Lecture Series

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Green Savings: How Policies and Markets Drive Energy Efficiency

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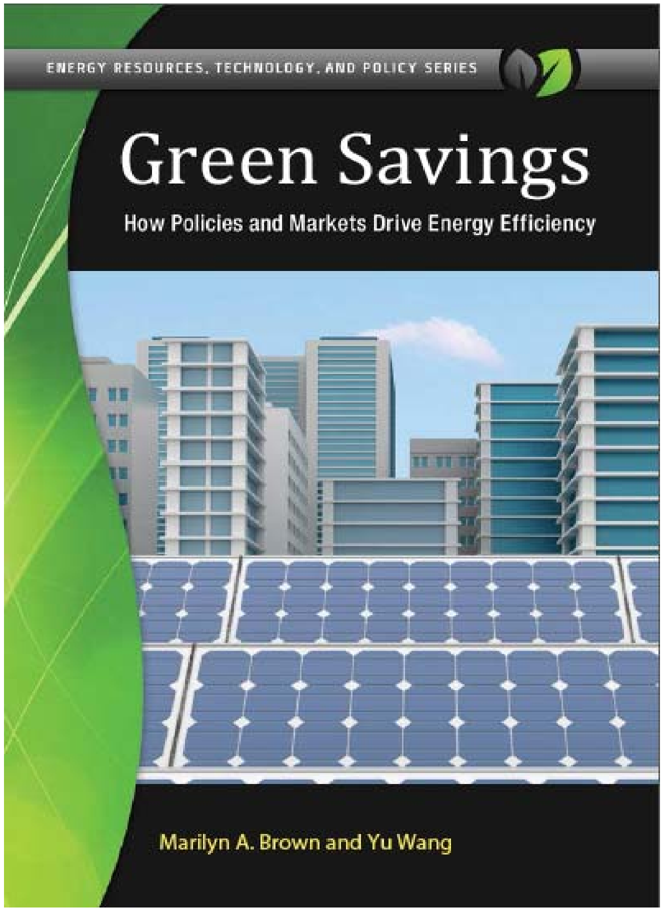
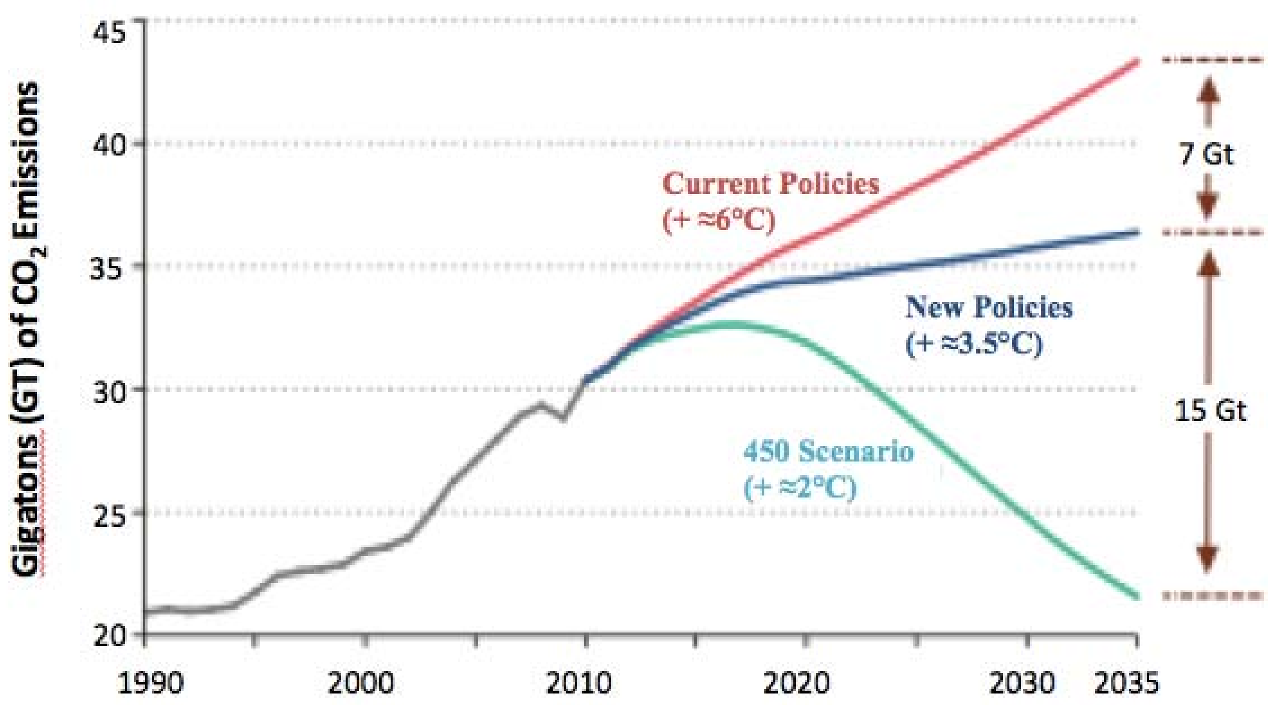
April 16, 2015



Context and Perspective

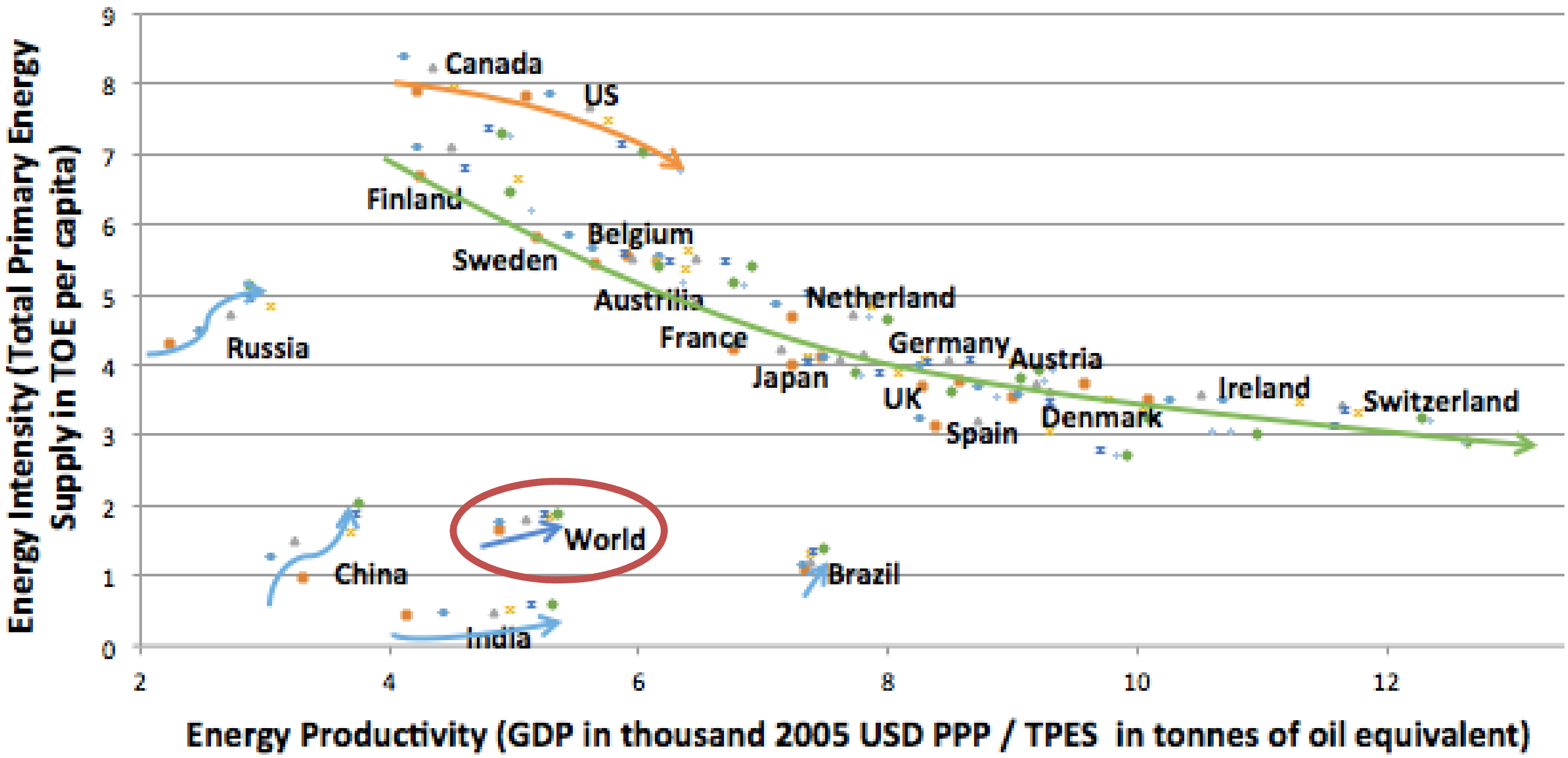
Energy Efficiency is a Dilemma Wrapped in a Paradox



