ORNL/TM-2010/78

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Making Industry Part of the Climate Solution:

Policy Options to Promote Energy Efficiency

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May 2011

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ORNL/TM-2010/78

Energy and Transportation Science Division

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May 2011

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Oak Ridge, Tennessee 37831-6283
managed by
UT-BATTELLE, LLC
for the
U.S. DEPARTMENT OF ENERGY
under contract DE-AC05-00OR22725

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ACKNOWLEDGMENTS

This report was sponsored by the U.S. Climate Change Technology Program (CCTP). We wish to acknowledge Dr. Robert Marlay, Deputy Director of the Department of Energy's Office of Climate Policy and Technology, and Deputy Director of CCTP, who saw the value in funding this study and contributed to its design and execution. Similarly, we thank Lindsay Brumbelow (DOE) who was an important contributor to the report's scope and content, and helped navigate through multiple revisions.

This report benefited from the results of a "Policy Options Workshop: Energy Efficiency in the Industrial Sector." The workshop was held on September 30, 2009, in Washington, DC, in order to engage experts from academia, national laboratories, corporations, trade associations, and government agencies in a discussion of barriers to industrial energy efficiency and policies that the federal government could pursue to increase the implementation of industrial efficiency measures. A short summary of this workshop and a list of participants is provided in Appendix A. A longer summary was prepared by Joan Pellegrino (Energetics, Inc.), who facilitated the workshop. As our research on specific policy options progressed, many of these workshop participants provided additional insights and views about barriers to industrial energy efficiency and the value of alternative federal policy options.

Throughout the preparation of this report, discussions and informal interviews were completed with energy managers and decision-makers at numerous industrial enterprises and trade associations representing U.S. manufacturing. These included individuals in companies related to automotive parts and assembly, motor manufacturing, forest products, combined heat and power, food processing, and primary chemicals.

Numerous individuals provided references to publicly available information that was valuable to the completion of this report. These sources of information included program managers and researchers at DOE and its national laboratories, the Environmental Protection Agency, nonprofit energy think tanks, energy service companies, and numerous state and local agencies. Their assistance is appreciated.

Preliminary findings of this report were presented at a variety of meetings that included representatives from U.S. industries, government officials, and policy analysts. These meetings provided opportunities for additional feedback on our policy designs and evaluation assumptions. These presentations are listed below:

- Policy dialogue with the Southeast Energy Efficiency Alliance, Nashville, Tennessee, June 7, 2010
- Institute of Paper Science & Technology, Executive Conference, Atlanta, Georgia, March 9, 2011

- Baker Center of Public Policy, University of Tennessee, Knoxville, Tennessee, April 7, 2011
- Open Forum on Energy and the Environment, National Governors Association, Washington, DC, May 7, 2011
- Rutgers University Energy Forum, New Brunswick, New Jersey, May 4, 2011

In addition, Abt Associates Inc. reviewed a prior version of this report. Led by Isabelle Morin, the Abt Associates review team provided excellent suggestions for improving the cost-benefit analysis, strengthening the stakeholder analysis, dealing with uncertainty and risk, and acknowledging non-monetized costs and benefits, among other topics. Their suggestions led to numerous improvements of the final report.

We also wish to thank Andrew Sproles, ORNL, and Yu Wang and Elizabeth Noll, Graduate Research Assistants from Georgia Tech, who designed and formatted the report’s graphics. Finally, special thanks to Charlotte Franchuk for assistance with the report’s references and formatting. Her attention to the details of manuscript production was invaluable.

Any remaining errors in this report are the responsibility of the authors alone.

ABSTRACT

Improving the energy efficiency of industry is essential for maintaining the viability of domestic manufacturing, especially in a world economy where production is shifting to low-cost, less regulated developing countries. Numerous studies have shown the potential for significant cost-effective energy-savings in U.S. industries, but the realization of this potential is hindered by regulatory, information, workforce, and financial obstacles. This report evaluates seven federal policy options aimed at improving the energy efficiency of industry, grounded in an understanding of industrial decision-making and the barriers to efficiency improvements. Detailed analysis employs the Georgia Institute of Technology's version of the National Energy Modeling System and spreadsheet calculations, generating a series of benefit/cost metrics spanning private and public costs and energy bill savings, as well as air pollution benefits and the social cost of carbon. Two of the policies would address regulatory hurdles (Output-Based Emissions Standards and a federal Energy Portfolio Standard with Combined Heat and Power); three would help to fill information gaps and workforce training needs (the Superior Energy Performance program, Implementation Support Services, and a Small Firm Energy Management program); and two would tackle financial barriers (Tax Lien Financing and Energy-Efficient Industrial Motor Rebates). The social benefit-cost ratios of these policies appear to be highly favorable based on a range of plausible assumptions. Each of the seven policy options has an appropriate federal role, broad applicability across industries, utilizes readily available technologies, and all are administratively feasible.

EXECUTIVE SUMMARY

Advanced technologies combined with manufacturing best practices offer significant potential to curb industry's energy consumption and greenhouse gases (GHG) emissions while becoming more competitive, but the realization of this potential has proven difficult. The Department of Energy's (DOE) Climate Change Policy and Technology Program commissioned this research on improving energy efficiency in industry, with an emphasis on developing and evaluating a series of federal policy options, grounded in an understanding of industrial decision-making and the barriers impeding efficiency improvements.

The U.S. industrial sector presents a large and significant opportunity to promote a clean energy economy. It consumes about one-third of the total energy in this country, and it is the source of green energy products. Large firms with more than 250 employees are responsible for about two-thirds of industry's energy consumption. While chemical manufacturing, petroleum refining, pulp and paper, and iron and steel manufacturing dominate industrial energy use, the sector is diverse in terms of products, manufacturing processes, and business practices. This diversity promotes competition and innovation, but it also can complicate the process of transformation and modernization. A large body of literature suggests that most firms could cost-effectively reduce their energy use and carbon emissions.

A number of barriers to increasing investments in industrial energy efficiency help to explain the existence of a large energy-efficiency gap in U.S. industry (CCCSTI, 2009; Brown, Cortes, and Cox, 2010). A DOE "Workshop on Policy Options to Address Non-Technical Barriers to Increased Energy Efficiency in U.S. Industry" was held on September 30, 2009, in Washington, DC, to provide broad-based input for this report. The workshop participants generated and rated a list of 34 specific non-technical barriers to advancing energy efficiency in industrial processes. Their results underscored the problems of capital rationing, efficiency as a non-core investment, lack of knowledge and specialized expertise, and utility disincentives. In addition, participants emphasized problems of overly layered permitting processes and new source review requirements under the Clean Air Act. This report assimilates the views of workshop participants with findings in publicly available literature on key obstacles using a three-fold typology focused on regulatory, information/training, and financing barriers.

Drivers that could motivate industrial energy efficiency are also numerous. Firms can achieve economic benefits and financial stability through energy efficiency – particularly in the wake of volatile and rising energy prices. In addition, pressure from shareholders, consumers, regulators, and internal actors to set and attain sustainability and environmental goals encourages action (National Academies, 2009a). Furthermore, efficiency helps American business to remain competitive in the global marketplace.

Selection of Policy Options

To arrive at the seven policy options for analysis presented in this report, the research team established eight evaluation criteria:

- **Appropriateness of the Federal Role**. The policy must clearly define an appropriate federal role, one that does not pre-empt state or local action.
- **Broad Applicability**. Since the number of proposed policy options and measures to be analyzed is small, but the desired impact is large, those policy options selected for analysis should be as broadly applicable as possible.
- **Significant Potential Benefits**. Those options that produce large benefits quickly should be favored over those producing fewer benefits, later.
- **Technology Readiness**. The policy options selected should address barriers and/or risks of mainly an institutional, policy, or non-technical nature.
- **Cost Effectiveness.** In selecting policies to study, consideration should be limited to those that would be expected to have reasonable costs, a strong social benefit, and a relatively high societal benefit-to-cost ratio.
- **Administrative Feasibility**. Policies selected should be fairly easy to implement, manage, and enforce. Some may require training a large workforce for implementation, while others may be able to focus training on limited players within the delivery system. The latter is obviously more desirable.
- **Additionality**. The selected policy options should each represent different approaches to barriers or to different market segments. Each policy option should be evaluated in terms of the independent contribution it could make above and beyond existing policies.
- **Potential for Rapid Implementation**. Preference should be given to policies that can deliver benefits rapidly.

The researchers met with stakeholders from government, industry, and other relevant sectors, consulted the academic and industry literature, and examined legislative actions to provide insights into the political feasibility of various federal policy options.

Figure ES.1 shows the seven analyzed policy options that passed the initial screen based on the eight evaluation criteria. The figure reflects the fact that any new policy initiatives must fit into the landscape of policies and programs that are already in place (illustrated by the left-hand boxes). The numerous arrows and linkages in this figure highlight the portfolio nature of the seven policies.

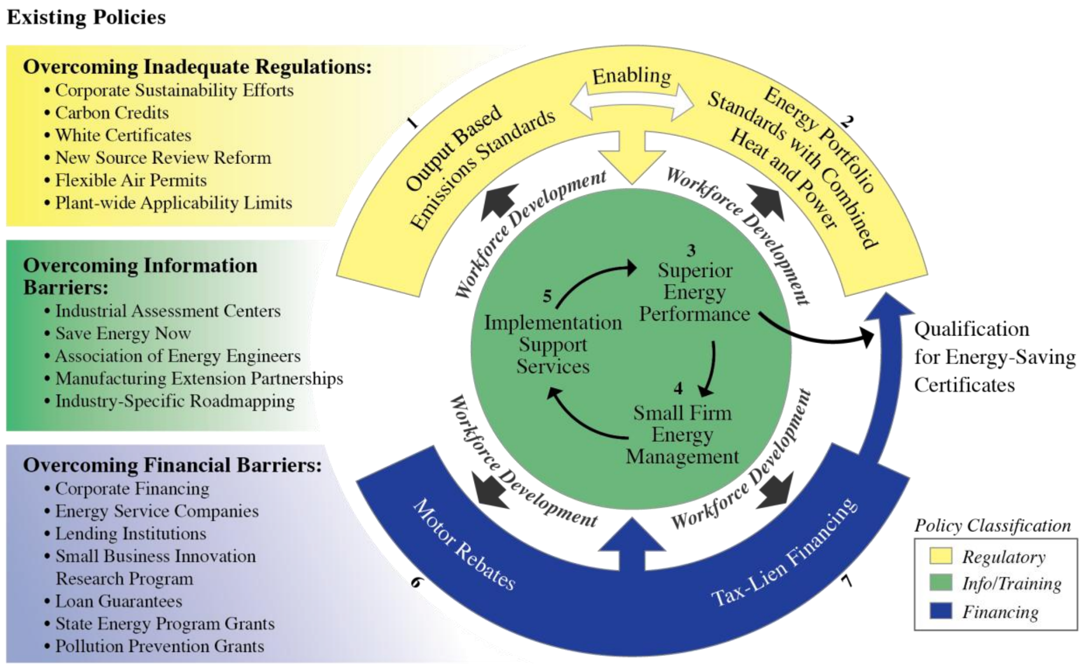

Figure ES.1. Policy Synergies

Policy Summaries

The seven policy options under consideration include two that would address federal and state regulatory hurdles that limit the opportunities for firms to invest in efficiency and, in particular, energy-saving combined heat and power (CHP) systems:

Output-Based Emissions Standards (OBES) would provide financial incentives and technical assistance to states to spur adoption of OBES – as authorized by the EPA – to reduce energy consumption, emissions of criteria air pollutants and GHG, and regulatory burdens. This program would not require any new authority for DOE, as it would use authorities and criteria of the State Energy Program to achieve this regulatory change. Several states have already implemented variants of these standards within their jurisdictions, and a national effort could lead to widespread cogeneration at factories and large facilities over the near and long terms.

A **Federal Energy Portfolio Standard (EPS) with CHP** would require federal legislation that mandates electric distributors to meet an EPS with CHP as an eligible resource and to extend and expand the current investment tax credits for CHP. Such standards exist in several states, and EPS proposals have been considered in several bills before Congress. This policy option would concurrently establish measurement and verification methods for qualifying CHP resources and encourage a national market for trading energy-efficiency credits.

Three of the policy options would help fill information gaps and workforce training needs in industry, targeting small, medium, and large firms:

Incentives to promote the adoption of the **Superior Energy Performance (SEP)** program[1] would facilitate a broader market penetration of energy management systems that foster continual improvement in the energy efficiency of industrial facilities. Incentives would include 1) a federal production tax credit for energy-efficiency savings of facilities that become SEP certified; 2) the ability of verified energy savings to be counted as an energy-efficiency credit in compliance with meeting energy-efficiency or renewable energy portfolio requirements; 3) an energy-efficiency grant for 30% of eligible certification costs; and 4) recognition programs. DOE, universities, and private sector partners are already laying the groundwork toward adoption of SEP, but a committed federal policy could lead to cultural changes and market transformation for facilities and service providers, particularly at large firms.

Implementation Support Services (ISS) would work with existing Industrial Assessment Centers (IAC) to increase the implementation of energy-saving opportunities identified in IAC energy audits. ISS would foster higher implementation rates by leveraging existing relationships between industrial facilities, financial institutions, and engineering firms. Providing this level of technical and business support subsequent to initial IAC energy assessments would not only generate additional energy savings, but would also facilitate the workforce development of undergraduate business students with an understanding and appreciation of energy management. This policy option would necessitate an increase in the funding level of the IAC program to permit additional energy assessments at industrial facilities.

Small Firm Energy Management (SFEM) would provide small manufacturing firms (five to 49 employees) with energy management software tools to build in-house capacity to manage energy use, identify potential energy savings opportunities, and qualify small firms to be part of IAC assessments. DOE's Industrial Technologies Program (ITP) currently provides few services and programs tailored to the needs of these important manufacturing enterprises, which are often the crucible of innovation and economic growth. While addressing only a small-percentage of industrial sector energy use, this cost-effective program would allow these small businesses without in-house capacity to reduce their energy bills and carbon footprints, thereby improving their economic viability. Establishment of this program would require Congressional appropriation of DOE funding.

The final two policies would tackle financial barriers, as they provide new opportunities for capital for energy-efficient systems, equipment, and operations:

Tax Lien Financing of industrial energy-efficiency improvements**,** also known as **Property Assessed Clean Energy (PACE)** financing, would require federal enabling legislation to allow municipalities to establish clean energy taxation districts, which can issue tax-free bonds for certified energy-efficiency and alternative energy projects. To address the risk of firm closures (particularly during economic recessions), DOE would offer federal loan guarantees to provide security for the bond purchasers and provide a standardized format for the application process.

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[1] At the Clean Energy Ministerial in July, 2010, U.S. Secretary of Energy Steven Chu announced the launch of the Global Superior Energy Performance (GSEP) Partnership. GSEP is the global expansion of the SEP program for industrial facilities, in addition to a broadening of its application to commercial buildings.

Municipalities have established PACE financing within their communities; however, the industrial sector has not yet been able to participate in these beneficial programs that would help increase access to capital for energy-efficiency projects.

Energy-Efficient Industrial Motor Rebates, similar to recent legislative proposals, would authorize and appropriate funding for DOE to implement a program to provide industrial firms and motor manufactures with rebates for purchases of certified high-efficiency motors of 25 to 500 horsepower that replace motors that predate the Energy Policy Act of 1992. The goal is to accelerate adoption of the Energy Independence and Security Act of 2007 standard motors. DOE would give priority and additional technical assistance to companies that include motor upgrades as part of a system-wide optimization of their facilities and promote further efficiency measures.

Quantitative Policy Analysis

The seven policies as a whole are designed to complement one another in order to achieve maximum savings, but each is also evaluated individually to determine if it could produce significant and cost-effective energy savings and carbon emissions reductions, if implemented on its own. Spreadsheet analysis is the principal evaluative tool, supplemented by Georgia Tech's version of the NEMS, where applicable. The *Annual Energy Outlook* (EIA, 2010) reference case forecasts the industrial fuel consumption of the nation by energy sources out to 2035. Investments stimulated from each policy are assumed to begin in 2011 and to occur through 2035 (or shorter in the case of the Industrial Motor Rebate program, which is a short-term "stimulus" policy). The spreadsheet modeling assumes that energy savings from investments in an improved technology degrade at an annual rate of 5%; thus, all benefits end by 2055.

The *AEO 2010* (EIA, 2010) also provides estimates of the carbon intensity of electricity generation based on generation resources over time. The carbon dioxide intensities of various types of combustion fuels used in industry were derived from the EPA (2007a). The benefits of reduced CO_2 emissions are estimated by subtracting the emissions in the reference case from the policy scenario and then multiplying by the social cost of carbon, an estimate of the damages caused by a ton of CO_2 in a given year. The social cost of carbon used in this analysis is the central value of the U.S. Government Interagency Working Group of the Social Cost of Carbon (EPA, 2010a), which range from $23/metric ton in 2011 to $47/metric ton in 2055 (in $2008).

The public health and environmental benefits of reduced emissions of criteria pollutants are estimated using the damage estimates contained in a recent National Research Council report (NRC, 2010). This report excludes climate change, mercury, ecosystem impacts, and other environmental damages, but does include public health and crop damages, for example. Damage estimates are provided for SO_2, NO_x, $PM_{2.5}$, and PM_{10}. For this analysis, emissions from the electricity sector and from industrial heat production are included and the policy scenarios are compared to the *AEO 2010* (EIA, 2010) reference case.

Policy Evaluation from the Private and Societal Perspectives

Each of the policies is first evaluated from a private-sector, industrialist's perspective to assess the business case for the required private-sector leverage. While a detailed financial analysis of each policy was not feasible, assessing the up-front private-sector investment costs relative to the stream of energy-expenditure reductions provides a basis for approximating the overall cash-flow attractiveness of the policy to industrialists. Without a sufficient motivation to invest private capital, the industrial policy options will not achieve their goals. Present-value calculations for the private-sector assessment were conducted using a 7% discount rate – less than the 10% value used in McKinsey and Company's analysis (Granade et al., 2009).

The policies are then evaluated in terms of their net societal benefits and their total social benefit-cost ratios. On the benefits side of the metrics we include monetized energy savings, carbon dioxide mitigation, and reductions of criteria air pollutants; on the costs side, we include both the private investments required as well as the public investments and administrative costs. Different benefit-cost ratios use different combinations of benefits and costs, depending on the purpose of the analysis. Present value calculations for the societal benefit-cost analysis were conducted using a 3% discount rate, with a 7% rate used in sensitivity analyses, consistent with OMB guidelines (OMB, 2002; 2009).

Additional sensitivities are conducted to evaluate uncertainties surrounding participation rates, free ridership, levels and timing of public subsidies, and rates of energy saving. Other uncertainties include social costs, technological innovation, degradation of the effectiveness of energy-saving technologies over time, and long-term costs and prices. The energy saved by free riders, who would have adopted these programs without the supporting policies, are not included in the benefit totals, but they do impact the public costs when subsidies are provided to such firms. Benefits of the seven policies are also not additive, as they can both overlap in addressing identical markets and opportunities, and they also can work synergistically, producing more benefits when one policy enables another, as happens with workforce development programs.

We also calculate leveraging ratios for each of the seven policies, based on its ability to save energy and reduce CO_2 emissions. The leveraging ratio for energy savings is calculated as the ratio of cumulative public costs (in present value terms) to the cumulative TBtu of energy saved. Similarly we calculate the leveraging of CO_2 mitigation, as the ratio of cumulative public costs to the cumulative metric tons of avoided CO_2.

Private-Sector Perspective. Comparing the present value of up-front private-sector investment costs with the present value of the stream of energy-expenditure reductions suggests that each of the policies would be attractive to industrialists.[2] OBES offer the largest present value of energy savings ($223 billion through 2055) relative to the associated private investment of $23

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[2] This general conclusion will not hold true for every firm, since returns on investments will depend on firm-specific characteristics such as tax liability, age of plant infrastructure, energy prices, and cost of capital.

billion. It also has the largest private benefit-cost ratio. In contrast, the Industrial Motor Rebates program saves manufacturers $820 million in energy savings, but it requires a private investment that is nearly one-fourth this benefit. Thus, it has the smallest net present value to industrialists and also the smallest private benefit-cost ratio.

Societal Perspective. Figure ES.2 compares the net total cost of each policy with the million metric tons of CO_2 avoided over the same timeframe.[3] For this chart, we calculated net total costs by subtracting the present value of the energy savings from the present value of the private and public costs. We do not include the value of local pollution abatement, similar to Granade et al. (2009). The result for each of the seven policies is a negative net total cost, meaning that the present value of the energy savings benefits exceeds the present value of the private and public costs.

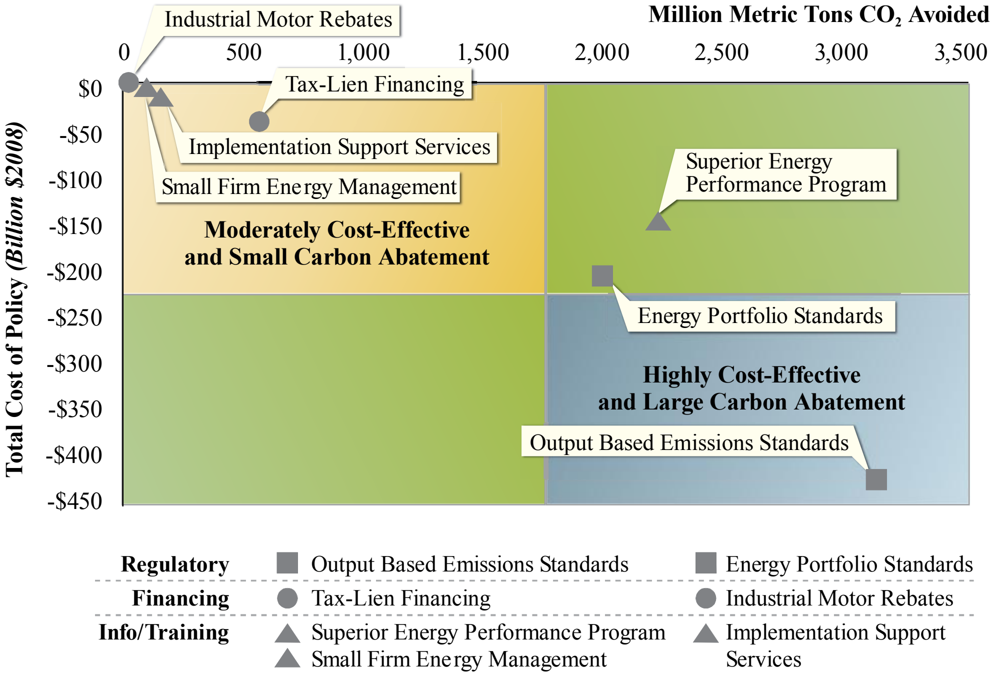

Figure ES.2. Net Costs and Carbon Abatement from Seven Industrial Energy-Efficiency Policies

Four of the seven policies are situated in the upper left-hand quadrant, characterized by small carbon abatement impacts (ranging from 4 to 566 million metric tons of CO_2 abated over the 2011-2055 evaluation period) and modest cost-effectiveness (ranging from $1 to $37 billion of negative costs). At the other extreme, OBES is the only policy that is situated in the lower right-hand quadrant described as highly cost-effective (at $424 billion of negative costs) with large carbon abatement (more than 3,000 million metric tons of CO_2). The remaining two policies (the SEP program and a federal EPS with CHP) offer large carbon abatement (1,990 to 2,230 million metric tons of CO_2), but they are only moderately cost-effective (at $146 to $206 billion of negative costs).

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[3] "Total Cost of Policy" refers to the present value of cumulative private and public investment and administrative costs minus the present value of cumulative energy savings

Social Benefit-Cost Ratios. The social benefit-cost ratios of these policies are highly favorable when one considers the avoided damages from carbon dioxide emissions and criteria pollutants. To emphasize the variable results produced by different sensitivity analyses, Figure ES.3 shows a range of four social benefit-cost ratios for each of the seven studies. These include sensitivities around discount rates (three versus seven percent), key policy features (e.g., the duration of subsidies in the energy portfolio standard), and variable assumptions about impacts and participation rates (e.g., a five-year versus a 10-year adoption period for output based emissions standards). In each case, benefits include the social cost of carbon abatement and reduced criteria pollution.

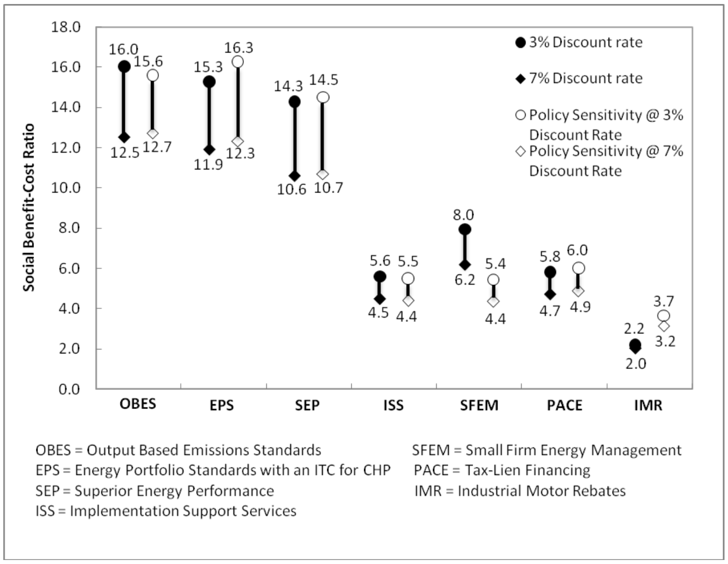

Figure ES.3. Social Benefit-Cost Ratios for Each Policy and Its Sensitivities

The results show that the benefits of each of these policies would likely outweigh their costs of implementation, even in the scenario with the higher discounting of energy savings over time and the less favorable assumptions about policy design and participation. The Industrial Motor Rebate policy has the lowest social benefit-cost ratios (ranging from 2.0 to 3.7). At the other extreme, the OBES and EPS with CHP have the highest ratios (ranging from 12 to 16).

Summary Assessment of Policy Options

Each of these seven policy options has an appropriate federal role, broad applicability across industries, relies mostly on readily available technologies, and are administratively feasible, with independent as well as synergistic effects. With the inclusion of a SFEM program, federal resources would be more attentive to energy efficiency opportunities achievable by assisting small enterprises. Other notable strengths are the workforce development and market transformation impacts of the ISS, SEP programs, and SFEM.

Tradeoffs among the seven policy options also exist. For example, OBES have a narrow focus on a single technology (CHP) compared with a federal Energy Portfolio Standard that would promote many clean energy options, but the OBES regulatory focus with an absence of subsidies makes it less prone to costly free riders. The voluntary information programs with limited subsidies would tend to have few free riders, but they also may be challenged by low rates of participations (SEP, ISS, and SFEM). The Industrial Motor Rebates policy has relatively small societal benefits, but the benefits exceed the policy’s costs and provide a short-term stimulus effect in an industry that might otherwise see a slow uptake of superior motors due to their cost increment and limited availability of capital.

Conclusions

The energy-efficiency gap in the U.S. industrial sector is large. Our analysis suggests that policies could help motivate businesses to focus more of their resources on lean energy systems. From the industrialists' perspective, the energy savings from each of the seven policy options exceed private investment costs under a wide range of plausible assumptions. A stakeholder assessment indicates that equipment suppliers, service providers, and others would support these policy options. Utilities, on the other hand, could experience revenue erosion and might view many of the policies with disfavor.

The seven federal policy options evaluated here would require sustained public commitment and resources, and their success would require substantial capital, time, and effort by industrial facilities. In turn, they could deliver substantial energy, environmental, and economic benefits and help American industry meet the challenges of a low-carbon economy while becoming more competitive in the global marketplace. These seven policies could bring expansive benefits to all regions of the country, but would have the greatest impact in manufacturing-heavy regions, such as the South and Midwest where energy-intensive industrial activity is concentrated.

A more complete analysis of the impacts of industrial energy-efficiency investments would likely increase the social benefit-cost ratios of these policies. There is a growing literature that documents several categories of "non-energy" financial benefits including reduced operating and maintenance costs, improved process controls, increased amenities or other conveniences, water savings and waste minimization, and direct and indirect economic benefits from downsizing or elimination of other equipment (Prindle, 2010). On the other hand, the avoidance of environmental damages that contributes to the high societal benefit-cost ratios of these seven policies could be overstated if EPA regulations are tightened over the next several decades and if a price is put on carbon. Under those circumstances, the additional value provided by these seven policies would be more limited. Acknowledging the uncertainties of policy analysis, we also examine plausible alternative assumptions about participation rates, technology costs, duration of subsidies, and discount rates.

With the right policy environment, industry could become a bigger part of the climate solution. These policy options are not the only means to build a low-carbon industrial sector; however, the detailed analysis using rigorous and fully documented analytic methods shows that this portfolio offers a significant opportunity for policy-makers to help industry reduce its consumption of energy resources, become more competitive, and protect the environment.

1 INTRODUCTION

Advanced energy technologies combined with best practices appear to afford significant cost-effective potential to reduce the consumption of fossil fuels and the emission of greenhouse gases (GHGs) across the U.S. economy. In practice, however, the realization of this potential has proven difficult because of multiple obstacles and complications. Individuals and firms often can act effectively only with enabling assistance to overcome misperceptions, budget constraints, regulatory hurdles and other non-technical barriers. While U.S. industry reduced the energy intensity of its operations following the Arab oil embargo of 1973-74, the existence of a persistent “energy-efficiency gap” – a term coined by Hirst and Brown (1990) – remains today.

Effective national strategies to accelerate improvements in U.S. energy efficiency have been handicapped by an incomplete understanding of the human dimensions of individual and firm decision-making, action-taking, and enabling circumstances. A broader understanding of socio-economic aspects of energy consumption and conservation behavior, it is hypothesized, would enable the formulation of more informed and effective national strategies and policies for improving energy efficiency and mitigating GHG emissions. In following up on its mandate from Title XVI of the Energy Policy Act of 2005 to examine barriers to progress and make recommendations in this regard, the Climate Change Technology Program (CCTP) commissioned this report on improving energy efficiency in industry, with an emphasis on developing a series of proposed policy options, grounded in an understanding of industrial decision-making and accompanied by supporting analysis of policy pros and cons.

The objective of this report is to develop and evaluate policy options that could encourage greater energy efficiency or reduce energy consumption in the industrial sector. These policy options should not be duplicative of existing policies; however, where appropriate, they could expand, build on, or enhance existing policies. In addition, they are intended to be grounded in an understanding of consumer and firm decision-making, behavioral research, corporate investment theory, and knowledge of the key barriers to greater adoption of efficient technologies and practices. This effort is motivated by an increased sense of urgency regarding the need to improve energy efficiency, lower energy expenditures, moderate pressures for new energy supply, and reduce GHG emissions and their associated environmental effects. In an increasingly resource-constrained world, improving the energy efficiency of industry is essential. In addition to its environmental, security, and competitiveness benefits, industrial energy efficiency delivers a return on investment that can improve the profitability of enterprises, generate jobs, improve energy security, and strengthen global economic competitiveness.

Despite the existence of an energy-efficiency gap today, industrial energy systems have improved over the past several decades in response to technological advances motivated by volatile fossil-fuel prices as well as global and domestic competition. U.S. manufacturing has undergone significant change to improve market competitiveness and increase profits. Reductions in the energy intensity of manufacturing were particularly significant following the oil crises in the 1970s. Over the past several decades, however, the pace of industrial efficiency investments has slowed, at the same time that opportunities to upgrade the efficiency of industrial energy systems have grown. The question addressed by this report is whether or not appropriate Federal policy options could motivate industrial enterprises to expand their investments in improving the energy efficiency of their facilities, processes, and practices.

1.1 Industrial Energy Use: An Overview

To understand the magnitude of the energy-efficiency gap in industry, and to consider key targets for possible new policies, it is useful to consider how industrial energy is currently consumed. Industry is the largest energy-consuming sector in most countries of the world, accounting for 37% of primary energy use globally (IPCC, 2007, p. 453). U.S. industrial energy use represented approximately 32% of total U.S. energy consumption in 2008 and about 27% of total U.S. carbon dioxide emissions (EIA, 2010, Tables A2 and A18). On a global perspective, U.S. industry accounts for approximately 8% of the world's energy consumption (EIA, 2009a, Table A1).[4]

Over the long term, industry is expected to continue to be a significant component of increasing global energy demand and a major source of CO_2 and other GHG emissions, driven largely by the continuing trends of development, population, and GDP growth. Because equipment and operations are routinely upgraded to lower costs and maintain competitiveness, the short-term potential for improving the energy integrity of the industrial sector is high. It is also concentrated within a few subsectors. The Energy Information Administration (EIA, 2006) estimates that more than half of U.S. industrial energy use is consumed by four industries; bulk chemicals, petroleum refining, pulp and paper, and iron and steel (Figure 1.1). Food processing is the fifth largest energy consumer in industry, but its energy-intensity is much lower than the four largest industrial subsectors.[5] Cement manufacturing on the other hand is energy-intensive, but it consumes only a fraction of the energy used by these four industries.[6]

Less energy-intensive industries include the manufacture and assembly of automobiles, appliances, electronics, textiles, and other products. Since energy is a smaller portion of their overall costs, these industries have historically tended to pay less attention to finding ways to

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[4] The EIA defines the industrial sector as: "An energy-consuming sector that consists of all facilities and equipment used for producing, processing, or assembling goods. The industrial sector encompasses the following types of activity manufacturing (NAICS codes 31-33); agriculture, forestry, fishing and hunting (NAICS code 11); mining, including oil and gas extraction (NAICS code 21); and construction (NAICS code 23)" (Source: http://www.eia.doe.gov/neic/datadefinitions/sectors25B1.htm). This is the scope covered by the *Annual Energy Outlook* to characterize the energy consumed by industry in the U.S. Some other EIA publications use a more limited scope, including the *Manufacturing Energy Consumption Survey*, which includes manufacturers but excludes agriculture, forestry, fishing, mining, and construction. The industrial module of EIA's National Energy Modeling System excludes these "non-manufacturing" activities and also excludes the refining industry, which is treated in a separate module. Our analysis is similarly variable in its definition of "industry" depending on the source of data and modeling tools; for each policy option evaluated in this report, we therefore specify the scope of the industrial sector that is included.

[5] The "energy intensity" of manufacturing is a common measure of energy efficiency. It is measured by dividing energy consumption (usually in thousand Btu) by the value of the commodities produced (usually using the value of shipments in million constant dollars).

[6] http://www.eia.doe.gov/emeu/plugs/plecp.html

cut energy use. However, as suggested by Prindle (2010), current evidence shows this may be changing with an increased focus on reducing carbon footprints. Completing the inventory of U.S. industrial energy use, “non-manufacturing” accounts for nearly six quads of consumption and is therefore another key target of opportunity. It includes crops and other agricultural activities, coal and other mining, oil and gas extraction, and construction.

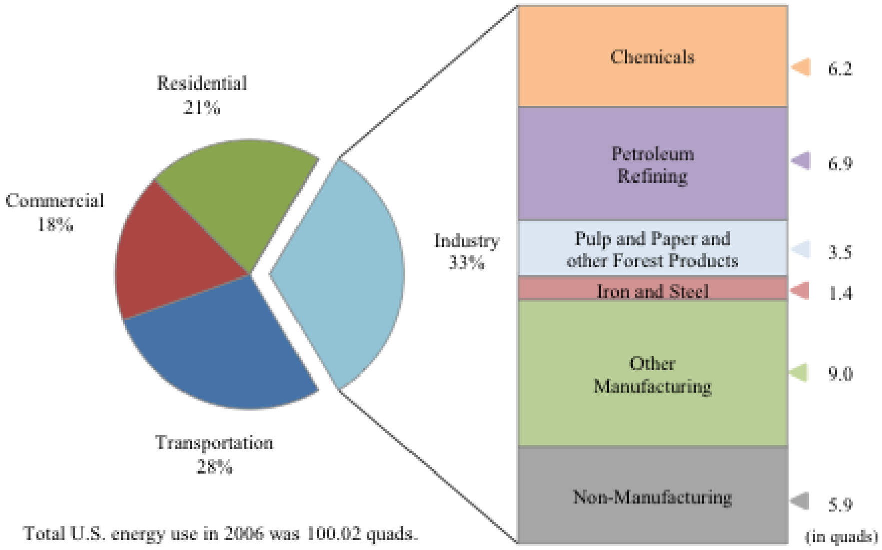

Figure 1.1. U.S. Industrial Energy Use in 2006
Source: EIA, 2006

Large enterprises dominate most energy-intensive industries across the globe, especially in industrialized countries, and the U.S. is no exception. Two-thirds of U.S. industrial energy use is consumed by approximately 8,600 large firms – those with 250 or more employees. Their annual energy bills typically exceed $3 million. At the other extreme, more than 160,000 small firms with fewer than 50 employees account for only 7% of total industrial energy use in the U.S., and their annual energy bills tend to be less than $250,000 (Figure 1.2).

