Consumer Federation of America

ENERGY EFFICIENCY PERFORMANCE STANDARDS:
The Cornerstone of Consumer-Friendly Energy Policy

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October 2013

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Consumer expenditures on household energy (electricity and natural gas at home and gasoline for transportation) average about $4600 per year. This makes household energy one of the largest items in the consumer budget – more than groceries (food at home, ~$3800), health care (~$3300), entertainment (~$2572), and clothing (~$1700).

Yet, economic analysis shows that technologies are available that could lower those bills substantially. Even after the cost of energy savings technologies are paid, consumer pocketbook savings approaching $1000 per year are possible. Moreover, the failure to capture cost-effective energy savings is not limited to the residential consumer market, it affects the commercial and industrial sectors as well.

Given this potential savings, it is not surprising to find that energy efficiency performance standards, which increase the minimum efficiency of energy using durable goods, receive a great deal of attention from policy makers and support from the public. In fact, proceedings affecting (or relating to) performance standards for almost two dozen consumer products are pending at the federal and state levels.

Yet, the existence of the large energy savings potential has always engendered doubts among some analysts because it implies a significant market failure. In our market economy, we would expect economically beneficial opportunities for investment like this to be quickly exploited. If markets are functioning well, there should not be an efficiency gap.

Although the efficiency gap has been the subject of considerable study since the oil price shocks of the 1970s, the past decade has witnessed a flowering of analysis that vastly improves the understanding of the causes of the efficiency gap and the policies that can help to close it. With the wide ranging scope of pending energy performance standards and the key role they are likely to play not only in energy policy, but also in the response to climate change, this is an appropriate juncture to review the empirical evidence on performance standards as a response to the efficiency gap.

Purpose and Outline

This paper reviews the conceptual and empirical analysis of the efficiency gap literature of the past decade and weaves the discrete pieces of empirical evidence and the broad conceptual frameworks into a comprehensive explanation of the efficiency gap.

Part I discusses the major conceptualization offered by academics, thinks tanks, private sector firms and government agencies and ties them to four dozen empirical studies completed in the past decade. It then evaluates estimates of costs and benefits of policies to enhance energy efficiency. It concludes with a discussion of the studies that show that performance standards are an economically attractive and effective approach to closing the efficiency gap.

Part II of the paper places the efficiency gap analysis in the context of two broader frameworks that add important depth to the understanding of the efficiency gap. The central themes in the diffusion of innovation literature and the climate change literature reinforce the conclusions drawn from the efficiency gap literature. The slow diffusion of energy saving technologies can be seen as an example of the broad process of the diffusion of innovation, which has a very long and rich literature. Concerns about climate change have focused a great deal of attention on the challenge of inducing change in energy consumption using behavior, which at heart is the same problem as the efficiency gap. A review of the intense empirical analysis of climate change is undertaken, not to estimate or debate the impact of the problem, but to extract insights into the barriers and obstacles to change in energy consumption in markets.

PART I: RECENT EFFICIENCY GAP ANALYSIS

Comprehensive Frameworks and Empirical Evidence on the Efficiency Gap (Section II)

The efficiency gap literature provides a clear answer to the question of "why don't producers sell and consumers buy more energy savings technologies and lower their energy costs?" It shows that the efficiency gap is caused by barriers and imperfections on both the supply and demand sides of the energy market that inhibit the development and distribution of energy saving technologies. The emphasis on the supply side of the market is recent and extremely important.

Among the most important and frequently cited factors that inhibit investment in energy savings technology are the following.

Producers of energy using durables hesitate to include energy saving technologies in the products they sell because they are unsure of the market (risk), lack familiarity (lack of information), and skill with the technology and are not confident in their ability to implement the technology or how it will perform (lack of expertise). They are uncertain about technology costs (hidden costs) and future energy prices (uncertainty). They cannot capture the value of investing in the basic research and development necessary to move the technology toward introduction in the market (public goods problem of appropriability). Routines and organizational structures retard the ability to undertake different types of investments (inertia), so they allocate their capital investment (lack of capital) to enhance other attributes of the durables they think are more important (creating bundles of attributes that de-emphasize energy consumption).

Consumers do not demand energy savings technology because in many cases the actors who make the decision about which technologies to use are not responsible for paying the energy bills (split incentives). Consumers lack the knowledge and ability to project energy consumption and price (lack of information) and calculate lifecycle costs (lack of expertise). Habit makes it difficult to adopt new technologies (inertia). Consumers are sensitive to the first cost of consumer durables (lack of capital) and pay more attention to other attributes of the durables (making energy consumption a shrouded attribute).

Other critical factors in the market also contribute to the underinvestment in energy efficiency technology. Financial institutions do not factor the energy consuming characteristics of durables into their calculations (limited rewards of efficiency). Regulators set prices and deliver bills that make it difficult for consumers to adjust their behavior and value energy saving technologies (ineffective price signals). Coordination between aspects of the supply train is difficult (network effects). Positive effects of energy savings, like macro-economic benefits and improved productivity do not enter into private calculations (positive externalities).

Performance Standards: Evaluations of policy options to close the efficiency gap consistently find that standards that require consumer durables to use less energy are a very attractive approach to closing the gap. Energy performance standards address many of the most important market barriers and imperfections. They tend to reduce risk and uncertainty by creating a market for energy saving technologies, lower technology costs by stimulating investment in and experience with new technologies, reduce the need for information and the effect of split incentives, all of which help to overcome the inertia of routine and habit.

However, the literature points out that performance standards have positive effects if they are well-designed, enforced and updated. Key principles for the design of performance standards to ensure they are effective include the following.

- **Long-Term:** Setting an increasingly rigorous standard over a number of years that covers several redesign periods fosters and supports a long-term perspective. The long term view lowers the risk and allows producers to retool their plants and provides time to re-educate the consumer.
- **Product Neutral:** Attribute based standards accommodate consumer preferences and allow producers flexibility in meeting the overall standard.
- **Technology-neutral:** Taking a technology neutral approach to the long term standard unleashes competition around the standard that ensures that consumers get a wide range of choices at that lowest cost possible, given the level of the standard.
- **Responsive to industry needs:** The standards must recognize the need to keep the target levels in touch with reality. The goals should be progressive and moderately aggressive, set at a level that is clearly beneficial and achievable.
- **Responsive to consumer needs:** The approach to standards should be consumer-friendly and facilitate compliance. The attribute-based approach ensures that the standards do not require radical changes in the available products or the product features that will be available to consumers.
- **Procompetitive:** All of the above characteristics make the standards pro-competitive. Producers have strong incentives to compete around the standard to achieve them in the least cost manner, while targeting the market segments they prefer to serve.

Cost-Benefit Analysis (Section III)

Cost benefit analyses of past efforts to increase energy efficiency support the conclusion that significant, economically beneficial energy savings opportunities can be captured with policies that target the development and acquisition of more energy efficient consumer durables.

Evaluations of policies to promote efficiency in general, as well as specific evaluations of performance standards show that they have proven to be highly cost effective, with benefits far exceeding costs. In fact, costs are frequently less than anticipated in regulatory proceedings because learning and economies of scale lower the cost of compliance. Benefits are underestimated because the economic stimulus that results from increasing the resources consumers have to spend on other goods and services is not taken into account.

The net benefit of policies to promote greater efficiency tends to be underestimated in the proceedings to set standard levels because cost estimates do not take account costs savings associated with implementing new technologies, and indirect economic benefits of lowering energy costs are not included.

It is noteworthy that well-designed standards have little or no effect on the other attributes of the products.

PART II: ANALYSIS OF COMPLEMENTARY FIELDS

The Diffusions of Innovation (Section IV)

Treating the efficiency gap as a special case of the diffusion of innovations allows us to draw on the much broader study of the factors that affect the speed with which technologies are developed and sold to the public.

- The literature emphasizes the importance of the supply-side, which has not received sufficient attention in the efficiency gap literature. A great deal of innovation and diffusion takes place on the supply-side, particularly in the early and most difficult period of the diffusion process, a period that performance standards address.
- The innovation diffusion literature exhibits concerns about factors that affect adoption that are similar to the market imperfections and barriers identified in the efficiency gap literature.
- There is a sharp difference in the literature between two views of the diffusion process that is similar to the difference of opinion about the efficiency gap. On the one side we find the neoclassical approach which assumes that consumers and producers have perfect information and act in a strictly rational fashion leading markets to be efficient. On the other side we find those who view the market as imperfect and actors as operating with bounded rationality, diverse motives, and imperfect information.

The Intersection of the Efficiency Gap and Climate Change Literatures (Section V)

The efficiency gap analysis and debate are not about externalities because we do not expect externalities to be priced into the market transactions. While environmental, national security and macroeconomic impacts of energy consumption stimulated interest in the value of reducing consumption, particularly after the oil price shocks and subsequent economic recessions of the 1970s, we would not expect market behavior to reflect their value. The efficiency gap arises from the failure of market transactions to reflect the costs of energy that are reflected in its price.. However, to the extent that the response to the externality of climate change is being analyzed, it sheds important light on the nature and importance of the efficiency gap.

- The climate change literature has squarely confronted the problem of market barriers and imperfections that affect innovation and diffusion of new technologies. The set of factors that underlies the inertia that slows the respond to climate change are similar to the market barriers and imperfections that underlie the efficiency gap.

- Thus, over the course of the last decade, the climate change analysis has come to highlight the question of the extent to which market processes through the reaction to price increases that might be associated with carbon taxes, can be relied upon. It is recognized broadly that price increases alone will elicit slow responses and impose unnecessary costs by prolonging the adjustment process.

- Instead, policies that seek to direct, target and accelerate technological innovation and diffusion are advocated. The evidence suggests that the cost of inertia is quite large, whereas targeted approaches lower costs and speed the transition.

- The causes of the sluggishness in the response to pricing carbon are identified as market barriers and imperfections, which parallel the barriers and imperfections identified in the efficiency gap literature.

To the extent that there are externalities associated with energy consumption, they magnify the concern about market barriers and imperfections that underlie the "efficiency gap," if only because the barriers and imperfections would make efforts to respond to externalities more difficult. If climate change is recognized as an external cost of energy consumption, it may magnify the importance and social cost of failing to address the efficiency gap. This is where the efficiency gap and climate change analysis intersect most strikingly.

I. INTRODUCTION

A. Purpose

Recently, energy efficiency standards have become a hot topic in energy policy circles. They had a very prominent place in the recent articulation of the Administration's climate policy[1] and several major standards are moving through analytic and regulatory reviews at the federal and state levels. Among the most prominent examples are major appliance efficiency standards in Washington D.C.[2] and Sacramento,[3] a sharp increase in energy efficiency building codes,[4] and National Research Council review of the fuel economy of medium and heavy duty trucks[5] tied to the first ever fuel economy standards for these vehicles.[6] At the same time, questions have recently been raised about the effectiveness of appliance standards by an academic researcher,[7] while the cost benefit analysis used to support recent performance standards across a broad range of consumer durables has been criticized, with a great deal of attention placed on the recent increase in CAFE standards that governs cars and pickup trucks (light duty vehicles).[8]

This exchange over energy efficiency performance standards is just the latest round in a debate that reaches back to the oil price shocks of the 1970s, when the dramatic increase in energy prices triggered intense analysis of U.S. energy consumption. The failure of U.S. households and businesses to adopt many apparently cost-effective technologies to reduce energy consumption came to be known as the" efficiency gap" or the "energy paradox."[9]

Consumer groups have participated in this debate from the outset.[10] Recently the Consumer Federation of America (CFA) has been involved in the development of many of the standards at issue, not only in regulatory proceedings,[11] but also in consensus standards reached with industry (ultimately approved by DOE.)

CFA has also conducted regular public opinion polls over the course of the past eight years to gauge consumer attitudes toward the underlying energy issues as well as the specific standards.[12] In those polls, CFA has found widespread concern about energy consumption and support for efficiency standards. In fact, the decision to double the fuel economy of light duty vehicles by 2025, which received so much attention, enjoyed broad based support, not only among consumers, but also from auto makers, auto workers, environmentalists and national security groups.[13] Similarly, the decision to increase the energy efficiency of light bulbs was supported by every American light bulb manufacturer,

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1 Executive Office of the President, 2013
2 Appliance Standards Awareness Project, 2013a.
3 Appliance Standards Awareness Project, 2013b.
4 U.S. Department of Energy, 2013; California Energy Commission, 2012.
5 Committee to Assess Fuel Economy for Medium and Heavy Duty Vehicles, 2010.
6 U.S. Environmental Protection Agency and Department of Transportation, 2011.
7 Levinson, 2013, rehashes an old argument about the extent to which California efficiency policy reduced consumption, although he did not challenge the cost effectiveness of the policy.
8 Grayer and Viscusi, 2012.
9 Stavins and Jaffee, 1994.
10 Cooper, 1980a, 1980b, 1981a, 1981b, 1982a, Cooper, Mark, 1982b.
11 CFA, 2010, 2011a, 2011b, 2011c, 2011d, 2012, ; Cooper 2008, 2009b, 2011a, 2011b, 2011c, 2011d.
12 CFA 2010, 2011a, 2011b.
13 CFA, 2012.

consumer groups and environmentalists.[14] CFA's economic and pocketbook analysis shows that this strong public support is well justified because efficiency standards are consumer-friendly energy and good economic policy.[15]

The contrast between the academic/think tank criticism of performance standards and our findings on the economic justification, not to mention the broad public support for standards and could not be sharper. This paper revisits the analysis of the efficiency gap by reviewing recent evidence on the underlying causes of the efficiency gap and the effectiveness of performance standards in closing it. It shows that the criticism and doubts about the efficiency gap and the beneficial effect of performance standards are unfounded and contradicted by a large body of empirical evidence and conceptual analysis.

B. THE CONSUMER INTEREST IN CLOSING THE EFFICIENCY GAP

The debate over the efficiency gap is not an esoteric academic exercise. It is a vitally important consumer and economic issue. Expenditures for household energy are among the largest of consumer expenditures, accounting for $4,600 in 2012 ($2,600 for gasoline and $2,000 for energy utilities). This is more than groceries (food at home, ~$3800), health care (~$3300), entertainment (~$2572), and clothing (~$1700).[16] Moreover, energy is a vital input for production of goods and services in a modern economy and electricity is the oxygen for the digital economy. Consumers also pay the cost of energy use in the commercial and industry sectors which is embedded in the cost of goods and services they produce. Thus, the direct and indirect stakes for consumers are huge.

Residential Appliances

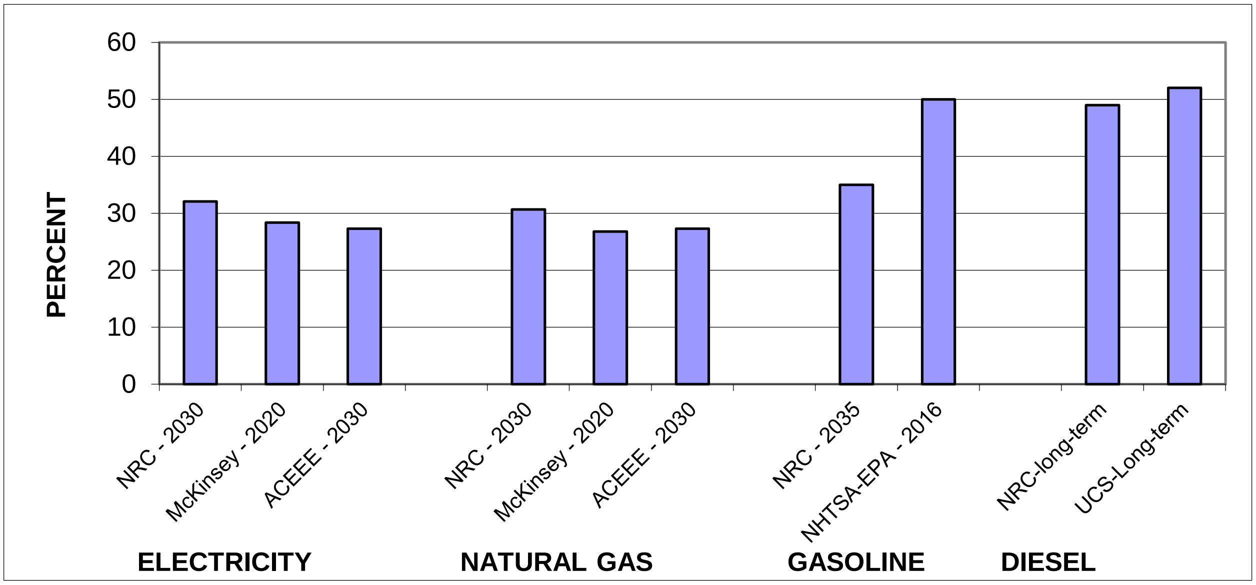
In comments filed in a proceeding that involved *Equipment Price Forecasting for Refrigerators, Refrigerator-freezers and Freezers,* CFA offered observations on the consumer benefits of more energy efficient appliances.

> CFA has been a party to numerous DOE rulemakings dealing with higher efficiency standards for home appliances, such as residential boilers and furnaces, air conditioners, water heaters, to name a few. We have long held that consumers benefit from more efficient products through lower energy costs. Incremental costs for efficiency improvements are paid back to the consumer in a reasonable amount of time—ultimately, the consumer saves money over the life of the product. For over eight years, CFA, working with its state and local affiliates, led a national public awareness campaign promoting increased consumer awareness of the economic, environmental and health benefits of energy efficient products and practices.[17]

Exhibit I-1, updated from the comments filed in the appliance efficiency proceeding, shows that there is a large potential to reduce the consumption of each of the forms of energy consumed by most households (electricity, natural gas, gasoline, and diesel). In those comments, CFA pointed out that there was widespread agreement among the most prestigious national research institutions that the potential benefit of greater energy efficiency is substantial.

[14] Cooper, 2011d, and hearing record.
[15] See note 10.
[16] Bureau of Labor Statistics, Consumer Expenditure Survey
[17] CFA, 2011c, p. 1.

EXHIBIT I-1: THE SIZE OF THE EFFICIENCY GAP ACROSS ENERGY MARKETS: TECHNICALLY FEASIBLE, ECONOMICALLY PRACTICABLE POTENTIAL ENERGY SAVINGS



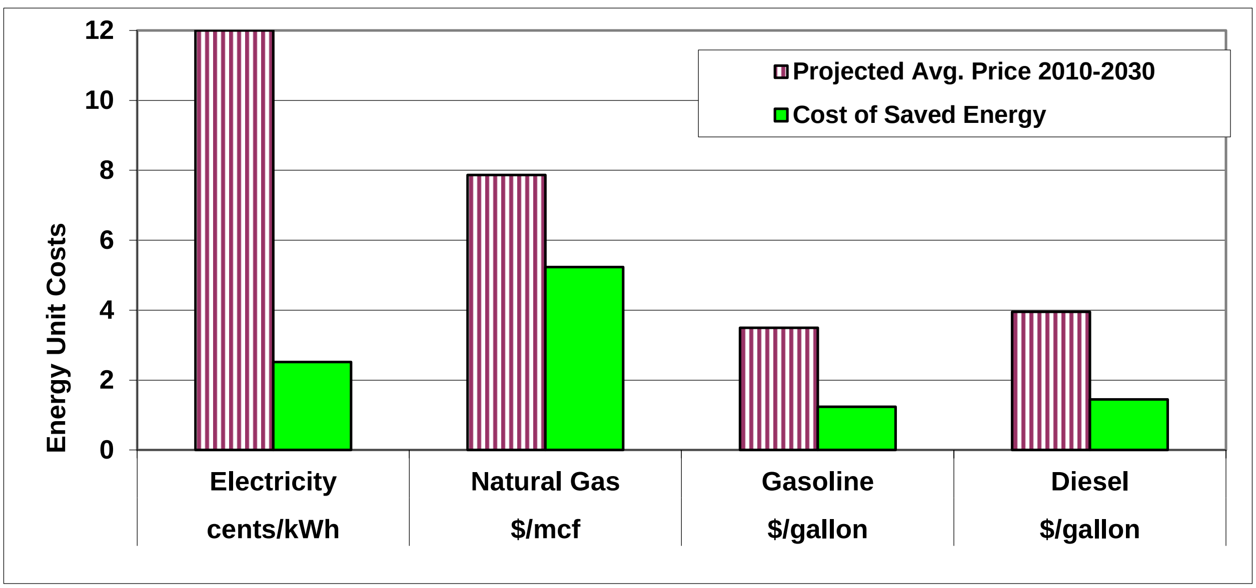
Sources and Notes: Updated from: Cooper, Mark, 2011b, *Comments of the Consumer Federation of America, Equipment Price Forecasting for Refrigerators, Refrigerator-freezers and Freezers,* Re: Docket Number EE–2008–BT–STD–0012, March 24. Energy prices 2010 and projections from Energy Information Administration, *Annual Energy Outlook: 2013;* Electricity and natural gas savings based on Gold, Rachel, Laura, et. al., *Energy Efficiency in the American Clean Energy and Security Act of 2009: Impact of Current Provisions and Opportunities to Enhance the Legislation*, American Council for an Energy Efficient Economy, September 2009), McKinsey Global Energy and Material, *Unlocking Energy Efficiency in the U.S. Economy* (McKinsey & Company, 2009); National Research Council of the National Academies, *America's Energy Future: Technology and Transformation, Summary Edition* (Washington, D.C.: 2009). The NRC relies on a study by Lawrence Berkeley Laboratory for its assessment (Richard Brow, Sam Borgeson, Jon Koomey and Peter Biermayer, *U.S. Building-Sector Energy Efficiency Potential* (Lawrence Berkeley National Laboratory, September 2008). Gasoline based on: National Highway Traffic Safety Administration, *Corporate Average Fuel Economy for MY2012-MY 2016 Passenger Cars and Light Trucks*, *Preliminary Regulatory Impact Analysis*, Tables 1b, and 10. The 7 percent discount rate scenario is used for the total benefit = total cost scenario; NAS -2010, National Research Council of the National Academy of Science, *America's Energy Future* (Washington, D.C.: 2009), Tables 4.3, 4.4; MIT, 2008, Laboratory of Energy and the Environment, On the Road in 2035: Reducing Transportation's Petroleum Consumption and GHG Emissions Cambridge: July, 2008), Tables 7 and 8; EPA-NHTSA - 2010, Environmental Protection Agency Department of Transportation In the Matter of Notice of Upcoming Joint Rulemaking to Establish 2017 and Later Model Year Light Duty Vehicle GHG Emissions and CAFE Standards, Docket ID No. EPA-HQ-OAR-0799 Docket ID No. NHTSA-2010-0131, Table 2, CAR – 2011. Diesel based on: Northeast States Center for a Clear Air Future, International Council on Clean Transportation and Southwest Research Institute, *Reducing Heavy Duty Long Haul Combination Truck Fuel Consumption and CO_2 Emissions,* October *2009;* Don Air, *Delivering Jobs: The Economic Costs and Benefits of Improving the Fuel Economy of Heavy-Duty Vehicles,* Union of Concerned Scientists, May 2010; Committee to Assess Fuel Economy for Medium and Heavy Duty Vehicles, *Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles,* National Research Council, 2010; Go 60 MPG, *Delivering the Goods: Saving Oil and Cutting Pollution from Heavy Duty Trucks.*

Exhibit I-1 shows that a 20 to 30 percent reduction in consumption for energy sources consumed directly by households is technically feasible and economically practicable. The potential long-term reduction in consumption of diesel fuel, which is used by heavy duty trucks is considerably larger, primarily because the first fuel economy standards were only recently adopted, almost forty years after the first fuel economy standards for light duty vehicles were adopted. We summarized the analytic consensus as follows:

> In the past year, four major national research institutions have released reports that document the huge potential for investments in energy efficiency to lower consumers' bills and greenhouse gas emissions, creating a win-win for consumers and the environment. The National Research Council of the National Academy of Sciences has estimated the potential reduction in electricity, natural gas and gasoline at approximately 30 percent, similar to the estimates of NHTSA/EPA. McKinsey and Company and the American Council for Energy Efficient Economy have reached a similar conclusion on electricity and natural gas. Across these three sectors, saving energy costs about one third of the price of producing it. With the publication of these studies, the question is no longer "Can efficiency make a major contribution to meeting the need for electricity in a carbon constrained environment?" These studies demonstrate that it can.[18]

As shown in Exhibit I-2, this potential energy savings can be achieved by including more energy efficient technologies in the consumer durables that use energy at a fraction of the cost of the energy consumption to consumers. Reduced energy consumption lowers the consumer energy bill much more than the cost of including the advanced technology to reduce the energy use of the durables. Simply put, it costs a lot less to save energy than to use it.

EXHIBIT I-2: THE COST OF SAVING ENERGY IS MUCH LOWER THAN THE PRICE PAID TO CONSUME ENERGY



Source: See Exhibit I-1, cost of saved energy is average of estimates across studies.

Cars and Light Duty Trucks

In commenting on the recently adopted long-term fuel economy standards for light duty vehicles, the Consumer Federation of America (CFA) pointed out that for new vehicles designed to meet the 2025 standard of 54.5 miles per gallon, the value of fuel savings to consumers was over 3 times the cost of the new technologies necessary to reduce gasoline consumptions.[19] Direct consumer

[18] CFA, 2011c, p. 7.
[19] CFA, 2012, p. 5.

pocketbook savings accounted for 80% of the total national savings (which also includes indirect benefits of reduced pollution, national security, public health, the environment, etc.). The comments described the results of the economic analysis as follows:

> At the end of the auto loan, the consumer will have saved an average of about $800. By the tenth year, the vehicle will have generated an average of over $3,000 in savings [and] resale values are likely to be much higher, by $1,000 to $2,000.
>
> Simple payback periods for new cars are less than three years; for new trucks, it will be less than two.
>
> The total discounted national benefits are close to $600 billion, a value that is well over three times the cost.
>
> Higher fuel economy standards are primarily a consumer benefit program, with consumer savings of close to $500 billion, over 80 percent of the total national benefits.[20]

With such large pocketbook benefits, CFA supported the new standards and urged the National Highway Traffic Safety Administration and the Environmental Protection Agency to implement them. With these savings available, we identified the obvious question:

- In a free-market economy, when the solution to an important problem is plentiful and cheap, one would expect that it would be widely adopted throughout society – If efficiency is such a bargain, why don't more people buy it?[21]

The answer to the question is well-known.

- Energy markets are imperfect, riddled with barriers and obstacles to efficiency, especially the market for electricity. Market imperfections lead to market failures and underinvestment in energy saving technologies.[22]

C. An Opposing View

Ironically, not long after our analyses of energy efficiency standards were filed as comments in federal regulatory proceedings, a White Paper from the Mercatus Center looked askance at the fact that

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[20] CFA, 2011a, p. xx

[21] McKinsey, 2009, p. 2. "The reasons to focus on energy efficiency are as simple as the questions are puzzling: If the economics of energy efficiency are so compelling and the technology is available and proven, why has the U.S. economy not captured more.of the energy efficiency available to it, particularly given the progression of efforts at federal and state levels, by government and non-government entities alike, over the past three decades? In other words, by what means could the United States realize a much greater portion of the energy efficiency available to it?"

[22] McKinsey, 2009, p. viii, "The highly compelling nature of energy efficiency raises the question of why the economy has not already captured this potential, since it is so large and attractive. In fact, much progress has been made over the past few decades throughout the U.S., with even greater results in select regions and applications. Since 1980, energy consumption per unit of floor space has decreased 11 percent in residential and 21 percent in commercial sectors, while industrial energy consumption per real dollar of GDP output has decreased 41 percent. As impressive as the gains have been, however, an even greater potential remains due to multiple and persistent barriers present at both the individual opportunity level and overall system level. By their nature, energy efficiency measures typically require a substantial upfront investment in exchange for savings that accrue over the lifetime of the deployed measures. Additionally, efficiency potential is highly fragmented, spread across more than 100 million locations and billions of devices used in residential, commercial, and industrial settings. This dispersion ensures that efficiency is the highest priority for virtually no one. Finally, measuring and verifying energy not consumed is by its nature difficult. Fundamentally, these attributes of energy efficiency give rise to specific barriers that require opportunity-specific solution strategies and suggest components of an overarching strategy."

"the preponderance of the estimated benefits stems from private benefits to consumers."[23] The Mercatus Center cannot accept the proposition that the market could possibly perform this poorly with respect to energy efficiency.

> How can it be that consumers are leaving billions of potential economic gains on the table by not buying the most energy-efficient cars, clothes dryers, air conditioners, and light bulbs? Moreover, how can it also be the case that firms seeking to earn profits are likewise ignoring highly attractive opportunities to save money? If the savings are this great, why is it that a very basic labeling approach cannot remedy this seemingly stunning example of completely irrational behavior? It should be quite simple to rectify decisions that are this flawed.[24]

Their view is that since "the preponderance of the assessed benefits is derived from an assumption of irrational consumer choice"[25] and such behavior is easily rectified by labeling programs, which already exist, "the main failure of rationality is that of the regulators themselves."[26] In their view, the fault lies in the agencies, whose analysis must be wrong because it was prepared under legal mandates structured so that "government officials act as if they are guided by a single mission myopia that leads to the exclusion of all concerns other than their agency's mandate."[27]

In fact, we showed in comments in every one of the rulemakings involving the major consumer durables about which the Mercatus Center complained (including light duty vehicles, clothes dryers and room air conditioners, among others)[28] that arguments like the ones made by the Mercatus Center are wrong. The efficiency gap does not rest on the assumption that consumers are irrational and regulators suffer from "institutional myopia."[29] Contrary to the claims of the critics of the efficiency gap analysis, there are a number of market barriers and imperfections that explain the poor performance of the market for consumer durables with respect to energy efficiency.[30] When these market barriers and imperfections are properly understood, the performance standards are not an example of "overriding consumer preferences with energy regulations,[31]" as Mercatus claims, rather

- Performance standards are a well-justified effort to overcome severe market constraints and cognitive limitations on human decision making that impose huge, unnecessary energy costs on consumers and the economy.

Put aside the conclusions of federal (National Highway Traffic Safety Administration, Environmental Protection Agency, Department of Energy) and state (California Air Resources Board, California Energy Commission) analysis. Ignore the analysis of institutions that can be seen as strongly environmentalist (American Council for an Energy Efficient Economy, Union of Concerned Scientists, Lawrence Berkeley Laboratory). Instead, focus on academic and more neutral organizations like the National Research Council, McKinsey and Company, Resources for the Future and MIT. The

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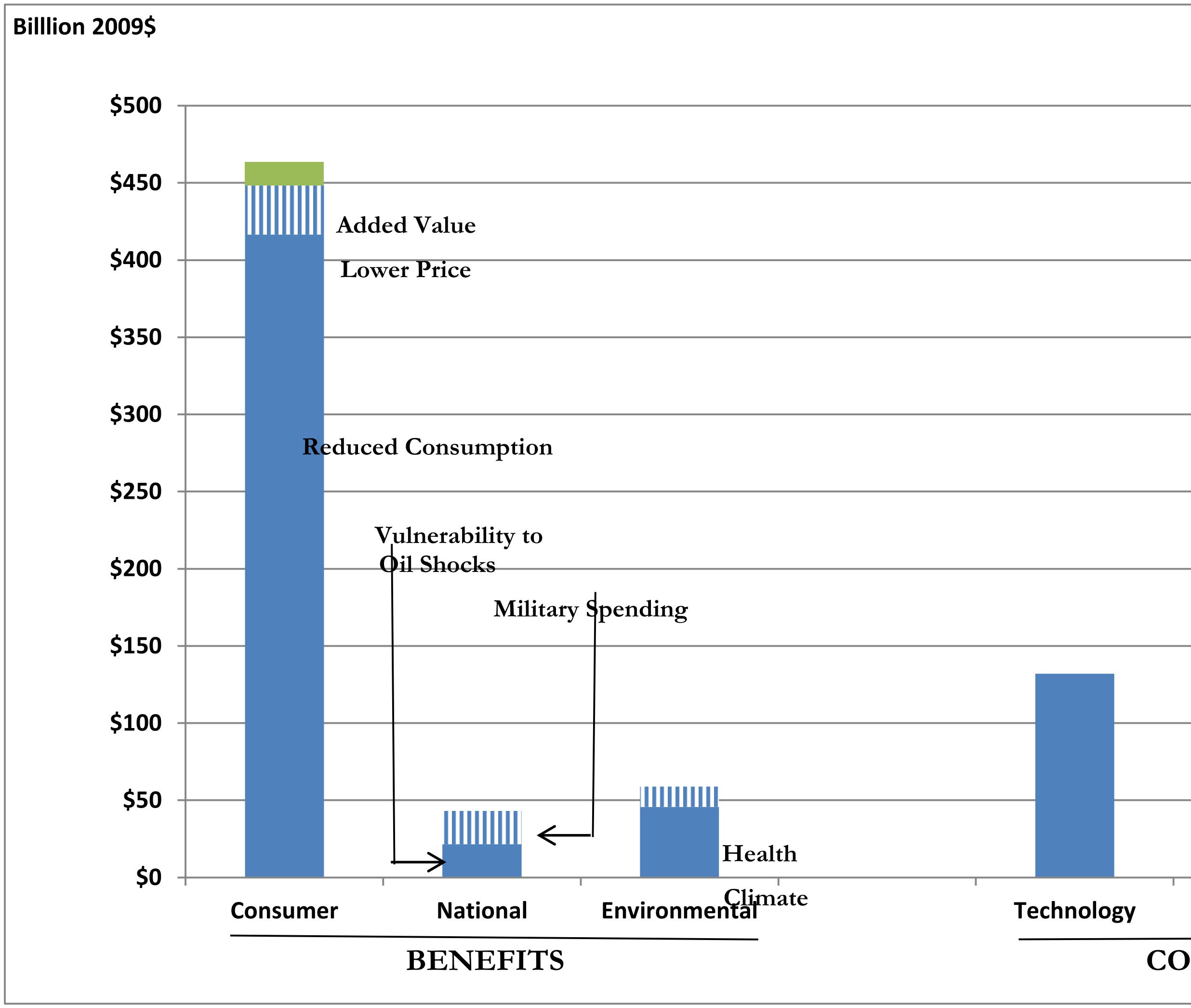
23 Grayer and Viscusi, 2012, p. i.
24 Id., p. 37.
25 Id., p. 1.
26 Id., p. 37.
27 Id., p. 38.
28 See note 11.
29 Grayer and Viscusi, 2012, p38.i.
30 The analytic weaknesses and biases in the recent criticism of the efficiency gap have been demonstrated by others. See for example Nadel and Langer, 2012, responding to Alcott and Greenstone, 2012, Alcott and Wozny, 2011.
31 Grayer and Viscusi, 2012, p. 1.