World Energy-Related CO_2 Emissions by Scenario

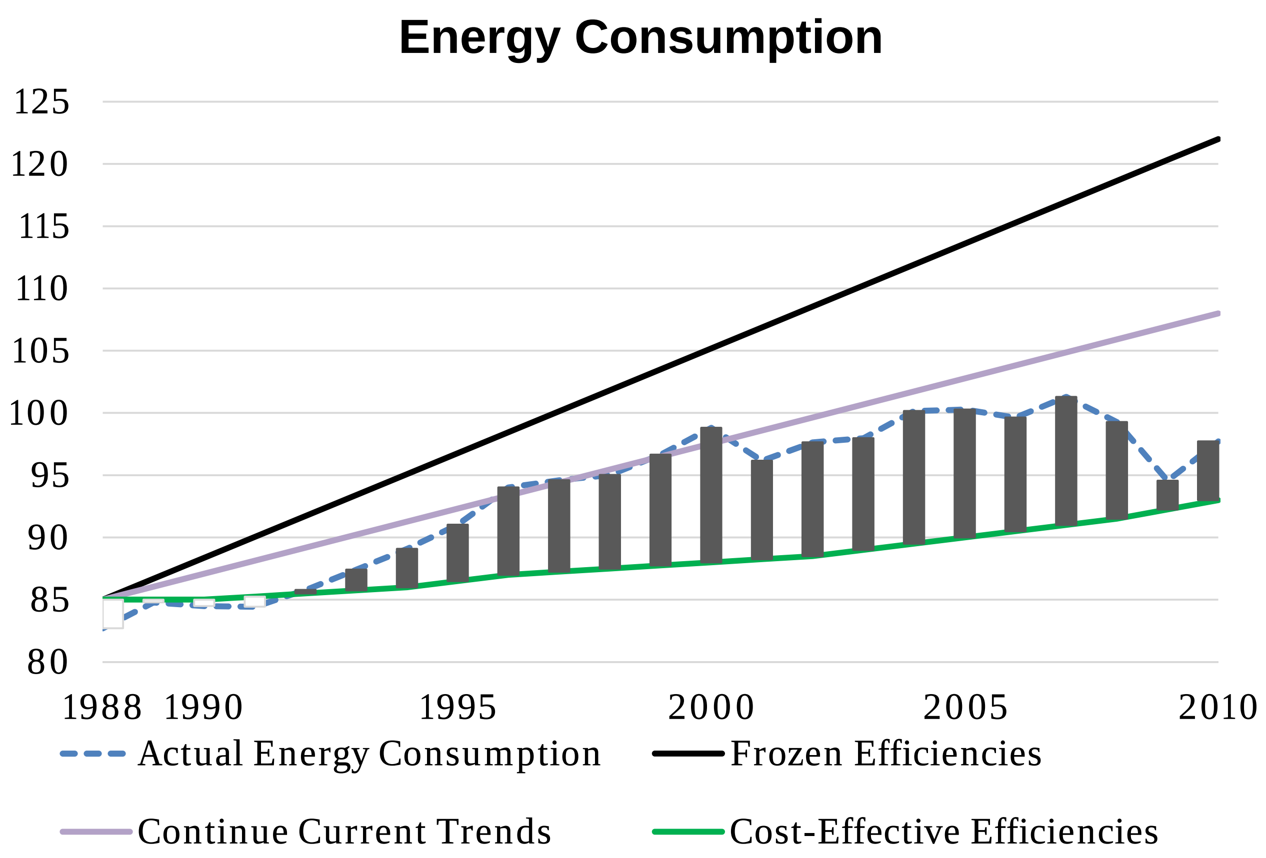
Source: International Energy Agency. 2011. *World Energy Outlook.*

Energy Productivity is Increasing, but So is Energy Consumption



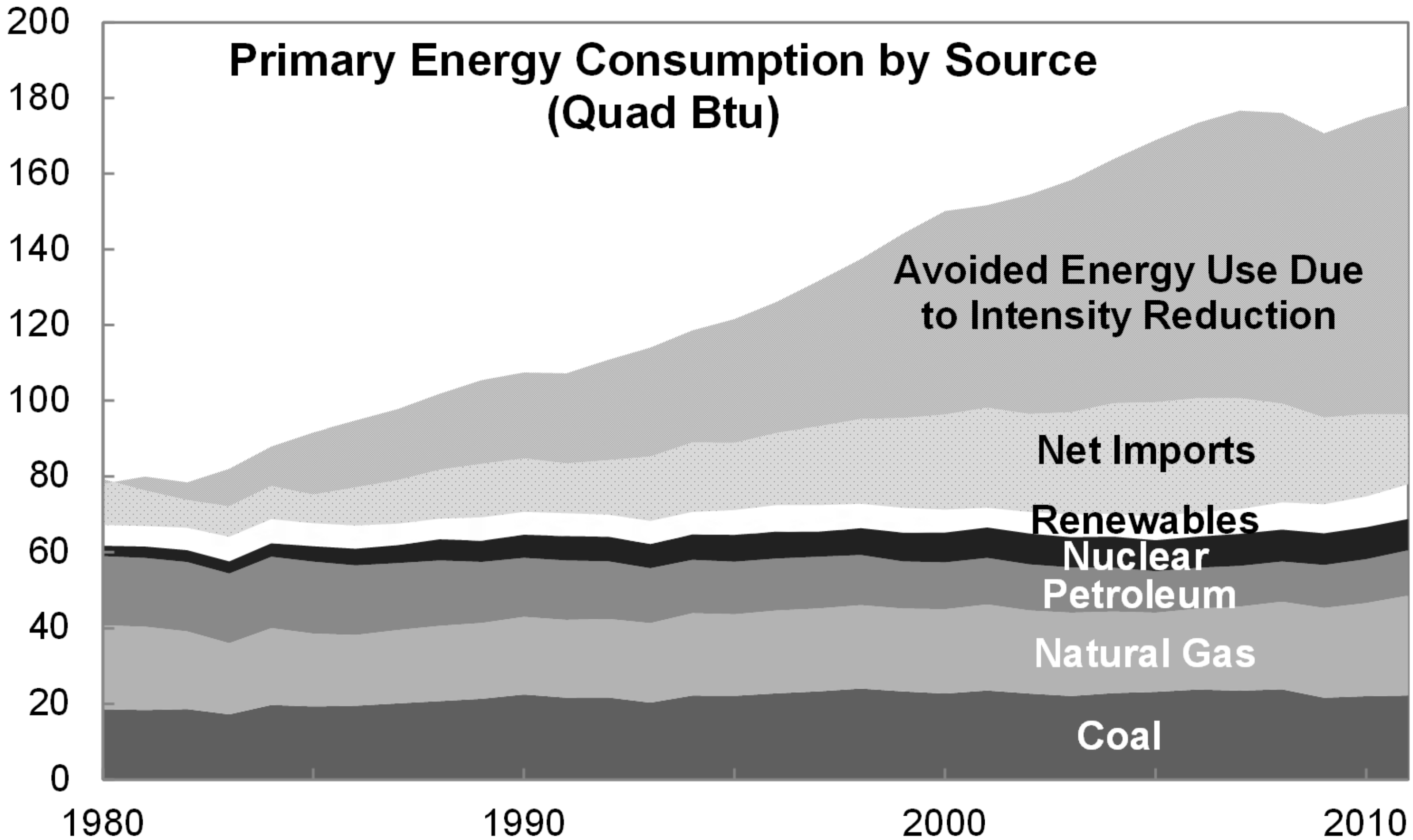
Source: Data from International Energy Agency, 2013, *Energy Efficiency Market Report.*

The Term "Energy-Efficiency Gap" was Coined in 1990



Source: Hirst, E. & Brown, M. A. "Closing the Efficiency Gap: Barriers to Improving Energy Efficiency." *Resources, Conservation and Recycling* 267–281 (1990).

