_2 emissions are projected to be $34/ton (EPA, 2010).

Value of Avoided Damages from Criteria Pollutant Emissions (Billions $2008)



* Assumes no new environmental regulations, but does include the Clean Air Interstate Rule limiting NO_x and SO_2 in 28 states.
** National Building code has significant natural gas savings (262 TBtu in 2035) in the residential sector.

Benefit/Cost Results are Highly Favorable*

	Cumulative Social Benefits** (Billions $2008)				Cumulative Social Costs** (Billions $2008)				
Year	Energy Savings	Value of Avoided CO_2	Value of Avoided Criteria Pollutants	Total Social Benefits***	Public Costs	Private Costs	Total Social Costs***	Social B/C Ratio	Net Societal Benefits (Billion $2008)
2020	5.9	0.35	1.0	7.2	0.0	13.4	13.5		
2035	70.4	4.91	11.2	86.6	0.4	38.4	38.8		
2055	123.7	9.77	18.4	151.9	0.4	38.4	38.8	3.9	113

* Sensitivities are forthcoming

** Present value of costs and benefits were calculated using a 3% discount rate.

*** Total costs and benefits do not include various non-monetized values (e.g. mercury pollution reduction, increased productivity, water quality impacts, etc.).

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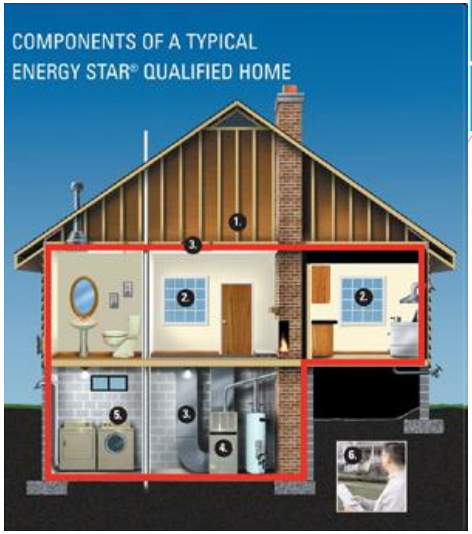
NEMS Modeling: Making Homes Part of the Climate Solution -- On-Bill Financing

Georgia Institute of Technology & Oak Ridge National Laboratory

April 5, 2011



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On-Bill Financing

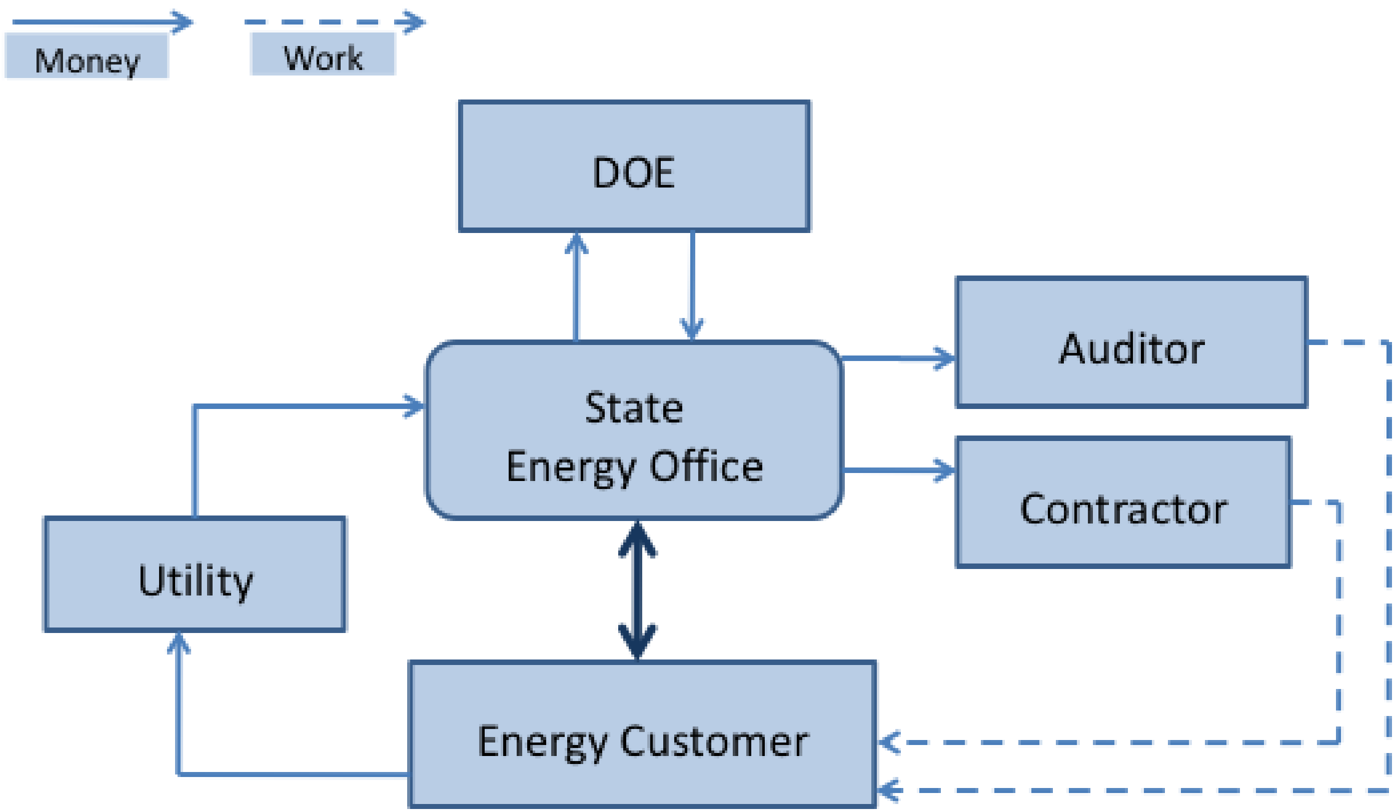
Recommended Federal Action: Provide financial assistance to State Energy Offices to establish revolving loan funds to enable on-bill utility financing of energy-efficiency improvements without up-front capital costs to the building owner.

- Addresses risk aversion by "mainstreaming" retrofit financing
- Overcomes the cash-flow barrier confronted by many homeowners and small businesses
- Loans are made by the utility company and are repaid by adding a charge to the utility bill
- A revolving loan fund could extend the positive impact of the State Energy Office funding by many years

Decision to Renovate

On-bill financing

- reduces the up front cost to the consumer
- returns funds to the system for re-use



On-Bill Financing Programs

- On-bill financing programs have two mechanisms: customer obligation and meter obligation
- More on-bill financing programs are available for small businesses than for residential customers
- On-bill financing programs usually offer zero interest loans to small businesses
- The interest rates of on-bill financing programs range from 0-7%
- The payback time ranges from 2 – 10 years

NEMS Modeling Methodology

Lever	Method	Location
Adding loan option for appliance capital costs	The current NEMS capital costs for appliances are up-front costs. By changes the lifecycle cost equation, the option for loans will be available for efficient equipment.	Residential source code
Adjusting interest rates and payback time for loan options	Three levels of interest rates were tested: 0%, 5% and 7%; three levels of payback time were tested: 5 year, 7 year and 10 year.	Residential input file: rtekty

- Sensitivities Conducted
  - Various options for interest rate and payback periods were tested for on-bill financing policy
  - The effects of offering Energy Star equipment through on-bill financing were examined
    - Expands the coverage of on-bill financing from the most efficient appliances to Energy Star appliances which satisfy the current Energy Star efficiency requirements

Policy Specific Assumptions & Methodology

- The source code equation for calculating the lifecycle costs for appliances was modified to allow loan options.
- Administration cost assumed to be $0.13/MBtu saved
- Public investment is the cost for providing the seed money for low interest loans
  - annual cost for the public equals the seed money for new loan applications generated each year minus the money paid back from existing borrowers
- The avoided damages of criteria air pollutants associated with on-bill financing policy is calculated based on the estimated damages of NO_x, SO_2, PMs from electricity generation and natural gas for spacing heating in the residential sector.

Projected Energy Savings in 2035 (Trillion Btu)

- On-bill financing option available for the most efficient appliances.
- Highest energy savings are associated with zero interest and 10-year payback time.

Interest rate	Total Energy Savings (Trillion Btu)		
	Payback time 5 years	Payback time 7 years	Payback time 10 years
0%	70 (0.3%)	240 (1.0%)	420 (1.8%)
5%	30 (0.1%)	130 (0.5%)	280 (1.2%)
7%	20 (0.1%)	100 (0.4%)	230 (1.0%)

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On Bill Financing from the Residents' Perspective: Savings Exceed Costs

Year	BAU Energy Consumption*	Annual Energy Savings			Cumulative Energy Savings		Annual Private Cost	Cumulative Private Cost
	Trillion Btu	Trillion Btu	$M (2008)	%	Trillion Btu	$M (2008)	$M (2008)	$M (2008)
2011	21,610							
2020	22,040	54	623	0.24	304	4,425	309	3,419
2035	23,890	128	570	0.54	1,705	13,772	186	7,082
2055	--	--	--	--	2,924	17,302		7,082

* Present value of costs and benefits were calculated using a 7% discount rate.
** Reference case residential energy consumption
***Investments stimulated from the policy occur through 2035. Energy savings are then modeled to degrade at a rate of 5% after 2035, such that all benefits from the policy have ended by 2055.

On-Bill Financing(interest rate = 5%, payback time = 7 year)