EXHIBIT I- 3: THE BENEFITS AND COSTS OF THE PROPOSED HIGHER FUEL ECONOMY STANDARDS: COMBINED CARS AND TRUCKS, 3% DISCOUNT



Benefits	Billion 2009$
Reduced Consumption	416.5
Lower Price	31.7
Added Value	24.4
Oil Vulnerability	21.5
Military Spending	21.5
Climate	45.6
Health	13.3
Subtotal	574.5
Costs	
Technology	(132.1)
Congestion	(30.0)
Health	(14.3)
Subtotal	(176.4)
Evaluation	
Net Benefit	398.1
Benefit Cost Ratio	3.26-to-1

Source and notes: Office of Regulatory Analysis and Evaluation National Center for Statistics and Analysis, *Preliminary Regulatory Impact Analysis Corporate Average Fuel Economy for MY 2017-MY 2025, Passenger Cars and Light Trucks,* November 2011, Tables 13, VIII-27b, Consumer Benefits include effect of $31.6 billion based on a value of $0.25/gallon. National benefits include reduced military spending valued at $0.17 per gallon.

conclusion is the same, consumers could lower their energy bills by about $1,000 per year if the market reached its full energy savings potential. Net consumer pocketbook savings would be two thirds of that, after the costs of the energy savings technology are paid.[32]

D. "The Efficiency Gap:" Past and Present

The two different views of the market performance fit squarely in a long standing economic debate. For over 30 years, economists, engineers and policy analysts have described a phenomenon in energy markets that came to be known as the "energy paradox" or the efficiency gap.[33] Engineering/economic analyses showed that technologies exist that could potentially reduce the energy use of consumer durables – everything from light bulbs to air conditioners, water heaters, furnaces, building shells and automobiles. Because the reduction in operating costs more than offset the initial costs of the technology, resulting in substantial potential economic benefits, we confront the "paradox:"

Even in the industrial sector, where firms are considered to be motivated primarily by economic profitability incentives, the efficiency gap is evident. A recent review of 160 studies of industrial energy efficiency investments conducted for the United Nations Industrial Development Organization (UNIDO) framed the analytic issue in terms that are similar to the terms we used.

> Why do organizations impose very stringent investment criteria for projects to improve energy efficiency?
>
> Why do organizations neglect projects that appear to meet these criteria?
>
> Why do organizations neglect energy efficient and apparently cost-effective alternatives when making broader investment, operational, maintenance and purchasing decisions?[34]

The answer offered in a UNIDO companion paper is grounded in both the new case studies and the long history of analysis of energy efficiency.

> Because of barriers to energy efficiency these seemingly profitable measures are not being adopted… these barriers may generally be characterized as "postulated mechanisms that inhibit a decision or behavior that appears to be both energy efficient and economically efficient. There is a large body of literature on the nature of barriers to energy efficiency at the micro and the macro level, which draws on partly overlapping concepts from neo-classical economics, institutional economics (including principal-agent theory and transaction cost economics), behavioral economics, psychology and sociology). Barriers at the macro level involve price distortions or institutional failures. In comparison, the literature on barriers at the micro level tries to explain why organizations fail to invest in energy efficiency even though it appears to be profitable under current economic conditions determined at the macro level.[35]

Thus, the Mercatus Center challenge to the existence of the efficiency gap and the finding of consumer benefit from performance standards is contradicted by three decades of evidence. Moreover, that evidence has been growing stronger in recent years, not only as a result of the collection of more

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32 This observation is based on the fact that the cost of saved energy is equal to about one-third of the cost of consuming the energy.

33 Golove and Eto, 1996.

34 Sorrel, Mallet and Nye , 2011, p. 11

35 Schleich and Gruber, 201, pp. 1-2. A similar formulation is offered by Thollander, Palm and Rohdin, p.3.

detailed and extensive data, but also as more sophisticated models of market behavior develop in economics.

However, even those who conclude that the market barriers and imperfections create a substantial efficiency gap have identified several areas where additional analysis is needed in order to build a stronger case that the efficiency gap exists and that it needs to be closed by effective policy responses. As Sanstad, Hanemann and Auffhammer put it,

> The technical knowledge base for energy efficiency that has developed over the past three decades is much greater than our understanding of the human elements that enter into efficiency adoption decisions, and the application of such knowledge to practical policy and program design… Over the past decade or more, the debate over market barriers and market failures and other arguments over first principles… have yielded rather limited output of theoretical and empirical research on the actual details of the energy-efficiency investment and adoption decisions of households and firms. Understanding these details is necessary if we are to design programs and other interventions that sharply increase the penetration of efficient end-use technologies.[36]

The decade that Sanstad, Hanemann and Auffhammer found wanting ended about ten years ago. Since then a considerable amount of empirical and conceptual progress has been made. The goal of this paper is to refine and deepen the understanding of the efficiency gap relying primarily on the recent work. It fills in the details and identifies the key characteristics for effective policy responses.

Within the broad body of new evidence and conceptual refinement, two important areas have received a great deal of attention in the past decade. First, decisions by firms about adoption of energy saving technology take on greater importance because firms are assumed to have economic efficiency motivations and skills. Second, the supply-side of the energy efficiency market has been recognized as particularly important. The market outcome reflects both the supply of and demand for technologies. As Carl Blumstein has recently noted:

> But what if the energy-efficiency gap was regularly framed as a *supply-side* problem, such as a concern about whether problems in the *supply-chain* create a gap between the energy-efficiency potential of goods and services and the adoption of energy-efficient goods and services? After all, in many instances consumer choices are constrained because it is not practical for manufacturers to produce a continuum of choices; suppliers can only provide a limited set of discrete choices within a range of prices, functionality and energy efficiency. In addition, even when the choice set of energy users is not constrained, limitations related to the behavior of actors in the supply chain may restrict consumer choices.[37]

E. OUTLINE

The paper is divided into two parts. Part I, which is comprised of Sections II-III, reviews recent efficiency gap literature. Part II which contains Sections IV-V reviews complementary fields of analysis.

Section II discusses several conceptual frameworks that identify the factors that inhibit investment in energy efficiency and cause the efficiency gap. We begin with an "old" framework, from the mid-1990s and then review six conceptualizations from the past ten years. The ssection also

[36] Sanstad, Hanemann and Auffhammer, 2006, pp. 6-3, 6-4…6-17.
[37] Blumstein and Taylor, 2013, p.2.

describes the empirical evidence from the past decade that supports the existence of an efficiency gap. The body of the paper presents our interpretation of the literature. Section II concludes with policy implications of the "efficiency gap literature." It begins with the results of several efforts to evaluate the effectiveness of various policy instruments to close the efficiency gap. These make a strong case that performance standards are a very attractive approach to reducing the efficiency gap.

Section III reviews cost benefit analyses of various standards. It confirms the relatively low cost of efficiency noted in Exhibit I-1. It identifies several factors that lead to the systematic underestimation of the net benefits of performance standards. These include the overestimation of the cost of meeting the standards, the failure to include indirect macroeconomic effects, and other non-energy benefits of the standards in regulatory analysis. Section III extracts policy implications for the design of effective performance standards. Performance standards are not the only policy that is needed, but given their ability to address numerous market barriers and imperfections, they are a critical cornerstone of consumer-friendly energy policy.

Appendix A provides citations for the conceptual frameworks and empirical evidence summarized in Section II, as well as descriptions of three dozen empirical studies conducted in the past decade that shed important light on the efficiency gap.

Part II provides brief reviews of two fields of analysis that are closely related to the efficiency gap and reinforce the findings of Part I. The discussion of the literature on two related subjects complement the analysis of the efficiency gap in two ways. The diffusion literature reinforces the conceptual understanding of how the efficiency gap develops. The climate change literature provides another layer of empirical analysis that describes market barriers and imperfections that affect energy technology investment decisions.

Section IV provides a brief review of the literature on the diffusion of innovation of new products and technologies. Since the innovation diffusion literature addresses a central question of the efficiency gap (how does technology get adopted) from a broader perspective and has a long history, it gives another perspective that reinforces the conceptualization of the efficiency gap. It has also recently come to emphasize the importance of the supply-side of the market in the diffusion process.

Section VI provides a brief review of the recent conceptual and empirical economic analyses of responses to climate change, which adds another perspective on the efficiency gap literature. Recent empirical work stimulated by concern about climate change has afforded the opportunity to shine a spotlight on the need to achieve rapid change in economic behavior. In analyzing market responses to a signal to change energy use patterns, the empirical work documents many market failures, barriers and imperfections that would inhibit investment in low carbon technologies. These failures, barriers and imperfections are similar to those observed in the efficiency gap literature. The immense amount of empirical work being done on this aspect of the climate change policy debate supports the validity of and deepens the understanding of the efficiency gap. Section VI concludes with some observations on the empirical and policy implications of these complementary literatures. Appendix B provides citations for the conceptual frameworks and empirical evidence summarized in Section VI.

PART I
RECENT EFFICIENCY GAP ANALYSIS

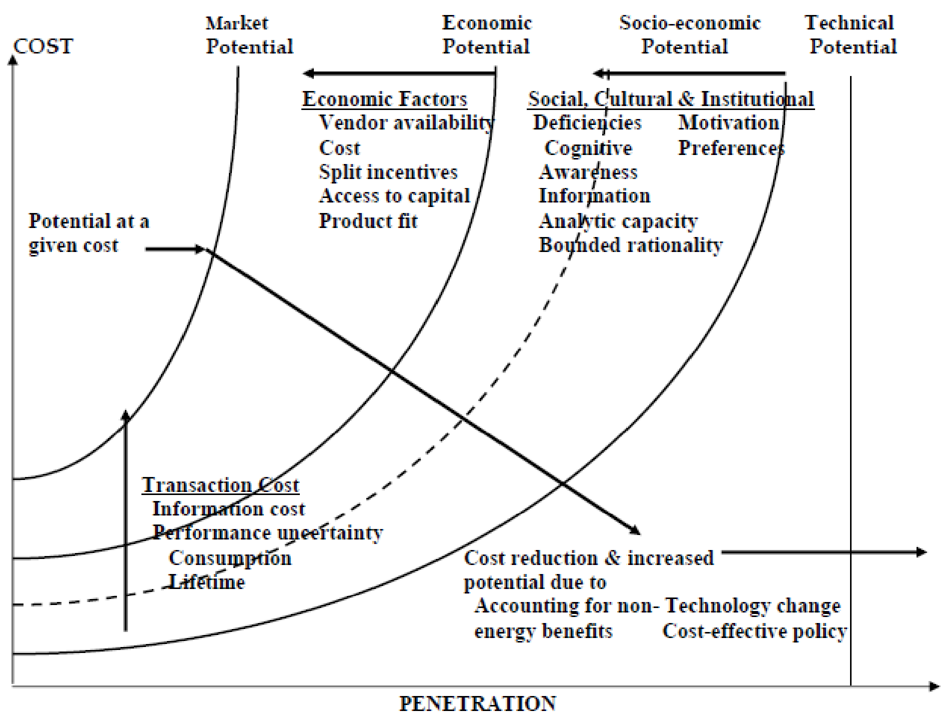
II. COMPREHENSIVE EXPLANATIONS OF THE EFFICIENCY GAP

This section presents a comprehensive analytic framework that explains the energy efficiency gap by examining several frameworks that have been developed over the past two decades. These frameworks rest upon a strong foundation of empirical analysis that has been developed over more than a quarter of a century and strengthened considerably in the past decade. After developing the overall framework, we review the recent empirical evidence that supports key pieces of the framework.

A. THE LBL FRAMEWORK

An analytic framework that rests on a technology investment approach was offered by analysts at Lawrence Berkeley National Laboratory (LBL). As shown in in Exhibit II-1, one can use a technology investment framework to assess the factors that cause investment in energy efficiency to fall well short of the technical potential.

EXHIBIT II-1: PENETRATION OF MITIGATION TECHNOLOGIES: A CONCEPTUAL FRAMEWORK



Source: **Jayant Sathaye and Scott Murtishaw, *Market Failures, Consumer Preferences, and Transaction Costs in Energy Efficiency Purchase Decisions* (California Energy Commission, November 2004), p. 11.**

The LBL study identified broad categories of market imperfections, barriers, and obstacles that are important in determining the level of investments – economic, transaction cost, and social cultural and institutional. The analysis emphasizes the important role that policy can play in determining where the market will settle. Thus, there are six broad categories of factors that must be incorporated into the analysis of the level of investment in energy saving technologies. Market performance is influenced by:

- behavioral factors (social, cultural & institutional)
- economic factors
- transaction costs
- externalities (non-energy costs)
- technological change
- public policy

Exhibit II-2 summarizes an earlier 1996 paper prepared by other analysts at the LBL.[38] Exhibit A-II-2 provides citations. The analysis was framed in terms of the role of policy intervention to promote efficiency as states restructured the electricity market. The paper "focuses on understanding to what extent some form of future intervention may be warranted and how we might judge the success of particular interventions."[39] Restructuring did not spread throughout the utility industry and in the past few years, reliance on interventions in the market to increase efficiency and renewables has grown, even in the deregulated states.[40] The growth of market interventions is consistent with the conclusions in the LBL paper.

> We conclude that there are compelling justifications for future energy-efficiency policies. Nevertheless, in order to succeed, they must be based on a sound understanding of the market problems they seek to correct and a realistic assessment of their likely efficacy.[41]

EXHIBIT II-2: MARKET BARRIERS TO ENERGY EFFICIENCY

Barriers[1]	**Market Failures**	**Transaction Cost[2]**	**Behavioral factors[16]**
Misplaced incentives	Externalities	Sunk costs[3]	Custom[17]
Agency[4]	Mis-pricing[20]	Lifetime[5]	Values[18] & Commitment[19]
Capital Illiquidity[8]	Public Goods[22]	Risk[6] & Uncertainty[7]	Social group & status[21]
Bundling	Basic research[23]	Asymmetric Info.[9]	Psychological Prospect[24]
Multi-attribute	Information	Imperfect Info.[10]	Ability to process info[27]
Gold Plating[11]	(Learning by Doing)[25]	Availability	Bounded rationality[26]
Inseparability[13]	Imperfect Competition/	Cost[12]	
Regulation	Market Power[28]	Accuracy	
Price Distortion[14]			
Chain of Barriers			
Disaggregated Mkt.[15]			

William H. Golove and Joseph H. Eto, *Market Barriers to Energy Efficiency: A Critical Reappraisal of the Rationale for Public Policies to Promote Energy Efficiency.* For citations, see Appendix A, Exhibit A-II-2

As shown in Exhibit II-2, the Golove and Eto paper identified four broad categories of factors that inhibited investments in energy efficiency – barriers, transactions costs, market failures, and behavioral (noneconomic) factors. It identifies about two dozen specific factors spread roughly equally across these four categories. A key aspect of the analysis is to identify each of the categories as coming from a different tradition in the economic literature. The barriers category is made up of

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38 Golove and Eto, 1996.

39 Golov and Eto, 1996, p. iv.

40 There has recently been a dramatic re-commitment to publicly-sponsored energy efficiency and a substantial increase in allocated resources, Sanstad, Hanemann and Auffhammer, 2006, p. 6-5.

41 Golove and Ito, 1996, p. x.

market structural factors. The market failure category is made up of externalities and imperfect competition. The LBL paper bases a substantial part of its argument on a transaction cost perspective as a critique of neo-classical economics.

> Neo-classical economics generally relies on the assumption of frictionless transactions in which no costs are associated with the transaction itself. In other words, the cost of activities such as collecting and analyzing information; negotiating with potential suppliers, partners and customers; and risk are assumed to be nonexistent or insignificant. This assumption has been increasingly challenged in recent years. The insights developed through these challenges represent an important way to evaluate aspects of various market failures (especially those associated with imperfect information).[42]

Starting from the observation that "transaction costs are not insignificant but, in fact, constitute a primary explanation for the particular form taken by many economic institutions and contractual relations"[43] the LBL paper identifies such costs and information as a critical issue, pointing out that "the key issue surrounding information is not its public goods character, but rather its asymmetric distribution combined with the tendency of those who have it to use it opportunistically."[44] Indeed, information plays a very large role in the analysis, entering in six different ways. In addition to the public goods and asymmetry concerns, the paper identifies four other ways information can create a barrier to efficiency –"(1) the lack of information, (2) the cost of information, (3) the accuracy of information, and (4) the ability to use or act upon information."[45]

C. THE RFF FRAMEWORK

A more recent paper from Resources for the Future (RFF), entitled *Energy Efficiency Economics and Policy,* addresses exactly the same issues as the earlier LBL paper – the debate over the efficiency gap observed in energy markets. The authors of the RFF paper characterize the efficiency gap debate as follows:

> Much of the literature on energy efficiency focuses on elucidating the potential rationales for policy intervention and evaluating the effectiveness and cost of such interventions in practice. Within this literature there is a long-standing debate surrounding the commonly cited "energy efficiency gap..." Within the investment framework… the energy efficiency gap takes the form of under investment in energy efficiency relative to a description of the socially optimal level of energy efficiency. Such under investment is also sometimes described as an observed rate or probability of adoption of energy-efficient technologies that is "too slow."[46]

The RFF framework is summarized in Exhibit II-3. Exhibit A-II-3 provides citations. Exhibit II-3 is taken from the RFF paper, but extended in two ways. In the market failure category, it shows the distinction between the structural and societal levels suggested by the paper. It also includes a few more specific failures that were discussed in the text, but not included in the original table. There are about a dozen specific market failures spread across these categories.

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[42] Golove and Eto, p. 22.
[43] Golove and Eto, p. 23.
[44] Golove and Eto, p. 23.
[45] Golove and Eto, p. 20.
[46] Gillingham, Newell and Palmer, p. 7.

EXHIBIT II-3: MARKET AND BEHAVIORAL FACTORS RELEVANT TO ENERGY EFFICIENCY

Societal Failures	***Structural Failures***	***Potential Behavioral Failures***[11]
Energy Market Failures	Capital Market Failures	Prospect theory[12]
Environmental Externalities[1]	Liquidity constraints[5]	Bounded rationality[13]
Energy Security	Information problems[6]	Heuristic decision making[14]
Innovation market failures	Lack of information[7]	Information[15]
Research and development spillovers[2]	Asymmetric info. >	
Learning-by-doing spillovers[3]	Adverse selection[8]	
Learning-by-using[4]	Principal-agent problems[9]	
	Average-cost electricity pricing[10]	

Source: Kenneth Gillingham, Richard G. Newell, and Karen Palmer, *Energy Efficiency Economics and Policy* (Resources for the Future, April 2009). For Citations, see Appendix A, Exhibit A-II-3

The RFF paper suggests three broad categories of market failures – the individual, the interaction between economic agents and the fit between economic agents and society. We refer to these three levels as the behavioral, the market structural and the societal levels. In the present context, we consider behavioral failures to represent consumer behavior that is inconsistent with utility maximization, or in the current context, energy service cost-minimization. In contrast, market failure analysis is distinct in presupposing individual rationality and focusing on the conditions surrounding interactions among economic agents and society.[47] The societal level market failures are closest to what the traditional sources of the economic literature refers to as market failure. These are primarily externalities and public goods. These were also considered market failures in the LBL framework. The LBL barriers and transaction costs fit in the category of interactions between economic agents, as would imperfect competition.

One obvious point is that, once again, information problems occur in all categories of the RFF analysis, with several manifestations in each. Information can be a problem at the societal level since it can be considered a public good that is not produced because the authors of the information cannot capture the social value of information. It is a structural problem because, where it is lacking, even capable, well-motivated individuals cannot make efficient choices. Finally, where it is asymmetric, individuals can take advantage of the less informed to produce outcomes that are not efficient. It is a problem at the behavioral level where individuals lack the ability to gather and process information.

D. OTHER RECENT COMPREHENSIVE EFFICIENCY GAP FRAMEWORKS

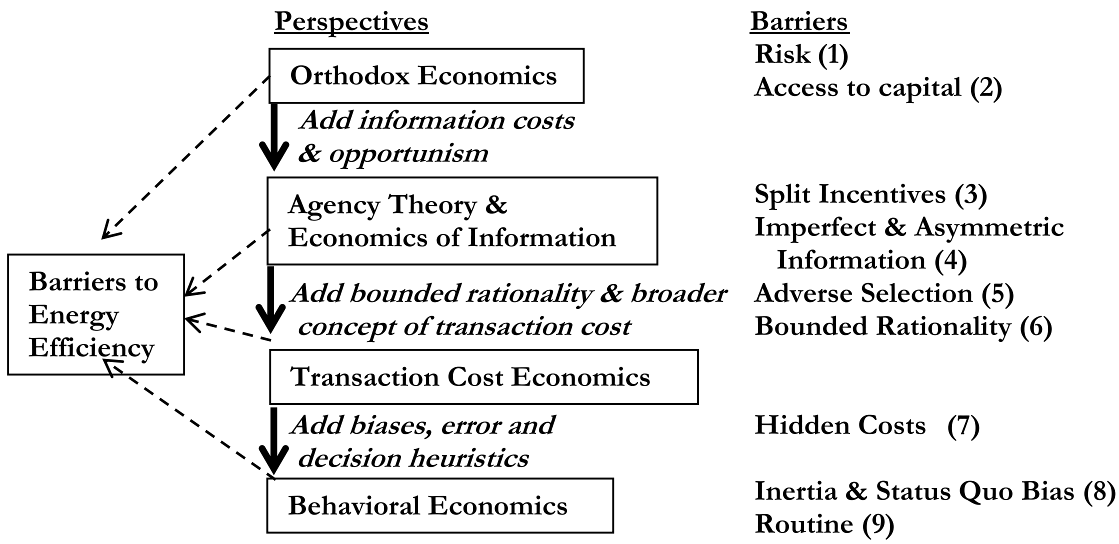
In the past few years, several comprehensive reviews have been offered that attempt to depict the many diverse factors that underlie the efficiency gap.

The United Nations Industrial Development Organization

Exhibit II-4 summarizes a recent comprehensive review of the causes of the efficiency gap in industrial sectors across the globe. Exhibit A-II-4 provides citations. It is based on a conceptualization and analysis prepared for the United Nations Industrial Organization by analysts at universities in the United Kingdom (hereafter UNIDO). It is based on a review of over 160 studies of barriers to energy efficiency in industrial enterprises.

[47] Id., p. 8.

EXHIBIT II-4: BARRIERS TO INDUSTRIAL ENERGY EFFICIENCY



Steve Sorrell, Alexandra Mallett & Sheridan Nye. *Barriers to industrial energy efficiency, A literature review,* United Nations Industrial Development Organization, Vienna, 2011, Figure 3.1 & Section 3. For citations, see Appendix A, Exhibit A-II-4.

It can be argued that the analysis of industrial sectors provides the most compelling evidence that an energy efficiency gap exists, since these are contexts in which the incentive to adopt economically rational technologies should be strong, if not pure, and the knowledge and ability to evaluate alternatives should be greater than society at large. Moreover, since energy is a cost of doing business, records and data should be superior to the residential sector, so evaluation and calculation should be better. In spite of these factors pointing toward economic rationality, and notwithstanding assumptions of motivation and capability, these authors find solid empirical evidence that the efficiency gap exists.

As was the case in the LBL analysis, the UNIDO analysis identified a school of economic thought that can be closely associated with each of the categories of market barriers and imperfections. The broad categories in the UNIDO analysis match up well with the perspectives offered by LBL and RFF with the addition of the category of externalities. The UNIDO document offers six broad types of barriers, with two dozen subtypes.

McKinsey and Company

A fourth comprehensive approach that adds depth to the analysis is the framework offered in a detailed analysis of efficiency in the building sector prepared by McKinsey and Ccompany, which is described in Exhibit II-5. Exhibit A-II-5 provides citations. The McKinsey conceptualization of barriers and obstacles to energy efficiency uses three broad categories – structural, behavioral and availability. There are about two dozen specific barriers described. Moreover, McKinsey identifies nine different clusters of activity in the building sector. The manifestation of the barriers is different in the clusters, so McKinsey ends up with fifty discrete barriers.

EXHIBIT II-5: MCKINSEY AND COMPANY MARKET BARRIERS TO HOME ENERGY EFFICIENCY

Kckinsey Category	McKinsey Nature	McKinsey Description	Cluster
Behavioral	Awareness	Low priority, Preference for other attributes	CD, RLA
Availability	Availability	Restricted procurement, 1st cost focus	CD
Behavioral	Awareness	Shop for price and features	RD
Behavioral	Awareness	Limited understanding of use and savings	CEPB, EH, GB, RLA
Behavioral	Custom & Habit	Little attention at time of sale	NH
Behavioral	Custom & Habit	Underestimation of plug load	RD
Behavioral	Custom & Habit	Aversion to change	CI,
Behavioral	Custom & Habit	CFLS perceived as inferior	RLA
Behavioral	Hurdle	Payback-Hurdle, 28% discount rate	CEPB
Behavioral	Hurdle	Payback-Hurdle,40% discount rate	EH
Behavioral	Use	Improper use and maintenance	CEPB, EH, RD
Behavioral	Awareness	Not accountable for efficiency	CI
Availability	Capital	Competing use of capital	EH, GB, RLA, CI
Structural	Agency	Tenant pays, builder ignores	CEPB, EH, RD
Availability	Availability	Lack of contractors	EH
Availability	Availability	Lack of availability in area	NH
Availability	Availability	Lack of demand => lack of R&D	RD
Availability	Availability	Emergency replacement	RLA
Availability	Bundling	Efficiency bundled with other features	RLA
Structural	Owner Transfer	Lack of premium at time of sale	CD, NH, NPB, RLA
Structural	Owner Transfer	Limits payback to occupancy period	EH
Structural	Transaction	Lack of information	NPB
Structural	Transaction	Disruption during improvement process	EH
Structural	Transaction	Difficult to identify efficient devices	RD
Behavioral	Risk/Uncertainty	Business failure risk	CEPB
Behavioral	Risk/Uncertainty	Lack of reliability	CI
Structural	Transaction	Research, procurement and preparation	EH, GB, RLA

Clusters
CD = Commercial Devices;
CEPB = Commercial Existing Private Buildings;
CI = Commercial Infrastructure;
EH = Existing Homes;
GB = Government Buildings;
NH = New Homes;
NPB = New Private Commercial Buildings;
RD = Residential Devices;
RLA = Residential Lighting and Appliances

SOURCE: McKinsey and Company, *Unlocking Energy Efficiency in the U.S. Economy,* July 2009, Tables 2, 3, 4, 5, 6, 8, 9, 10, 11, 12, Exhibits 14, 15, 16, 19, 21, 24, 26, 27, 29, 30. For citations, see Appendix A, Exhibit A-II-5

Exhibit II-6 presents the framework utilized by the California Energy Institute in evaluating policies to increase energy efficiency in businesses. It is notable in two respects. First, it is oriented toward businesses, which is a useful antidote to the overemphasis on residential consumers in the efficiency gap debate. Second, it explicitly endeavors to summarize and compile the various approaches to analyzing the "efficiency gap," used by others. In doing so, it returns to the traditional distinction that is made between market failures, which are recognized in neoclassical approaches, and other obstacles to investment in energy efficiency in the market. It identifies two other broad categories – market barriers and non-economic factors.

E. EMPIRICAL EVIDENCE OF MARKET BARRIERS AND IMPERFECTIONS

Appendix B provides brief descriptions of recent empirical studies that lend support to various aspects of the efficiency gap analysis. It provides descriptions of almost four dozen empirical studies (or reviews of empirical studies) from which these specific examples are drawn. We divide the literature into three broad areas: General (which address the market failures, barriers and imperfections), surveys (which are frequently used to determine willingness to pay and identify attitudinal obstacles to investment in energy efficiency), and cost benefit analyses (which test the central question: 'are standards worth it?')

EXHIBIT II-6: MARKET FAILURES, BARRIERS AND NON-ECONOMIC FACTORS

Neo Classical Economics

Explanations for the gap:

1. The gap is illusory
2. There are hidden or unaccounted for costs of energy efficiency investments
3. Consumer markets are heterogeneous
4. High discount rates assigned to energy efficiency investments resulting from perceived risk

Conditions that are known to cause market failure:

1. externalities
2. public goods
3. imperfect information
4. imperfect competition

Market Barriers

1. Situations involving Misplaced or Split Incentives (also called agency problems)
2. Limited Availability of Capital,
3. Market Power
4. Regulatory Distortions
5. Transaction Costs
6. Inseparability of energy efficiency features from other desirable or undesirable product features

Non-Economic Explanations

1. Rationality is only one of several decision-making heuristics that may be applied in a given decision-making situation.
2. Decision makers employ varying decision-making heuristics depending on the situation.
3. Decision-making units are often not individuals.
4. Decisions made by organizations are affected by a wide variety of social processes and heavily influenced by the behaviors of their leaders.

Organizational Influences:

Authority

Size

Hierarchy of needs (1. Health and Safety Requirements,2. Regulatory Compliance, 3. Corporate Improvement Initiatives, 4. Maintenance) 5. Productivity, 6. Importance of Energy Efficiency to Profitability

Management policy 1. Whether the organization has annual energy efficiency goals. 2. Whether reserves and budgets are established for funding energy efficiency investments. 3. Whether hurdle rates for energy efficiency investments are high or low. 4. The review process that is to be used to evaluate energy efficiency improvements. 5. Who is responsible for "managing" the company's energy efficiency program).

Sources: Edward Vine, 2009, *Behavior Assumptions Underlying Energy Efficiency Programs For Businesses,* California Institute for Energy and Environment, January.

Exhibit II-7 lists the full array of market failures, barriers and imperfections that cause the underinvestment in energy saving technologies derived from the conceptual discussion above. It identifies the individual problems that the recent empirical literature observed in the energy market. Citations are provided in Appendix A, Exhibit A-II-7.

Embedded in the literature reviews for each of the recent studies are citations to earlier empirical studies that provide the context for the more recent research. All of the failures, barriers and imperfections have been supported in the empirical literature, which is why they have been recognized in the conceptual frameworks. We will not review all the many studies that support each problem. Here we summarize several important, repeated broad themes.

EXHIBIT II-7: RECENT EMPIRICAL EVIDENCE ON MARKET FAILURES, BARRIERS AND IMPERFECTIONS

TRADITIONAL ECONOMICS & INDUSTRIAL ORGANIZATION

Externalities
- Public goods[1] & Bads[2]
- Basic research
- Network effects
- Information as a public good
- Learning-by-doing & Using[9]

Industry Structure
- Imperfect Competition
  - Concentration[13]
  - Barriers to entry
  - Scale[18]
  - Switching costs[20]
- Technology[23]
  - R&D
  - Investment[25]
- Marketing
  - Bundling: Multi-attribute[26]
  - Substitutes[27]
- Cost-Price
  - Limit impact of price[29]
    - Fragmented Mkt.[30]
    - Limited payback[31]

Regulation
- Price[34]
  - Infrequent
  - Aggregate, Avg.-cost[35]
- Lack of commitment[36]

NEW INSTITUTIONAL ECONOMICS

Endemic Imperfections
- Asymmetric Info[3].
- Agency[5]
- Adverse selection[6]
- Perverse incentives
- Lack of capital[10]

TRANSACTION COST
- Search and Information
- Imperfect info[14]
  - Availability[16]
  - Accuracy
  - Search cost[21]
- Bargaining
  - Risk & Uncertainty[24]
  - Liability
- Enforcement
- Sunk costs
- Hidden cost[28]

Political Power
- Power of incumbents to hinder alternatives
- Monopolistic structures and lack of competition
- Importance of institutional support for Alternatives[32]
- Inertia[33]

BEHAVIORAL ECONOMICS

Motivation & Values
- Non-economic[4]

Influence & Commitment
- Custom[7]
- Social group & status[8]

Perception
- Bounded Vision/Attention[11]
- Prospect[12]

Calculation.
- Bounded rationality[15]
- Limited ability to process info[17]
- Heuristic decision making[19]
- Discounting difficulty[22]

See Appendix A Exhibit A-II-7 for citations.

Positive Externalities

There is a very large literature on the externalities associated with energy consumption. Importantly, it goes well beyond the negative national security and environmental externalities, which are frequently noted in energy policy analysis. The macroeconomic effects of energy consumption and energy savings are important externalities of the efficiency gap.

There are two macroeconomic effects that have begun to receive a great deal of attention – multipliers and price effects. These will be discussed in greater length in the next section, as they belong in the cost benefit analysis as a substantial benefit. They can be briefly described as follows. Reducing energy consumption tends to reduce economic activities that have relatively small multipliers (especially when energy imports are involved as in the transportation sector) and increase economic activities that have large multipliers (including the direct effects of spending on technology and the indirect effect of increased household disposable income).

A second set of externalities that receives considerable attention is the effect of learning that can be stimulated by a performance standard that pushes firms to make investments they would not have made without the presence of the standard. This will be discussed in the next section, since it affects the cost side of the cost-benefit calculation.

Information and Behavior

Consumers and producers are poorly informed, influenced by social pressures and constrained in their ability to make the calculations necessary to arrive at objectively efficient decisions. Consumers and producers apply heuristics that reflect rationality that is bounded by factors like risk and loss aversion. Inattention to energy efficiency is rational, given the magnitude, variability and uncertainty of costs, as well as the multi-attribute nature of energy consuming durables. Consumers are influenced by social norms and advertising.

The product is a bundle of attributes in which other traits are important and energy costs are hidden costs. The resulting energy expenditures are important components of total household spending. Important benefits of energy consuming durables may be "shrouded" in the broader multi-attribute product.

Market Structure and Transaction Costs

Uncertainties about the nature of the market and the value and cost of technology and limitations of technological expertise and information play an important role, increasing the cost and raising the risk of adopting new technologies.

As a result of these factors, the marketplace yields a limited set of choices because producers and consumers operate under a number of constraints. Split incentives flowing from the agency problem are a frequently analyzed issue. When the purchaser of the energy consuming durables and the users are different people, inefficient choices result.

The market exhibits a high "implicit" discount rate, which we interpret as the result of the many barriers and imperfections that retard investment in efficiency enhancing technology. There are several aspects of the high discount rate that deserve separate attention. There is a low willingness to pay and a low elasticity of demand.

F. PERFORMANCE STANDARDS AS A POLICY RESPONSE TO THE EFFICIENCY GAP

A number of the comprehensive studies we have reviewed above also include evaluations of potential policy options for addressing the market barriers and imperfections. These are described in Exhibits II-8 through II-10. One of the clearest conclusions that can be derived from these assessments is that performance standards – appliance efficiency standards, auto fuel economy standards and building codes – are seen as a very attractive policy options because they are effective and address many important barriers.

For example, the European study summarized in Exhibit II-9 identifies over half a dozen ways in which performance standards address more than half a dozen barriers.