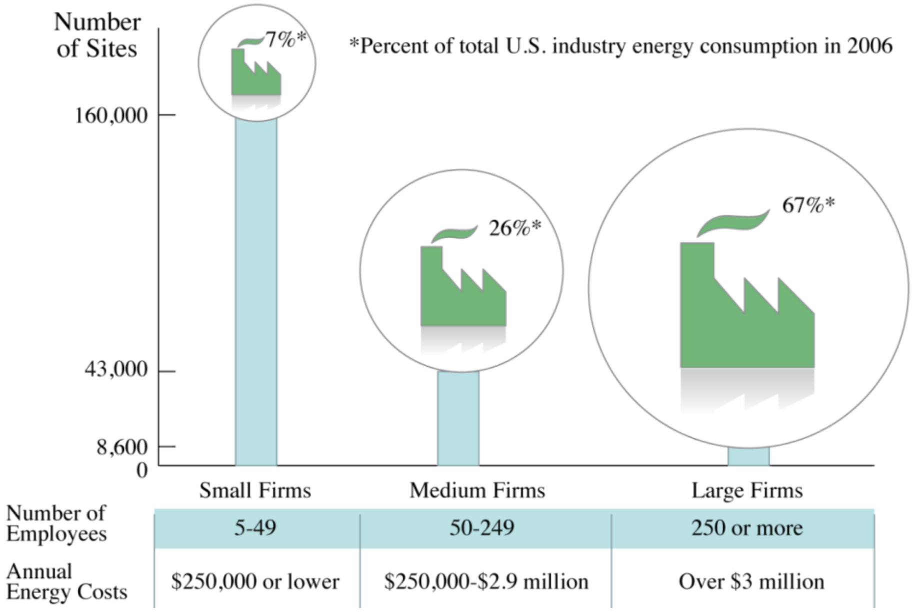

Figure 1.2. U.S. Industrial Consumption by Size of Firm

Source: EIA, 2006 and U.S. Census Bureau, 2007

Energy intensity indicators suggest that improvements in energy efficiency were significant during the decade following the 1973-74 oil crisis. The petroleum and coal products manufacturing industry experienced particularly noteworthy improvements in energy intensity with a reduction of 60% in 2004 relative to 1977, followed by chemical manufacturing with a 42% reduction, plastic and rubber with 31%, nonmetallic minerals with 25% and primary metals with 23% (Figure 1.3). Since 1986, however, the decline in energy intensity of many energy-intensive industries in the country has been modest (Brown, Cortes, and Cox, 2010). Given the major advances in the performance and cost-effectiveness of many process technologies over this period, greater reductions in the energy intensity of manufacturing might have been expected.

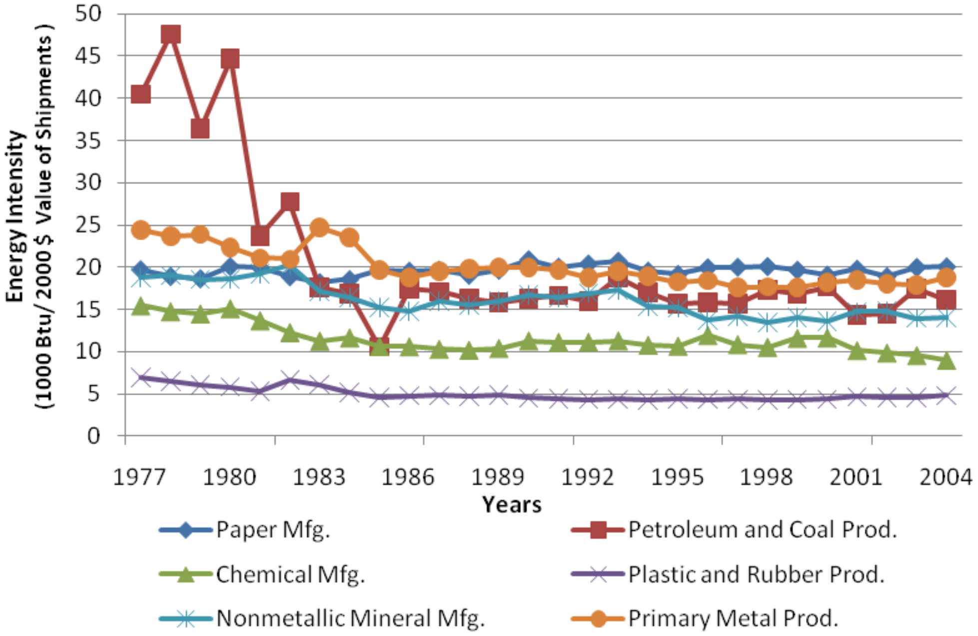

Figure 1.3. Changes in Energy Intensity in Six Key U.S. Industries (1977-2004)

Source: DOE, 2010a

This trend is consistent with the findings of numerous studies documenting high energy-savings potential in energy-intensive industries in the U.S. (Granade et al., 2009). The National Academies (2009a) reviewed the literature on several energy-intensive industries to evaluate their potential for cost-effective improvements out to the year 2020. The results are summarized in Figure 1.4.[7] In the chemicals industry, potential cost-effective energy savings are estimated to reduce energy consumption from 6.08 to 5.89 – 4.98 quads (3% – 18% savings, respectively) in 2020. Larger potential savings are envisioned for the petroleum refining industry, ranging from 5% to 23% of energy consumption in 2020. Estimates for the pulp and

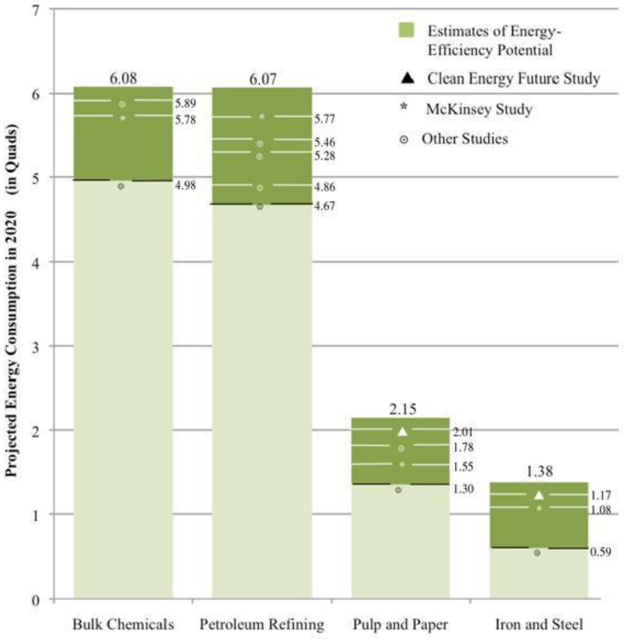

Figure 1.4. Potential for Improving Energy Efficiency in Four Key Industries in 2020

Source: Brown, Cortes, and Cox (2010)

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[7] The Clean Energy Future Study refers to Interlaboratory Working Group (2000), and the McKinsey Study refers to Granade et al. (2009). The "other studies" of the chemical industry are NREL (2002) and DOE (2006); for petroleum, they are LBNL (2005) and DOE (2006); for pulp and paper, they are Martin, et al., (2000) and Jacobs Engineering and IPST (2006); and for iron and steel, the other study is by AISI (2005).

paper industry range from 6% to 37% reductions in 2020. The broad range of these estimates highlights the lack of consensus about the magnitude of the opportunity. Nevertheless, all of the studies concur that sizeable energy savings can occur while providing a positive cash flow to investors.

A good portion of the savings potential described in the literature would require an overhaul by companies of their major process technologies to bring them closer to state-of-the-art operations. This, in itself, is an important barrier to improved efficiency if it means that production equipment would need to be “scrapped” before the end of their scheduled depreciation period and useful life in order to install newer, more energy-efficient production equipment. Writing off capital that has not been fully depreciated under book accounting, produces an immediate, potentially significant, charge against earnings – a material consideration for public-reporting firms. The capital vintaging issue is less documented than some issues as an impediment to improved energy efficiency. It is one of the reasons why the energy intensity of U.S. manufacturing exceeds that of many expanding economies such as Korea and India, where there is an opportunity for new facilities to deploy the latest energy-saving technologies and practices. In the U.S., there is a substantial existing infrastructure of older, inefficient manufacturing facilities that need to be upgraded, where the vintage of existing equipment is a deterrent. Still, other industrialize economies such as Denmark and Japan significantly outpace the U.S. in the energy productivity of their manufacturing (Brown, Cortes, and Cox, 2010).

Major process technologies are often unique to specific industry subsectors, such as advanced anodes in aluminum and distillation systems in petroleum refining. Throughout industry, however, crosscutting technology opportunities also exist for reducing energy use and carbon emissions, such as improvements to steam, compressed air, and motor and drive systems.

Based on an analysis of the Industrial Assessment Center (IAC) audits of mostly medium-sized companies conducted from September of 2005 through March 5, 2010, by colleges and universities under contract with DOE, numerous opportunities for cost-effective energy-savings improvements exist in a broad range of industrial sectors. Figure 1.5 shows the average energy savings in thousands of dollars for technology upgrades with more than 100 recommendations. The average payback periods for these recommended actions range from 0.59 years for demand management and steam processes to 2.3 years for water use measures, and 2.5 years for improved power factors.

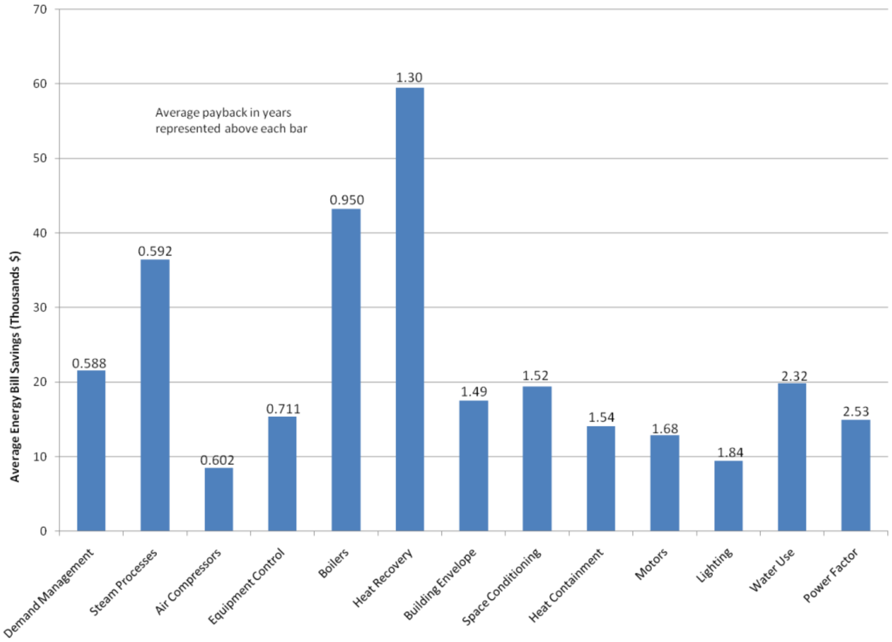

Figure 1.5. Average Energy Bill Savings and Payback for Selected Industrial Efficiency Measures
Source: Derived from: http://iac.rutgers.edu/database/

For large companies, the Save Energy Now program and other public-private partnerships with large industrial firms have identified numerous areas of significant efficiency gains, typically from the overhaul of major process technologies. Numerous "technology roadmaps" (e.g., Agenda 2020 Technology Alliance, 2010) and "energy bandwidth" studies (e.g., DOE/EERE, 2006) have itemized specific process improvements available to specific industries. The National Academies (2009a) study, DOE/EERE (2010), and Brown, Cox, and Cortes (2010) describe an array of these opportunities. For example,

- Potential technological improvements to distillation processes include technologies such as latent heat integration, multiple-effect distillation, and solution-thermodynamics-altering azeotropic or extractive distillation. Material methods, notably membrane and micro- and nano-particle separation methods, offer tantalizing possibilities. The challenges are in developing materials and methods with high throughput, high selectivity, low energy requirements, resistance to fouling, durability and affordable costs.
- Membrane separation is the most widely applicable of all technologies for reducing energy of separation processes in the petroleum, chemical and forest products industries. Membranes may be made of organic materials for relatively low-temperature processes, inorganic materials such as ceramics for high temperature use, or a combination of the two. Membranes are currently used successfully to separate light hydrocarbons as well as hydrogen from gas streams.
- Several energy-efficient methods of drying have been developed, many of which are cost-effective today. One of these, a systems approach, involves using waste heat from heat-generating processes including from power generation and ethanol production, as the energy source for evaporation in the paper industry.

- Changing the chemistry of cement using recycled materials to reduce the need for calcination can decrease the high share of clinker that characterizes U.S. production. Options for blended cements include fly ash and steel slag.
- Wireless sensors for process stream sampling minimizes the energy needed to heat up and cool down a process. Low-cost wireless sensors increase the number of measurements available to improve process efficiency.

These examples illustrate the array of technology opportunities available to reduce the energy required in the manufacturing of goods.

1.2 Barriers to Industrial Energy Efficiency

A number of barriers to increasing investments in industrial energy efficiency help to explain the existence of a large energy-efficiency gap in U.S. industry. Based on a review of the literature, seven types of barriers to industrial energy efficiency were emphasized by the Committee on Climate Change Science and Technology Integration (CCCSTI, 2009).

- **Technical risks –** Uncertainty about the benefits and risks of new technology is a major barrier in today's manufacturing environment with 24/7 operations; reliability and operational risks represent major concerns for industry when adopting new technologies.
- **High upfront costs –** New energy-efficient technologies often have longer payback periods than traditional equipment and represent a greater financial risk since there is significant uncertainty in future energy prices. New technologies must compete for financial and technical resources against projects that achieve other company goals.
- **External benefits and costs –** External environmental benefits – including GHG emission reductions – are not usually considered in evaluating energy-efficiency investments.
- **Lack of specialized knowledge –** Industrial managers can be overwhelmed by numerous energy-efficiency products and programs and lack in-house energy experts. Energy service companies (ESCOs) could fill this gap, but uncertainty about the long-term financial viability of manufacturers poses too much risk for alternative financing.
- **Incomplete and imperfect information –** Researching new technology consumes time and resources, especially for small firms, and many industries prefer to expend human and financial capital on other investment priorities.
- **Market risks caused by uncertainty –** Uncertainty about future electricity and natural gas prices and long-term product demand can represent a powerful barrier.
- **Competing fiscal policies –** Tax treatments favoring operating versus capital expenses can slow the pace of capital stock turnover; outdated tax depreciation schedules can disfavor efficiency investments; standby charges, buyback rates and uplift fees inhibit distributed generation; and lack of marginal cost pricing and time-of-use rates are also examples of competing fiscal policies (CCCSTI, 2009, p. 7).

These barriers are also consistent with the results of a DOE “Workshop on Policy Options to Address Non-Technical Barriers to Increased Energy Efficiency in U.S. Industry” that was held on September 30, 2009, in Washington, DC, to provide broad-based input for this report. The workshop participants generated and rated a list of 34 specific non-technical barriers to advancing energy efficiency in industrial processes. Their results underscored the problems of capital rationing, efficiency as a non-core investment, lack of knowledge and specialized expertise, and utility disincentives. In addition, participants emphasized problems of overly layered permitting processes and new source review requirements under the Clean Air Act. The consensus views of workshop participants regarding key obstacles are summarized below, focused on financial, information, and regulatory barriers.

1.2.1 Financial Barriers

One of the overarching barriers to energy efficiency is that energy is relatively inexpensive and the costs and risks to companies for inefficiency are small. When energy costs are low, industry has little incentive to make investments in efficiency measures. As a result, the economic benefits from efficiency projects are sometimes more difficult to justify. While exceptions exist, hurdle rates for efficiency investments are typically higher than for other projects, as firms tend to perceive them as non-core investments. The difficulty in justifying new, more efficient equipment is also exacerbated by the long useful life of large, costly capital equipment (boilers, generators, turbines, motors, etc.) used in industrial processes, which is amortized over many years. The frequent long remaining useful life and undepreciated asset balances associated with existing production technology are important factors impeding installation of more efficient production technology when the energy-efficiency improvement is an embedded technology element of the newer production vintage.

Lack of access to capital, or the prohibitively high cost of capital, is a primary barrier to investment in industrial energy efficiency. When capital is limited, product or production expansion is favored over efficiency projects with uncertain returns. Business decision-making and priorities that emphasize revenue enhancement over cost reduction have long been a challenge to energy efficiency investments. This challenge has weakened some recently as U.S. businesses realize the importance of cost management in an open global economy and are also facing limits on revenue growth as a way to increase shareholder earnings.

Another issue is the structure of depreciation schedules under current corporate tax codes, which makes few allowances for efficiency and may discourage investments that improve efficiency. The federal tax code forces firms to depreciate energy efficiency investments over a longer period of time than many other investments. For example, a new back-up generator would be depreciated over three years while a new CHP system would be depreciated over twenty years. The CHP system would provide both reliability and energy efficiency while the back-up generator provides reliability at the expense of energy efficiency and clean air (Brown and Chandler, 2008). Modification of depreciation schedules would remove a significant barrier to industrial efficiency investments, but it would require legislative action.

Currently, carbon emissions from industrial processes and fuel combustion are not a liability on corporate balance sheets in most regions of the U.S. The absence of an international agreement on climate change and GHGs has resulted in concerns over the ability of U.S. industries to compete with foreign companies that may not be subject to the same emission standards. Also, within the U.S., the political division in Congress over energy and climate policy has resulted in a lack of clear direction on the extent of proposed and pending climate legislation.

1.2.2 Information Barriers

The lack of specialized in-house engineering knowledge and energy management expertise represents a barrier in many industries, and especially in smaller firms (Brown et al., 2008). This problem is compounded by the resistance of managers to using third-party installers, such as ESCOs and utilities, which could help to fill knowledge gaps.

The industry sector is highly diverse and there is no one-size-fits-all energy-efficiency solution, which challenges the ability of in-house and contracted staff to learn from the experiences of other firms. Some industries are dominated by a handful of large firms, while in others hundreds of small- and medium-sized enterprises (SMEs) control a large portion of the market. For many of these SMEs, especially those with smaller management operations and which may be more resource-constrained, energy efficiency may not receive much attention. Even for larger companies that have the capacity to pursue high-level energy-efficiency initiatives, this may not happen due to operational reasons. The need to keep a process running in a predictable fashion, for example, often overrides the inclination to replace equipment with a more efficient model.

In general, corporate decision-makers are predisposed towards investments which result in more output. Although the reduction of costs through investments in efficiency may have the same impact as increases in productivity on overall profit, investments tend to be focused on increasing revenue as opposed to decreasing costs. These generalizations are perhaps least true of larger firms in energy-intensive industries, where energy-management expertise is explicitly embedded into teams with key process responsibilities such as heating, drying, and assembly. Investments in energy efficiency are “the same” as increases in productivity, based on a total factor productivity concept.

1.2.3 Regulatory Barriers

Major disincentives exist with current utility and regulatory structures that discourage industry from developing the capacity to generate electricity with their waste heat. These include significant interconnection fees, a lengthy permitting process, and the lack of net-metering policies that would provide a reliable buyer for excess generation. There is also limited interaction between utilities and industry to better manage the grid. However, in response to increasing peak demand and growing strain on existing capacity, utilities are pursuing demand response and energy-efficiency strategies.

Regulatory requirements can sometimes have an adverse effect on industrial energy efficiency. For example, National Ambient Air Quality Standards (NAAQS) require large point source emitters of sulfur dioxide (SO_2), nitrogen oxides (NO_X), and other criteria pollutants to install scrubbers and other exhaust treatment technology on their plants. In many cases, these systems impose significant parasitic loads on generation capacity. Avoiding a new source review (NSR) – a regulatory procedure required for all "new" large emitters of air pollutants – can limit efficiency projects. For example, much of the capital equipment in use by U.S. industry is aging, and some inefficient facilities have been grandfathered in under Clean Air Act regulations. Plant owners and managers who want to invest in newer, cleaner, and more efficient technology that may be cost-effective could face losing their "grandfathered" status if a NSR is triggered. As a result, some plants may continue operating under inefficient and uneconomic conditions to avoid what is perceived as an onerous regulatory burden (Brown and Chandler, 2008). In general, overly complicated or layered regulation and permitting processes (e.g., different regulations between state and federal) can make efficiency projects less attractive.

1.2.4 Barriers in the Context of Energy Management Capacity

The barriers to industrial energy efficiency are not uniformly distributed across all manufacturing enterprises. Their importance and influence depend on the level of maturity in plant energy management that characterizes a particular firm or facility. A typology useful in this context distinguishes between three levels of plant energy management maturity and sophistication. An expanded description of this typology is provided below.

- *Manufacturers with highly sophisticated energy management capacity,* as a group have extensive knowledge of energy management and have successfully implemented many projects. They track energy data for each plant in detail by subsystem, monitor their electricity demand charges and energy costs using sophisticated monitoring equipment, set efficiency goals, and consider efficiency projects using rigorous decision tools.
- Manufacturers with *basic energy management* include enterprises with a rudimentary knowledge of the benefits of energy management. They may have implemented some basic projects, but many project opportunities remain. They track energy data sporadically and without detailed submetering or sophisticated monitoring equipment, generally have not set specific efficiency goals, and utilize simple decision tools to allocate resources across alternative investment options including efficiency projects.
- Manufacturers with little or no knowledge of energy management are just beginning to learn about managing energy in their plants and facilities. They have not tracked their energy consumption data in any detail, and they do not have energy-efficiency goals or systems for selecting between alternative energy-saving projects.

Information barriers are more important to enterprises with a low energy management capacity. Financing barriers and regulatory obstacles impede firms across the spectrum of energy management competency, but the specific impacts may differ significantly. For instance, access to capital would likely be a greater problem for manufacturers with little or no knowledge of energy management, while competing demands for capital might be a more dominant obstacle for manufacturers with highly sophisticated energy management capacity. Attention should be given to the types of firms to be targeted by any future policy options.

1.3 Drivers of Industrial Energy Efficiency

Apart from barriers, effective design of federal policy options must also consider drivers of industrial energy efficiency. The business case for energy efficiency varies across industry subsectors, firm size, and region of the country, and it reflects a variety of motivations for using energy more wisely. Nevertheless, common motivations emerged from a review of the literature, including the report from the report on “Strategies for the Commercialization and Deployment of Greenhouse Gas Intensity-Reducing Technologies and Practices” (CCCSTI, 2009).

- **Volatile and rising energy prices –** “The sustained pain” of rising oil, coal, natural gas, and electricity prices is motivating a renewed interest in energy efficiency
- **Environmental concerns and regulations –** Energy-efficiency investments can tap into potentially lucrative revenue streams from NO_x and SO_2 offsets in non-attainment zones, RES/EERS compliance requirements, and tradable carbon allowances
- **Demand charges and demand response incentives –** The ability of industry to cut peak electric loads motivates many utilities to incentivize demand-side management (DSM) in industry.
- **Collateral benefits –** Increased productivity, improved product quality, reduced labor costs, and enhanced reliability can result from energy-efficiency investments. In addition, improved stability of financial performance should lead to lower cost of capital, in terms of both access and cost of financing.
- **International competition –** When the cost of energy inputs makes a firm unable to compete, energy-efficiency improvements are often sought out. Energy cost reductions can also be used to offset other rising costs, such as labor.
- **Corporate sustainability –** Energy efficiency as a climate change mitigation strategy offers a way to boost shareholder/investor confidence, profit from future legislation, and access new markets.
- **Shareholder activism, good corporate governance, and reputation management –** ENERGY STAR® designations, for example, have proven to be a strong motivator for energy-efficiency and other investments in sustainability.
- **Insurance access and costs, legal compliance, and concerns regarding fiduciary duty –** All represent additional potential drivers.

These drivers were also outlined in the study of *Real Prospects for Energy Efficiency in the United States* (National Academies, 2009a) and are consistent with the DOE Workshop dialogue.

1.4 The Existing Policy Landscape

Federal, state, and local policies also act as drivers for change in the sustainable operations and energy productivity of industry. In order to identify promising policy options for the future, it is important to understand the existing policy landscape aimed at promoting industrial energy efficiency.

Based on the CCTP/Energetics Deployment Inventory Database (2010), the implementation of federal activities addressing energy-efficiency and GHG emissions in the industrial sector is distributed amongst more than a dozen federal agencies involved in the administration of 72 currently funded and active deployment programs (Figure 1.6).

Reflecting the importance of informed decision-making in industry, about half of the identified activities involve labeling or the dissemination of information about energy-efficient technologies currently available to industry. For example, EPA's National Pollution Prevention Vendor Database maintains a repository of more than 1,200 listings of pollution prevention equipment, products, and services. EPA's VendInfo database helps industrial clients find providers of industrial energy-efficiency services.[8]

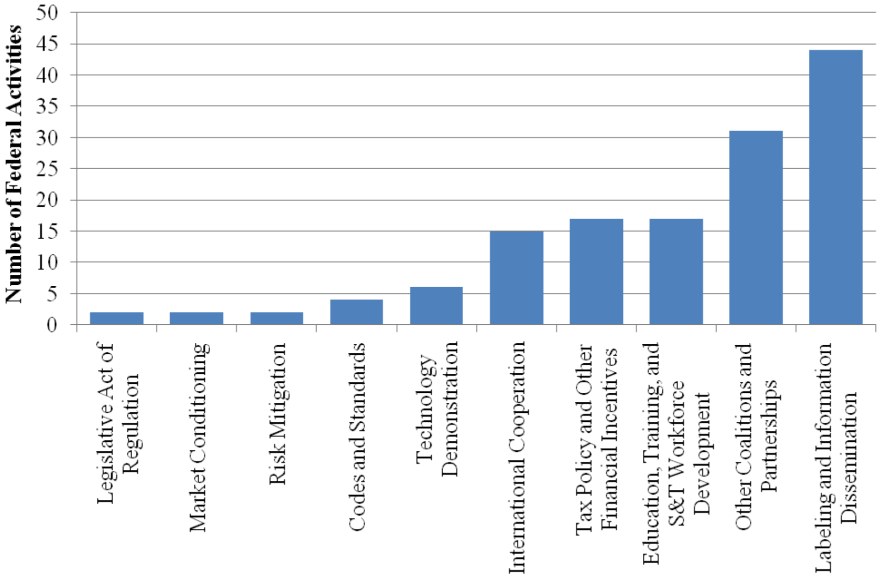

Figure 1.6. Federal Policies to Reduce GHGs in Industry
Source: CCTP/Energetics Deployment Inventory Database dated January 2010

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[8] http://www.epa.gov/vendors/

Compared with other countries such as China, Japan, and India, the U.S. focus has been driven less by regulation and more by the promotion of voluntary actions (Brown, Cortes, and Cox, 2010). Numerous technical assistance activities and public-private partnerships work with industry; perhaps most notable among these are the “Save Energy Now” (SEN) and “Industrial Assessment Centers” (IAC) programs administered through DOE’s Industrial Technologies Program.

Save Energy Now is an initiative through which DOE partners with industry on a voluntary basis to support progress toward the industrial energy intensity reduction goals set forth in Section 106 of EPAct 2005.. It focuses on large industrial partners in energy-intensive industries to identify areas for significant efficiency gains. The program recognizes industrial energy-efficiency leaders in a public-private partnership, with DOE providing a technical account manager, recognition for performance, tool and training workshops (e.g., covering baselining, process heating steam systems, motors, pump, and fans), plant demonstrations to test the elements of SEP, and technical support to plant personnel.

The ITP also works with small and medium-sized firms through the audits performed by the Industrial Assessment Centers (IAC) at 26 university-based centers throughout the country (Figure 1.7). This program identifies cost-effective opportunities for energy efficiency throughout the firms’ operations. The IACs serve hundreds of plants each year and have motivated significant energy-saving investments; nevertheless, many recommended measures have not been implemented by the participating firms (see Chapter 3 for an overview of the IAC program and its impacts to date).

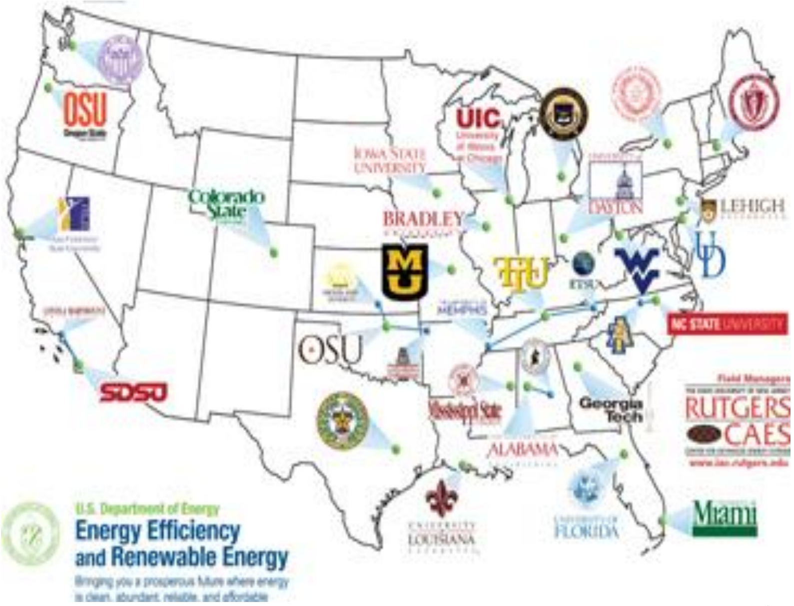

Figure 1.7. Industrial Assessment Centers: 2006-2011[9]

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[9] http://www1.eere.energy.gov/industry/bestpractices/industrial_assessment_center_locations.html

EPA is also an active participant in public-private partnerships with industry. For example, its Climate Leaders program works with companies to develop comprehensive GHG emissions inventories and climate change strategies, and recognizes companies as corporate environmental leaders.[10] In 2010, EPA Assistant Administrator Gina McCarthy announced that the Climate Leaders program would phase down in 2011, as a result of determining that "climate programs operated by the states and NGOs are now robust enough to service our Partners and other entities that wish to continue to advance their climate leadership through comprehensive reporting (that exceed mandatory reporting requirements) and/or the establishment of facility or corporate-level GHG reduction goals."[11]

Some of the links between current federal activities and specific deployment barriers in industry are illustrated in Table 1.1. For example, recognizing the high costs and market risks of investments in industrial efficiency, particularly among small firms, the U.S. Energy Infrastructure and Security Act of 2007 established a new program – the Small Business Energy Loans Program – that is intended to help small businesses develop, invest in, and purchase energy-efficient buildings, fixtures, equipment, and technology.

Despite the numerous federal activities currently operating to encourage the more efficient use of energy in industry, many opportunities for improving efficiency exist that are not being explored. New policies combined with expanded efforts by existing policies and programs may be needed to effectively address barriers that continue to thwart the more rapid diffusion and greater adoption of cost-competitive, low-carbon technologies in the industrial sector.

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[10] http://www.epa.gov/stateply/faq/index.html
[11] http://www.epa.gov/climateleaders/documents/partners_letter_15sep2010.pdf

Table 1.1. Illustrative Activities Addressing Key Barriers in the Industrial Sector

Key Barriers	Illustrative Activities
Activities Addressing Financial Barriers:	
Technical Risks	• Industrial Technologies Program (DOE) • Renewable Energy Innovation Manufacturing Partnership (DOE)
High Upfront Costs	• Waste Energy Recovery Incentive Grants (DOE) • State Energy Program (DOE) • Pollution Prevention Grants Program (EPA) • Small Business Energy Loans (SBA)
Market Risks	• Clean Energy Technology Exports Initiative (DOE, DOC, USAID)
External Benefits and Costs	• Pay As You Throw Program (EPA)
Activities Addressing Information Barriers:	
Lack of Specialized Knowledge	• Industrial Assessment Centers (DOE) • Industrial Technology Program Best Practices (DOE) • Save Energy Now (DOE) • Manufacturing Extension Partnership (DOC) • Energy Efficiency and Renewable Energy Worker Training Program (DOL, DOE)
Incomplete and Imperfect Information	• Energy Efficiency for Data Center Buildings (DOE) • National Pollution Prevention Vendor Database (EPA) • Climate VISION (DOE) • Landfill Methane Outreach Program (EPA) • Climate Leaders (EPA)
Activities Addressing Regulatory Barriers:	
	• Flexible Air Permits (EPA) • Plant-Wide Applicability Limits (EPA)

Source: Derived and expanded from CCCSTI (2009) Table 2-3

1.5 Research Approach

This section begins by explaining the selection of policy options for detailed evaluation. It then describes the spreadsheet and modeling approach used to evaluate each policy option, and our treatment of uncertainty through sensitivity analysis.

1.5.1 Identification of Policy Options

The identification of policy options drew on an assessment of barriers and drivers influencing the deployment of GHG mitigation technologies summarized above, the DOE Workshop on Policy Options with industrial experts, and various consultations with industry stakeholders, analysts, and policymakers. We also researched recently drafted legislation on Capitol Hill containing sections that address energy efficiency and reducing GHG emissions in industry.

A short list of possible policy options was presented for discussion at the DOE workshop; participants evaluated these, suggested modifications, and nominated additional policy options. The entire process was completed within the context of a set of eight policy evaluation criteria developed in advance of the workshop:

- **Appropriateness of the federal role**. Many of the more effective policy options and measures in this area require state or local action, as the jurisdictional responsibilities reside most strongly at this level of governance. However, state and local action may be encouraged by supportive federal policy options and measures. In other instances, state actions have resulted in a mosaic of policy inconsistencies that inhibit the creation of national markets for clean energy technologies. In this case, federal intervention can rationalize policy inconsistencies and prevent a race to the bottom whereby local jurisdictions and state agencies promulgate lax regulations in order to successfully compete for new industrial plants (Sovacool and Brown, 2009a; Stewart, 1976-1977). Clarity must be provided with respect to specificity and appropriateness of the federal role.
- **Broad applicability**. The small number of options selected for analysis should have broad applicability across the national scene, encouraging action at a fairly comprehensive scale with large energy savings.
- **Significant potential benefits**. Policy options and measures with significant and early quantitative benefits are to be favored over those with later and fewer benefits. The principal benefit of interest is carbon dioxide emission reductions through improvements in industrial energy efficiency. In addition, the value of avoided local pollutant damages are also monetized. In addition, other benefits are enumerated and considered, consistent with OMB circular A-4, which states that in regulatory policy analysis all benefits (and costs) must be considered, including monetized, quantified but not monetized benefits, and qualitative benefits.[12] Omitting potentially important benefit categories from consideration may lead to inefficient policies and misallocation of social resources.

  For policy impacts that were difficult to quantify and monetize, such as the productivity impacts of energy-efficiency upgrades and the possibility of job losses or gains, we provided at least an estimate of its directional influence on the policy's potential benefits.

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[12] http://www.whitehouse.gov/omb/circulars_a004_a-4/#e

- **Technology readiness**. The policy options and measures selected should address barriers and/or risks of mainly an institutional, policy, or non-technical nature. The solutions to some non-technical barriers, such as lack of enablers, may reside in the technological arena, but the barrier itself should not be seen primarily as a technology R&D limitation.
- **Cost effectiveness.** Two perspectives comprise the cost-effectiveness evaluation.

  From the industrialists' perspective, we evaluate whether or not participation in a policy or program would result in cost savings to a manufacturer or industrial firm. In the analysis, both costs and benefits must be weighed. In the selection of policy options to study, consideration should be limited to those that would be expected to have reasonable costs, a strong economic and social benefit, and a relatively high benefit-to-cost ratio. A detailed financial analysis of each policy is not feasible; however, assessing the up-front private-sector investment costs relative to the stream of energy-expenditure reductions provides a basis for approximating the overall cash-flow attractiveness of the policy to industrialists. For this analysis, we discount the stream of future costs and benefits using a 7% discount rate. This is lower than the discount rate often used in evaluating private-sector investments, such as the 10% discount rated used by McKinsey & Company (Granade, et al., 2009), but it provides consistency with the sensitivity analysis described below.