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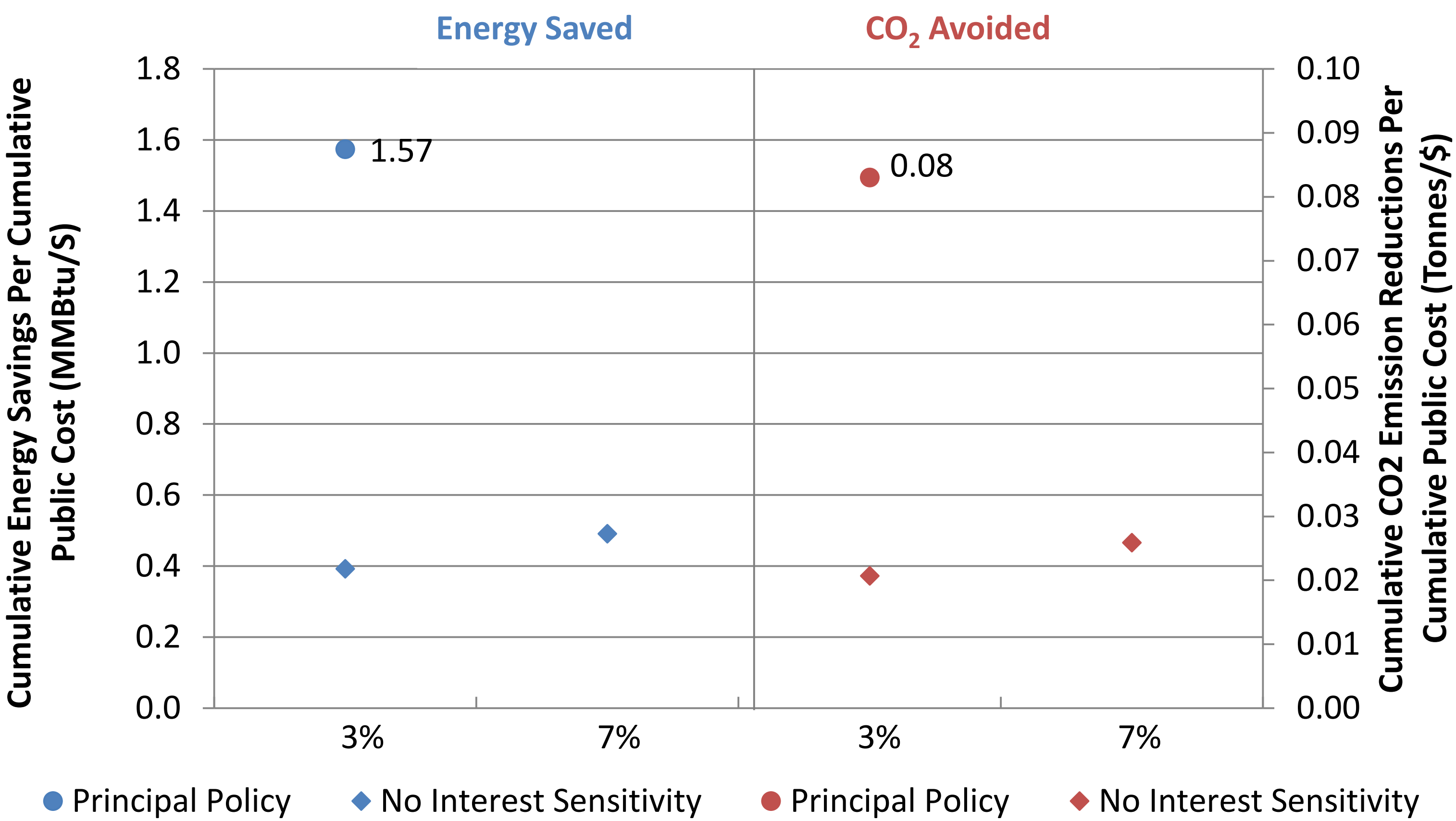
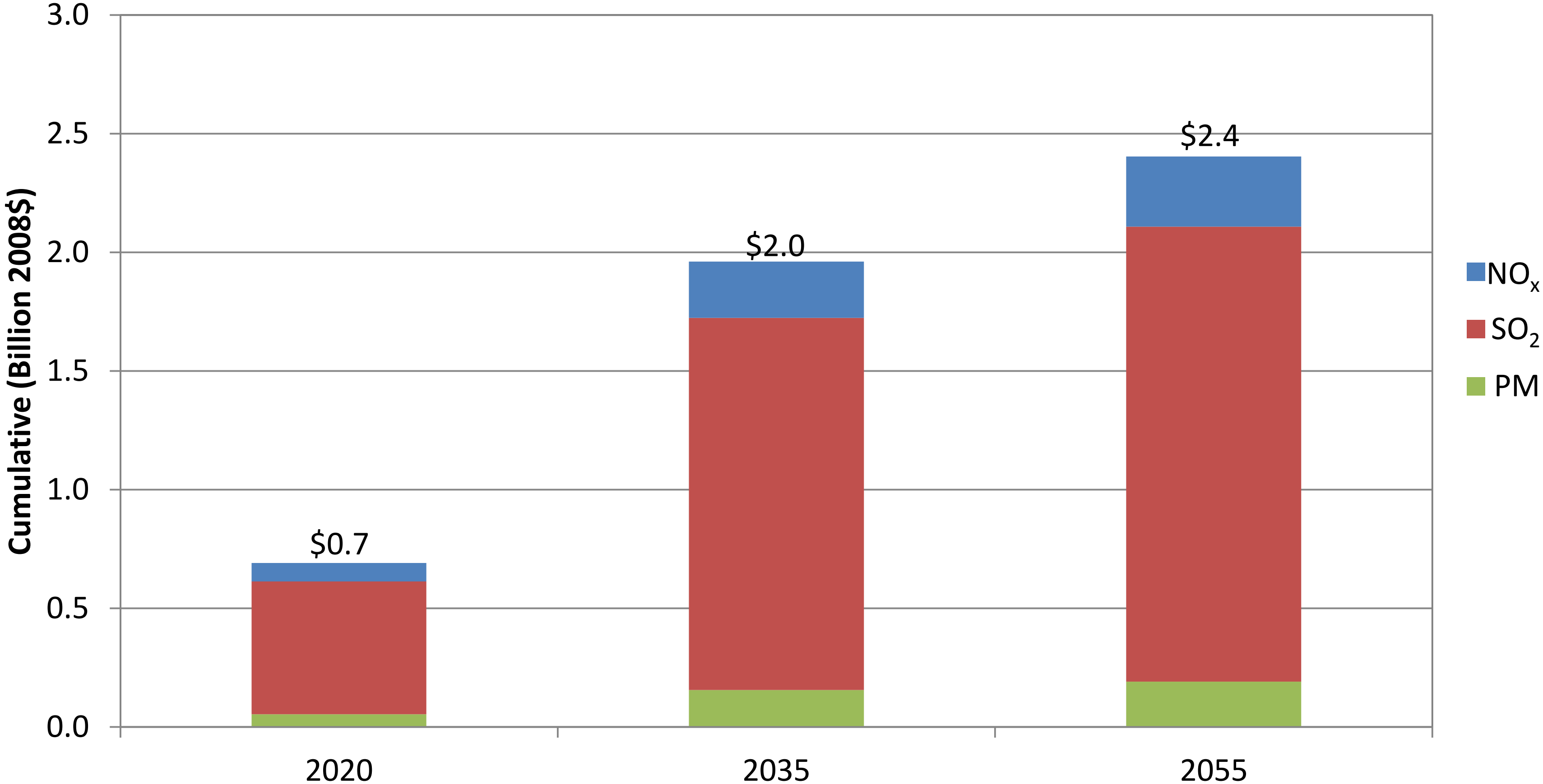
Leveraging Ratios for On-Bill Financing



Note: It costs the public $0.64 for each MMBtu energy saved from the National Building Code policy. The cost effectiveness for the National Building Code policy for carbon abatement is $12.0/ton. Comparatively, the estimated damages from CO_2 emissions are projected to be $34/ton (EPA, 2010).

On-Bill Financing(interest rate = 5%, payback time = 7 year)

Value of Avoided Damages from Criteria Pollutant Emissions* (Billions $2008)



* Assumes no new environmental regulations, but does include the Clean Air Interstate Rule limiting NO_x and SO_2 in 28 states.

** On-bill Financing has significant natural gas savings (49 TBtu in 2035) in the residential sector.

On-Bill Financing(interest rate = 5%, payback time = 7 year)

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Benefit/Cost Results are Highly Favorable

	Cumulative Social Benefits* (Billions $2008)				Cumulative Social Costs* (Billions $2008)				
Year	Energy Savings	Value of Avoided CO_2	Value of Avoided Criteria Pollutants	Total Social Benefits**	Public Costs	Private Costs	Total Social Costs**	Social B/C Ratio	Net Societal Benefits (Billions $2008)
2020	5.5	0.35	0.9	6.7	1.4	4.1	5.4		
2035	23.5	1.80	3.3	28.6	1.9	11.0	12.9		
2055	34.6	2.87	4.7	42.1	1.9	11.0	12.9	3.3	29

* Present value of costs and benefits were calculated using a 3% discount rate.

** Total costs and benefits do not include various non-monetized values (e.g. mercury pollution reduction, increased productivity, water quality impacts, etc.).

On-Bill Financing(interest rate = 5%, payback time = 7 year)

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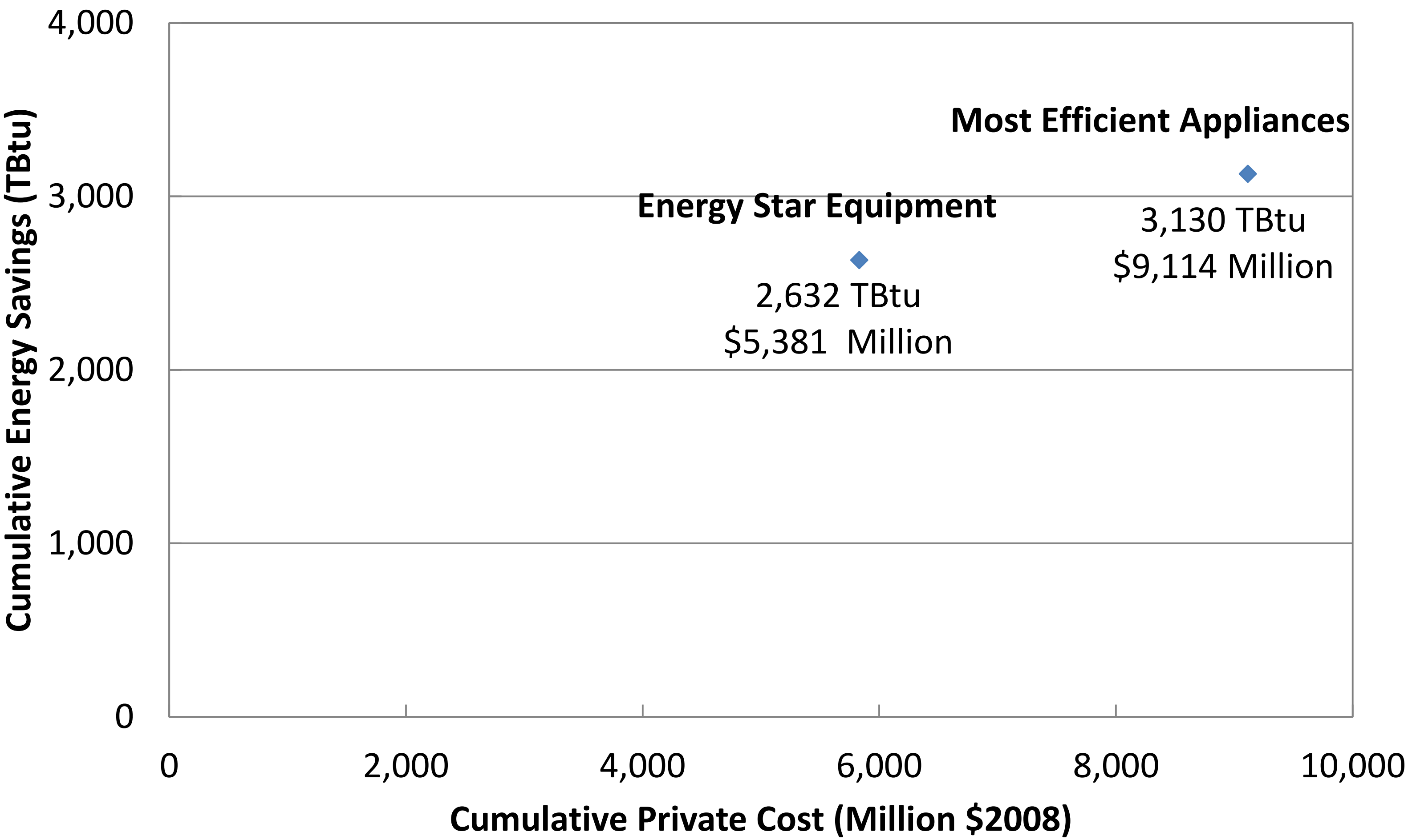
On-Bill Financing for Energy Star Equipment: Lower Cost, Lower Energy Savings



On-Bill Financing(interest rate = 5%, payback time = 7 year)