EXHIBIT II-8: POLICY INSTRUMENT FOR REDUCING GREENHOUSE GAS EMISSIONS FROM BUILDINGS

Policy	Energy/CO2 Effectiveness	Cost Effectiveness	# of Barriers Addressed	Economic	Hidden Cost	Market Failure	Culture	Political
Appliance standards	High	High	3	1	1	1		
Energy efficiency obligations	High	High	2	1		1		
DSM	High	High	2	1		1		
Tax exemptions/ reductions	High	High	2	1		1		
EPC/ESCO	High	Medium/High	3	1	1	1		
Building codes	High	Medium	3	1	1	1		
Coop. Procurement	High	Medium	2	1		1		
Public leadership programs	Medium/High	High/Medium	4		1	1	1	1
Labeling and certification programs	Medium/High	High/Medium	3	1		1	1	
Procurement.	Medium/High	High/Medium	3	1	1	1		
Energy certificates	Medium/High	High/Medium	2	1		1		
Energy certificates	Medium/High	High/Medium	1	1				
Voluntary and negotiated agreements	Medium/High	Medium	2			1	1	
Mandatory audit requirement	High & variable	Medium	1				1	
Public benefit charges	Medium	High	2	1		1		
Capital subsidies,	High	Low	2	1		1		
Detailed disclosure programs	Medium	Medium	2			1	1	
Education and information programs	Low/Medium	Medium/high	2			1	1	
Taxation (on CO2 or fuels)	Low/Medium	Low	1	1				
Kyoto Protocol flexible	Low	Low	1			1		

Source: Sonja Koeppel, Diana Urge-Vorsatz and Veronika Czako, 2007,*Evaluating Policy Instruments for Reducing Greenhouse Gas Emissions from Buildings – Developed and Developing Countries,* Assessment of Policy Instruments for Reducing Greenhouse Gas Emission from Buildings, Center for Climate Change and Sustainable Energy, Central European University, Tables 1 and 3.

EXHIBIT II-9: ASSESSMENT OF POLICY INSTRUMENTS IN PLACE IN THE EUROPEAN UNION

POLICY EVALUATION CRITERIA / POLICY APPROACH	Importance of main barrier the policy instrument addresses	Impact/ expected impact of policy instrument	Increased impact by further broadening or strengthening	Policy for specific barrier/ tackles several barriers	Clear/ appropriate to target/ barrier	Compatible with other instruments	Compatible with MS/ appropriate as EU instrument
Directive on energy end-use efficiency and energy services	5	5	3	4	3	3	4
Energy performance of buildings directive	4	5	4	2	4	3	5
EPBD-related CEN mandate to develop a set of standards	3	4	4	2	4	3	4
Eco-design directive	3	3	4	2	3	4	4
Eco-label regulation	3	2	3	3	5	3	3
Energy labeling directive	2	3	4	3	4	4	4
Environmental technology verification	2	3	na	2	3	2	3
'Intelligent energy Europe" programme	2	2	na	3	3	1	4
Structural, Cohesion Funds & European Investment Bank	3	2	2	2	3	1	3
Energy taxation	1	1	2	1	3	1	1

Source: Andreas Uihlein and Peter Eder, 2009, *Toward Additional Policies to Improve the Environmental Performance of Buildings,* European Commission, Joint Research Centre, Institute for Prospective Technological Studies, Table 9.

EXHIBIT II-10: EVALUATION OF 20 POLICIES

Policy Type	Policy Instrument	Target	Achieved
Regulation	Building performance standards	2	4
	Building regulations	2	1
	Efficiency commitment	2	2
	Mandatory target on consumption	2	2
	Top runner	2	2
	Labelling of appliances	2	2
	Obligation on management	1	1
Financial	Soft loans	2	3
	Investment deductions	1	1
Information	Local advice	1	1
	Energy audits public	2	4
	Energy audits private	2	2
	Network	1	1
	Industry concepts	1	1
	Individual advice service	1	1
	Eco-driving	2	3
	FEMP	2	2
Voluntary	Efficiency agreements	2	2
	ACEA	2	2
Procurement	Energy	1	1
	BELOK	1	4
		2=Quantitative	4=Achieved or overachieved

Source: Mirjam Harmeling, Lara Nilsson, and Robert Harmsen, 2008, "Theory-based Policy Evaluation of 20 Energy Efficiency Instruments, *Energy Efficiency,* 1, p.48.

- The barriers addressed include transaction costs, economic uncertainties, lack of technical skill, Barriers to technology deployment, inappropriate evaluation of cost efficiency, insufficient and incorrect information on energy features, operational risks, and bounded rationality constraints.
- Mechanisms that reduce barriers include information and capacity building by stimulating the demand side, creation and promotion of a stable market, establishment of a methodology for calculating the energy performance of a building, standards on calculation of energy need for heating and cooling, standards on energy performance rating, ensure that there are sufficient incentives, demand side stimulation, creation of a functioning efficiency supply market, ensure that qualification, accreditation and certification schemes are available, reliable monitoring and diagnostics procedures.

Simply put, performance standards address more barriers and are more effective in overcoming them and more likely to achieve their goals. Similarly, in the McKinsey analysis discussed above, the combination of building codes and appliance standards addresses every one of the barriers.

We have long argued that performance standards are attractive for exactly this reason. Our earlier analysis identified a long list of market barriers and imperfections that are addressed by performance standards, as shown in Exhibit II-11. The ability of standards to address the market failure problems goes beyond their ability to address the barriers to investment in efficiency enhancing technologies that focus on consumer behavioral and transaction cost economics. Standards can address the behavioral and transaction cost problems that afflict the supply-side of the market, as well as some of the structural problems. [48] This evaluation of the important role of performance standards is supported by the recent evaluations.

EXHIBIT II-11: CAUSES OF MARKET FAILURE ADDRESSED BY STANDARDS

TRADITIONAL ECONOMICS & INDUSTRIAL ORGANIZATION	NEW INSTITUTIONAL ECONOMICS		BEHAVIORAL ECONOMICS
SOCIETAL FAILURES Externalities Information	**ENDEMIC FLAWS** Agency Asymmetric Information Moral Hazard	**TRANSACTION COSTS** Sunk Costs Risk Uncertainty Imperfect Information	**BEHAVIORAL FACTORS** Motivation Calculation/ Discounting
STRUCTURAL PROBLEMS Scale Bundling Cost Structure Product Cycle Availability			

Source: Mark Cooper, 2009, Comments of the Consumer Federation of America, Proposed Rulemaking to Establish Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards, Department of Transportation, Environmental Protection Agency, 40 CFR Parts 86 and 600, 49 CFR Parts 531,633, 537, et al., November 28, p. 64.

[48] Cooper, 2009b, p . 64

III. COST/ BENEFIT ANALYSIS

A. THE COST AND QUANTITY OF SAVED ENERGY

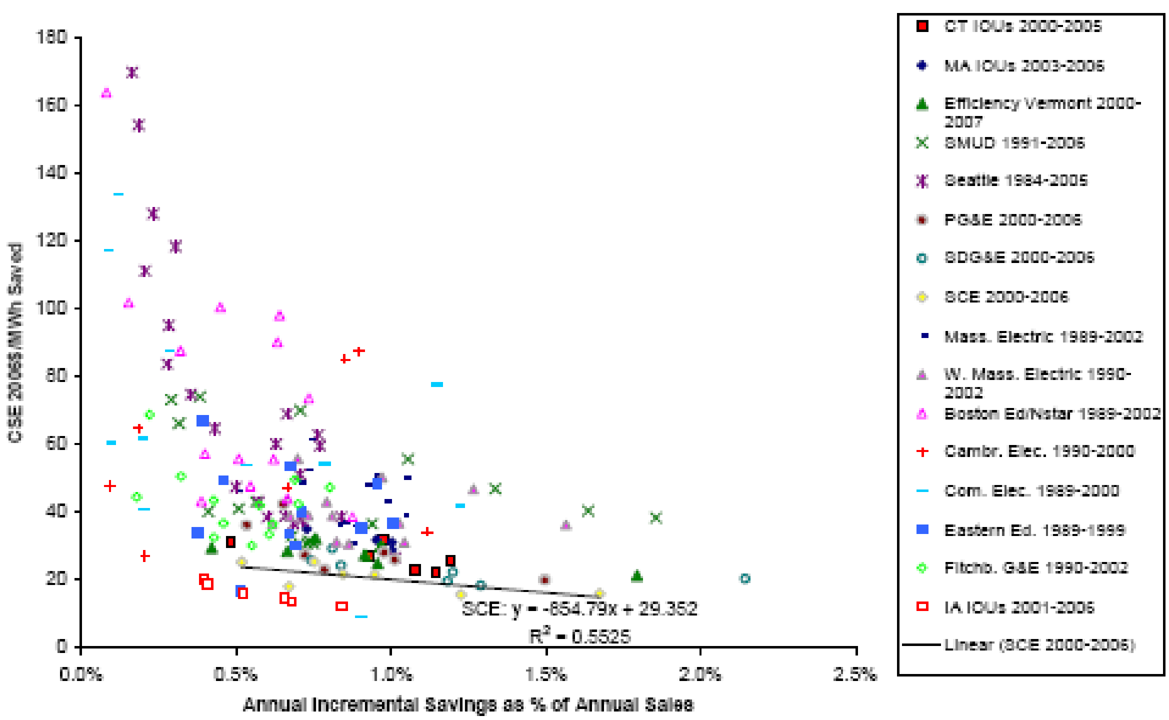
Cost

Engineering economic analyses provided the initial evidence for the efficiency gap. *Ex ante* analyses indicated that there would be substantial net benefits from including technologies to reduce energy consumption in consumer durables. As these policies were implemented *ex post* analyses were conducted to ascertain whether the *ex ante* expectations were borne out.

The most intense and detailed studies were conducted by utilities subject to regulation. Exhibit III-1 shows the results of analyses of the cost of efficiency in sixteen states over various periods covering the last twenty years. The data points are the annual average results obtained in various years at various levels of energy savings. The graph demonstrates two points that are important for the current analysis.

- First, the vast majority of costs fall in the range of $20/MWh to $50/MWh (i.e. 2 to 5 Cents/kwh).
- Second, the higher the level of energy savings, the lower the level of costs. There is certainly no suggestion that costs will rise at high levels of efficiency.

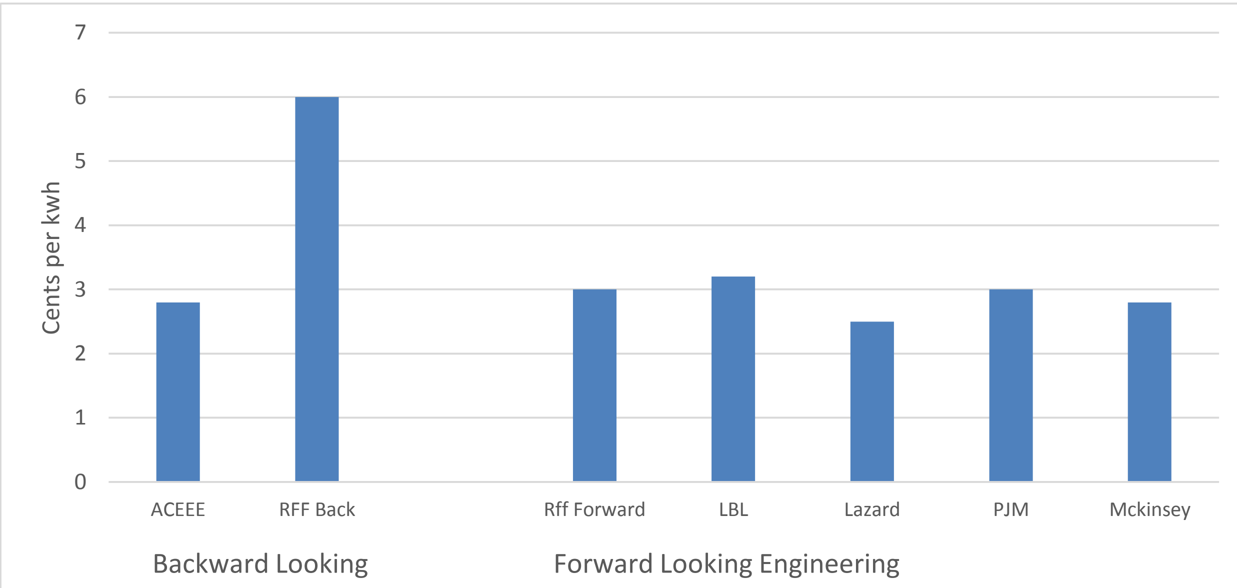
EXHIBIT III-1: UTILITY COST OF SAVED ENERGY (2006$/MWH) VS. INCREMENTAL ANNUAL SAVINGS AS A % OF SALES



Source: Kenji Takahasi and David Nichols, "Sustainability and Costs of Increasing Efficiency Impact: Evidence from Experience to Date," *ACEEE Summer Study on Energy Efficient Buildings* (Washington, D.C., 2008), p. 8-363.

This analysis of the actual cost of saved energy is consistent with several other analyses that look back at what has been achieved by efficiency policy. As shown in Exhibit III-2, several other efforts to look back at achieved costs reach similar conclusions, including estimates from Resources for the Future and the U.S. Department of Energy. The forward looking estimates from research institutions like Lawrence Berkeley labs and McKinsey and Company are similar. In fact, utilities and Wall Street analysts use similar estimates.

EXHIBIT III-2: THE COST OF SAVED ELECTRICITY



Source: Kenji Takahasi and David Nichols, "Sustainability and Costs of Increasing Efficiency Impact: Evidence from Experience to Date," ***ACEEE Summer Study on Energy Efficient Buildings*** **(Washington, D.C., 2008), p. 8-363, McKinsey Global Energy and Material,** ***Unlocking Energy Efficiency in the U.S. Economy*** **(McKinsey & Company, 2009); National Research Council of the National Academies,** ***America's Energy Future: Technology and Transformation, Summary Edition*** **(Washington, D.C.: 2009). The NRC relies on a study by Lawrence Berkeley Laboratory for its assessment (Richard Brown, Sam Borgeson, Jon Koomey and Peter Biermayer,** ***U.S. Building-Sector Energy Efficiency Potential*** **(Lawrence Berkeley National Laboratory, September 2008).**

Quantity

The cost of technologies to reduce energy consumption are frequently converted to the a simple measure of the cost of saved energy by dividing the investment cost (with appropriate discount rates and deflators) by the quantity of energy saved. These estimates of the cost of saved energy (COSE) enjoy a strong consensus. The quantity of energy that has been or can be saved is subject to more debate. The best empirical evidence is that at least 40% of the reduced electricity consumption in California can be attributed to its energy policies – appliance efficiency standards, building codes, and utility efficiency programs.[49] The recent study by Levinson mentioned in the introduction corroborates this finding using the same basic model. It shows that about 39% of the

[49] Kandel, Shieridan and McCAuliffe, 2008, p. 10. This study addresses the research need identified by Sudarshan and Anant, 2008. Some results are closer to 50%, which is consistent with Bernstein, 2003.

reduction could be attributed to California policies. However, it then goes on to challenge that finding by introducing a new set of variables, but that final analysis is fatally flawed and deserves to be given no weight.[50]

All of the above analyses of the effect of energy policy arrive at the estimate indirectly, by trying to estimate the other factors that affected electricity consumption and attributing the unexplained variance to policy. However, as suggested by the analysis of price, the impact of some of the policies can be examined directly. In fact, the 2008 paper that estimated that policy accounted for 43% of the variance, showed a strong correlation between a ranking of energy efficiency programs,[51] and the level of electricity consumption.[52] The strong correlation between program ranking and the level of energy consumption is instructive but imprecise.[53] Efforts to directly assess the impact of policy instruments more precisely support the conclusion that policy matters.

Charles Cicchetti examined the relationship between spending on utility energy efficiency programs and incremental savings attributed to those programs. As shown in the upper graph in Exhibit III-3, he found a strong relationship, with spending explaining almost of half of the variance in energy savings. Exhibit III-3 also identifies the states that equaled or exceeded California's performance on electricity growth over the past 30 years. Even in this elite group, policy effort matters.

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[50] The analysis that includes the additional variables is methodologically flawed, statistically inferior, and substantively meaningless. The introduction of 26 regional variables wreaks havoc on the analysis.

- It adds almost nothing to the explained variance.
- It renders the key analytic variables on which the most of the paper focuses (climate and income) statistically insignificant (half of the variables are not even larger than their standard errors).
- It reverses the sign of the climate variables.

With a large number of cases (32,000), when a small number of variables has this large effect on the variables already in the equation, there must be a severe colinearity problem. Kandel, Sheridan and McAuliffe (2008) identified this problem in explaining why they did not introduce state-specific dummy variables. Yet, the Levinson study presents no analysis of the magnitude and meaning of colinearity.

- It does not show the coefficients and statistics for the newly introduced variables.
- It does not show results for regressions with the 26 variables alone or in combination with an analytically meaningful subset of variables.
- It apparently shifts away from robust standard errors, which are most important when there is a colinearity problem.
- It provides no statistical tests to assess the impact of colinearity.

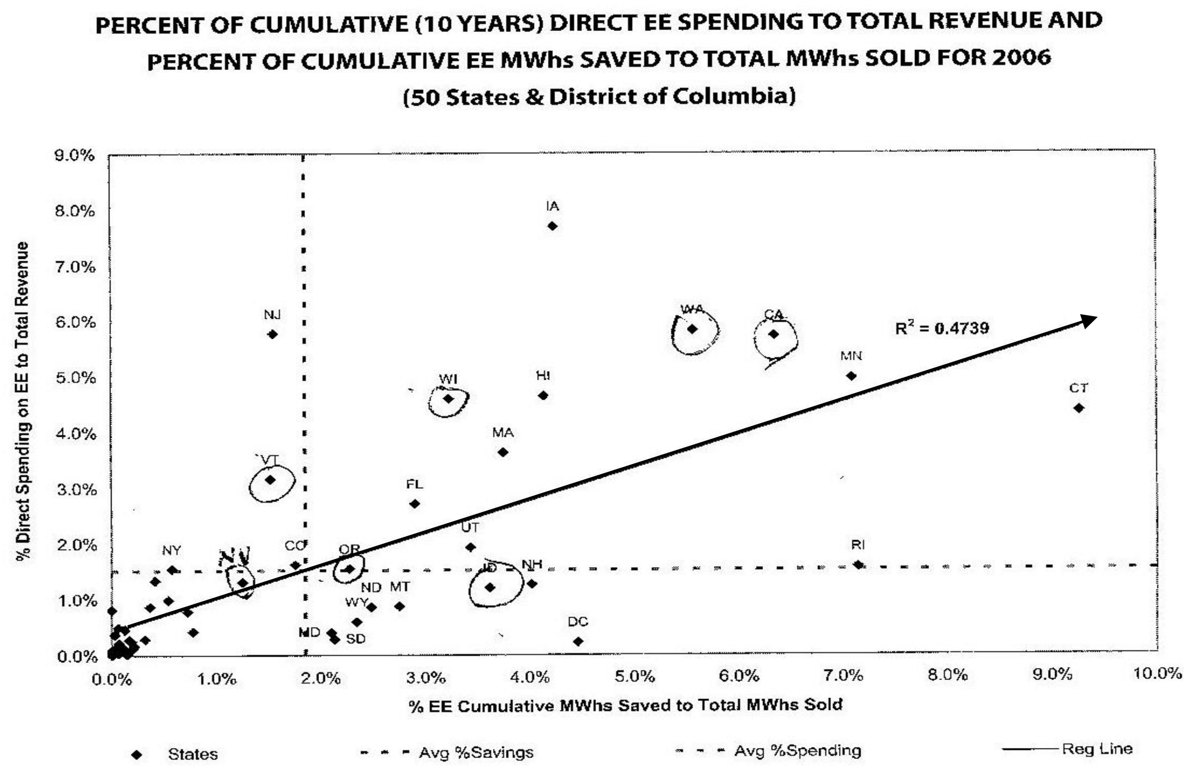
Given these statistical characteristics and problems, it is certain that the model without the regional variables is a better model (more parsimonious and statistically efficient). There are other methodological problems with the paper. It singles out California because it has held electricity consumption per capita flat over a thirty year period. Yet, there are six other states that have done the same thing. These other states are included in the comparison group, when they belong in the treatment group. Moving these six states from the comparison to the treatment group increases the growth of consumption of the comparison group by 15 percentage points (unweighted average). That these six states belong in the treatment group is demonstrated by the fact that their average ACEEE score on electricity programs is twice as high as the remainder of the comparison group. The average score for these six is almost 15, which is much closer to California's score of 19, than the score of the remainder of the comparison group, which is 7.

[51] Eldridge, 2007

[52] Kandel, Shieridan and McCAuliffe, 2008.

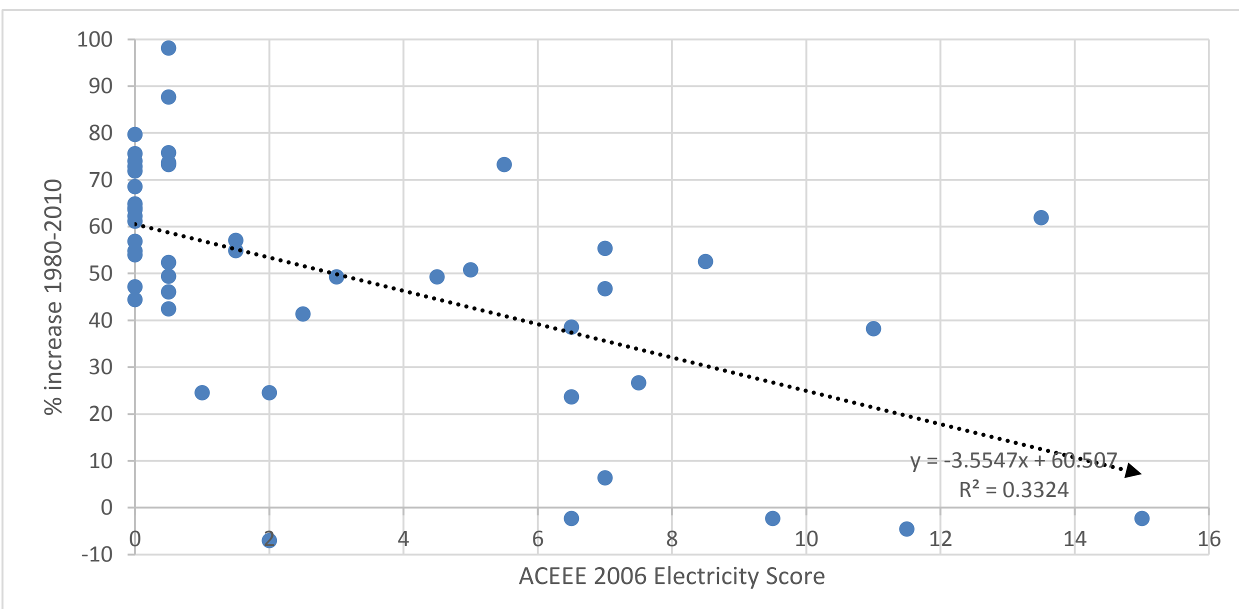
[53] In fact, the authors did not calculate correlation coefficients. Moreover, the graph uses total energy consumption, which is vulnerable to criticism, since it is the change in consumption that matters.

Exhibit III-3: Utility Energy Efficiency Spending and Savings



Source: Charles Cicchetti, *Going Green and Getting Regulation Right,* Public Utilities Reports, 2009, p. 105.

ACEEE Spending 2006, EIA Consumption (contiguous, lower 48 states)



Source: U.S. EIA State Database; Eldridge, Maggie, et al. The State Energy Scorecard for 2006, American Council for and Energy Efficient Economy, June 1.

The lower graph uses the ACEEE 2006 spending (as in Kandel, Sheridan and McCAuliffe, 2008) as a proxy for long term effort at efficiency and correlates it with the growth of consumption over the 1980-2010 period. Again, the correlation is strong and significant.

If the policy accounts for 40% or more of the savings in growth of electricity consumption, over the long term that represents about a 20% reduction in electricity consumption. This is consistent with the engineering estimates cited in Section I.

B. OVERESTIMATION OF COSTS

While the aggregate data in Exhibit III-1 appear to suggest a very strong downward trend, the data for individual utilities suggest a moderate downward trend. Exhibit III-1 shows the trend line for one individual utility. The trend is very slightly negative. The authors suggest that declining costs for higher levels of efficiency can be explained by economies of scale, learning and synergies in technologies. As utilities do more of the cost effective measures, costs decline. Also, if technical potential is much higher than achievable savings, economies of scale and scope and learning could pull more measures in and lower costs. This explanation introduces an important area of analysis in the "energy gap" debate – learning curves.

Policies to reduce the efficiency gap, like performance standards, will improve market performance. By overcoming barriers and imperfections, well-designed performance standards will stimulate investment and innovation in new energy efficient technologies. A natural outcome of this process will be to lower not only the level of energy consumption, but also the cost of doing so. The efficiency gap literature addresses the question of how "learning curves" will affect the costs of new technologies as they are deployed.[54] There are processes in which producers learn by experience to lower the cost of new technologies dramatically. The strong focus on the supply-side and innovation underlies the observation above that aggressive policies to stimulate innovation and direct technological change can speed the transition and lower the ultimate costs.

In the efficiency gap area, the issue of declining costs driven by technological change has received significant examination as a natural extension of the effort to project technology costs. One of the strongest findings of the empirical literature is to support the theoretical expectation that technological innovation will drive down the cost of improving energy efficiency and reducing greenhouse gas emissions. A comprehensive review of *Technology Learning in the Energy Sector* found that energy efficiency technologies are particularly sensitive to learning effects and policy.

> For demand-side technologies the experience curve approach also seems applicable to measure autonomous energy efficiency improvements. Interestingly, we do find strong indications that in this case, policy can bend down (at least temporarily) the experience curve and increase the speed with which energy efficiency improvements are implemented.[55]

The findings on learning curve analysis are extremely important because decisions to implement policies that promote efficiency and induce technological change are subject to intensive, *ex ante* cost-benefit analysis. Analyses that fail to take into account the powerful process of technological innovation that lowers costs will overestimate costs, undervalue innovation, and

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[54] The issue was made explicit in the appliance efficiency standards proceeding.

[55] Junginger, et al., 2008, p. 12; Kiso, 2009, find for Japanese automobiles that "fuel economy improvement accelerated after regulations were introduced, implying induced innovation in fuel economy technology."

perpetuate the market failure. Detailed analysis of major consumer durables including vehicles, air conditioners, and refrigerators find that technological change and pricing strategies of producers lowers the cost of increasing efficiency in response to standards.

> 1. For the past several decades, the retail price of appliances has been steadily falling while efficiency has been increasing.
>
> 2. Past retail price predictions made by the DOE analysis of efficiency standards, assuming constant price over time, have tended to overestimate retail prices.
>
> 3. The average incremental price to increase appliance efficiency has declined over time. DOE technical support documents have typically overestimated the incremental price and retail prices.
>
> 4. Changes in retail markups and economies of scale in production of more efficient appliances may have contributed to declines in prices of efficiency appliances.[56]

> The more specific point here is that, while regulatory compliance costs have been substantial and influential, they have not played a significant role in the pricing of vehicles. Vehicle prices have steadily increased over time, far exceeding the costs of emission control and safety equipment…
>
> These cost increases, to the extent they are substantial, are dealt with in the short run by a variety of pricing and marketing strategies and by allocating R&D costs further into the future and over more future models. As with any new products or technologies, with time and experience, engineers learn to design the products to use less space, operate more efficiently, use less material, and facilitate manufacturing. They also learn to build factories in ways that reduce manufacturing cost. This has been the experience with semiconductors, computers, cellphones, DVD players, microwave ovens – and also catalytic converters.
>
> Experience curves, sometimes referred to as "learning curves," are a useful analytical construct for understanding the magnitude of these improvements. Analysts have long observed that products show a consistent pattern of cost reduction with increases in cumulative production volume. …
>
> In the case of emissions, learning improvements have been so substantial, as indicated earlier, that emission control costs per vehicle (for gasoline internal combustion engine vehicles) are no greater, and possibly less, than they were in the early 1980s, when emission reductions were far less.[57]

A comparative study of European, Japanese and American auto makers prepared in 2006, before the recent reform and reinvigoration of the U.S. fuel economy program, found that standards had an effect on technological innovation. The U.S. had lagged because of the long period of dormancy of the U.S. standards program and the fact that the U.S. automakers did not compete in the world market for sales, (i.e. it did not export vehicles to Europe or Japan).

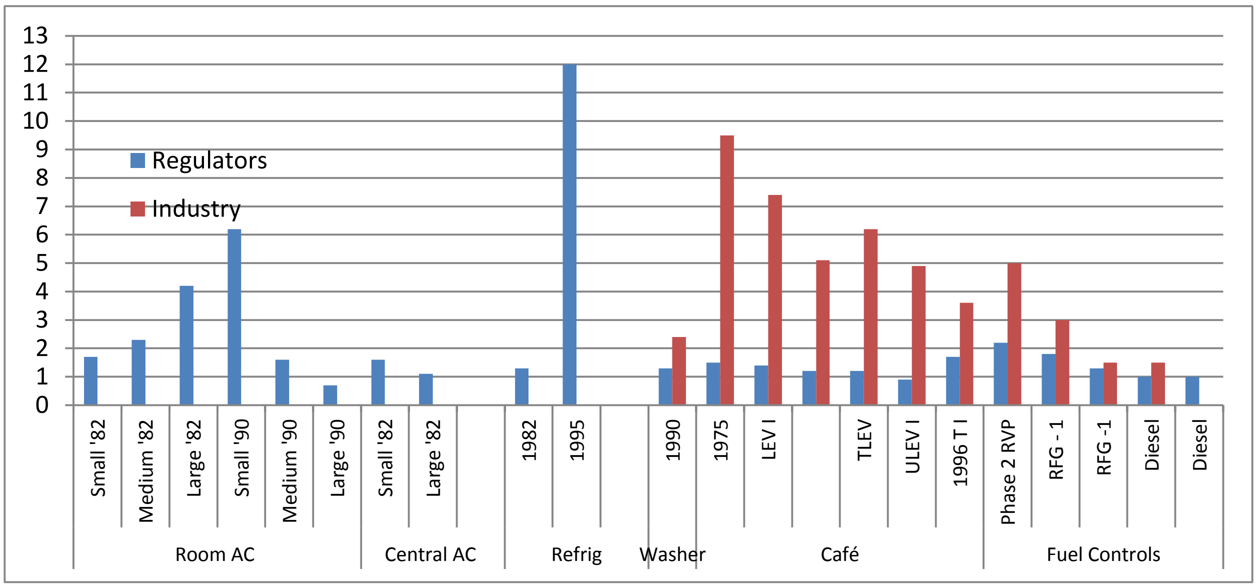
> The European car industry is highly dynamic and innovative. Its R&D expenditures are well above average in Europe's manufacturing sector. Among the most important drivers of innovation are consumer demand (for comfort, safety and fuel economy), international competition, and environmental objectives and regulations… One element of success of technology forcing is to build on one or more existing technologies that have not yet been proven (commercially) in the area of application. For improvements in the fuel economy of cars, many technological options are potentially available… With respect to innovation, the EU and Japanese policy instruments perform better than the US CAFE program. This is not surprising, given the large gap between the stringency of fuel-efficiency standards in Europe and Japan on the one hand and the US on the other….
>
> One of the reasons for the persistence of this difference is that the US is not a significant exporter

[56] Dale, et. al., 2009, p. 1.
[57] Sperling, et al., 2004, p.p. 10-15.

of cars to the European and Japanese markets.[58]

Exhibit III-4, shows the systematic overestimation by regulators of the cost of efficiency improving regulations in consumer durables. The cost for household appliance regulations was overestimated by over 100% and the costs for automobiles were overestimated by about 50 percent. The estimates of the cost from industry were even father off the mark, running three times higher for auto technologies.[59] Broader studies of the cost of environmental regulation find a similar phenomenon, with overestimates of cost outnumbering underestimates by almost five to one with industry numbers being a "serious overestimate."[60]

EXHIBIT III-4: THE PROJECTED COSTS OF REGULATION EXCEED THE ACTUAL COSTS: RATIO OF ESTIMATED COST TO ACTUAL COST BY SOURCE



Sources: Winston Harrington, Richard Morgenstern and Peter Nelson, "On the Accuracy of Regulatory Cost Estimates," *Journal of Policy Analysis and Management* 19(2) 2000, *How Accurate Are Regulatory Costs Estimates?,* Resources for the Future, March 5, 2010; ; Winston Harrington, *Grading Estimates of the Benefits and Costs of Federal Regulation: A Review of Reviews,* Resources for the Future, 2006; Roland Hwang and Matt Peak, *Innovation and Regulation in the Automobile Sector: Lessons Learned and Implications for California's CO_2 Standard,* Natural Resources Defense Council, April 2006; Larry Dale, et al., "Retrospective Evaluation of Appliance Price Trends," *Energy Policy* 37, 2009.

While the very high estimates of compliance costs offered by the auto manufacturers can be readily dismissed as self-interested political efforts to avoid regulation, they can also be seen as a worst case scenario in which the manufacturers take the most irrational approach to compliance under an assumption that there is no possibility of technological progress or strategic response. A simulation of the cost of the 2008 increase in fuel economy standards found that a technologically static response was 3 times more costly than a technologically astute response.