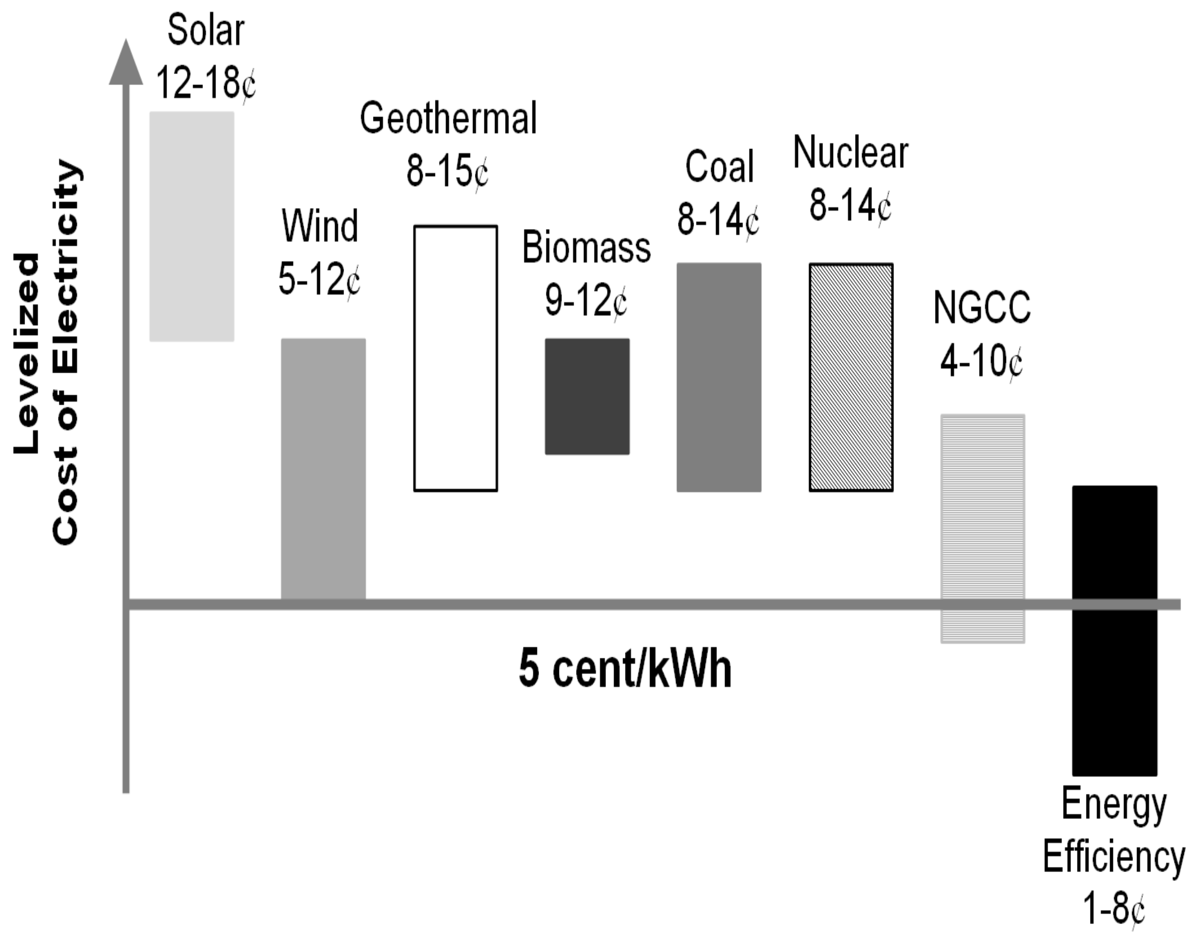
The Energy-Efficiency Wedge: 1980-2010



The Energy Efficiency of the US Economy Has Improved

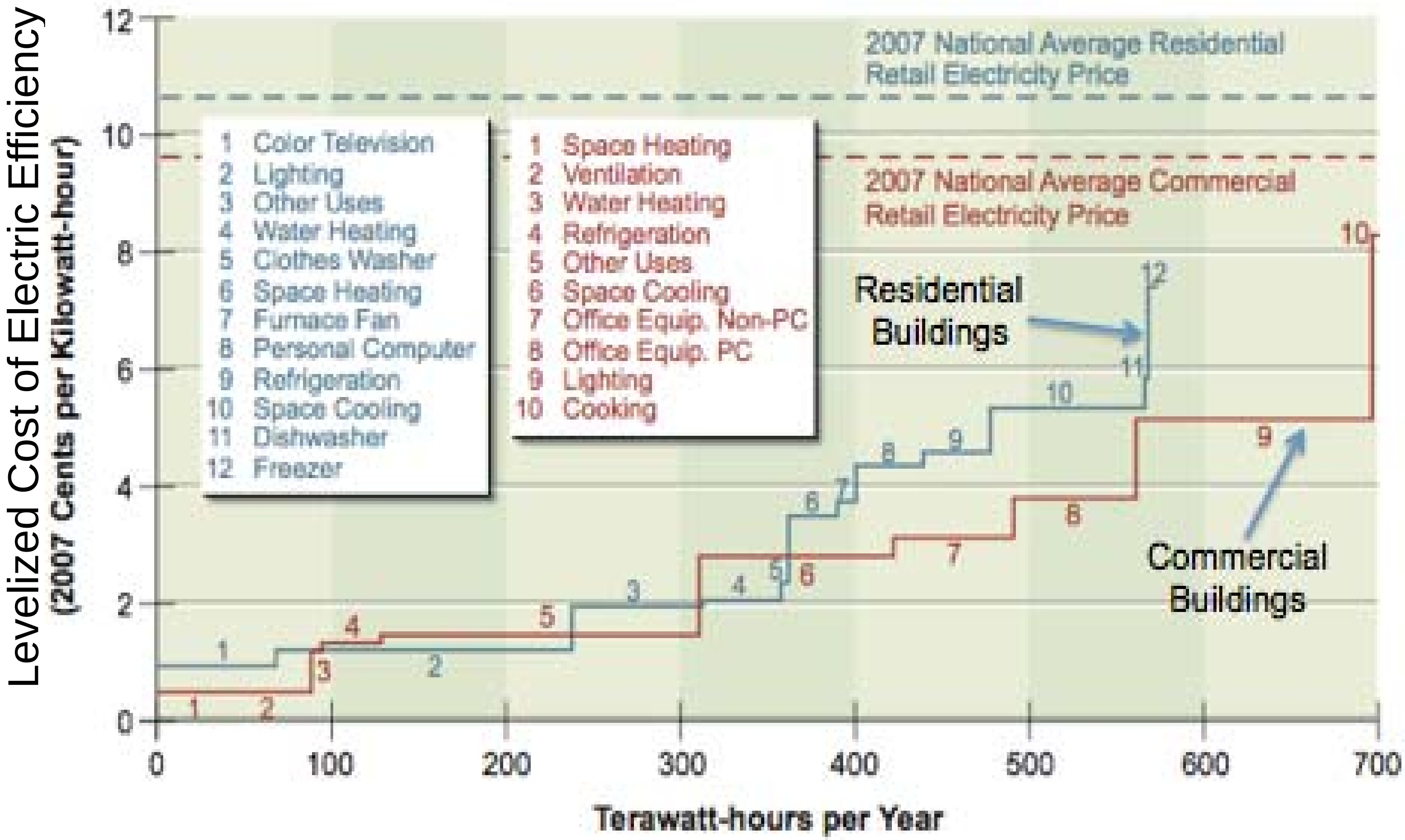
Data source: U.S. Energy Information Administration (EIA), Jan 2014 Monthly Energy Review

The Levelized Cost of Supply- and Demand-Side Options



Data source: Bloomberg's *Sustainable Energy in America 2014 Factbook* .

Efficiency Appears to be A Cost-Competitive Electricity Resource



Source: National Academy of Sciences. 2009. *America's Energy Future.*

Levelized Cost of Electricity Assesses Supply- and Demand-Side Resources

$$LCOE(\$/kWh) = \frac{\sum_{n=0}^{N} C_n/(1+r)^n}{\sum_{n=1}^{N} kWh_n/(1+r)^n}$$

Where the stream of costs (C_0 … C_N) are the real expenditures (in period n dollars) needed to generate or save the stream of electricity (kWh_n, …,kWh_N),

r is the discount rate, and

n is the lifetime of the energy system.

The Debate:
Skeptics Versus Advocates

The Views of Skeptics and Advocates (1)

Skeptics	**Advocates**
Failures in energy markets are insignificant and are not a strong basis for assuming that an energy-efficiency gap exists. Energy prices are reasonable reflections of total producer costs and consumer demand.	Energy prices do not fully reflect the cost of a range of significant negative externalities including climate change. Other market failures exist, as well.
Competing opportunities for using capital are more rewarding. Scarce capital is allocated to other options with higher returns.	Opportunity costs for energy-efficiency investment may appear to be high because of market flaws such as the global commons problem posed by climate change.
Past achievements of energy efficiency are often over-estimated, attributing too much of the change in total energy consumption to efficiency.	Decomposition methods are now available to isolate the energy-efficiency effect, and experience with them is growing.

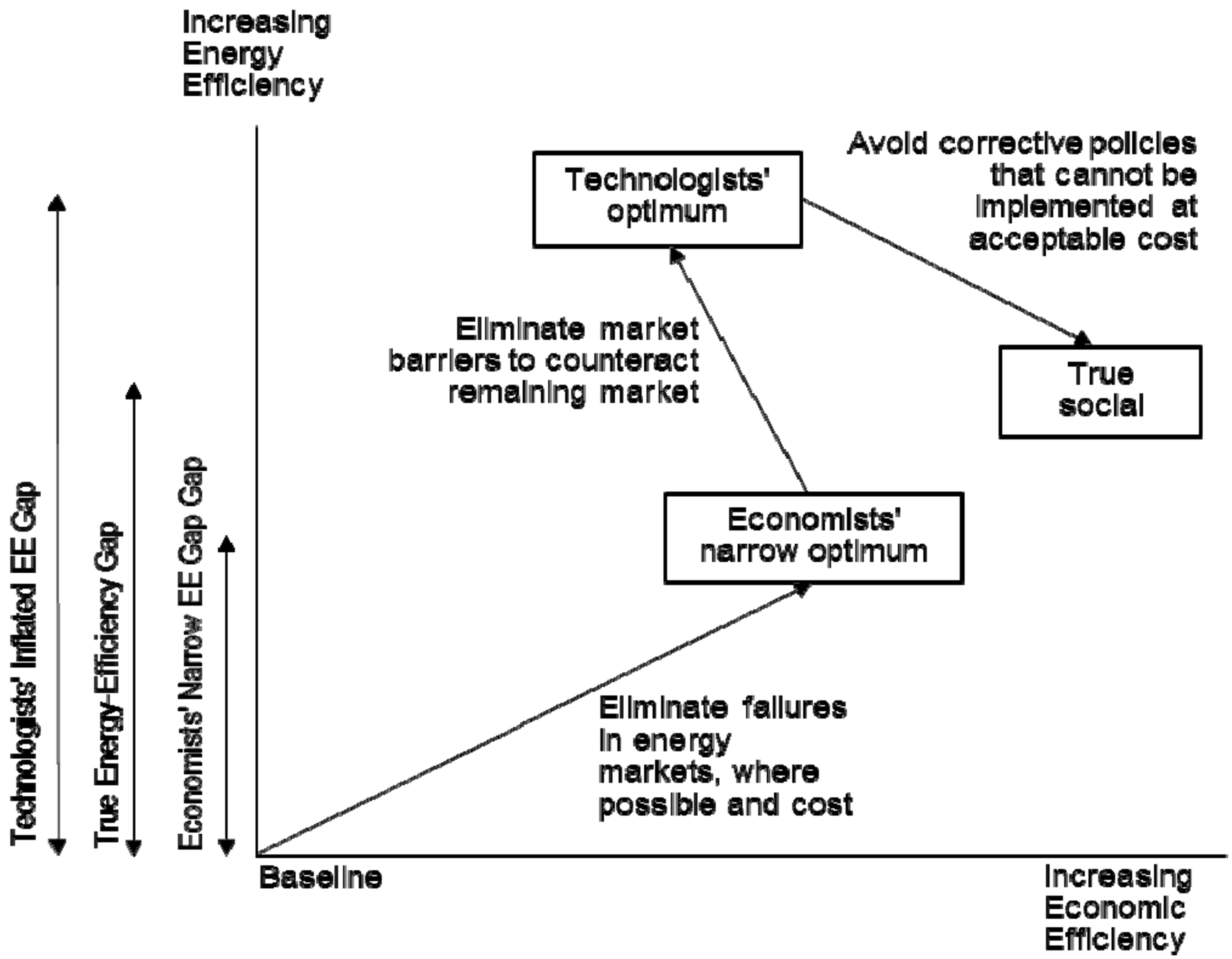
The Views of Skeptics and Advocates (2)

Skeptics	Advocates
Double counting occurs when program evaluators and modelers fail to account for “natural efficiency improvements,” attributing past and future improvements entirely to policy interventions.	Naturally occurring energy efficiency is increasingly acknowledged in program evaluations and forecasts, and generally is not considered on the benefits side of the leger in program evaluations.
There are hidden costs that models often overlook, such as program administration costs and the effort required by participants to find and install new equipment and process rebates of incentive payments.	These hidden costs are increasingly considered in program evaluations; program designs are also being developed to minimize these costs.
Modelers underestimate the discount rates used by consumers and firms. Because of opportunity costs, risk, illiquid investments, and rational inattention, firm and household discount rates are high.	Discount rates can be lowered by reducing market uncertainties as occurs, for instance, with improved benchmarking and labeling. Also, uncertainty over discount rates are increasingly being considered.