  From society's perspective, we assess net societal benefits and total social benefits-to-cost ratios as alternative perspectives for evaluating emissions reduction policies. Among the benefits, we quantify the value of energy savings, the social cost of carbon, and avoided damages from air pollution. Among the costs, we quantify the private sector investment, the public sector investment, and the public administrative costs. We use a 3% real discount rate as our main assumption, and also use a 7% real discount rate as a sensitivity; these are the two discount rates recommended in OMB Circular A-4. We chose to use the 3% rate as our principal metric because our cost-effectiveness policy evaluation criterion calls for a societal perspective.

  Cost effectiveness also involves assessing the overall public costs of each policy and the ability of these public investments to leverage energy savings and carbon dioxide emission reductions. The focus on overall government costs is particularly important given current concerns regarding public deficits and the desire to constrain government spending. In addition we estimate the extent of government leveraging by calculating the ratio of public costs to the TBtu of energy saved and the ratio of public costs to metric tons of avoided CO_2.
- **Administrative feasibility**. For policy options to be implemented, they need to be capable of being fairly easily established and, if necessary, managed and/or enforced. Some may require special training or expertise, broadly applied across the nation. Other approaches can be focused on a limited set of players in the delivery system. Some policies require the creation of entirely new program operations, while other policies can be implemented by expanding the responsibilities and capacity of existing programs. Such implementation factors are considered here

- **Additionality**. If an energy-efficiency investment would not have occurred without the implementation of a particular policy or program, then the activity can be considered "additional." Each policy option is evaluated in terms of the independent contribution it could make above and beyond the influences of existing policies. To maximize the additionality of a portfolio of policy options, the options should be diverse, such that each option represents a somewhat different approach to a barrier or to different market segments.

  Additionality is most likely when a project investment is not profitable without a federal subsidy, when the prospect of subsidies raises the expected return to an adequate level, when the project owner lacks access to the capital required to make an investment, and when there are other barriers to implementation such as technical uncertainty and regulations that the policy can overcome.

  Because the exact magnitude of "additionality" of each policy is difficult to estimate, we used a range of assumed policy penetration rates and timelines of policy adoption, as a means of examining the sensitivity of results to alternative additionality assumptions.

- **Potential for rapid implementation**. Preference should be given to policies that can deliver benefits rapidly.

A summary of the workshop's discussion of policy options is provided in Appendix A. The workshop elicited six important themes that could be developed into policy options.

1. Industrial plants as power plants
2. Benchmarking of energy and CO_2 intensity
3. "Set-point"-driven technology deployment
4. Market-determined price for carbon
5. Revenue-side (vs. tax-side) incentives for clean energy
6. Industrial clean energy tax lien financing

Following the workshop, brief assessments of 12 policy options were prepared focusing on the seven criteria. The selection process involved ranking each policy on a scale of one to three on each of the eight evaluation criteria. In order not to over-presume its scientific validity of these rankings, they are not reported here. Nevertheless, the assessments led to a preferred short list of seven policies that the DOE, ORNL, and Georgia Tech team members evaluated most favorably (Box 1). Two of these policy options address inadequate regulations, three tackle information and training barriers, and two are designed to help overcome financial obstacles. The five policy options that were set aside during the final selection process were judged to be potentially meritorious, but not as strong as the seven others. They include the following:

- Update the IRS capital depreciation schedule
- Decouple utility profits from sales

- Promote ESCO financing of industrial energy efficiency
- On-bill financing of industrial energy-efficiency upgrades
- Lifecycle CO_2-equivalent labeling of industrial goods

Each of the remaining policies was examined in white papers, which comprise Chapters 2 through 4 of this report.

These seven policies are consistent with the workshop's policy themes. OBES and EPS with CHP are consistent with the view that policy options could transition at least some industrial plants into power plants. SEP emphasizes the role of benchmarking. Motor rebates are consistent with the focus on revenue-side incentives versus tax-side incentives for clean energy. Both SEP and EPS with CHP are consistent with developing a market-determined price for carbon, by emphasizing that energy-efficiency improvements be integrated into new markets for energy-efficiency credits. Tax-lien financing is a policy that directly addresses the workshop participants' priorities for new federal policy initiatives.

Box 1. Policy Options to Promote Industrial Energy Efficiency

• Overcoming Inadequate Regulations

–Output-Based Emissions Standards (OBES): Provide financial incentives and technical assistance to states to spur adoption of output-based emissions standards (as authorized by EPA) to reduce, primarily via expanded deployment of CHP, energy consumption, emissions of criteria air pollutants and GHG, and regulatory burden. Using authorities under DOE's State Energy Program, no new federal legislation would be required.

–Federal Energy Portfolio Standard (EPS) with Combined Heat and Power: Promulgate federal legislation requiring electric distributors to meet an EPS that includes CHP as an eligible resource; concurrently establish measurement and verification methods for qualifying CHP resources and to encourage a national market for trading energy-efficiency credits.

• Overcoming Information and Training Barriers

–Superior Energy Performance Program (SEP): Establish incentives for the adoption of SEP program such as energy-efficiency credits for compliance with energy portfolio requirements, grants to subsidize required training and eligible adoption costs, and recognition programs.

–Implementation Support Services (ISS): Appropriate necessary funding to create and fund ISS in addition to increasing the current funding level for the DOE Industrial Assessment Center (IAC) program, which would manage these new services.

–Small Firm Energy Management (SFEM): Authorize and appropriate funding for DOE to implement a program to provide small manufacturing firms (five to 49 employees) with energy management software tools to build in-house capacity to manage energy use and identify potential energy savings opportunities, and potentially qualify small firms be part of IAC assessments.

• Overcoming Financial Barriers

–Tax Lien Financing: Pass Federal enabling legislation to allow municipalities to establish clean energy taxation districts, which can issue tax-free bonds for certified energy-efficiency and alternative energy projects. Have DOE offer federal loan guarantees to provide security for the bond purchasers and provide a standardized format for the application process.

–Motor Rebates: Authorize and appropriate funding for DOE to provide industrial firms with rebates to replace large pre-EPAct motors with certified high-efficiency motors, and provide additional incentives to manufacturers of efficient motors. Give priority and additional technical assistance to companies that include motor upgrades as part of a system-wide optimization of their facilities.

1.5.2 Spreadsheet and GT-NEMS Analysis of Policy Options

Many different approaches have been used to quantitatively evaluate energy and climate policy options in the U.S. They are often classified as either "bottom-up" or "top-down."[13] Our preferred approach was to use a version of the National Energy Modeling System (NEMS) – a multi-regional general equilibrium model that is a hybrid of these two approaches – referred to as

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[13] Supply curves of energy savings and carbon mitigation opportunities are an example of a "bottom up approach." They provide a means of identifying least-cost technology investments (Granade et al., 2009); however, they do not fully account for cross-sector influences and price feedback effects. "Top-down" approaches use macroeconomic models to identify the response of markets to changes in energy prices. They typically do not offer the degree of technology specificity needed to understand how markets are responding.

"GT-NEMS" (GT is short for the Georgia Institute of Technology). Our goal was to model all of the policies together in a single assessment, thereby enabling the consideration of synergies and competing effects.

After experimentation with GT-NEMS as the basis for evaluating each of the seven policy options, we concluded that the modeling tool was only able to accurately evaluate two of the seven policies. (See Appendix A for further details on the attempted GT-NEMS analyses.) The following section provides an overview of the spreadsheet analysis used to model five policy options and the GT-NEMS methodology used to evaluate two policies.

The following general assumptions underpin the assessments of each of the seven industrial efficiency policy options. Further details about the analysis of each policy is provided in a series of appendices. Appendix A expands on several aspects of the overall analysis approach.

Baseline energy assumptions. The baseline energy consumption is drawn from the *Annual Energy Outlook 2010* (EIA, 2010), which forecasts that industrial energy consumption will increase from 32.07 quads in 2008 to 33.71 quads in 2035. In a few cases, the baseline forecast only included manufacturing energy and excludes, for instance, agriculture and construction. The coverage of each analysis is dictated by available data and is explained in the following chapters.

If industry were to maintain a constant rate of energy consumption per dollar value of shipment (that is, a constant unit energy consumption or energy intensity), industrial energy consumption in the U.S. would instead grow to 46.17 quads by 2035. Because manufacturing output from non-energy-intensive manufacturing sectors is expected to grow at twice the rate of output from energy-intensive manufacturing, the anticipated energy consumption in 2035 is significantly lower. Specifically, 82% of the difference between the straight-line projection based on a constant energy intensity and the forecast consumption of 33.7 quads is attributed to such "structural effects" from changes in the composition of American industry (Figure 1.8).[14]

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[14] The definition and measurement of structural change in industry and other sectors of the economy is described in an EIA website (http://www.eia.doe.gov/oiaf/aeo/intensity_trends.html). It concludes that among the factors impacting energy use in the U.S. between 1990 and 2006, the "End-Use Energy Intensity Effect" contributed more than the structural effect. However, according to the EIA website, structural change will dominate going forward to 2035 (at 76%).

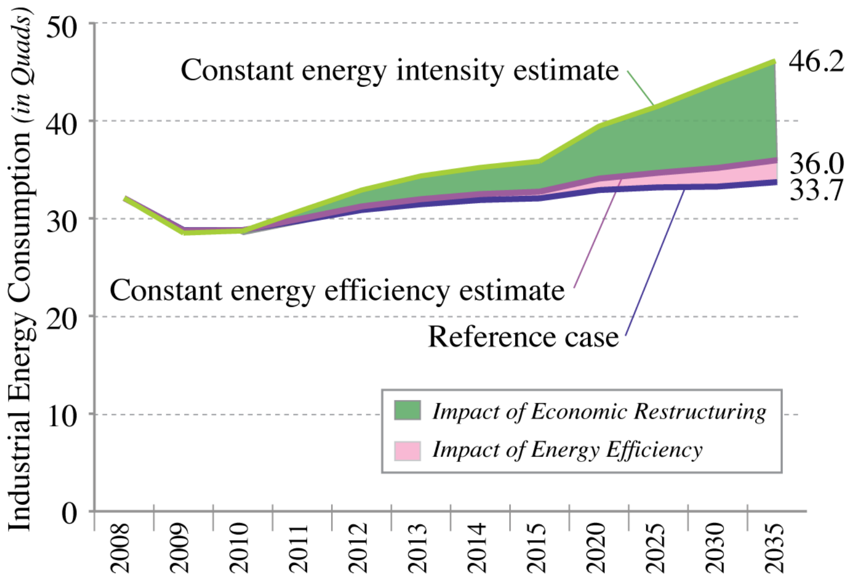

Figure 1.8. Structural and Efficiency Effects on Primary Energy Consumption in the *AEO 2010* Reference Case (Quads)

Source: Derived from http://www.eia.doe.gov/oiaf/aeo/intensity_trends.html

Improvements in energy efficiency account for the remaining 18% reduction in energy intensity. That is, energy efficiency is assumed to bring about a 6.2% decline in energy consumption from 2008 to 2035.[15] This corresponds to a 0.24% annual rate of decrease of industrial energy consumption that is captured in the EIA baseline. In assessing the potential impacts of policies on industrial energy use, this “endogenous” energy efficiency is considered.

The expanded use of combined heat and power (CHP) accounts for a portion of this endogenous energy-efficiency improvement. Between 2008 and 2035, CHP is projected to experience a 2.9% annual growth rate in capacity (expanding from 26 to 56 GW), and a 3.7% annual growth rate in generation expanding from 137 to 363 billion kWh) (EIA, 2010, Table A6).

Energy prices. The reference case forecast of industrial energy prices from the *AEO 2010* (EIA, 2010) provides the baseline for our policy analysis. For the two policies that are evaluated with GT-NEMS, energy price interactions can be captured and alternative energy price trajectories result. For the remaining five policies, we are not able to adjust energy prices to account for energy price interactions, as when significant levels of improved efficiency cause energy prices to drop, thereby causing a “rebound” effect that encourages additional energy

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[15] The reference unit energy consumption (UEC) in 2008 is 5.93 and in 2035 it is 4.33. Energy consumption of the industrial sector was 32.07 quads in 2008 and is projected to increase to 33.71 quads in 2035. With a constant UEC, industrial energy consumption in the U.S. would grow to 46.165 by 2035. 18% of this difference (25.17-33.71) is 2.24 quads. This represents the quantity of endogenous energy efficiency assumed to occur in the year 2035, bringing energy consumption down from what would otherwise be 35.95 quads in that year (33.71 + 2.24 quads).

consumption. Since evidence of a significant rebound effect is weak, the omission of this interaction term is not considered problematic.[16]

Carbon dioxide emissions. The carbon emissions associated with energy consumption are derived from EPA (2007a) and the *AEO 2010* (EIA, 2010). EIA (2010) estimates the industrial fuel consumption by source for each year between 2008 and 2035. It also forecasts the changing grid mix over time based on the energy resources used for electricity generation each year. Over time, the electric fuel mix becomes slightly less carbon intensive. We assume the same trajectory of industrial fuel and electric grid mix over time. Using the conversion factors reported in EPA (2007a), we derive the million metric tons of CO_2 emitted per quad of industrial energy consumption.

Where a policy is anticipated to promote energy efficiency across all fuels (as with EPS program), the industry sector average emissions factor was used. When a policy was more targeted to particular fuels (as with the industrial motor rebates, which only conserve electricity), conversion factors were based on the carbon intensity of individual fuels (Table 1.2). For the five policies evaluated with a spreadsheet analysis, the electricity saved is expected to have an average fuel mix, and is not based on reduced peak loads.

Table 1.2. Conversion of Energy Consumption to Carbon Dioxide Emissions

	Million Metric Tons of CO_2 Emitted per Quad of Energy Consumption		
	2008	**2020**	**2035**
Industry Sector Average	49.55	48.33	46.71
Residual Fuel (No. 5 & 6 Fuel Oil)	77.64	77.64	77.64
Natural Gas (Pipeline)	52.27	52.27	52.27
Bituminous Coal	91.65	91.65	91.65
Electricity	58.70	53.99	54.77

Sources: Derived from EPA (2007a) and EIA (2010)

We estimate the financial value of reduced CO_2 emissions in a particular year by multiplying the decrement in emissions by the “social cost of carbon” (SCC) for that year. The SCC is defined as an estimate of the monetized damages associated with an incremental increase in carbon emissions in a given year. It is intended to include (but is not limited to) changes in net agricultural productivity, human health, property damages from increased flood risk, and the value of ecosystem services due to climate change.

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[16] Economy wide evidence for the rebound effect has not been observed (Owen, 2010). Even though historical evidence shows efficiency improvements along with increased energy consumption and economic activity, the causal links between these variables are still unclear (Sorrell, 2009). Over the last 40 years, the energy to GDP ratio for the world has declined steadily, suggesting that economic growth can occur without a corresponding increase in energy consumption (Cullenward et al., 2010).

The SCC used in this analysis is based on the central value estimates of the U.S. Government Interagency Working Group on the Social Cost of Carbon (EPA, 2010a). In this report, the central value SCC estimates ranged from $23/metric ton of CO_2 in 2011 to $34/metric ton and $47/metric ton in 2030 and 2050, respectively (all values are in 2008 dollars [$2008]). Appendix A provides a more detailed description of the derivation of the SCC of CO_2.[17]

Emissions of criteria air pollutants. A recent report from the National Research Council (NRC, 2010) examined the damages of pollution from energy production and consumption in the U.S. The report estimated that pollution damages totaled $120 billion in 2005, excluding damages from climate change, effects of mercury, impacts on ecosystems, and other difficult-to-monetize damages. The total costs are dominated by human health damages from air pollution associated with electricity generation and vehicle transportation. Also included in the estimates are damages sustained by grain crops and timber yields, buildings, and recreation. Altogether, non-climate damages from coal power plants are estimated to exceed $62 billion annually. These damages average 3.3 cents per kWh in $2008 (NRC, 2010).

Natural gas use in the industrial sector also generates significant human health and environmental externalities when combusted to produce heat. NO_x emissions are particularly high. In contrast, natural gas used for industrial feedstocks (as in the chemicals industry) have much lower NO_x emissions. The NRC report (2010, p. 172) concludes that “a very rough order of magnitude estimate of average externalities associated with the industrial sector usage of natural gas is therefore 18 cents/MCF, excluding GHG damages. Thus, the six quads of natural gas used for industrial heat would generate about $4,600 million in damage.” See Table 1.3 for a summary of the air pollutant damages associated with emissions from electricity generation and industrial heat production. Appendix A provides a more detailed description of the cost of avoided criteria air pollutants.

There is a great deal of regional heterogeneity in benefits per ton of emissions reduction, as emphasized by Fann and Wesson (2011). The three reasons for this are:

- heterogeneity in the emissions profile of electricity generation
- heterogeneity in meteorological conditions that affect the conversion of emissions to ambient concentrations of certain air pollutants (e.g., $PM_{2.5}$)
- heterogeneity in the distribution of populations relative to pollution sources

While we recognize that using a national average benefit from NRC (2010) is not ideal, the implication is likely to be an underestimation of actual human health benefits, since energy-intensive industries tend to be located in the midwest and south, two regions with greater-than-average coal use for power production. (See Chapter 5 for a discussion of the geographic distribution of industrial activity in the United States.)

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[17] Interestingly, these SCC values are similar to the allowance price projections estimated by the EIA (2009b) in its analysis of the American Clean Energy and Security Act of 2009. While the Bill is not longer being debated, EIA’s estimates of CO_2 mitigation costs based on the proposed cap and trade system start at $17 per ton of CO_2 (2008 dollars) in 2012, growing at 7% annually, and reaching $78 per ton in 2035.

In contrast, the avoidance of environmental damages that contribute to the high societal benefit-cost ratios of these seven policies could be overstated if EPA regulations are tightened over the next several decades and if a price is put on the cost of carbon. Putting a price on GHG emissions and more fully reflecting the cost of local pollutants not yet captured by existing regulations would provide additional incentives for expanded investments in industrial energy efficiency. Under those circumstances, the additional value provided by these seven policies would be more limited because more pollution reduction would take place in the absence of stronger incentives and enabling policies.

Table 1.3. Criteria Air Pollutant Damages Associated with Emissions from Electricity Generation and Industrial Heat Production ($2008)*

	NO_x	**SO_2**	**PM_{10}**	**$PM_{2.5}$**	**Total (Equally weighted across plants)**	**Total (Weighted by net generation of plants)**
Natural gas for electricity (¢/kWh)	0.239	0.019	0.009	0.176	0.447	0.166
Coal for electricity (¢/kWh)	0.353	3.946	0.018	0.312	4.569	3.323
Natural gas for industrial heat (¢/MCF)	16.25	0.375	N/A	1.375	18.0	N/A
Petroleum for industrial heat	N/A	N/A	N/A	N/A	N/A	N/A
Coal for industrial heat	N/A	N/A	N/A	N/A	N/A	N/A

*N/A = not available. Excludes avoided pollutant damages from petroleum and coal for industrial heat.
Source: National Research Council (2010), Tables 2-9, 2-15, and 4-4 (inflated to $2008).

The two policy options that are evaluated by NEMS benefit from the inclusion of some environmental regulations in its modeling framework. The *AEO 2010* reference case assumes that the long-term reduction goals of the Clean Air Interstate Rule (CAIR) will be met through the existing cap-and-trade system specified in the current rule. Thus, reduced levels of SO_2 and NO_x over time are built into the reference case (with SO_2 emissions capped at 2.5 million metric tons and NO_x emissions at 1.3 million metric tons in the affected 28 States). Any electricity rate impacts of CAIR are presumably also incorporated into the NEMS price forecasts.

On the other hand, the Clean Air Mercury Rule (CAMR), which was to set up as a cap-and-trade system for reducing mercury emissions by approximately 70%, is not represented in the *AEO2010* projections, because the ruling was "vacated" by the DC Circuit Court in February 2008. Our analysis also does not include the potential impact of a rule proposed by EPA in March, 2011, to reduce emissions of mercury and many other hazardous air pollutants from power plants and industrial sources (EPA, 2011). There is also no consideration of the utility and boiler Maximum Achievable Control Technology (MACT) rule in the NEMS modeling. If these EPA regulations are enacted over the next three to five years, our monetization of emission-reduction benefits from these seven policies may be overstated, but it is difficult to estimate the magnitude of such a potential bias.

At the same time, the benefits from reduced externalities calculated for these seven policies may be understated because they exclude land and water impacts, and only partially incorporate air impacts. Some of the policy options, particularly those focused on CHP, result in reducing the importance of coal from the *AEO 2010* reference case. Surface mining for coal leads to irreparable ecosystem damage (Bernhardt and Palmer, 2011), such as loss of topsoil (Negley and Eshleman, 2006), increased propensity for flooding (McCormick et al, 2009), declining water quality (Hartman et al, 2005), and biodiversity loss (Pond et al, 2008; Sams and Beer, 2000). Human health impacts, such as increased selenium levels from eating contaminated fish and elevated exposure to dust and particulates from mining operations, which lead to increased hospitalizations (Palmer et al 2010), are left out of our analysis. All policy options in this report would reduce damages associated with transmission and distribution (Sovacool, 2008; U.S. Office of Technology Assessment, 1993), also not quantified but acknowledged as an additional benefit.

Timeline of energy-efficiency policies. All of the policy options are assumed to be implemented in 2011. Investments in the policies end in various years between 2015 and 2035, depending on the policy. The Industrial Motor Rebate, for instance, is assumed to operate for only five years, while the EPS remains in place through 2035. Energy-efficient technologies are assumed to operate and produce energy savings for 20 years, but their savings are assumed to degrade at 5% annually. This assumption is consistent with the literature on the longevity of energy savings (Brown et al., 1996). Thus, for example, investments made in 2035 are expected to save the most energy in that year, declining in a straight-line trajectory to 2055, the last year when energy savings are anticipated. The savings between 2035 and 2055 are added "externally" to the energy savings estimates produced by NEMS, which end in 2035.

Discount rates. Our analysis uses $2008 dollars for all of its financial analyses. Benefits and costs are adjusted for the time value of money, so that all flows of estimated benefits and costs from implementing a new policy over time are expressed on a common basis in terms of their "present value." How this is done is particularly important in evaluating investments in energy efficiency and GHG mitigation, because costs tend to occur up front, while benefits occur at subsequent points in time.

To calculate present values, each future cost and benefit is discounted to reflect the opportunity cost of capital, which is a function of how much the capital would have earned if invested elsewhere, or how much interest would have been paid to borrow money, including any risk premium. Risk premiums are the extra return investors demand because they want to account for the risk that the cash flow or future stream of environmental benefits might not materialize.

The OMB Circular No. A-94 (OMB, 2002) includes "Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs." It provides the following guidance about the use of discount rates.

> **"Discount Rate Policy**. In order to compute net present value, it is necessary to discount future benefits and costs. This discounting reflects the time value of money. Benefits and costs are worth more if they are experienced sooner. All future benefits and costs, including nonmonetized benefits and costs, should be discounted. The higher the discount rate, the lower is the present value of future cash flows. For typical investments, with costs concentrated in early periods and benefits following in later periods, raising the discount rate tends to reduce the net present value." [18]

Similarly, 2003 OMB Circular A-4 states that that "analyses should show the sensitivity of the discounted net present value and other outcomes to variations in the discount rate." It further suggests the use of 3% discount rates for regulatory policy analysis, with 7% to be used in sensitivity analyses. For further discussion of the role of discount rates in computing the cost of carbon dioxide, see Aldy et al. (2009) and EPA (2010a).

When modeling the cost-effectiveness of investments by the private sector, higher discount rates are typically used. For instance, McKinsey and Company (Granade et al., 2009) used a 7% real discount rates and characterized carbon abatement supply curves using a minimum of a 10% real internal rate of return. In modeling the investment choices of industry, it is often assumed that capital rationing drives internal hurdle rates much higher. However, with broader access to capital through various public policy levers, lower rates can be justified.

Data sources. The databases from the Save Energy Now (SEN) and IAC Programs are key sources of information for the spreadsheet analysis of the SFEM program and the ISS. We analyzed the results of IAC assessments conducted from 2002 through the first quarter in 2010, and three years of SEN data. Assessments were clustered by three-digit North American Industry Classification System (NAICS) codes. We did not simply use nationwide results for each NAICS code category. Rather, we considered the geographic uniqueness of different industries with respect to their energy savings potential. That is, we recognized that the energy savings potential of a food processor in Georgia would be distinct from the energy savings potential of a food processor in Oregon.

As a result, we evaluated the results of the IAC assessments for each state and its surrounding states. Then we projected the results to the population of firms in that state by NAICS code. That required using U.S. Department of Commerce data for each state and NAICS code. This information is stratified by size of firm based on employment and not energy consumption. Thus we had to convert information between energy consumption and employment, which we evaluated by also referring to value of shipments. This geographically refined approach is analytically rigorous and unique.

Data internal to NEMS are critical to the analysis of OBES and the EPS with CHP. This modeling system reflects the geographic variability of nine Census Districts. Additional data

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[18] http://www.whitehouse.gov/omb/circulars_a094_a94_appx-c/

sources are used in the analysis of the other policies, as detailed in the policy option white papers.

Geographic analysis. Table 1.4 shows the geographic distribution of industrial energy use by region. The South has the greatest share of industrial energy use, followed by the Midwest. At the state level, Texas and Louisiana in the South Census Region have the highest levels of industrial energy consumption. California has the third most consumption in this sector, but it is a smaller percentage than its share of total national energy use in all sectors. Ohio and Indiana in the Midwest are also in the top five states for industrial energy consumption (EIA, 2010). These states and regions with large industrial energy consumption would likely be the major target market and beneficiaries of the policy options discussed in this report.

Table 1.4. Share of Industrial Energy Use by Census Region

Census Region	Industrial Energy Use in Quads in 2008	Share of U.S. Industry Total Energy Use	Share of U.S. Total Energy Use for All Sectors
Northeast	2.63	8.4%	14.1%
Midwest	7.99	25.5%	23.9%
South	15.55	49.6%	42.7%
West	5.13	16.4%	19.4%

Source: EIA, 2010

Market penetration. Rates of diffusion of technology into the marketplace are based on several different approaches, depending on the policy being modeled. For example, the SEP program is modeled using logistic diffusion rates (in particular, based on ISO 9000 and ISO 1400 Certificates Worldwide). The rate of CHP adoption resulting from state implementation of Output-Based Emissions Standards is estimated using a multivariate statistical analysis of past CHP penetration. The adoption of CHP from EPS with an Investment Tax Credit is based on the economics of competing investments modeled in GT-NEMS.

The policy options target different populations for participation, for instance, small or medium firms, the population of industrial electric motors, and large facilities. Market penetration is expressed relative to the facilities that the policy could affect. Each of the chapters describes the specific market penetration assumptions in further detail.

Free riders and spillovers. Assessing the causal link between implementation of a public policy and the resulting investments in energy efficiency is a critical step in policy evaluation. In some instances, a business may be a “free rider” because it would have installed the same energy-efficiency measures at the same time whether or not the policy existed. In other instances a company may be a partial or deferred free rider because they would have installed less-efficient measures or would have installed them at a later time. In some situations, a business is not at all a free rider because it would not have installed the energy-efficiency measure without the influence of the program (NAPEE, 2007a, b). The existence of free riders reduces the estimation of energy savings that might otherwise be attributed to an energy-efficiency policy or program.

On the other hand, spillover effects can expand the influence of policy beyond participants by transforming markets for energy efficiency. Spillover occurs when there are reductions in energy-efficiency consumption or demand caused by the presence of the energy-efficiency program, but which the program does not directly influence. Business investments stemming from participation in programs are a positive program spillover, increasing the program effect. Such effects can result from:

- Additional energy-efficiency actions that program participants take outside the program as a result of having participated, as when a multi-national corporation replicates technology improvements throughout its facilities. These actions that go beyond those directly subsidized or required by a policy.
- Changes in the array of energy-using equipment that manufacturers, dealers, and contractors offer all customers as a result of program availability.
- Changes in specification practices employed by contractors.
- Savings from efficiency projects implemented by those who did not directly participate in a program, but that nonetheless occurred due to the influence of the program. Such investments could come about, for instance, as a result of the diffusion of information from participants to the rest of an industry

Quantifying spillover effects can be challenging, which is why they often are not included in evaluations of policy cost-effectiveness. The result is an underestimation of policy benefits. We consider both free riders and spillover effects in conjunction with each of our seven policies (Table 1.5).

Three of the policies do not benefit free riders, while the ratios vary from 5% to 30% for 2030 for the other four options. In quantifying the overall benefits of the policy options in this report, we exclude the energy-efficiency upgrades of free-rider firms, since they would have made the improvement regardless of the regulations and incentives. We also exclude the market transformation effects of these policies, which occur when nonparticipants (firms that do not receive subsidies or assistance) nonetheless increase their investment in energy efficiency because of positive signals in the marketplace, such as more widespread availability of high-efficiency products and services. Alternative free-rider participation rates and market transformation assumptions were not tested in our sensitivity analyses, but such review would be a valuable next step.

Table 1.5. Free-Rider Ratios and Rationales by Policy

Policy	Free-Rider Ratio	Rationale
Output Based Emissions Standards	N/A	Regulatory policy funded through private investment.
Energy Portfolio Standards	50% (2020) 30% (2030)	Free riders implemented relevant efficiencies in the reference case modeling (difference between policy and baseline scenarios in NEMS analysis).
Superior Energy Performance Program	5%	Based on historical adoption rates, 5% of facilities would choose to qualify for SEP certification without the policy.
Small Firm Energy Management	N/A	Small firms would not make energy-efficiency improvements without education and training.
Implementation Support Services	N/A	Firms would not make the upgrades without the energy audits from this policy.
Tax-Lien Financing	10%	Upgrades would occur in 10% of facilities without PACE implementation.
Industrial Motor Rebates	20%	Advertising alone (without financial incentives) has historically led to 20% market share for certified efficient motors.

1.6 Treatment of Uncertainty and Risk

The inherent uncertainties involved in policy assessments are daunting. Assumptions embodied in the baseline forecast illustrate the extent of uncertainties impacting the results of policy analysis. We use the *AEO 2010* baseline forecast as a starting point for analyzing each of the seven policy options. As recognized by EIA (2009b, p. xv), these projections of energy markets over a 25-year period “are highly uncertain and subject to many events that cannot be foreseen, such as supply disruptions, policy changes, and technological breakthroughs. In addition to these phenomena, long-term trends in technology development, demographics, economic growth, and energy resources can evolve along a different path than expected in the projections.” Additional unknowns surround the assumptions made about responses to the introduction of new policies.

Recognizing the high level of uncertainty and risk suggests that ranges of assumptions and possible outcomes should be explicitly treated.[19] Such approaches are particularly useful when:

- there is uncertainty about the outcomes of a policy (e.g., how will companies respond to financial incentives?)

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[19] A full analysis of uncertainty would involve the development of spider plots or tornado diagrams comparing base case values with ranges of alternatives (Eschenbach, 2006; Lavingia, 2005).

- there is uncertainty about the benefits of an outcome (e.g., what is the social costs of carbon dioxide and will it be regulated in the future?)
- alternative policy designs are possible (e.g., what level and duration of subsidy is most effective, or is the provision of information and training preferable and sufficient?)
- stakeholders have different priorities (e.g., how do we treat trade-offs between social goals and private financial accounting?)
- there is disagreement about policy evaluation criteria (e.g., at what rate should we discount future benefits and which benefits are to be given priority?)

We rely on sensitivity analysis to provide a plausible range of results. For example, we evaluate an EPS supported by an investment tax credit that operates for 25 years (in the principal policy) but consider a 10-year duration in a sensitivity analysis. In addition, we evaluate the difference between assuming a rate of penetration of 60% versus 40% of recommended measures by participants in the SFEM program. We also use alternative discount rates, and we calculate benefit/cost ratios from different perspectives with and without public costs and with and without the inclusion of benefits from reduced carbon dioxide and criteria pollutants. Finally, we discuss a range of other uncertainties in terms of the directional influence they might have on our benefit-cost analysis. Our examination of uncertainties and the robustness of our policy analysis is furthered by using multiple discount rates, examining costs and benefits from both a private and societal perspective, and by considering an array of benefit-cost metrics (e.g., benefit-cost ratios, net societal benefits, and the reduced energy and pollution that could be leveraged by public dollar expenditures).

Table 1.6 summarizes the modeling assumptions for the seven principal policies and the sensitivities examined with respect to industrial market penetration, policy duration, and free ridership.

Table 1.6. Summary of Modeling Assumptions for Principal Policies and Sensitivities: Industrial Market Penetration, Policy Duration, and Free Ridership

Policy	Principal Policy	Sensitivities
Output Based Emissions Standards	5-year adoption of OBES by states, generating accelerated CHP market penetration modeled in GT-NEMS model.	10-year adoption of OBES by states.
Energy Portfolio Standards	Starting with the NEMS default penetration rate of 5%, GT-NEMS estimates future levels of market penetration based on a 25-year 30% ITC and incremental improvements in CHP system efficiencies.	10-Year ITC: subsidies end in 2020.
Superior Energy Performance Program	Logistic adoption curve with a saturation of 40% of all industrial energy consumption (60% of large firms) ultimately participating in SEP program.	20% of all industrial energy consumption (30% of large firms) participate in the SEP program following a logistic adoption curve.
Small Firm Energy Management	Linear participation rate rising to 40% of small firms in top 10 NAICS groups, with 60% rate of penetration of recommended measures.	Same 40% participation rate; rate of penetration is 40% of recommended measures.
Implementation Support Services	Implementation rate increased to 53% from an original rate of 32%; annual IAC assessments increased to 1300 (twice number of assessments completed in 2000).	Implementation rate of 53%; annual IAC assessments increased to 650.
Tax-Lien Financing	5-year adoption period reaching 9% saturation.	5.7% of all industrial firms utilize tax-lien financing.
Industrial Motor Rebates	1% of all industrial motors are replaced using rebates for purchasing certified high-efficiency motors of 25 to 500 horsepower that replace pre-EPACT-92 motors. A 5-year acceleration of purchase is assumed.	Same penetration rate, but a 10-year acceleration is assumed.

2 POLICY OPTIONS TO ADDRESS REGULATORY BARRIERS

As with many energy-efficiency technologies, numerous barriers stall the market penetration of combined heat and power systems (CCCSTI, 2009). The following two sections present policies that would address some of these barriers: Section 2.1 discusses an output-based emissions standard that would tackle a regulatory barrier, and Section 2.2 discusses an energy portfolio standard, combined with an investment tax credit, targeted at promoting new CHP installations.

Combined heat and power (CHP) refers to a group of technologies that concurrently produce electricity and useful thermal energy from a single integrated system. It is a type of distributed generation that recycles otherwise-wasted energy and produces it more efficiently than separate heat and power systems. A traditional system separately producing heat and power operates at 45% to 49% efficiency, while a CHP system can be 75% to 80% efficient (Figure 2.1).

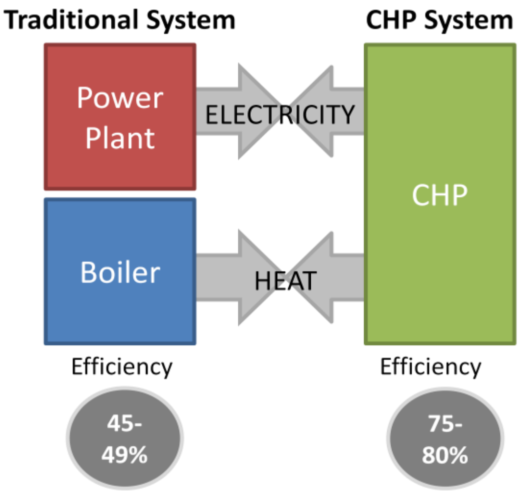

Figure 2.1. CHP Process Flow Diagram

Sources: EPA Fact Sheet: http://www.epa.gov/chp/state-policy/obr_factsheet.html and Shipley et al. (2008)

CHP systems in the commercial, industrial, and residential sectors are typically fueled by natural gas, representing about 68% of the CHP installations in the U.S. Within the industrial sector, the percentage of CHP systems using natural gas is similar, at 66% of total installations (ICF, 2009). Many fuel types and waste energy systems can be used in CHP systems, including biomass, oil, coal, hot exhaust gases, and high pressure steam and gas (this is not an exhaustive list). Various technologies are also employed in CHP systems, like reciprocating engines and boiler steam turbines. There is a large potential for CHP to increase industrial energy efficiency and reduce industrial emissions of CO_2 and criteria pollutants, as the following sections and a great deal of literature show (Brown et al., 2001; Shipley et al., 2008; Granade et al., 2009).