We perform counterfactual simulation of firms' pricing and medium-run design responses to the

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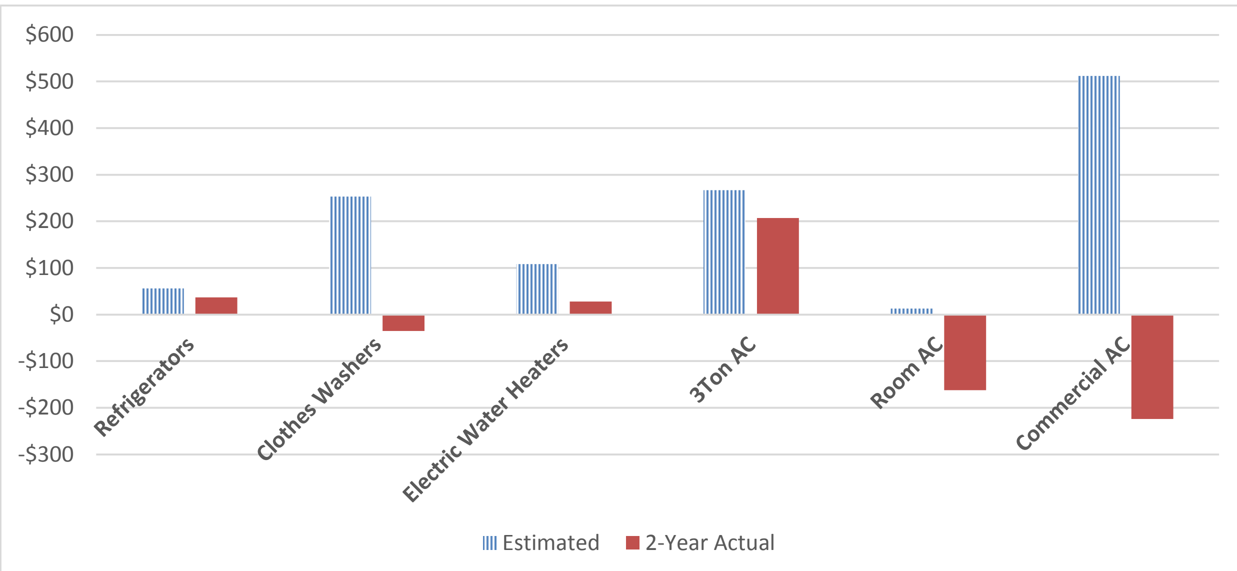
[58] Kuik, 2006,
[59] Hwang, and Peak, 2006.
[60] Harrington, 2006, p. 3.

reformed CAFE regulation. Results indicate that compliant firms rely primarily on changes to vehicle design to meet the CAFE standards, with a smaller contribution coming from pricing strategies designed to shift demand toward more fuel-efficient vehicles... Importantly, estimated costs to producers of complying with the regulation are three times larger when we fail to account for tradeoffs between fuel economy and other vehicle attributes.[61]

A recent analysis of major appliance standards adopted after the turn of the century shows a similar and even stronger pattern (see Exhibit III-5). Estimated cost increases are far too high. There may be a number of factors that produce this result, beyond an upward bias in the original estimate and learning in the implementation, including pricing and marketing strategies. Sperling et al, 2004, emphasized the adaptation of producers in the analysis of auto fuel economy standards.

EXHIBIT III-5: ESTIMATED AND ACTUAL COST INCREASES ASSOCIATED WITH RECENT STANDARDS FOR MAJOR APPLIANCES



Source: Steven Nadel and Andrew Delaski, *Appliance Stnadards: Comparing Predicted and Observed Prices,* American Council for an Energy Efficient Economy and Appliance Standards Awareness Project, July 2013.

As shown in Exhibit III-6, in comments on the light duty truck and auto standards, CFA presented a historical analysis of cost increases associated with mandates that reflects the ability and strategy of producers to keep cost increases within the broad limits of industry practices.

Many of the factors that are cited as causes of the declining cost, such as learning, standardization and homogenization of components, competitive outsourcing of components, and technological improvements in broader socio-economic environment),[62] represent market factors or externalities that are difficult for individual firms to control or profit from (appropriate), so they constitute externalities that policy must address, if the externalities are to be internalized in transactions. At the same time, performance standards simply shift the baseline of competition to a higher level of energy efficiency. To the extent that markets are competitive, normal competitive

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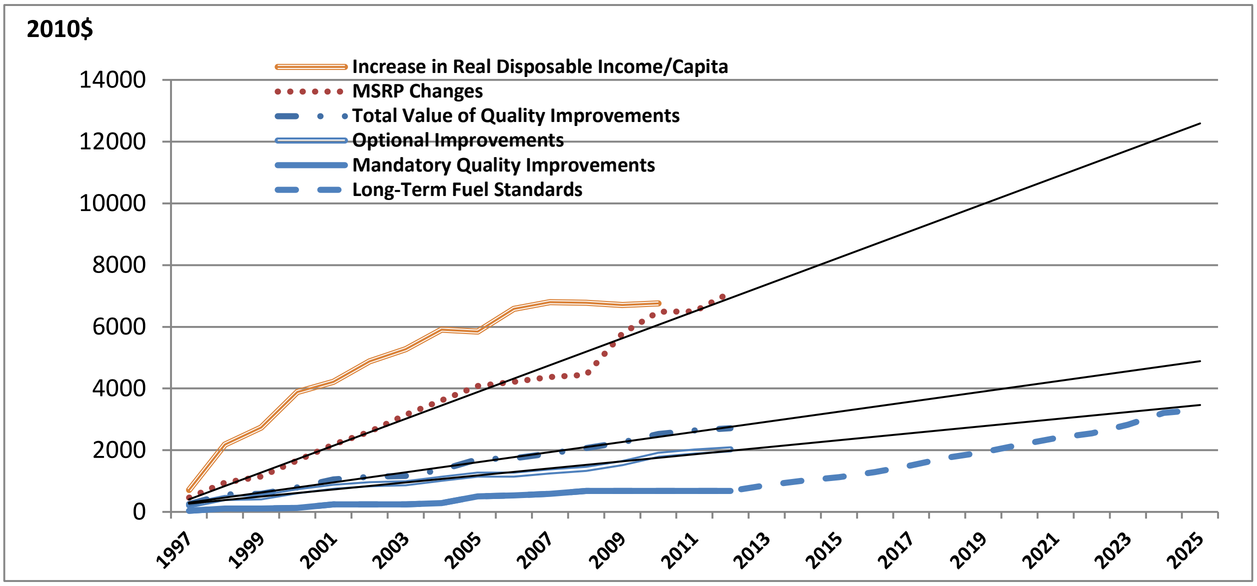
[61] Whitefoot, et al., 2012, pp. 1…5.
[62] Weiss, et al., 2010, pp.774-775.

processes drive down the costs of innovation such as competition driven technological change, declining markups, and economies of scale.[63]

EXHIBIT III-6: GRADUAL IMPROVEMENT IN FUEL ECONOMY CAUSES A SLOW AND STEADY PRICE INCREASE WHILE THE INDUSTRY HAS HANDLED QUALITY IMPROVEMENT WITH MUCH GREATER COSTS



Source: Bureau of Labor Statistics, Quality Changes for Motor Vehicles, various years; Consumer Price Index data base; Sources: Office of Regulatory Analysis and Evaluation, *Regulatory Impact Analysis, Corporate Average Fuel Economy,* 2011, 2012-2016, 2017-2025.

Even more fundamentally, there is evidence that the decision to increase energy efficiency can stimulate broader innovation and productivity growth.

> The case-study review suggests that energy efficiency investments can provide a significant boost to overall productivity within industry. If this relationship holds, the description of energy-efficient technologies as opportunities for larger productivity improvements has significant implications for conventional economic assessments.. … This examination shows that including productivity benefits explicitly in the modeling parameters would double the cost-effective potential for energy efficiency improvement, compared to an analysis excluding those benefits.[64]

C. NON-ENERGY BENEFITS

A second aspect of regulatory cost-benefit analysis that has begun to receive increased attention in the formal review of specific regulation involves non-energy benefits of energy efficiency technologies. While the economic externalities of energy consumption originally entered the policy arena through the study of the negative recessionary impact of oil price shocks,[65] the positive impact of energy efficiency is becoming widely recognized and consistently modeled.[66] A

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[63] Dale et al, 2009; Taylor, 2009; Freidrich, et al. 2009; Sperling, et al., 2004; Takahashi and Nichols, 2004.

[64] Worrell, et al., 2003, p. 1081.

[65] Hamilton, 2009, Warr Ayers and Williams, 2009; Belke, Dreger and de Haan, 2010;

[66] In addition to the recent U.S. analysis by U.S. EPA/NHTSA, 2011, see Howland, et. al., 2009, and New York State Energy Research & Development Authority, 2011, for individual states; Homes and Mohanty (2012) and Cambridge Centre for Climate Mitigation Research (2006), and Ryan and Campbell, 2012 for a general global review.

recent analysis prepared for the OECD/IEA catalogued the varied positive impacts of energy efficiency, identifying over a dozen specific impacts (see Exhibit III-7).

EXHIBIT III-7: SUMMARY OF OUTCOMES FROM IMPROVEMENT IN ENERGY EFFICIENCY

Area of impact & Specific Benefits	Time Frame		Level of Effect			Country context		Energy Impact	Effects Rebound
	Short	Long	Ind.	Nat.	Intl.	Energy Mix	Devel-opment	savings	
Economic									
Provider Benefit & Infrastructure	x	x	x	x		x	x	x	-
Energy Prices	x	x		x	x	x	x	x	+
Public Budgets		x		x	x	x	x	x	+
Energy Security		x		x		x	x	x	-
Macro-economic effects		x		x			x		+
Social									
Health	x		x	x			x		+
Affordability	x		x				x	x	+
Access		x	x	x			x		+
Development	x			x	x	x	x		+
Job Creation	x		x	x			x		+
Asset Values	x		x	x					-
Disposable Income	x		x	x			x		+
Productivity	x		x	x			x		+
Environment									
GHG Emissions	x			x	x	x	x	x	-
Resource Mgmt.			x	x	x	x	x	x	-
Air/Water Pollutants			x	x		x	x	x	-

Sources: Lisa Ryan and Nina Campbell, *Spreading the Net: The Multiple Benefits of Energy Efficiency Improvements* (International Energy Agency, Insight Series 2012), p. 25.

An evaluation of the non-energy benefits of whole house retrofits produces a similar, long list of benefits (see Exhibit III-8). The magnitude of these potential gains is difficult to estimate, but they are likely to be substantial. Direct estimates of the non-economic benefit have been estimated at between 50% and 300% of the underlying energy bill savings.

D. MACROECONOMIC BENEFITS OF PERFORMANCE STANDARDS

These discussions of the non-energy benefits are framed in terms of the benefits to the individual. Another significant potential benefit is in the macroeconomic multiplier effect of reduced energy expenditures. Expenditures are shifted from purchasing energy to purchasing technology, which has a larger multiplier. The decrease in energy expenditures is substantially larger than the increase in technology costs, resulting in an increase in the disposable income of individuals to spend on other things.

The macroeconomic impact of energy policy has taken on great significance in the current round of decision making for two reasons.

- With the economy mired in recession, every policy is evaluated for its ability to stimulate growth and create jobs.
- Because climate policy requires a demand shift in economic activity, its impact on growth and job is extremely important.

Assessing the macroeconomic impact of policy choice generally relies on complex models of the economy. Economically beneficial energy efficiency investments yield net savings; the reduction in energy costs exceeds the increase in technology costs. Such investments have three economic effects from the point of view of the economy.

- The inclusion of energy efficient technologies in energy using durables increases the output of the firms that produce the technology.

EXHIBIT III-8: NON-ENERGY BENEFITS FROM WHOLE HOUSE RETROFITS

Benefit Type	Specific Benefit
Financial (other than energy cost savings)	Water and waste bill savings Reduced repaid and maintenance Increased resale value Improved durability
Comfort	Improved airflow Reduced drafts and temperature swings Better humidity control
Aesthetic	More attractive windows/ appliances Less dust Reduced mold and water damage Protection of furnishings Dimmable lighting
Health & Safety	Improved respiratory health Reduced allergic reactions Lower fire/accident risk (from gas equipment)

Benefit Type	Specific Benefit
Noise Reduction	Quieter equipment Less external noise intrusion
Education-related	Reduced transaction costs (knowing what to look for when purchasing equipment; ease of locating products) Persistence of savings Greater understanding of home operation
Convenience	Automatic thermostat controls] Easier filter changes Faster hot water delivery Less dusting and vacuuming
Other	Greater control over energy use/bills Reduced sick days Ease of selling home Enhanced pride Improved sense of environmental responsibility Enhanced peace of mind/responsibility for family well-being

Source: Jennifer Thorne Amann, 2006, *Valuation of Non-Energy Benefits to Determine Cost-Effectiveness of Whole-House Retrofit Programs: A Literature Review,* American Council for an Energy Efficient Economy, p. 8.

- To the extent that the energy using products are consumer durables, they increase the disposable income that households have to do other things, such as buy other goods and services.
- To the extent that the energy using products are utilized as inputs in the production of other goods and service, like trucks used to deliver packages or vegetables, they lower the cost of those goods and services. In competitive markets, those costs are passed on to the consumer in the form of lower prices. This also increases the disposable income of the household to buy other goods and services.

The increase in economic activity resulting from spending on new technology and the increase in consumer disposable income flows through the economy, raising the income of the producers of the additional products that are purchased and increasing employment.

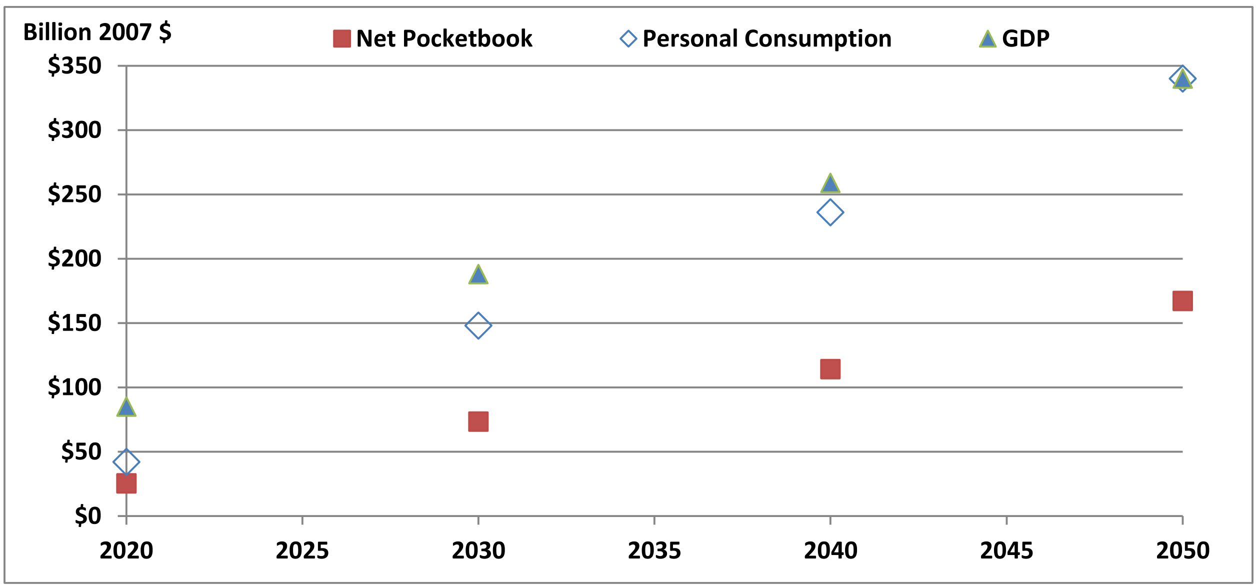
> Higher vehicle costs are projected to reduce household consumption slightly in the first few years of the rule implementation. Over time, fuel savings increase and the price of world oil decreases, which leads to lower prices economy-wide. As a result, household consumption increases over the

long term.

The fuel savings and lower world oil prices that result from this rule lead to lower prices economy-wide, even when the impact of higher vehicle costs are factored into this analysis. Lower prices allow for additional purchase of investment goods, which, in turn, lead to a larger capital stock. These price reductions also allow higher levels of government spending while improving U.S. competitiveness thus promoting increased exports relative to the growth driven increase in imports. As a result, GDP is expected to increase as a result of this rule.[67]

For example, in the recent regulatory proceeding that finalized the long-term fuel economy standard of 54.5 miles per gallon for 2025, the standard was projected to increase the size of the economy by over $100 billion, in 2010 dollars. This indirect benefit was equal to the direct consumer pocketbook benefit of the standard (see Exhibit II-9).

EXHIBIT III-9: IMPACTS OF THE 2012-2016 CORPORATE AVERAGE FUEL ECONOMY RULE: SAVINGS AND INCREASE S IN ECONOMIC ACTIVITY



Source: Assessment and Standards Division Office of Transportation and Air Quality U.S. Environmental Protection Agency, Final Rulemaking to Establish Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average: Regulatory Impact Analysis, EPA-420-R-10-009, April 2010, Table 6-18. Docket EPA-HQ-OAR-2009-0472, *Memorandum: Economy Wide Impacts of Greenhouse Gas Tailpipe Standards,* March 4, 2012, Tables 1 and 2.

Exhibit III-9 shows the relationship between the net pocketbook savings, increases in consumption and increases in GDP. Although the figure was estimated using standard econometric models of the economy, it was not included in the final published cost benefit analysis.[68] Another popular measure is to estimate jobs per dollar invested. In the electricity space, a comparative analysis of efficiency compared to generation found that efficiency created twice as many jobs per dollar spent on nuclear power and 50% more jobs than coal and gas generation.[69]

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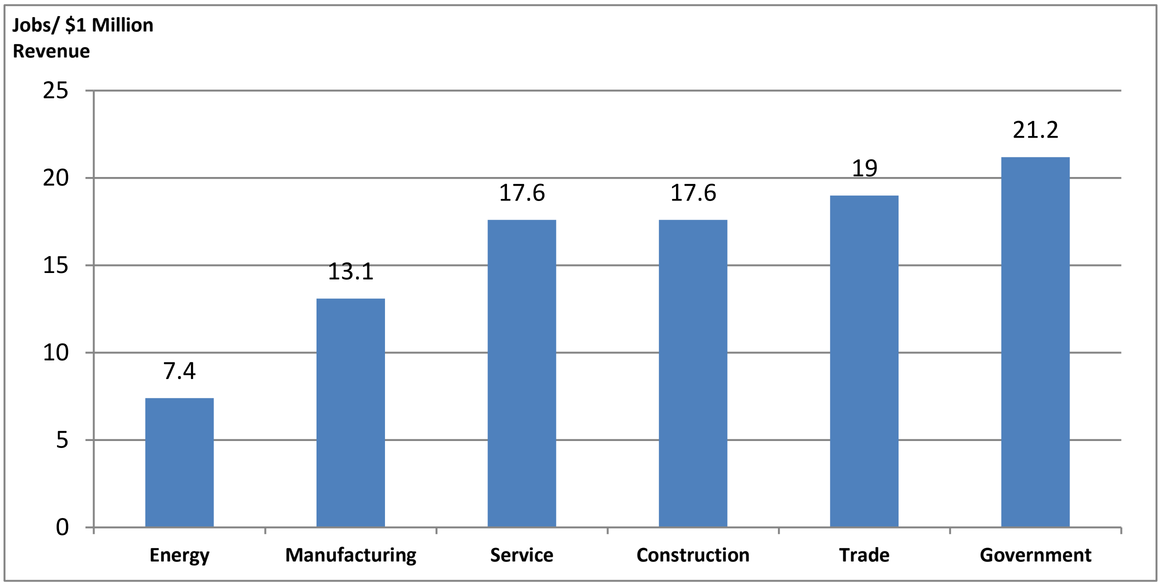
[67] U.S. EPA, 2010, pp. 3-4.
[68] Cooper, 2011a, CFA, 2012, pp. 53-54.
[69] Wei, Patadia and Kammen, 2010; Anair, and Hall, 2010; Gold, et al., 2011; Roland-Holst, 2008.

These large increases in economic activity lead to increases in employment. The effect is magnified by the fact that the non-energy sectors of the economy are substantially more labor intensive than energy production. As shown in Exhibit III-10, the energy sector is less than half as labor intensive as the rest of the economy. This effect is compounded where energy is imported (as in the transportation sector). As consumers substitute away from energy, the goods and services they purchase stimulate economic and disproportionately large job growth.

EXHIBIT III-10: LABOR INTENSITY OF KEY ECONOMIC SECTOR IN THE U.S.



Source: Rachel Gold, et al., *Appliance and Equipment Efficiency Standards: A Money Maker and Job Creator,* American Council for an Energy Efficient Economy, January 2011, p. 9, based on the IMPLAN Model, 2009.

These efforts to model the economic impact of energy efficiency have proliferated with different models[70] being applied to different geographic units, including states[71] and nations.[72] The results differ across studies because the models are different, the impact varies according to the size of the geographic unit studied and because the assumptions about the level and cost of energy savings differ. These differences are not an indication that the approach is wrong. On the contrary, all of the analyses conclude that there will be increases in economic activity and employment. Given that there are different regions and different policies being evaluated, we should expect different results.

The Rebound Effect

The shift in spending stimulated by increased energy efficiency has another impact on consumption known as a rebound effect. Some of the increase in disposable income resulting from the net savings is used to increase the consumption of energy directly and indirectly. If the reduction in demand for energy is large enough, the price of energy may fall, further increasing

[70] For example, EPA, 2010, IGEM; Gold, 2011, IMPLAN, Howland and Murrow and NYSERDA 2011, REMI),
[71] For example, New York (NYSERDA, 2011), New England (Howland and Murrow), California (Roalnd Holst, 2008)
[72] For example, U.S. (Gold,, 2011, EPA, 2010, Warr, Ayres and Williams, 2009) and UK (Cambridge Center, 2006). Warr, Ayres and Williams, 2009, note recent studies on Asian economies, Korea, Canada and Spain,

energy consumption. However, the rebound effect is generally much smaller than the overall reduction in energy consumption and expenditure.

From the simple economic point of view, the rebound effect is a positive aspect of increased energy efficiency. The fact that consumers choose to consume more energy with the increase in their disposable income simply affirms the fact that the economy is operating at a more efficient level and consumer welfare has increased. The economic gains resulting from the economy-wide increase in disposable income resulting from energy efficiency investments is much larger than the reduced economic activity in the energy sector.

From the point of view of energy policy or environmental policy, where the goal is to reduce the absolute level of energy consumption or emissions, the rebound effect must be subtracted from the benefit column. However, the rebound effect is relatively small, so there are substantial reductions in net energy consumption to go along with the large increase in economic activity and consumer welfare. Because much energy policy has been driven by the goal of the reduction of energy imports or environmental concerns, the framing of the rebound effect has been far too negative, and it has received far too much attention, given its relatively small size.

The key characteristic of energy consumption that underlies both the constrained impact of the rebound effect and the increase in consumer welfare and macroeconomic activity is the fact that household energy consumption tends to be an inferior good.[73] Exhibit III-11shows expenditures on the two key components of household energy consumption – gasoline and home energy (electricity, natural gas and fuel oil) and the associated energy using consumer durables.

The top graph shows the absolute value of expenditure. The bottom graph shows expenditures as a percent to of total expenditures.

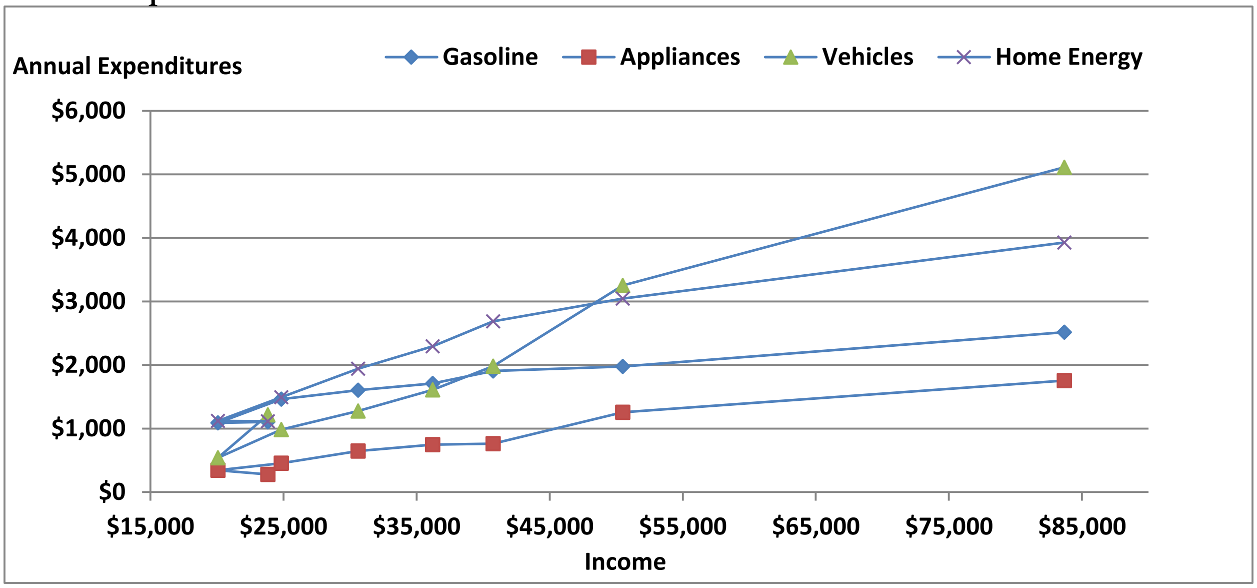
Home energy is an inferior good across the entire income distribution. As income increases, consumers spend a smaller share of their income on energy. When they have more disposable income, they devote a smaller share to energy and the other goods and services they purchase are less energy intensive. Superior goods have the opposite pattern, as income increases consumers spend a larger share of their income on superior goods. For normal goods, the percentage of income they spend is constant.

Gasoline is mildly superior up to median income, then becomes clearly inferior. On average, as efficiency lowers consumption and expenditures, consumers substitute away from energy. Vehicles (and to a lesser extent appliances) are superior goods across the lower levels of income, then they become normal. As consumers spend their net pocketbook savings, the rebound effect is likely to cause an increase in energy consumption that is substantially smaller than the direct reduction in energy consumption resulting from the new technology.

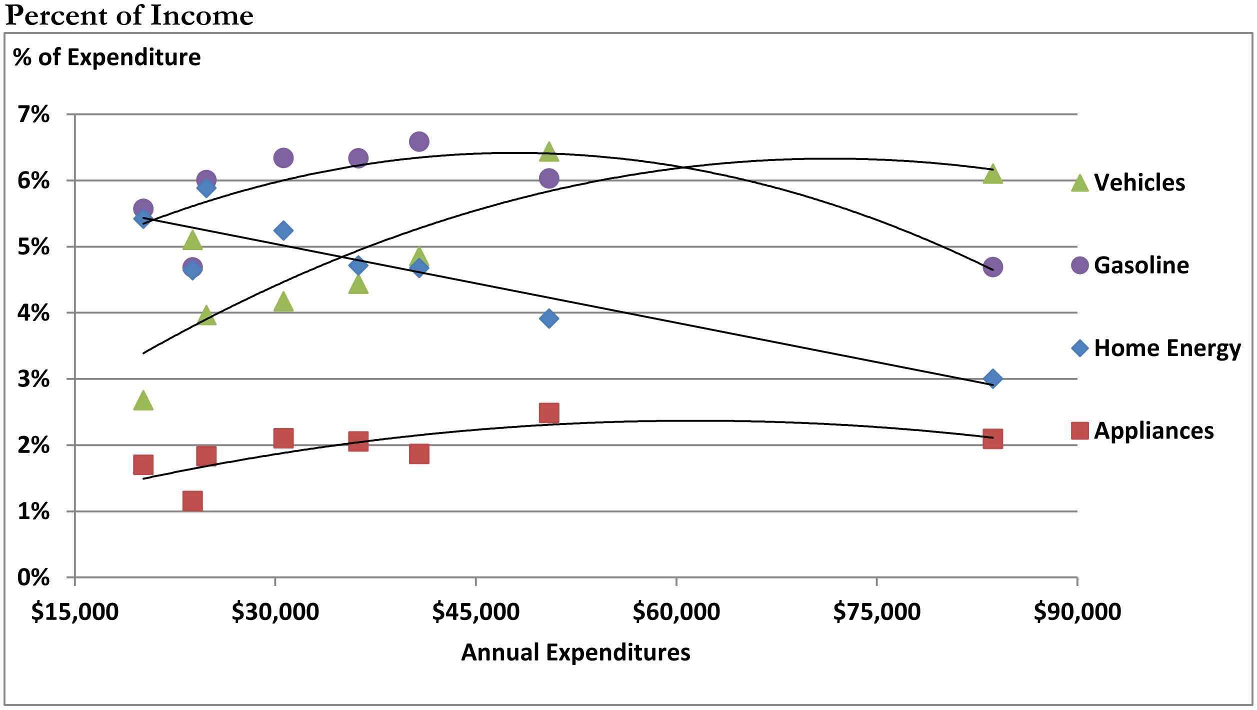
[73] Taylor, 1998, p. 58.

EXHIBIT III-11: CONSUMER EXPENDITURES FOR ENERGY AND ENERGY USING DURABLES (Q3 2011-Q2 2012)

Annual Expenditures



Percent of Income

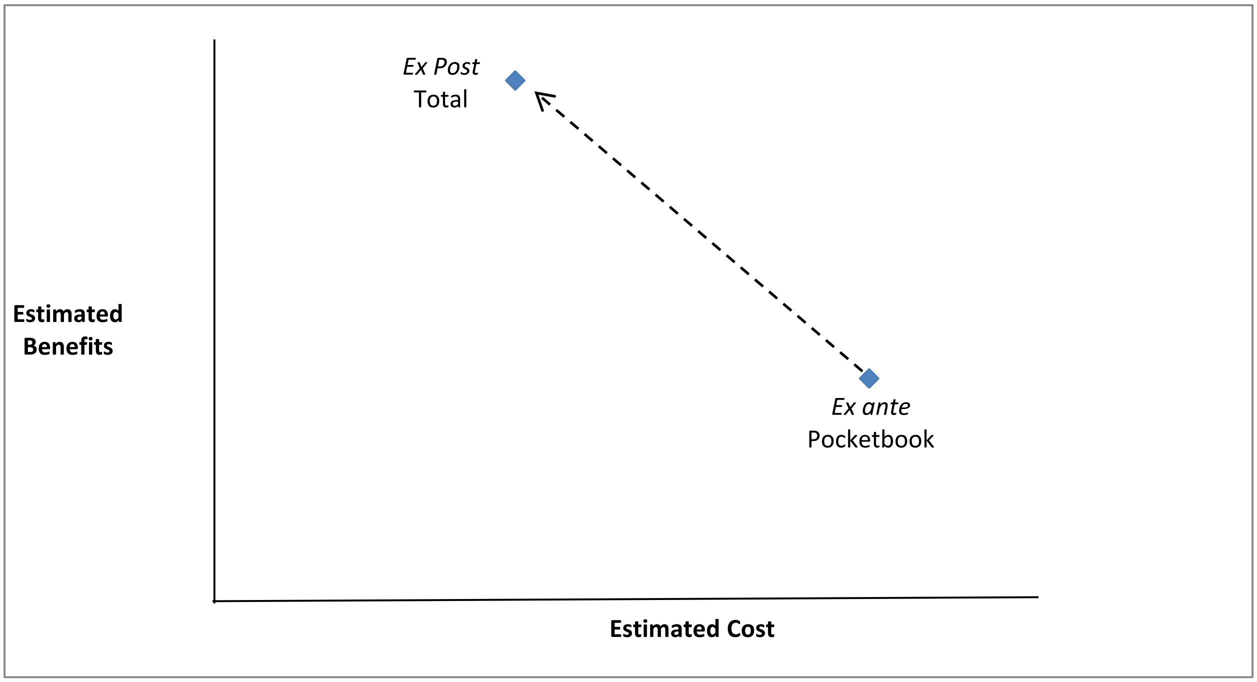


Source: Bureau of Labor Statistics, Consumer Expenditure Survey, Data Base.

E. CONCLUSION: VALUING AND ACHIEVING THE BENEFITS OF PERFORMANCE STANDARDS

Taken together, the overestimation of costs and underestimation of benefits lead to a substantial and systematic underestimation of the net benefits of efficiency gains, as shown conceptually in Exhibit III-12. Because the impact of the efficiency improvements depends on the size of the improvement and the type of consumer durable being studied, the sector in which it occurs and the region being analyzed, one cannot offer a single, simple estimate. Exhibit III-7 is drawn to reflect the likely order of magnitude impact of the underestimation of the benefits of the recent fuel economy standards. The *ex ante* calculation of costs and benefits is likely to underestimate the benefit/cost ratio by a factor of at least two because of the failure to reflect the macroeconomic benefits and cost reducing trends, both of which are positive externalities of the adoption of performance standards.

EXHIBIT III-12: CONCEPTUALIZATION OF THE IMPACT OF UNDERESTIMATION OF BENEFITS AND OVERESTIMATION OF COST ON THE EVALUATION OF BENEFIT/COST RATIOS



Strategic Considerations

These positive findings on performance standards must not obscure two important strategic considerations that will have a major impact on the ultimate effectiveness of the standards. Our analysis of the dramatic increase in and broad support for the doubling of the fuel economy standard from new light duty vehicles identified a series of characteristics that are important to ensure a successful standards program. Our conclusions about standards setting are supported by the evaluations described above. They caution that performance standards have positive effects if they are maintained, enforced and upgraded. More broadly speaking, performance standards must be well designed. The redesign of the fuel economy standards for light duty vehicles appears to have included a series of characteristics that will improve performance (see Exhibit III-13). We have noted that the standards are technology neutral, procompetitive, long-term, attribute sensitive, and moderately aggressive.[74]

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[74] CFA,2012, pp. 41-44.

EXHIBIT III-13: KEY DESIGN FEATURES OF EFFECTIVE PERFORMANCE STANDARDS (Modelled in Current Fuel Economy Standards for Light Duty Vehicles)

Long-Term: Setting a high standard for the next fifteen years is intended to foster and support a long-term perspective for automakers and the public, by reducing the marketplace risk of investing in new technologies. The long-term view gives the automakers time to re-orient their thinking, retool their plants and help re-educate the consumer. The industry spends massive amounts on advertising and expends prodigious efforts to influence consumers when they walk into the show room. By adopting a high standard, auto makers will have to expend those efforts toward explaining why higher fuel economy is in the consumer interests. Consumers need time to become comfortable with the new technologies.

Technology-neutral: Taking a technology neutral approach to the long term standard unleashes competition around the standard that ensures that consumers get a wide range of choices at that lowest cost possible, given the level of the standard. There will soon be hundreds of models of electric and hybrid vehicles using four different approaches to electric powertrains (hybrid, plug-in, hybrid plug-in, and extended range EVs), offered across the full range of vehicles driven by American consumers (compact, mid-size family sedans, large cars, SUVs, pickups), by half a dozen mass market oriented automakers. At the same time, the fuel economy of the petroleum powered engines can be dramatically improved at consumer friendly costs as gasoline will continue to be the primary power source in the light duty fleet for decades.

Product Neutral: The new approach to standards accommodates consumer preferences; it does not try to negate them. The new approach to standards is based on the footprint (size) of the vehicles and recognizes that SUVs cannot get the same mileage as compacts. Standards for larger vehicles will be more lenient, but every vehicle class will be required to improve at a fast pace. This levels the playing field between auto makers and removes any pressure to push consumers into smaller vehicles.

Responsive to industry needs: The rule recognizes the need to keep the standards in touch with reality in several important ways. The standards are set at a moderately aggressive level that is clearly beneficial and achievable. The cost estimates are consistent with the results of independent analyses of technology costs made over the past decade. The standards are consistent with the rate of improvement that the auto industry achieved in the first decade of the fuel economy standard setting program. In practical terms, the standard also moves the U.S. into a position that is comparable to the other major car producing/buying nations in the world.