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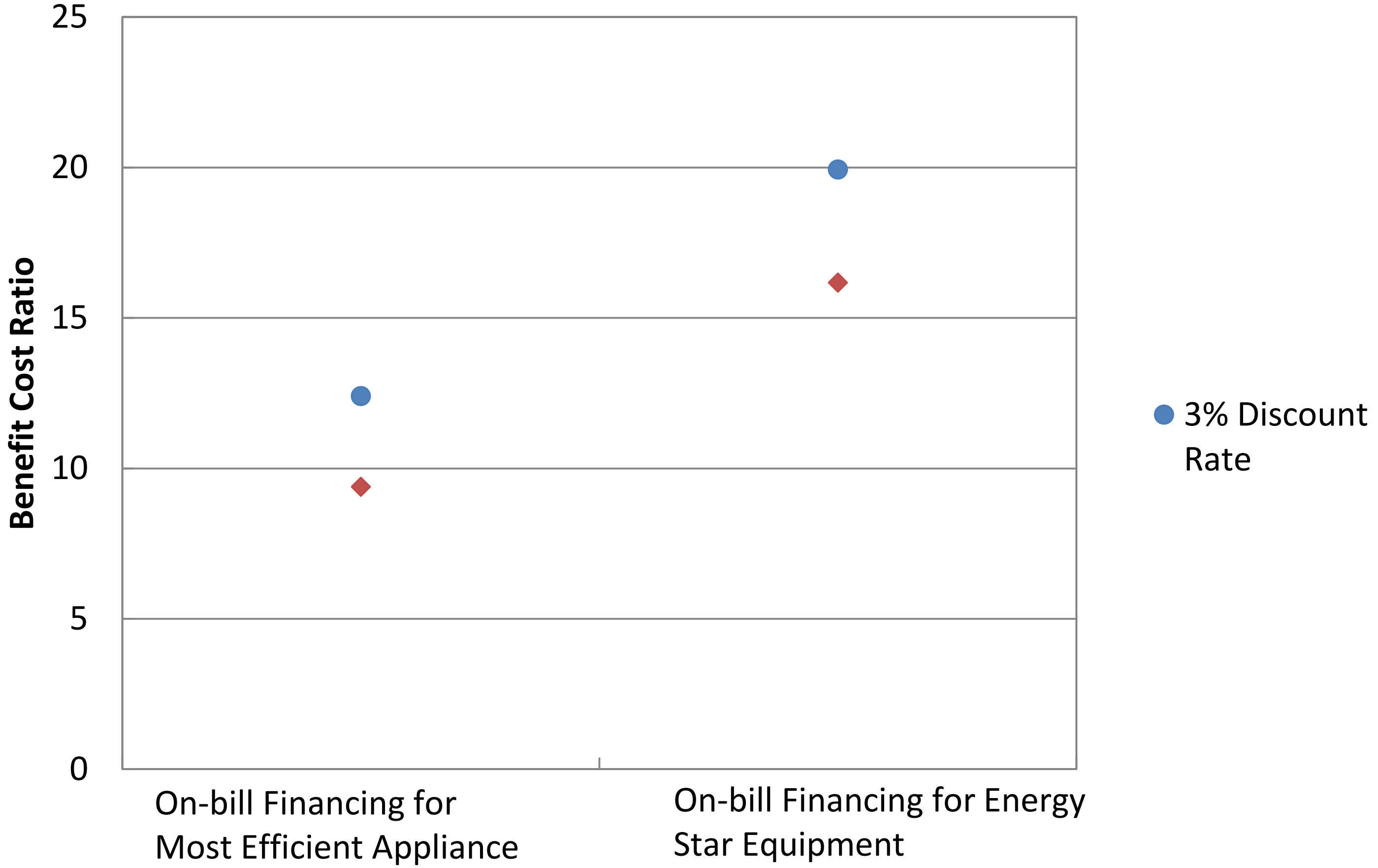
On-Bill Financing for Energy Star Equipment: Higher B/C Ratios



On-Bill Financing(interest rate = 5%, payback time = 7 year)

Appendix A. On-bill Financing Programs

	Utility	State	Sector	Interest rate	Max Payback Time	Rebate and Incentives
Customer obligation	Southern Califonia Gas Company	CA	Institutional	0	10	varies
			Non-institutional	0	5	
	SDGE, Sempra Energy	CA	Institutional/business	0	5	~26.7%
	United Illuminating	CT	Small business	0	3	30-40%
	Midwest Energy's How$Smart program	Kansas	Residential	5.05	15	
			Commercial	6.6	10	
	Pacific Gas & Electric	CA	Non-residential	0	5	
	Southern Califonia Edison	CA	Institutional	0	10	
			Business	0	5	
	National Grid	MA, RI, NH	Business	0	2	40-70%
	Connecticut Light & Power	CT	Small business	0	3	
	First Electric Cooperative	AK	Residential	5.5	5	
	Southwest Arkansas Electric	AL	Residential	5	7	
	Northern Plains EC	North Dakota	Residential / commercial	5	7	
	Maui electric company	Hi	Residential	0	8	35% state tax credit
	Manitoba Hydro	Manitoba, Ca	Residential	6.5	5	
Meter obligation	Hawaiian Electric Company; Maui electric company; Hawaiian Electric Light Company	HI	Residential	0	-	
	Midwest Energy	KS	Residential	4	15	
			Commercial	7.25	10	
	New Hampshire Electric Cooperative	NH	Residential	-	5	

Appendix B. NEMS Source Code Changes – Allowing On-Bill Financing Option for Capital Cost

$$LFCY_{y,es,b,r,v} = CAPITAL_{es} + OPCOST_{y,es,b,r,v} * \left(\frac{1-(1+DIST)^{-HORIZON}}{DIST}\right)$$

Now the lifecycle equation has been changed to:

$$LFCY_{y,es,b,r,v} = (ANNUALPAY_{es} + OPCOST_{y,es,b,r,v}) * \left(\frac{1-(1+DIST)^{-HORIZON}}{DIST}\right)$$

where

$$ANNUALPAY = \frac{CAPITAL}{CAPHOR}$$

When interest rate equals to 0%:

$$ANNUALPAY = CAPITAL * \frac{CAPDISRT}{1-(1+CAPDISRT)^{-CAPHOR}}$$

When interest rate is greater than 0%

- Where LFCYCLE: the lifecycle costs for appliances
  CAPITAL: the capital costs for appliances
  OPCOST: the operational costs for appliances
  DIST: the discount rate for the operational cost during the life time of the appliances
  HORIZON: the life time of the applicances
  ANNUALPAY: the annual payment for on-bill financing equipment
  CAPHOR: the payback time
  CAPDIST: the interest rate

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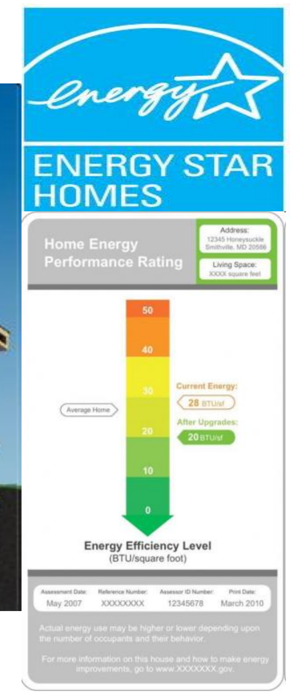
NEMS Modeling: Making Homes Part of the Climate Solution -- Smart Meters

Georgia Institute of Technology

&

Oak Ridge National Laboratory

April 5, 2011



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Smart Meters with Dynamic Pricing

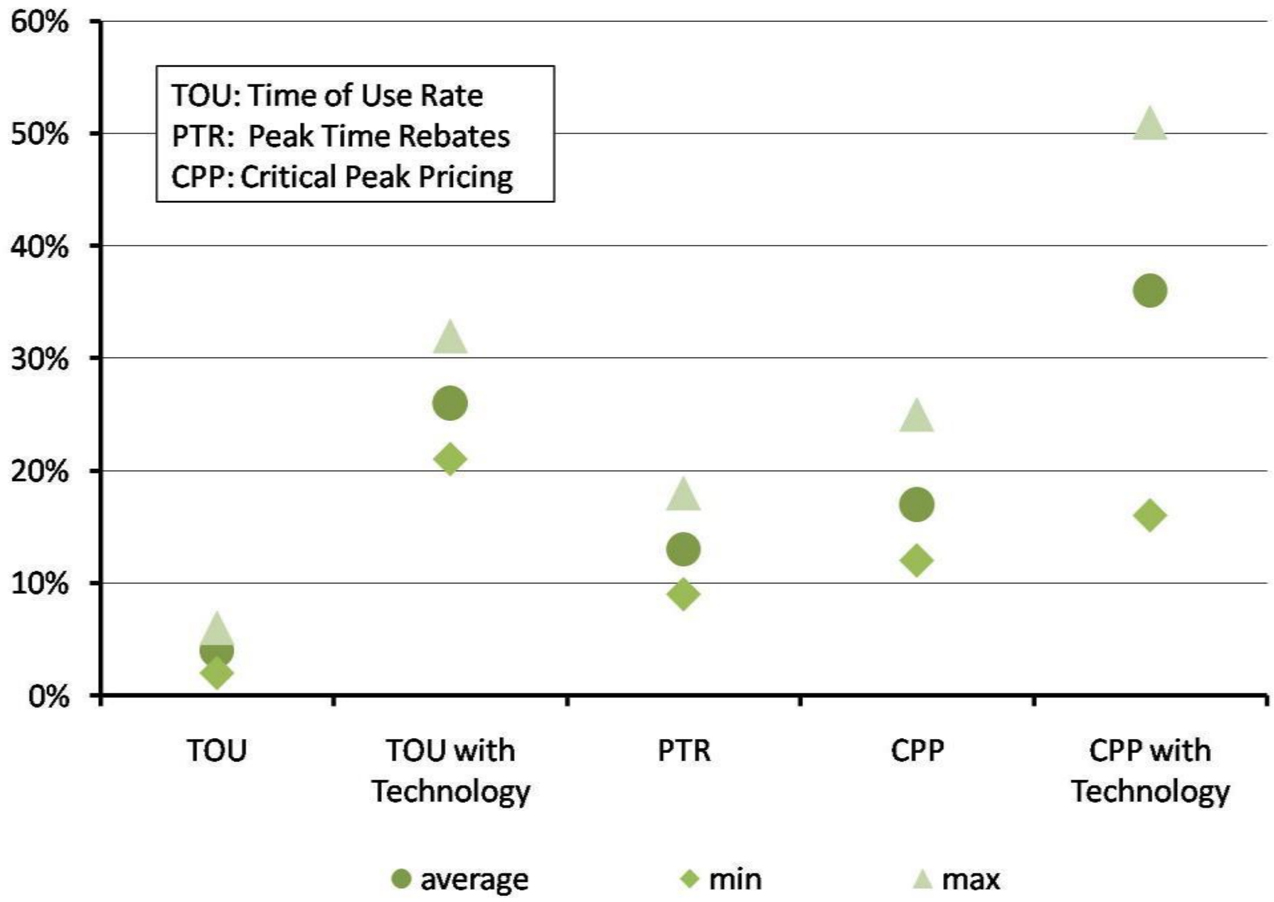
Recommended Federal Action: Provide technical and financial assistance to States and utilities to provide for expanded demand response of residential electric loads through smart metering technologies and dynamic pricing schemes.