The Views of Skeptics and Advocates (3)

Skeptics	**Advocates**
Because of the rebound effect, engineering spreadsheets typically overestimate energy savings.	Models are increasingly accounting for the rebound effect and various behavioral “wrinkles.” In addition, the magnitude of the takeback effect can be reduced.
Models don’t always reflect how hard it is to deliver energy efficiency. The pros and cons of different policy instruments are still being hotly debated.	Experience with energy-efficiency policies and programs is growing rapidly. Leaders and laggards have been identified, along with best practices.
Energy efficiency should be seen as a customer service and not as a utility resource.	New business models are able to integrate energy efficiency into utility resource planning
Most of the cost-competitive energy efficiency has been fully exploited; it has been largely tapped out.	In addition to the existing energy-efficiency gap, new opportunities for low-cost energy savings are being invented every day.

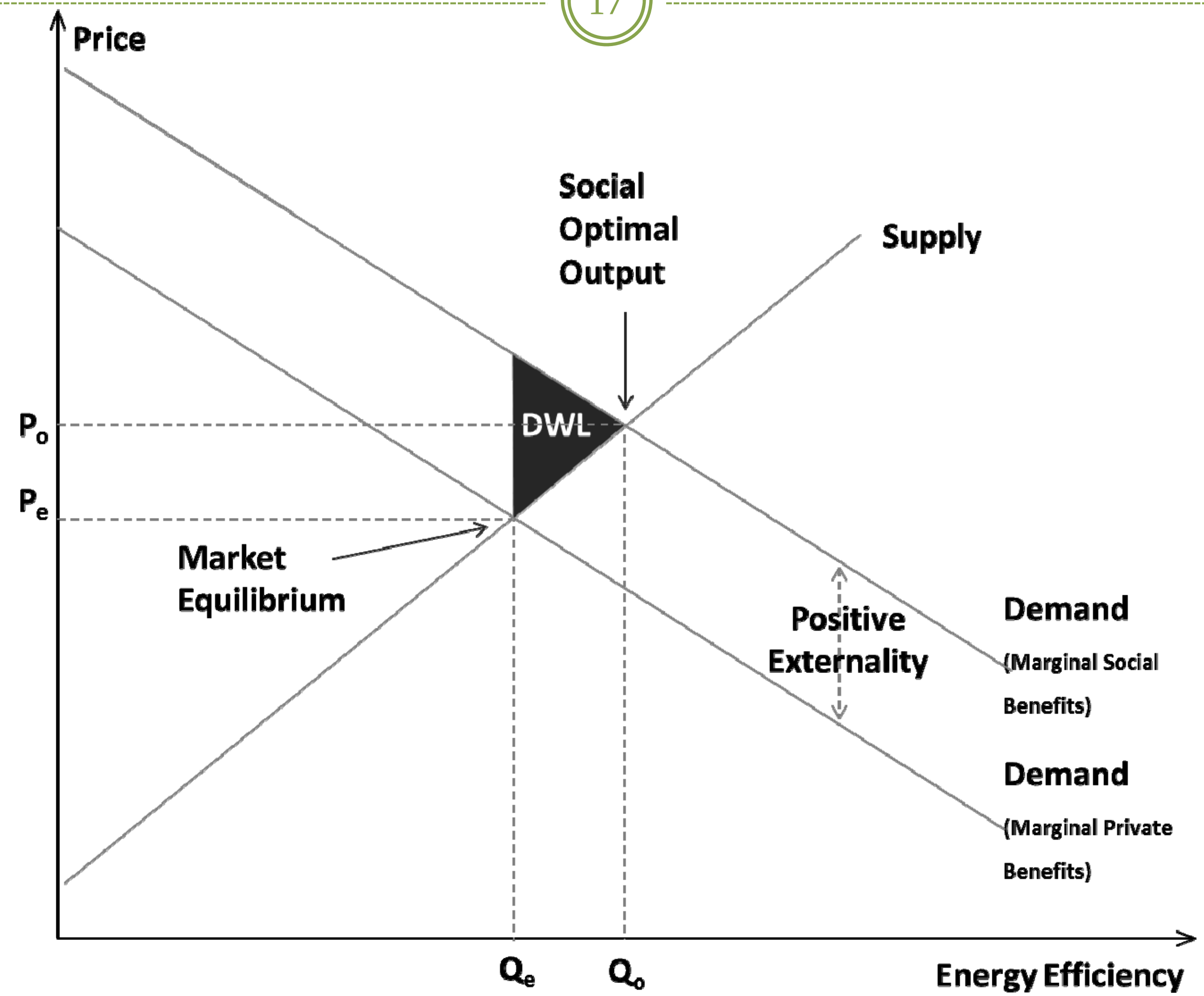
Alternative Views of the Energy-Efficiency Gap



Markets for Energy Efficiency are Imperfect

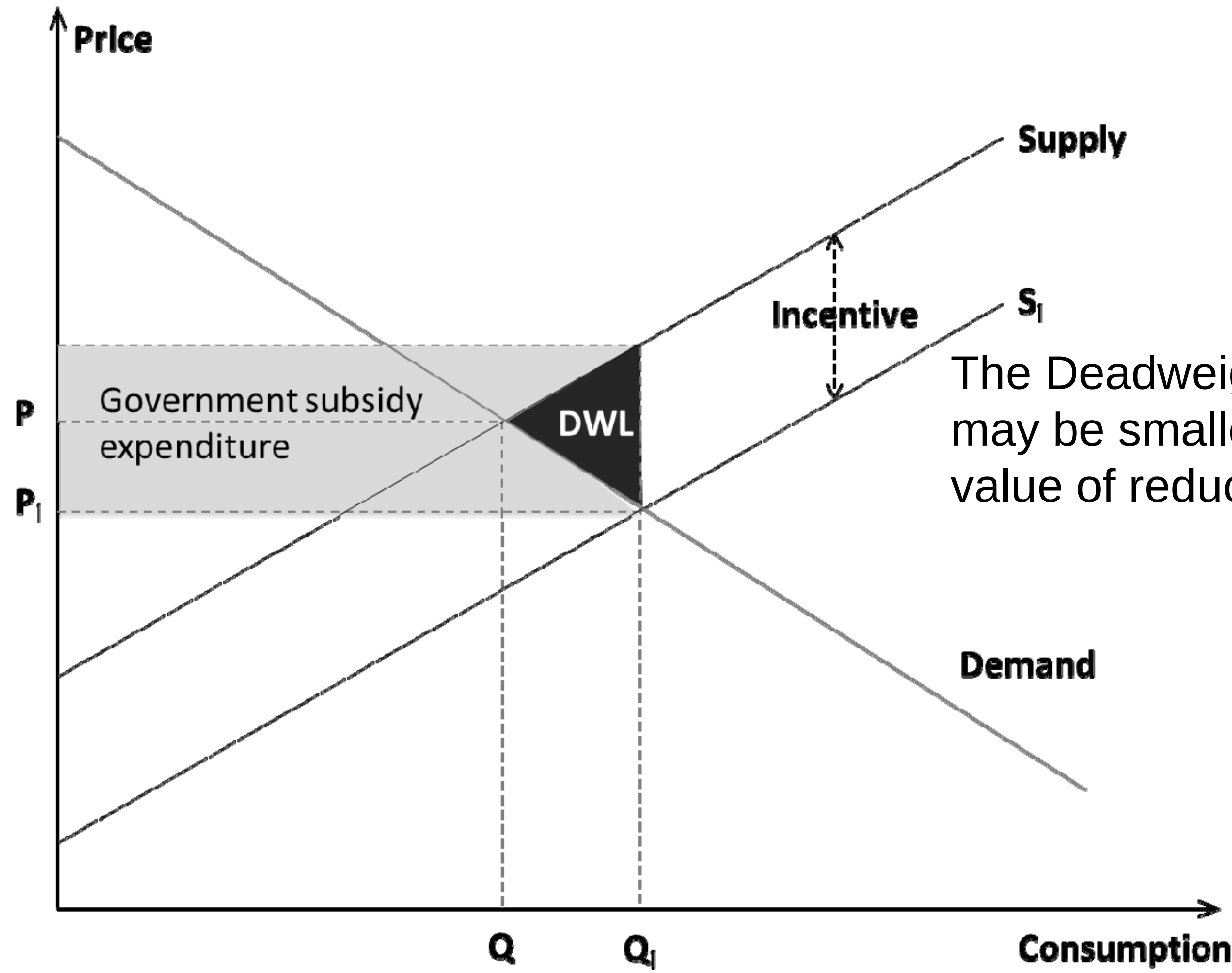
Criteria	Characteristics of a "Perfect" Market
Information	Participants in the market are fully informed of the quantitative and qualitative characteristics of goods and services, and the terms of exchange among them. Decision-makers know how much energy they consume for different services, and how efficient their workplaces, homes, and appliances are.
Transaction Cost	Market exchanges are instantaneous and costless. High-efficiency equipment and trained personnel are readily available.
Rational Consumer	Consumers maximize utility and producers maximize profits. Consumers take the time to research options and make optimal choices, and producers value gains the same way that they value losses.
Competition	No specific firm or individual can influence any market price by decreasing or increasing the supply of goods and services. There are many buyers and sellers of energy services.
Internalization	All costs associated with exchanges are borne solely by the participants of the transaction or internalized in prices so that all assets in the economic system are adequately priced. There are no environmental externalities.
Excludability	Those involved in market exchanges are able to exclude others from benefiting. The benefits of making a steel mill more energy efficient accrue entirely to the mill's owners and investors.