Despite the apparent economic attractiveness of CHP, the technology is penetrating the market at a slow pace. As briefly mentioned previously, much of this is the result of regulatory, financial, and workforce barriers. Broadly defined, regulatory barriers impose significantly on CHP – these include government regulatory policies, such as input-based emissions standards and the Sarbanes-Oxley Act of 2002, but also utility regulatory power and grid access difficulties. Interconnection standards and net metering opportunities are examples (Shirley, 2005; Brooks, Elswick, and Elliott, 2006; Brown and Chandler, 2008). Numerous studies identify financial barriers, including access to credit and project competition, as key issues blocking the diffusion and implementation of new technologies like CHP across firms and industries (Canepa and Stoneman, 2005; Rohdin, Thollander, and Solding, 2006; Worrell, et al 2001). Lastly, adopting a new technology like CHP without a trained workforce and adequate engineering know-how increases the perceived risk to managers, lessening technology transfer and deployment (Bozeman, 2000; Worrell et al, 2001). The final report of the Committee on Climate Change Science and Technology Integration (2009) and Granade, et al (2009) provide more comprehensive views of barriers and opportunities for the interested reader.

2.1 Output-Based Emissions Standards (OBES)

Policy Option: Provide financial incentives and technical assistance to states to spur adoption of output-based emissions standards (as authorized by the Environmental Protection Agency) to reduce energy consumption, emissions of criteria air pollutants and greenhouse gases, and regulatory burden primarily via expanded deployment of combined heat and power (CHP). Using authorities under DOE's State Energy Program, no new federal legislation would be required, although a broad array of other efforts could assist CHP implementation.

2.1.1 Policy Summary

CHP provides thermal and electric energy more efficiently than stand-alone systems, with gains of up to 35% (Shipley et al., 2008). Expanded deployment of CHP and similar industrial energy-efficiency technologies could be enabled with the adoption of OBES. The approval of such standards already exists at the federal level; however, adoption at the state level has been slow. As a result, this policy option remains underutilized and opportunities for increased industrial energy efficiency are foregone. Incentivizing the adoption of OBES by the states could enable efficiency gains nationally.

As this policy option focuses on operations requiring air permits, it is anticipated that adopting this policy will largely benefit the industrial sector and those regions of the country that have failed to meet air quality standards and are in "non-attainment." Potential incentives for adopting OBES may be tied to expanded efficiency allowances in a renewable energy standard (RES) for demonstrated savings or as a selection criterion for competitively funded projects of the DOE State Energy Program. DOE could drive more efficient technologies into the industrial sector by creating these incentives to assist in changing the regulatory framework where the EPA has struggled.

The approach involves the following elements:

- Direct the State Energy Program to include the option of OBES as a criterion for evaluating grant applications.
- Provide assistance to the states in establishing output-based emission standards through interaction and materials like the *Output-Based Regulations: A Handbook for Air Regulators* (EPA, 2004) and training programs related to air permits.
- Adjust incentives and assistance over time to reflect progress with efficient technologies and quality programs implemented by the states.

This comprehensive approach does not currently exist, but could widely expand the usage of OBES throughout the nation. States have been steadily adopting OBES since California's SB 1298 in 2000, but only 17 currently use this approach (Table 2.1). States may be wary to adopt OBES due to the regulatory momentum of input-based emissions standards that have been used since early rulemaking efforts of the Clean Air Act or a lack of awareness of alternatives to traditional regulatory approaches. However, the older regulatory regime does not allow efficiency to compete with other means of reducing pollution (EPA, 2004) (see Figure 2.2 later in this section).

Output-based emissions standards would address some of the regulatory barriers (real and perceived) posed by the Clean Air Act on industry as well as allowing for efficiency-increasing upgrades on industrial sites like CHP or more efficient boilers, which are currently disincentivized by input-based emissions standards. These approaches have historically reduced regulatory burden on industry and decreased emissions (EPA, 2004).

2.1.2 Policy Experience

The EPA has established OBES for a number of industries and pollutants, including iron and steel production and NO_x emissions from boiler units. Pollutants other than NO_x regulated by an output-based emissions standard include mercury, SO_2, PM, VOCs, CO, and CO_2; ammonia has been proposed at least twice as well. Seventeen states have incorporated OBES into their regulatory approaches (EPA, 2008). The implementation of output-based emission standards by the states has been achieved through allowance allocations, allowance set-asides, allowance trading, multi-pollutant regulations, and distributed generation (DG) rules. An allowance allocation program provides permits for pollution. These permits can be allocated by the state, traded, or set-aside for future use, depending on program specifics. Multi-pollutant regulation recognizes that OBES can be effective in achieving net reductions in multiple pollutants. A DG rule creates emissions standards for many types of distributed generation, including CHP. Table 2.1 summarizes the regulatory approach taken by each state with an output-based emissions standard.

Table 2.1. State Output-Based Emissions Standards

	Regulation				
State	**Allowance Allocation**	**Allowance Set-Asides**	**Allowance Trading**	**Multi-Pollutant**	**Small DG Rule**
Arkansas	√				
California					√*
Connecticut	√		√		√*
Delaware					√*
Illinois	√	√			
Indiana	√	√			
Maine					√
Maryland	√	√			
Massachusetts	√	√	√*	√	√
New Hampshire				√	
New Jersey	√	√	√		
New York	√	√			√
Ohio	√	√			
Pennsylvania	√				
Rhode Island					
Texas					√*
Wisconsin	√	√			

*Recognizes CHP

Source: Modified and updated from the EPA CHP Partnership (EPA, 2008)

States have not adopted OBES alone; rather, the standard has always been part of larger regulatory reform. The approaches taken by different states have resulted in different outcomes. California largely delegated implementation to local authorities except for installations over 50 MW and instituted their OBES through legislation. This approach has successfully increased CHP implementation rates throughout the state, which already led the nation in total CHP installations (EPA, 2004; ICF International, 2009).

As Table 2.1 makes clear, California actually has one of the smaller policy packages enabling OBES nationally; Massachusetts, on the other hand, adopted a much more expansive suite of reforms. Some of these came through legislation while the Massachusetts Department of Environmental Protection created others. Much of their design was based on rules proposed by the Regulatory Assistance Project (RAP), an organization that was formed in 1992 by experienced utility regulators, to provide research, analysis, and educational assistance to public officials on electric utility regulation[20] (EPA, 2004; RAP, 2003). While the impact on the number of new CHP installations is uncertain, the average capacity of projects has increased (ICF International, 2009).

Recognizing the multiple energy outputs of CHP is essential to properly characterizing the emissions and efficiency benefits of CHP. Connecticut, as an illustrative example, changed their regulations surrounding small distributed generation (< 15 MW), including CHP technologies. They created an output-based standard for NO_x, CO, CO_2, PM, and the sulfur content of fuel.[21] Connecticut also initiated NO_x allowance allocations based on energy output for these sources, and allowed them to enter the established NO_x trading market. Since CHP reduces overall emissions from factory and power plants, the factory-owner is given credit for avoided emissions that would have been released by separately producing electricity and useful thermal energy (EPA, 2008).

From this experience, the EPA has gathered a list of best practices for implementation. It recommends that programs:

- Conduct internal education to ensure that regulators understand the benefits and workings of output-based emissions regulations and CHP;
- Evaluate the state's overall air pollution regulatory program to ensure that regulations are structured to encourage efficiency, pollution prevention, and renewables;
- Coordinate with other state agencies that can lend support, like State Energy Offices and economic development offices, which can be important in advancing efficiency and CHP efforts;
- Determine what types of efficiency technologies might be affected and what specific issues the regulation needs to address;
- Gather and review available output-based emission data for regulated sources or convert the available data to an output-based format to establish a benchmark;
- Evaluate alternative approaches to account for multiple outputs of CHP units;
- Train permit writers on new rule implementation.

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[20] RAP workshops cover a wide range of topics including electric utility restructuring, power sector reform, renewable resource development, the development of efficient markets, performance-based regulation, demand-side management, and green pricing. RAP also provides regulators with technical assistance, training, and policy research and development. RAP has worked with public utility regulators and energy officials in 45 states and Washington, DC. (For more information on RAP, see http://www.raponline.org/).

[21] Connecticut Department of Environmental Protection http://ct.gov/Dep/cwp/view.asp?a=2709&q=324138&depNav_GID=1643

The EPA has offered assistance in developing programs and has published a number of different handbooks to this end.

2.1.3 Policy Rationale and Description

States currently submit State Implementation Plans to the EPA to ensure compliance with the Clean Air Act. While the EPA currently supports output-based emissions, historically, these regulations were input-based (either determined on a parts-per-million or MMBtu input-heat basis). Most states have yet to allow OBES as a regulatory option, and the traditional input-based standard is still compliant with the Clean Air Act. Thus, the EPA has little ability to demand a regulatory change by the states, and can only recommend adopting an OBES.

Experiences with the OBES have shown increases in cost-effective efficiency investments and decreases in net pollution. This is at least partly due to the fact that the regulatory framework no longer disincentivizes efficiency upgrades like CHP, as described in the following paragraphs. Historically, states that have adopted an OBES have, on average, installed 69% more CHP projects in the three years following the regulatory change in comparison to the three years preceding it (ICF International, 2009), although not all of the new installations can be attributed to the OBES due to the other policy changes in the participating states (this increase is calculated from all CHP installations, not just industrial applications). Figure 2.2 provides an example of why this regulatory change enables more CHP projects.

Figure 2.2 represents the same plant operating before and after the adoption of an output-based emissions standard. Initially, the plant has a CHP opportunity. However, installing CHP would cause it to exceed the input-based emissions standard for NO_x, set at 0.10 lbs/MMBtu. The higher combustion temperatures that achieve greater energy efficiency and result in overall pollution reduction also create more NO_x emissions per fuel input. As a result, the plant purchases electricity from the grid and generates heat with boilers.

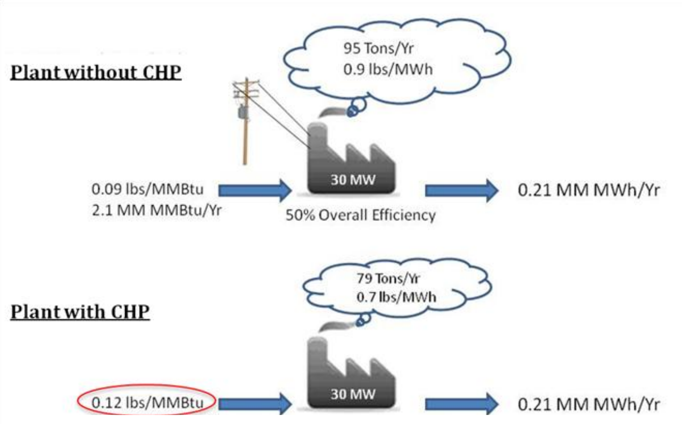

Figure 2.2. Efficiency and Environmental Benefits of OBES for Industry

Source: Modified from EPA Handbook (EPA, 2004)

Then assume the state adopts an OBES, replacing the 0.10 lbs/MMBtu standard with a “metric tons per year” or a “lbs/MWh” standard, enabling the CHP upgrade. The plant with CHP would be the same plant operating after the newly-enabled CHP upgrade. Without the OBES, this facility would not be able to implement the CHP upgrade without jeopardizing its operating permit, even though there are fewer emissions and greater energy productivity after the new equipment is installed. Under an OBES, such an efficiency upgrade would be permitted, lowering energy costs for the producer and reducing overall emissions.

The input-based standards create misplaced incentives that could be addressed through the adoption of OBES by the states. For example, a Midwestern university operating coal-fired boilers was investigating efficiency upgrades for their power plant. The estimates of future emissions showed net reductions, but an increase in the parts-per-million emissions, which threatened the operating permit of the facility. Thus, the university chose to continue operating the plant with the old technology, even though the upgrade would have been a positive economic and environmental change. If an OBES had been implemented by the state, the proposed upgrade could have been implemented without threatening the continued operation of the plant (Casten, Mularkey, and Casten, 2010).

The proponents of this regulatory change have generally been industry and manufacturers or the legislature, which is reflected in the make-up of states that currently have implemented OBES (with the Midwest, Texas, and California having large manufacturing bases). While these groups can be influential in establishing new laws, they are not always successful in achieving regulatory reform, and many opportunities for expanded efficiency gains remain underutilized (see Appendix B and the remainder of section 2.1 for a description of this potential). Additional incentives from the federal government may provide the necessary push to expand output-based emissions standards nationally.

2.1.4 Stakeholders and Constituencies

Main stakeholders include industrial firms, the manufacturers of CHP systems, environmentalists, regulators, electric utilities, gas suppliers, and the general public. The support of these groups is likely to depend on their understanding of OBES and how these standards would impact their economic interests.

Industrial firms and the manufacturers of CHP systems. Industrial firms could be expected to largely support this type of regulatory switch. Since OBES don't dictate technology choices or industrial processes, these firms are likely to see costs of production decrease. An OBES would also enable the implementation of efficiency investments that otherwise may have been eliminated from consideration due to permitting difficulties. The National Association of Manufacturers supports the installation of CHP systems, and argues that states and utilities should not discourage such developments (National Association of Manufacturers, 2009). Manufacturers of CHP systems would also likely support this measure as it creates new business opportunities and allows for greater use of their products (Casten and Munson, 2009).

Environmentalists. Environmentalists could oppose or support OBES, depending on their point-of-view. One view would oppose changes that extend the life of emitting facilities, which an OBES may do. Also, industrial CHP installations could potentially increase emissions near city populations if electricity production from distant power plants is replaced by CHP grid sales. This same effect could also lead to environmental justice concerns, depending on the location of the industrial sites. Another view could see the emission reduction possibilities of allowing more efficient technologies into industrial operations on a national scale. The experience of the Bush

Administration with New Source Review (NSR) reform highlights the support the Clean Air Act receives from environmentalists interested in maintaining what is seen as the integrity of the law (EPA, 2002). Educational efforts may be successful in moving more environmental groups to a supportive position on OBES, especially as they understand the emissions benefits.

Regulators. State regulators are involved in the implementation of NSR in most of the states in the country. Reforms to the Clean Air Act have received mixed responses from regulators, as discussed in the EPA's NSR Report to the President (2002). While many regulators and independent groups have thought some reforms represented positive changes in policy (Andracsek, 2009; Blankinship, 2008), others have continued to disagree with changing current implementation measures because many of the current permits have been carefully negotiated over years. As such, this group is likely to neither be fully supportive nor opposed to proposed changes in the implementation of the Clean Air Act. However, educational efforts from the EPA and the Regulatory Assistance Project on this topic can assist. DOE and the EPA could work together to promote this regulatory option to increase the deployment of CHP in the industrial sector.

Utilities. Traditional utilities will probably view this measure unfavorably. Efficiency improvements will be enabled, which utilities may generally support. According to the EIA, more CHP is installed in the electricity sector than any other in the U.S. (EIA, 2010). New generators also provide grid and voltage stability for the electric system. However, utilities will likely be opposed to this policy reform because it could allow for more DG and independent power production, which utilities have historically opposed and discouraged (Freedman, 2003).

Natural gas suppliers and utilities. Natural gas suppliers and utilities will likely be supportive, since the majority of CHP systems use natural gas as a fuel.

Table 2.2. Stakeholder Assessment of a Federal OBES

Stakeholder	Pros	Cons	Dominant Position
Industrial Firms	Reduced energy costs and potentially additional revenue from grid sales	None	Favorable
Manufacturers of CHP Systems	Increased sales	None	Favorable
Environmentalists	Reduced overall emissions	Emissions location, extended life of emission sources, environmental justice	Mixed
Regulators	Reduced overall emissions	Initial concerns about permits, retraining for a new permitting process	Mixed
Electric Utilities	Efficiency upgrades enabled, grid and voltage stability	Expanded distributed generation as a concern	Unfavorable
Natural Gas Suppliers and Utilities	Increased market share and customers	None	Favorable
General Public	Improved air quality	If the potential for environmental justice and the emissions location problem is realized, these would be concerns	Favorable

2.1.5 Policy Evaluation

Appropriateness of the federal role. Advancing regulatory changes on environmental policy by linking funding for programs to the adoption of a regulatory change has been done before, most famously when transportation funding was linked to Clean Air Act efforts. That effort is probably beyond what would be feasible for this regulatory change. However, DOE oversees many grants to the states; the presence of an OBES could be a criterion to consider when scoring competitively awarded grant applications.

Broad applicability. Output-based emissions standards could be adopted in every state throughout the country. Such a change would enable serious gains in energy and economic efficiency by removing regulatory barriers to cost-effective energy-efficiency investments. The immediate economic gain of this regulatory modification would largely be limited to the industrial and electricity sectors, but certain commercial and retail operations would benefit as well.

Significant potential benefits. An example of potential private gains from CHP that was not undertaken due to an input-based emissions standard was provided by Casten, Mularkey, and

Casten (2010). They describe a glass manufacturing plant that was interested in installing a CHP system. The glass manufacturer had a thermal resource available for a 1 MW steam turbine system and also could have displaced the use of a nearby boiler on a dairy farm. However, under the input-based emissions standard calculation, on-site NO_x emissions would have increased and triggered New Source Review, a potentially costly process that may have jeopardized the operating permit of the glass manufacturer. Plantwide applicability limits and other flexible means of permitting were not sufficient to overcome the significant unease of plant managers, and the project failed to move forward. Casten, Mularkey, and Casten (2010) estimate this project would have reduced CO_2 emissions by roughly 33 thousand metric tons per year and reduced energy consumption by 492 billion Btu.

To determine energy benefits of the policy, a GT-NEMS analysis was performed. The most important assumption related to the OBES analysis is the selection of a CHP market penetration rate, which was modified to reflect two adoption scenarios by state governments. These scenarios show adoption by all states after five years in the “fast adoption” case and 10 years in the “slow adoption” case by increasing the market penetration rate of CHP. These were modeled as a 20% and 10% market penetration rate, respectively. The penetration rate assumptions and a discussion of the uncertainty surrounding these estimates can be found in Appendix B, with a regression analysis of existing CHP sites providing further support for these assumptions. While the reference case shows essentially a doubling of CHP generation through 2035, the modeling estimates that CHP generation could be 3.5 to 5.3 times greater in 2035 than in 2010 with the suggested regulatory modification, as shown in Figure 2.3.

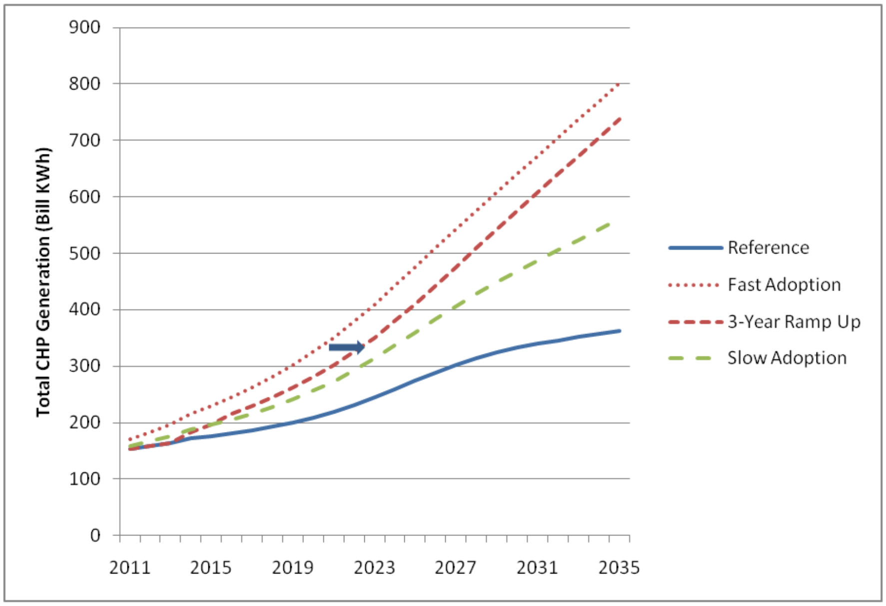

Figure 2.3. Total Industrial CHP Generation as a Result of OBES

The results presented in Figure 2.3 and 2.4 may be slowed by the long lead times needed to install and bring online new CHP systems, frequently on the order of three to five years. The “3-Year Ramp Up” line presents the results if no additional CHP were brought online for three years after the regulatory change occurred; such a lag would decrease cumulative energy savings by 16.6% from the Fast Adoption case (corresponding with an 8.0% reduction in installed capacity and a 27% reduction in cumulative generation through 2035). However, many businesses have developed projects that are rapidly implementable, given the right policy landscape. The number of these projects is unknown, making it difficult to speculate on which policy scenario is most realistic. This analysis also estimates that such a policy change would enable the installation of 27.5 – 60.6 GW of CHP beyond the reference case, as shown in Figure 2.4.

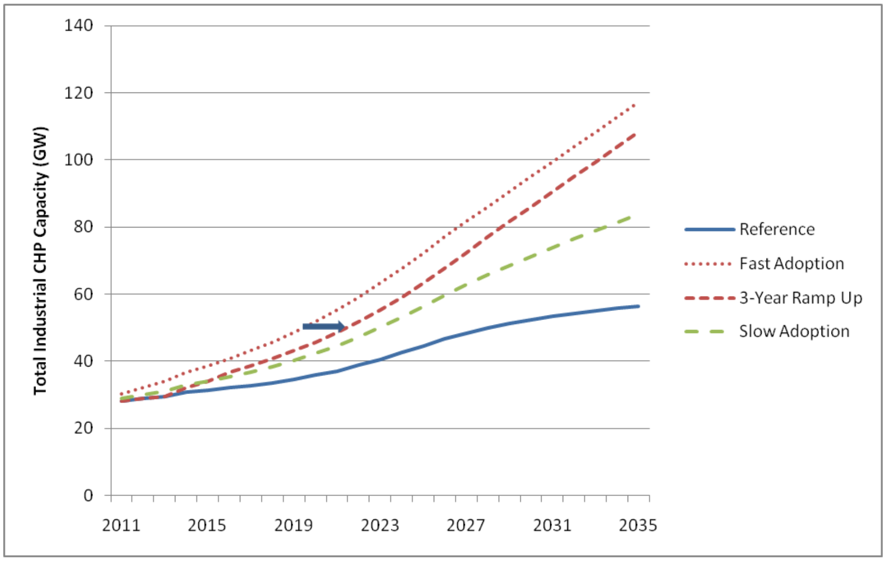

Figure 2.4. Total Industrial CHP Capacity as a Result of OBES

Figures 2.5 through 2.7 show the increase in CHP generation in the pulp and paper, bulk chemicals, and food industries as a result of the OBES. While the reference scenario shows an increase in these industries, this is greatly accelerated by the regulatory modification. The food industry sees the greatest percentage increase (nine times greater than the reference case in 2035), reflecting the widespread availability of food-process residues and the premium that the food industry places on electricity reliability[22] and the benefits from having on-site generation (Shipley et al., 2008). The bulk chemicals industry sees the greatest overall increase (roughly 200 GWH more in the fast adoption scenario than in the reference case in 2035).

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[22] See the case study of an Entenmann bakery in Shipley et al. (2008, p. 16).

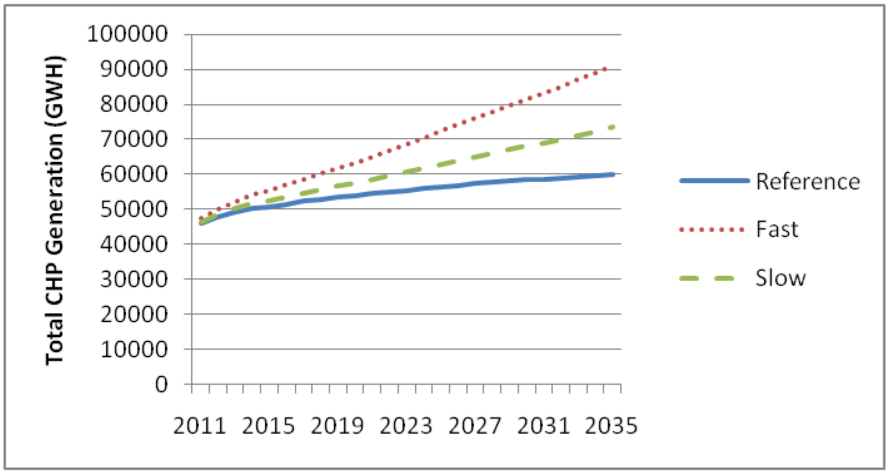

Figure 2.5. Pulp and Paper CHP Generation

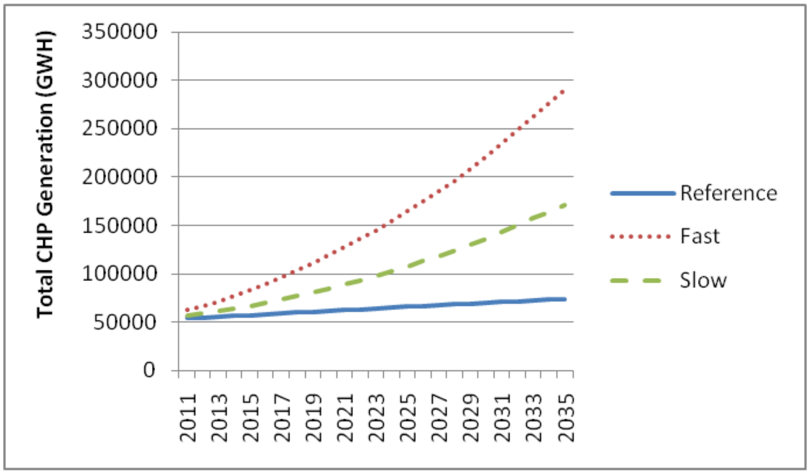

Figure 2.6. Bulk Chemicals CHP Generation

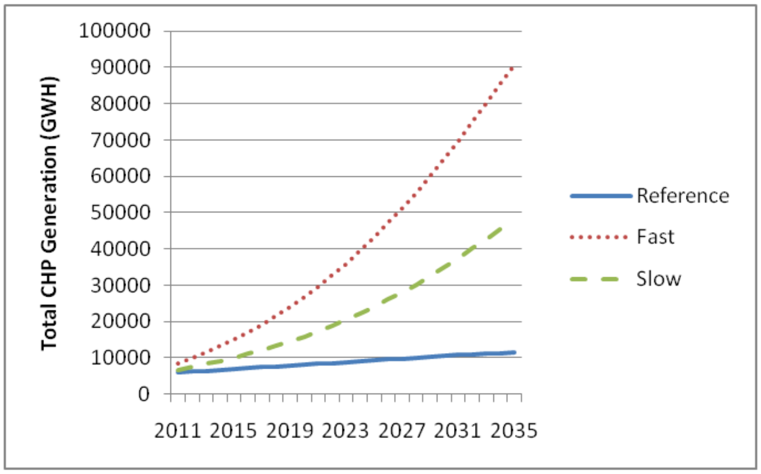

Figure 2.7. Food Industry CHP Generation

The modeling of overall energy consumption shows some interesting trends, which are highlighted in Figure 2.8. In the faster adoption scenario, industrial energy consumption increases towards the end of the modeled period; this is due to industrial CHP electricity generation exceeding on-site use and the increasing value of grid-sales (Figure 2.8). Since the majority of CHP energy is generated with natural gas, overall emissions fall as it displaces other fossil fuels (such as petroleum and coal) used on-site or for generation in the electricity sector. The energy savings, which are tallied on a net consumption basis and account for reduced energy requirements in the electric power sector, are substantial, resulting in roughly 30 to 53 quads of energy savings through 2035, and the avoided emissions of about 1750 to 3000 million metric tons of carbon dioxide. For a discussion of these calculations see Appendix B.

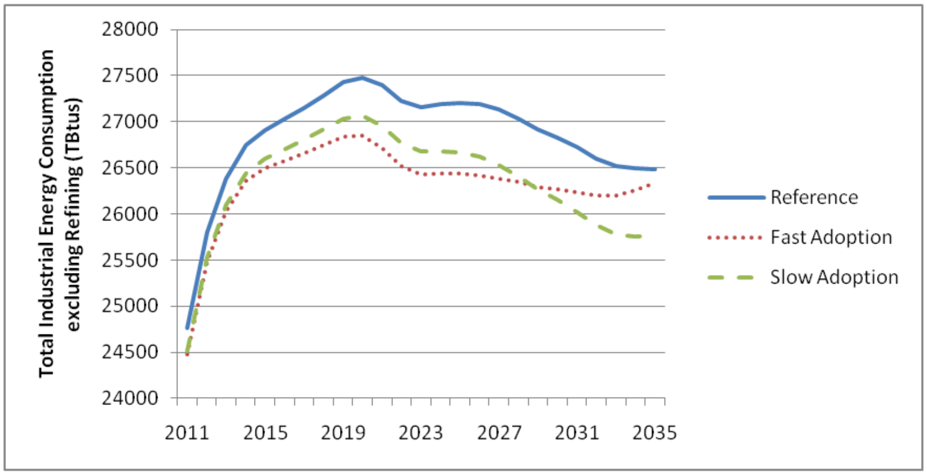

Figure 2.8. Industrial Energy Consumption

Table 2.3 presents the results of the analysis in terms of energy consumption and energy expenditures from the perspective of industrialists, utilizing a 7% discount rate. For OBES, it is estimated that 2,380 TBtus of energy would be saved in 2035, representing 8.8% of the business-as-usual industrial energy consumption in that year. Over the lifetime of equipment installed through 2035, there would be 53,500 TBtus of energy saved. These energy savings come at a cost of $22.6 billion, but result in $223 billion in savings over the lifetime of the installed equipment.

Table 2.3. OBES Policy Option from the Industrialists' Perspective*

Year	BAU Energy Consumption**	Annual Energy Savings			Cumulative Energy Savings***		Annual Private Cost	Cumulative Private Cost
	Trillion Btu	Trillion Btu	$M (2008)	%†	Trillion Btu	$M (2008)	$M (2008)	$M (2008)
2011	24,770							
2020	27,480	939	4,850	3.42	6,090	36,000	1,020	9,980
2035	26,480	2,380	8,850	8.98	30,900	139,000	639	22,600
2055	--	--	--	--	53,500	223,000	2,055	22,600

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

** Reference case industrial energy consumption excludes refining.

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

†Percent of annual industrial energy consumption.

The pulp and paper industry provides a useful example of increasing grid sales, especially after seeming to maximize what can be used on-site. This is shown in Figures 2.9 and 2.10, where around 2021 or 2031 (depending on which scenario is studied), the industry maximizes on-site usage and finds it profitable to sell back to the grid.

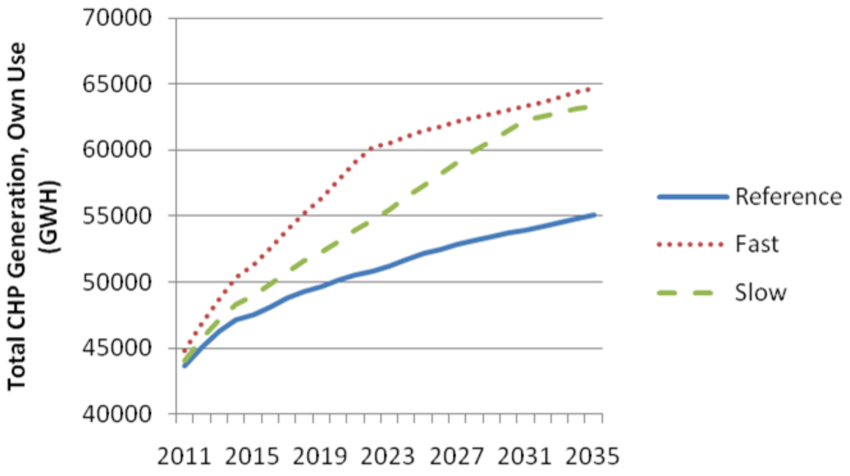

Figure 2.9. Pulp and Paper Generation for Own-Use

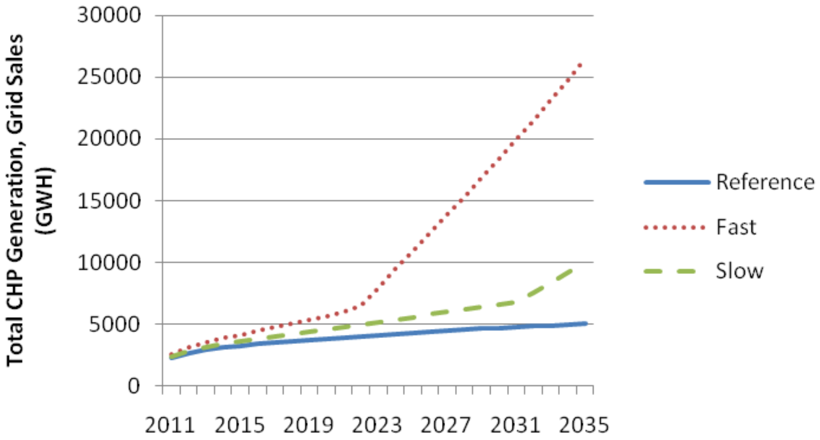

Figure 2.10. Pulp and Paper Generation for Grid Sales

Technology readiness. This policy focuses on removing regulatory barriers to energy efficiency. It is not selecting technologies, only enabling the selection of existing efficient technologies. As more efficient technologies emerge in the industrial sector, more of them should be implementable as a result of this regulatory modification.

However, in modeling this policy, we assume that the overall efficiency of the most commonly installed CHP systems improve 0.7% annually. The reference case projects roughly a 0.1% increase in overall efficiency. To generate this learning curve, this policy also models a $10 million/year R&D program for 10 years.

Cost effectiveness. This regulatory modification will enable the implementation of many more cost-effective CHP installations nationally. This option requires little in the way of new federal cost, especially if grant rewards are used as an incentive for the adoption of OBES by the states, as these funds were already due to be dispersed. A change in regulatory approach that enables output-based emissions standards can achieve significant cost savings over the next 25 years.

Table 2.4 presents the ability of the public sector to leverage industrial energy savings with OBES. Public costs include the costs of training programs for regulators and the R&D investment described previously. Through 2035, public expenditures are estimated at $90 million with a 3% discount rate, and lead to energy savings of 53,500 TBtus. This yields an energy leveraging ratio of 595 TBtu/$1 million or 595 MMBtu/$1.

Table 2.4. Leveraging of Energy Savings from Cumulative Public Investments in OBES

Year	Public Costs				Cumulative Energy Savings	Leveraging Ratio*
	Million $2008					
	Annual Administration Cost	Annual Investment Cost	Total Annual Costs	Total Cumulative Costs	TBtus	MMBtu/$
2020	0.09	7.66	7.75	89.4	6,090	--
2035	0.01	0.00	0.01	90.0	30,900	--
2055	--	--	--	90.0	53,500	595

*Ratio of cumulative energy savings in MMBtu to cumulative public costs in $2008. Present value of public costs was calculated using a 3% discount rate.

Table 2.5 presents the ability of the public sector to leverage carbon dioxide savings in the industrial sector using output-based emissions standards. In 2035, public expenditures lead to CO_2 savings of 142 million metric tons, representing 9.4% of the business-as-usual CO_2 emissions in the industrial sector that year. Over the lifetime of the equipment installed by 2035 as a result of this policy change, 3,140 million metric tons of CO_2 emissions are avoided, yielding a carbon-dioxide leveraging ratio of 34.9 metric tons per dollar.

Table 2.5. Leveraging of CO_2 Emission Reductions from Cumulative Public Investments in OBES

Year	Public Costs	CO_2 Emission Reductions			Leveraging
	Million $2008	Million Metric Tons CO_2			Ratio*
	Cumulative Costs	Annual MMT Saved	% Annual Emissions	Cumulative MMT Saved	Metric Tons/$
2020	89.4	53.2	3.3	345	--
2035	90.0	142	9.4	1,790	--
2055	90.0	--	--	3,140	34.9

*Ratio of cumulative emission reductions in million metric tons to cumulative public costs in $2008. Present value of public costs was calculated using a 3% discount rate.

Figure 2.11 shows the leveraging ability of the 5-year and 10-year output-based emissions standards (OBES) adoption scenarios for energy and carbon dioxide savings. The circle markers represent the 5-year scenario and the diamond markers represent the 10-year scenario. Results are shown using both 3% and 7% discount rates.