Responsive to consumer needs: The new approach to setting standards is consumer-friendly and facilitates automaker compliance. The attribute-based approach ensures that the standards do not require radical changes in the types or size of vehicles consumers drive; so, the full range of choices will be available to consumers. The standards do not require dramatic shifts in power train technologies or reductions in weight and offer flexibility and incentives for new technologies, and include a mid-term review. The setting of a coordinated national standard that lays out a steady rate of increase over a long time period gives consumers and the industry certainty and time to adapt to change.

Procompetitive: All of the above characteristics make the standards pro-competitive. Automakers have strong incentives to compete around the standard to achieve them in the least cost manner, while targeting the market segments they prefer to serve.

Mobilizing Public Support

The strong analytic support for energy performance standards for consumer durables does not address significant social obstacles to their implementation. Performance standards are not front page news, and they do incur the wrath of free market ideologues. They require educational and mobilization efforts to ensure they get the social support they deserve.

Our survey research over the course of the last decade shows that there is strong general support in public opinions polls for some performance standards, like fuel economy standards. However, public opinion about other standards, like appliance efficiency standards or building energy codes, has not been as intensively studied. Strategic efforts to enhance awareness and support for performance standards can serve two purposes that are important in a policy context where the need for vigorous policy action is urgent.

- The public can promote higher levels of efficiency by supporting higher standards for consumer durables and a broad shift toward effective long-term performance standards.
- The public must be educated and motivated to buy the more efficient products that are made available in the market as a result.

The literature review provides evidence that these are key parts of the effort to mobilize social action in support of better policy, as shown in Exhibit III-14.

EXHIBIT III-14: SOCIAL ACTION IN SUPPORT OF ENERGY POLICY CHANGE

SOCIAL ACTION	CHANGE PROCESS	ULTIMATE EFFECT
Recognizing and articulating problems that existing institutions do not address Developing evidence about negative effects of the problem Educating the public through media attention	Challenge the Status Quo Disrupt existing institutional arrangements Unresolved problems call into into question the prevailing logic & institutional arrangements	Overcome inertia Undermine incumbents
Promote new assumptions and norms to influence the way people apply knowledge	Motivate change in consumption Create opportunities for entrepreneurs	Create demand
Mobilize members Foster diverse coalitions Community-based marketing	Introduce alternative solutions Take collective action Affect media framing	Change Policy

Source: Claudia Doblinger and Birhe Soppe, 2011, *The Role of Social Movements in Legitimating New Technologies: Evidence from the Electric Utility Industry,* DIME-DRUID Academy Winter Conference, January 20-22, pp. 3-4.

PART II
COMPLEMENTARY FIELDS OF ANALYSIS

IV. DIFFUSION OF INNOVATION AND THE IMPORTANCE OF THE SUPPLY-SIDE OF THE MARKET

A. RECOGNIZING THE ROLE OF SUPPLY AND DEMAND

The innovation diffusion process has typically been represented as a logistic (S) curve that represents the overall flow of product development and adoption actions (see Figure V-1). Figure V-1 shows the supply-side process preceding and overlapping with the demand-side process. It depicts the supply-side of the innovation process as moving through three phases, while the demand side of the process moves through five phases. The phases are created by processes that take place within organizations and markets.

SUPPLY: Incubation > R&D > Launch > Commercialization > Business Success
Research > Concept > Tech. > Prod. > Prod.
Invent Dev. Dev. Mktg.

DEMAND: Takeoff > Growth > Slowdown > Early Maturity
(acceleration) (inflection) (Deceleration)

On the supply side, in the first phase, technology incubates and emerges from research and development to be launched. The early supply-side period is very challenging and has been called the "valley of death" that must be traversed if the product is to advance.[75] The product undergoes continuous development as it is commercialized and is successful, a process that has been called the slope of enlightenment.[76] The product stabilizes as it matures and then saturates the market. Saturation may not be at 100 percent, since some parts of the market may never adopt a product for a variety of reasons.

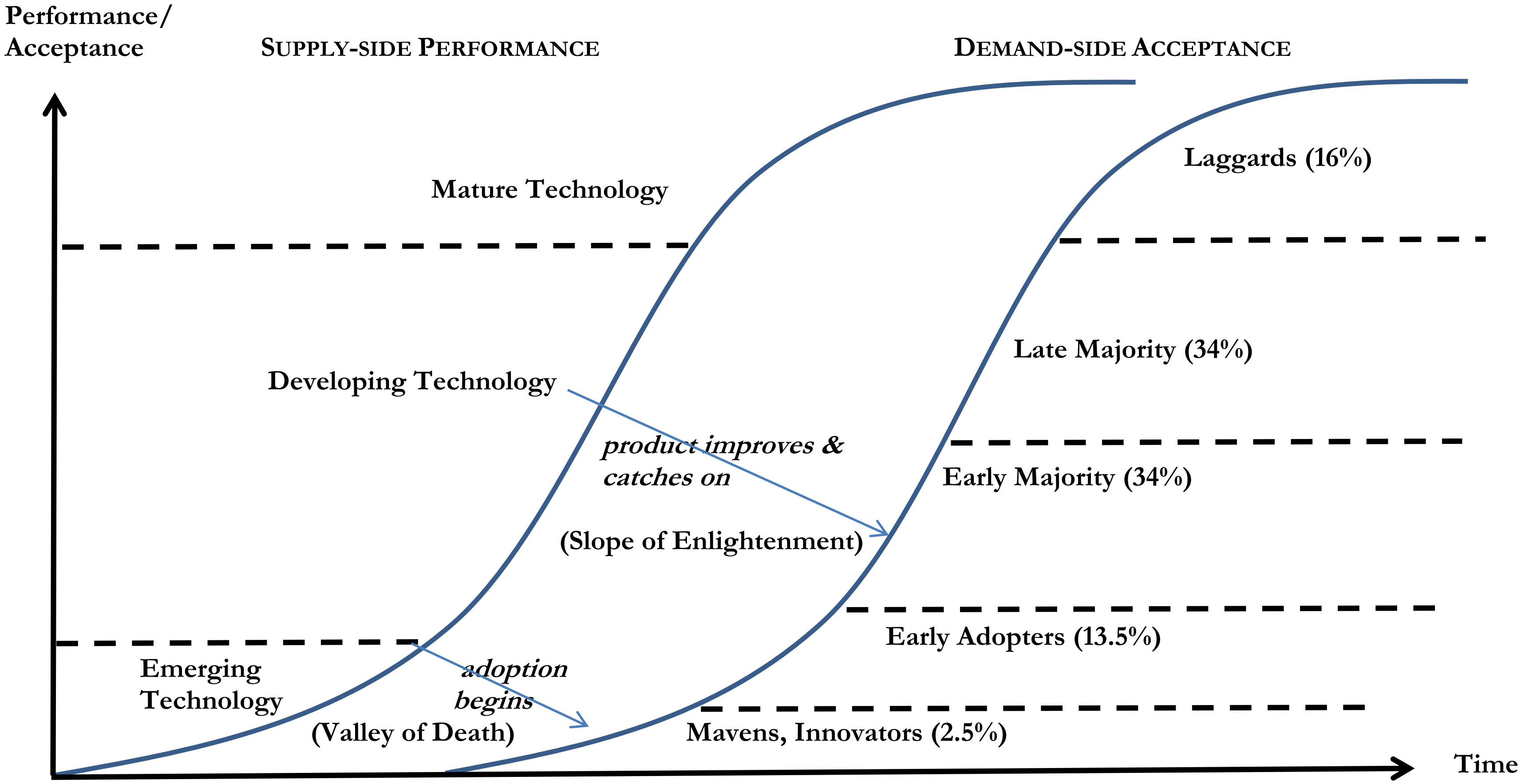
On the demand side, the process begins with initial adoption by market mavens and innovators, then spreads through early adopters, early and late majorities and finally laggards. The adoption process accelerates rapidly with takeoff then slows with maturity. The speed and ultimate level of adoption have been primary focal points of analysis on the demand side.

The analysis of the diffusion of products has shifted its focus between the supply-side of the market and the demand side several times over the past century. The pre-World War II focus was on ""invention and innovation," but the three decades after the war focused much more on the demand side, so much so that by the 1990s, the field was criticized for ignoring the importance of the supply-side. The definition of technological diffusion offered in a 1998 review of the field, reflects this central tension.

> Technological diffusion can be defined as a mechanism that spreads successful varieties of products and processes through an economic structure and displaces wholly or partly the existing 'inferior' varieties. While the process of invention and innovation are necessary preconditions for the development of a new technology, it is the process of diffusion that determines the extent to which the new technology is being put to productive use.[77]

[75] Osawa and Miazaki, 2006.
[76] Gartner, 2013,
[77] Sarkar, 1998:131.

EXHIBIT IV-1: THE INTERACTION OF SUPPLY AND DEMAND IN THE CREATION/DIFFUSION OF INNOVATIVE TECHNOLOGIES



Sources: Sources: Mahajan, Vijay, Eitan Muller and Frank M. Bass,1990, "New Product Diffusion Models in Marketing: A Review and Directions of Research," *Journal of Marketing,* 54; Rick Brown, "Managing the "S" Curve of Innovation," 1992, *Journal of Consumer Marketing;* Fenn, Jackie, 1995, *When to Leap on the Hype Cycle,* Gartner Group; Paul Gilder and Gerard J. Tellis, 1997, "Will it Ever Fly? Modeling the Takeoff of Really New Consumer Durables," *Marketing Science,* 16: 3, "Growing, Growing Gone: Cascades, Diffusion, and Turning Points in the Product Life Cycle," *Marketing Science,* 23: 2 (2004); Kohli, Rajeev Donald R. Lehman and Jae Pae, 1999,"Extent and Impact of Incubation Time in New Product Diffusion, *Journal of Product Innovation Management,* 16; Osawa, Yshitaka and Kumiko Miazaki, 2006, "An Empirical Analysis of the Valley of Death: Large Scale R&D Project Performance in a Japanese Diversified Company," *Asian Journal of Technology Innovation,* 14:2; Sood, Ashish, et al., 2012, "Predicting the Path of Technological Innovation: SAW vs. Moore, Bass, Gompertz and Jryder," *Marketing Science,* 31: 6; Gartner, 2013, *Interpreting Technology Hype.*

The bottom line in a review of the diffusion literature prepared at roughly the same time as Sanstad, Hanemann and Auffhammer called for deepening the understanding of the "efficiency gap," was a call for balance: "What is needs to be achieved in the field of diffusion research now is a *Balance* between the two archetypical modeling mechanisms of diffusion, their underlying assumptions, and the postulated modes of interaction."[78] The definition of technological diffusion offered in this review of the field, reflects this central tension.

Exhibit IV-2 shows the factors that have been identified as affecting the diffusion process. The causal factors on the supply-side are shown on the upper part of Exhibit IV-2.

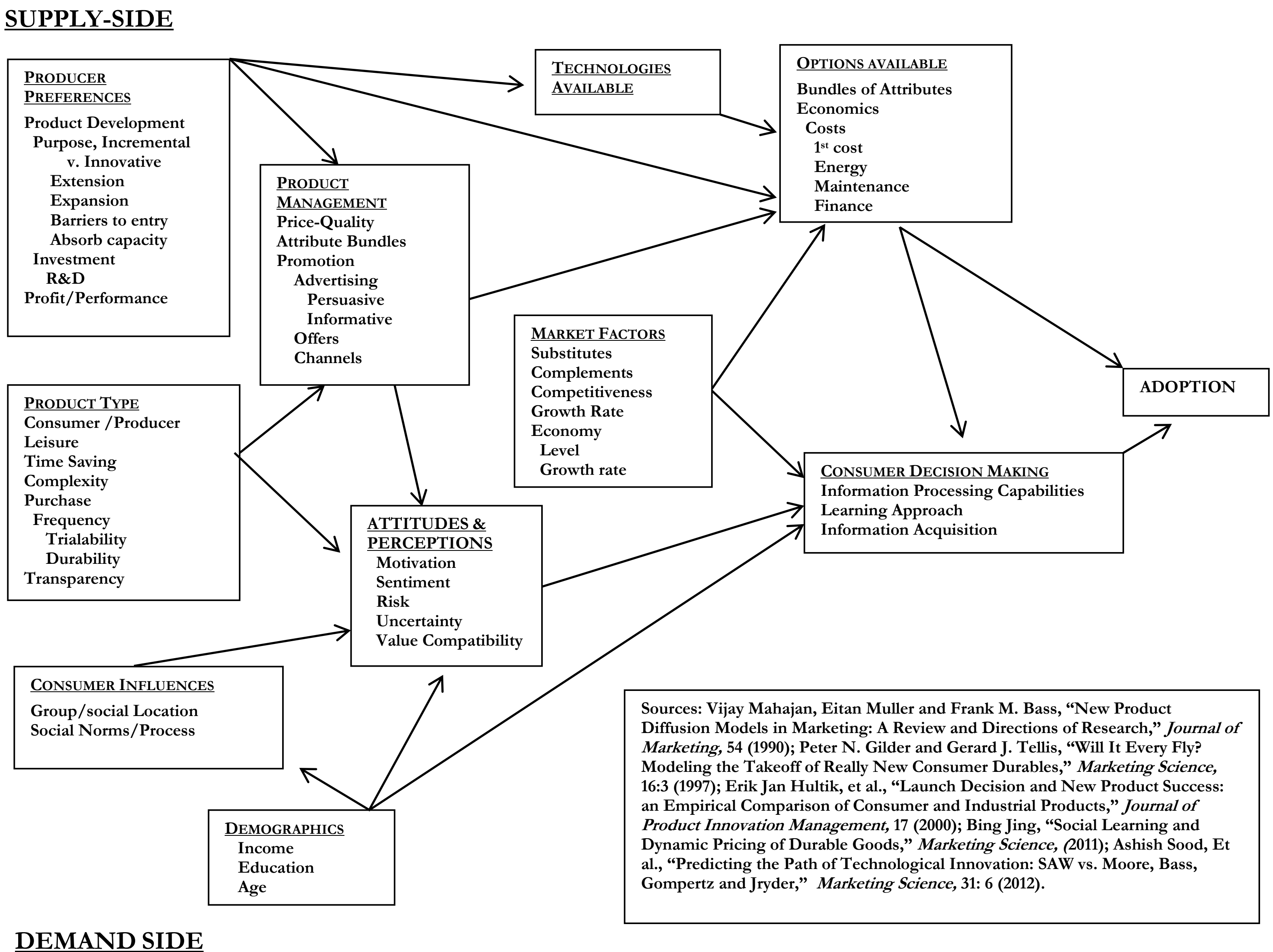
The challenge of diffusion is first, and foremost, a matter of supply-side innovation. This is a perspective that has been significantly under-analyzed in the efficiency gap literature. The assumption frequently made, particularly among the critics of the efficiency gap is that the demand-side totally dominates the outcome, with suppliers, passively responding to consumer demand. This unbalanced approach has been rejected in the broader literature on the diffusion of innovation. To put the matter simply, consumers cannot adopt technologies until they are offered to them in the marketplace. Innovation must precede diffusion.

> Marketing literature has traditionally portrayed new product development as essentially a market/consumer-led process, but paradoxically, many, major market innovations appear in practice to be technology driven, to arise from a technology seeking a market application rather than from a market opportunity seeking a technology. This, of course, is the antithesis of the marketing concept, which is to start with the customer, then design something to meet his needs. While this may be intuitively reasonable, and indeed appropriate in a market where changes are slow and can reasonably be anticipated, it may be less appropriate in faster changing markets with higher technology content. However, for successful technology – driven market development, in addition to a technological discovery, there needs to be an element of insight as to how it should be applied… It would seem that innovation is fundamental to the strategic management of businesses, but that it is a complex and potentially risk-laden activity… No doubt the debate over the extent to which radical innovation is caused by "technology push or by "market pull" will continue [79]

Recognition of the importance of the supply-side also reflects a greater emphasis on the role of entrepreneurship and management in the innovation process because "takeoff is not instantaneous and requires patience and careful planning on the part of managers."[80] Management

[78] Sarkar, 1998:167.
[79] Brown, 1992, p. 65.
[80] Gilder and Tellis, 1997, p. 267.

Exhibit IV-2: Causal Factors that Drive the Supply and Diffusion of Innovative Products



Sources: Vijay Mahajan, Eitan Muller and Frank M. Bass, "New Product Diffusion Models in Marketing: A Review and Directions of Research," *Journal of Marketing,* 54 (1990); Peter N. Gilder and Gerard J. Tellis, "Will It Every Fly? Modeling the Takeoff of Really New Consumer Durables," *Marketing Science,* 16:3 (1997); Erik Jan Hultik, et al., "Launch Decision and New Product Success: an Empirical Comparison of Consumer and Industrial Products," *Journal of Product Innovation Management,* 17 (2000); Bing Jing, "Social Learning and Dynamic Pricing of Durable Goods," *Marketing Science, (*2011); Ashish Sood, Et al., "Predicting the Path of Technological Innovation: SAW vs. Moore, Bass, Gompertz and Jryder," *Marketing Science,* 31: 6 (2012).

faces a variety of challenges in shepherding innovative technologies to business success.[81]

Management can have different motives for technology innovation and use different tools to increase the likelihood that the technology will achieve a large enough market to be profitable.[82] Entrepreneurs make the decisions about what technologies to develop and products to market, as well as how those products are priced, brought to market and promoted. They do so in response to their perception of the market they are located in and their understanding of consumers, as well as their own preferences. Their ability to perform these activities is neither perfect nor uniform.[83]

Of course, the demand side is important too. The causal factors on the demand-side of the diffusion process are presented in the lower part. The literature identifies four broad categories of factors that affect adoption on the demand side: demographics, social influences, attitudes and the ability to make calculations. Because of its focus on the consumer adoption decision, the diffusion literature was very sensitive to causal factors that drive diffusion, factors that are grounded in behavioral economics including: "Perception: Type of Uncertainty, Uncertainty Model, Preference Structure: Attributes, Risk Attitude, Adoption Decision Rules: Maximize Expected Utility, Learning: Model, Sources of Information [84]

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[81] Gilder and Tellis, 1997, p. 267. [S]ome other variable may also help explain the takeoff of new durables. Such variables include technological change, product quality, relative advantage of the new product over substitute products, availability of complementary products that increase the utility of the new product, and the number of competitors.

[82] Gilder and Tellis, 1997p. 267 Increasing the rate of price reduction *increases the peak probability* of takeoff in each curve, as well as *advances the time* at which the peak occurs. Ironically, as Hultik, et al., 2000, p. 5, point out, the advice given to management in the standard texts does not reflect the findings of the analysis of innovation diffusion, "The relationship found in these data between success and launch decisions differ quite markedly from the standard normative prescriptions… None of the extensive advice provided in the normative literature on competitive or innovation strategy decisions, as found, in this research, to be associated with success. Additionally, a number of strategic objectives related to success for consumer goods were identified in this study, none of which are mentioned in the normative literature."

[83] Gilder and Tellis, 1998: 263-264. "No matter how inexpensive the product is, or how high consumers' incomes are or how strong consumer sentiment is, the likelihood of purchase still increases as products become more visible and available to consumers. Widespread distribution will lead to higher market presence and will tend to increase the likelihood of new product success. Market presence reflects the opportunities that potential consumers have to observe a product. These opportunities occur in several ways. First, as sales increase, interest and excitement among consumers about a product increases… Second, as sales of a product increase, retail promotions will increase leading to enhanced visibility. Since store displays are designed to attract consumers' attention and led to sales, retailers promote products they know consumers have some interest in buying. Therefore, products capable of accomplishing this objective are those that already have a demonstrated sales record. Third, as sales increase, the number of stores carrying a product will increase leading to enhanced visibility. Once consumers begin to buy a new product, additional stores carry that product." These authors conclude that "Individual level diffusion models or models that combine economic and communications elements seem especially promising," pointing to a number of studies including Chatterjee and Eliashberg, 1990; Horky, 1990' Kalish, 1985; Lattin and Roberts, 1989. Brown, 1992: 73, "Consider, for example, the development of the market for pocket calculators… The first purchasers were engineers and scientists because they had extensive can complex calculations to perform and existing technology (the slide rule and the log table)… As the early manufacturers of calculators began to benefit from technological advances and from economies of experience and scale prices began to fall. Calculators then began to become attractive to accountants and other commercial users… Compared to engineers and scientists, accountants and commercial users have a lower utility value and could only justify purchase when the price came down… As calculator prices fell still further, so they began to become attractive to the general public. Of course, the utility value to these users was lower than to commercial users, but again the potential larger."

[84] Mahajan, Muller and Bass, 1990: 6-7.

On the demand side, the assumption is that the underlying process "is a social learning process which results in consumers slowly changing their attitudes and values… some individuals change their views quicker than others; it is a "rolling snowball" phenomenon which starts with just a few people and gets bigger as it fathers momentum."[85] The demand side approach looked both at the aggregate level of penetration and the individual adoption decisions.

> [A]ttempts have been made… to develop diffusion models by specifying adoption decisions at the individual level. In these models… a potential adopter's utility for an innovation is based on his uncertain perception of the innovation's performance, value or benefits. The potential adopter's uncertain perception of the innovation, however, changes over time as he learns more about the innovation from external sources (e.g., advertising) or internal sources (e.g., word of mouth). Therefore, because of this learning, whenever his utility for the innovation becomes greater than the status quo, (he is better off with the innovation), he adopts the innovation. [86]

B. The Importance of Transaction Costs and Behavioral Factors

The larger field of the analysis of innovation diffusion has grappled with exactly the same issues that we have seen in efficiency gap analysis. A major source of tension in the innovation diffusion field flows from the approach to modeling behavior and process, which is similar to the tension that has typified the efficiency gap literature: the efficient market hypothesis underlying neoclassical economics v. institutional, transaction and behavioral economics views of imperfect markets.

> The issue relates to whether the diffusion process should be formalized as [*neoclassical equilibrium*]… with diffusion patterns reflecting a sequence of shifting equilibria over time in which agents are fully adjusted…modeled as being infinitely rational and fully informed… or as a disequilibrium process… modeled as being constrained by lack of information or understanding on the part of adopters about the worth of an innovation.[87]

The dramatic difference between the approaches to the analysis of innovation diffusion parallels the division in the efficiency gap debate closely, as the side-by-side comparison of the two dominant approaches summarized in Exhibit IV-3 shows. As described in a 1998 survey of the literature (published two years after the major LBL analysis presented by Golove and Eto), the two schools of thought differ on the quality of information, nature of rationality, extent of disequilibrium and the possibility of inefficiency.

The broad critique of the neoclassical economic model that echoes in the efficiency gap debate rested primarily on the fact that the underlying assumptions of infinitely rational/fully informed actors in the neoclassical model does not fit real world behaviors at all.

> As Simon stressed in his Nobel Memorial Lecture, the classical model of rationality requires knowledge of all the relevant alternatives, their consequences and the probabilities, and a predictable world without surprises. These conditions, however, are rarely met for problems that individuals and organizations face. Savage, known as the founder of modern Bayesian decision theory, called such perfect knowledge small worlds… In large worlds, part of the relevant information is unknown or has to be estimated from small samples, so that the conditions for

[85] Brown, 1992, p. 62.
[86] Mahajan, Muller and Bass, 1990, pp. 6-7.
[87] Sarkar, 1998:132.

rational decision theory are not met, making it an inappropriate norm for optimal reasoning. In a large world…one can no longer assume that "rational" models automatically provide the correct answer.[88]

EXHIBIT IV-3: DECISION THEORETIC APPROACHES TO MODELING DIFFUSION

	Neoclassical Equilibrium	Evolutionary Disequilibrium
Scientific Analogy	**Newtonian mechanics**	**Evolutionary Biology**
Assumptions:	**Full/limited information**	**Necessarily limited-information**
	Infinite rationality	**Bounded rationality**
	Equilibrium mechanism	**Disequilibrium mechanism**
	Exogenous/endogenous	**Necessarily endogenous**
	Continuous & quantitative	**Continuous & Quantitative (Darwinian)**
		Discontinuous & qualitative (non-Darwinian)
Characteristics of the	**Predictable**	**Unpredictable**
Diffusion Process	**Ahistorical**	**Path-dependent (historicity)**
	Efficient	**Efficient (Darwinian)**
		Possible inefficiency (non-Darwinian)

Source: Jayati Sarkar, "Technological Diffusion: Alternative Theories and Historical Evidence, *Journal of Economic Surveys,* 2: 1998, p. 149.

The effort to understand the complex influences on human behavior has moved well beyond the simple "rational v. irrational" dichotomy.[89] The middle ground recognizes that "intelligent choice," "useful inferences" and "smart" decisions are possible without reference to "the classic model of rationality."[90] "Ecological rationality" is a term applied to this middle ground that recognizes the limitations imposed on choice by the environment and the capacity of individuals to make decisions.

> The study of ecological rationality is related to the view that human cognition is adapted to its past environment. [91]
>
> In a complex and uncertain world, humans draw inferences and make decisions under the constraints of limited knowledge, resources, and time…. These heuristics perform well because they are ecologically rational: they explore the structure of environmental information and are adapted to this structure.
>
> Models of ecological rationality describe the structure and representation of information in actual environments and their match with mental strategies, such as bounded rational heuristics. The simultaneous focus on the mind and its environment, past and present, put research on decision

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[88] Gigerenzer and Gaissmaier, 2011, p. 453.

[89] However, stepping back from the assumption of perfect rationality can lead to an overemphasis on the irrational, or error in decision making. Hoffrage and Reimer, 2004, p. 456 "[H]euristics were invoked as explanation for systemic errors found in human reasoning – mainly deviation from the laws of probability. Although Tversky and Kahneman repeatedly asserted that heuristics sometimes succeed and sometimes fail, they and many of their colleagues focused on the latter category and interpreted their experimental findings as indicating some kind of fallacy…."

[90] Hoffrage and Reimer, 2004, p. 456, "Fast and frugal heuristics, in contrast, are not associated with the value laden term bias. On the contrary, by taking advantage of the structure of information in the environment, these heuristics can lead to accurate and useful inferences; hence they do not necessarily lead to biases but they can "make us smart." Gigerenzer and Gaissmaier, 2011, p. 473 quoting James March [I]f behavior that apparently deviates from standard procedures of calculated rationality can be shown to be intelligent, then it can plausibly be argued that models of calculated rationality are deficient not only as descriptors of human behavior but also as guides to intelligent choice.

[91] Gigerenzer and Gaissmaier, 2011, 2011, pp. 457-458.

making under uncertainty into an evolutionary and ecological framework, a framework that is missing in most theories of reasoning, both descriptive and normative.[92]

If the baseline assumption of infinite rationality and full information is as far from reality as this discussion suggests, it is reasonable to argue that the baseline should shift to a set of assumptions that are closer to reality. This would make it more likely that the model will avoid the error of assuming that a little more information fed into a context where the underlying forces are almost right will solve the problem. It will avoid the Mercatus Center mistake.[93]

Recognizing the environmental and cognitive constraints on decision making shifts the focal point of the analysis to internal criteria of performance. The focus of study shifts to the origin and impact of constraints on decision making and the tools humans use to make decisions under those constraints.

> Within ecological rationality it is of utmost importance to look at how the environment influences the tasks and how the environment shapes and has shaped the cognitive capacity of social actors. Humans have an evolutionary past in which they constantly learned and adapted to biological and social environment and this shaped their cognitive capacities… In addition, humans are not error free and, even more importantly; they face a wide range of tasks in a modern technological environment.[94]

Exhibit IV-4 presents a common framing of the behavioral considerations. In our earlier analysis, we have identified three broad categories of concepts from the behavioral economics literature that are roughly equivalent to those in Exhibit IV-4:

> For purposes of policy analysis, we believe the findings of behavioral economics can be usefully divided into three groups – motivation, perception and calculation. Wilkinson, 2008, has two sets of chapters, one foundational, one advanced, that can be organized according to this scheme as follows:

Motivation:	Foundations: Values, Attitudes, Preferences and Choice, Nature and Measurement of Utility, Advanced: Fairness and Social Preferences
Perception	Foundations: Decision-making under Risk and Uncertainty, Utility Theory, Prospect Theory, Reference Points, Loss aversion, Decision Weighting Advanced: Behavioral Game Theory, Bargaining, Signaling, Learning
Calculation	Foundations: Mental Accounting, Framing and Editing, Budgeting and Fungibility, Choice Bracketing, Advanced: The Discounted Utility Model, Alternative Intertemporal Choice Models.[95]

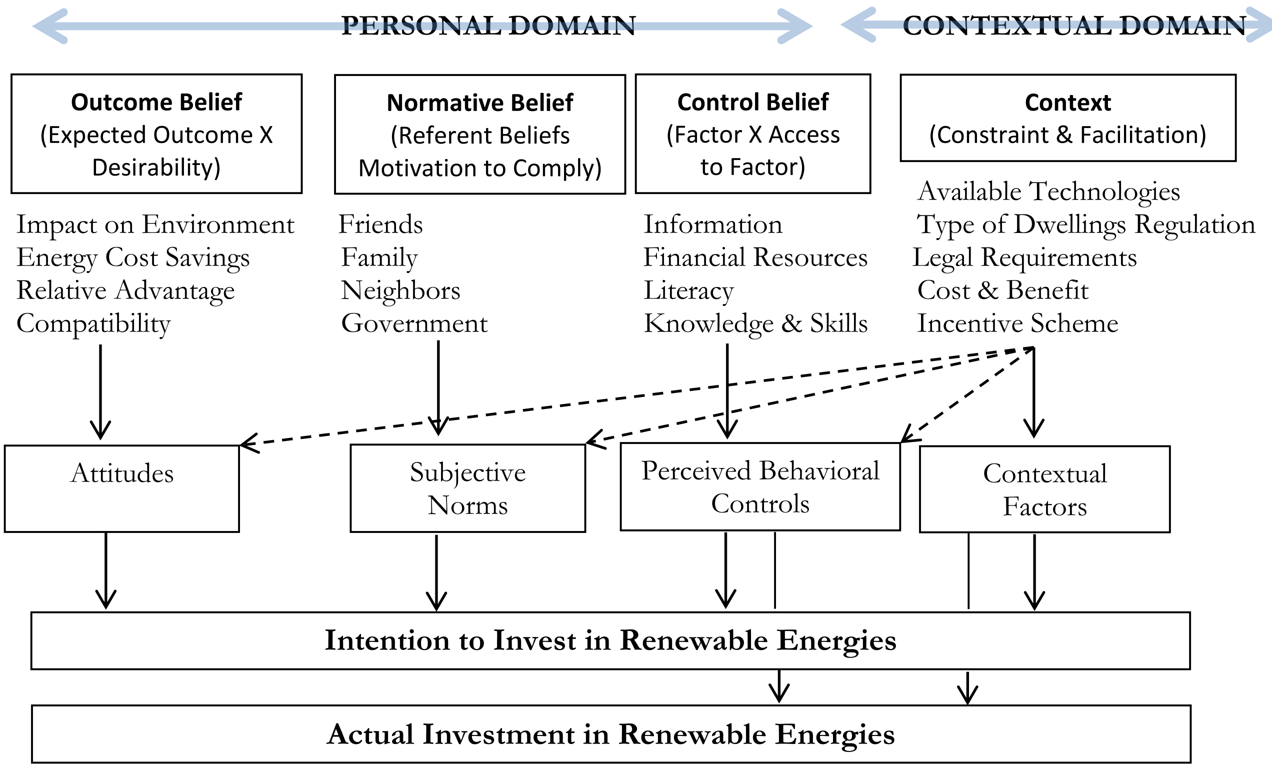
[92] Hoffrage and Reimer, 2004, p. 442 cited in Basel and Bruhl, 17-1; Hoffrage and Reimer, 2004, p. 443.

[93] Hoffrage, and Reimer, 2004, p. 437, From such a perspective it is straightforward to study the adaptation of mental and social strategies to real-world environments rather than compare strategies to the norms of probability theory (e.g., *Bayes's rule*, which can be used to update prior beliefs in the light of new data) and logic (e.g., the *conjunction rule*… Rather, the performance of a heuristic is evaluated against a criterion that exists in the environment – the distinction between internal consistency versus external correspondence.

[94] Basel and Bruhl, 2011, p. 19.

[95] Cooper, 2009, p. 46.

EXHIBIT IV-4: INTEGRATED MODEL TO EVALUATE DETERMINANTS OF ENERGY EFFICIENT TECHNOLOGY UPTAKE



Source: Marius Claudy and Aidan O'Driscoll, "Beyond Economics: A Behavioral Approach to Energy Efficiency in Domestic Buildings," *Dublin Institute of Technology*, 2008; based on Stern, Paul C., "Towards a Coherent Theory of Environmentally Significant Behavior, *Journal of Social Issues,* 56: 2000; see also, Charlie Wilson and Hadi, Dowlatabadi, "Models of Decision Making and Residential Energy Use, *Annual Review of Environmental Resources,* 32:2007, p. 183.