Positive Externalities Reduce the Consumption of Energy Efficiency



DWL= Deadweight Loss

Impact of Government Subsidies on Energy Efficiency



The Deadweight Loss (DWL) may be smaller than the value of reduced pollution.*

*Marilyn A. Brown, Matt Cox, and Paul Baer. 2013. "Reviving manufacturing with a federal cogeneration policy." *Energy Policy*. 52 (2013) 264–276.

Polycentric Analysis of EE Policies

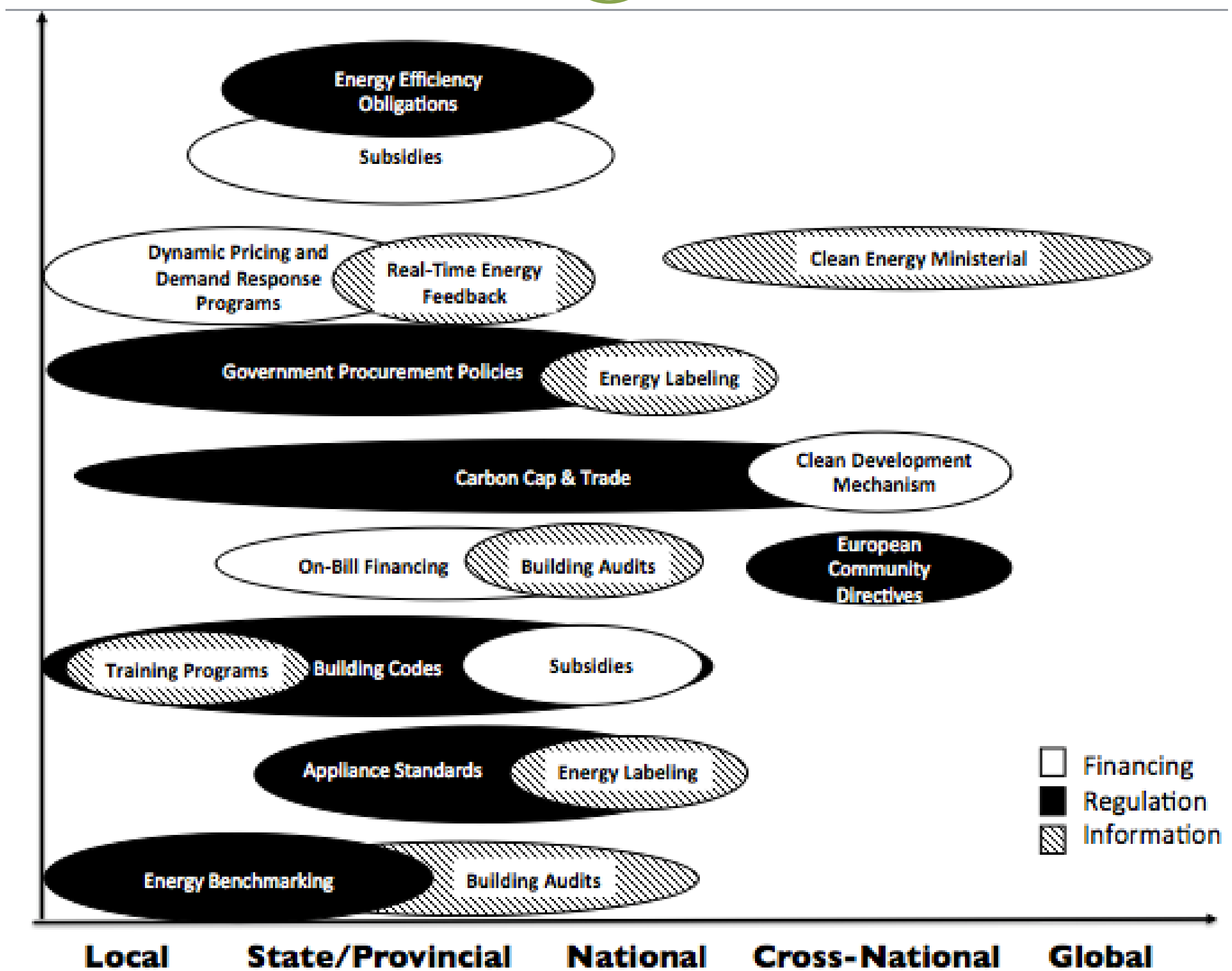
Polycentrism incorporates multiple scales and multiple stakeholder groups in the resolution of a policy problem, making it possible to harness the benefits of global and local action together instead of having them tradeoff.

- U.S. – E.U. Comparison
  - State Case Studies
    - Cities
    - Utilities
- Country Case Studies
  - State EE Performance
    - Cross-sectional Analysis
- National EE Performance
  - State vs City EE Performance

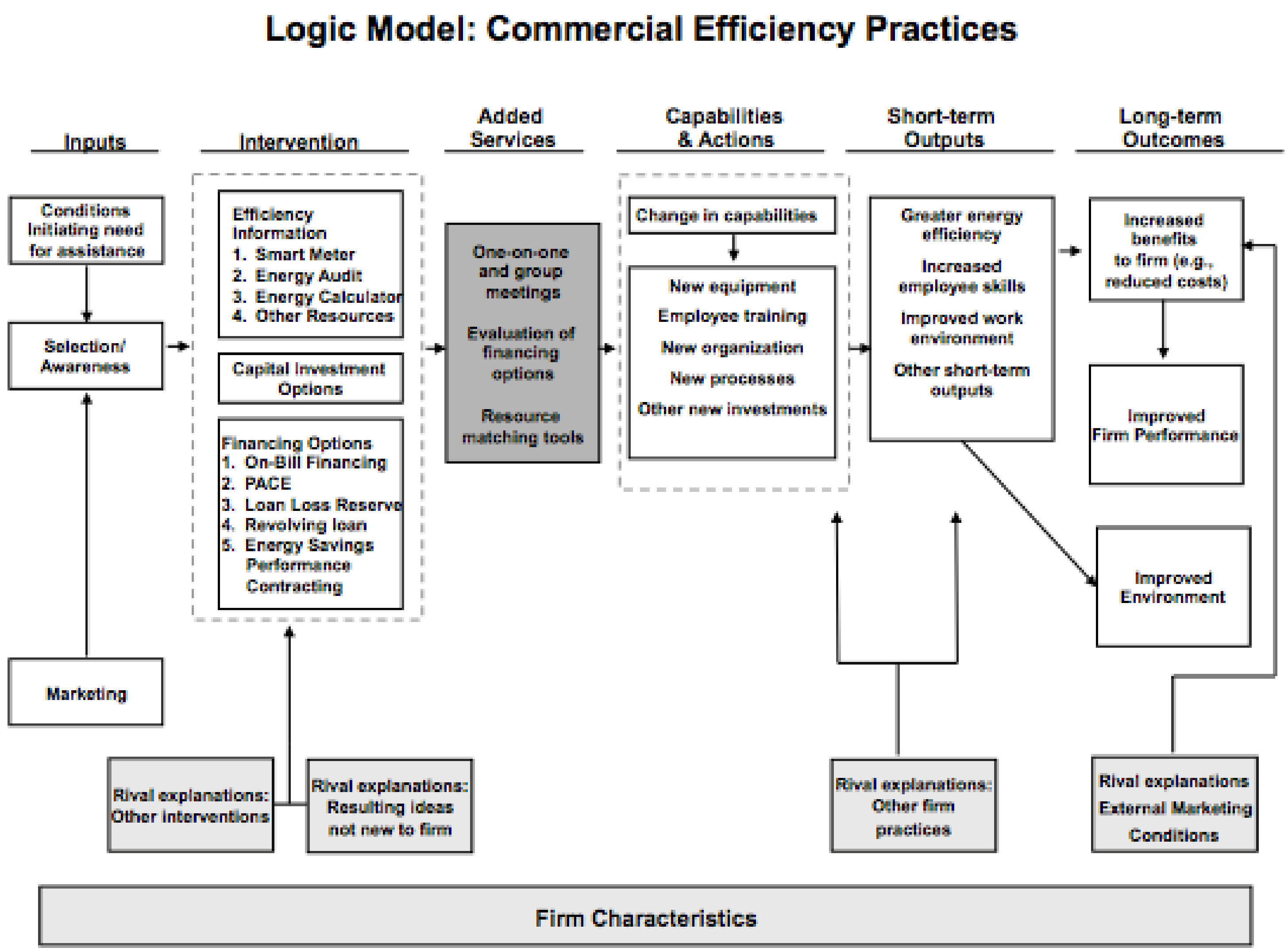
Scales of Policy Intervention

Favors Local/ State Policy	Local/State	National/Global
Diversity	Encourages innovation and experimentation in designing policy; provides diverse energy services that may be more responsive to changing needs	Stifles innovation and experimentation, is prone to diseconomies of scale, and changes slowly
Flexibility	More flexible and able to adapt to local conditions; reduces costs by connecting customers with local professionals; promotes administrative efficiency	More uniform and rigid; tends to fail to account for local conditions
Accountability	Allows for closer fit between policies and preferences and affords option to sort between jurisdictions	Promotes “rent seeking” behavior, which wastes resources trying to garner local advantages
Favors National/ Global Policy	Local/Regional	National/Global
Consistency	Building national markets for technology solutions is difficult when policies vary; local influence major appliance manufacturers and large consumers can be challenging	Standardization minimizes transaction costs and policy uncertainties; promotes inter-state trade of efficiency goods and services
Economies of Scale	Inefficient due to redundancies of R&D; evaluation, measurement and verification (EM&V) systems can be costly	Better matched to promote economies of scale and avoid redundancies; EM&V systems can be aggregated
Spillovers	Vulnerable to free ridership and emissions leakage; job creation may not be coincident with local investment	Minimizes free ridership and emissions leakage; accounts for dispersed non-energy benefits (e.g., green jobs)