- Relates actions to energy use and cost by providing real-time feedback to consumers.
- Creates savings immediately following implementation.
- Reduces peak load – avoiding the construction of new plants.

Picture from: http://www.ecobee.com/product/smart-overview/

Everyday Decisions

- Policy to Link Actions with Outcomes: Smart Meters with Dynamic Pricing



Source: Brown, et al., 2009, *Making Homes Part of the Climate Solution*

Information Can Reduce Energy Consumption and Rebound Effect

- Information has been shown to reduce energy consumption
  - Experiments: Savings range from 3.5 - 22% [1]
- Information framing affects energy use [2]
  - Consumption information
    - Decreases energy consumption, generally
    - If average consumption provided →lowest consumers may increase use.[3]
  - Social Norms
    - Removes “boomerang effect” [3]
    - Consumer believes norms are least influential in their decisions, but actually influential in achieving energy conservation[4]

- Experimental results with information and smart meters suggest:
  - Rebound effect already occurred
    - Information provided only, no new equipment added
  - Consumers unaware of it or its magnitude
- Suggests energy consumption information can decrease rebound effect

1. Sudarshan, 2010; Peterson, 2010; Houde, 2010; Hodge, 2010; Frader, 2010; Hodge, 2010; Amann, 2010
2. Lindenberg & Steg, 2007
3. Schultz, et al. 2007
4. Nolan, et al., 2008

Two Levers were Pursued in NEMS.

Lever	Reason	Location
Increase price elasticity of demand	Consumer price elasticity increases with greater price information (Gaudin, 2006).	Residential source code
Decrease rebound effect	Instant feed-back on energy use will likely moderate the rebound effect.	Residential source code

- Sensitivity Analysis
  - Three different rebound effects were tested
    - 75%, 50%, and 25% of reference case rebound effect
  - Three difference price elasticities were tested
    - Added -0.15, -0.25, and -0.35 to base price elasticity values of -0.15 and -0.30
  - All 9 combinations tested with reference case prices, a 10% electricity price escalation from 2012-2035, and a 10% electricity price escalation from 2012-2017.
  - Total combination of 27 different sensitivity runs for price elasticity and rebound effect variations were examined
  - Rates of full smart meter uptake by households varied from 5 years to 10 years

Policy Specific Methodology

- NEMS source code changed to accommodate both levers
  - Price elasticity source code changes
    - New equation: $ALPHA_{new}$ = $ALPHA_{old}$ + RTPALPHA
      - Where RTPALPHA = user defined value for price elasticity increase in rtekcl file
    - Retains increase in price elasticity included in AEO 2010 (-0.15 to -0.30 for some end-uses given stimulus)

  - New Rebound Effect Equation for $RB_{y,eg,b,r}$ >1:

$$Revised\ RB_{y,eg,b,r} = \left(RB_{y,eg,b,r} - 1\right) * \beta + 1$$

where

- $Revised\ RB_{y,eg,b,r}$ is the scenario rebound effect
- $RB_{y,eg,b,r}$ is the reference case rebound effect
- β is the scaling factor (<1)
  - Ex. β = 0.25 → new rebound effect is 75% less than original

Policy Specific Assumptions

- Households are the single family (SFH) and multi-family households (MFH) projected by AEO 2010.
- After 5 years, all SFH and MFH have installed smart meters.
- Only new households each year require smart meters to be installed thereafter.
- Private cost for smart meter implementation is $500 per meter per home.
  - Can be paid over 10 years with 7% discount rate.
  - 5% cost reduction each year in cost
- No administration cost
- Public costs of $10 million investment per year into the Regulatory Assistance Project for the first 10 years to provide dynamic pricing assistance.

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Smart Meters and Dynamic Pricing from the Residents' Perspective*

Year	BAU Energy Consumption **	Annual Energy Savings			Cumulative Energy Savings***		Annual Private Cost	Cumulative Private Cost
	Trillion Btu	Trillion Btu	$M (2008)	%	Trillion Btu	$M (2008)	$M (2008)	$M (2008)
2012	21,611							
2020	22,032	-28.9	1,811	-0.13	-652	4,511	64.6	43,735
2035	23,915	317	9,416	1.33	1,393	29,385	42.2	60,973
2055	--	--	--	--	4,406	41,678		60,973

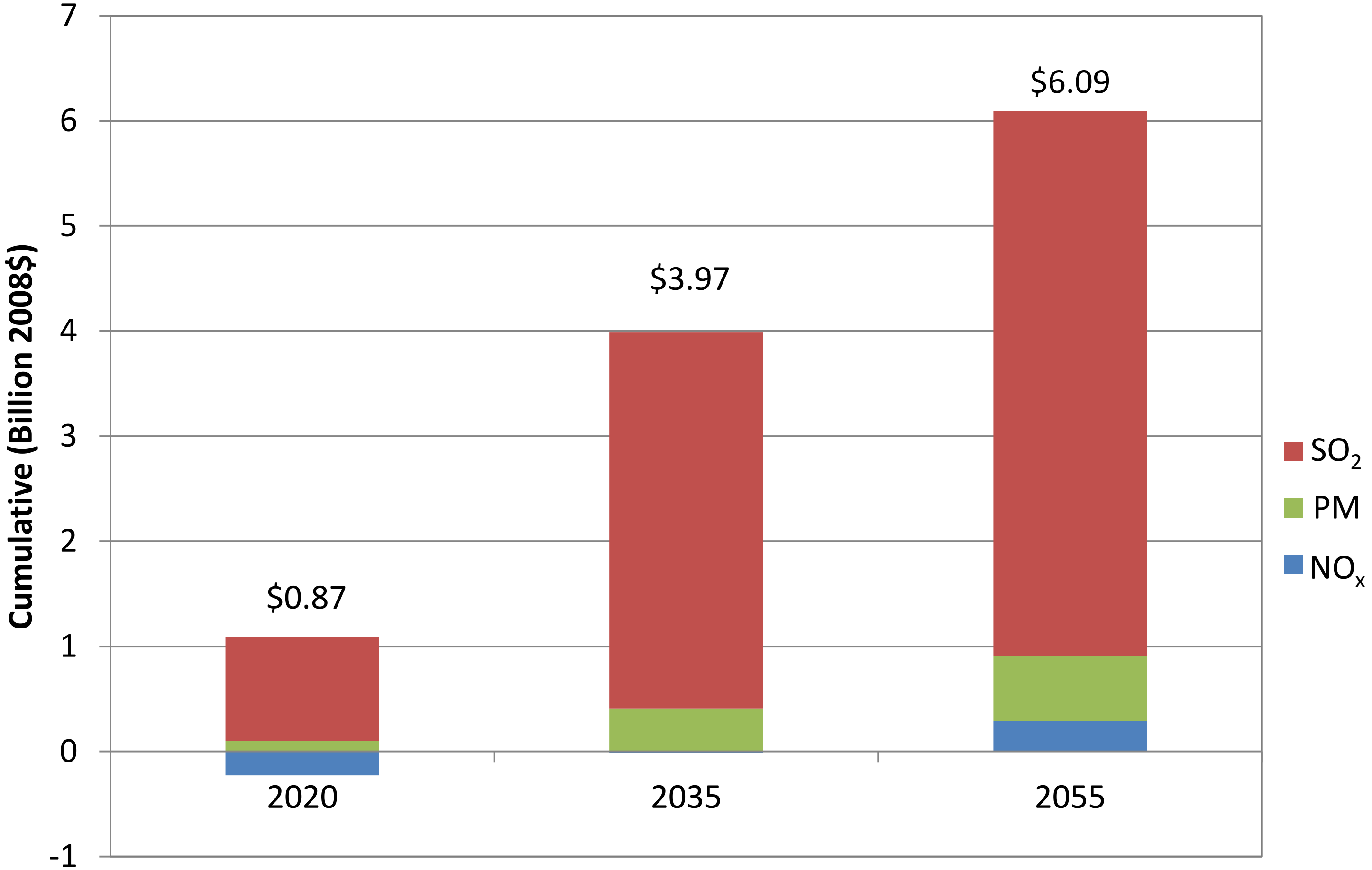
* Present value of costs and benefits were calculated using a 7% discount rate.
** Reference case residential energy consumption
***Investments stimulated from the policy occur through 2035. Energy savings are then modeled to degrade at a rate of 5% after 2035, such that all benefits from the policy have ended by 2055.

Note: For sensitivity with 50% rebound effect reduction and -0.25 added price elasticity.

Energy Savings and Cost by Households

Description	2012	2020	2035
Annual number of new homes served (million)	23.49	1.41	1.07
% of Total SFH and MFH Housing stock	21.2%	1.16%	0.77%
Annual average total energy savings per home (MBtu/home)	-4.56	-20.5	296
Annual private cost per home ($/home)	$74	$93	$61
Annual public cost per added home ($/home)	$0.43	$7.09	$0

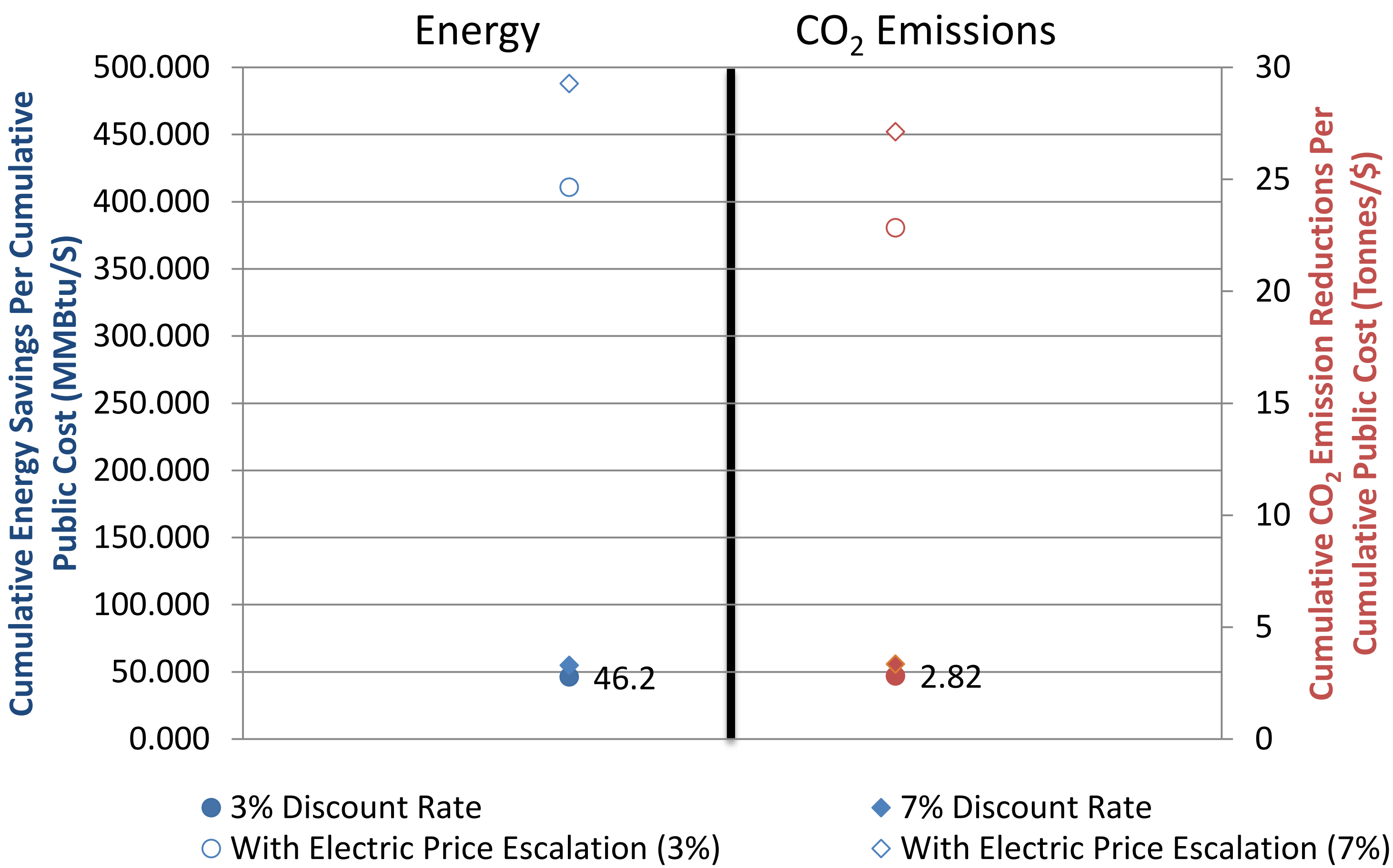
Value of Avoided Damages from Criteria Pollutant Emissions*



Note: For sensitivity with 50% rebound effect reduction and -0.25 added price elasticity.