C. MARKET BARRIERS AND THE INNOVATION DIFFUSION PROCESS

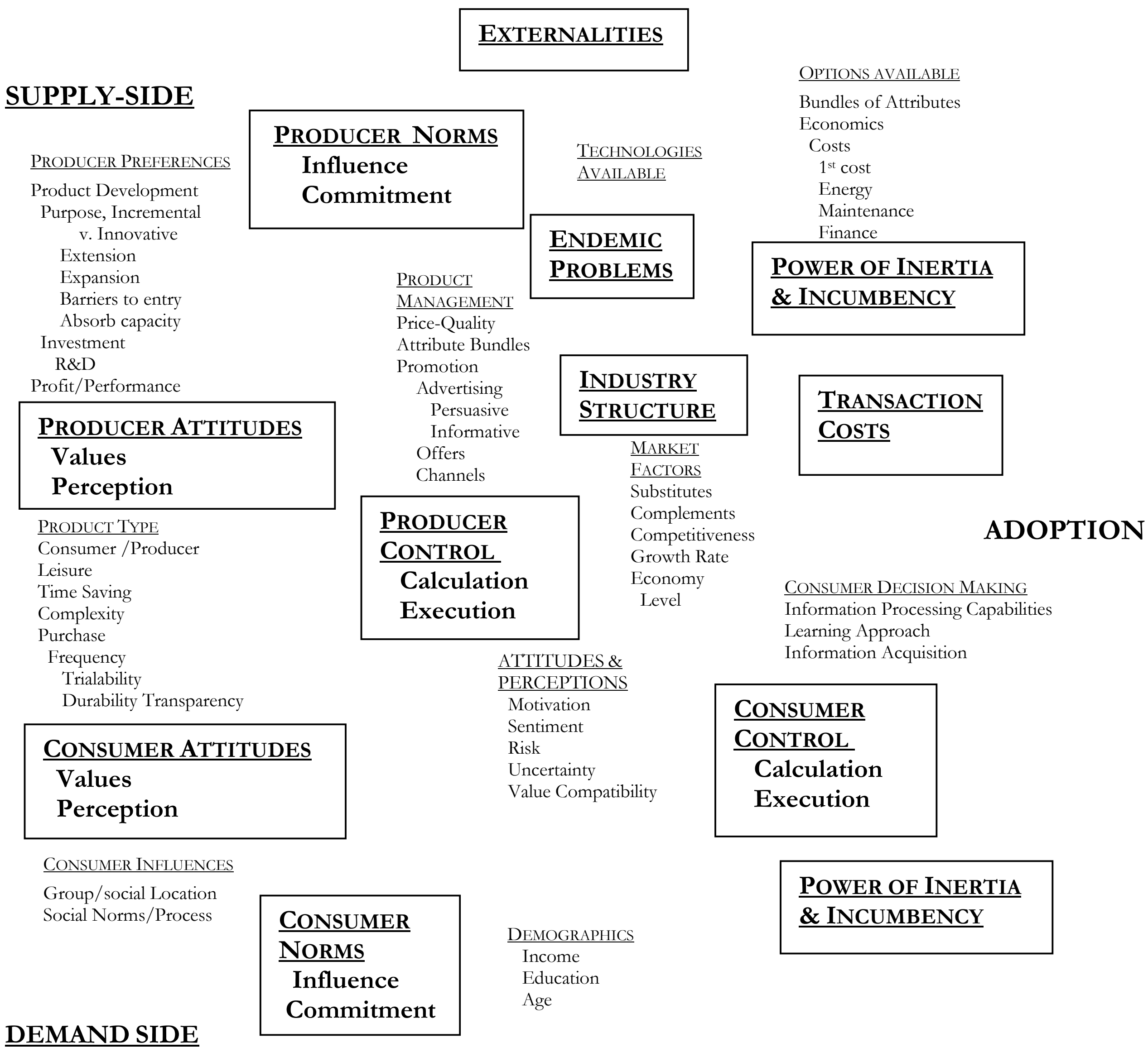
Exhibit IV-5 locates impediments to diffusion in the broad categories of market failure identified in in the "efficiency gap" analysis of Section II. We locate the barriers and imperfections at different points in the flow of innovation/diffusion. We include the three major types of behavioral factors on both the supply-side and the demand side. Arguably, the supply-side is less affected by these factors, since the assumption of profit (welfare) maximizing economic enterprises fits the supply-side better. However, the fit is certainly not perfect and several of the barriers that we observe on the supply-side, like status quo bias and internal structural constraints fit in the behavioral arena. We also include the power of inertia and incumbents on both the supply and demand sides of the market.

The central questions in the efficiency gap analysis involve the process of the adoption of new technologies. Treating the efficiency gap as a special case of the diffusion of innovations allows us to draw on the much broader study of the factors that affect the speed with which technologies are developed and sold to the public. By examining some of the key themes and developments in innovation diffusion literature, we deepen the understanding of the efficiency gap.

- The literature emphasizes the importance of the supply-side, which does not receive sufficient attention in the efficiency gap literature because of the focus on consumer behavior.
- The literature identifies the factors that account for slow innovation and diffusion on both the supply and demand sides of the market.

The innovation diffusion literature exhibits concerns about factors that affect adoption that are similar to the market imperfections and barriers identified in the efficiency gap literature.

EXHIBIT IV-5: MARKET BARRIERS AND IMPERFECTIONS AND THE CAUSAL FACTORS THAT DRIVE THE SUPPLY AND DIFFUSION OF INNOVATION



V. THE INTERSECTION OF THE EFFICIENCY GAP AND CLIMATE CHANGE LITERATURES

A. THE CENTRAL ECONOMIC DEBATE IN THE CLIMATE POLICY ARENA

A recent exchange in *Energy Economics* provides a direct link from the climate change debate to the central issue of the market imperfection/barrier framework. It was set up as a debate between William Nordhaus and Jon Weyant who offered contrasting points of view, with Roger Noll commenting.

Exhibit V-1 summarizes the market barriers and imperfections identified in the exchange between Nordhaus, Weyant and Noll. It sorts the specific barriers into six generic categories that we have identified in the literature of several sectors, including the energy sector. Sometimes the exception proves the rule.[96] That is the case when the exception is rare and demonstrates the robustness of the rule's underlying assumption. However, when the exceptions are numerous and important, they are more likely to consume the rule than prove it.[97]

EXHIBIT V-1: MARKET BARRIERS & IMPERFECTIONS: NORDHAUS, WEYANT AND NOLL

SOCIAL EXTERNALITIES
Sufficiently high & "right" price on the externality
Other externalities
Research & Development
- Non-profit
- Private Appropriability
  - Process innovation
  - Transparency of innovation
  - Institutional innovation

Network Effects
Global Connections

MARKET STRUCTURE
Large Scale
Oligopolistic structure
Regulation

ENDEMIC PROBLEMS
Asymetrric (Strategically Withheld) Information
Principle Agent problems
Lack of financing opportunities
Insufficient incentive to make optimal investment

POLITICAL
Incumbent incentives to delay
Political inability to sustain tax

TRANSACTION COSTS
Uncertainty
Risk
Information
- Lack
- Difficulty

BEHAVIORAL
Consumer Decision Making
Limitations
- Knowledge
- Time
- Calculation

Nordaus' defense of what he calls the "price fundamentalism" approach to climate change analysis and policy making concedes a long list of exceptions to "price fundamentalism" that are seen as extremely important by a growing number of energy analysts.

> Getting the price of carbon right is fundamentally important for stimulating innovations in technologies to mitigate global warming. The major necessary condition for ensuring that climate friendly innovation occurs is that the price of carbon is sufficiently high…Under very limited

[96] Wikipedia, "Scientific sense: A case may appear at first sight to be an exception to the rule. However, when the situation is examined more closely, it is observed that the rule does not apply to this case, and thus the rule is shown to be valid after all." http://en.wikipedia.org/wiki/Exception_that_proves_the_rule

[97] Wikipedia, The statement may also be an argument that the initial rule is flawed, and instead the exception should be the rule….: "Exception that was successful enough to create a new rule or prove the assumed rule was flawed". It could also be argued the rule simply changed." http://en.wikipedia.org/wiki/Exception_that_proves_the_rule

> conditions, setting carbon prices to reflect the damages from carbon emission is also a sufficient condition for the appropriate innovation to be undertaken in market-oriented sectors. This conclusion, which I have labeled "price fundamentalism," must be qualified if the price is wrong and for those parts of research that are not profit-driven (particularly basic research), and when energy investments have particular burdens such as networking or large scale…
>
> If the environmental externality is mispriced, the marginal social return to green investment will be misaligned with those in normal industries…
>
> Technology policy may not optimally internalize the innovation spillovers. This may occur because appropriability differs across sectors and technologies and perhaps even within technologies. It is clear that appropriability is low for fundamental research. Some economists believe that appropriability is low for process (as opposed to product) innovations, transparent (as opposed to easily hidden) innovations, administrative or institutional (as opposed to production) innovations, and networked (as opposed to stand-alone) innovations…
>
> A final important qualification is that this analysis applies primarily to research that is profit-oriented… One issue involves sectors that have a substantial component of not-for-profit research…A second important question is where government should draw the line between areas that are viewed as appropriate for not-for-profit support and those that are governed by the market...
>
> Most other possible qualifications turn out to be specific applications of one of the first three.
>
> [Qualification 1]… Energy production has many other externalities… Energy technology has a particularly global dimension.
>
> [Qualification 2]… Green innovations have important network characteristics… Green innovations require especially large investments (or involve a large component of basic research, or have great inertia)… Outcomes of energy research are highly uncertain.[98]

What Nordhaus calls qualifications are frequently called market imperfections or barriers. Weyant starts with the R&D imperfection.

> This lack of "appropriability" of the benefits of one's own innovation creates a strong motivation for public support of R&D. Such support augments the extent to which simply increasing the price of clean energy relative to that of dirty energy induces innovation. A number of studies… estimate the social rate of return for innovation expenditures at approximately double the rate of return on private R&D expenditures… a close look at the energy sector industries and their potential entrants leads to the conclusion that they are industries where appropriability is difficult.[99]

However, Weyant elaborates on and goes well beyond the list of qualification offered by Nordhaus. He sees several additional supply-side problems.

> A close look at the energy industries and their potential entrants leads to the conclusion that… entry is risky and expensive, market organization is more likely to be oligopolistic than perfectly competitive, and information is strategically held and difficult to obtain…
>
> Further complicating matters, existing companies in energy-related industries --- those that produce energy, those that manufacture the equipment that produces, converts and uses energy, and those that distribute energy – can have substantial incentives to delay the introduction of new technologies. This can happen if their current technologies are more profitable than the new ones that might be (or have been) invented, or if they are in explicitly (oil and gas) or implicitly (electric generation equipment producers and automakers) oligopolistic structured, or if they are imperfectly

[98] Nordhaus, 2011, pp. 672… 670-671.
[99] Weyent, 2011, pp. xx

> regulated (electric and gas utilities). The incentive arises partly because the infrastructure for producing, distributing, and promoting the industries' current products require large investments that have already been incurred.[100]

He also looks beyond the early phases of research and development on which Nordhaus focuses and notes market imperfections that may retard the adoption and diffusion of technologies on the demand-side.

> Imperfections in the market for energy-converting and energy-consuming equipment may be impeding the rate of diffusion of new technologies that are already economically competitive and welfare improving. This situation can result for several different types of market failure, including poor or asymmetric information available to purchasers, limits on individual's ability to make rational decisions because of time or skill constraints, principal-agent incongruities between building owners and building residents, and lack of financing opportunities.[101]

Roger Noll looks at the contrasting views and concludes that "Superficially, these messages conflict, but both are offered with sufficient caveats that, with minor amendments, these articles provide the right approach to near-term U.S. climate policy. Here I elaborate on the amendments that integrate these articles." [102] His amendments add important considerations that further complicate the terrain of policymaking.

> In principle, one could impose taxes on GHG emissions that correct for information imperfection, coordination failures, and market concentration, but the financial cost to consumers of using price instruments to overcome these problems plausibly could be too high to be politically feasible and higher than the cost of simply subsidizing green energy R&D…
>
> In the absence of targeted government interventions utilities are unlikely to make socially optimal investments in these technologies simply on the basis of an optimal emissions tax and a general R&D subsidy… potential entrants face a problem that, for the foreseeable future, the infrastructure is… a complement as well as a substitute… Thus, efficient diffusion of new green technologies requires involving the incumbents.[103]

Noll worries about the "misapplication of a valid principal," and cautions that "the key question is how much delay is the commercialization of new green technologies likely to occur even if Pigovian taxes and subsidies are imposed. The answer to this question remains unclear." While the available answer is not precise, the evidence suggests that the cost of inertia is quite large, and targeted approaches lower costs and speed the transition.[104]

- The general finding that the social return to R&D is twice as large as the private return appears to hold in the energy technology space.[105]
- Because of the magnitude of the change required, the macroeconomic impacts of policy take on great significance, with analysis of the macroeconomic savings from a

[100] Weyent, 2011, pp. 677.
[101] Weyent, 2011, pp. 675.
[102] Noll, 2011, pp. 683.
[103] Noll, 2011, pp. 685.
[104] Acemoglu, et al, 2012, pp. 132.
[105] Qui, 2012, Massetti and Nicita, 2010.

smoother, swifter transition yielding very substantial projected economic savings of at least 50%.[106]

- Estimates of the speed of innovation suggest a one to two decade delay in the introduction of new technologies, if targeted policies to accelerate the diffusion of innovation are not adopted.[107]
- Targeted financial incentives deliver three times as much monetary support for alternatives.[108]

The intense interest in the issues of barriers to change has broken through to the popular press, as demonstrated by a report by Ryan Avent, the Washington-based economic correspondent for the *Economist.* Reporting on "a great session on climate policy"[109] focused on "the environment and directed technical change" and Avent noted that it suggested

> [E]conomics is clearly moving beyond the carbon=tax alone position on climate change, which is a good thing. If the world is to reduce emissions, it needs technologies that are both green and cheap enough to be attractive to economically-stressed countries and people. And a carbon tax alone may not generate the necessary innovation… [T]he carbon externality isn't the only relevant externality in the mix. There is another important dynamic in which technological innovation draws on previous research, and so firms are more likely to continue on established innovation trajectories than to start new ones."[110]

About a year later, David Leonhardt (2013), an economic columnist for the New York Times discussed the practical implications of the growing recognition of the challenge of overcoming inertia and closing the "innovation gap."

> "Over the last several years, the governments of the United States, Europe and China have spent hundreds of billions of dollars on clean-energy research and deployment. And despite some high-profile flops, like ethanol and Solyndra, the investments seem to be succeeding more than they are failing… The successes make it possible at least to fathom a transition to clean energy that does not involve putting a price on carbon — either through a carbon tax or a cap-and-trade program that requires licenses for emissions… To describe the two approaches is to underline their political differences. A cap-and-trade program sets out to make the energy we use more expensive. An investment program aims to make alternative energy less expensive… Most scientists and economists, to be sure, think the best chance for success involves both strategies: if dirty energy remains as cheap as it is today, clean energy will have a much longer road to travel… Still, the clean-energy push has been successful enough to leave many climate advocates believing it is the single best hope… Governments have played a crucial role in financing many of the most important technological inventions of the past century. That's no coincidence: Basic research is often unprofitable. It involves too much failure, and an inventor typically captures only a tiny slice of the profits that flow from a discovery. Although government officials make mistakes when choosing among nascent technologies, one success can outweigh many failures."[111]

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106 Grubb Chapuis and Duong, 1995, p. 428,
107 Dechezlepetre, et al., 2011.
108 Nordhaus, Shellenberger and Trembath, 2012, calculate that that targeted subsidies yield approximately three times the incentive to invest in low carbon alternatives (compared to coal) as a general carbon tax.
109 Avent, 2011.
110 Avent, 2011.
111 Leohhardt, 2013.

B. Empirical Evidence on the Importance of Market Barriers and Imperfections

Exhibit V-2 presents observations on the factors that can inhibit the transition to energy sources and usage that would reduce greenhouse gas emissions significantly. Exhibit A-IV-2 provides citations. They are presented in the categories of market barriers and imperfections we have used throughout this analysis. For purposes of this literature review, we have applied the same criteria used in the review of the recent efficiency gap literature. We limit the scope to the last ten years and include studies that are empirical or review empirical studies. We see strong parallels between the empirical findings in the analysis of the response to climate change and the efficiency gap analysis.

Exhibit V-2: Market Barriers and Imperfection in Climate Change Analysis

Traditional Economics & Industrial Organization

Externalities
Knowledge Externalities that are not captured by markets, e
Research and Development (20, 22, 23, 48, D), a, b
Importance of learning by searching (27, 31, 38, E), c
Deployment: Importance of learning by doing (27, 10, 31, 38, B), c
Economics of Scale/returns to scale (6, 38, 41, 47, G), d
Localization (24, 38, 45, H))

Market Structure:
Cost Structures: Long investment cycles, increasing returns to scale, network effects (8, 28, 33, 498 I)
Challenge of creating new markets: Undifferentiated product (20, 23, 28, 42, J)
Entry Barriers: Capital Cost, access to network (20, 41, 47 48, K)
Lack of competition hinders innovation (41, 48, L)
Inertia:
Cost of Inertia (1, 14, 28, M)
Importance of inertia/stock of knowledge (9, 24, 37, 45, N)

New Institutional Economics

Endemic
Perverse incentives: in allocation of fuel price volatility (20, 50, O), carbon tax level and permanence (21, 30, 40, 44, P) g
Asymmetric information (21, 48, Q)
Shot-term view, h, i

Transaction Cost
Uncertainty: as a cause of underinvestment (8, 21, 26, 43, 47, R)
Fuel price volatility, carbon tax level and permanence (fuel price volatility, carbon tax level and permanence (20, 33, S)
High risk premia on new technologies (28, T)
Information: Value of information (2, 22, U)
Sunk costs and embedded infrastructure (21, 48, V)
Incomplete markets f

Political Power
Power of incumbents to hinder alternatives (20, 45, ZA)
Monopolistic structures and lack of competition (24, 39 41, 46, 47, ZB)
Importance of institutional support for Alternatives (22, 30, ZC)

Behavioral Economics

Behavior
Sluggish demand response (20, 23, W)
Agency (18, 8, X)
Risk Aversion (6, Y)
Calculation (17, 47, Z)

Effective Policy RESPONSES
Public goods (24, 49, ZC)
Institution Building (22, 30, 49, ZE)
Research and Development (5, 10, 20, 23, 25, 26, 28, 32, 35, 37, 47, ZF)
Capital subsidies Adders, premium prices (6, 41, ZG)
Obligations/Consenting (25, 28, 35, 47, M, (ZH)
Standards (8, 22, ZI)
Feed in Tariffs (28, 41, 45, 47, ZJ)
Merit order (20, 21, ZK)

Evidence on the ineffectiveness of price/ tax as policy
Price Insufficiency (4, 11, 15, 20, 19, 25, 29, 35, 41, 47, 48 A)
Tax: Difficulty of setting and sustaining "optimal" levels (20, 19, 47, B)
Tradable permits do not increase innovation (5, 36, C)

Sources: See Appendix C, Exhibit A-V-2

Supply-Side

The central observation is that many of the benefits of alternative generation technology resources or the processes by which their costs would be reduced – e.g. learning by doing, network effects – are positive externalities themselves. This means the private sector will underinvest. Long lead times for technology development, increasing returns to scale and network effects make entry difficult.

Dislodging a dominant technology requires overcoming a great deal of physical and institutional inertia that has built up over decades. New technologies face significant barriers to entry that are compounded by the existence of entrenched incumbents. Thus, the inertia that supports the dominant incumbent technology is a central factor. Inertia is the result of several sets of market imperfection – market and institutional factors including market structure, endemic, behavioral and transaction costs issues. Some of the market imperfections exacerbate the problem of underinvestment in knowledge creation, but their impact on inertia is paramount.

A long period in which fossil fuels were dominant and created a large market makes it the focal point of resources and investment and will be the focal point of innovative activity. Since the alternative technologies are at a disadvantage in terms of development and the ability to attract resources, just raising the cost of the dominant fuels does not overcome the inertia and actually allows the gap between the incumbent and alternative technologies to persist or even grow as the entrenched interests use their resource advantage and political power to protect their incumbency.[112]

The inertia can be compounded by several other factors including monopolistic distortions in the incumbent market, a lack of substitutability between the alternatives and limited spillovers from innovation in the incumbent technology. With an exhaustible resource the problem can be particularly acute, as a tendency to underestimate the long term consequences of continuing dependence on it are not fully reflected in current decision making.

Demand-side

The existing skill sets and economic infrastructure costs create a great deal of inertia. The ability of dominant incumbents to implement practices and promote policies that magnify the barriers to entry can compound the difficulty of entry if they are allowed to hamper access to the network, like incumbent control of access to the grid or dispatch. The allocation of fuel price risk creates a disincentive to innovation. Price volatility and other sources of uncertainty reduce the incentive to invest in new technologies.

Consumers respond sluggishly to price increases, so the shifting of the risk of price volatility onto the consumers does not have the hoped for effect in stimulating demand for alternative resources. The undifferentiated nature of the product makes it hard for new entrants to secure a foothold (niche) from which to build scale and learn-by doing. Energy consuming durables have long lives, and consumers frequently do not make the purchase decision. The agents who make the purchase decisions and consumers are first cost sensitive and have difficulty projecting energy prices and quantities to make lifecycle cost calculations. The demand–side does not receive the attention commensurate with its importance as a source of market failure or its potential impact on the transition to a decarbonized sector.

These factors weaken the ability of price to deliver the first best outcome and trigger the search for second best solutions. Moreover, while "picking winners" is fraught with dangers, setting the right level of the tax is equally difficult and the benefits of overcoming inertia and other barriers

[112] Acemoglu, et al, 2012, pp. 137.

to cost reducing innovation are large. A portfolio of policies that includes both carbon taxes and targeted intervention to stimulate innovation, is widely seen as the best approach.

C. BROAD FRAMEWORKS

Exhibit V-3 presents the market barriers and imperfections from an analysis conducted by Oak Ridge National Laboratory in response to a congressionally mandated "report describing barriers to GHG [Greenhouse Gas] intensity reducing technologies. It covers 15 technologies that would affect four goals "reducing emissions from energy end use and infrastructure, reducing emissions from energy supply, capturing and sequestering carbon dioxide, and reducing emissions of non-CO_2 GHGs."

The Oak Ridge document refers to an Iron Triangle of Barriers defined by Incumbent Support, Transaction Costs and Business Innovation Risk. In fact, in one representation of the analysis it is really an Iron Rectangle, with unfavorable and uncertain policy in a number of areas as the fourth side. The Oak Ridge analysis also highlights the power of incumbents, which is identified as an important barrier in the climate change literature.

EXHIBIT V-3: CAUSES OF CARBON LOCK-IN

Business Innovation Risk – Cost Effectiveness and Fiscal Barriers	Incumbent Support
Technical risk	Industry structure
Volatile Energy Prices	Inadequate supply chain
Market risk	Monopoly power
High up-front costs	
	Policy Obstacles – Regulatory/Statutory barriers
Transaction Costs	Unfavorable policy environment
Inadequate workforce/infrastructure	Unfavorable regulation
Misinformation	Uncertain Regulations
Imperfect information	Burdensome Permitting
Lack of specialized	Uncertain/Unfavorable fiscal policy
Inadequate validation	Misplaced incentives

Marilyn A. Brown, et al., 2008, *Carbon Lock-In: Barriers to Deploying Climate Mitigation Technologies,* Oak ridge National Laboratory, January. See Appendix D, for citations.

Exhibit V-4 compares the results of the UNIDO crossnational study of barriers to industrial energy efficiency with the Oak Ridge analysis of barriers to adoption of technologies that would lower greenhouse gas emissions. While the analysts use different terms to describe the broad categories and the specific detail, there is a great deal of similarity between the frameworks.

D. CONCLUSION: THE INCREASING URGENCY OF CLOSING THE EFFICIENCY GAP

The efficiency gap analysis and debate are not about externalities, although the environmental, national security and macroeconomic impacts of energy consumption stimulated interest in the value of reducing consumption, particularly after the oil price shocks and subsequent

EXHIBIT V-4: COMPARISON OF BARRIERS TO INDUSTRIAL ENERGY EFFICIENCY WITH IRON TRIANGLE OF BARRIERS

BARRIERS TO INDUSTRIAL ENERGY EFFICIENCY	IRON TRIANGLE OF BARRIERS		
	Incumbent Support	Transaction Costs	Business Innovation Risk
Inertia: Difficulty of implementation due to internal organization	Industry structure		
Lack of organizational resources/technical skill		Inadequate supply chain	Inadequate workforce/infrastructure
Long decision chains			
Resistance to change	Monopoly power		
Technology Implemented when current is replace			
Lack of Information		Misinformation	
Lack of quality information about efficiency opportunities		imperfect information	
Lack of staff awareness		Lack of specialized	
No good overview of existing technologies		Inadequate validation	
Risk/Uncertainty			Volatile Energy Prices
Better to wait for experience/subsidies	Inadequate technical		
New technology may not meet future standards	validation	Uncertain regulation	
Risk & cost of production disruption/poor performance			Market risk
Technology will become cheaper			Technical risk
Uncertain about quality			
Rejected, Risk/Uncertainty			
Inconsistent, irregular enforcement of regulation	Unfavorable regulation	Uncertain Regulations	
		Burdensome Permitting	
Split incentives: Conflicts of interest within the company		Misplaced incentives	
Lack of sub-metering/Workers not accountable			
Access to capital: Internal constraints on budget	High up-front costs		
Problems with External Financing		Uncertain fiscal policy	
Bounded rationality: Current technology adequate			
Production most important			
Energy low priority, unimportant/Other more important			
Currently introducing new technology			
Hidden costs:		Unfavorable policy	
Cost of information gathering and processing		environment	
Cost of staff retraining, replacement			
Investment cost		Unfavorable fiscal policy	
Lost Utility Cost of production disruption			

Sources: Steve Sorrell, Alexandra Mallett & Sheridan Nye, 2008, *Barriers to Industrial Energy Efficiency, A Literature Review,* United Nations Industrial Development Organization, Vienna, 2011; Marilyn A. Brown, et al., 2008, *Carbon Lock-In: Barriers to Deploying Climate Mitigation Technologies,* Oak Ridge National Laboratory, January.

economic recessions of the 1970s. Although externalities like these attract attention, these are not the underlying cause of the efficiency gap. Because they are externalities, they are not priced into the market transactions, and we would not expect market behavior to reflect their value. The efficiency gap arises from the failure of market transactions to reflect the costs of energy that are reflected in its price.

To the extent that there are externalities associated with energy consumption, they magnify the concern about market barriers and imperfections, if only because they would make efforts to respond to externalities more difficult. If climate change is recognized as an external cost of energy consumption, it may magnify the importance and social cost of failing to address the efficiency gap. This is where the efficiency gap and climate change analysis intersect.

The climate change debate reinforces the lessons of the efficiency gap and innovation diffusion literatures in another way. The climate change literature has squarely confronted the problem of market barriers and imperfections that affect innovation and diffusion of new technologies. In order to induce rapid change in economic activities, policy must overcome the inertia created by established investment and behavior patterns built up over decades. The set of factors that underlies the inertia to respond to climate change are similar to the market barriers and imperfections that underlie the efficiency gap. Targeted innovations and induced technological change are advocated.

Thus, the debate among economists grappling with the analysis of climate change replicates and parallels the efficiency gap debate. The conceptual and empirical analysis of climate change adds a great deal of evidence to reinforce the conclusions about the barriers and imperfections that affect energy markets. Because the potential external costs are so large, climate change puts a spotlight on technological innovation. The growing concern over adjustment leads to concern over an "innovation gap."[113]

Thus, over the course of the last decade, the climate change analysis has come to highlight the question of the extent to which market processes through the reaction to price increases can be relied upon, or policies that seek to direct, target and accelerate technological innovation and diffusion are needed. The evidence suggests that the cost of inertia is quite large, whereas targeted approaches lower costs and speed the transition.[114]

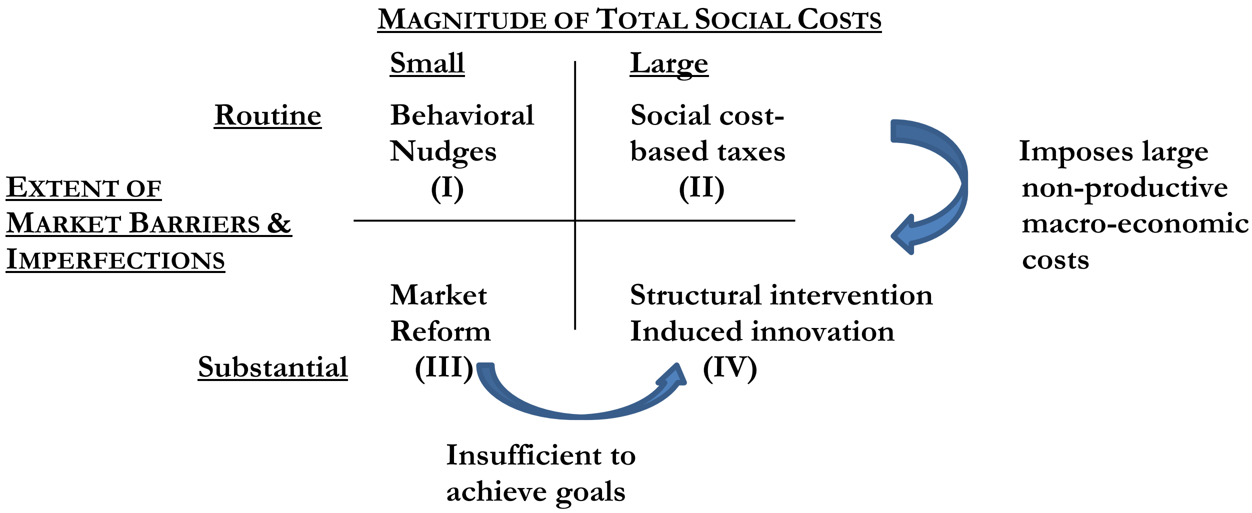
At a high level, the most important implication of this broadening of the framework to include large externalities is to underscore the need for vigorous policy action to address a problem that is now seen as larger and more complex than it was in the past. It is the combination of substantial market imperfections and large externalities that demonstrates there is an urgent need for vigorous policy action, as suggested by Exhibit V-5.

If market imperfections are routine and the social costs of poor market performance are small (cell I), modest policies like behavioral nudges may be an adequate response. If market imperfections are small and costs are large (cell II), then price signals might be sufficient to deal with the externalities. If market imperfections are substantial but costs are small, market reform would be an appropriate response (cell III), since the slow response and long time needed to overcome inertia does not impose substantial costs. If both market imperfections and social costs are large

[113] Gross, et al., 012.
[114] Acemoglu, et al, 2012, pp. 132.

(cell IV), more aggressive interventions are in order. The challenge is to choose policies that reduce the market barriers in an effective (swift, low cost) manner.

EXHIBIT V-5: TYPOLOGY OF POLICY CHALLENGES AND RESPONSES



We believe the energy consumption of consumer durables has been located in cell IV for decades. Reducing the energy consumption of consumer durables has had the potential for substantial consumer pocketbook benefits and significant national security, energy policy and macroeconomic benefits. The existence of these potential benefits reflected significant market barriers, imperfections and failures. The current context of concern about climate change merely increases the urgency for taking action by adding major environmental costs to the calculation.

APPENDIX A
ANNOTATED VERSIONS OF SECTION II EXHIBITS

EXHIBIT A-II-2: MARKET BARRIERS TO ENERGY EFFICIENCY

Barriers[1]	Market Failures	Transaction Cost[2]	Behavioral factors[16]
Misplaced incentives	Externalities	Sunk costs[3]	Custom[17]
Agency[4]	Mis-pricing[20]	Lifetime[5]	Values[18] & Commitment[19]
Capital Illiquidity[8]	Public Goods[22]	Risk[6] & Uncertainty[7]	Social group & status[21]
Bundling	Basic research[23]	Asymmetric Info.[9]	Psychological Prospect[24]
Multi-attribute	Information	Imperfect Info.[10]	Ability to process info[27]
Gold Plating[11]	(Learning by Doing)[25]	Availability	Bounded rationality[26]
Inseparability[13]	Imperfect Competition/	Cost[12]	
Regulation	Market Power[28]	Accuracy	
Price Distortion[14]			
Chain of Barriers			
Disaggregated Mkt.[15]			

William H. Golove and Joseph H. Eto, *Market Barriers to Energy Efficiency: A Critical Reappraisal of the Rationale for Public Policies to Promote Energy Efficiency;*

1) Six market barriers were initially identified: 1) misplaced incentives, 2) lack of access to financing, 3) flaws in market structure, 4) mis-pricing imposed by regulation, 5) decision influenced by custom, and 6) lack of information or misinformation. Subsequently a seventh barrier, referred to as "gold plating," was added to the taxonomy (p.9).

2) Neo-classical economics generally relies on the assumption of frictionless transactions in which no costs are associated with the transaction itself. In other words, the costs of such activities as collecting and analyzing information; negotiating with potential suppliers, partners, and customers; and assuming risk are assumed to be nonexistent or insignificant. This assumption has been increasingly challenged in recent years. The insights developed through these challenges represent an important new way to evaluate aspects of various market failures (especially those associated with imperfect information). Transaction cost economics examines the implications of evidence suggesting that transaction costs are not insignificant but, in fact, constitute a primary explanation for the particular form taken by many economic institutions and contractual relations (p. 22).

3) Transaction cost economics also offers support for claims that the illiquidity of certain investments leads to higher interest rates being required by investors in those investments (p. 23).

4) Misplaced, or split, incentives are transactions or exchanges where the economic benefits of energy conservation do not accrue to the person who is trying to conserve (p. 9).

5) Thus, as the rated lifetime of equipment increases, the uncertainty and the value of future benefits will be discounted significantly. The irreversibility of most energy efficiency investments is said to increase the cost of such investments because secondary markets do not exist or are not well-developed for most types of efficient equipment. This argument contends that illiquidity results in an option value to delaying investment in energy efficiency, which multiplies the necessary return from such investments (p. 16)

6) If a consumer wishes to purchase an energy-efficient piece of equipment, its efficiency should reduce the risk to the lender (by improving the borrower's net cash flow, one component of credit-worthiness5) and should, but does not, reduce the interest rate, according to the proponents of the theory of market barriers. (p.10). Potential investors, it is argued, will increase their discount rates to account for this uncertainty or risk because they are unable to diversify it away. The capital asset pricing model (CAPM) is invoked to make this point (p. 16).

7) Perfect information includes knowledge of the future, including, for example, future energy prices. Because the future is unknowable, uncertainty and risk are imposed on many transactions. The extent to which these unresolvable uncertainties affect the value of energy efficiency is one of the central questions in the market barriers debate. Of course, inability to predict the future is not unique to energy service markets. What is unique is the inability to diversify the risks associated with future uncertainty to the same extent that is available in other markets (p. 20).

8) In practice, we observe that some potential borrowers, for example low-income individuals and small business owners, are frequently unable to borrow at any price as the result of their economic status or "credit-worthiness." This lack of access to capital inhibits investments in energy efficiency by these classes of consumers (p. 10).

9) Finally, Williamson (1985) argues that the key issue surrounding information is not its public goods character, but rather its asymmetric distribution combined with the tendency of those who have it to use it opportunistically (p. 23).

10) [K]nowledge of current and future prices, technological options and developments, and all other factors that might influence the economics of a particular investment. Economists acknowledge that these conditions are frequently not and in some cases can never be met. A series of information market failures have been identified as inhibiting investments in energy efficiency: (1) the lack of information, (2) the cost of information, (3) the accuracy of information, and (4) the ability to use or act upon information (p. 20).

11) The notion of "gold plating" emerged from research suggesting that energy efficiency is frequently coupled with other costly features and is not available separately (p.11).

12) Even when information is potentially available, it frequently is expensive to acquire, requiring time, money or both (p. 20).

13) Inseparability of features refers specifically to cases where availability is inhibited by technological limitations. There may be direct tradeoffs between energy efficiency and other desirable features of a product. In contrast to gold plating where the consumer must purchase more features than are desired, the inseparability of features demands purchases of lower levels of features than desired. (p.12)

14) The regulation barrier referred to mis-pricing energy forms (such as electricity and natural gas) whose price was set administratively by regulatory bodies (p. 11).

15) On the cost-side of the equation, the critics contend that, among other things, information and search costs have typically been ignored or underestimated in engineering/economic analyses. Time and/or money may be spent: acquiring new information (search costs), installing new equipment, training operators and maintenance technicians, or supporting increased maintenance that may be associated with the energy efficient

equipment (p.16). [T]he class, itself, consists of a distribution of consumers: some could economically purchase additional efficiency, while others will find the new level of efficiency is not cost effective (p. 13).