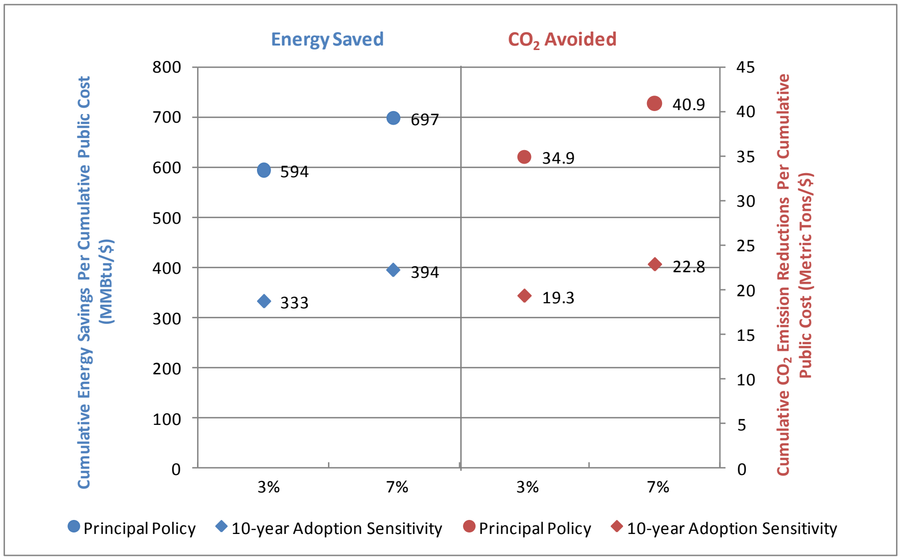

Figure 2.11. Energy and CO_2 Leveraging for OBES

Further benefits accrue to society as a whole from increased energy efficiency in the industrial sector and reduced energy consumption from the electricity sector. Estimates of the reduction of criteria pollutant emissions are shown in Table 2.6 and Figure 2.12, with SO_2 emissions reductions providing the greatest economic benefit at $51.8 billion cumulatively through 2055. The avoided damages of NO_x, SO_2, PM_{10}, and $PM_{2.5}$ due to the energy-efficiency measures are calculated using a 3% discount rate. These emissions reductions represent additional significant benefits of the output-based approach, with savings of almost $60 billion for the 5-year adoption scenario.

Table 2.6. Value of Avoided Damages from Emissions of Criteria Pollutants for OBES (Billion $2008)*

	NO_x		SO_2		PM_{10}**		$PM_{2.5}$	
	Annual	**Cumulative**	**Annual**	**Cumulative**	**Annual**	**Cumulative**	**Annual**	**Cumulative**
2020	0.085	0.643	1.25	7.33	0.007	0.038	0.112	0.668
2035	0.023	1.37	1.90	33.8	0.010	0.181	0.165	3.03
2055		1.14		51.8		0.297		4.59

*Values are based on the National Research Council report estimating damages from energy production and consumption in the U.S. (NRC, 2010). Excludes avoided pollutant damages from petroleum and coal for industrial heat. Present value of avoided damages was calculated using a 3% discount rate.
**Excludes PM_{10} from the production of industrial heat.

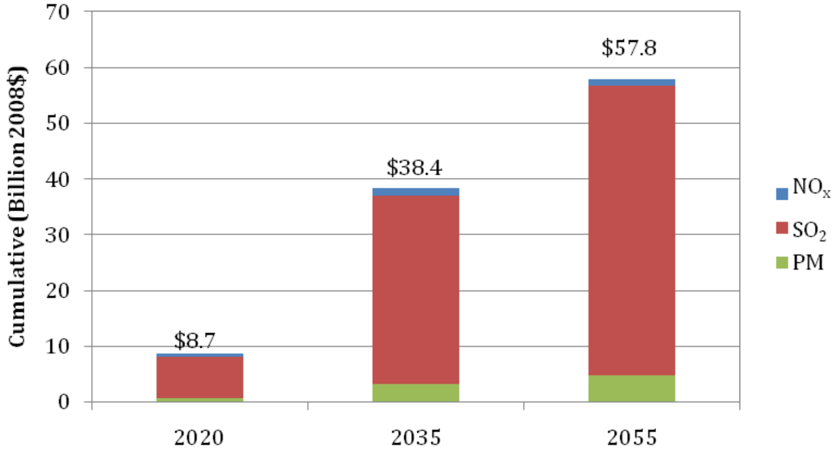

Figure 2.12. Value of Avoided Damages from Criteria Pollutants for OBES

Next we estimate the B/C ratios when the value of avoided damages from CO_2 and the four criteria pollutants are included (Tables 2.7a and 2.7b). We determined the economic value of reduced CO_2 emissions in each year by multiplying the decrement in emissions by the "social cost of carbon" (SCC) for that year. The SCC is defined as an estimate of the monetized damages caused by each incremental ton of CO_2 emitted. The SCC used in this analysis is the central value estimates of the U.S. Government Interagency Working Group on the Social Cost of Carbon (EPA, 2010a). In this report, the central value SCC estimates ranged from $23/metric ton of CO_2 in 2011 to $34/metric ton and $47/metric ton in 2030 and 2050, respectively (all values are in $2008). Considering all emissions benefits raises the B/C ratio to 16.0 with a 3% discount rate and 12.5 with a 7% discount rate for the 5-year adoption scenario.

Table 2.7a. Total Social Benefit/Cost Analysis of an OBES

	Cumulative Social Benefits (Billions $2008)				Cumulative Social Costs (Billions $2008)			Benefit/Cost Analysis	
Year	**Energy Savings**	**Value of Avoided CO_2**	**Value of Avoided Criteria Pollutants**	**Total Social Benefits****	**Public Costs**	**Private Costs**	**Total Social Costs****	**Social B/C Ratio**	**Net Societal Benefits (Billions $2008)**
2020	44.6	7.49	8.68	60.7	0.09	11.9	12.0		
2035	250	35.7	38.4	324	0.09	36.0	36.1		
2055	460	60.6	57.8	578	0.09	36.1	36.1	16.0	542

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

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

Table 2.7b. Total Social Benefit/Cost Analysis of an OBES (7% Discount Sensitivity)

	Cumulative Social Benefits (Billions $2008)				Cumulative Social Costs (Billions $2008)			Benefit/Cost Analysis	
Year	**Energy Savings**	**Value of Avoided CO_2**	**Value of Avoided Criteria Pollutants**	**Total Social Benefits****	**Public Costs**	**Private Costs**	**Total Social Costs****	**Social B/C Ratio**	**Net Societal Benefits (Billions $2008)**
2020	36.4	6.14	7.01	49.6	0.08	9.93	10.0		
2035	139	20.6	22.6	182	0.08	22.6	22.7		
2055	223	30.5	30.4	284	0.08	22.6	22.7	12.5	262

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

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

It should be noted that these estimates do not include savings in technologies beyond CHP, such as boilers or furnaces, which an output-based emissions standard would also enable. It also does not include savings to the firm from reduced regulatory burden or savings from the expansion of CHP systems in the refining industries.

Table 2.8 provides a summary of the social benefit/cost ratios for the 5-year adoption scenario and the 10-year adoption scenario, analyzed at both the 3% and 7% discount rates. This sensitivity analysis highlights the economic advantage of promoting a faster adoption rate for OBES.

Table 2.8. Social Benefit/Cost Analysis of Policy and Discount Rate Sensitivities

		Alternative Discount Rates	
		3%	**7%**
OBES 5-Year Adoption Scenario	Benefit/Cost Ratio	16.0	12.5
	Net Societal Benefits (Billions $2008)	542	262
OBES 10-Year Adoption Scenario	Benefit/Cost Ratio	15.6	12.7
	Net Societal Benefits (Billions $2008)	238	119

Administrative feasibility. The main difficulty of this policy would result from developing the OBES by state government and training state regulators. Federally, there may be a slight additional administrative burden from modifying the State Energy Program grant review process, although this should be minor. The EPA has already approved OBES for 17 states and has written handbooks to assist with their implementation and design (EPA, 2004, 2008). This should lower administrative burden for states that choose to adopt OBES in the future, as well as for the EPA, which will have experience in reviewing and approving such regulatory changes.

Additionality. This policy addresses a specific regulatory barrier to industrial energy efficiency. Several additional activities could address other regulatory barriers that handicap similar industrial energy-efficiency efforts, including the following four policy options. These options are not discussed further in this report, but merit further consideration:

Since industrial sites need to be compliant with the state regulatory framework to continue operating, OBES would likely be well received by industry. An OBES would also likely be taken advantage of without a large educational effort, due to industrial sites needing to renew their operating permits.

2.1.6 Summary

Output-based emissions standards have a proven track record of reducing net emissions of pollution by enabling greater on-site energy efficiency. Despite this option's encouragement of certain types of technology in industry – CHP systems, particularly, in this analysis – its potential benefits are significant because of the large remaining potential for expanding CHP implementation (Table 2.9). There would be benefits for other sectors that have not been analyzed here. While states already have the option to implement OBES, a federal-level incentive for the adoption of OBES may provide the catalyst for this modification of the regulatory framework, enabling gains in both economic and energy efficiency. Overcoming other barriers, such as interconnection standards and power purchase agreements, would allow for greater realization of the CHP potential.

Table 2.9. Overall Assessment of OBES Policy

	Strengths	Weaknesses	Time Horizon*
Output-Based Emissions Standards	Significant Potential Benefits, Cost-Effectiveness, Leveraging of Public Resources, Additionality	Narrow Technology Focus	Short to Long

*See the Introduction for a definition of the time horizons

The benefits from such a change in regulatory framework considerably outweigh their costs and enable cost-effective investment by the private sector in energy-efficient technologies. When the social damage of emissions is included in the analysis, the benefits are even greater.

2.2 Federal Energy Portfolio Standard (EPS) with Combined Heat and Power (CHP)

Policy Option: Promulgate federal legislation requiring electric distributors to meet an energy portfolio standard (EPS) that includes CHP as an eligible resource; concurrently expand and extend the investment tax credit to 30% of the basis of CHP and industrial recycled energy projects, and establish measurement and verification methods for qualifying CHP resources.

2.2.1 Synopsis of Policy Option

The federal government could *establish a federal Energy Portfolio Standard that includes CHP as an eligible technology for meeting minimum levels of renewable and energy-efficiency resources.* Energy portfolio standards have been established as requirements in 29 states and as goals in an additional seven states, as of July 2010.[23] At least 14 of these states include CHP or waste heat recovery as a qualifying resource (EPA, 2009). By including CHP (sometimes referred to as “cogeneration”) as an eligible technology in a federal EPS, the nation will expand the economic and environmental benefits of capturing and utilizing thermal energy that is normally wasted when heating and power systems operate independently. While some states are already encouraging CHP systems in their EPS, a federal EPS would significantly accelerate this trend. It would also overcome the difficulty of developing national markets for CHP and other technologies when state-by-state inconsistencies in eligibility, measurement and verification (M&V) protocols, and other procedures exist.

To achieve the desired stimulus effect, the current *investment tax credit for CHP resources* of 10% through 2016 could be strengthened and extended. In addition to being time-limited, the current incentive is capped at 50 megawatts (MW) and is limited to a project’s first 15 MW. Alternatively, the investment tax credit (ITC) could be increased to 30%, extended to 2020 or 2035, and the 50 MW limit could be removed or replaced with a requirement for high-efficiency CHP.[24] Such changes would accelerate the implementation of CHP in response to a federal EPS. Without a strong financial incentive, the risks, lack of familiarity, and other adoption barriers associated with CHP would remain strong deterrents to the installation of new CHP systems.

Measurement and verification (M&V) requirements also need to be clearly defined and designed so that the benefits of cost-effective CHP projects outweigh the time and expense of the M&V burden. To this end, the federal government could issue guidelines on *M&V methods for CHP projects.* Whether enforcement of M&V methods is at the federal or state level, if parties agree to M&V methods, non-compliance can be dealt with swiftly rather than spending time litigating accounting issues.

The EPS policy option would benefit from being accompanied by a nationwide market for trading energy-efficiency credits. Such a market could be used to trade or bank energy savings between utilities across the nation. With a confident market – supported by financial incentives and a reliable measurement and verification – the energy savings from CHP could be traded to achieve savings at competitive costs.

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[23] http://www.dsireusa.org/

[24] We analyze the 2035 expiration data as the main policy in this report and treat the 2020 expiration as a sensitivity analysis.

2.2.2 Policy Experience

The most common quotas for clean electricity are state renewable portfolio standards (RPS). An RPS is a legislative mandate requiring electricity suppliers (often referred to as "load serving entities") in an area to employ renewable resources to produce a certain amount or percentage of power by a fixed date. Typically, electric suppliers can either generate their own renewable energy or buy renewable energy credits. This policy therefore blends the benefits of a "command and control" regulatory paradigm with a free market approach to environmental protection.

There is no universal definition of a renewable resource. Eligible sources typically include wind, solar, ocean, tidal, geothermal, biomass, landfill gas, and small hydro. However, waste coal generation qualifies in at least one state, Pennsylvania, while solar water heaters are allowed in some states (such as North Carolina and Texas), but are disallowed in other states (such as New Mexico and California). Several states have expanded the scope of their qualifying energy resources to include energy efficiency, and some of these allow CHP and other technologies that re-use waste heat. Inclusion of CHP may require meeting a minimum efficiency percentage, such as the 50% total efficiency required in Connecticut. Alternatively, CHP may be eligible only if it is a "qualifying facility" under the Public Utilities Regulatory Policies Act (PURPA) of 1978.[25] In addition, there may be a minimum thermal efficiency requirement, such as the 20% threshold required by Connecticut. In addition, the RPS may set maximum emissions limits for CHP systems. For example, California requires that CHP and other distributed generation technologies stay under the 2007 state emission limits to qualify[26] (EPA, 2009, p. 2-3).

Many of the states that have an RPS also have an Energy Efficiency Resource Standard (EERS). While EERS and RPS regulations have similarities, the distinction between them is that the former requires a level of energy *demand or generation reduction* whereas the latter requires an increased level of renewable energy *supply*. In addition, some states include energy efficiency as an acceptable "source" of renewable energy supply for an RPS (Harmin, Vine, and Sharick, 2007). This extension of the RPS rules reflects the growing recognition of energy efficiency as a "resource" – on par with raw energy supplies – that can lower energy demand and provide economic and environmental benefits including the reduction of greenhouse gases (GHG) and preservation of water quality, since significant quantities of water are consumed and withdrawn during power generation.[27]

Conceptually, CHP could qualify as an eligible resource for either an RPS or an EERS. This "crossover" status of CHP reflects the fact that CHP recycles energy that would otherwise be wasted (similar to renewable energy resources), while it also converts fuels into electricity at a high rate of efficiency (qualifying it as an energy-efficiency resource). CHP requires much less

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[25] "Qualifying facilities" fall into two categories: small power production facilities and cogeneration facilities.

[26] www.arb.ca.gov/energy/dg/dg.htm

[27] For a general introduction to future electricity-water challenges, see generally Andrew McNemar (2007). For an analysis of the relationship between energy savings and water consumption in the U.S. South, see Brown, Gumerman et al., 2010a.

fuel to achieve the same energy output as separate heat and power system. According to Shipley et al. (2008) and DOE,[28] a traditional system of separately producing heat and power operates at 45 - 49% efficiency while a CHP system can bring that efficiency up to 75 - 80% (Figure 2.1).[29]

As a result of its cross-cutting benefits, we find CHP systems being incorporated into a subset of both RPS and EERS programs. The targets and specifications for 14 states that qualify CHP in their energy portfolio standards are described in Table 2.10.

Table 2.10. A Selection of States that Include CHP and/or Waste Heat Recovery in their EPS

State	Mandatory Requirements	Target (% of electric sales)	Specific Provisions
AZ		15% by 2025	4.5% from DG by 2012
CO	√	Investor-owned utilities (IOUs) 20% by 2020; electric cooperatives and municipal utilities 10% by 2020	IOUs: 0.4% solar by 2020
CT	√	27% by 2020	4% Energy Efficiency and CHP by 2010
HI	√	20% by 2020	
MA	√	Class I: 4% by 2009 (+ 1%/year after); Class II: 3.6% renewable, 3.5% waste energy by 2009; APS: 5% by 2020 increasing by 0.35% each year after.	Class II: 3.6% renewable, 3.5% waste energy by 2009
MI	√	10% by 2015	
NV		20% by 2015	1% solar by 2015
NC	√	12.5% of 2020 retail electricity sales by 2021 (IOUs). Municipal utilities and rural electric coops must meet a target of 10% by 2018.	12.5% up to 25% of requirements may be met through energy-efficiency measures including CHP. After 2018, 40%.
ND		10% by 2015	
OH	√	25% by 2025 (12.5% renewable energy)	1% solar by 2025
PA	√	18% by May 31, 2021 (8% renewable energy)	0.5% solar by 2025
SD		10% by 2015	
UT		20% by 2025	
WA	√	15% by 2020	

Source: EPA, 2009; DSIRE, 2010

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[28] http://www1.eere.energy.gov/industry/distributedenergy/chp_basics.html
[29] GT-NEMS assumptions for the efficiency of CHP systems are not quite as high – see Appendix B.

The following three state case studies illustrate the variation in implementation details, which is one of the justifications for developing a federal policy, since state-by-state inconsistencies make it difficult to develop national markets for CHP and other technologies. The case studies are also helpful for anticipating how a federal EPS policy might evolve (ACEEE, 2009a).

- **North Carolina** established a Renewable Energy and Energy Efficiency Portfolio Standard (REPS) in 2007, requiring that 12.5% of 2020 retail electricity sales by investor-owned utilities (IOUs) come from eligible resources by 2021. Municipal utilities and rural electric coops must meet a target of 10% by 2018. Up to 25% of these requirements may be met through energy-efficiency measures including CHP. After 2018, 40% may be met by CHP and other energy-efficiency improvements. To qualify, a CHP system must perform the same function or provide the same level of service at the customer's facility using less energy. Thermal energy as well as electricity earns equivalent renewable energy credits (RECs) based on the end-use energy value of electricity, measured as 3.413 MMBtu of heat output per MWh of electricity.[30]
- In June 2005, the **Connecticut** legislature modified its RPS to add a third tier to its resource requirements that must be filled with CHP, demand response, and electricity savings. Starting in 2007, the state's utilities must procure electricity sales from "Class III" resources, including systems that recover waste heat.[31] In that year, 1% of the generation of electric suppliers and distribution companies was to be obtained from Class III resources, and an additional 1% was added to the tier's requirement in 2008, 2009, and 2010 when the requirement plateaus. Energy savings from CHP investments are entitled to Class III credits, equal to at least one cent per kWh. The revenue from these credits is then divided between the customer and the state conservation and load management programs (ACEEE, 2009a; EPA, 2009). To qualify, CHP systems must meet a minimum 20% thermal efficiency requirement.
- In 2005, **Nevada** expanded its existing RPS from 15% to 20% of electricity sales by 2015, and was amended to allow energy efficiency to meet up to 25% of the total portfolio standard. The state's utilities are quickly ramping up efficiency programs to hit the maximum allowed efficiency threshold (Furrey, Nadel and Laitner, 2009). CHP systems are eligible as a qualified energy recovery process. Units must be smaller than 15 MW, and only waste heat used to generate electricity is eligible for inclusion.[32]

Many states have increased their annual energy-savings goals over time and have been achieving or are on track to achieve their stated energy-savings goals. For example, the first 19 states to implement an EERS are positioned to achieve a little over 5% electricity savings in 2020 (Furrey, Nadel and Laitner, 2009). Nevertheless, the state case studies presented here show the variation in implementation details with respect to the treatment of CHP.

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[30] http://ncuc.commerce.state.nc.us/cgi-bin/webview/senddoc.pgm?dispfmt=&itype=Q&authorization=&parm2=SAAAAA06080B&parm3=000127195

[31] http://www.cga.ct.gov/2007/act/pa/2007pa-00242-r00hb-07432-pa.htm

[32] Nevada Revised Statues Annotated, www.dsireusa.org/documents/Incentives/NV01R.htm

As a result of this variation, standardized M&V requirements for qualifying CHP in EPS have not emerged. Nationwide protocols are needed so that the benefits of cost-effective CHP projects outweigh the time and expense of the M&V burden. This is a key point justifying the role for federal government involvement. Robust M&V is also essential to maintaining a credible, transparent, and viable market trading system in which all parties have confidence that investments in CHP will be cost-effective and will deliver the anticipated benefits.

For meeting EPS requirements, M&V protocols should fully evaluate the benefits of CHP systems both in terms of their thermal and electric output. Protocols need to evaluate the pros and cons of qualifying the full kWh output from CHP systems versus discounting their electricity generation based on relative efficiency. They also need to consider how to credit the thermal output, perhaps by requiring a minimum thermal efficiency as is done in Connecticut, which requires 50% efficiency, or as is proposed in the ICF analysis of a 30% ITC for CHP, where a 70% efficiency is required to qualify for financial support. M&V protocols are particularly important if a federal EPS were to include industrial waste energy recovery from hot exhaust, flared gas, and pressure drops, where much less experience with on-the-ground projects and verification exists.

Renewable and energy-efficiency certificates (RECs and EECs) could lead to the integration of EPS programs within and across regions. These certificates are trading commodities that can be used to meet EPS requirements, if allowed by state regulators. Most RPS programs measure compliance by calibrating the purchase of RECs from renewable generators. Trading energy savings via Energy Savings Certificates, Tradable White Certificates (TWC), or White Tags™[33] fits well within the these policies by allowing crediting, banking, or trade of savings to keep aggregate costs low (WRI, 2008). In 2003, New South Wales adopted a trading scheme for energy savings (Friedman, Bird, and Barbose, 2008). Since then, Italy, France, and the United Kingdom, along with four states, have developed systems for trading energy savings certificates. Among the four states – Connecticut, Pennsylvania, Nevada, and Michigan – only Connecticut has a working program while the other three allow trading to meet requirements (Friedman, Bird, and Barbose, 2008). Several European countries have implemented white certificate schemes, including Italy (beginning in 2005) and France and Denmark (starting one year later).[34] The European Union is also considering the development of a European market for trading energy savings.[35]

A voluntary national market for energy savings certificates could develop, like the market for RECs, but it is not clear when this would happen under current policies; similarly, energy savings certificates might be used to comply with carbon restrictions, like in the Regional Greenhouse Gas Initiative (Friedman, Bird, and Barbose, 2008). After reviewing existing programs, Vine and Hamrin (2008) itemize the elements of an effective energy-savings trading

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[33] Any of these names can be considered "an instrument representing a unit of energy savings that has been measured and verified" (Friedman, Bird, and Barbose, 2008).

[34] http://en.wikipedia.org/wiki/White_certificates

[35] Directive 2006/32/EC of the European Parliament and of the Council of 5 April 2006 on energy end-use efficiency and energy services and repealing Council Directive 93/76/EEC (http://eur-lex.europa.eu)

program, which includes having a measurement and evaluation system to ensure real, measurable, verifiable, and additional energy savings. They also call for:

- Independent third-party auditing for verification and compliance
- A process for issuing and tracking certificates that avoids double counting
- A system for detecting and penalizing non-compliance

Some of the effort to create M&V protocols may be reduced by private efforts already undertaken. For example, the North American Renewables Registry claims to be prepared to meet the need for energy-efficiency trading markets, “APX is closely following the development of energy-efficiency standards and state programs and is prepared to provide a market infrastructure solution to ensure trust and transparency for these new environmental commodities”.[36]

2.2.3 Policy Rationale

On the one hand, implementing policies such as the RPS and EERS simultaneously in multiple states encourages innovation and experimentation. Decentralized environmental decision-making, in general, provides for inter-jurisdictional competition and creates “laboratories of democracy,” a metaphor coined by Justice Brandeis in 1932. It encourages adaptation to local circumstances and needs, creating “ecologies of scale” that can maximize social welfare and minimize cost. State and local policies tend to be more representative, creating regulations and public services that better match local interests and preferences, in contrast to federally imposed uniformity (Anderson and Ostrom, 2008; Sovacool and Brown, 2009b).

On the other hand, a federal EPS could reduce the regulatory confusion and administrative burdens that have resulted from the patchwork of state-regulated EPS efforts. A federal EPS mandate would produce a standardized regulatory environment that would provide manufacturers and industry with consistent and predictable business rules that are important when attempting to create national markets for green technologies such as combined heat and power. In contrast, a multiplicity of state standards increases transaction costs, causes confusion in the marketplace, and prevents economies of scale.

A patchwork of state policies allows stakeholders to manipulate the existing market to their advantage, using regulatory loopholes to waste energy and emit GHG wherever regulators are the most lax. An example of this is provided by the Regional Greenhouse Gas Initiative (RGGI), a regional carbon cap-and-trade initiatives involving 10 northeastern states (Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island, and Vermont). RGGI has experienced “leakage” rates as high as 60% to 90% due to coal-generated electricity being imported into RGGI states. Power plants in adjacent states have actually increased their output to sell into the higher-priced RGGI electricity markets (Weiner, 2007). Additional examples are provided by Brown and Sovacool (2011, Chapter 7).

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[36] http://narenewables.apx.com/about/FAQ.asp

A federal EPS with standardized M&V guidelines would likely be less costly to operate than having a variety of state-defined M&V approaches. In addition, a federal EPS could provide greater economic efficiency by facilitating a national market for trading energy savings credits.

2.2.4 Stakeholders and Constituencies

Important stakeholders include the industrial hosts, manufacturers, suppliers, and financiers of CHP systems; environmentalists, the general public, and consumers; and regulating bodies, electric utilities, and natural gas suppliers. Support or objection from these groups is likely to depend on the aggressiveness of targets set in a federal EPS and the ease of trading renewable energy and energy-savings certificates in the national market.

Industrial firms and facilities, CHP developers, and equipment suppliers. CHP developers and manufacturers of CHP equipment such as boilers, turbines, and heat recovery steam generators would be expected to largely be supportive of making CHP an eligible resource in a federal EPS. The CHP industry has been growing rapidly in many other countries of the world, but growth in U.S. markets has been sluggish. CHP represents more than 50% of the power generation in Denmark, the world leader, and nearly 40% in the Netherlands, while it represents less than 8% in the U.S. (Casten and Ayres, 2007, p. 210). Denmark has taken extensive steps to address industrial energy efficiency. The Danish government has negotiated agreements with industry, modeled after the Dutch approach. But its taxes on petroleum-based fuels levied following the OPEC oil embargo of the early 1970s and a carbon tax levied in 1992 has created a strong incentive for energy efficiency. The guarantee of grid connectivity and the ease of implementation for power producing efficiency measures like CHP has also been influential (Brown, Cortes, and Cox, 2010). By qualifying CHP systems to meet federal EPS requirements and by providing financial incentives, a strong national market for CHP could emerge in the U.S.

The website of the U.S. Combined Heat and Power Association (USCHPA) provides evidence that the industry recognizes the value of this policy option. The USCHPA, which represents CHP developers and equipment suppliers, "encourages states to adopt policies that recognize energy efficiency and clean heat and power as an integral component of a renewable portfolio standard."[37]

Industrial firms and facilities that could host CHP systems would be supportive because the savings from industrial energy efficiency including CHP technologies are significant and they compound over time as industrial energy prices have trended up over the past several years following an historic decline since the mid 1980s (EIA, 2008a, Table 8.10). The provision of an ITC to subsidize investment costs will allow many facilities to adopt CHP that would otherwise be unable to afford the capital costs. In addition to reducing on-site energy costs, industrial facilities could sell excess electricity to utilities, creating an additional revenue stream for their operations.

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[37] http://www.uschpa.org/i4a/pages/index.cfm?pageid=3282

Industries with the largest technical potential for CHP would appear to have much to gain from this policy option and would therefore probably be most supportive. This includes chemical, paper, food processing, petroleum refining, primary metals, and lumber and wood (ICF International, 2010, Table 5, p. 13). The policy is also most attractive to private, for-profit firms that could utilize the CHP tax credits. Many entities that do not have tax liabilities, such as waste water treatment districts, post offices, state universities, and government facilities, could benefit from CHP systems, but they would not benefit from an investment tax credit.

Energy services companies (ESCOs). ESCOs could play a significant role in a federal EPS program. There are about 60 active ESCOs in the U.S with estimated annual revenues of nearly $4 billion (in 2006). Consumer-sited generation, including renewables, is a growth area for these ESCOs, but industrial facilities represent a small fraction of their activities. Nearly half of ESCO activity is focused in four states (New York, New Jersey, California, and Texas), and most ESCO projects serve the institutional sector (schools, government, and health care projects).

ESCOs use multiple business models for implementation of energy-efficiency projects, including the Guaranteed Savings Model and the Shared Savings Model. Some ESCOs have the resources that allow them to fund the customer’s project. ESCOs may also receive money from a Public Benefit Fund (PBF). Policy measures such as subsidies that lower capital costs, would further improve ESCOs’ cost-benefit profile – thereby expanding existing markets, enabling access to as-yet untapped markets, and cost-effectively amplifying energy and environmental benefits. However, ESCOs have not been successful in penetrating the industrial market in the U.S. – even in CHP. One reason for this lack of success is the mismatch between the typical ESCO’s 15 to 20 year contractual approach and the inability of industrials to guarantee next year’s performance let alone 10 years from now.

Environmentalists and consumer groups represent the interests of citizens, but from different perspectives. A National EPS including CHP would be supported by clean air advocates. However, it may be attacked on environmental justice grounds if trading mechanisms allow energy savings to accrue in some areas while others face new plant construction. Without a trading mechanism, a federal EPS may be attacked on economic grounds as some utilities and regions can support efficiency programs at lower costs than others. Environmentalists may also oppose including CHP at the expense of renewable sources because CHP systems can use fossil fuels, which makes them less than equal in their eyes. In addition, distributed power generation has the potential to move emissions sources closer to population centers. Thus, while the overall emission reductions of a CHP system may be significant, local effects in nonattainment regions could be an issue.

One equity issue that may create opposition to a federal EERS is “credit for early action.” Current drafts of federal EPS legislation do not provide credit to states that have already enacted EPS policies or other energy-efficiency initiatives. Instead, states are required to realize annual savings based on averages of the previous two years’ sales relative to business-as-usual (BAU) projections; this benchmark will change every year and will include efficiency gains from previous years. Credit for early action could be awarded by allowing pre-existing

EERS policies to be considered as part of the BAU. The resolution of this additionality issue will either favor or penalize states that have taken early action to promote energy efficiency.

Research has shown that federal funding can crowd-out state funding of projects (Knight, 2002), and federal regulations can preempt more aggressive state actions (National Academy of Sciences, 2010). Design of any incentive program to support an EPS with CHP will need to take this phenomenon into account. It may be just as effective for the federal government to make clear statements of its preferences for state policy action regarding energy efficiency (Allen, Pettus, and Haider-Markel, 2004). However. multiple and diverse state and local standards and incentive programs can place a heavy burden on business interests that operate in multiple states, providing a strong justification for federal action (National Academy of Sciences, 2010, Chapter 7).

Federal funds might be saved by allowing states greater flexibility in designing EERS programs, as governors have shown a willingness to accept less grant funding for fewer restrictions (Volden, 2007). The cost structure of a federal mandated program could be based on customary practices in the states that are leading in EPS programs. Typically, the customer pays two-thirds of the cost and utilities pay one-third of the cost of investment in efficiency measures (Furrey, Nadel, and Laitner, 2009).

Local, state and federal agencies. Since many CHP components are manufactured in the U.S., enhanced tax credits and a federal EPS could help grow the nation’s industrial base. Agencies concerned with environmental protection will recognize the air pollution reduction potential of CHP over conventional fossil-fueled plants that operate at much lower efficiency levels. Still, the current emphasis on government debt reduction will result in considerable scrutiny of expanded taxpayer-funded programs.

Utilities and regulators. Traditional electric utilities will likely not support a federal EPS that supports CHP unless their rate recovery procedures are adjusted to ensure that they will be held harmless from the loss of profits due to customer owned generation and the erosion of utility sales (i.e., “decoupling”). Utilities have historically discouraged distributed generation because it erodes their revenue base (Freedman, 2003; Brown et al., 2009a). Only 10 states and the District of Columbia have passed electricity decoupling rules.[38] Electric utilities might be supportive of including CHP in a national portfolio standard if they were convinced that a national standard was inevitable. They might see CHP as a more predictable and cost effective source than some other options.

Natural gas suppliers would gain market share if CHP projects were to grow rapidly. Unlike electric utilities, they might be expected to support a federal EPS that qualified CHP projects.

The position of utility regulators regarding CHP eligibility is unclear and would depend on the balance of fuels in the state, air quality issues, and whether or not a state’s electricity suppliers are traditionally regulated or operating in a competitive market. Distributed power generation

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[38] The Database of State Incentives for Renewable Energy, www.dsireusa.org/

has the potential to move emissions sources closer to population centers, and these local effects in nonattainment regions could result in disapproval by regulators.

Table 2.11. Stakeholder Assessment of a Federal EPS with CHP

Stakeholder	Pros	Cons	Dominant Position
Industrial Firms and Facilities	Will reduce energy bills and possibly create profits from electricity sales	Facilities without tax liabilities would not benefit as much as tax-liable facilities	Favorable
CHP Developers and Equipment Suppliers	Will grow sales and business	None	Favorable
Electric Utilities	In the 10 states with decoupling, CHP might be supported	In the 40 states without decoupling, CHP would erode utility profits	Unfavorable
Natural Gas Utilities	Natural gas suppliers would gain market share	None	Favorable
Energy Service Companies	Consumer-sited generation is a growth area for ESCOs	Less success of ESCOs in penetrating the industrial market	Favorable
Local, State, and Federal Government	Prospects of growing the U.S. industrial base would lead to policy support by many government agencies	Emphasis on federal debt reduction will cause scrutiny of proposals to expand government subsidies	Favorable
Regulators and Public Utility Commissions	Will likely be most supportive in the 10 states with decoupling	Will likely be unfavorable in the 40 states without decoupling	Unfavorable
General Public/Consumers	Citizens in states with key CHP growth industries and manufacturers may be most supportive	Federal debt will cause skepticism	Mixed
Environmentalists	Emission reductions of CHP systems over conventional fossil power	Local effects in nonattainment regions could be an issue	Favorable

2.2.5 Policy Evaluation

Appropriateness of the federal role. The U.S. has a long history of using investment tax credits to encourage the growth of CHP. Shortly after enacting PURPA in 1978, Congress passed a limited term investment tax credit (ITC) of 10% and a shortened depreciation schedule for CHP systems. PURPA and the tax incentives spurred the growth of CHP from an installed capacity of 12 GW in 1980 to 66 GW in 2000 (across the industrial, commercial and institutional sectors) (Shipley et al., 2008). ITCs for CHP projects were authorized again in the Energy Improvement and Extension Act of 2008. Congress passed this law on October 3, 2008, establishing a new 10% ITC for CHP systems. It applies to the first 15 MW of capacity for projects up to 50 MW in size.[39] The credits began in 2008 and are currently scheduled to continue through 2016. Senators Feinstein and Merkley have supported an option to increase CHP ITCs to 30%. This has been supported by the U.S. Clean Heat and Power Association, which advocates that this expanded tax credit should be applied to the first 25 MW of a project of any size. Other proposals (Tonko – H.R. 4751) have considered establishing a 30% ITC for highly-efficient CHP projects.

The Energy Independence and Security Act (EISA) of 2007, signed into law on December 19, 2007, created and enhanced a number of programs related to industrial waste heat (EIA, 2008b, p. 16). For example, Sections 451, 452, and 453 direct the EPA to survey all major industrial combustion sources and create a registry of the quantity and quality of waste energy at each site. DOE may provide up to 50% of the funding for a feasibility study to determine whether the waste heat can be captured with a 5-year payback. In addition, EISA authorizes DOE to spend nearly $200 million on industrial energy efficiency R&D partnerships. In addition, DOE has established eight regional CHP application centers to provide local technical and educational assistance for CHP development.

Several recent U.S. House and Senate bills have proposed establishing a federal EPS. The American Clean Energy and Security Act of 2009 (ACESA) would require electricity providers to meet a combined renewable energy and energy-efficiency standard, gradually increasing to 20% by 2020. Up to 5% can be achieved through energy efficiency, or with a governor's petition, up to 8% for utilities in that state. The American Clean Energy Leadership Act of 2009 (ACELA) would require electricity providers to meet a combined 15% renewable energy and energy-efficiency standard by 2021; up to 4% can be met through energy efficiency in a given state if a governor petitions for it.

Broad applicability. EPS are generally applied only to large investor-owned electric utilities, although there are exceptions and economy-wide participation is most efficient. A federal EPS that qualifies CHP would have broad applicability, given that 36 states do not currently allow CHP to participate to meet the goals of either an RPS or an EERS.

Significant potential benefits. A federal EPS that qualifies CHP could be a driver for employment, manufacturing, and environmental quality. Consumers will benefit from reduced costs if efficiency is cheaper to supply than other sources and the savings are passed through to them. Many of the benefits, such as energy security and climate change mitigation will accrue to society as a whole.