* Assumes no new environmental regulations, but does include the Clean Air Interstate Rule limiting NO_x and SO_2 in 28 states.

Leverage Ratios Change Substantially with 10% Electric Price Escalation from 2012-2035.



Note: It costs the public $0.02 for each MMBtu of energy saved from the Smarter Meters with Dynamic Pricing policy option at 3% discount rate. The cost effectiveness for the policy option for carbon abatement is $0.35/ton. Comparatively, the estimated damages from CO_2 emissions are projected to be $34/ton (EPA, 2010).

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Benefit/Cost Results are Favorable

	Cumulative Social Benefits* (Billions $2008)				Cumulative Social Costs* (Billions $2008)			Benefit/Cost Analysis	
Year	Energy Savings	Value of Avoided CO_2	Value of Avoided Criteria Pollutants	Total Social Benefits**	Public Costs	Private Costs	Total Social Costs**	Social B/C Ratio	Net Societal Benefits (Billions $2008)
2020	5.78	-0.66	0.86	5.98	0.08	52.35	52.43		
2035	53.2	1.86	3.97	59.05	0.10	78.80	78.90		
2055	90.4	4.81	6.09	101.30	0.10	78.80	78.90	1.3	22.4

* Present value of costs and benefits were calculated using a 3% discount rate.

***Total costs and benefits do not include various non-monetized values (e.g. mercury pollution reduction, increased productivity, water quality impacts, etc.)*

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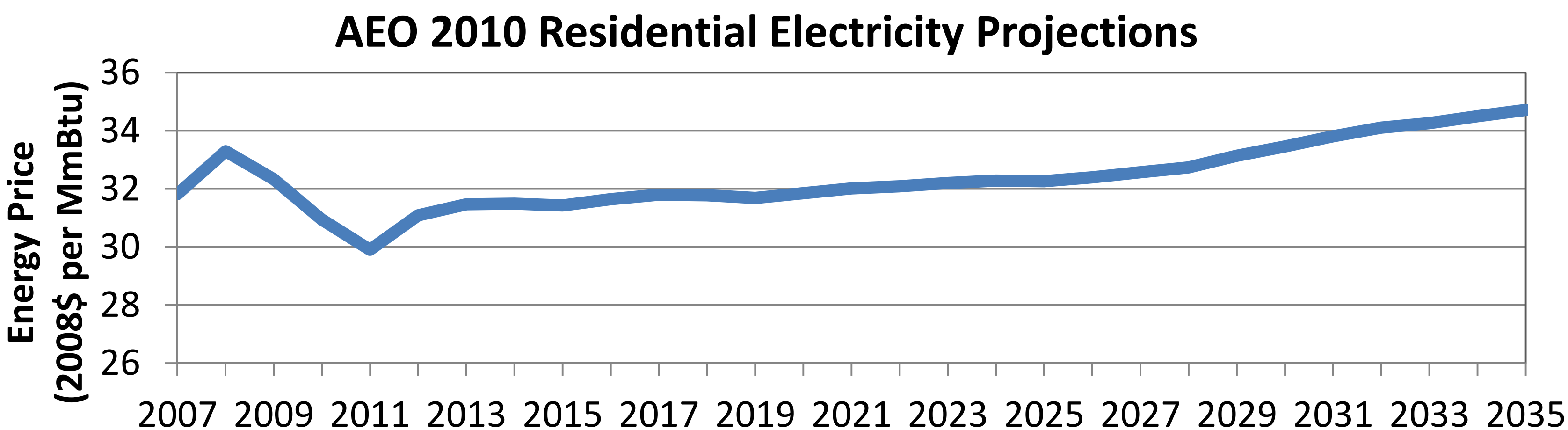
Variable Impact of Price Elasticity and Rebound Effect

Percentage of Total Energy Savings of Baseline - No Price Escalation							
		2020			2035		
		Price Elasticity Change			Price Elasticity Change		
		-0.15	**-0.25**	**-0.35**	**-0.15**	**-0.25**	**-0.35**
% RE Used	**75%**	-0.14%	-0.36%	-0.59%	0.71%	1.00%	1.34%
	50%	0.05%	-0.09%	-0.27%	0.96%	1.34%	1.71%
	25%	0.23%	0.14%	0.00%	1.21%	1.63%	2.05%



Uncertain Future of Electricity Price

- EIA does not usually include policies until promulgated.
- Therefore, a future with higher electricity prices due to potential legislation is not considered.
- Two sensitivities with a 10% electricity price escalation were conducted.
  - Period 1: From 2012-2017
  - Period 2: From 2012-2035

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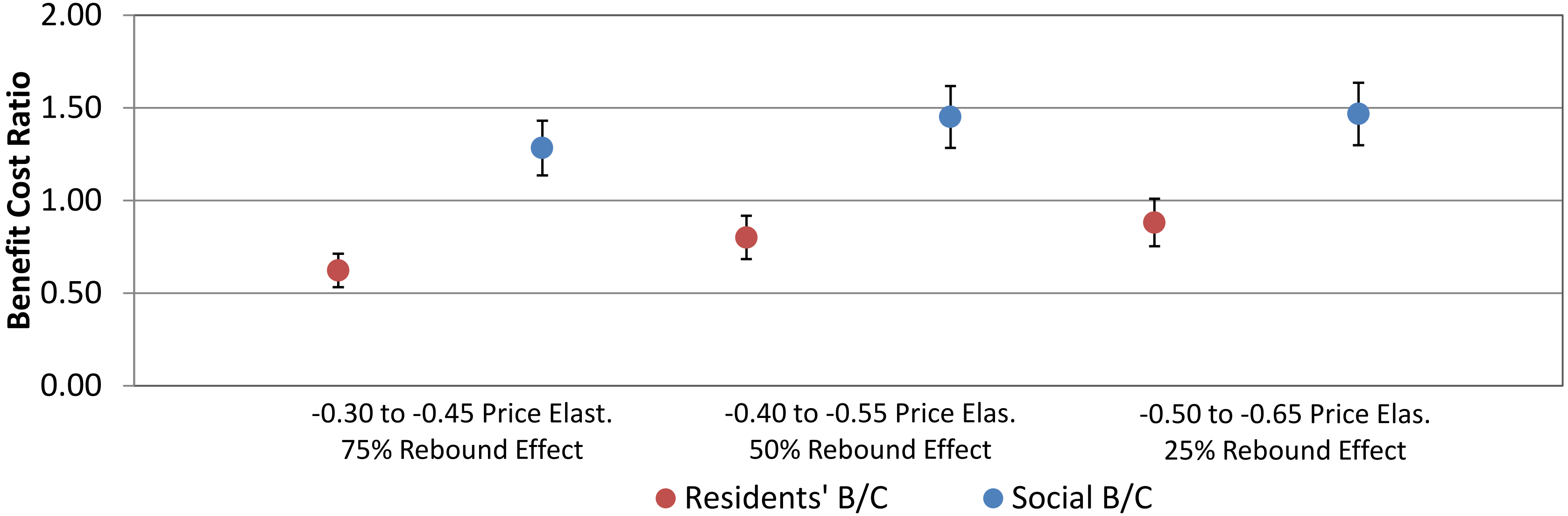
Predicted Savings Increase with Higher Electricity Prices

Percentage of Total Energy Savings of Baseline 10% Electricity Price Escalation from 2012-2017							
		2020			2035		
		Price Elasticity Change			Price Elasticity Change		
		-0.15	-0.25	-0.35	-0.15	-0.25	-0.35
% RE Used	75%	0.14%	-0.05%	-0.27%	0.92%	1.25%	1.55%
	50%	0.36%	0.18%	0.05%	1.17%	1.55%	1.92%
	25%	0.54%	0.45%	0.32%	1.42%	1.84%	2.30%

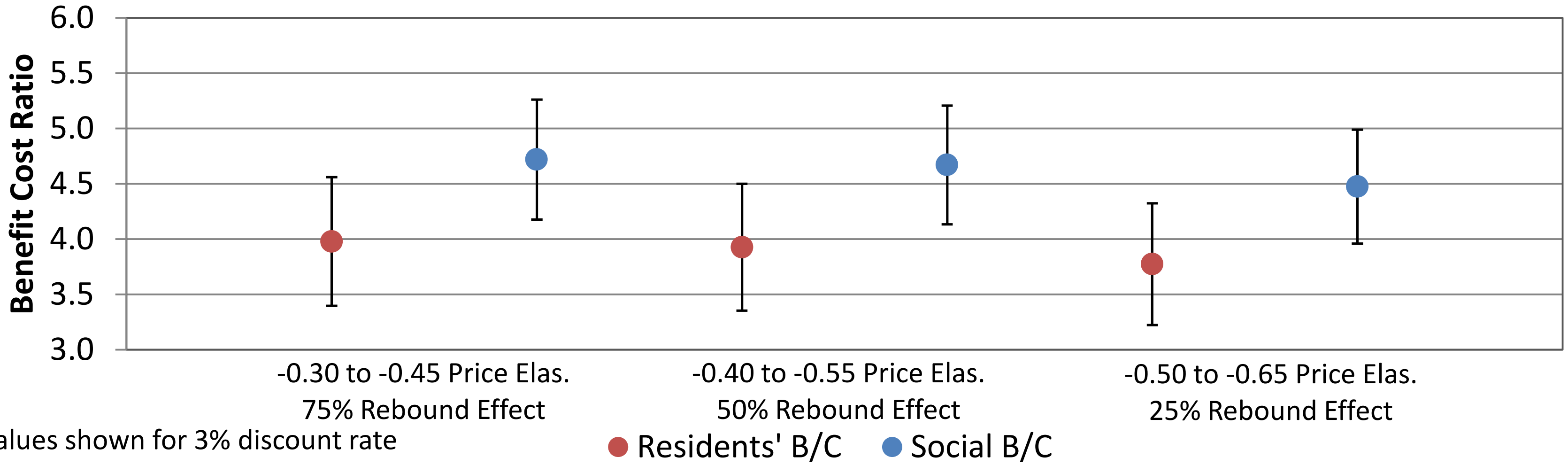
Percentage of Total Energy Savings of Baseline 10% Electricity Price Escalation from 2012-2045							
		2020			2035		
		Price Elasticity Change			Price Elasticity Change		
		-0.15	-0.25	-0.35	-0.15	-0.25	-0.35
% RE Used	75%	3.94%	4.12%	4.26%	5.18%	5.85%	6.48%
	50%	4.12%	4.35%	4.53%	5.43%	6.14%	6.85%
	25%	4.30%	4.58%	4.85%	5.68%	6.44%	7.19%