Energy-Efficiency Policies: From the Local to the Global Scale



Logic Diagram of an Energy-Efficiency Program for Commercial Buildings



Leaders and Laggards

Summary of State Descriptive Data

Variable	Obs	Mean	Standard Deviation	Min	Max
Energy-Efficiency Score	51	19.1	9.8	3.5	42
Income per capita ($1000)	51	44.5	7.8	33.9	75.3
GSP ($Billion)	51	327.5	401.2	29.5	2202.7
Population (Million)	51	6.2	7.0	0.6	38.3
Unemployment rate (%)	51	6.8	1.6	2.9	9.8
Food and health (%)	51	10.4	2.4	5.9	19.8
Finance and real estate (%)	51	18.8	5.4	10.4	42.5
Energy-intensive industries (%)	51	4.6	2.9	0.1	13.5
Total Primary Energy Consumption (Quad Btu)	51	1.86	2.04	0.13	12.28
Retail gasoline price ($/Million Btu)	51	29.0	1.7	27.09	35.56
Retail electricity price ($/Million Btu)	51	30.4	12.2	20.29	99.96
CDD	51	1116	901	57	4512
HDD	51	5419	2343	0	10069
Electric efficiency program budget ($Million)	51	117.4	199.6	0	1166.6
Energy-Efficiency budget as % utility revenue	51	1.6	1.7	0	7.61
NG efficiency program budget ($Million)	51	25.2	49.1	0	263.7
NG budget per residential customer ($)	51	17.5	21.5	0	97.28
Annualized EERS saving target (%)	51	0.7	0.8	0	2.6
Decoupling	51	1.6	1.0	0	3
Building Codes	51	4.1	1.2	1	7
Lead by Example	51	1.6	0.5	0	2.5

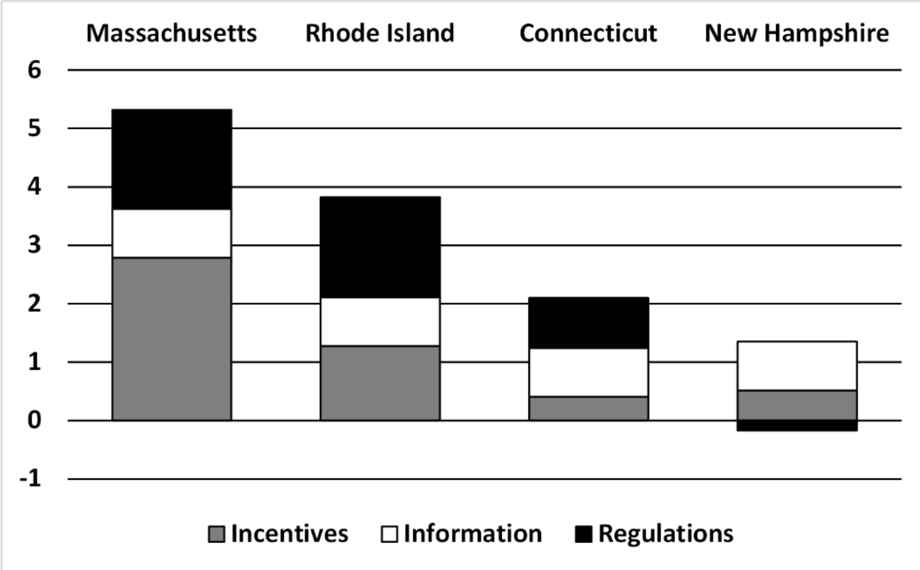
Estimation of Policy Impacts

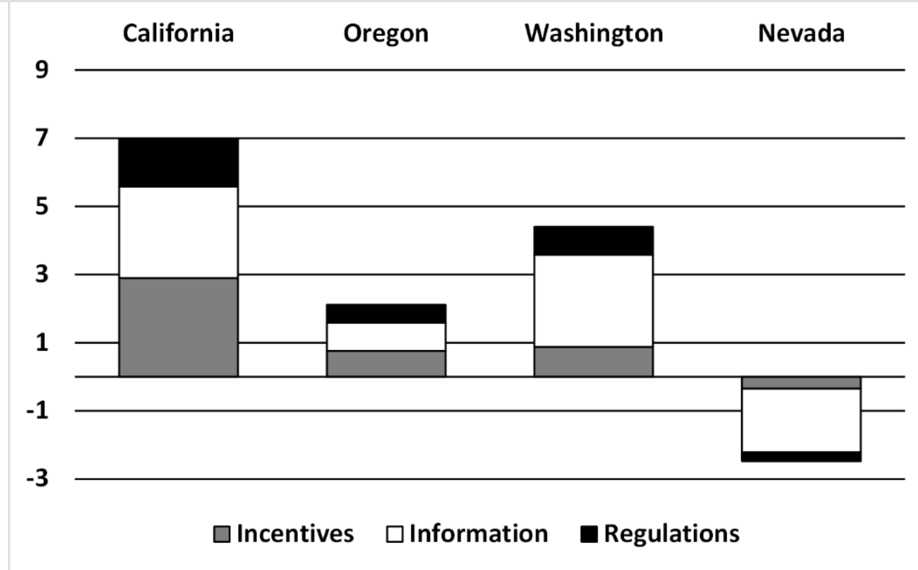
Variable	Measurement	Model 1 Forward Selecting	Model 2 Backward Selecting
Financial Incentives	Total Energy-Efficiency Budget ($Million)	.0116*** (.0023)	.0096*** (.0023)
	EE Budget as % Utility Revenue	1.4262*** (.3968)	.9383** (.4490)
	Total Natural Gas Budget ($Million)		
	$Per Residential Customer		.0655** (.0287)
Regulations	EERS (%)	3.7312*** (.6725)	4.2951*** (.6483)
	Decoupling		
	Building Code	1.6396** (.4951)	1.3896** (.4964)
Information Programs	Lead By Example		1.5491* (.8173)
	. . .		
Constant	Constant	4.4675 (3.2624)	-7.3182 (6.9456)
Model Fitness	Number of observations	51	51
	Adjusted R^2	0.9258	0.9331

*p<0.1; **p<0.01; ***p<0.005.