ACEEE estimated a benefit-to-cost ratio of 2.6 for a national EERS of 0.75% per year (after a two year ramp-up period) over the period 2007-2020 (Nadel, 2006). While CHP was included in this analysis, it did not play a large role. Although efficiency has been shown to have levelized costs equal or less than that of other supply options, new programs are often developed, with associated costs, to help promote efficiency efforts when programs are challenged by low participation levels (NAPEE, 2007a) and other documents. There is not enough state

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[39] http://www.uschpa.org/files/public/ITCjust.pdf

experience with EERS to fully understand consumer benefits or costs, or to understand the distribution of the costs and benefits in terms of who gains, who loses, and how this changes over time. In addition, previous national studies of efficiency potential for the U.S. show that goals of the current EERS often discussed (15% electricity and 10% natural gas by 2020) are not likely to occur unless under a very aggressive policy scenario such as a federal EERS.

Based on a GT-NEMS analysis of this policy option, significant energy savings could be achieved. The modeling reflects a federal EPS that qualifies CHP and includes a 30% ITC, extended to 2035 in our main case, and to 2020 in our sensitivity analysis. It also assumes an expanded DOE R&D program focused on CHP technologies and spending an additional $10 million annually for ten years to cost share the R&D of research entities. Because of the significant expansion of CHP facilities across the country and the additional R&D investment focused on CHP technologies, the NEMS analysis also assumes that CHP technologies improve their efficiency at a rate that is 0.7% per year more rapidly than in the reference case. (See Appendix C for further details.)

Figures 2.13 and 2.14 illustrate the magnitude of CHP expansion as a result of the EPS with CHP policy. The total electricity generation from CHP facilities grows nearly twice as rapidly under the EPS policy case, compared with the reference case forecast. In 2035, nearly 600 billion kWh of industrial CHP electricity generation is produced, compared with 363 billion kWh projected in the EIA reference case for the same year.

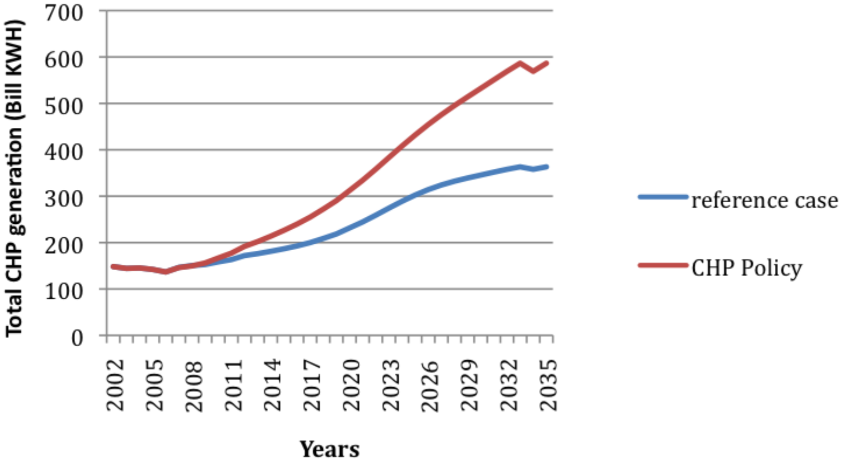


Figure 2.13. Total Industrial CHP Generation as the Result of an EPS with CHP Policy

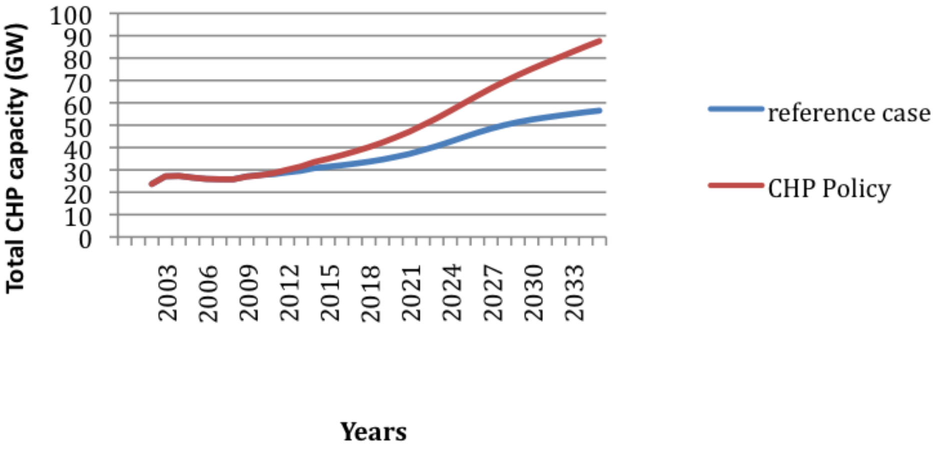
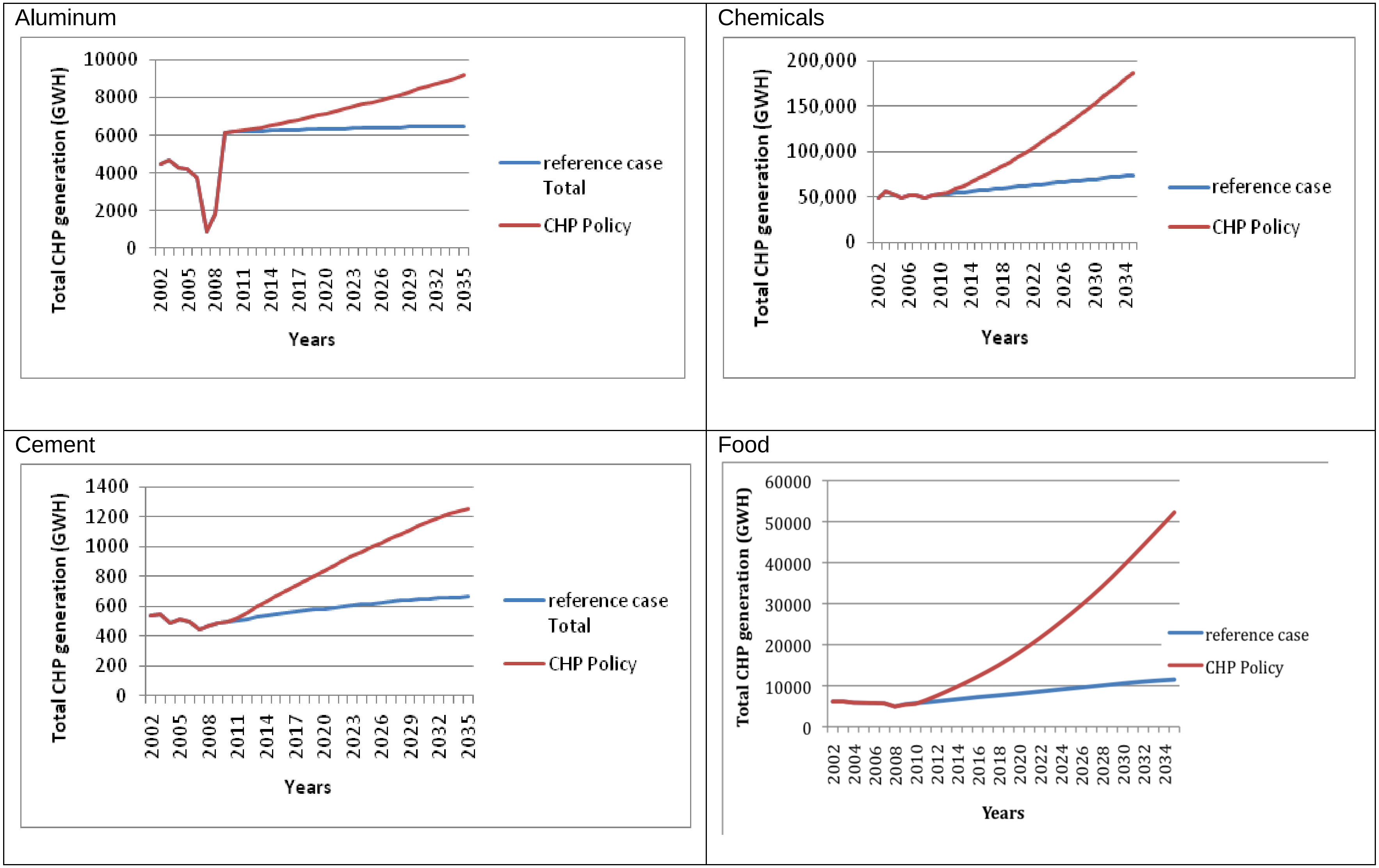


Figure 2.14. Total Industrial CHP Capacity as the Result of an EPS with CHP Policy

In the reference case, the total CHP industrial capacity almost doubles from 28 GW in 2010 to approximately 55 GW in 2035. When the EPS policy is modeled, CHP industrial capacity more than triples over this same period, increasing to 90 GW. This is a proportionately larger increase than is prescribed by the most recent economy-wide DOE goal for CHP.

A similar acceleration in CHP industrial capacity was described in our assessment of Output-Based Emissions Standards. It is important to keep in mind that these two policies overlap to an unknown but likely considerable extent; thus, if both policies were implemented simultaneously, their overall impact would be much less than the sum of their individual impacts. As with the OBES policy, the CHP growth trajectories estimated for the EPS policy may be slowed by the long lead times needed to bring new CHP systems online, frequently on the order of three to five years. In some cases, businesses have developed projects that are rapidly implementable given the right policy landscape; in other cases, a lead time of several years would be required.

Figure 2.15 illustrates that the accelerated market penetration of CHP technology results in highly variable increases in CHP-produced electricity generation across different industries. CHP in the chemicals and pulp and paper industries generate approximately 50 billion kWh of electricity today, and both are seen as accelerating under the policy scenario – especially the chemicals industry, which generates almost 200 billion kWh by 2035, compared with a more modest expansion for pulp and paper, which grows to about 75 billion kWh. The food industry, on the other hand, starts at only about 5 billion kWh today, but grows to more than 50 billion kWh in 2035, nearly matching the pulp and paper industry.

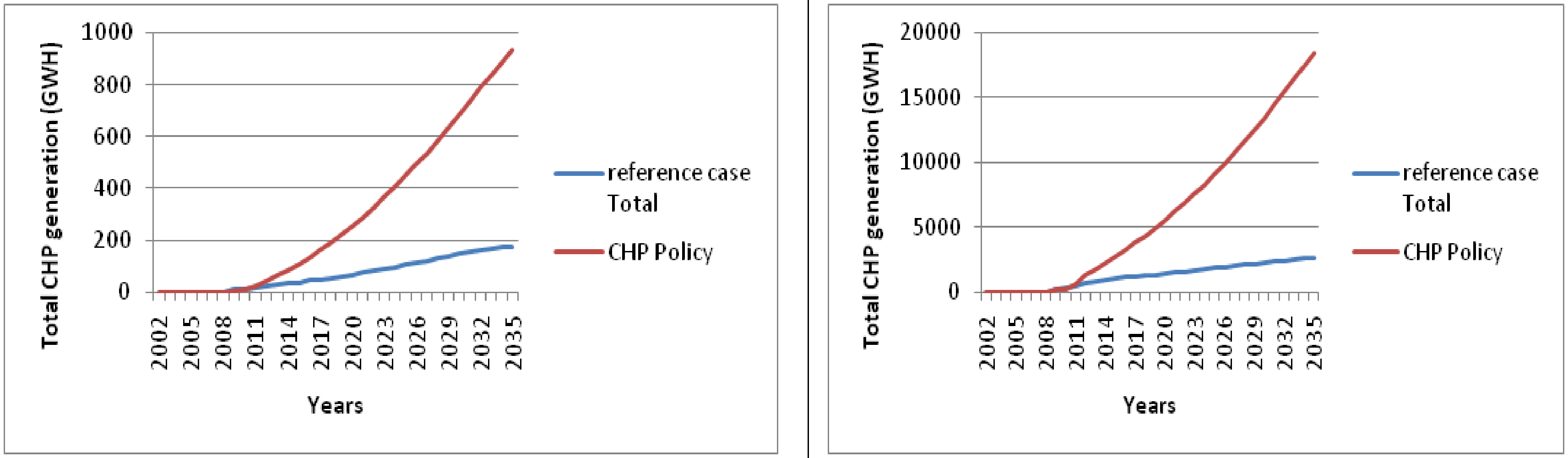

Aluminum

Chemicals

Cement

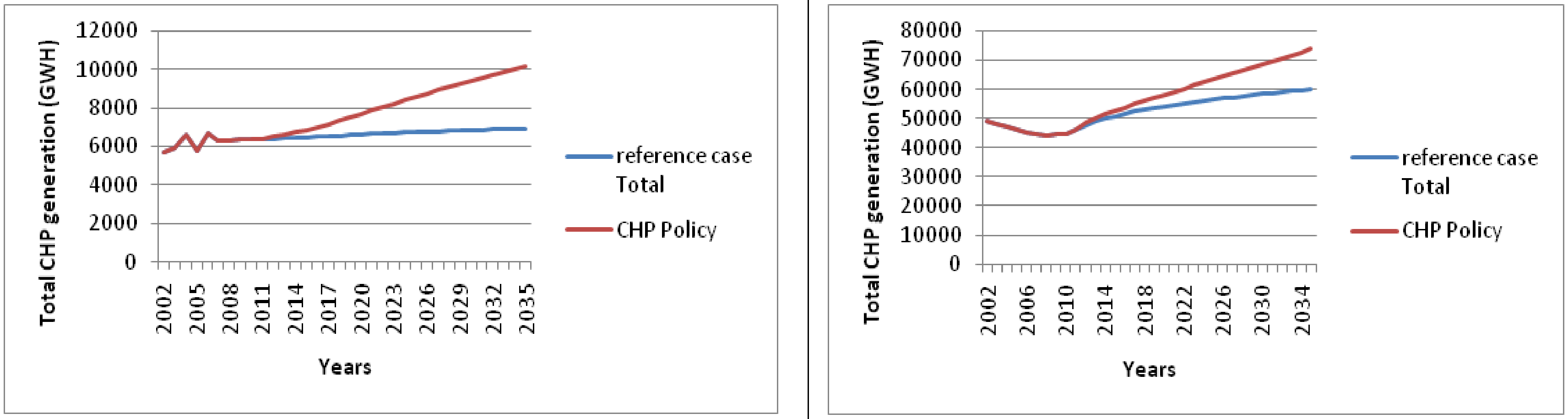
Food

Figure 2.15. Total CHP Generation in Eight Industries



Glass

Oil and Gas Mining



Iron and Steel

Paper

Figure 2.15. Total CHP Generation in Eight Industries (continued)

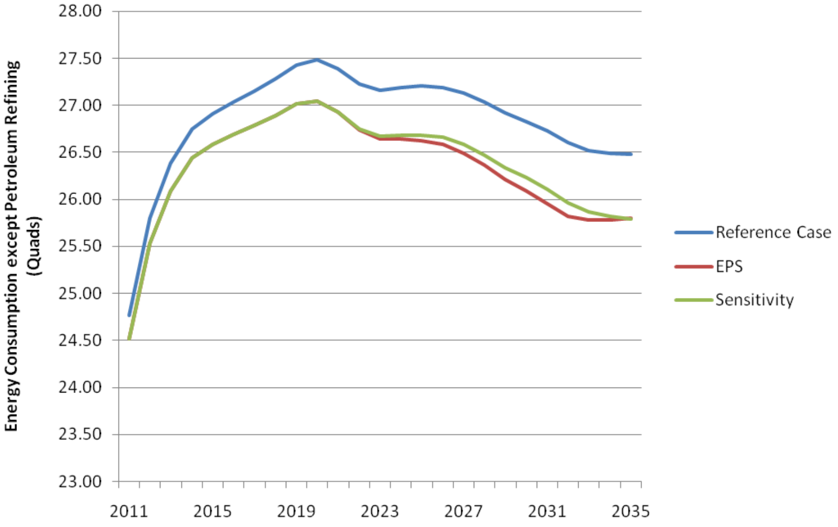


Figure 2.16. Total Industrial Energy Consumption (TBtu): Reference Case vs. the EPS Scenario and Sensitivity

These findings are comparable to an analysis by ICF International, which evaluated the projected impact on CHP development of the introduction of a 30% ITC for high efficiency CHP (projects with overall efficiencies of 70% lower heating value or greater). The analysis was limited to traditional topping cycle CHP systems utilizing reciprocating engines, gas turbines or microturbines (bottoming cycle CHP opportunities, sometimes referred to as waste heat recovery or recycled energy, were not reviewed). The 30% ITC for highly efficient CHP increases CHP deployment by more than 60% over a no-ITC baseline (1,600 additional MW between now and 2017).

The federal EPS with CHP is first evaluated from a private-sector, industrialist's perspective; if the business case cannot be made for the required private-sector leverage, then this policy will not achieve its goals. A detailed financial analysis of each policy is not feasible; however, assessing the up-front private-sector investment costs relative to the stream of energy-expenditure reductions provides a basis for approximating the overall cash-flow attractiveness of the policy to industrialists.

Table 2.12 presents the results of the analysis in terms of energy consumption and energy expenditures from the perspective of industrialists, utilizing a 7% discount rate. It is estimated that nearly 620 TBtu could be saved in 2035, representing 2.3% of the business-as-usual industrial energy consumption in that year (26,480 TBtu, excluding refining). By 2035, the estimated savings rise to nearly 1,500 TBtus, representing a reduction of 5.6% of the business-as-usual industrial energy consumption in that year. Over the lifetime of equipment installed through 2055, an accumulation of 34 quads of energy would be saved.

Table 2.12. Federal EPS with CHP Policy Option from the Industrialists' Perspective*

Year	BAU Energy Consumption**	Annual Energy Savings ***			Cumulative Energy Savings****		Annual Private Cost	Cumulative Private Cost
	Trillion Btu	Trillion Btu	$M (2008)	%	Trillion Btu	$M (2008)	$M (2008)	$M (2008)
2011	24,770							
2020	27,480	620	3,060	2.3	4,310	23,860	220	2,610
2035	26,480	1,480	4,000	5.6	20,150	76,320	170	5,130
2055	--	--	--	--	34,210	114,300	--	5,130

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

** Reference case industrial energy consumption excludes refining. These Business-as-Usual (BAU) estimates are output from the GT-NEMS industrial module. They differ slightly from the *AEO 2010* (EIA, 2010) published estimates, which are produced from a fully integrated NEMS analysis.

*** The percentages refer to the percent of energy use and carbon dioxide emissions from industrial energy use.

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

These energy savings come at a private investment cost of $220 million in 2020 and $170 million in 2035, considerably less than the value of the energy saved – $3.1 and $4.0 billion in 2020 and 2035, respectively. This suggests a highly positive NPV from the industrialists' perspective.

At the same time, the expansion of CHP systems saves energy by reducing the need for purchased electricity, which is generated less efficiently and is more carbon intensive than co-generated electricity. This shift to CHP-produced electricity results in 498 TBtu of primary energy saved in 2020 and 1,471 TBtu in 2035. The CHP systems also allow an increase in total electric sales to the grid, which displaces the energy that would otherwise have been required to generate this electricity, mostly from inefficient coal plants. These savings are estimated to amount to 180 TBtu of primary energy in 2020 and 830 TBtu in 2035. In calculating the primary energy from estimates of electricity generation, we consider the fact that the *AEO 2010* reference case projects a slight improvement in overall efficiency of electricity generation, increasing from 31.6% in 2008, to 32.0% in 2020, and 33.1% in 2035 (EIA, 2010).

If the 30% investment tax credit for CHP systems is designed to end in 2020, the cumulative energy savings from this policy would be reduced by approximately 20% (from 34 to 27 quads). The savings are identical through 2020, but the rate of CHP-generated energy savings declines after that, since installation costs rebound to their higher levels as modeled in the EIA reference case forecast.

The allocation of CHP electricity generation for on-site use versus sales to the grid is illustrated for the chemicals industry in Figures 2.17 and 2.18. As with the paper industry, it appears that electricity generated for use at chemical facilities becomes saturated in the 2030 time frame, after which sales of electricity to the grid experience a rapid expansion.

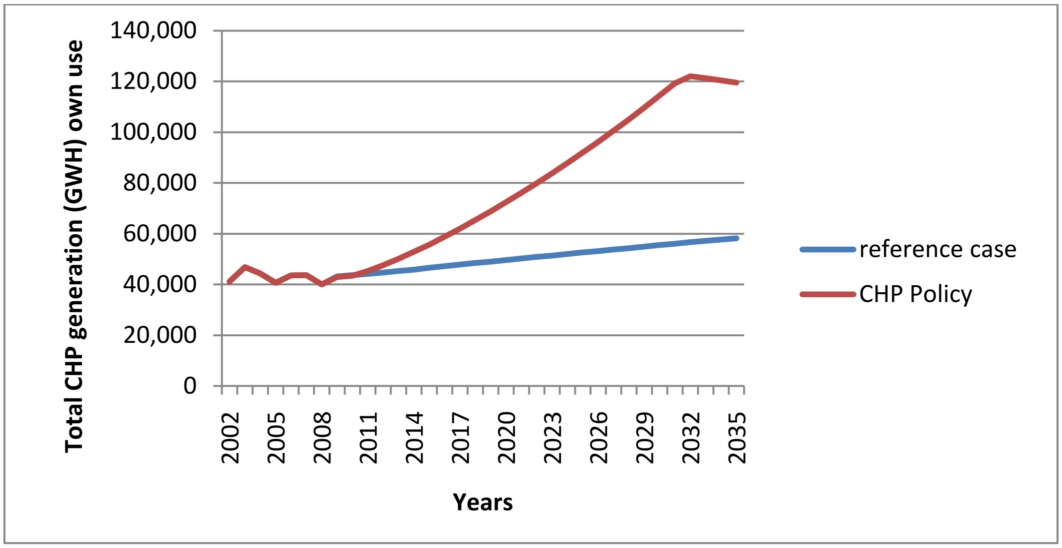


Figure 2.17. CHP Generation by the Chemicals Industry for Its Own Use

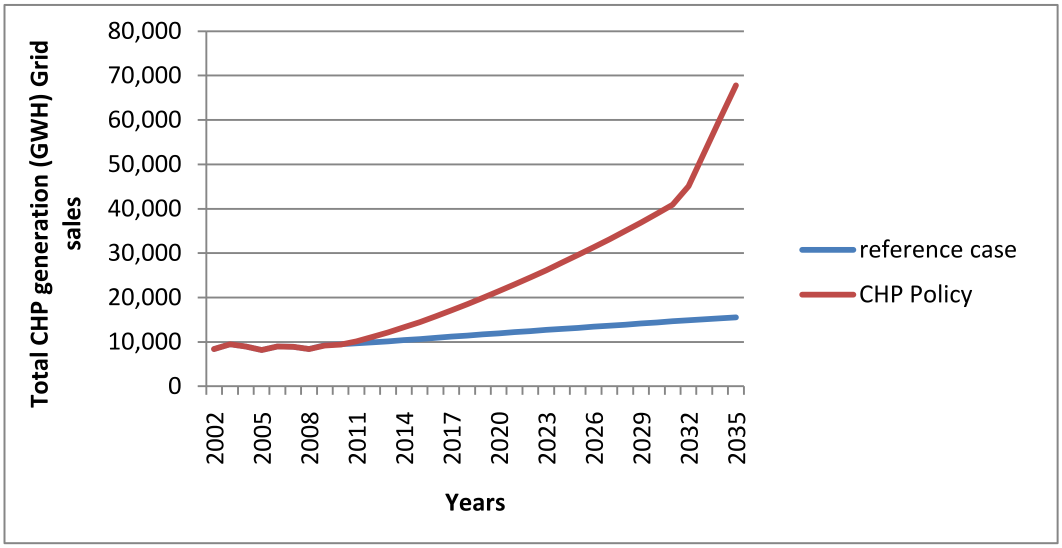


Figure 2.18. CHP Generation by the Chemicals Industry Sold to the Grid

Technology readiness. It is likely that the learning curve from increased production of CHP systems and from an expanded R&D effort could improve the performance of CHP systems. We assume that the overall efficiency of CHP systems would be improved by 0.7% annually, under the federal EPS policy, as the result of learning curves and greater R&D investment. We further assume that the performance improvement would occur without any additional increase in installation costs. CHP systems are typically identified by the type of prime mover deployed: reciprocating engines, combustion or gas turbines, steam turbines, microturbines, and fuel cells

(Shipley et al., 2008).[40] To illustrate the influence of a 0.7% annual improvement, consider the performance of a 25 MW gas turbine CHP system, according to the GT-NEMS:

- In 2008, a new CHP system operated at a 71% efficiency level, and in the reference case its efficiency improves to 72% by 2020 and to 74% by 2035.
- With a federal EPS, an ITC, and expanded R&D, the same system is assumed to improve to 76% efficiency in 2020 and 84% in 2035.

Altogether, the R&D expenditure is estimated to be responsible for 19% of the energy saved by the EPS with CHP policy.

Cost Effectiveness. Energy efficiency, in general, and CHP in particular, helps to stretch available energy resources while providing retail electricity price relief to manufacturers and consumers (Elliott, 2006). Brown and Baek (2010), for example, have shown in an analysis of a federal RPS policy using GT-NEMS modeling, that the escalation of electricity prices resulting from an RPS could be moderated by the simultaneous implementation of policies to promote energy efficiency. Laitner, Ehrhardt-Martinez, and Prindle (2007) estimate that approximately 25% of total electricity use can be saved at an average cost of $0.03/kWh whereas new generation sources cost $0.05/kWh.

Table 2.13 characterizes the ability of the public sector to leverage energy savings in the industrial sector with a federal EPS that qualifies CHP. Through 2035, cumulative public expenditures are estimated to be $11 using a 3% discount rate. These expenditures, in turn, lead to energy savings of 34,200 TBtus. This yields an energy leveraging ratio of 3.0 TBtu/million $2008 or 3.0 MMBtu for each $2008 dollar expended.

Table 2.13. Leveraging of Energy Savings from Cumulative Public Investments in a Federal EPS with CHP*

Year	Public Costs				Cumulative Energy Savings	Leveraging Ratio*
	Million $2008				TBtus	MMBtu/$
	Annual Administration Cost	Annual Investment Cost	Total Annual Costs	Total Cumulative Costs		
2020	10.13	514	524	4375	4,306	--
2035	6.26	313	319	11729	20,149	--
2055	--	--	--	11729	34,209	3

*Ratio of cumulative energy savings in MMBtu to cumulative public costs in $2008. Present value of public costs was calculated using a 3% discount rate.

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[40] http://www1.eere.energy.gov/industry/distributedenergy/chp_basics.html

Table 2.14 presents the ability of the public sector to leverage carbon dioxide savings in the industrial sector with this same policy. In 2035, public expenditures lead to CO_2 savings of 88 million metric tons, representing 5.8% of the business-as-usual CO_2 emissions in the industrial sector that year. Over the lifetime of the equipment installed by 2035 as a result of this policy change, 1,990 million tons of CO_2 emissions are avoided, yielding a carbon-dioxide leveraging ratio of 0.17 tons per dollar.

Table 2.14. Leveraging of CO_2 Emission Reductions from Cumulative Public Investments in a Federal EPS with CHP*

Year	Public Costs	CO_2 Emission Reductions			Leveraging Ratio*
	Million $2008	Million Metric Tons CO_2			
	Cumulative Costs	Annual MMT Saved	% Annual Emissions	Cumulative MMT Saved	Metric Tons/$
2020	4374.6	34.7	2.2	240	--
2035	11728.7	88.0	5.8	1,160	--
2055	11728.7	--	--	1,990	0.17

*Ratio of cumulative emission reductions in million metric tons to cumulative public costs in $2008. Present value of public costs was calculated using a 3% discount rate.

Figure 2.19 shows the leveraging ability of the EPS with a 25-year ITC (shown with solid markers) compared with the sensitivity case of the EPS with a 10-year ITC ending in 2020 (shown with open markers). The leveraging of energy savings per public dollar is shown on the left and the leveraging of carbon dioxide emission reductions is shown on the right. For both the energy and CO_2, the leveraging metrics are greater for the 10-year ITC, reflecting the lower level of free ridership per dollar of public expenditure for the short-term policy.

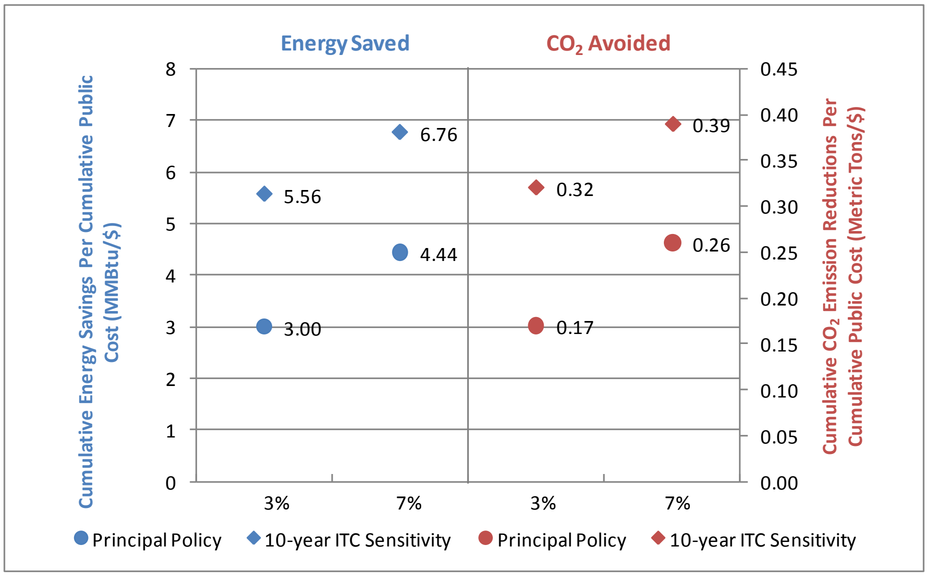

Figure 2.19. Energy and CO_2 Leveraging for a Federal EPS with CHP

Further benefits accrue to society as a whole from increased energy efficiency in the industrial sector and reduced energy consumption from the electricity sector. Estimates of the reduction of criteria pollutant emissions are shown in Table 2.15 and Figure 2.20. Of the four criteria pollutants considered, SO_2 emission reductions deliver the greatest human health and environmental benefits, totaling almost $35 billion in avoided damages through the year 2055, as the result of a federal EPS with CHP. In total, these emissions reductions represent additional significant benefits of a federal EPS with CHP, with savings of more than $38 billion. The avoided costs of NO_x, SO_2, PM_{10}, and $PM_{2.5}$ due to the energy-efficiency measures are calculated using a 3% discount rate. The present value of avoided damages for all four local pollutants drops to less than $20 billion using a 7% discount rate.

Table 2.15. Value of Avoided Damages from Emissions of Criteria Pollutants from a Federal EPS with CHP (Billion $2008)*

	NO_x		SO_2		PM_{10}**		$PM_{2.5}$	
	Annual	**Cumulative**	**Annual**	**Cumulative**	**Annual**	**Cumulative**	**Annual**	**Cumulative**
2020	0.055	0.483	0.681	3.73	0.004	0.019	0.062	0.352
2035	0.048	1.42	1.29	20.3	0.007	0.109	0.118	1.88
2055		1.88		32.6		0.176		2.99

*Values are based on the National Research Council report estimating damages from energy production and consumption in the U.S. (NRC, 2010). Excludes avoided pollutant damages from petroleum and coal for industrial heat. Present value of avoided damages was calculated using a 3% discount rate.
**Excludes PM_{10} from the production of industrial heat.

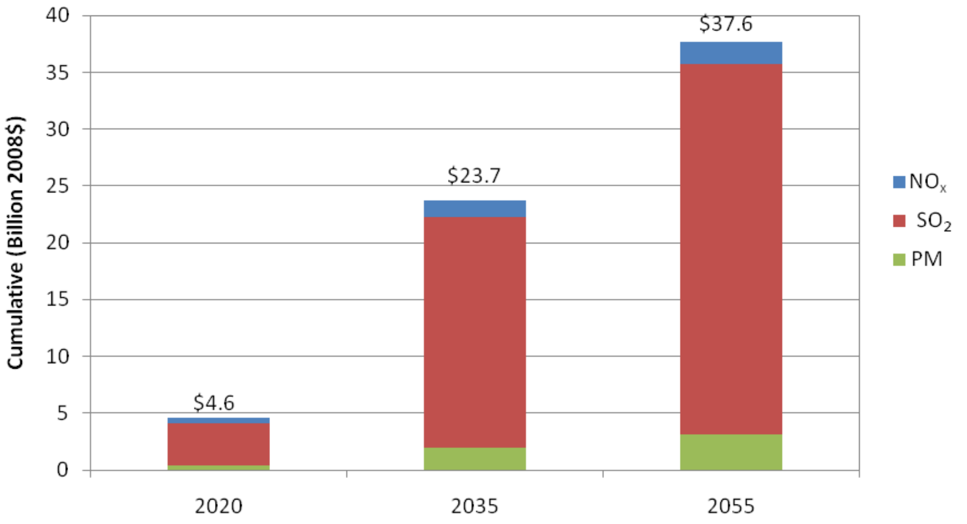

Figure 2.20. Value of Avoided Damages from Criteria Pollutants for an EPS with CHP

Next we estimate the B/C ratios when the value of avoided damages from CO_2 and the four criteria pollutants are included (Tables 2.16a and 2.16b). We determine the economic value of reduced CO_2 emissions in each year by multiplying the decrement in emissions by the “social cost of carbon” (SCC) for that year. The SCC is defined as an estimate of the monetized damages caused by each incremental ton of CO_2 emitted. The SCC used in this analysis is central value estimates of the U.S. Government Interagency Working Group on the Social Cost of Carbon (EPA, 2010a). In this report, the central value SCC estimates ranged from $23/metric ton of CO_2 in 2011 to $34/metric ton and $47/metric ton in 2030 and 2050, respectively (all values are in $2008). Consideration of these emissions benefits raises the B/C ratio for this policy to 15.3 with a 3% discount rate and 11.9 with a 7% discount rate. It should be noted that these estimates do not include savings from the expansion of CHP systems in the refining industries, or the benefits to grid reliability that expanded CHP would provide to ratepayers.

Table 2.16a. Total Social Benefit/Cost Analysis of a Federal EPS with CHP*

	Cumulative Social Benefits (Billions $2008)				Cumulative Social Costs (Billions $2008)			Benefit/Cost Analysis	
Year	**Energy Savings**	**Value of Avoided CO_2**	**Value of Avoided Criteria Pollutants**	**Total Social Benefits****	**Public Costs**	**Private Costs**	**Total Social Costs****	**Social B/C Ratio**	**Net Societal Benefits (Billions $2008)**
2020	29.1	5.21	4.58	38.9	4.4	3.1	7.5		
2035	132	23.2	23.8	179	11.4	8.4	19.8		
2055	226	38.5	37.7	303	11.4	8.4	19.8	15.3	283

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

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

Table 2.16b. Total Social Benefit/Cost Analysis of a Federal EPS with CHP* (7% Discount Sensitivity)

	Cumulative Social Benefits (Billions $2008)				Cumulative Social Costs (Billions $2008)			Benefit/Cost Analysis	
Year	**Energy Savings**	**Value of Avoided CO_2**	**Value of Avoided Criteria Pollutants**	**Total Social Benefits****	**Public Costs**	**Private Costs**	**Total Social Costs****	**Social B/C Ratio**	**Net Societal Benefits (Billions $2008)**
2020	23.9	4.30	3.68	31.8	3.67	2.61	6.28		
2035	76.3	13.5	13.6	103	7.70	5.13	12.8		
2055	114	19.6	19.2	114	7.70	5.13	12.8	11.9	140

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

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

Table 2.17 provides a summary of the social benefit/cost ratios for the EPS with a 25-year ITC and the EPS with a 10-year ITC, analyzed at both the 3% and 7% discount rates. This sensitivity analysis highlights the greater societal benefits of the 25-year ITC, but it also shows that the shorter ITC has a more attractive benefit-cost ratio because of the lower level of free ridership.

Table 2.17. Social Benefit/Cost Analysis of Policy and Discount Rate Sensitivities

		Alternative Discount Rates	
		3%	**7%**
EPS 25-year ITC	Benefit/Cost Ratio	15.3	11.9
	Net Societal Benefits (Billions $2008)	283	140
EPS 10-year ITC	Benefit/Cost Ratio	16.3	12.3
	Net Societal Benefits (Billions $2008)	212	111

Administrative feasibility. Because there is extensive policy experience with RPS and EERS across the nation, a federal EPS qualifying CHP can be assumed to be administratively feasible. The federal role includes developing and enforcing regulations, providing incentives, establishing M&V protocols, and expanding its R&D program. These actions have been taken for other areas, and are not expected to be significantly burdensome. Nevertheless, the special complexities associated with qualifying energy savings from industrial CHP projects must be noted. In particular, developing protocols to credit thermal energy as well as electricity and assessing system energy efficiencies relative to business-as-usual technologies are complicated issues with competing stakeholder positions that must be negotiated.