A 10% Price Escalation Increases the Realized Benefit-Cost Ratios

B/C Ratio without Price Escalation



B/C Ratio with Price Escalation from 2012-2017



Note: Values shown for 3% discount rate

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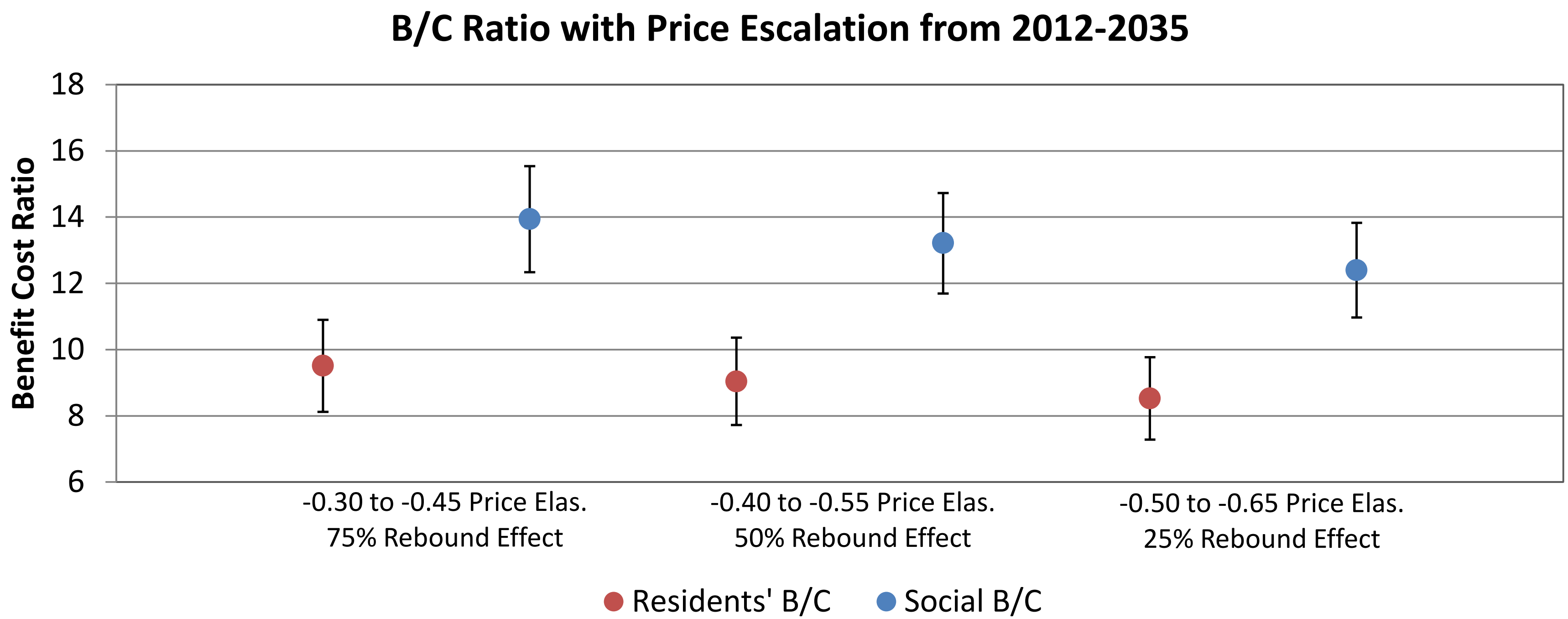
A 10% Price Escalation from 2012-2035 Significantly Increases the Realized Benefit-Cost Ratios



Note: Values shown for 3% discount rate

Appendix 1. NEMS Source Code– Rebound Effect Defined

- General Rebound Effect Equation:

$$RB_{y,eg,b,r} = (WTEQCEFFR_{y,eg,b,r} * RTBASEFF_{2005,eg})^{\alpha_1}$$

where:

- $RB_{y,eg,b,r}$ is the rebound effect by year, equipment class, building type, and region
- $WTEQCEFFR_{y,eg,b,r}$ is the replacement equipment efficiency weighted by market share of from technology choice
- $RTBASEFF_{2005,eg}$ is the efficiency of the weighted average of retiring units from 2005 existing
- α_1 is the short term price elasticity of energy demand (rebound effect elasticity), valued at -

- Equation for three rebound effects:
  - surviving equipment (RBA)
  - replacement equipment (RBR)
  - new equipment (RBN)

Appendix 2. Rebound Effect used in Consumption Calculations.

$$HTRCON_{y,f,r} =$$

$$\sum_{b}\sum_{eg}\left[\begin{pmatrix} EQCESE_{y,eg,b,r} * ECQCUEC_{eg,b,r} * EHSHELL_{y,f,r,b} \\ + EQCADD_{y,eg,b,r} * EQCNUEC_{y,eg,b,r} * NHSHELL_{y,f,r,b} * RBN_{y,eg,b,r} \\ + EQCRP90_{y,eg,b,r} * EQCRUEC_{y,eg,b,r} * EHSHELL_{y,f,r,b} * RBR_{y,eg,b,r} \\ + EQCRP90RP_{y,eg,b,r} * EQCNUEC_{y,eg,b,r} * EHSHELL_{y,f,r,b} * RBN_{y,eg,b,r} \\ + EQCSR90_{y,eg,b,r} * EQCAUEC_{y,eg,b,r} * EHSHELL_{y,f,r,b} * RBA_{y,eg,b,r} \\ + EQCREP_{y,eg,b,r} * EQCNUEC_{y,eg,b,r} * AHSHELL_{y,f,r,b} * RBN_{y,eg,b,r} \\ + EQCSUR_{y,eg,b,r} * EQCAUEC_{y,eg,b,r} * AHSHELL_{y,f,r,b} * RBA_{y,eg,b,r} \end{pmatrix} * RSELAST(f,r,\alpha,EF1,EF2,EF3,2005)\right] \quad \text{(B-49)}$$

where

$HTRCON_{y,f,r}$	is heating energy consumption by year, fuel type, and region
RSELAST	is short-term price elasticity function with distributed lag weights Efi and alpha (SR price elasticity)
$EQCESE_{2005,eg,b,r}$	is pre-2006 vintage stock of equipment in pre-2006 vintage houses in 2005 by housing type and CDIV
$EQCADD_{y,t,eg,b,r}$	is number of post-2005 vintage equipment units added to new houses in year y, vintaged to year t, by housing type and CDIV
$EQCRP90_{y,t,eg,b,r}$	is number of replacement units required for pre-2006 homes in year y, vintaged to year t by housing type and CDIV
$EQCRP90RP_{y,t,eg,b,r}$	is number of replacement units required to replace post-2005 equipment in pre-2006 houses by forecast year, housing type, and CDIV
$EQCREP_{y,t,eg,b,r}$	is number of equipment replacements of post-2005 equipment in post-2005 houses
$EQCSUR_{y,eg,b,r}$	is surviving post-2005 equipment purchased as additions/replacements in post-2005 houses by housing type and CDIV

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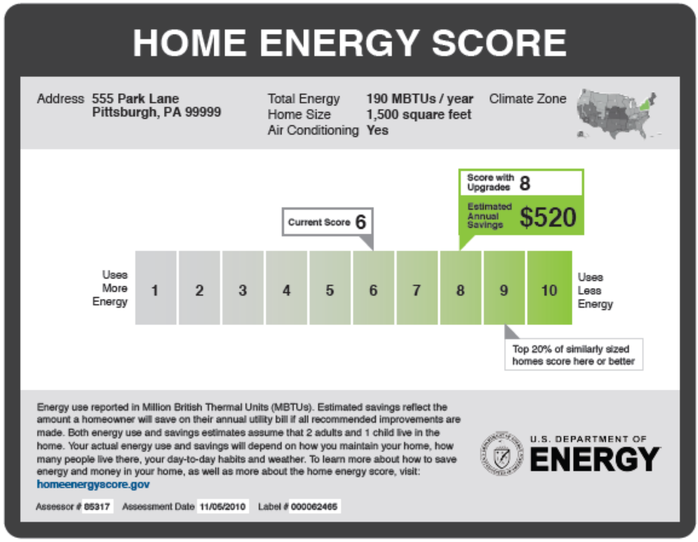
Mandated Disclosure with Building Energy Performance Ratings

Recommended Federal Action: Require disclosure of home energy consumption or home energy performance at the point of sale or lease of a residential unit.

- Promotes accounting of energy efficiency of a residential unit in selling or rental price
  - A premium is realized at time of sale for energy efficient homes.
    - In the ACT, every star improvement in home rating increased expected sales price by ~3% (NFEE, 2008).
    - For every dollar saved in fuel costs, an additional $10-$25 of added home value occurs at time of sale (Nevin & Watson, 1998).
  - Though little on residential rental units, rental and sales prices for energy efficient commercial buildings are higher than traditional buildings (Cooperman et al., 2010).