16) Discounted cash-flow, cost-benefit, and social welfare analyses use price as the complete measure of value although in very different ways; behavioral scientists, on the other hand, have argued that a number of "noneconomic" variables contribute significantly to consumer decision making (p. 17).
17) [C]ustom and information have evolved significantly during the market barrier debate (p. 11).
18) In the language of (economic) utility theory, the profitability of energy efficiency investments is but one attribute consumers evaluate in making the investment. The value placed on these other attributes may, in some cases, outweigh the importance of the economic return on investment (p. 19).
19) [P]sychological considerations such as commitment and motivation play a key role in consumer decisions about energy efficiency investments (p. 17).
20) Externalities refer to costs or benefits associated with a particular economic activity or transaction that do not accrue to the participants in the activity (p. 18).
21) Other factors, such as membership in social groups, status considerations, and expressions of personal values play key roles in consumer decision-making (p.17). In order for a market to function effectively, all parties to an exchange or transaction must have equal bargaining power. In the event of unequal bargaining positions, we would expect that self-interest would lead to the exploitation of bargaining advantages (p. 19).
22) Public goods are said to represent a market failure. It has been generally acknowledged by economists and efficiency advocates that public good market failures affect the energy services market. (p. 19) [T]he creation of information is limited because information has public good qualities. That is, there may be limits to the creator's ability to capture the full benefits of the sale or transfer of information, in part because of the low cost of subsequent reproduction and distribution of the information, thus reducing the incentive to create information that might otherwise have significant value (p. 20).
23) Investment in basic research in believed to be subject to this shortcoming; because the information created as a result of such research may not be protected by patent or other property right, the producer of the information may be unable to capture the value of his/her creation (p. 19).
24) Important theoretical refinements to this concept, known as prospect theory, have been developed by Tversky and Kahneman (1981, 1986). This theory contends that individuals do not make decisions by maximizing prospective utility, but rather in terms of difference from an initial reference point. In addition, it is argued that individuals value equal gains and losses from this reference point differently, weighing losses more heavily than gains (p.21).
25) The information created by the adoption of a new technology by a given firm also has the characteristics of a public good. To the extent that this information is known by competitors, the risk associated with the subsequent adoption of this same technology may be reduced, yet the value inherent in this reduced risk cannot be captured by its creator (p. 19).
26) This work is consistent with the notion of bounded rationality in economic theory. In contrast to the standard economic assumption that all decision makers are perfectly informed and have the absolute intention and ability to make decisions that maximize their own welfare, bounded rationality emphasizes limitations to rational decision making that are imposed by constraints on a decision maker's attention, resources, and ability to process information. It assumes that economic actors intend to be rational, but are only able to exercise their rationality to a limited extent (p.21).
27) Finally, individuals and firms are limited in their ability to use — store, retrieve, and analyze — information. Given the quantity and complexity of information pertinent to energy efficiency investment decisions, this condition has received much consideration in the market barriers debate (p. 20).
28) This barrier suggests that certain powerful firms may be able to inhibit the introduction by competitors of energy-efficient, cost-effective products (p. 10).

EXHIBIT A-II-3: MARKET AND BEHAVIORAL FAILURES RELEVANT TO ENERGY EFFICIENCY

Societal Failures

- Energy Market Failures
  - Environmental Externalities[1]
  - Energy Security
- Innovation market failures
  - Research and development spillovers[2]
  - Learning-by-doing spillovers[3]
  - Learning-by-using[4]

Structural Failures

- Capital Market Failures
  - Liquidity constraints[5]
- Information problems[6]
  - Lack of information[7]
  - Asymmetric info. >
    - Adverse selection[8]
  - Principal-agent problems[9]
  - Average-cost electricity pricing[10]

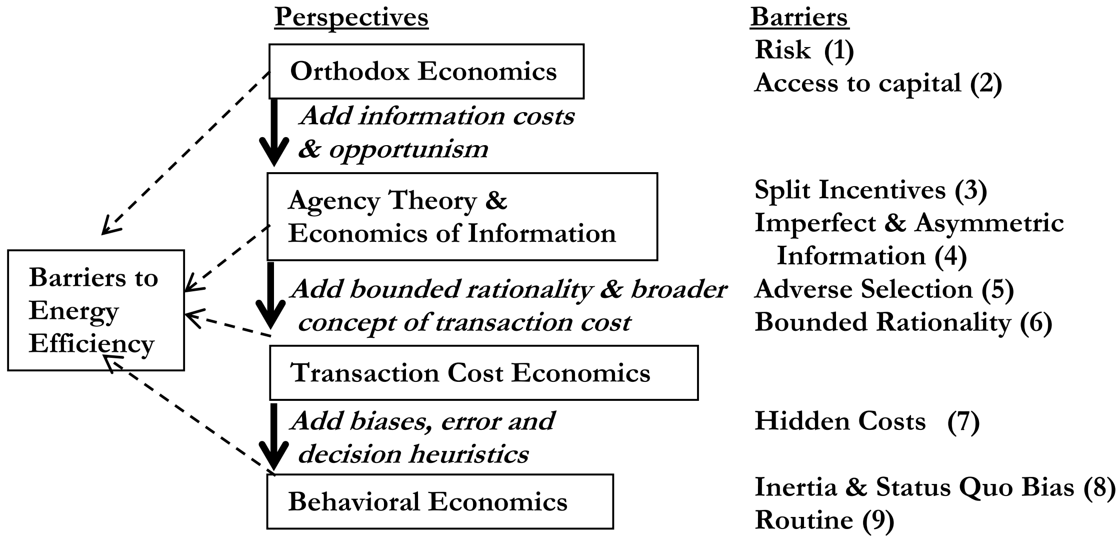
Potential Behavioral Failures[11]

- Prospect theory[12]
- Bounded rationality[13]
- Heuristic decision making[14]
- Information[15]

1) Externalities: the common theme in energy market failures is that energy prices do not reflect the true marginal social cost of energy consumption, either through environmental externalities, average cost pricing, or national security (9).
2) R&D spillovers may lead to underinvestment in energy-efficient technology innovation due to the public good nature of knowledge, whereby individual firms are unable to fully capture the benefits from their innovation efforts, which instead accrue partly to other firms and consumers (11).
3) Learning-by-doing (LBD) refers to the empirical observation that as cumulative production of new technologies increases, the cost of production tends to decline as the firm learns from experience how to reduce its costs (Arrow 1962). LBD may be associated with a market failure if the learning creates knowledge that spills over to other firms in the industry, lowering the costs for others without compensation.
4) Positive externalities associated with learning-by-using can exist where the adopter of a new energy-efficient product creates knowledge about the product through its use, and others freely benefit from the information generated about the existence, characteristics, and performance of the product (12).
5) Capital: Some purchasers of equipment may choose the less energy-efficient product due to lack of access to credit, resulting in underinvestment in energy efficiency and reflected in an implicit discount rate that is above typical market levels (13).
6) Information: Specific information problems cited include consumers' lack of information about the availability of and savings from energy-efficient products, asymmetric information, principal-agent or split-incentive problems, and externalities associated with learning-by-using (11).
7) Lack of information and asymmetric information are often given as reasons why consumers systematically underinvest in energy efficiency. The idea is that consumers often lack sufficient information about the difference in future operating costs between more-efficient and less-efficient goods necessary to make proper investment decisions (11).
8) Asymmetric information, where one party involved in a transaction has more information than another, may lead to adverse selection (11).
9) Agency: The principal-agent or split-incentive problem describes a situation where one party (the agent), such as a builder or landlord, decides the level of energy efficiency in a building, while a second party (the principal), such as the purchaser or tenant, pays the energy bills. When the principal has incomplete information about the energy efficiency of the building, the first party may not be able to recoup the costs of energy efficiency investments in the purchase price or rent charged for the building. The agent will then underinvest in energy efficiency relative to the social optimum, creating a market failure (12).
10) Prices faced by consumers in electricity markets also may not reflect marginal social costs due to the common use of average-cost pricing under utility regulation. Average-cost pricing could lead to under- or overuse of electricity relative to the economic optimum (10).
11) Systematic biases in consumer decision making that lead to underinvestment in energy efficiency relative to the cost-minimizing level are also often included among market barriers. (8); The behavioral economics literature has drawn attention to several systematic biases in consumer decision making that may be relevant to decisions regarding investment in energy efficiency. Similar insights can be gained from the literature on energy decision-making in psychology and sociology. The evidence that consumer decisions are not always perfectly rational is quite strong, beginning with Tversky and Kahneman's research indicating that both sophisticated and naïve respondents will consistently violate axioms of rational choice in certain situations (15).
12) The welfare change from gains and losses is evaluated with respect to a reference point, usually the status quo. In addition, consumers are risk averse with respect to gains and risk seeking with respect to losses, so that the welfare change is much greater from a loss than from an expected gain of the same magnitude (Kahneman and Tversky 1979). This can lead to loss aversion, anchoring, status quo bias, and other anomalous behavior (16).
13) Bounded rationality suggests that consumers are rational, but face cognitive constraints in processing information that lead to deviation from rationality in certain circumstances (16); Assessing the future savings requires forming expectations of future energy prices, changes in other operating costs related to the energy use (e.g., pollution charges), intensity of use of the product, and equipment lifetime. Comparing these expected future cash flows to the initial cost requires discounting the future cash flows to present values (3).
14) Heuristic decision-making is related closely to bounded rationality and encompasses a variety of decision strategies that differ in some critical way from conventional utility maximization in order to reduce the cognitive burden of decision-making. Tversky (1972) develops the theory of elimination-by-aspects," wherein consumers use a sequential decision making process where they first narrow their full choice set to a smaller set by eliminating products that do not have some desired feature or aspect (e.g., cost above a certain level), and then they optimize among the smaller choice set, possibly after eliminating further products. (16) For example, for decisions regarding energy-efficient investments consumers tend to use a simple payback measure where the total investment cost is divided by the future savings calculated by using the energy price today, rather than the price at the time of the savings— effectively ignoring future increases in real fuel prices (p. 17). The salience effect may influence energy efficiency decisions, potentially contributing to an overemphasis on the initial cost of an energy-efficient purchase, leading to an underinvestment in energy efficiency. This may be related to evidence suggesting that decision makers are more sensitive to up-front investment costs than energy operating costs, although this evidence may also be the result of inappropriate measures of expectations of future energy use and prices (17).
15) Alternatively, information problems may occur when there are behavioral failures, so that consumers are not appropriately taking future reductions in energy costs into account in making present investments in energy efficiency (12).

Source: Kenneth Gillingham, Richard G. Newell, and Karen Palmer, *Energy Efficiency Economics and Policy* (Resources for the Future, April 2009)

EXHIBIT A-II-4: BARRIERS TO INDUSTRIAL ENERGY EFFICIENCY



Steve Sorrell, Alexandra Mallett & Sheridan Nye. *Barriers to industrial energy efficiency, A literature review,* United Nations Industrial Development Organization, Vienna, 2011, Figure 3.1 & Section 3.

(1) Risk: The short paybacks required for energy efficiency investments may represent a rational response to risk. This could be because energy efficiency investments represent a higher technical or financial risk than other types of investment, or that business and market uncertainty encourages short time horizons.

(2) Access to capital: If an organization has insufficient capital through internal funds, and has difficulty raising additional funds through borrowing or share issues, energy efficient investments may be prevented from going ahead. Investment could also be inhibited by internal capital budgeting procedures, investment appraisal rules and the short-term incentives of energy management staff.

(3) Split incentives: Energy efficiency opportunities are likely to be foregone if actors cannot appropriate the benefits of the investment. Wide applicability… Landlord-tenant problems may arise in the industrial, public and commercial sectors through the leasing of buildings and office space. The purchaser may have a strong incentive to minimise capital costs, but may not be accountable for running costs….maintenance staff may have a strong incentive to minimize capital costs and/or to get failed equipment working again as soon as possible, but may have no incentive to minimise running costs. If individual departments within an organization are not accountable for their energy use they will have no incentive to improve energy efficiency.

(4) Imperfect information: Lack of information on energy efficiency opportunities may lead to cost-effective opportunities being missed. In some cases, imperfect information may lead to inefficient products driving efficient products out of the market. Information on: the level and pattern of current energy consumption and comparison with relevant benchmarks; specific opportunities, such as the retrofit of thermal insulation; and the energy consumption of new and refurbished buildings, process plant and purchased equipment, allowing choice between efficient and inefficient options.
Asymmetric information exists where the supplier of a good or service holds relevant information, but is unable or unwilling to transfer this information to prospective buyers.

(5) Asymmetric information may lead to the adverse selection of energy inefficient goods.

(6) Bounded rationality: Owing to constraints on time, attention, and the ability to process information, individuals do not make decisions in the manner assumed in economic models. As a consequence, they may neglect opportunities for improving energy efficiency, even when given good information and appropriate incentive consumers do not attempt to maximise their utility or producers their profits.

(7) Hidden costs Engineering-economic analyses may fail to account for either the reduction in utility associated with energy efficient technologies, or the additional costs associated with them. As a consequence, the studies may overestimate energy efficiency potential. Examples of hidden costs include overhead costs for management, disruptions to production, staff replacement and training, and the costs associated with gathering, analysing and applying information.
General overhead costs of energy management: employing specialist people (e.g., energy manager); energy information systems (including: gathering of energy consumption data; maintaining sub metering systems; analysing data and correcting for influencing factors; identifying faults; etc.); energy auditing;
Costs involved in individual technology decisions: i) identifying opportunities; ii) detailed investigation and design; iii) formal investment appraisal; formal procedures for seeking approval of capital expenditures; specification and tendering for capital works to manufacturers and contractors additional staff costs for maintenance; replacement, early retirement, or retraining of staff; disruptions and inconvenience;
Loss of utility associated with energy efficient: problems with safety, noise, working conditions, service quality etc. (e.g., lighting levels); extra maintenance, lower reliability,

(8) Inertia and the status quo bias: Routines can be surprisingly persistent and entrenched. … This type of problem has been labeled *inertia* within the energy efficiency literature and identified as a relevant explanatory variable for the efficiency gap

(9) Routines as a response to bounded rationality the use of formal capital budgeting tools within investment decision-making. Other types of rules and routines which may impact on energy efficiency include: operating procedures (such as leaving equipment running or on standby); safety and maintenance procedures; relationships with particular suppliers; design criteria; specification and procurement procedures; equipment replacement routines and so on.

EXHIBIT A-II-5: MCKINSEY AND COMPANY MARKET BARRIERS TO HOME ENERGY EFFICIENCY

Kckinsey Category	McKinsey Nature	McKinsey Description	Cluster
Behavioral	Awareness	Low priority, Preference for other attributes	CD, RLA
Availability	Availability	Restricted procurement, 1st cost focus	CD
Behavioral	Awareness	Shop for price and features	RD
Behavioral	Awareness	Limited understanding of use and savings	CEPB, EH, GB, RLA
Behavioral	Custom & Habit	Little attention at time of sale	NH
Behavioral	Custom & Habit	Underestimation of plug load	RD
Behavioral	Custom & Habit	Aversion to change	CI,
Behavioral	Custom & Habit	CFLS perceived as inferior	RLA
Behavioral	Hurdle	Payback-Hurdle, 28% discount rate	CEPB
Behavioral	Hurdle	Payback-Hurdle,40% discount rate	EH
Behavioral	Use	Improper use and maintenance	CEPB, EH, RD
Behavioral	Awareness	Not accountable for efficiency	CI
Availability	Capital	Competing use of capital	EH, GB, RLA, CI
Structural	Agency	Tenant pays, builder ignores	CEPB, EH, RD
Availability	Availability	Lack of contractors	EH
Availability	Availability	Lack of availability in area	NH
Availability	Availability	Lack of demand => lack of R&D	RD
Availability	Availability	Emergency replacement	RLA
Availability	Bundling	Efficiency bundled with other features	RLA
Structural	Owner Transfer	Lack of premium at time of sale	CD, NH, NPB, RLA
Structural	Owner Transfer	Limits payback to occupancy period	EH
Structural	Transaction	Lack of information	NPB
Structural	Transaction	Disruption during improvement process	EH
Structural	Transaction	Difficult to identify efficient devices	RD
Behavioral	Risk/Uncertainty	Business failure risk	CEPB
Behavioral	Risk/Uncertainty	Lack of reliability	CI
Structural	Transaction	Research, procurement and preparation	EH, GB, RLA

SOURCE:
McKinsey and Company, *Unlocking Energy Efficiency in the U.S. Economy,* July 2009, Tables 2, 3, 4, 5, 6, 8, 9, 10, 11, 12, Exhibits 14, 15, 16, 19, 21, 24, 26, 27, 29, 30.

Clusters
CD = Commercial Devices;
CEPB = Commercial Existing Private Buildings;
CI = Commercial Infrastructure;
EH = Existing Homes;
GB = Government Buildings;
NH = New Homes;
NPB = New Private Commercial Buildings;
RD = Residential Devices;
RLA = Residential Lighting and Appliances

McKinsey Categories Defined:

Structural. These barriers arise when the market of environment makes investing in energy efficiency less possible or beneficial, preventing measures that would be NPV-positive from being attractive to an end-user:

Agency issues energy efficiency less possible or beneficial, preventing a measure that would be NPV misaligned between economic actors, primarily between landlord and tenant These barriers arise when the market or environment makes investing in (split incentives), in which energy bills and capital rights are

Ownership transfer issues, in which the current owner cannot capture the full duration of benefits, thus requiring assurance they can capture a portion of the future value upon transfer sufficient to justify upfront investment; this issue also affects builders and buyers… Because developers do not receive the future energy savings from efficient buildings and are often unaware or uncertain of the market premium energy efficient building can command, developers have little financial incentive to invest in energy efficiency above the required minimum.

"Transaction" barriers, a set of hidden "costs" that are not generally monetizable, associated with energy efficiency investment; for example, the investment of time to research and implement a new measure High transaction barriers arise as consumers incur significant time "costs" in researching, identifying, and procuring efficiency upgrades

Pricing distortions, including regulatory barriers that prevent savings from materializing for users of energy-savings devices.

Behavioral: These barriers explain why an end-user who is structurally able to capture a financial benefit still decides not to

Risk and uncertainty over the certainty and durability of measures and their savings generates an unfamiliar level of concern for the decision maker. Many operators are risk averse and put a premium on reliability; they may not be inclined to pursue energy efficiency activities for fear of disrupting essential services.

Lack of awareness, or low attention, on the part of end-users and decision makers in firms regarding details of current energy consumption patterns, potential savings, and measures to capture those savings. Homeowners typically do not understand their home energy consumption and are unaware of energy-saving measures.

Custom and habit, which can create inertia of "default choices" that must be overcome. Enduring lifestyle disruptions during the improvement process. End-users retain preconceived and often inaccurate ideas about differences in functionality that limit the acceptance of certain products.

Elevated hurdle rates, which translate into end-users seeking rapid pay back of investments - typically within 2 to 3 years. This expectation equates to a discount rate of 40 percent for investments in energy efficiency, inconsistent with the 7-percent discount rate they implicitly use when purchasing electricity (as embodied by the energy provider's cost of capital). It is beyond the scope of this report to evaluate the appropriate risk-adjusted hurdle rate for specific end-users, though it seems clear that the hurdle rates of energy delivery and energy efficiency are significantly different.

Availability: These barriers prevent adoption even for end-users who would choose to capture energy efficiency opportunities if they could

Adverse bundling or "gold plating," situations in which the energy efficient characteristic of a measure is bundled with premium features, or is not available in devices with desirable features of higher priority, and is therefore not selected

Capital constraints and access to capital, both access to credit for consumers and firms and (in industry and commerce) competition for resources internally within balance-sheet constraints. Energy efficiency projects may compete for capital with core business projects.

Product (and service) availability in the supply chain; energy efficient devices may not be widely stocked or available through customary purchasing channels, or skilled service personnel may not be available in a particular market

Inconsistent quality of installation (sizing, sealing and charging, code compliance and enforcement) and improper use eliminates savings

EXHIBIT A-II-7: RECENT EMPIRICAL EVIDENCE ON MARKET FAILURES, BARRIERS AND IMPERFECTIONS

TRADITIONAL ECONOMICS & INDUSTRIAL ORGANIZATION

Externalities
- Public goods[1] & Bads[2]
- Basic research
- Network effects
- Information as a public good
- Learning-by-doing & Using[9]

Industry Structure
- Imperfect Competition
  - Concentration[13]
  - Barriers to entry
  - Scale[18]
  - Switching costs[20]
- Technology[23]
  - R&D
  - Investment[25]
- Marketing
  - Bundling: Multi-attribute[26]
  - Substitutes[27]
- Cost-Price
  - Limit impact of price[29]
    - Fragmented Mkt.[30]
    - Limited payback[31]

Regulation
- Price[34]
  - Infrequent
  - Aggregate, Avg.-cost[35]
- Lack of commitment[36]

NEW INSTITUTIONAL ECONOMICS

Endemic Imperfections
- Asymmetric Info[3].
- Agency[5]
- Adverse selection[6]
- Perverse incentives
- Lack of capital[10]

TRANSACTION COST
- Search and Information
- Imperfect info[14]
  - Availability[16]
  - Accuracy
  - Search cost[21]
- Bargaining
  - Risk & Uncertainty[24]
  - Liability
- Enforcement
- Sunk costs
- Hidden cost[28]

Political Power
- Power of incumbents to hinder alternatives
- Monopolistic structures and lack of competition
- Importance of institutional support for Alternatives[32]
- Inertia[33]

BEHAVIORAL ECONOMICS

Motivation & Values
- Non-economic[4]

Influence & Commitment
- Custom[7]
- Social group & status[8]

Perception
- Bounded Vision/Attention[11]
- Prospect[12]

Calculation.
- Bounded rationality[15]
- Limited ability to process info[17]
- Heuristic decision making[19]
- Discounting difficulty[22]

Citations

1. Macroeconomic: Edelstein and Killian, 2009, p. 13, [T]he cumulative effects on real consumption associated with energy price shocks are quantitatively important. We showed that the responses of real consumption aggregates are too large to reflect the effects of unanticipated change in discretionary income alone. Our analysis suggests that the excess response can be attributed to shifts in precautionary savings and to changes in the operating costs of energy using durables.
2. Committee On Health, Environmental, And Other External Costs And Benefits Of Energy Production And Consumption, 2011, p. I, D]espite energy's many benefits, most of which are reflected in energy market prices, the production, distribution, and use of energy also cause negative effects. Beneficial or negative effects that are not reflected in energy market prices are termed "external effects" by economists. In the absence of government intervention, external effects associated with energy production and use are generally not taken into account in decision making. When prices do not adequately reflect them, the monetary value assigned to benefits or adverse effects (referred to as damages) are "hidden" in the sense that government and other decision makers, such as electric utility managers, may not recognize the full costs of their actions. When market failures like this occur, there may be a case for government interventions in the form of regulations, taxes, fees, tradable permits, or other instruments that will motivate such recognition.
3. UNIDO, 2011, p. 19, Asymmetric information exists where the supplier of a good or service holds relevant information, but is unable or unwilling to transfer this information to prospective buyers. The extent to which asymmetric information leads to market failure will depend upon the nature of the good or service…. In contrast to

energy commodities, energy efficiency may only be considered a search good when the energy consumption of a product is clearly and unambiguously labelled and when the performance in use is insensitive to installation, operation and maintenance conditions. But for many goods, the information on energy consumption may be missing, ambiguous or hidden, and the search costs will be relatively high. In the absence of standardised performance measures or rating schemes, it may be difficult to compare the performance of competing products. Taken together, these features tend to make energy efficiency closer to a *credence good* and hence more subject to market failure. Thus, to the extent that energy supply and energy efficiency represent different means of delivering the same level of energy service, the latter is likely to be disadvantaged relative to the former. The result is likely to be overconsumption of energy and under-consumption of energy efficiency.

4. Alcott, 2011, p. 1, Results show that beliefs are both highly noisy, consistent with imperfect information and bounded computational capacity, and systematically biased in manner symptomatic of "MPG illusion;" Alcott and Wozny, 2010.
5. Davis, xxx, p. 1; Extensive analysis of U.S. and global markets support the conclusion that this is an important impediment to greater energy efficiency of consumer durables. "The results show that, controlling for household income and other household characteristics, renters are significantly less likely to have energy efficient refrigerators, clothes washers and dishwashers."
6. UNIDO, 2011, p. 19, In some circumstances, asymmetric information in energy service markets may lead to the adverse selection of energy inefficient goods. Take housing as an example. In a perfect market, the resale value of a house would reflect the discounted value of energy efficiency investments. But asymmetric information at the point of sale tends to prevent this. Buyers have difficulty in recognising the potential energy savings and rarely account for this when making a price offer. Estate agents have greater resources than buyers, but similarly neglect energy efficiency when valuing a house. Since the operating costs of a house affect the ability of a borrower to repay the mortgage, they should be reflected in mortgage qualifications. Again, they are not. In all cases, one party (e.g., the builder or the seller) may have the relevant information, but transaction costs impede the transfer of that information to the potential purchaser. The result may be to discourage house builders from constructing energy efficient houses, or to discourage homeowners from making energy efficiency improvements since they will not be able to capture the additional costs in the sale price.
7. Ozaki and Sevastyanove, 2009.
8. Claudy and O'Dricoll, 2008, p. 11, "A growing body of literature around energy conservation contends that investment into energy efficiency measure is often motivated by "conviction" rather than "economics." Behavioral factors, including attitudes and values, explain a greater amount of variation in proenvironmental behaviour and provide valuable insights for policy makers and analysts."
9. Deroches, 2011, p. 1, Costs and prices generally fall in relations to cumulative production, a phenomenon known as experience and modeled as a fairly robust empirical experience curve… These experience curves… incorporated into recent energy conservation standards… impact on the national modeling can be significant, often increasing the net present value of potential standard levels… These results imply that past energy conservation standards analyses may have undervalued the economic benefits of potential standard levels.
10. UNIDO, 2011, p. iii, If an organization has insufficient capital through internal funds, and has difficulty raising additional funds through borrowing or share issues, energy efficient investments may be prevented from going ahead. Investment could also be inhibited by internal capital budgeting procedures, investment appraisal rules and the short-term incentives of energy management staff.
11. Alcott, 2009, p. 1. "I provide evidence to suggest that at least some of this effect is because consumers' attention is malleable and non-durable." UNIDO, pp. viii, Owing to constraints on time, attention, and the ability to process information, individuals do not make decisions in the manner assumed in economic models. As a consequence, they may neglect opportunities for improving energy efficiency, even when given good information and appropriate incentive consumers do not attempt to maximise their utility or producers their profits.
12. Sardiano, 2007, p. 1417, Decision making process to invest in energy efficiency improvement, like other investments, is a function of the behavior of individual or of various actors within the industrial firm. In this context, managerial attitudes toward energy conservation are also important factors… [E]nergy efficiency measures are often not overlooked by management because it is not a core business activity and it is thus not worth much attention.
13. Blumstein, 2013, p. 5, [T]he existence of market power dampens the responsiveness of suppliers of goods or services to consumer demand, as actors in a monopolistic or oligopolistic setting can more or less set prices and quality attributes.
14. Atari, et. al., 2010, p. 1. For a sample of 15 activities, participants underestimated energy use and savings by a factor of 2.8 on average, with small overestimates for lower-energy activities and large, underestimates for high-energy activities." Jessoe and Rapson, 2013, p. 34, "These results confirm the practical importance of one of economics' most ubiquitous assumptions – that decision makers have perfect information. Indeed, the absence of perfect information is likely to cause substantial efficiency loses both in this setting and others in which quantity is also

infrequently or partially observed by decision makers." Consumers Union, 2012, p. 8, "this suggests that many consumers are misinformed about the program requirements.

15. Green, German and Delucchi, 2009, p. 203; "The uncertainty/loss aversion model of consumers' fuel economy decision making implies that consumers will undervalue expected future fuel savings to roughly the same degree as manufacturers' perception that consumers demand short payback periods."
16. UNIDO, 2011, p. iii, Lack of information on energy efficiency opportunities may lead to cost-effective opportunities being missed. In some cases, imperfect information may lead to inefficient products driving efficient products out of the market. Information on: the level and pattern of current energy consumption and comparison with relevant benchmarks; specific opportunities, such as the retrofit of thermal insulation; and the energy consumption of new and refurbished buildings, process plant and purchased equipment, allowing choice between efficient and inefficient options.
17. Atari, et. al., 2010, p. 1. For a sample of 15 activities, participants underestimated energy use and savings by a factor of 2.8 on average, with small overestimates for lower-energy activities and large, underestimates for high-energy activities."
18. Montvalo, 2007, p. S10, Due to the size of investment and longevity or production processes it is very likely that the diffusion of new processes will occur in an incremental way.
19. Ito, 2010, p. 1, Evidence from laboratory experiments suggests that consumers facing such price schedules may respond to average price as a heuristic. I empirically test this prediction using field data.
20. Sardianou, 2007, p. 1419, Our empirical results also confirm that organizational constraints and human related factors can be thought of as barriers in incorporating the energy saving technology in incorporating the energy saving technology in the existing production process.
21. Sardianou, 2007, p. 1419, Having limited information with regard to energy conservation opportunities and their profitability is considered an obstacle…. Other possible barriers include lack of documentation of energy data.
22. Kurani and Turrentine, 2004, p. 1, One effect of limited knowledge is that when consumers buy a vehicle, they do not have the basic building blocks of knowledge to make an economically rational decision. When offered a choice to pay more for better fuel economy, most households were unable to estimate potential savings, particularly over periods of time greater than one month. In the absence of such calculations, many households were overly optimistic about potential fuel savings, wanting and thinking they could recover an investment of several thousand dollars in a couple of years.
23. Montvalo, 2007, p. A10, Finally, firms face the challenge of technological risk. The gains promised by new technologies have yet to materialize, a situation that contrasts strongly with the perceived reliability of the current, familiar operating process. In the literature on technology management it has been established that adoption or development of new production processes implies the capacity to integrate new knowledge and large organizational change.
24. UNIDO, 2011, p. iii, The short paybacks required for energy efficiency investments may represent a rational response to risk. This could be because energy efficiency investments represent a higher technical or financial risk than other types of investment, or that business and market uncertainty encourages short time horizons.
25. Montvalo, 2007, p. s10, Closely related to these technological opportunities are the firm and sector level capabilities to actually adopt new technologies. It has been reported that insufficient availability of expertise in clear production (eco-design) the current training and clean technology capacity building at the sector level and the insufficient understanding and experience in cleaner production project development and implementation, play a role in the adoption of new cleaner production processes. These factors can be expected to become even more critical at the level of small- and medium sized enterprises..
26. Gabaix and Laibson, 2005, p. 1; "We show that information shrouding flourishes even in highly competitive markets, even in markets with costless advertising, and even when the shrouding generation allocational inefficiencies." Hosain and Morgan, Brown, Hossain and Morgan
27. Sallee, 2012, "The possibility of rational inattention has two key implications. First, if consumers rationally ignore energy efficiency, this could explain the energy paradox. In equilibrium, firms will underprovide energy efficiency if consumers ignore it. If true, this would qualitatively change the interpretation of empirical work on the energy paradox. Most empirical work tests for the rationality of consumer choice across goods that are actually sold in the market. If rational inattention leads to an inefficiency set of *product offerings* (emphasis added), consumer might choose rationally among goods in equilibrium but a paradox still exists. Second, if consumers are rationally inattentive to energy efficiency, this could provide direct justification for regulatory standards and "no tech policies, such as the Energy Star Label System." Green, German and Delucchi, 2009, p. 203; This suggests that increasing fuel prices may not be the most effective policy for increasing the application of technologies to increase passenger and light truck fuel economy. This view is supported by the similar levels of technology applied to U.S. and European passenger cars in the 1990s, despite fuel prices roughly three times higher in Europe. It is also circumstantially supported by

the adoption by governments around the world of regulatory standard for light-duty vehicle fuel economy and carbon dioxide emissions.

28. UNIDO, 2011, p. iii, Hidden costs Engineering-economic analyses may fail to account for either the reduction in utility associated with energy efficient technologies, or the additional costs associated with them. As a consequence, the studies may overestimate energy efficiency potential. Examples of hidden costs include overhead costs for management, disruptions to production, staff replacement and training, and the costs associated with gathering, analysing and applying information. General overhead costs of energy management: employing specialist people (e.g., energy manager); energy information systems (including: gathering of energy consumption data; maintaining sub metering systems; analysing data and correcting for influencing factors; identifying faults; etc.); energy auditing; Costs involved in individual technology decisions: i) identifying opportunities; ii) detailed investigation and design; iii) formal investment appraisal; formal procedures for seeking approval of capital expenditures; specification and tendering for capital works to manufacturers and contractors additional staff costs for maintenance; replacement, early retirement, or retraining of staff; disruptions and inconvenience; Loss of utility associated with energy efficient: problems with safety, noise, working conditions, service quality etc. (e.g., lighting levels); extra maintenance, lower reliability.
29. Li, Timmins and von Haefen, 2009, "we are able to decompose the effects of gasoline prices on the evolution of the vehicle fleet into changes arising from the inflow of new vehicles and the outflow of used vehicles. We find that gasoline prices have statistically significant effects on both channels, but their combined effects results in only modest impacts on fleet fuel economy. The short-run and long-run elasticities of fleet fuel economy with respect to gasoline prices are estimated at 0.o22 and 0.204in 2005. "
30. Committee to Assess Fuel Economy, 2010, p. 2, The [Medium and Heavy Duty] truck world is more complicated. There are literally thousands of different configurations of vehicle including bucket trucks, pickup trucks, garbage trucks, delivery vehicles, and long-haul trailers. Their duty cycles vary greatly… the party responsible for the final truck configuration is often not well defined.; Lutzenheiser, et al., (2001, cited in Blumstein, 2013), p. viii, The commercial building "industry" is in fact a series of linked industries arrayed along a "value chain" or "value stream" where each loosely coupled link contributes value to a material building in process. Each link, while aware of the other links in the process, is a somewhat separate social world with its own logic, language, actors, interests, and regulatory demands. For the most part "upstream" actors constrain the choices and actions of "downstream" actors.
31. Sardianou, 2007, p. 1419, The lack of access to capital (76%) and the slow rate of return (74%) of energy savings investments are categorized as barriers.
32. UNIDO, 2011, p. iii, Routines as a response to bounded rationality the use of formal capital budgeting tools within investment decision-making. Other types of rules and routines which may impact on energy efficiency include: operating procedures (such as leaving equipment running or on standby); safety and maintenance procedures; relationships with particular suppliers; design criteria; specification and procurement procedures; equipment replacement routines and so on.
33. Montvalo, 2007, A11, organization capabilities refer to the firm's endowments and capabilities to carry out innovation… When the knowledge is not present in the firm adoption will depend on the firm's capacity to overcome shill lock-in, and to unlearn and acquire new skills. UNIDO, Inertia and the status quo bias: Routines can be surprisingly persistent and entrenched. … This type of problem has been labeled inertia within the energy efficiency literature and identified as a relevant explanatory variable for the efficiency gap.
34. Sardianou, 2007, p. 1419, Uncertainty about future energy prices (62%) is also characterized as a barrier [leading] to the postponement of energy efficiency measures.
35. Ito, 2010, p. 1, I find strong evidence that consumers respond to average price rather than marginal or expected marginal price.
36. UNIDO, 2011, p. 67, The government does not give financial incentives to improve energy efficiency, Lack of coordination between different government agencies, Lack of enforcement of government regulations, There is a lack of coordination between external organizations; Sardianou, 2007, p. 1402, [B]ureaucratic procedure to get government financial support is a barrier to energy efficiency improvements for the majority (80%) of industries.