Additionality. The efficiency provisions in a federal EPS would set a target, goal, or requirement for efficiency to meet compared to the consumption forecast. Other policies could also be used to promote greater investment in industrial CHP, such as output-based emissions standards. If such standards were implemented nationwide, the number of free riders receiving tax credits for CHP systems as part of an EPS might drive down the cost-effectiveness of the EPS policy.

2.2.6 Summary

Significant improvements in industrial energy efficiency could result from the promulgation of a federal EPS that qualifies CHP, particularly if the policy is accompanied by financial incentives and M&V protocols. Table 2.18 summarizes the key strengths and weaknesses of this policy.

Table 2.18. Overall Assessment of a Federal EPS with CHP

	Strengths	Weaknesses	Time Horizon*
Federal Energy Portfolio Standard with Combined Heat and Power	Broad Applicability, Cost-Effectiveness, Significant Potential Benefits	Free Riders; Need to develop M&V Protocols; Stricter Standards Require Improved Technologies	Short to Long

*Time horizons when significant energy savings begin: short (five years or less), medium (five to 10 years), and long (more than 10 years).

It is estimated that the benefits of a federal EPS that qualifies CHP outweigh their costs several times over and offer a positive cash-flow investment opportunity for industrial facilities. With attention to the measurement and verification of savings, an EPS can support low-cost savings through credit trading. Evidence indicates that CHP would be among the least-cost industrial energy-efficiency options. When the full array of climate change and air quality benefits is considered, the return on the public investment ramps is even greater.

Opposition to a federal EPS will likely be grounded in issues of equity including the subsidies provided to "free riders," the reduced profits of electric utilities in states that have not decoupled profits from sales, the redistribution of environmental emissions, and federalist issues. A modest improvement in the energy efficiency of CHP systems is also assumed, which critics might question. However, learning curves driven by the expansion of production and R&D have been shown repeatedly to deliver technology performance improvements.

3 Policy Options to Address Information Gaps

Each of the three information and workforce training policies described in this chapter would build on the success of DOE's Industrial Assessment Center program. Currently, 26 IACs located at engineering schools across the U.S. provide funding and training for engineering students to complete energy assessments at local industrial facilities. After an IAC team performs an initial survey of eligible industrial plants, a one or two day site visit is conducted to take engineering measurements as a basis for energy saving recommendations. The IAC team subsequently provides the facility with a detailed report of the analysis and estimates of performance and payback times. Follow-up phone calls are made to the facility manager to verify the implementation status of specific recommendations, but no further implementation assistance is provided.

Over 14,000 assessments and 100,000 recommendations have been conducted for small to mid-sized industrial facilities (Trombley, Elliott, and Chittum, 2009). As history has shown, investments in the IAC programs yield significant energy savings at high benefit-to-cost ratios. For example, from 2000 to 2009, every $1 invested in the IAC program has been leveraged to generate approximately $5.5 in energy savings per year for industrial facilities (IAC database, 2010). In 2005, $5 million in IAC funding resulted in over $25.5 million in newly implemented energy and dollar savings (IAC fact sheet, 2006).

In addition to technical assistance provided to the industrial sector, these assessments have also trained a significant number of next-generation engineers skilled in energy-efficient industrial facility operation. As of 2009, there were over 2,745 fully trained IAC alumni, where more than 50% have applied their learned energy skills in their careers (Nimbalkar, et al., 2009). Moreover, with 120-180 students completing the program each year, IACs are effectively supplying the workforce with engineers trained in identifying energy-efficient industrial solutions.

Through successfully enhancing industrial workforce development, facilitating reduced industrial energy consumption, and enhancing the diffusion of new energy-efficient technologies into the industrial sector, the IAC program has been a key industrial resource. However, due to competing fiscal priorities, funding for IAC assessments has decreased from $8 million in 2000 to $4 million in most recent years (Elliot and Kaufman, 2009). Moreover, similar funding at $4 million is forecasted in future years.

The success of each of the following three policies would depend on reinvigorated and expanded roles for IACs to more fully capitalize on energy-efficiency opportunities in the industrial sector.

3.1 Superior Energy Performance Program

Policy Option: Establish incentives, such as a production tax credit for energy-efficiency savings, energy-efficiency credits for compliance with energy portfolio requirements, grants to subsidize initial certification costs, and recognition programs, to increase participation in the Superior Energy Performance program.

3.1.1 Policy Summary

The Superior Energy Performance[41] (SEP) program, a result of cooperative development efforts by U.S. industry and the federal government, has an overall goal to provide industrial facilities with a roadmap for achieving continual improvement in energy efficiency while supporting global competiveness.[42] SEP seeks to foster a culture of continuous improvement in energy efficiency within a transparent system that validates energy performance improvements and management practices and also provides a verified record of savings. The strong measurement and verification (M&V) protocol encompassed within SEP affords an effective method to validate energy savings from efficiency improvements. The SEP M&V protocol gives a best practice methodology to 1) verify energy savings resulting from SEP implementation; 2) quantify energy savings from specific measures or projects; and 3) track energy performance improvements over time for the entire facility.[43] Through the strategic plan to continuously identify, measure, and verify energy-efficiency improvements, SEP creates a company-wide culture of sustainable and efficient energy stewardship. SEP program elements are currently being piloted in manufacturing facilities in Texas. The national launch of SEP is anticipated in Fall 2011.[44]

The federal government could establish strong incentives for industrial facilities to implement the SEP program that include 1) a federal production tax credit for energy-efficiency savings of facilities that become SEP certified; 2) the ability of verified energy savings to be counted as an energy-efficiency credit in compliance with meeting energy efficiency or renewable energy portfolio requirements; 3) an energy-efficiency grant for 30% of eligible certification costs; and 4) recognition programs. Federal incentives included in this policy could continue for 10 years to encourage adoption throughout large facilities within the industrial sector.

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[41] At the Clean Energy Ministerial in July, 2010, U.S. Secretary of Energy Steven Chu announced the launch of the Global Superior Energy Performance (GSEP) Partnership. GSEP is the global expansion of the Superior Energy Performance (SEP) program for industrial facilities, in addition to a broadening of its application to commercial buildings.

[42] http://www.superiorenergyperformance.net/pdfs/SEP_Overview.pdf

[43] http://www.superiorenergyperformance.net/MandV.html

[44] See footnote 42 above

3.1.2 Elements of the Recommended Policy Approach

Because SEP leverages energy management practices with M&V protocols to achieve sustainable and verifiable energy performance improvements, the federal government could encourage widespread adoption of SEP in the industrial sector to generate significant energy savings. Specifically, the federal government could establish incentives that include the following:

- **Federal production tax credit for energy-efficiency savings of facilities that become SEP certified.** Consistent with existing federal renewable energy production tax credits (PTC), SEP facilities could receive a per-kilowatt-hour (kWh) tax credit for verified energy savings. For energy savings from non-electricity sources, an equivalent kWh, based on source energy, could be determined so that all fuel source energy savings are eligible for receiving the tax credit. A PTC rate of $0.011/kWh saved would be consistent with existing federal PTCs offered for renewable sources.[45] PTC eligibility for industrial facilities would occur for the first three years of their participation in the SEP program.
- **Allow verified energy savings of facilities that are SEP certified to be counted as an energy-efficiency credit in compliance with Energy Efficiency Resource Standard (EERS) or Renewable Energy Standard (RES) requirements.** The ability to count savings as an efficiency credit places a market value on energy efficiency, particularly in an environment where renewable and efficiency credits are traded. Consequently, energy efficiency can then generate top-line revenue growth, while continuing to increase bottom-line profits. As such, energy efficiency could better compete with other investments for corporate attention and capital. Similar to the manner in which the federal PTC would be determined, savings from all energy sources would be eligible to be counted as an efficiency credit by determining an equivalent kWh. While there is not an existing energy portfolio trading program in place on the national level, Pennsylvania and Nevada, for example, currently consider energy-efficiency measures as a part of portfolio standard compliance.
- **Provide an energy-efficiency grant for 30% of eligible certification costs.** Similar to the grant authorized in the American Recovery and Reinvestment Act (ARRA, 2009) for 30% of eligible expenditures related to the installation of renewable technologies, the federal government could refund 30% of eligible costs associated with SEP certification to facilities. These costs would include audit costs for certification, in addition to the facility's cost of training one certified energy manager or energy management practitioner to facilitate SEP implementation. We estimate total costs of $25,000, such that a one-time grant for the initial SEP certification would be approximately $7,500 per industrial facility that adopts SEP and could be capped at $10,000 per facility.
- **Establish recognition program for SEP certified facilities.** Following the lead of successful recognition programs, such as *Save Energy Now* LEADER Companies,

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[45] http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=US13F&re=1&ee=1

ENERGY STAR® for Industry, and *Save Energy Now* Energy Champions, SEP awards could identify facilities as having demonstrated a strong commitment to efficient energy management. This would drive industry participation and innovation.

Other incentives could be considered as an approach to increase SEP adoption; however, the aforementioned incentives were determined by the authors to be the most feasible to implement and administer. Other possible incentives that could be used, but are not examined or suggested in this policy option include an accelerated tax depreciation schedule for investments, carbon allowances to reward a commitment to energy efficiency under a cap-and-trade program, or in the presence of a federal carbon tax system, a reduced carbon tax for industrial facilities that become SEP certified. If carbon allowances are utilized as an incentive, the amount should be sufficient to encourage SEP adoption, but not so large as to compromise the overall integrity of the carbon emissions cap.

3.1.3 Policy Experience

In 2000, Denmark and the U.S. initiated the development of energy management standards, such as those included in SEP, through voluntary programs with industry. Shortly thereafter, Sweden, Ireland, and the Netherlands established comparable national energy management standards. Korea and Thailand followed, in 2008, with similar management standards for industrial energy consumption. The original U.S. standard, ANSI/MSE 2000, was crafted by the Georgia Institute of Technology (Georgia Tech). The most recent version of the U.S. standard, ANSI/MSE 2000:2008, reflects a broader stakeholder representation on the consensus board, expanded ownership of potential users, and increased implementation.

In the countries with national energy management standards, adoption is voluntary and targets larger industrial plants. However, incentives to encourage adoption have proven successful and beneficial when employed, and result in significantly improved participation rates and energy savings (Price, 2005). Unlike the U.S., Denmark, Ireland, the Netherlands, and Sweden all offer financial incentives for meeting compliance targets. These incentives typically include an energy or tax relief (McKane et al., 2005). For example, heavy process industrial facilities in Denmark have a CO_2 tax of 3.35 €/ton CO_2, while facilities that have entered a voluntary agreement for efficient energy management pay a reduced tax of 0.40 €/ton CO_2 (an 88% savings). With the exception of Sweden, these countries also provide technical training on standards compliance.

The impact of incentives-based policies is significant. Ericsson (2006) notes that the voluntary agreements and associated incentives are a significant driver for encouraging energy efficiency through the use of energy management standards and cover 98% of the energy use in heavy processes in Denmark. For Danish industry of all sizes, energy management standards guide 60% of energy use (McKane et al., 2005). Energy intensive companies under Danish voluntary agreements must commit to implementing all energy-efficient measures related to heavy processes with a payback period of four years or less, while other companies must implement measures with a payback period of six years or less for compliance. A 2002 evaluation of the voluntary system in Denmark found that half of the participating companies reduced their energy use by 20% (McKane et al., 2005). Companies under the voluntary agreements also cited better product quality, increased production capacity, and increased employee engagement as other benefits of participation.

Sweden offers an energy tax exemption for companies that establish a standardized energy management system and undertake energy-efficiency improvements through voluntary agreements with the Swedish government. Companies that do not elect to participate are levied with a $0.0006 per kWh tax (SEA, 2007). The Swedish program requires a five-year commitment with benchmarking requirements. After two years, a company must implement an energy management standard certified by of an accredited certification body. As of January 2007, companies representing 50% of all industrial electricity use in Sweden participated in the program (McKane et al., 2007).

The U.S. has adopted a different approach to encouraging the adoption of energy management standards in industry. The U.S. has not explicitly promoted adoption of its national energy management standard or offered financial incentives or regulatory penalties, but has educated industry about facility energy-efficiency opportunities. As of 2007, market penetration of the energy management standard was distributed in less than 5% of the total industrial energy use (McKane et al., 2007). This small adoption percentage is particularly unfortunate given the benefits to companies that have used energy management approaches to achieve major energy intensity improvements. For example, Dow Chemical achieved 22% improvement (over $4 billion in aggregate savings) between 1994 and 2005 and is now seeking an additional 25% improvement from 2005 to 2015 (Scheihing, 2009). United Technologies reduced global GHG emissions by 46% per dollar of revenue from 2001 to 2006, while Toyota's North American Energy Management Organization has reduced energy intensity by 23% since 2002 and saved $9.2 million in energy costs since 1999 (Scheihing, 2009). In the absence of widespread adoption of formal energy management standards, the U.S. has developed significant technical capability in industrial energy efficiency, particularly with regard to motor, steam, and process heating systems (McKane et al., 2007). Federal activities and programs led by DOE's Industrial Technology Program (ITP), such as *Save Energy Now*, Industrial Assessment Centers, and Best Practices have played a key role in fostering this increased energy efficiency in industry. However, larger, sustained efficiency improvements can be achieved by implementing energy management protocols as companies such as Dow Chemical, United Technologies, and Toyota have demonstrated.

The incentives that could drive SEP adoption are well established in energy programs. The federal government has provided investment tax credits (ITC) and PTC to promote renewable and alternative generation[46] Furthermore, the American Recovery and Reinvestment Act of 2009 allowed industrial taxpayers eligible for the energy ITCs or renewable electricity PTCs to receive a grant from the U.S. Treasury Department instead of a tax credit. A similar approach is described in this policy to incentivize efficient industrial energy management.

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[46] http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=US13F&re=1&ee=1

Federal recognition programs have encouraged desired practices or behaviors. For example, the Environmental Protection Agency's (EPA) Clean Water Act (CWA) Recognition Awards Program consists of official recognition to industrial organizations that demonstrate an outstanding technological achievement or an innovative process, method, or device in their waste treatment and pollution abatement programs (EPA, 2010b). EPA also leverages the internationally recognized ENERGY STAR brand to encourage facilities to adopt energy-efficient practices such as energy management and benchmarking tools. DOE's *Save Energy Now* program uses recognition to highlight the energy saving efforts of industrial facilities to encourage similar practices by their industrial peers (DOE, 2009).

Despite the lack of a federal Energy Efficiency Resource Standard or Renewable Energy Standard, 36 states operate with Renewable Portfolio Standards, Energy Efficiency Portfolio Standards, or Alternative Energy Standards (PCGCC, 2010). Twenty-four states include energy efficiency as an eligible resource (ACEEE, 2010). For example, Pennsylvania requires that a specific percentage of the electricity sold to Pennsylvania customers be generated from alternative resources, geothermal, and/or biomass. Energy reductions achieved via energy-efficiency measures are counted as eligible resources for alternative energy credits (AECs) (PPUC, 2010). Facilities can receive AECs that can be traded with potential buyers, which include electric distribution companies and electric generation suppliers. Pennsylvania has established specific algorithms to define the M&V of energy savings from the implementation of energy-efficiency measures. The algorithms are driven by a change in efficiency level for the installed measure compared to a baseline level of efficiency. The change in efficiency is then reflected in both demand and energy savings for electric measures and energy savings for gas (PPUC, 2009). Applicants for efficiency credits must submit sufficient information, such as physical verification of the measures installed and certified performance of the measures (e.g., efficiency ratings) to support verification of performance. While North Carolina and Connecticut also permit trading of credits gained through efficiency measures, Nevada multiplies the number of kWh saved by energy-efficiency measures by 1.05 to determine the number of eligible efficiency credits. For electricity saved from efficiency measures during peak periods, the credit multiplier is increased to 2.0.[47] The ability to trade alternative energy credits gained from energy-efficiency measures places a present capital value on efficiency gains that is in addition to the future income generated from energy savings.

3.1.4 Policy Rationale and Description

U.S. efforts to increase energy efficiency in industrial facilities have historically included a large focus on component level improvement rather than system optimization. This approach tends to yield short term and unrealized potential since energy efficiency in industry is mostly achieved through improvements in how energy is managed versus simply through the installation of new technology. As noted by engineers in Georgia Tech's Energy and Environmental Management Center, energy savings realized by energy-efficient projects often were not sustained.[48] Even when energy-efficient recommendations resulted in significant savings between 15% and 30%,

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[47] http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=NV01R&re=1&ee=1

[48] www.innovate.gatech.edu/default.aspx?tabid=2008

the operational and behavioral changes needed to sustain the savings were lost over time. Employing energy management standards helps to reverse the trend of lost energy savings with time. Through the strategic plan to identify, measure, and verify continuous energy-efficiency improvements, energy management standards create a company-wide culture of sustainable and efficient energy stewardship.

As a partner of the U.S. Council for Energy-Efficient Manufacturing (U.S. CEEM), DOE's ITP has been working with U.S. industrial companies, the American National Standards Institute (ANSI), EPA, the U.S. Department of Commerce (DOC), and Texas Industries of the Future on the development of SEP. Central to SEP is implementation of ANSI/MSE 2000-2008, which is the accepted American National Standard for the development of a management system for energy. Forthcoming is ISO 50001, which will replace ANSI/MSE 2000-2008 as the guiding energy management standard for SEP. Similar to ISO standards for quality management (ISO 9001) and environmental management (ISO 14001), ISO 50001 will be an internationally accepted management standard. ISO 50001 conformance includes the implementation of sustainable energy management systems, baseline energy consumption verification, and a corporate commitment to continual energy performance improvement.

While ISO 50001 and other energy management standards are effective systems to identify methods and pathways to achieve energy savings, when employed alone they do not offer sufficient mechanisms to ensure that energy performance improvements are achieved. However, the M&V system contained within SEP does enable a certifiable approach to facilitate actual achievement and accountability of energy saving goals. As a second primary criteria for acquiring certification, the SEP M&V protocol gives a best practice methodology to 1) verify energy savings resulting from SEP implementation; 2) quantify energy savings from specific measures or projects; and 3) track energy performance improvements over time for the entire facility.[49]

To encourage greater energy savings, SEP offers silver, gold, and platinum performance level designations through either an energy performance or mature energy pathway.[50] The energy performance pathway is likely the method that most companies will choose to achieve initial SEP certification. Facilities that wish to attain a silver performance level must achieve a 5% or better energy performance improvement over the last three years. Gold and platinum levels must achieve energy performance improvements of 10% and 15% respectively.

Achieving these percentages of energy performance improvements will be more challenging for plants that have already implemented significantly high levels of energy-efficiency improvements, either through earlier SEP certifications via the energy performance pathway or through other energy management systems. For these plants, the mature energy pathway takes into account both a plant's energy management system and continued efforts to improve energy performance. Companies that become SEP certified through either pathway will have made an accountable commitment to improving energy performance and maintaining a culture

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[49] See footnote 43 above.
[50] See footnote 42 above.

of efficient energy use and management. SEP will help the industrial sector move beyond energy performance objectives to proven results. These incentives described in this policy are envisioned to accelerate and deepen the levels of participation in the SEP program.

Implementation of SEP will address existing barriers to industrial energy efficiency. Energy typically receives a low level of awareness and attention from senior management at industrial companies (Granade et al., 2009), but successful SEP implementation would instill a culture of sustainable and efficient energy stewardship throughout the organizational structure. Because continual energy performance improvement is a requirement of SEP, employees at all levels in the organization must communicate and practice efficient energy management. SEP facilitates a broader dispersion of the “institutional memory” associated with energy-efficient industrial process operation and management than is typically achieved when technical expertise is localized with individuals within the facility. Since sustained SEP achievement requires a broader group of personnel within the organization with technical and/or management expertise to efficiently manage energy performance, SEP will also address the lack of workforce knowledge and specialized skills. Elevated hurdle rates and capital allocation for energy-efficiency improvement measures will also decrease under SEP. Finally, energy-efficient improvements in industrial facilities are often short-lived. SEP addresses this barrier to sustained energy savings from energy-efficient upgrades by encouraging a system level approach that includes the operational and behavioral changes needed to achieve optimal energy performance. SEP can also improve energy data, since capturing and analyzing energy data is a key component of an energy management program (Brown and Key, 2003).

Since May 2008, DOE has worked with the University of Texas at Austin to pilot SEP at various industrial facilities. This pilot enabled field testing of the processes, standards, and performance criteria to ensure they were 1) practical and achievable, 2) a benefit to the industrial facility, and 3) a reliable method to verify that proposed certification criteria were met.[51] Five facilities were certified to Superior Energy Performance in this pilot at performance levels of silver (3 facilities), gold (1 facility), and platinum (1 facility).[52]

International experiences have demonstrated the success that voluntary agreements, which include energy management programs, have achieved in overcoming barriers to industrial energy efficiency. In The Netherlands, an energy-efficiency improvement of 22.3% was achieved from 1989 – 2000, which surpassed the 20% goal and was more than twice what would be anticipated under business as usual (Price, 2005). Similarly, participating companies in Denmark reduced energy use by 20% (McKane et al., 2005). Within two years of beginning the Swedish Energy Agency’s program for improving energy efficiency (PFE), 98 companies submitted first reports identifying investments of over SEK 1000 million (U.S. $131 million) to generate potential energy-efficiency savings of at least 1 TWh of electricity per year (SEA, 2007).

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[51] http://www.superiorenergyperformance.net/texas_pilot.html

[52] See footnote 42 above.

While implementation of SEP has significant promise to address many barriers to industrial energy efficiency, without incentives such as those described by this policy option, it is likely that the adoption of SEP will not achieve the desired penetration into the industrial sector. Past rates of adoption of energy management standards in the U.S. contrast sharply to European countries with strong incentives to support this conclusion (McKane et al., 2005). Because most facilities will initially become SEP certified through the energy performance pathway, early investment costs in energy efficiency will be significant. The federal grant to partially cover original SEP certification costs along with the PTC will provide industries an initial incentive to enroll in the voluntary SEP program by offsetting some of the inaugural investment costs. Moreover, the ability to count energy-efficiency savings as credit for EERS/RES compliance could place a revenue value on efficiency gains that will incite a market-driven push for energy-efficiency credits from industrial facilities with SEP certification. Because of the difficulty in effectively evaluating energy saved from energy efficiency in the industrial sector, quantifying the value of a unit of conserved energy has been a continuing challenge. However, the strong M&V protocol embodied within the SEP framework facilitates a higher economic confidence in the initial and continued savings from energy-efficient measures. The top-line revenue generated from trading efficiency credits will foster sustained enrollment in the SEP program long after federal financial incentives have ended. Finally, rewards and competition will also drive participation. As such, the incentives described in this policy option are consistent with national and international activities to encourage energy-efficient practices.

3.1.5 Stakeholders and Constituencies

Important stakeholders include industrial firms and manufacturers, environmentalists, the general public, consumer groups, utilities and regulators, energy service companies, along with local state and federal governments.

Industrial firms and manufacturers. Incentives to adopt SEP would have a significant impact on industrial facilities. Implementing SEP would result in improved energy management and in turn considerably reduce overall energy consumption and energy costs of participating facilities. The financial benefits from implementing cost effective energy saving projects will outweigh the costs to firms. However, the initial cost of certification and subsequent financial investments needed to generate energy savings will have to compete for capital with other core business projects. Because these types of efficiency projects often compete unfavorably with core projects, industry has typically been reluctant to pursue strong energy-efficiency programs. Since SEP includes validation of energy improvements and thereby promotes a better valuation of energy savings, we believe that facilities will be more supportive of this effort. Furthermore, the incentives suggested in this policy are meant to offset initial costs while savings accrue and thereby induce industrial support.

The PTCs offered as an incentive may not be desirable to all industrial firms since some firms do not have tax liabilities. In these cases, increased profits from reduced energy expenditures and additional revenue from energy-efficiency credit trading may still be sufficient motivation for facilities to become SEP certified.

Additionally, equipment manufacturers will benefit from increased demand for new, energy-efficient technologies to help industrial facilities achieve energy performance improvement goals.

Environmentalists. Because of the significant potential impact on reduced industrial energy consumption and associated reduction in pollutant emissions, we anticipate that environmentalists will strongly support this policy option. The standards embodied within SEP provide an avenue for industrial firms to measure and validate improved energy efficiencies, which in turn, improves the facility's environmental performance (SEPCF, 2010).

General public and consumer groups. Because continual energy-efficient improvements will require personnel and capital to complete, SEP implementation will positively impact the local and national economy through increased project and employment opportunities for local engineering firms and financial institutions. Moreover, the continuous improvement nature of SEP fosters long-term job growth for local residents.

Consumer groups, as a subset of the general public, may withhold support of federal funding to incentivize industrial energy efficiency, since industrial firms will directly reap the energy saving benefits of energy efficiency and the revenue generated from the sale of energy-efficiency credits. If emphasized, the public benefits of lower economy-wide energy consumption and reduced emissions from CO_2 and criteria pollutants may be utilized to gain consumer group support.

Utilities and regulators. By allowing energy savings to count towards EERS compliance, gas and electric utilities will have an additional partner and pathway to procure energy credits. However, in the absence of a federal EERS and an efficiency trading market, gas and electric utilities' support may be limited since they will face lower retail energy sales. Even though utilities may face a reduction in costs facilitated by industrial energy efficiency, the reduction in revenue from sales are larger, thereby negatively affecting the utility's balance sheet (ACEEE, 2011). However, as states employ mechanisms such as program cost recovery, lost margin recovery, and performance incentives, the resistance expected from utilities may diminish (NAPEE, 2007c).

The gap between real energy-efficiency savings and claimed savings is a significant challenge to regulators that attempt to provide a framework that decreases the disincentive that utilities have to invest in energy efficiency **(**Schellenberg, 2010). For example, four major California utilities claimed they had achieved 160% of their energy-efficiency goals, when in fact, they only achieved 70% of the targeted energy savings (Gupta, 2010). However, the M&V protocol required through SEP should provide a consistent and reliable methodology to attribute and account for energy savings, through which regulators can base goal achievement.

Energy service companies (ESCOs). We expect that encouraging SEP adoption through incentives will be supported by ESCOs. ESCOs have traditionally not had a significant penetration into the industrial sector (Elliot, 2002). However, ESCOs have demonstrated the ability to deploy mature methods to provide technical expertise, labor, and additional capital financing in the public sector. ESCO projects have identified and completed cost effective energy-efficient upgrades with estimated net benefits delivered on the order of $15 billion (Goldman, Hopper, and Osborn, 2005). We believe the increased demand for energy-efficiency services in order to meet the energy performance improvements required by SEP may increase the market penetration of ESCOs into the industrial sector.

Federal, state, and local governments. The state and federal government will be stakeholders in this policy through the administration of energy savings as energy-efficiency resource credits. Even though a federal EERS is not currently in place, many states already have an EERS. In the absence of a federal EERS, states can encourage adoption through their policies.

As a partner in the initial development of SEP, DOE will be a key stakeholder in this policy. Implementation of SEP will help DOE's efforts to partner with industry on a voluntary basis to support progress toward the industrial energy intensity reduction goals set forth in Section 106 of EPAct 2005. DOE has invested in the development of industrial best practices and M&V protocols embodied in SEP, and will continue to provide support to foster the broad implementation of SEP throughout the industrial sector.

Given the current emphasis on federal, state, and local debt reduction, there may be some resistance to providing the incentives suggested in this policy option.

Table 3.1. Stakeholder Assessment of Incentives to Encourage SEP

Stakeholder	Pros	Cons	Dominant Position
Industrial Firms and Manufacturers	Will reduce energy bills and provide additional revenue stream through the sale of energy-efficiency credits.	Significant capital investment required	Favorable
Environmentalists	Through increased energy efficiency, SEP will improve the environmental performance of participating facilities.	None	Favorable
General public and consumer groups	SEP implementation will positively impact the local and national economy through increased project and employment	Consumer groups may resist federal funding to incentivize industrial energy efficiency since industrial firms directly reap the energy savings.	Favorable
Utilities and regulators	By allowing energy savings to count towards EERS compliance, gas and electric utilities will have an additional partner and pathway to procure energy credits.	Without decoupling, energy efficiency can negatively affect balance sheets.	Unfavorable
Energy Service Companies	Through increased demand for energy efficiency, ESCOs can increase their industrial sector penetration.	None	Favorable
Local, State, and Federal Government	Prospects of increasing industrial productivity through energy efficiency would lead to policy support by many government agencies.	Emphasis on federal debt reduction will cause scrutiny of proposals to expand government subsidies.	Favorable

3.1.6 Policy Evaluation

Appropriateness of the federal role. Historically, the federal government has taken an active role to promote and facilitate market penetration of alternative energy sources and efficient energy consumption. ITCs and PTCs for wind, solar, geothermal, and combined heat and power are examples of federal action to promote renewable and alternative generation.[53] The EPA's CWA Recognition Awards Program and DOE's *Save Energy Now* are further federal examples of incentives and programmatic activities that encourage positive environmental and energy-efficient behaviors.

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[53] http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=US13F&re=1&ee=1

Numerous international examples exist of the federal role in encouraging efficient energy management in industry. Canada, Denmark, Ireland, New Zealand, Switzerland, and the United Kingdom all have energy/GHG taxes or regulations in place that motivate industrial facilities to adopt energy management standards that facilitate significant energy savings (Price, 2005). Because of the public nature of reduced industrial energy consumption, it is appropriate for the U.S. government to likewise provide incentives to encourage adoption of SEP. Moreover, DOE has been one of the leaders in the development of SEP and as such, it is fitting that a federal role be taken to support SEP deployment. The promotion of SEP through incentives will help the U.S. achieve its goal of supporting industries as they pursue a 2.5% reduction in their energy intensity each year through 2016 (EPAct, 2005). Furthermore, energy savings induced by SEP also support the federal mission to accelerate the development and deployment of advanced technologies and best practices to mitigate climate change.

Broad applicability. Initially targeted for large and medium-sized industrial facilities, SEP will likely not achieve high penetration levels into smaller sized facilities. SEP certification requires a significant long-term commitment to energy-efficient investments, which may be difficult for smaller firms to maintain even in light of potential savings. In addition to capital availability for technology purchases, small firms often lack the personnel needed to champion energy efficiency while the mindset is instilled throughout the corporate culture. However, as SEP becomes more broadly applied in larger firms, opportunities for integration in smaller firms can be identified and tested.

While SEP certification may be hindered in smaller size facilities, large and medium sized facilities will likely realize the benefits that derive from SEP adoption. The efficient energy management culture and continuous improvement encouraged by SEP are broadly applicable to all manufacturing process and energy end-uses.

Significant potential benefits. In order to evaluate the estimated impact of incentivizing SEP adoption, we assumed that the primary groups of facilities that will implement SEP are medium to large industrial sites (facilities with energy consumption of at least 300 billion British thermal units (Btu) of combined energy per year, or its equivalent, and generally more than 250 employees). According to the Manufacturing Energy Consumption Survey, (EIA, 2006) as of 2006, there were approximately 10,000 facilities in this classification, accounting for 67% of U.S. industrial energy consumption. While it is probable that other medium and possibly small industrial sites will adopt SEP, the primary impact will be from large facilities, given their significant proportion of energy use in the industrial sector. For analysis, we assumed two different policy scenarios to describe a higher and lower penetration of SEP into the industrial sector. In the first policy scenario (PS1), 60% of facilities that comprise the large category, or about 5,760 sites, will adopt the SEP program. This is equivalent to approximately 40% of the total U.S. industrial energy consumption. This level of participation was chosen as a primary policy scenario because it is within the range of international adoption of energy management standards in countries with government sponsored strong incentives (McKane et al., 2005). For example, the adoption rate of voluntary energy management standards in Ireland was approximately 25% of industrial energy consumption. In contrast, Denmark and the

Netherlands had penetration rates of 60% and more than 70% of industrial energy consumption, respectively. The estimated number of sites is also consistent with the number of industrial sites that have adopted the internationally accepted environmental management standard, ISO 14000. As of 2006, 5,585 U.S. firms had received ISO 14000 certification. The authors believe that sites that have demonstrated their commitment to a management standard focused on the environment will be likely candidates to pursue an energy management standard certification.

The policy sensitivity assumes a lower penetration, 30% of large facilities (i.e., 20% of industrial energy use). In this scenario, we did not model any bias in the participation of facilities. While it could be posited that the largest facilities would be more likely to participate because they have the most to gain, the authors determined that it would be sufficient for analysis to assume no preference would exist. Tables outlining the benefits and costs of this policy sensitivity are shown in detail in Appendix D.

Without the incentives offered in this policy, we estimate that many sites will pursue ISO 50001 certification, but only a small number will implement SEP. Based on the historical adoption rate of energy management standards in the U.S., in the absence of the incentives provided in this policy, we assume that 5% of large facilities would become SEP certified and are hereafter modeled as “free riders”. Figure 3.1 illustrates the penetration into the industrial sector that both policy scenarios are projected to induce. Free ridership is also illustrated in the figure. Subsequent analysis of the policy and its sensitivity scenario in this report will exclude the benefits and costs of projected free riders. Additionally, the impact of business as usual (BAU) energy-efficiency improvements forecasted by *AEO 2010* (EIA, 2010) was also determined and removed from benefit projection and cost effectiveness evaluation.

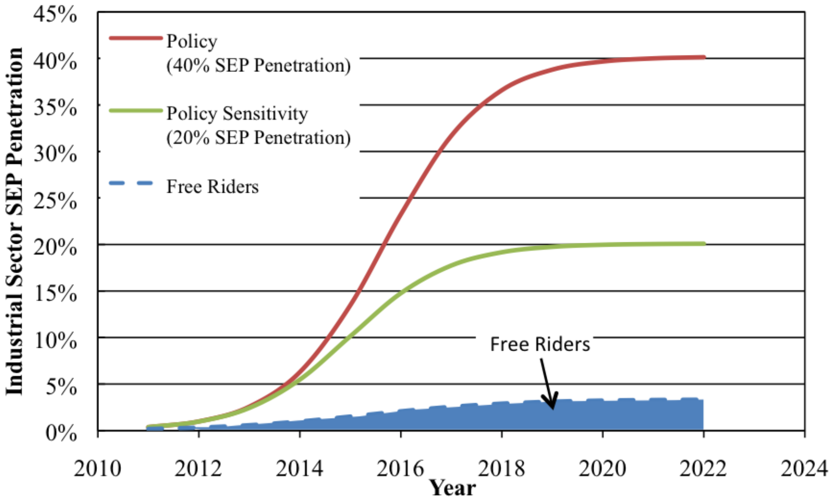

Figure 3.1. Estimated SEP Implementation in the Industrial Sector without Policy and with Policy
(Free ridership estimate is shaded in the figure)

In both policy scenarios, we predict that approximately 35% of facilities that become SEP certified will achieve a performance level of silver, while an additional 30% will achieve gold, and 15% will achieve a performance of platinum Descriptions of the requirements for certification for different performance levels are shown in Table D.1. Performance level estimations are based on a survey enquiring of executives the level of LEED certification their company would most likely seek (Turner Construction, 2008). LEED has a similar performance level structure, and insight with regard to the performance level executives would seek is a reasonable measure of future SEP performance level attainment.