Picture from: http://www.eere.energy.gov/pdfs/homeenergyscore.pdf

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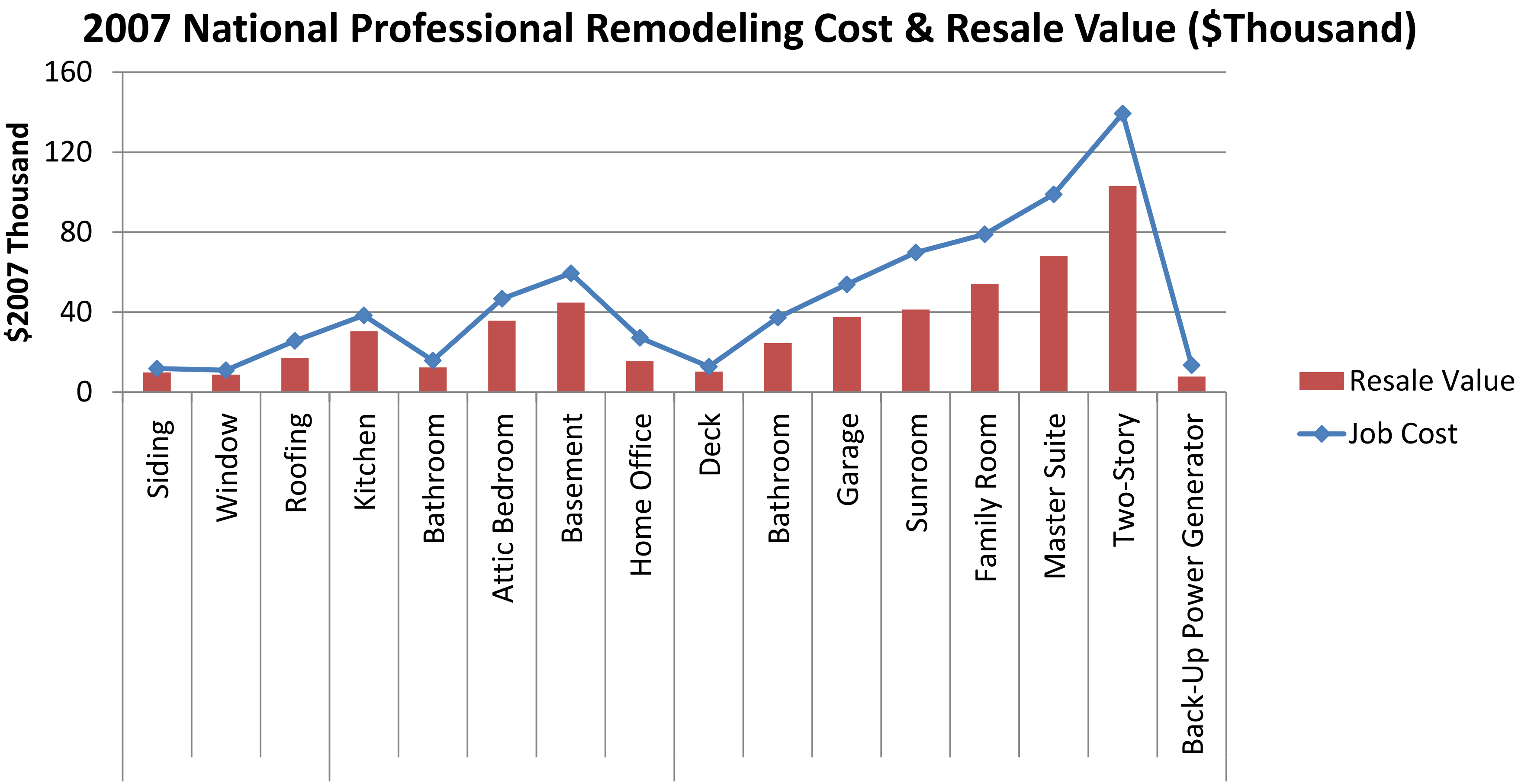
Home Equity Improvement with Remodeling and Energy Retrofits

- 71.4% of the renovation and retrofit costs can be recouped in resale value.



Source: U.S. DOE Buildings Technologies Program, October 2009. 2009 Buildings Energy Data Book, Table 2.6.4

Policy Specific Assumptions & Methodology

- NEMS levers of lower discount rate and longer times horizons for operating costs did not increase EE investments as expected.
- Spreadsheet assumptions:
  - Energy savings from Weatherization Assistance Program (WAP) for insulation and infiltration measures
    - Electric heated : 10.5% of pre-weatherized energy saved (Berry & Schweitzer, 2003)
    - Natural gas heated : 22.9% of pre-weatherized energy saved (Schweitzer, 2005)
  - WAP upper estimate for weatherization cost per home of $3,000 assumed (Schweitzer, 2005).
  - America's Energy Future cost curves used for equipment installation
    - Dishwasher, refrigeration, furnace fans, space cooling/heating, and water heating (AEF, 2009)
    - Only 50% energy savings assumed to be available due to overlap with WAP
  - Turnover rate for homes (US Census Bureau, 2011)
    - Single family: 4.25% for sale or rent per year, average from 2000-2010
    - Multi-family: 10.7% average vacancy rate for rentals with units > 5 from 2000-2010

Policy Specific Assumptions & Methodology

- Assumptions continued:
  - Diffusion curve assumed for implementation
    - 10 years for full adoption
    - Market penetration saturated at 50% of all eligible homes (WAP)/energy savings (AEF)
    - 5% of market penetration initially participate
  - 2 year lag between when energy efficiency measures installed and home sells for an equity premium
  - $10 equity premium for every $1 annual energy savings (NFEE, 2008; Nevin & Watson, 1998)
  - Administration cost of $0.065/MBtu energy saved
- Sensitivity conducted for:
  - Penetration (50% to 25%)
  - Weatherization cost per home ($3,000/home to $6,000/home)
  - Home equity premium ($10 to $1 home equity per $1 energy savings)

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Mandated Disclosure with Building Energy Performance Ratings from the Residents' Perspective*

Year	BAU Energy Consumption **	Annual Energy Savings			Cumulative Energy Savings***		Annual Home Equity Premium	Cumulative Savings & Benefit	Annual Private Cost Million $2008		Cumulative Private Cost
	Trillion Btu	Trillion Btu	$M (2008)	%	Trillion Btu	$M (2008)	$M (2008)	$M (2008)	Implementation Costs	Energy Rating Cost	$M (2008)
2012	21,611										
2020	22,032	459	5,299	2.08	1,760	23,124	17,111	68,388	8,496	809	37,897
2035	23,915	1,011	4,796	4.23	14,189	110,100	21,933	257,090	10,126	967	91,720
2055	--	--	--	--	20,688	131,979		287,540			91,720

* Present value of costs and benefits were calculated using a 7% discount rate.

** Reference case residential energy consumption

***Annual energy savings modeled to degrade at a rate of 5% for a 20 year life. All benefits from the policy end by 2055.

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Energy Savings and Costs by Households

Description	2012	2020	2035
Annual number of new homes served (million)	0.12	2.70	3.22
Total number of homes with energy savings(million)	0.12	15.6	57.4
% of Total SFH and MFH housing stock	0.11%	2.22%	2.31%
Average energy savings per home (MBtu/home)	35.8	29.4	17.6
Private cost per home (2008$/home)	$3,460	$3,451	$3,442
Public cost per home (2008$/home)	$2.33	$2.17	$2.03

Source: Spreadsheet calculations based from AEO 2010 Reference case projections for residential population, delivered energy consumption, and electricity related losses.

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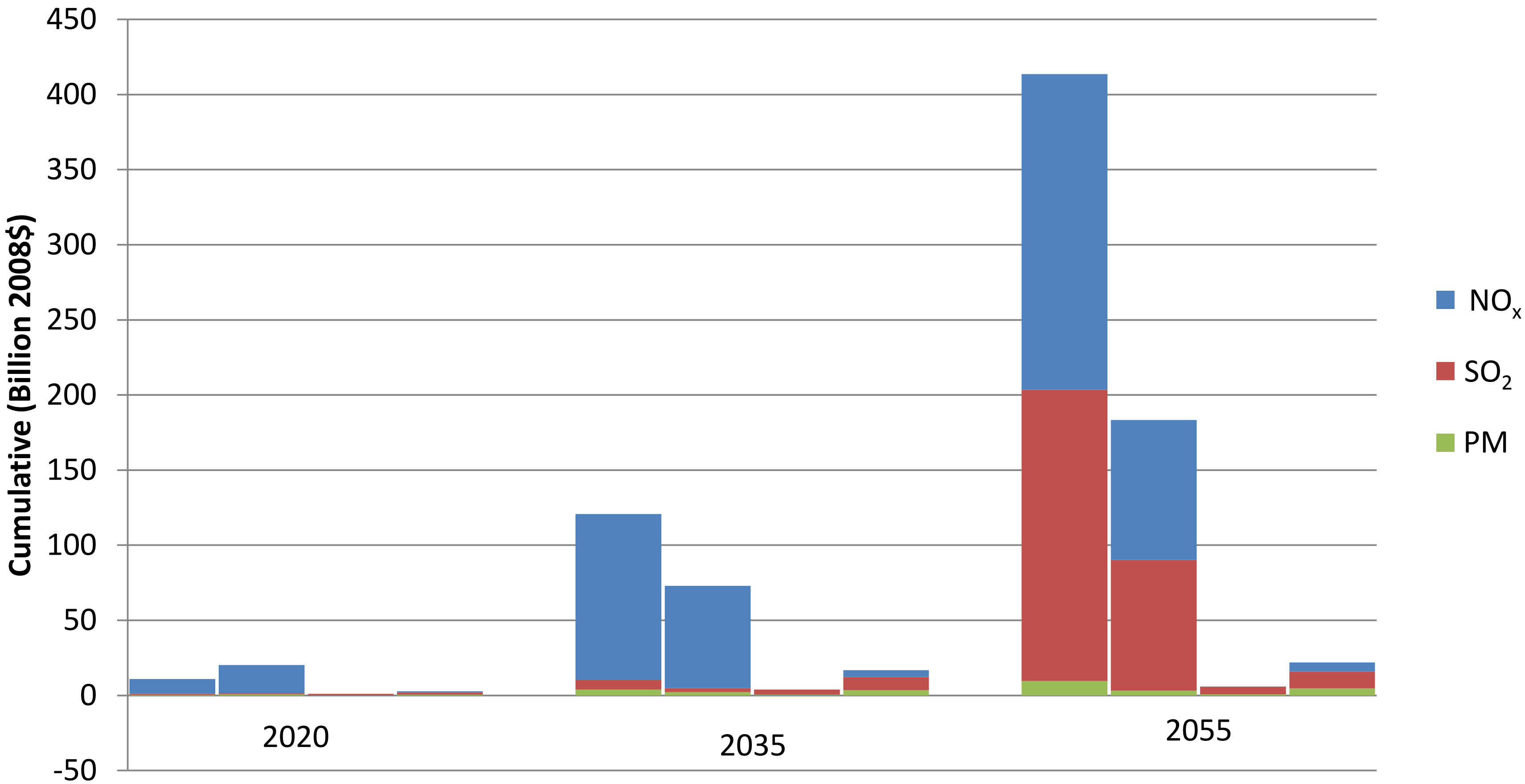
Value of Avoided Damages from Criteria Pollutant Emissions*



* Assumes no new environmental regulations, but does include the Clean Air Interstate Rule limiting NO_x and SO_2 in 28 states.