APPENDIX B:
KEY CHARACTERISTICS OF AND FINDINGS OF EMPIRICAL STUDIES

General

Author, date	Geller, et al., 2006	Montevallo, 2007	Scleigh & Gruber, 2008	Brown et al., 2008	Sardinaou, 2008
Products	Multiple, aggregate sectors	Clean technologies	Commercial 19 sectors, 2848 Cos.	4 type of GHG emitters	Industrial
Method, period, size	Historic trend, 1973-2000	Review of empirical studies	Econometric. 9 variables	Review of Case studies 27 Expert Interviews	Survey
Scope		Primarily US, EU	Germany	US 15 sectors	Greed
National	US. Japan, Europe, Calif.				
Cross National					
Actors	Regulator		Producer	Producers	Perception of barriers
Aspect Studied	Policy	Economic barriers	Attitude, Action	Barriers	Barriers
Key Findings	Substantial energy savings	appropriability access to capital lack of expertise Technological factors inertia stock of opportunities lack of capability in firms technology risk Organizational barriers capabilities coordination	Most important factors: Split incentives, Lack of information Policy recommendation Lower transaction cost, Performance stds, Financial incentives Audits, Benchmarks Focus on smaller firms	Iron Triangle of Barriers Incumbent Technology Support Systems Business Risk of Innovation High Transaction Costs Unfavorable Policy Environment	Risk, Lack of knowledge Lack of skill, adjustment costs operating costs, Capital rationing, hurdle rates Culture, Gov't policy
Framing observations & assumptions			Cites barriers in previous research: information, & transaction costs, access to split incentives, bounded rationality uncertainty & risk small savings, behavior organizational factors		

General, cont'd.

			Specific Products		
Author, date	UNIDO, 2011 (Sorrell, Mallett & Nye	Jesseo & Rapson, 2013	Allcott & Wozny, 2010	Kok et al., 2010	Li, 2010
Products	Industrial production process		Autos, new and used	Buildings	Appliance
Method, period, size	160 case studies (64 evaluated)	Field Experiment 1150+ subjects	National 1.1 million auto sales	Regression 48 MSAs	Regression
Scope National Cross National		US	US	US 48 Metro areas	UC California, PG&E sample
Actors	Market outcome	Consumers	Market outcome		Consumer
Aspect Studied	Attitude, Action	Response to information	Willingness to Pay	% Energy Star or LEED	Structural characteristics
Key Findings	7 main barriers: Imperfect information, Hidden costs. Access to capital, Split incentives, Bounded rationality, Risk/uncertainty Inertia 24 sub-types of barriers	3 st dev. Large reduction with info. $\simeq$ 15%	$.61/$1.00 of potential economic gains Efficiency is a shrouded attribute	Accredited professionals local policy increase % of building	agency and information are important factors
Framing observations & assumptions	Information Access to capital Split incentives Inertia Transaction costs	Shrouded attribute due to shrouded attribute intermediate input coarse billing Low elasticity			

Specific Products Cont'd

Author, date	Ito, 2010	Ozaki & Sevastyanova, 2011	Noailly, 2012	Mareur, et al., 2013
Products	Appliance	Hybrid Autos	Buildings	Appliances
Method, period, size	Regression	Survey, Jan. 2009, 1200+	Econometric, 9 nations 9 variables	Historical analysis
Scope National Cross National	Southern CA	US		US
Actors	Consumer	Consumer	Regulator	Policy makers
Aspect Studied	Price response	Attitude	Attitude, Policy	Cost, impact on features
Key Findings	Consumers respond to average, not marginal prices	Financial benefits are important, Social norms influence consumer behavior Practical, experimental & affective values should be communicated	Regulations significantly stimulate innovation, R&D expenditures slightly increase innovation, Energy price has little effect on innovation	Declining cost no reduction in features
Framing observations & assumptions	Cites:Liebman & Zechhauser	Cites Rogers' adoption facilitators: Advantage, Compatabilty Complexity, Trialability Observability	Cites: Johnstone on effectiveness of renewable obligations Jaffe/Sterns, Popp on little effect of price Invokes agency, split incentives	

Surveys

Author, date	Poortinga, 2003	Kurani & Turentine, 2004	Li, et al., 2009	Consumer Fed. , 2010
Products	Energy-saving measures	Autos	Willingness to pay for R&D Expenditures	Autos
Method, period, size	National Poll 455 respondents	Interview, 57 respondents	Contingent Valuation, National Referendum 2000+ respondents, split sample	National Poll 2000
Scope National Cross National	Netherlands	US	US	US
Actors	Consumers	Consumer Market outcome	Consumers	Consumer
Aspect Studied	Preference for types	Attitudes	Attitudes	Attitudes
Key Findings	Technical > Behavior > Shift in consumption Home > Transport Amount of energy saved is unimportant Environmental concern increases support	Consumers: do not pay much attention to fuel cost have ephemeral knowledge, at best are unable to estimate savings are overly optimistic about savings associate fuel economy with poor quality see vehicle as multi-attribute where fuel economy is not important use crude reference points: loan life, monthly cash flow	Willingness to pay: $137 per year > Increase R&D spending Reduce dependence on foreign Promote crop based fuels Demographics are important Income Gender Attitudes that matter Importance of energy issues Political ideology	Payback periods tested 3-5 yrs garner majority Lack awareness of US oil resources Information increases support for higher stds. 2/3 want higher mileage
Framing observations & assumptions		Notes Importance of advertising & promotion	Cites: NRC 2007 call for more research on NRC 2007 call for more research on social valuation and behavior Public concern about energy security, need to address climate change	

Surveys. Cont'd

Author, date	Consumer Fed, 2011a	Consumer Fed., 2011b	Consumer Rpts. 2010	Consumer Repts., 2012	Arimura, 2009
Products	Autos	Appliances	Household Energy	Autos	Electricity efficiency programs
Method, period, size	National Poll 1000+	National Poll 1003	National Poll 1536 Home Owners	National Poll 1702 random	Regression ~ 700 utilities, 5,000 obs.
Scope National Cross National	US	US	US	US	US
Actors	Consumers	Consumer	Consumers	Consumers	Utility-regulator
Aspect Studied	Concerns	Attitudes	Purchases, Attitudes	Concerns in purchase	Cost of saved energy
Key Findings	Great concern about: Gasoline prices (80+%) Mideast oil Dependence (70+%) Strong majority support for stds. 80% support of stds. 60% with 5 yr payback	Payback periods tested 3-5yr garner strong 70+% favorable 70+% support for stds Awareness increases support for stds.	Purchases of Efficient: Bulbs (81%) Energy Star (44%) Windows (29%) Insulation (24% HVAC/Water Heat (21-23%) Renewable system (3%)	Fuel economy (34%) Quality *17%) Safety (16%) Performance (6%) Style (6%) Small cars most popular 2/3 want higher mileage	$0.06/kwh existing states $0.03/kwh new states
Framing observations & assumptions					

Cost Benefit

Author, date	Freidrich, et al. 2009	Dale et al., 2009	Kiso, 2009	Hwang & Peak, 2010	Weiss, et al., 2010
Products	Utility efficiency programs	RAC, Refrig CAC, Clothes Wash	Autos	Autos, 11 innovations	6 Large Appliances
Method, period, size	Direct cost estimates, 14 states 53 year covered	Historic trend, 1965-2005 Time series/cross sectional	Historic trends 1988-2006	Historic trends 1975-2001	Historic Trends Energy & cost data
Scope National Cross National	US	US	Japanese Cars sold in US	US	Europe
Actors	Utility-regulator	Regulator Market outcome	Market outcome	Regulators Market outcome	Market Outcome
Aspect Studied	Cost of saved energy	Projected cost increase	Regulation	Regulation	Productivity Growth
Key Findings	Electricity: Avg. $0.025/kwh Range - $0.016-$0.044 Gas: Avg. $0.37/therm Range - $0.27-$0.55	2.1 times actual cost increase expected due to: Price increase less than expected due to: Technological change, Decreasing mark-ups, Economics of scale	Regulation induces innovation	Projected cost increase 1.48 times actual	faster after policy intervention
Framing observations & assumptions	Updates ACEEE 2004 study		Cites Newell that price & regulation impact efficiency Popp that price & regulation	Cites NESCAUM, 2000 Anderson & Sherwood, 2002 Harrington Et al, 1999	Evidence that efficiency improvement does Cites: Ellis, 2007 Bertoldi & Atanasiu, 2007 Dale, et al., 2009

Cost Benefit Cont'd

Author, date	Wie, Patadia & Kammen, 2010	Desroches, et al., 2011	Woolf, et al., 2011
Products	Electricity Resources	Learning Curves for Appliances	Learning curves for Standard
Method, period, size	Cost data 2010	Energy & cost data Long term series	Energy & cost data Long term series
Scope National Cross National	US	US	US
Actors	Market Outcome	Market Outcome	Market Outcomes
Aspect Studied	Jobs/Gwh equiv.	Productivity Growth	Productivity growth
Key Findings	Efficiency yields 2 to 3 times as many jobs	faster after policy intervention	
Framing observations & assumptions			

APPENDIX C

ANNOTATED VERSIONS OF SECTION V EXHIBITS

EXHIBIT C-V-2: MARKET BARRIERS AND IMPERFECTION IN CLIMATE CHANGE ANALYSIS

TRADITIONAL ECONOMICS & INDUSTRIAL ORGANIZATION

EXTERNALITIES
Knowledge Externalities that are not captured by markets, e
Research and Development (20, 22, 23, 48, D), a, b
Importance of learning by searching (27, 31, 38, E), c
Deployment: Importance of learning by doing (27, 10, 31, 38, B), c
Economics of Scale/returns to scale (6, 38, 41, 47, G), d
Localization (24, 38, 45, H))

MARKET STRUCTURE:
Cost Structures: Long investment cycles, increasing returns to scale, network effects (8, 28, 33, 498 I)
Challenge of creating new markets: Undifferentiated product (20, 23, 28, 42, J)
Entry Barriers: Capital Cost, access to network (20, 41, 47 48, K)
Lack of competition hinders innovation (41, 48, L)
INERTIA:
Cost of Inertia (1, 14, 28, M)
Importance of inertia/stock of knowledge (9, 24, 37, 45, N)

NEW INSTITUTIONAL ECONOMICS

ENDEMIC
Perverse incentives: in allocation of fuel price volatility (20, 50, O), carbon tax level and permanence (21, 30, 40, 44, P) g
Asymmetric information (21, 48, Q)
Shot-term view, h, i

TRANSACTION COST
Uncertainty: as a cause of underinvestment (8, 21, 26, 43, 47, R)
Fuel price volatility, carbon tax level and permanence (fuel price volatility, carbon tax level and permanence (20, 33, S)
High risk premia on new technologies (28, T)
Information: Value of information (2, 22, U)
Sunk costs and embedded infrastructure (21, 48, V)
Incomplete markets f

POLITICAL POWER
Power of incumbents to hinder alternatives (20, 45, ZA)
Monopolistic structures and lack of competition (24, 39 41, 46, 47, ZB)
Importance of institutional support for Alternatives (22, 30, ZC)

BEHAVIORAL ECONOMICS

BEHAVIOR
Sluggish demand response (20, 23, W)
Agency (18, 8, X)
Risk Aversion (6, Y)
Calculation (17, 47, Z)

EFFECTIVE POLICY RESPONSES
Public goods (24, 49, ZC)
Institution Building (22, 30, 49, ZE)
Research and Development (5, 10, 20, 23, 25, 26, 28, 32, 35, 37, 47, ZF)
Capital subsidies Adders, premium prices (6, 41, ZG)
Obligations/Consenting (25, 28, 35, 47, M, (ZH)
Standards (8, 22, ZI)
Feed in Tariffs (28, 41, 45, 47, ZJ)
Merit order (20, 21, ZK)

EVIDENCE ON THE INEFFECTIVENESS OF PRICE/ TAX AS POLICY
Price Insufficiency (4, 11, 15, 20, 19, 25, 29, 35, 41, 47, 48 A)
Tax: Difficulty of setting and sustaining "optimal" levels (20, 19, 47, B)
Tradable permits do not increase innovation (5, 36, C)

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49 Weyant, John P., "Accelerating the Development and Diffusion of New Energy Technologies: Beyond the Valley of Death," Energy Economics, 33: 2011

49 Wilson, Charlie, et al., "Marginalization of End Use Technologies in Energy Innovation for Climate Protection
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a) Public Goods:, Many technologies have competing or multiplicative (rather than additive) impact. The most compelling economics typically reside with the first abatement options in the analytical sequence. Pursuing energy efficiency in electric power, for example, has the potential to reduce the number of new coal-fired power plants needed (p. xx); The mismatch between near-term technology investment and long-term needs is likely to be even greater in a situation where the magnitude of desired GHG reductions can be expected to increase over time. If more stringent emissions constraint will eventually be needed, society will benefit from near-term R&D to lower the cost of achieving those reductions in the future. Similarly, rationales for public support of technology demonstration projects tend to point to the… inability of private firms to capture the rewards for rewards for designing and constructing first-of-a-kind facilities. (p. 120)

(b) R&D tends to be underprovided in a competitive markets because its benefits are often widely distributed and difficult to capture by individual firms…. economics literature on R&D points to the difficulty firms face in capturing all the benefits from their investments in innovation, which tend to spill over to other technology producers and users.. (pp. 118-120); In addition, by virtue of its critical role in the higher education system, public R&D funding will continue to be important in training researchers and engineers with the skill necessary to work in either the public or private sector to product GHG-reducing technology innovations (p. 120)… Generic public funding for research tends to receive widespread support based on significant positive spillovers that are often associated with the generation of new knowledge. (p. 136).

(c) "Another potential rationale involves spillover effects that he process of so-called "learning-by-doing" – a term that describes the tendency for production costs to fall as manufacturers gain production experience."(p. 136)

(e) Network Effects: Network effects provide a motivation for deployment policies aimed at improving coordination and planning – and where appropriate, developing compatibility standards – in situations that involve interrelated technologies, particularly within large integrated systems (for example, energy productions, transmission, and distribution networks). Setting standards in a network context may reduce excess inertia (for example, the so-called chicken-and-egg problems with alternative fuel vehicles), while simultaneously reducing search and coordination costs, but standard scan also reduce the diversity of technology options offered and may impede innovation over time. (p. 137)

(e) Similarly, rationales for public support of technology demonstration projects tend to point to the large expense; (p.120).

(f) Similarly, rationales for public support of technology demonstration projects tend to point to the large expense; high degree of technical, market and regulatory risk; and inability of private firms to capture the rewards for rewards for designing and constructing first-of-a-kind facilities. (p. 120)

(g) Finally, incomplete insurance markets may provide a rationale for liability protection or other policies for certain technology options (for example, long-term CO2 storage). (p. 137)

(h) Regulatory risk: Similarly, rationales for public support of technology demonstration projects tend to point to the… high degree of technical, market and regulatory risk. The problem of private-sector under investment in technology innovation may be exacerbated in the climate context where the energy assets involved are often very-long lives and where the incentives for bringing forward new technology rest heavily on domestic and international policies rather than natural market forces. Put another way, the development of climate-friendly technologies has little market value absent a sustained, credible government commitment to reducing GHG emissions. (p. 120)

g) The mismatch between near-term technology investment and long-term needs is likely to be even greater in situation where the magnitude of desired GHG reductions can be expected to increase over time. If more stringent emissions constraint will eventually be needed, society will benefit from near-term R&D to lower the cost of achieving those reductions in the future. (p. 120)."

h) Finally, incomplete insurance markets may provide a rationale for liability protection or other policies for certain technology options (for example, long-term CO2 storage, (p.137)."

i) The problem of private-sector under investment in technology innovation may be exacerbated in the climate context where the energy assets involved are often very-long lives and where the incentives for bringing forward new technology rest heavily on domestic and international policies rather than natural market forces… "Put another way, the development of climate-friendly technologies has little market value absent a sustained, credible government commitment to reducing GHG emissions (p.12).

A Walz, Schleich and Ragwitz, 2011, p. 16, Power prices, however, are not found to drive patent activity. Hence power prices alone would likely not be sufficient to spur innovation activities in wind and arguably also other, currently less cost-efficient renewable technologies.

B The stability and long term vision of policy target setting are important policy style variables, which contribute to the legitimacy of technology and provide guidance of search…

C Calel and Dechezlloprete, 2012, p. 1. "[M]ore refined estimates that combine matching methods with different-in-difference provide evidence that the EU ETS has not impacted the direction of technological change. This finding appears to be robust to a number of stability and sensitivity checks. While we cannot completely rule out the possibility that the EU ETS has impacted only large companies for which suitable unregulated comparators cannot be found, our findings suggest that the EU ETS so far has had at best a very limited impact on low-carbon technological change.

D Massetti and Nicita, 2010, p. 1The presence of market failures in the R&D sector, as emphasized by Griliches, is confirmed by the evidence, virtually found in all studies, that the social rate of return on R&D expenditure is higher than the corresponding private rate; estimates of the marginal social rate of return on R&D range between 30 and 50 percent and of private return between 7 and 15 percent… When it comes to technologies for carbon emissions reduction, the difference between private and social rate of return to R&D investment arises from a double externality; the presence of both environmental and knowledge externalities. First, without a price on carbon that equates the global and the private cost of emitting GHGs, all low emissions technologies are relatively disadvantaged and the level of investment is therefore sub-optimal. Second, the private return to investment in R&D is lower than the social return of investment due to the incomplete appropriability of knowledge creation, thus pushing further away investment for the socially optimal level.

E Massetti and Nicita, 2010, p. 17, We find that a [carbon] stabilization policy together with an R&D policy targeted at the only energy sector is significantly less costly than the stabilization policy alone. We find that energy R&D does not crowd-out non-energy R&D, and thanks to intersectoral spillovers, the policy induced increase in energy efficiency R&D spills over to the non-energy sector, contributing to knowledge accumulation and the reduction of knowledge externalities.

F Gross, et al., p.18, The phenomenon of "learning by doing", whereby costs for technologies reduces as experience is gained from deployment of the technology creates lock-in. It also creates better, cheaper technologies. The incumbent fossil and nuclear forms of generation have had many decades of technical refinement through experience which have driven their costs down to low levels relative to new, renewable technologies. In part, this was financed by considerable public subsidy… The very same effects that created lock-in to high carbon systems offer the potential to decrease the costs and improve the commercial/consumer attractiveness of new forms of low carbon energy.

G Qui and Anadon, pp. 782, The size of the wind farm is another significant factor in all specifications… indicate that a doubling in wind farm size could lead to price reductions of about 8.9%.

H Qui and Anadon, pp. 782, Localization rate is a significant factor in all specifications… indicate that a doubling of localization rate was associated with reductions in wind electricity price ranging from 10.9% to 11,4%.

I Cian and Massimo, 2011, p. 123, Uncertainty and irreversibility are two features of climate change that contribute to shape the decision making process. Technology cost uncertainty can depress the incentive to invest. The risk of underinvestment is even more severe considering that energy infrastructure has a slow turnover. Capital irreversibility and uncertainty heighten the risk of locking into existing fossil-fuel-based technologies. Additional investments are sunk costs that increase the opportunity cost of acting now… The result is reinforced when uncertain costs have a large variance, showing that investments decrease with risk. Jamasb and Nicita, (2007, p 8) R&D activity can be subject to three main types of market failure namely indivisibility, uncertainty and externalities.

J J. Kalkuhl, Edenhofer and Lessmann, 2012, p. 10, The energy sector is highly vulnerable to lock-in because electricity is an almost perfect substitute for consumers. In contrast, many innovations in the manufacturing or entertainment electronics sector provide a new product different from existing ones (e/g/ flat screens vs. CRT monitor). The low substitutability implies a high niched demand and, thus, provokes ongoing learning-by-doing although considerable spillovers exist and market prices are distorted.

K K. Gross, et al. 2012, p. 18, In the energy sector, such "network externalities" rise for example in the physical structures of large scale high voltage alternating current (AC) power grids themselves (themselves a reminders of early energy planners' desire to locate power stations close to the source of coal) which now provides a cost advantage to large scale centralized station over distributed alternatives.

L Gross, et al., 2012, p. 10, Either policymakers around the world are blind to the logic of economic theory, or there are factors that overwhelm or undermine the theoretical Pigouvian considerations. The rest of this paper discusses the considerations t

M Grimaud and Lafforgue, 2008, p. 1…20,The main results of the paper are the following: i) both a carbon tax and a green research subsidy contribute to climate change mitigation; ii) R&D subsidies have a large impact on the consumption, and then social welfare, as compared to the carbon tax alone; IV) those subsidies allow to spare the earlier generations who are, on the other hand, penalized by a carbon tax….In a second-best world, a carbon tax used alone leads to a higher social cost (with respect to first-best) than a research policy alone;

N Jamasb and Kohler, 2007, p. 9, Information technology and pharmaceuticals, for example, are both characterized by high degrees of innovation, with rapid technological change financed by private investment amounting typically to 10-20% of sector turnover. This is in dramatic contrast with power generation, where a small number of fundamentals technologies have dominated for almost a century and private sector RD&D has fallen sharply with privatization of energy industries to the point where it is under 0.4% of turnover.

O Gross, et al., 2012, p. 14, Capital intensive, zero fuel cost power stations like wind farms, need to cover their long run average costs—namely the cost of capital. They can neither actively affect/set marginal power prices nor respond to power price changes, except to curtail output, which does not save costs (as there are no fuel cost to save), but does lose revenue. However, carbon prices only affect the marginal price of fuel and power. We should therefore expect that an emissions trading scheme will encourage fuel switching from coal to gas, and efficiency first and renewable energy (or indeed nuclear) investment last. This is exactly what we have seen in reality.

P Reuter, et al., 2012, p. 253, If there is uncertainty about the future development of feed-in-tariffs, much higher levels will be needed to make renewable investment attractive for energy companies.

Q Gross, 210, p. 802, "A range of factors that relate to the amount and quality of information about technology costs and risks available to policymakers and market participants are relevant when considering incentives and investment in new technologies: Policymakers may have relatively poor information about costs for emerging technologies. 'Appraisal optimism' (where technology/project developers under estimate the cost of unproven technology/systems) is a common feature in the development of new technologies. When providing cost data to policymakers technology developers or equipment suppliers may also have incentives to up or play down costs and potential according to circumstances. Where new or unproven technologies are being utilized for the first time, information about costs may be limited for all concerned... There may be an 'option value' to potential investors in waiting (delaying investment) where there is poor information and high levels of technology and market risk. The first conclusion is that policymaking in the energy area needs new tools of analysis that can deal with the market risks associated with policy design… In particular, policymakers need to be mindful of the role of revenue risk as well as cost risk in the business case for investment.

R Fuss and Szolgayosva, 2010, p.2938, We find that the uncertainty associated with the technological progress of renewable energy technologies leads to a postponement of investment. Even the simultaneous inclusion of stochastic fossil fuel prices in the same model does not make renewable energy competitive compared to fossil-fuel-fired technology in the short run based on the data used. This implies that policymakers have to intervene if renewable energy is supposed to get diffused more quickly. Otherwise, old fossil-fuel-fired equipment will be refurbished or replaced by fossil-fuel-fired capacity again, which enforces the lock-in of the current system into unsustainable electricity generation.

S Gross, et al., 2012, In short,, whilst carbon pricing can create conditions that make investment in wind more attractive, there are uncertainties associated with wholesale power prices, carbon permit prices, and future political decisions on carbon tax levels. These make wind investment more risky, which drives up the cost of capital investors require higher returns), and discourage investment.

T Gross, Blyth and Heponstall, 2012, p. 802.The first conclusion is that policymaking in the energy area needs new tools of analysis that can deal with the market risks associated with policy design… In particular, policymakers need to be mindful of the role of revenue risk as well as cost risk in the business case for investment.

U Horbach, 2007, p. 172, Environmental management tools help to reduce the information deficits to detect cost savings (especially material and energy savings) that are an important driving force of environmental innovation.

V Weyant, 2011, p. 677, The infrastructure for producing, distributing, and promoting the industries' current products require large investments that have already been incurred.

W Jamasb and Kohler, 2007, Thus, the 'market pull' forces reach deep into the innovation chain…This is in contrast with power generation, where a small number fundamental and private sector RD&D has fallen sharply with privatization of energy industries. technologies have dominated for almost a century and private RD&D has fallen sharply with privatization... In turn, market pull measures are devised to promote technical change by creating demand and developing the market for new technologies.

X Weyant, 2011, p. 675, The situation can develop from several different types of market failure, including poor or asymmetric information available to purchasers, limits on individual's ability to make rational decisions because of time or skill constraints, principle agent incongruities... and lack of financing opportunities.

Z Green, 2010, p. 6, The rational economic consumer considers fuel saving over the full life of a vehicle, discounting future fuel savings to present value. This requires the consumer to know how long the vehicle will remain in operation; he distances to be traveled in each future year, the reduction in the rate of fuel consumptions, and the future price of fuel…. The consumer must also estimate the fuel economy that will be achieved in real world driving based on the official estimate. Finally, the consumer must know how to make a discounted present value calculation, or must know how to obtain one… The utility-maximizing rational consumer has fixed preferences, possesses all complete and accurate information about all relevant alternatives, and has all the cognitive skills necessary to evaluate the alternatives. These are strict requirements indeed….

ZA Nicolli and Vona, p. 1, Our empirical results are consistent with predictions of political-economy models of environmental policies as lobbying, income and to a less extent, inequality have expected effects on policy. The brown lobbying power, proxied by entry barriers in the energy sector, has negative influence on the policy indicators even when taking into account endogeneity in its effect. The results are also robust to dynamic model specifications and to the exclusion of groups of countries

ZB Weyant, 2011, p. 677, Further complicating matters, existing companies in energy-related industries --- those that produce energy, those that manufacture the equipment that produces, converts and uses energy, and those that distribute energy – can have substantial incentives to delay the introduction of new technologies. This can happen if their current technologies are more profitable than the new ones that might be (or have been) invented, or if they are in explicitly (oil and gas) or implicitly (electric generation equipment producers and automakers) oligopolistic structured, or if they are imperfectly regulated (electric and gas utilities). The incentive arises partly because the infrastructure for producing, distributing, and promoting the industries' current products require large investments that have already been incurred.

ZC Horbach, 2008, p. 172, An environmentally oriented research policy has not only to regard traditional instruments like the improvement of the technological capabilities of a firm but also the coordination with soft environmental policy instruments like the introduction of environmental management systems.

ZD Johnstone and Haccic, 2010, p.25 "Since innovating in storage technologies is an important complement to innovation in all intermittent renewable generating technologies such a strategy reduces the risk of (not) picking winners. Moreover, the technologies are at a relatively early stage of development, with greater need for support.

ZE Wilson, et al., p. 781, The institutions emphasized in our analytic framework are twofold: the propensity of entrepreneurs to invest in risky innovation activities with uncertain pay-offs; and shared expectation around an innovation's future trajectory. Other important and related institutions include law, markets and public policy. Public resources are invested directly into specific innovation stages, or are used to leverage private sector resources through regulatory or market incentives structured by public policy…. New technologies successfully diffuse as a function of their relative advantage over incumbent technologies. For energy technologies, this can be measured by the difference in cost and performance of energy service provision in terms of quality, versatility, environmental impact and so on. Many of these attributes of relative advantage can be shaped by public policy as well as the other elements of the innovation system.

ZF Walz, Schleich and Ragwitz, 2011, p. 5, The specific advantage of feed-in tariffs is seen in lower transaction costs and reduced risk perception for investors and innovators, which are extremely important especially for new entrants and for financial institutions.

ZH Walz, Schleich and Ragwitz, 2011, p. 16, Our econometric analyses also imply that the existence of targets for renewables/wind and a stable policy support environment are associated with higher patent activity.

ZI de Chien and Massimon, 2012, pp. 13…15, Against this evidence, regulation such as Emissions Performance Standards (EPS) that set a maximum threshold for the emission intensity of power generation in terms of grams of CO2 per kilowatt hour could be justified as a way to reduce uncertainty exposure... [W]e have also pointed out that the optimal penetration of renewables is slow, even when facing a given deterministic carbon price.

ZG Rubbeike and Weiss, 2011, Including non-price-based variable increases the fit of the model… the coefficients for grants is positive and highly significant.

ZJ Gross, Blyth and Heptonstall, 2010, 802,The international evidence suggests that in most cases countries with fixed price schemes have been more successful at deploying renewables than those with trading scheme. Whilst the reasons for this are complex and varied it appears likely that investment r k plays an important role.

ZK Gross, Blyth and Heptonstall, 2010, 798,The result is that significant long-run fuel price uncertainty.. cannot usually be hedged through contractual arrangements. Long-run fuel price changes, like time of day rates, are mediated by the current market arrangements but remain fundamental to electricity prices.

EXHIBIT C-V-3: CAUSES OF CARBON LOCK-IN

<u>Business Innovation Risk – Cost Effectiveness and Fiscal Barriers</u> Technical risk Volatile Energy Prices Market risk High up-front costs <u>Transaction Costs</u> Inadequate workforce/infrastructure Misinformation Imperfect information Lack of specialized Inadequate validation	<u>Incumbent Support</u> Industry structure Inadequate supply chain Monopoly power <u>Policy Obstacles – Regulatory/Statutory barriers</u> Unfavorable policy environment Unfavorable regulation Uncertain Regulations Burdensome Permitting Uncertain/Unfavorable fiscal policy Misplaced incentives

Cost-Effectiveness Barriers

External Benefits and Costs: External benefits of GHG-reducing technologies that the owners of the technologies are unable to appropriate (e.g., GHG emission reductions from substitutes for high GWP gases and carbon sequestration).

External costs associated with technologies using fossil fuels (e.g., GHG emissions and health effects from small particles) making it difficult for higher priced, GHG-reducing technologies to compete.

High Costs: High up-front costs associated with the production and purchase of many low carbon technologies; high operations and maintenance costs typical of first-of-a-kind technologies; high cost of financing and limited access to credit especially by low-income households and small businesses.

Technical Risks: Risks associated with unproven technology when there is insufficient validation of technology performance. Confounded by high capital cost, high labor/operating cost, excessive downtime, lack of standardization, and lack of engineering, procurement and construction capacity, all of which create an environment of uncertainty.

Market Risks: Low demand typical of emerging technologies including lack of long-term product purchase agreements; uncertainties associated with the cost of a new product vis-à-vis its competitors and the possibility that a superior product could emerge; rising prices for product inputs including energy feedstocks; lack of indemnification.

Lack of Specialized Knowledge: Inadequate workforce competence; cost of developing a knowledge base for available workforce; inadequate reference knowledge for decision makers.

Fiscal Barriers

Unfavorable Fiscal Policy: Distortionary tax subsidies that favor conventional energy sources and high levels of energy consumption; fiscal policies that slow the pace of capital stock turnover; state and local variability in fiscal policies such as tax incentives and property tax policies. Also includes various unfavorable tariffs set by the public sector and utilities (e.g., import tariffs for ethanol and standby charges for distributed generators) as well as unfavorable electricity pricing policies and rate recovery mechanisms.

Fiscal Uncertainty Short-duration tax policies that lead to uncertain fiscal incentives, such as production tax credits; uncertain future costs for GHG emissions.

Regulatory Barriers

Unfavorable Regulatory Policies: Distortionary regulations that favor conventional energy sources and discourage technological innovation, including certain power plant regulations, rules impacting the use of combined heat and power, parts of the federal fuel economy standards for cars and trucks, and certain codes and standards regulating the buildings industry;

burdensome and underdeveloped regulations and permitting processes; poor land use planning that promotes sprawl.

Regulatory Uncertainty: Uncertainty about future regulations of greenhouse gases; uncertainty about the disposal of spent nuclear fuels; uncertain siting regulations for off-shore wind; lack of codes and standards; uncertainty regarding possible future GHG regulations.

Statutory Barriers

Unfavorable Statutory Policies: Lack of modern and enforceable building codes; state laws that prevent energy saving performance contracting.

Statutory Uncertainty: Uncertainty about future statutes including renewable and energy efficiency portfolio standards; unclear property rights relative to surface injection of CO_2, subsurface ownership of CO_2 and methane, and wind energy.

Intellectual Property Barriers

High Intellectual Property

Transaction Costs: High transaction costs for patent filing and enforcement, conflicting views of a patent's value, and systemic problems at the USPTO.

Anti-competitive Patent Practices Techniques such as patent warehousing, suppression, and blocking.

Weak International Patent Protection: Inconsistent or nonexistent patent protection in developing countries and emerging markets.

University, Industry, Government Perceptions: Conflicting goals of universities, national laboratories, and industry concerning CRADAs and technology commercialization.

Other Barriers

Incomplete and Imperfect Information: Lack of information about technology performance – especially trusted information; bundled benefits and decision-making complexities;

High cost of gathering and processing information; misinformation and myths; lack of sociotechnical learning; and lack of stakeholders and constituents.
Infrastructure Limitations: Inadequate critical infrastructure – including electric transmission capabilities and long-term nuclear fuel storage facilities; shortage of complementary technologies that encourage investment or broaden the market for GHG-reducing technologies;
insufficient supply and distribution channels; lack of O&M facilities and other supply chain shortfalls.
Industry Structure: Natural monopoly in utilities disenabling small-scale competition;
Industry fragmentation slowing technological change, complicating coordination, and
limiting investment capital.
Misplaced Incentives: Misplaced incentives when the buyer/owner is not the consumer/user (e.g., landlords and tenants in the rental market and speculative construction in the buildings industry) – also known as the principal-agent problem.
Policy Uncertainty: Uncertainty about future environmental and other policies; lack of leadership

Marilyn A. Brown, et al., *Carbon Lock-In: Barriers to Deploying Climate Mitigation Technologies,* Oak ridge National Laboratory, January 2008.

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