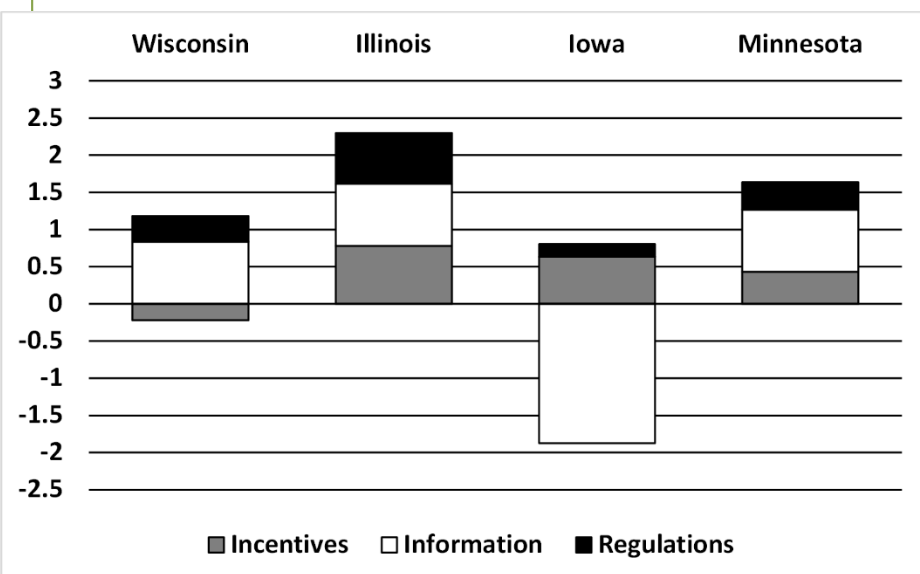
Performance of Control Variables

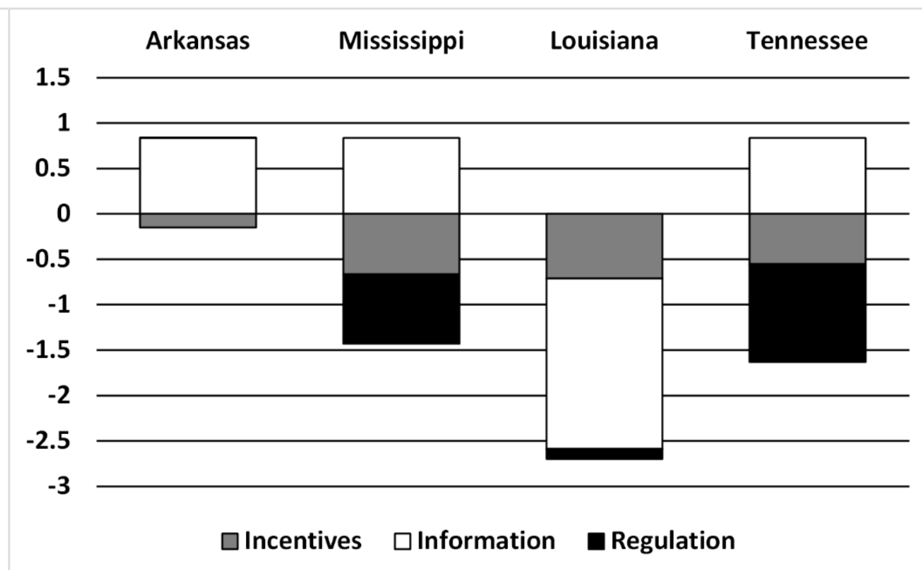
Variable	Measurement	Model 1 Forward Selecting	Model 2 Backward Selecting
	. . .		
Climate	CDD (1000)	-1.5535** (.5158)	-2.6585** (.9749)
	HDD (1000)		-.8228* (.4192)
Energy Market Characteristics	Per Capita Energy Consumption (Billion Btu/capita)	-6.1520* (3.1391)	
	Electricity Price ($/MBtu)	.0847** (.0375)	
	Gasoline Price ($/MBtu)		.5193** (.2450)
Economic Structure	% Financing and Real Estate	.1594* (.0864)	.2103** (.0783)
	% Food and Health		
	% Energy-intensive Industries		
Macroeconomic Characteristics	Per Capita Income ($1000/capita)		
	Per Capita GSP ($1000/capita)		
	Unemployment Rate (%)		





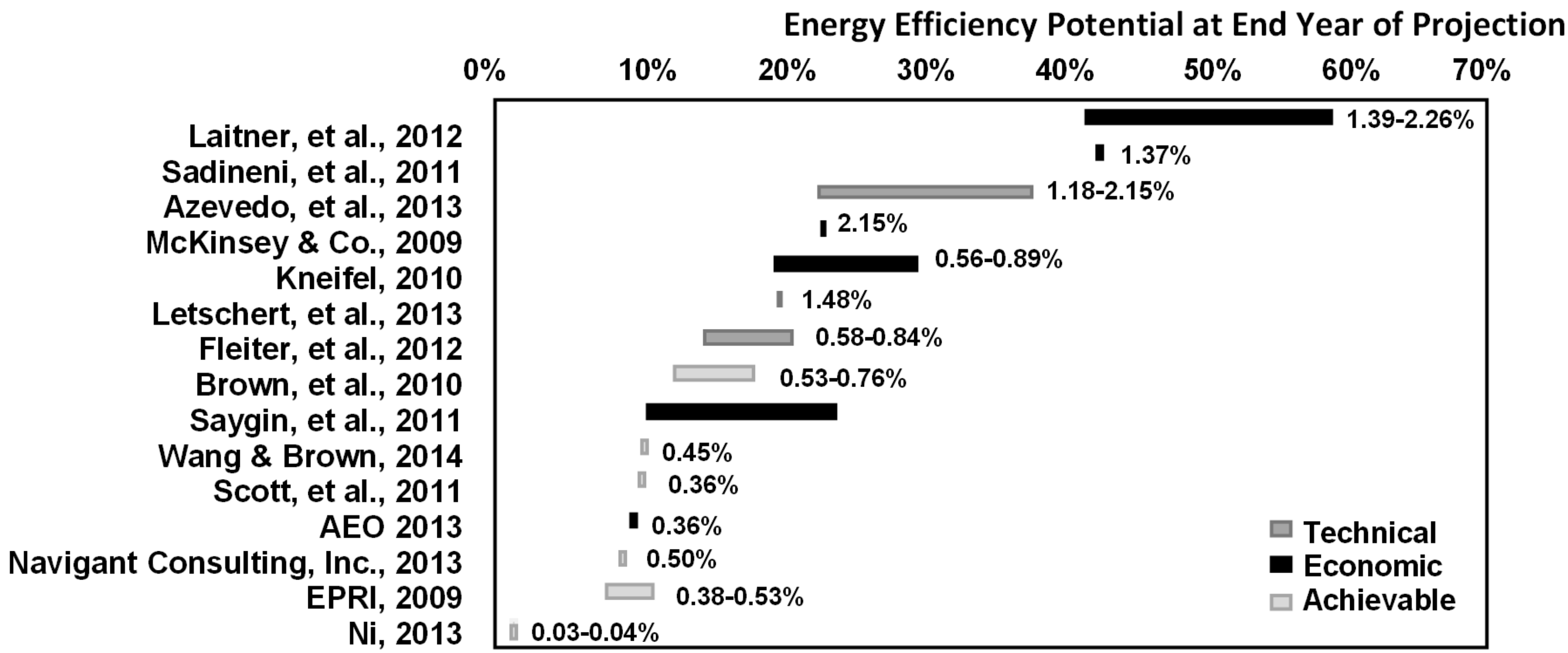
Policies of Two State Leaders↑, Two Improving States↓ (and Their Neighbors)