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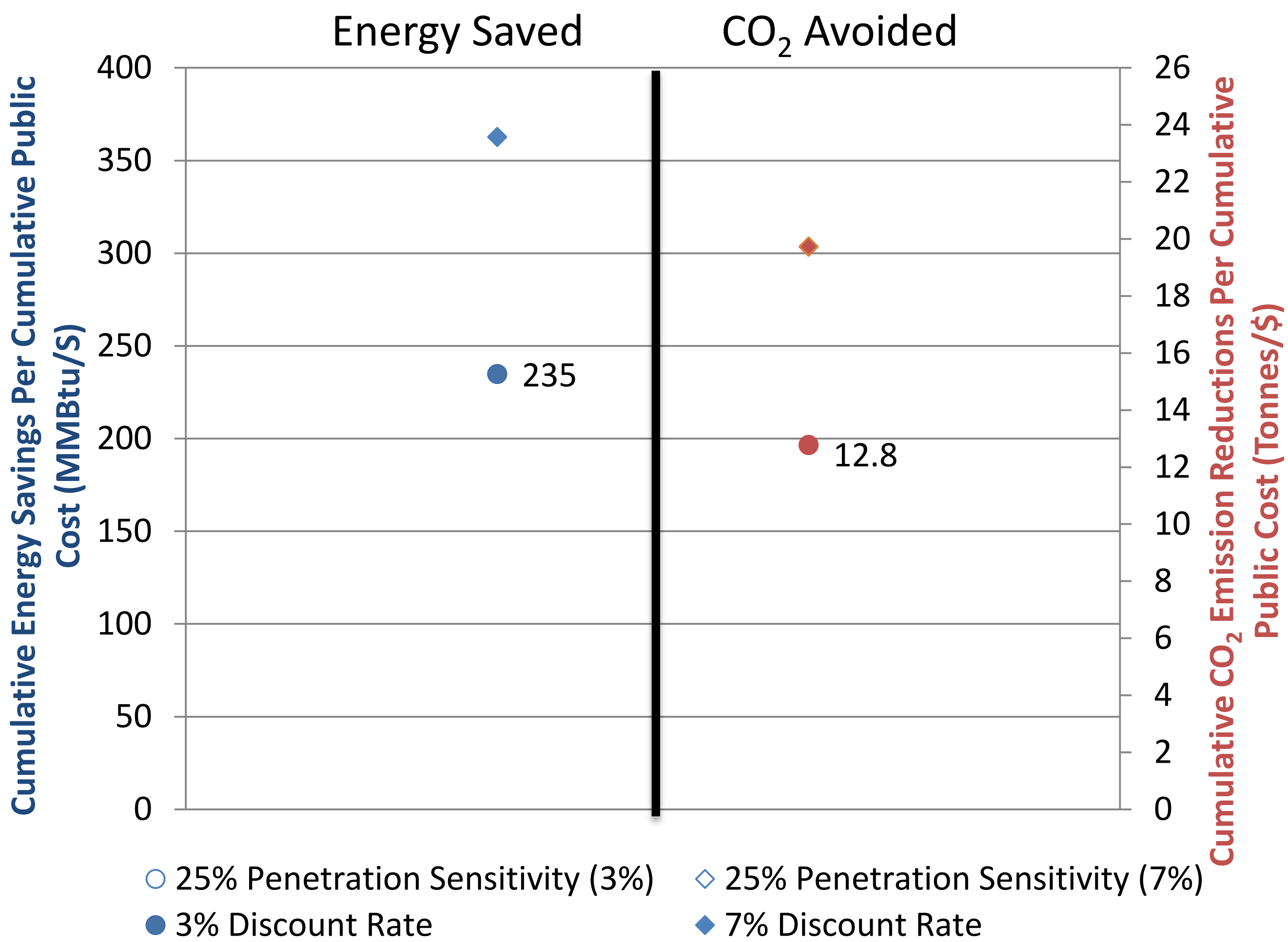
Public Costs Leverage Significant Energy Savings and Carbon Mitigation



Note: It costs the public $0.004 for each MMBtu energy saved from the Mandated Disclosure with Building Energy Performance Ratings policy option at 3% discount rate. The cost effectiveness for the policy optionfor carbon abatement is $0.08/ton. Comparatively, the estimated damages from CO_2 emissions are projected to be $34/ton (EPA, 2010).

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Benefit/Cost Results are Favorable

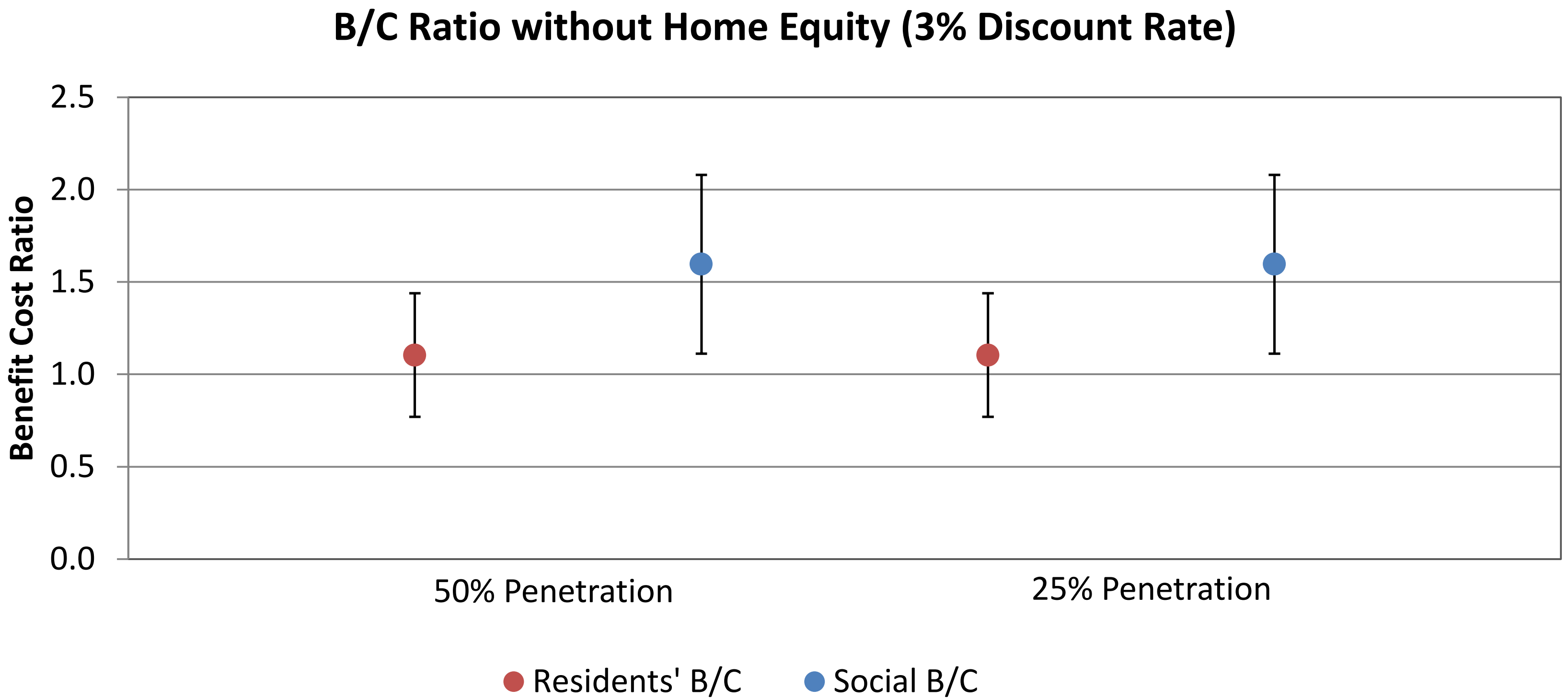
	Cumulative Social Benefits* (Billions $2008)					Cumulative Social Costs* (Billions $2008)			Benefit/Cost Analysis	
Year	Energy Savings	Value of Avoided CO_2	Value of Avoided Criteria Pollutants	Home Equity Benefits	Social Benefits**	Public Costs	Private Costs	Total Social Costs**	Social B/C Ratio	Net Societal Benefits (Billions $2008)
2020	29.0	2.10	2.78	57.2	91.0	0.03	46.1	46.2		
2035	190	15.7	16.8	240	462	0.09	143	143		
2055	253	22.0	21.9	262	559	0.09	143	143	3.91	416

* Present value of costs and benefits were calculated using a 3% discount rate.

**Total costs and benefits do not include various non-monetized values (e.g. mercury pollution reduction, increased productivity, water quality impacts, etc.)

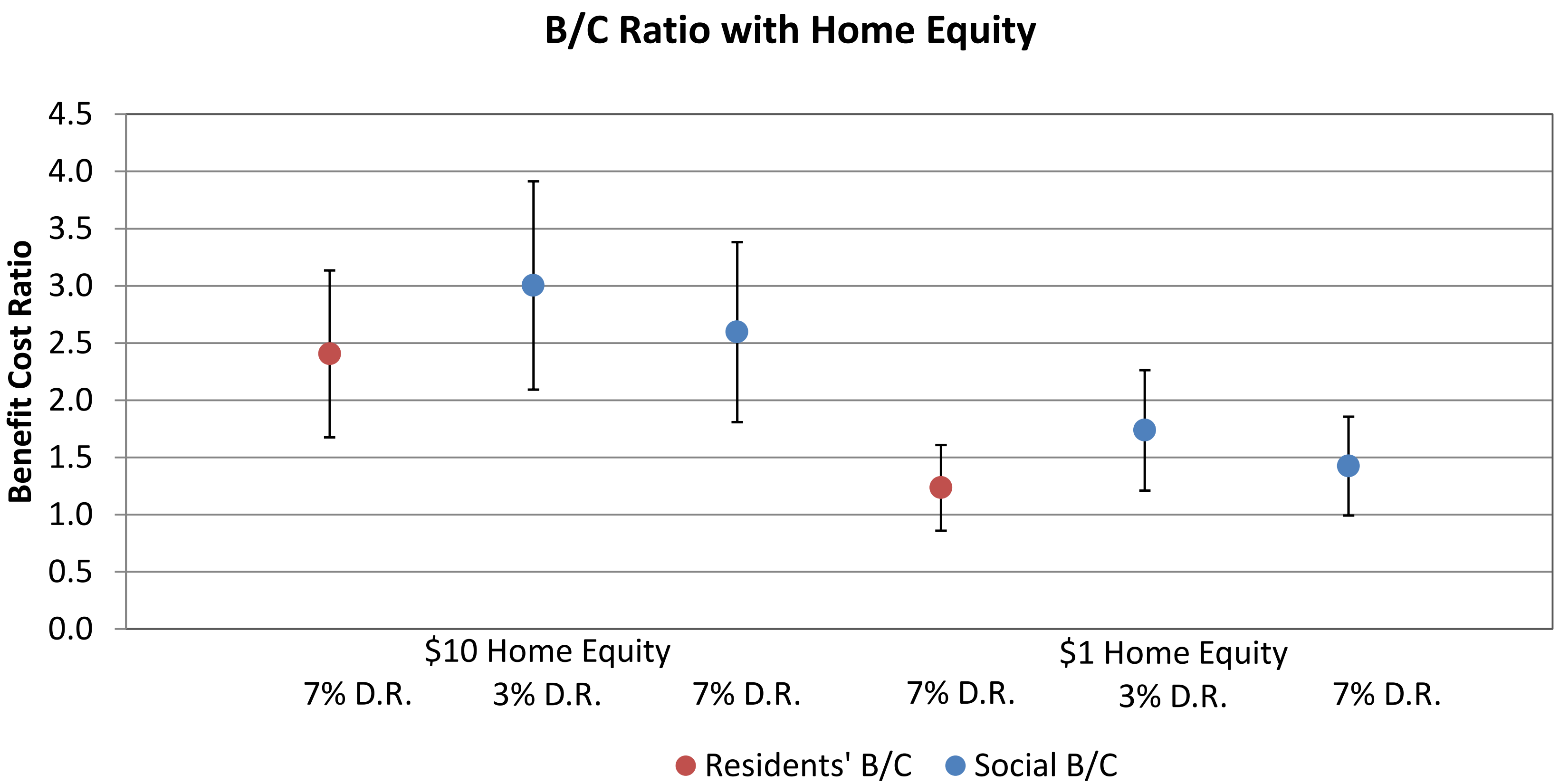
NOTE: Social B/C ratio is 2.08 when not including home equity benefits.
Social B/C ratio is 2.26 when home equity benefits are included, but the equity premium is assumed to be $1 per $1 energy savings instead of $10 per $1 energy savings.

Cost Effectiveness of Mandated Disclosure Impacted by Assumed Cost to Weatherize Homes



- Error bars show estimates of B/C ratio at different weatherization costs per home
  - Low estimate: $6,000 per home to weatherize
  - High estimate: $3,000 per home to weatherize

Mandated Disclosure is Cost Effective with a $10 Home Equity Premium



- Error bars show estimates of B/C ratio at different weatherization costs per home
  - Low estimate: $6,000 per home
  - High estimate: $3,000 per home

Note: D.R. = Discount Rate