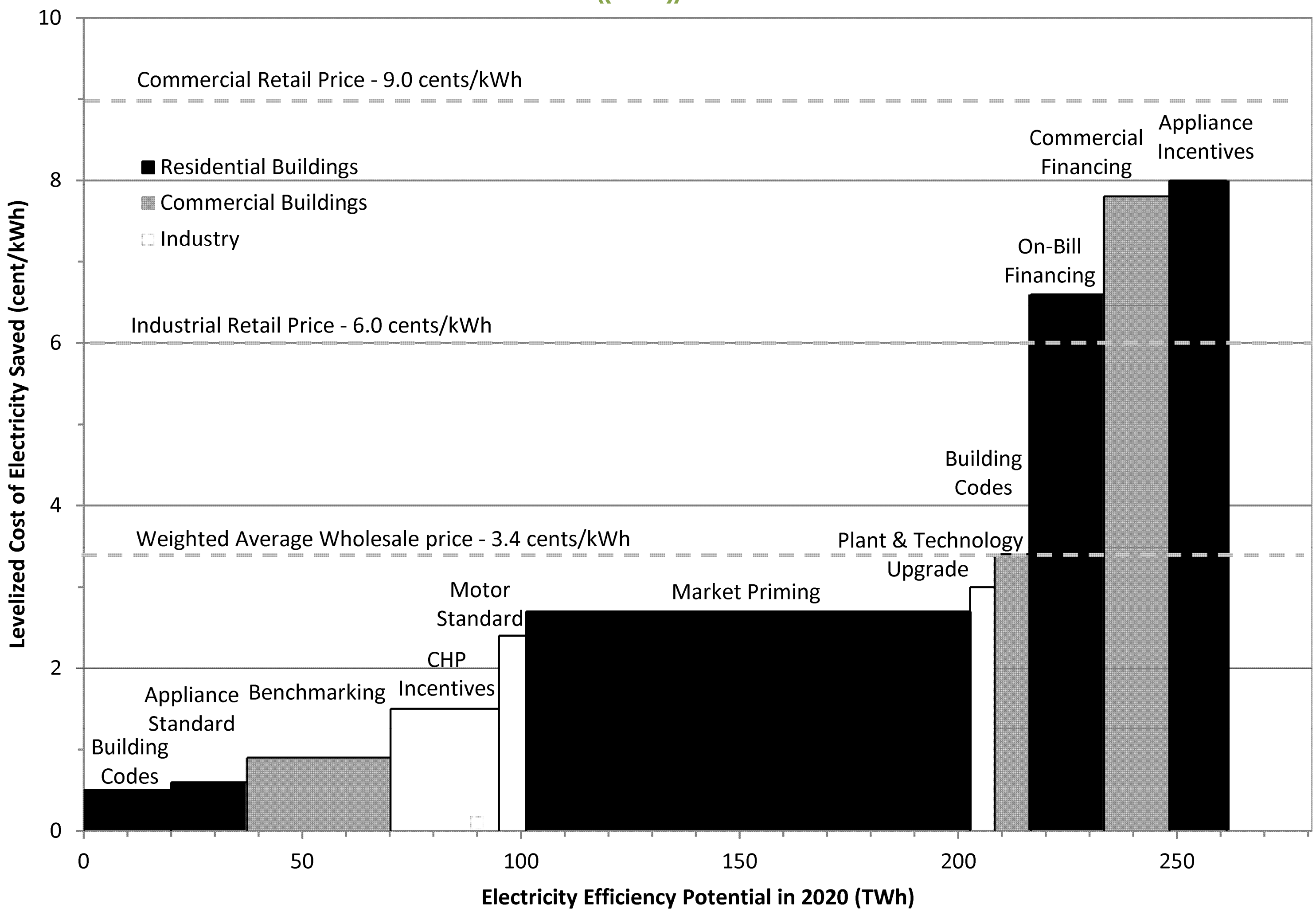


Potential for the Future

Estimates of Energy-Efficiency Potential: Annual Savings Rates

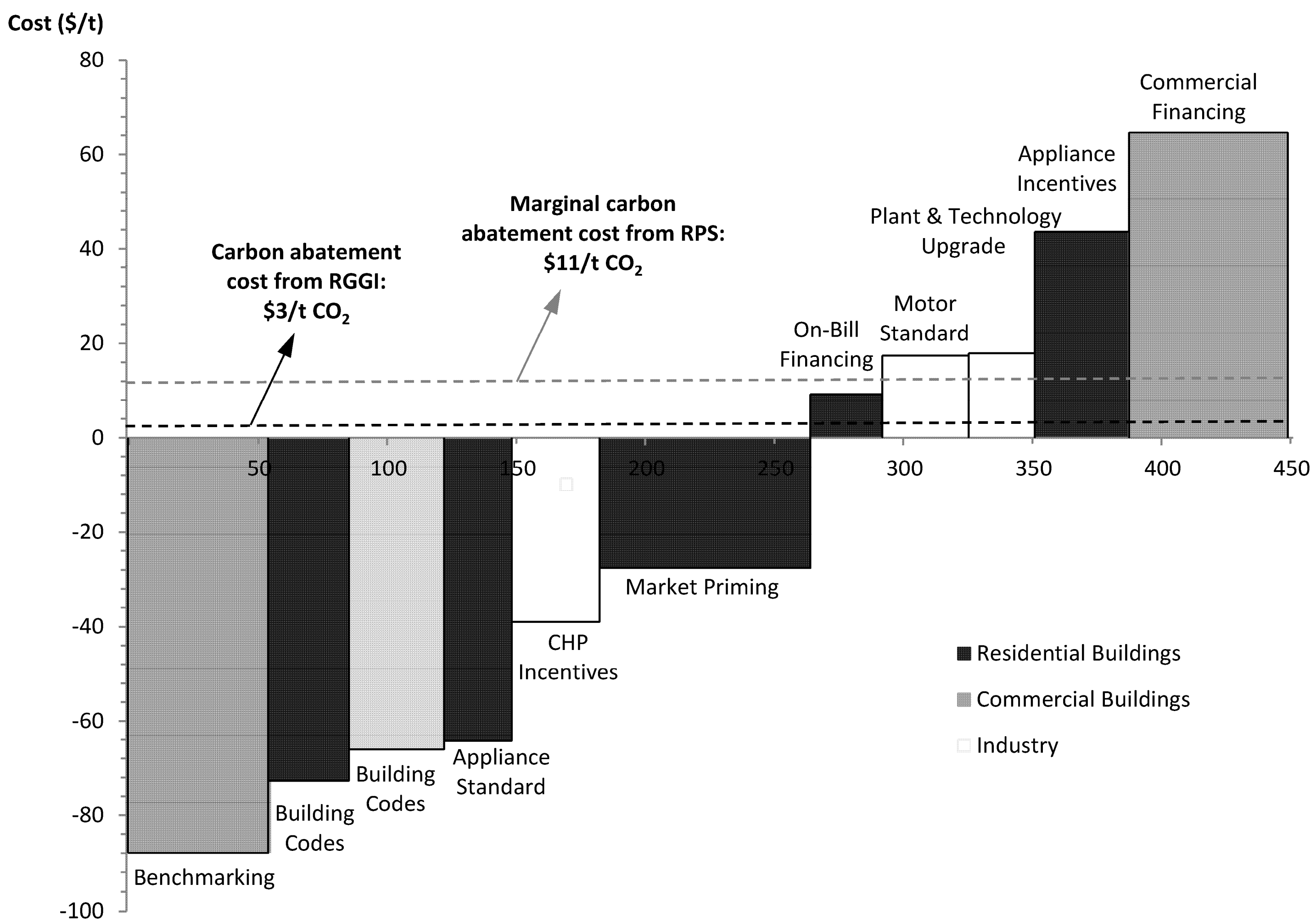


U.S. Policy Supply Curve for Electric Efficiency Resources in 2020



Source: Wang, Yu and Marilyn A. Brown. 2014. "Policy Drivers for Improving Electricity End-Use Efficiency in the U.S.: An Economic-Engineering Analysis". *Energy Efficiency,* 7(3): 517-546.

Potential Carbon Emission Reductins in 2020 ($MMtCO_2$)



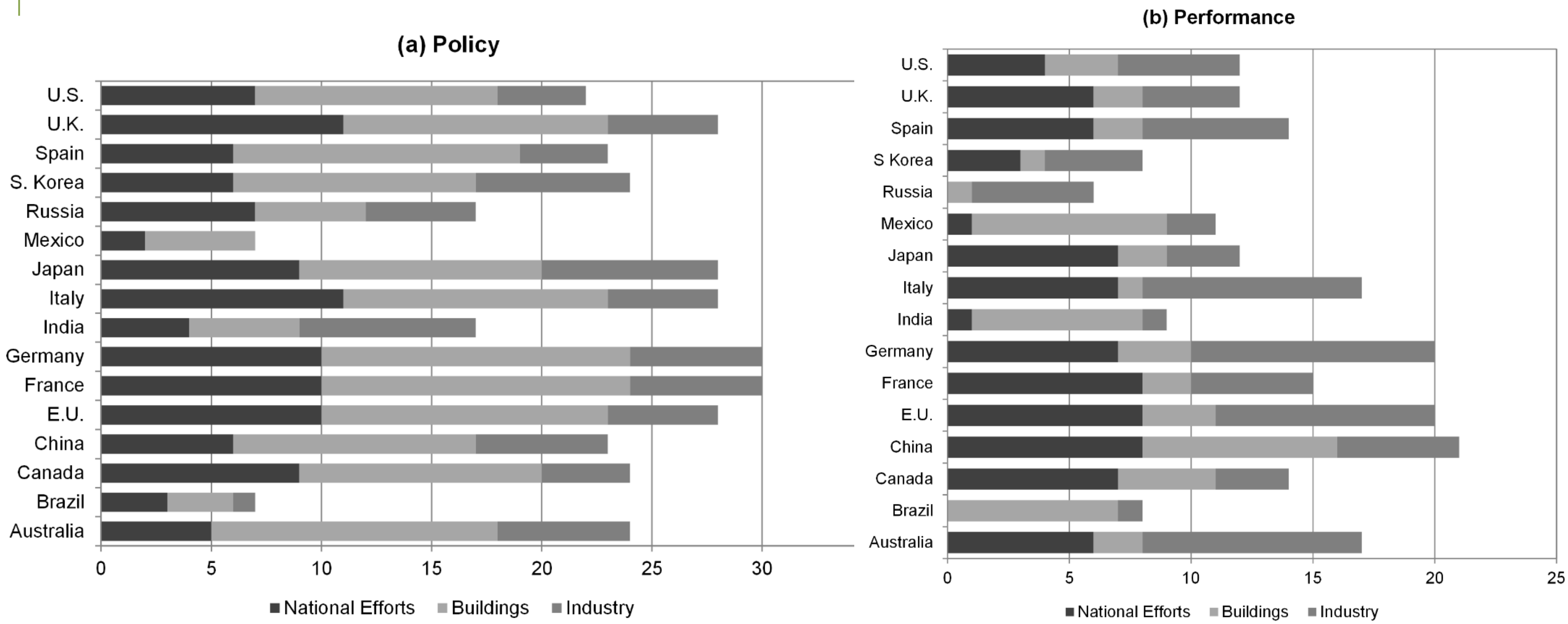
Cost-Effectiveness of Energy Efficiency Policies by Type

Type of Energy-Efficiency Policy	Levelized Cost of Electricity (cents/kWh)	Cost of Carbon Abatement ($/ton) **
Financing	6.2 – 6.4	27.0 – 37.6
Regulation	1.3 – 1.8	(45.4) – (25.9)
Information	2.1 – 3.0	(37.0) – (20.5)
Weighted Average	3.4 – 3.9	(18.1) – (2.7)

*Lower bound of the cost estimations was derived from 3 percent discount rate for public and private costs. Upper bound of the cost estimations was derived from 7 percent discount rate for private costs and 3 percent discount rate for public costs.

** Numbers in parentheses are negative numbers.

ACEEE Scores for Energy Efficiency: Room for Improvement



Data Source: Young, Rachel, Sara Hayes, Meegan Kelly, Shruti Vaidyanathan, Sameer Kwatra, Rachel Cluett, and Garrett Herndon. *The 2014 International Energy Efficiency Scorecard*. Washington D.C., 2014.

Characteristics of Case Study Nations

Table 7.5 Socio-economic Characteristics of Case Study Nations in 2010 [a]

Country	Energy per GDP intensity (tBtu/2005US$GDP)	Electricity use (kWh/ capita)	Real electricity retail price (US¢/ kWh)	Oil import dependence (%) [b]	Natural gas import dependence (%) [c]	SO_2 emissions (tons/ capita) [d]	CO_2 emissions (tons/ capita)
Germany	5.3	6,666	26.3	75.5%	78%	0.005	9.7
China	10.3	2,843	8.4	52.5%	11.5%	N/A	5.6
Japan	5.6	7,801	20.6	78.4%	95.6%	0.006	9.3
U.K.	4.2	5,307	23.1	13.9%	40.4%	0.007	8.5
U.S.	7.5	12,564	11.6	47.8%	10.8%	0.022	18.2

Policy Recommendations

- Keep Up with Technology Assets
- Follow the Leaders
- Employ Polycentric Policy Systems
- Exploit the Energy-Efficiency Gap

For More Information

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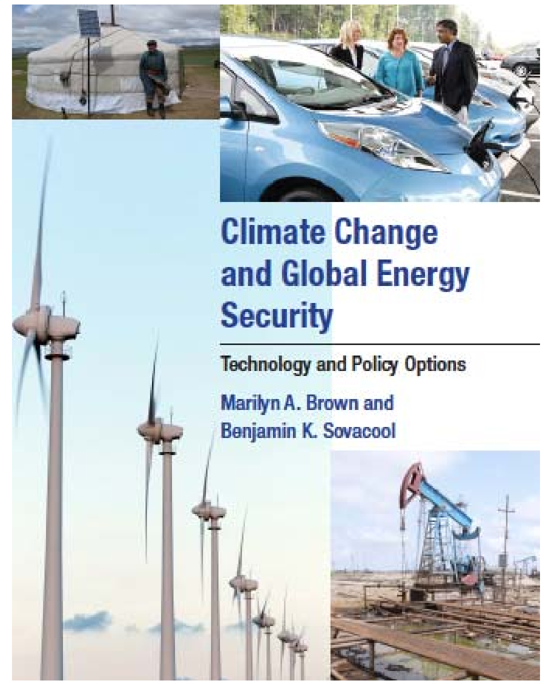

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