Significant energy and carbon dioxide emissions reductions projected as a result of this policy are shown in Figure 3.2 and Table 3.2, which illustrate the impact on industrial energy consumption relative to private costs – as a result, we call this the "industrialists" perspective. While BAU annual energy consumption is forecasted to grow by an average of 0.5% annually from 2011 to 2035 (an increase of 3,760 TBtu) the annual energy saved would reduce this anticipated increase by 2,380 TBtu (a 63% reduction). To place the forecasted energy saved in perspective, the projected 2,380 TBtu of energy savings in 2035 account for 8% of total industrial energy consumption. Additionally, almost 49 quads of energy savings are estimated from 2011 to 2055. For comparison, the policy sensitivity is expected to result in approximately 22 quads over the same period. The methodology utilized to determine energy efficiency-based reductions in consumption are described in detail in Appendix D.3

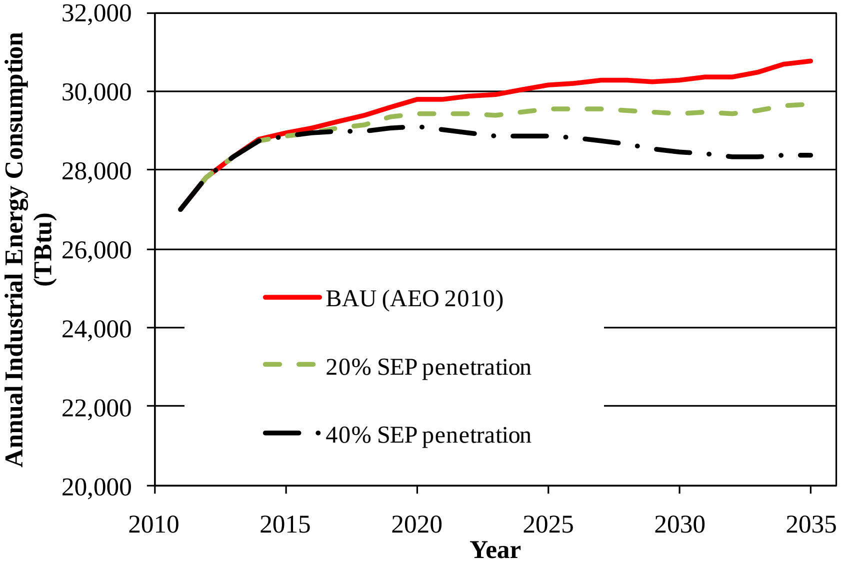

Figure 3.2. Business as Usual (BAU) Energy Consumption and Energy Consumption after Policy Implementation

(Industrial consumption includes all manufacturing and mining sub-sectors)

Table 3.2 SEP Program Impact from the Industrialists' Perspective*
(40% SEP Penetration)

Year	BAU Energy Consumption**	Annual Energy Savings			Cumulative Energy Savings***		Annual Private Cost	Cumulative Private Cost
	Trillion Btu	Trillion Btu	$M (2008)	%	Trillion Btu	$M (2008)	$M (2008)	$M (2008)
2011	27,000							
2020	29,800	656	2,220	2.2	2,050	7,600	769	3,300
2035	30,800	2,380	3,180	7.7	26,300	55,100	227	10,200
2055	---	---		---	48,800	74,800	---	10,200

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

** Reference case industrial energy consumption excludes refining

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

Technology readiness. The goal of this policy is to achieve greater energy efficiency in the industrial sector and thereby reduce energy consumption by focusing on how energy is used, in contrast to which components or technologies are employed. Therefore, the institutional and behavioral approach taken by this policy is not dependent on new technologies entering the marketplace. However, this policy creates an environment in the industrial sector such that facility managers and engineers seek the most cost-effective, efficient technologies available and as a consequence, promotes the market penetration of available energy-efficient technologies today and into the future.

Cost effectiveness. The investment incentives suggested by this policy and their associated impact on private and federal costs are illustrated in Figure 3.3 for the primary policy where a 40% of industrial energy consumption is assumed to be SEP certified. Net private costs shown in the figure are equal to the total investment costs minus the PTC and revenue from energy-efficiency credits. The PTC and revenue generated from energy-efficiency savings have the overall combined impact of mitigating the private investment costs of energy-efficiency measures by roughly half throughout the modeled period. As seen in the figure from 2011 through 2018, the PTC helps to offset the high initial investment costs of industrial sites as they first gain SEP certification through the energy performance pathway. The energy performance improvement goals in the energy performance pathway range from 3% to 15%, as described earlier. Details of how different facilities are modeled to pursue SEP certification are described in Appendix D.

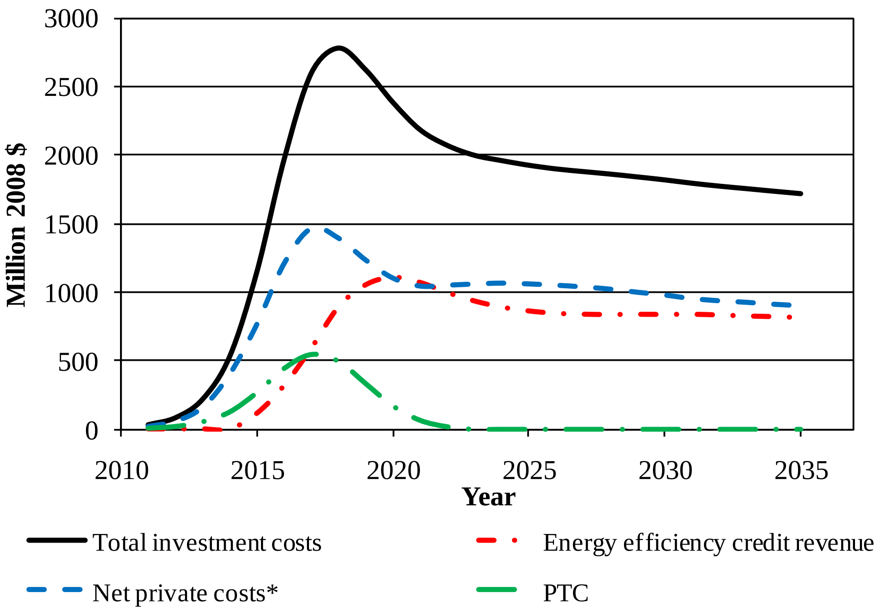

Figure 3.3. Impact of PTC and Energy-Efficiency Credits on the Total Investment Costs

Because there is currently not a national EERS or RES framework, revenue from energy-efficiency credits is not modeled to begin until 2015. We estimate this framework to be in place by this time. We also assume that energy-efficiency savings have a contract period of four years, such that efficiency measures are able to generate revenue for a four-year period under our assumptions. Beginning in 2015, the revenue from energy-efficiency credits increases with energy-efficiency savings. After the initial period of savings accumulation, the revenue from energy-efficiency credits begins to level off and subsequently experiences a slight decrease in later years, as SEP sites transfer from making large energy improvement gains (i.e., energy improvement pathway) to utilizing industrial best practices to efficiently manage energy consumption (i.e., mature energy pathway).

The benefits and costs of this policy are shown in Tables 3.3 and 3.4. With a 40% SEP penetration rate, this policy is expected to generate $75 billion in cumulative energy savings from cumulative private investments of $10.2 billion that are leveraged from approximately $2.2 billion in federal funding. Moreover, these public expenditures lead to energy savings of approximately 49 quads. This yields an energy leveraging ratio of 23 TBtu/million $2008 or MMBtu/$2008. Similarly in the policy sensitivity case, $1.1 billion in public investments generate $35.8 billion in cumulative energy savings. This yields an energy leveraging ratio of 21 TBtu/million $2008 or MMBtu/$2008.

Table 3.3: Leveraging of Energy Savings from Cumulative Public Investments in Incentives to Promote SEP in Industry

	Public Costs*				Cumulative Energy Savings	Leveraging Ratio*
	Million $2008				TBtus	MMBtu/$
Year	**Annual Administration Cost**	**Annual Investment Cost**	**Total Annual Costs**	**Total Cumulative Costs**		
2020	0.4	127	127	2,100	2,050	
2035	0.1	0	0.1	2,160	26,300	
2055	---	---	---	2,160	48,800	23

*Ratio of cumulative energy savings in MMBtu to cumulative public costs in $2008. Present value of public costs were calculated using a 3% discount rate.

Table 3.4 presents the ability of the public sector to leverage carbon dioxide savings in the industrial sector with incentives to promote the adoption of SEP. In 2035, public expenditures lead to CO_2 savings of 107 metric tons, representing 8% of the business-as-usual CO_2 emissions in the industrial sector that year. Over the lifetime of the equipment installed by 2035 as a result of this policy change, 2,230 metric tons of CO_2 emissions are avoided, yielding a carbon-dioxide leveraging ratio of one ton per dollar. For the policy sensitivity, a cumulative of 1,040 metric tons of CO_2 is avoided through 2055 via leveraging of 0.9 metric tons per dollar of public investment.

Table 3.4. Leveraging of CO_2 Emission Reductions Cumulative Public Investments in Incentives to Promote SEP in Industry

Year	Public Costs	CO_2 Emission Reductions			Leveraging Ratio*
	Million $2008	Million Metric Tons CO_2			
	Cumulative Costs	Annual MMT Saved	% Annual Emissions	Cumulative MMT Saved	Metric Tons/$
2020	2,100	31	2.2%	98	--
2035	2,160	107	7.7%	1,210	--
2055	2,160	--	--	2,230	1.0

*Ratio of cumulative emission reductions in million metric tons to cumulative public costs in $2008. Present value of public costs was calculated using a 3% discount rate.

Figure 3.4 shows the leveraging ability of public expenditures in the principal policy case of 40% SEP penetration (shown with solid markers) compared with the sensitivity case of the 20% SEP penetration (shown with open markers). The leveraging of energy savings per public dollar is shown on the left and the leveraging of carbon dioxide emission reductions is shown on the right.

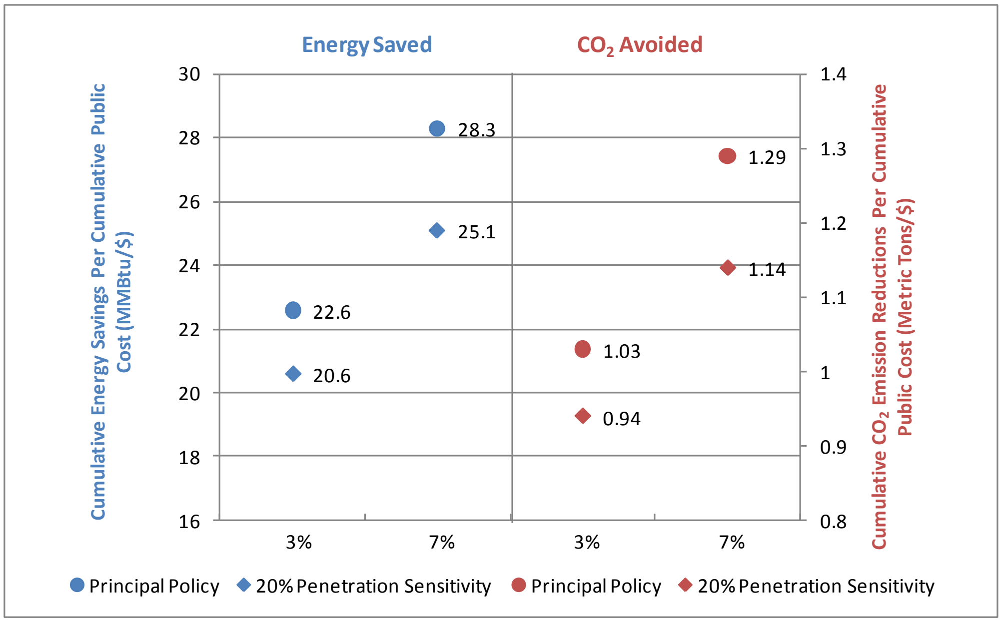

Figure 3.4. Energy and CO_2 Leveraging for Incentives to Promote SEP in Industry

Additional benefits from avoided air pollution damages due to the combustion of less fossil energy are also a significant benefit. Estimates of the reduction of criteria pollutant emissions are shown in Table 3.5 and Figure 3.5. Of the four criteria pollutants considered, SO_2 emission reductions deliver the greatest human health and environmental benefits, totaling $46.7 billion in avoided damages through the year 2055, as the policy. Similarly, $22.1 billion in avoided damages from SO_2 occur in policy sensitivity case.

Table 3.5. Value of Avoided Damages from Criteria Pollutant Emissions* (Billions $2008)

	NO_x		SO_2		PM_{10}**		$PM_{2.5}$	
	Annual	**Cumulative**	**Annual**	**Cumulative**	**Annual**	**Cumulative**	**Annual**	**Cumulative**
2020	0.12	0.39	0.94	3.11	0.01	0.02	0.09	0.29
2035	0.26	3.63	1.98	27.92	0.01	0.15	0.20	2.72
2055	---	6.12	---	46.73	---	0.26	---	4.58

* Values are based on the National Research Council report estimating damages from energy production and consumption in the U.S. (NRC, 2010). Excludes pollutant damages from petroleum and coal for industrial heat. Present value of avoided damages was calculated using a 3% discount rate.

** Excludes PM_{10} from the production of industrial heat.

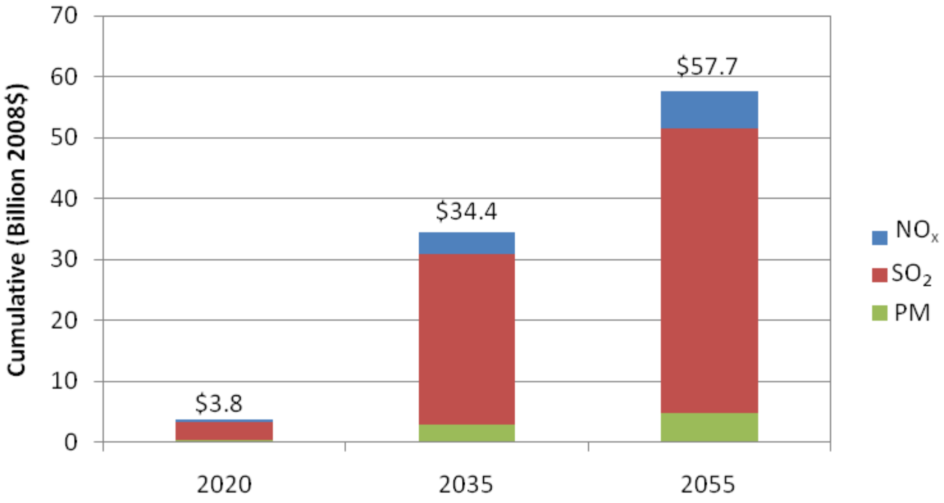

Figure 3.5. Value of Avoided Damages from Criteria Pollutants for Incentives to Promote SEP in Industry

We determined the financial value of reduced CO_2 emissions in each year by multiplying the decrement in emissions by the "social cost of carbon" (SCC) for that year. The SCC is defined as an estimate of the monetized damages caused by each incremental ton of CO_2 emitted. The SCC used in this analysis is central value estimates of the U.S. Government Interagency Working Group on the Social Cost of Carbon (EPA, 2010a). In this report, the central value SCC estimates ranged from $23/metric ton of CO_2 in 2011 to $34/metric ton and $47/metric ton in 2030 and 2050, respectively (all values are in $2008). Cumulatively, the principal policy option described in this report facilitates a present value of $40.8 billion in avoided CO_2 costs, while $19.2 billion in avoided CO_2 costs are achieved in the policy sensitivity. Considering the benefits of avoided CO_2 and damage from criteria pollutants in pollution reduction along with cumulative energy savings, the total discounted savings derived from the primary policy through 2055 are $274 billion (Table 3.6a). The social benefit/cost ratio is approximately 14.3 with an estimated net societal benefit of $255 billion. In the case of the policy sensitivity, there are approximately $120 billion in net societal benefits with a social benefit/cost ratio of 14.5. Table 3.6b shows the discount rate sensitivity of the total social benefits and costs monetized in this report for the principal policy case. Even in this higher discount rate case, the social benefit/cost ratio is approximately 10.6 with an estimated net societal benefit of $115 billion.

Table 3.6a. Total Social Benefit/Cost Analysis of Cumulative Public Investments in Incentives to Promote SEP in Industry

	Cumulative Social Benefits (Billions $2008)				Cumulative Social Costs (Billions $2008)			Benefit/Cost Analysis	
Year	**Energy Savings**	**Value of Avoided CO_2**	**Value of Avoided Criteria Pollutants**	**Total Social Benefits****	**Public Costs**	**Private Costs**	**Total Social Costs****	**Social B/C Ratio**	**Net Societal Benefits (Billions $2008)**
2020	10.1	2.1	3.8	19.0	2.10	4.34	6.4		
2035	103	23.8	34.4	172	2.16	17.1	19.2		
2055	165	40.8	57.7	274	2.16	17.1	19.2	14.3	255

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

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

Table 3.6b. Total Social Benefit/Cost Analysis of Cumulative Public Investments in Incentives to Promote SEP in Industry (7% Discount Sensitivity)

	Cumulative Social Benefits (Billions $2008)				Cumulative Social Costs (Billions $2008)			Benefit/Cost Analysis	
Year	**Energy Savings**	**Value of Avoided CO_2**	**Value of Avoided Criteria Pollutants**	**Total Social Benefits****	**Public Costs**	**Private Costs**	**Total Social Costs****	**Social B/C Ratio**	**Net Societal Benefits (Billions $2008)**
2020	7.6	1.6	2.9	14.4	1.69	3.3	5.0		
2035	55.1	12.6	18.7	92.8	1.73	10.2	12.0		
2055	74.8	18.0	28.0	127.4	1.73	10.2	12.0	10.6	115.4

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

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

Table 3.7 shows a range of benefit/cost ratios for both the primary policy and the policy sensitivity under alternative discount rate scenarios of 3% and 7%. In the first scenario, all cost and benefits are evaluated at 3% (i.e., private costs, energy savings, value of emission savings, and public costs). Similarly all costs and benefits are evaluated at 7% for the second scenario. As seen in the table, both the primary policy and the policy sensitivity have highly favorable benefit/cost ratios and net societal benefits.

Table 3.7. Social Benefit/Cost Analysis of Policy and Discount Rate Sensitivities

		Alternative Discount Rates	
		3%	**7%**
Superior Energy Performance Program with 40% of Industrial Penetration	Benefit/Cost Ratio	14.3	10.6
	Net Societal Benefits (Billions $2008)	255	115
Superior Energy Performance Program with 20% of Industrial Penetration	Benefit/Cost Ratio	14.5	10.7
	Net Societal Benefits (Billions $2008)	120	55.2

Administrative feasibility. Administration of all incentives will require multi-agency collaborations from Public Service/Utilities Commissions for EERS/RES credit, the EPA for the allotment of credit allowances, DOE for recognition programs, and the U.S. Treasury for grant payments. Coordination of incentives may be required to ensure ease of delivery and reduced bureaucratic friction. Recognition programs and grant payments for energy efficiency are not without federal precedence and as such, administration should be straightforward. While there is no federal experience with EERS and/or RES administration, state examples of energy-efficiency credits for compliance can serve as models for federal action (see section 2.2 on EPS). International exchanges and information sharing can also help improve the administrative activity with regard to energy-efficiency credits valuation and trading.

Because recognition programs such as *Save Energy Now* LEADER Companies, ENERGY STAR for Industry, and *Save Energy Now* Energy Champions are currently in place, there is an opportunity for a SEP recognition program to contain overlapping initiatives. To prevent market confusion, DOE and EPA could work together to differentiate programs and identify appropriate opportunities for program mergers.

Additionality. SEP will induce and instill a culture of continuous energy performance improvement into the corporate workforce and institutional memory of the industrial site. This policy does not target specific technologies, regulatory policies, financial barriers, workforce expertise, and availability. However, as facility managers continually seek to increase energy performance, they will be able to build on other policies and programs to achieve and expand their SEP goals.

3.1.7 Summary

The energy management standard provided within SEP is an important tool to give industrial facilities a roadmap to efficient energy management. Because SEP combines this energy management standard with a strong M&V protocol, SEP can yield a certifiable approach to facilitate actual achievement and accountability of energy saving goals in the industrial sector. As U.S. and international experience indicates, penetration of energy management standards into the industrial sector is minimal without incentives to encourage adoption. This policy option has described the following four incentives to encourage adoption of SEP:

- provide a federal production tax credit for initial energy-efficiency savings
- allow verified energy savings of facilities that are SEP certified to be counted as an energy-efficiency credit in compliance with meeting Energy Efficiency Resource Standard or Renewable Energy Standard requirements
- provide an energy-efficiency grant for 30% of eligible certification costs
- establish a recognition program for SEP certified facilities.

Key strengths and weaknesses of this policy are summarized in Table 3.8. Overall, SEP will have some challenges, but offers significant long-term potential. We estimate that incentivizing SEP adoption in the industrial sector can facilitate approximately 48.8 quads and $255 billion of cumulative present value savings when energy savings and the social costs of avoided emissions are considered. With a total present value cost of federal and private investments to provide these savings approximated as $19.2 billion, this policy has both significant potential benefits and has high benefit/cost ratios.

Table 3.8 Overall Assessment of Superior Energy Performance Program

	Strengths	Weaknesses	Time Horizon*
Superior Energy Performance	Significant Potential Benefits; Cost-Effectiveness, Market Transformation; Measurement and Verification	Public Costs; Dependence on Energy-Efficiency Credits	Short to Long

*Time horizons when significant energy savings begin: short (five years or less), medium (five to 10 years), and long (more than 10 years).

As a culture of efficient energy management is incited in the industrial sector via this policy, market transformation will likely occur as efficient energy technologies are disseminated into facilities. However, because this policy leverages benefits achieved through a national market for energy-efficiency credits, which is currently not in place, administrative feasibility will be a challenge while a national efficiency market is established and developed.

3.2 Implementation Support Services

Policy Option: Increase funding to the DOE Industrial Assessment Center (IAC) program to facilitate additional energy saving assessments and to create and support Implementation Support Services (ISS).

3.2.1 Policy Summary

In order to increase the quantity of energy saving audits completed at industrial facilities and improve the implementation rate of audit recommendations, the federal government could increase the current funding level of the IAC program. Due to competing fiscal priorities, funding for IAC assessments has decreased from approximately $8 million in 2000 to $4 million in most recent years. Moreover, similar funding at $4 million is forecasted in future years (Elliot and Kaufman, 2009). An increase in the funding level of the IAC program would enable a higher number of completed energy assessments over present levels.

As a complement to increased energy assessments, this policy option also includes funding for DOE to establish and support Implementation Support Services (ISS) at universities with existing IACs. ISS would leverage existing relationships between industrial facilities, financial institutions, and engineering firms to increase implementation of energy saving measures by providing additional technical and business support subsequent to initial IAC energy assessments. This support could include opportunity awareness education to local financial institutions and engineering firms, assistance with the review, proposal, and implementation of project financing and/or performance contracting, coordination of training on industrial best practices, coordination of technical support for energy-efficient equipment identification, and other assistance that would promote the implementation of energy-efficient retrofit measures. In synergy with the IAC energy saving assessments, the ISS program would provide facilities additional resources to help follow through with identified opportunities.

In addition to increased energy savings from IAC assessments, a primary outcome of ISS would be to facilitate the workforce development of undergraduate business students with an understanding and appreciation of energy efficiency. Similar to the successful model employed by IAC in which engineering students are given application-level energy-efficiency experience in industry, the ISS program would utilize business students to perform key roles. ISS could then help meet a growing need for business managers with an increased awareness of the benefits of energy efficiency in industry. These managers would not only understand the energy-efficiency opportunities available, but also understand how to realize savings by managing relationships with engineering firms and financial institutions through conventional and alternative clean energy financing tools available to industry.

3.2.2 Elements of the Recommended Policy Approach

- **Increase the number of energy saving assessments completed by the IAC program:** Through increased appropriation to ITP's "Industrial Technical Assistance", an increase in the funding level of the IAC program could enable a higher number of completed energy saving assessments in industrial facilities. In 2000, IAC funding was approximately $8 million, which facilitated 619 energy saving assessments at industrial facilities (IAC database, 2010). However, IAC funding has decreased significantly to half of the amount received in 2000 (Elliot and Kaufman, 2009). Additional money, sufficient to set IAC funding equal to twice the level in 2000, could be appropriated to this program to permit a fourfold increase in the number of energy savings assessments with respect to 2010.
- **Create and support ISS within IAC program:** Through increased appropriation to ITP's "Industrial Technical Assistance", ISS could be created at universities with existing IACs. The current IAC program would be expanded to support the creation of ISS. ISS would leverage existing relationships between industrial facilities, financial institutions, and engineering firms to increase implementation of energy saving measures by providing additional technical and business support subsequent to initial IAC energy assessments. Established at universities with existing IACs, ISS would utilize business students from local universities, similar to the successful model employed by IAC to work with engineering students. This structure would support education and provide business graduates with a better understanding of energy and energy efficiency. ISS could initially be piloted for two years to evaluate potential effectiveness and to identify best approaches to foster increased capital, personnel, and expertise availability for energy-efficiency projects. In particular, pilot ISS could help establish initial pathways for successful financial models for financial institutions and energy-efficiency project contracting for engineering firms.

3.2.3 Policy Experience

Implementation assistance programs. Both state authorities and utilities have demonstrated successful implementation assistance programs for energy-efficiency projects. The New York State Energy Research Authority (NYSERDA) FlexTech program has exhibited significant success with helping customers implement energy savings. FlexTech offers cost-sharing incentives for customers to receive energy saving assessments, thereby fostering the implementation of 60% of recommended measures. Every dollar spent by FlexTech leverages a $17 investment in energy saving measures by customers to generate $5 in net energy bill savings (ACEEE, 2009b). FlexTech offers implementation assistance services that include coordination and cost-sharing of help from energy engineers and experts on energy procurement, energy-efficiency retro-commissioning, long term energy management, and technical support for energy performance contracting, project financing, and other assistance that promotes the implementation of energy-efficiency products or services.

The New Jersey Industrial Energy Program (NJIEP) also provides implementation assistance services to industrial facilities within the state. While NJIEP primarily focuses on energy assessments that incorporate IAC practices, implementation services are also provided to industrial customers. These services include technical support to identify barriers and aid in project implementation, follow-up to encourage a high rate of successful implementation and client feedback, and metric development to gauge implementation success (DOE/ITP, 2010a). NJIEP was one of 23 state projects funded in FY 2009 by ITP to help facilitate a 25% reduction in industrial energy use in 10 years. Similar to NJIEP, most funded state projects included an implementation assistance component (DOE/ ITP, 2009).

3.2.4 Policy Rationale and Description

Increased funding to the IAC program will facilitate an expanded reach of their energy saving opportunity identification programs. Furthermore, because IACs play a vital role in educating engineering students on how to assess energy-efficiency opportunities in industrial facilities, lower funding not only decreases the number of assessments completed, but also increases the number of next generation engineers trained to deliver energy-efficient industrial operations. Increased funding will therefore help the U.S. meet its goals of educating an energy-efficient workforce in addition to reducing overall energy use in the industrial sector.

While increasing the quantity of energy saving assessments performed will have significant impact on the energy consumption of the U.S. industrial sector, the implementation rate of recommended energy saving actions could be improved as well for maximum benefit. When viewed in light of the number of assessments completed compared to the number of available facilities, it is evident that a considerable amount of energy and dollar savings are left unrealized. For example, the IAC located at Mississippi State University performed only 308 energy assessments from 1994 through August 2006 even though there were over 4,500 eligible candidate clients in their service area (Hodge, 2007). Furthermore, as shown in Table 3.9, for every $1 of energy saving recommendations that were implemented from 2000 to 2009, more than $2 in savings were foregone (IAC database, 2010). In addition, of the $685 million in IAC energy savings recommendations not implemented $493 million have a simple payback[54] of 1.5 years or less (IAC database, 2010).

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[54] In this case, simple payback period refers to the amount of time to recover the initial investment from the savings resulting from the implemented measure.

Table 3.9. Sample Historical Energy Assessment Implementation Data for IAC Energy Saving Assessments*

IAC Energy Assessment Savings Implementation**			
Program	**Time Period**	**Savings Implemented**	**Savings Not-Implemented**
IAC	2000-2009	$335 million (35 TBtu)	$685 million (59TBtu)

* Source: IAC database, 2010

** Recommended savings with an unknown status (ca. $85 million) or pending status (ca. $68 million) are not included in the table

Two of the most often cited reasons for not implementing cost-effective energy-efficient measures in industry are capital and technical expertise constraints (Granade et al., 2009). According to a survey of industrial facilities' reasons for rejecting energy saving measures recommended by ITP's Save Energy Now (SEN) program, approximately 50% were not implemented due to capital or payback requirements (Wright and Nimbalkar, 2010). In the public sector, Energy Service Companies (ESCOs) have been largely successful in overcoming implementation barriers such as lack of capital by providing third-party resources through energy performance contracts. ESCO projects have identified and completed cost effective energy-efficient upgrades with estimated net benefits delivered on the order of $15 billion (Goldman, Hopper, and Osborn, 2005). However, their penetration into the industrial sector has been mostly absent, due in large part to the reluctance of industrial facilities to work with ESCOs with whom they have no existing relationship and established trust (Elliot, 2002). Conversely, the ISS described by this policy leverage existing relationships and trust between financial institutions, engineering firms, and industrial facilities to surmount primary barriers that preclude ESCO involvement. As a result of the partnerships fostered by ISS to provide expertise, manpower, and capital for energy saving recommendations made by IAC energy audits, the percentage of achieved energy savings would increase. ISS would:

- increase local financial institutions' awareness of various conventional and alternative clean energy financing tools being utilized throughout the country to facilitate energy-efficient measure implementation in industry, and
- work with engineering firms currently aligned with the industrial facility to foster their increased involvement in providing technical personnel for implementing measures within the site.

An illustration of the environment fostered by ISS is shown in Figure 3.6. Because engineering firms are already perceived by the industrial facility as a source of expertise, often with existing knowledge of the plant and processes (Elliott, 2002), they are well positioned to implement energy savings within the facility. ISS would be an important enabler of engineering firms working with facilities to capture energy-efficiency savings by providing business support to plant-level engineers typically not well trained in the ability to convey the energy and costs savings opportunities to higher level management.

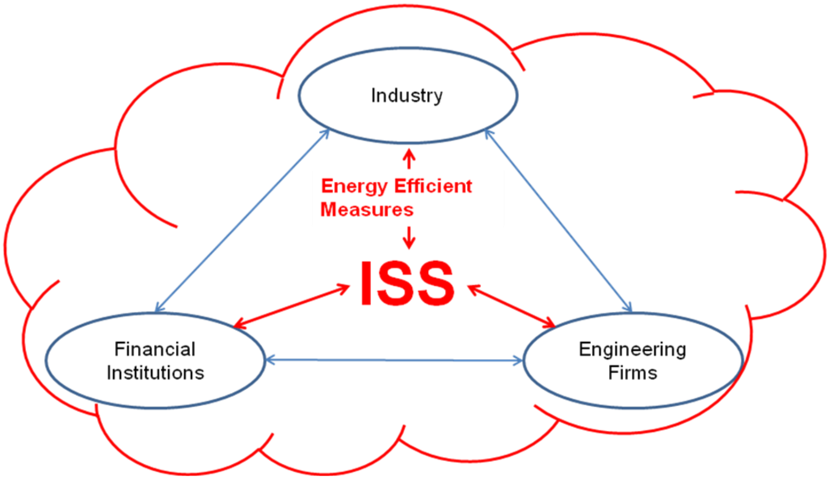

Figure 3.6. Environment Created by ISS Working with Financial Institutions, Engineering Firms, and Industrial Facilities

After initial energy saving assessments are completed, ISS would bring engineering firms and financial institutions with an increased awareness of revenue opportunities and pathways to the table with industrial facilities seeking cost savings from energy-efficient, yet cost effective, retrofit measures. In circumstances in which the industrial facility has available capital but no available in-house personnel to “push-through” energy saving measures, ISS could help engineering firms provide the necessary expertise and labor. Conversely, when capital is a constraint, ISS could work with the industrial facility to secure project financing through local institutions. Additionally, when appropriate, ISS could work with the financial institution and engineering firm to provide assistance with the review, proposal, and implementation of energy performance contracting. Energy performance contracts are often employed by ESCOs to generate energy savings for industrial facilities in a pay-as-you-save mechanism that enables financing of retrofit measures while permitting a transfer of risks associated with energy savings. ISS could foster an environment where engineering firms and local financial institutions implement energy savings in industrial facilities in a manner functionally indistinguishable from ESCOs and other third-party financing services. Therefore, ISS would employ the successful energy saving model of ESCOs, but by leveraging existing working relationships, they could overcome the reluctance that industrial plants have to allowing “outside firms inside their facility”. Additionally, ISS could serve as an honest broker for the industrial facility as a reviewer of energy performance contracts and annual energy savings.

As described, the establishment of ISS could help address existing market barriers of insufficient capital and technical personnel that currently impede energy efficiency in the industrial sector. As suggested by Shipley, Elliott, and Hinge (2002), successful programs that achieve implemented and sustained energy savings in industrial facilities, particularly mid-sized facilities such as those serviced by IACs, utilize a multi-tiered approach that includes opportunity identification along with subsequent follow up assistance that includes technology identification and project design, project financing, installation, startup, and training. IAC energy assessments have been very successful in identifying energy saving opportunities; however, follow up assistance is often not completed. Since ISS can provide necessary follow up assistance to the industrial facility through coordinated efforts with financial institutions and engineering firms, increased implementation of cost effective energy saving measures would be a policy outcome.

As evidenced with increased existence of regional programs, implementation assistance is becoming a point of emphasis of state, regional, and federal industrial energy reduction programs. However, most implementation assistance is focused primarily on technical assistance, which is only partly responsive to the principal energy-efficiency barriers of capital and technical expertise availability. Unique to the ISS program is a focus on making capital more available by leveraging existing relationships industrial facilities have with financial institutions. It is expected that this distinction will enable ISS to achieve significant energy savings in the industrial sector.

ISS will not compete with existing technical implementation assistance programs, such as those employed by NYSERDA's FlexTech, Wisconsin's Focus on Energy, or other utility sponsored programs. Rather, ISS would complement their services by working with facilities to find available program offerings they could utilize. ISS would look for opportunities to leverage local, state, regional, or federal clean energy incentives offered by many of these programs to facilitate greater energy savings through reduced costs of implementation. Given the finite time and labor resources industrial facilities have, often the transaction costs of obtaining assistance provided by other programs are too high for them to assume. By reducing these transaction costs, ISS would likely increase the impact of regional programs by increasing the industry awareness of available programs, and by bundling their implementation assistance with other financial assistance, when appropriate. ISS could also coordinate on a federal level to disseminate best practices employed in different regions to other parts of the country that could benefit. By serving as a focal point for the facility, engineering firm, and financial institution, ISS can utilize the network of other ISS across the country to easily gather and disseminate pertinent information regarding implementation best practices. This will in turn help reduce the transaction costs associated with implementing energy-efficient measures.

A final market barrier to industrial energy efficiency addressed by ISS is the lack of a trained energy-efficient workforce. ISS would support education and workforce training by employing business students from the local university in a manner similar to the successful model utilized by IACs. IACs have had significant success in training next-generation engineers skilled in energy-efficient industrial training. ISS could achieve mirrored success in training next-generation managers for industry. Energy efficiency is often under-realized in industry due to a low awareness and attention on energy efficiency by top management in industrial facilities. ISS would fill a growing need for business managers who not only understand the energy-efficiency opportunities available, but also understand how to realize savings by managing relationships with engineering firms and financial institutions through conventional and alternative clean energy financing tools available to industry. While necessary, it is not sufficient to only educate and train next-generation engineers to capture energy-efficiency savings in industry, effort must also be given to increasing the awareness and attention of next-generation industry managers as well. ISS, as described by this policy, would address this market failure by exposing business students to industrial best practices for achieving energy, production, and maintenance costs savings through collaborative partnerships with engineering firms and/or local financial institutions.

3.2.5 Stakeholders and Constituencies

Important stakeholders include industrial firms and manufacturers, environmentalists, the general public, consumer groups, utilities and regulators, energy service companies, along with local state and federal governments.

Industrial firms and manufactures. Increased number of energy saving assessments afforded by increased IAC funding, along with the establishment of ISS, would have significant impact on industrial facilities within the industrial sector. In addition to the ability of more industrial facilities to receive energy saving assessments, participating sites would be able to receive additional assistance to significantly increase the percentage of implemented energy savings. In most cases, implementation of energy savings will require an initial financial investment by the industrial facility. However, as demonstrated in the analysis provided in this report, implemented projects can have net-positive energy and non-energy related benefits. Also, because ISS can foster the growth of pay-as-you-save performance contracts between industrial facilities and partnerships between engineering firms and financial institutions, some energy savings may be implemented at no cost and little risk to the facility.

Given the increased level of energy assessments and higher implementation rates, a greater number of energy-efficient retrofits will occur, many of which will require the purchase of additional equipment. Consequently, equipment suppliers will be supportive of this policy unless they currently engage in the energy performance market and are not receptive to additional competition from engineering firms and financial institutions.

While ISS will leverage existing relationships that industrial facilities have with engineering firms, ISS success could be impeded if industrial facilities are unwilling to allow the firms to gain needed access to processes and products. This reluctance to allowing access has been a key barrier to the penetration of ESCOs into the industrial sector.

Environmentalists. Because of the potential impact on reduced industrial energy consumption and associated reduction in pollutant emissions, we anticipate that environmentalists will strongly support this policy option.

General public and consumer groups. Because ISS will promote long term partnerships to achieve continual energy-efficient improvements, this policy will positively impact the local and national economy through increased project and employment opportunities for local engineering firms and financial institutions.

Since IACs and proposed ISS are located near or at engineering and business schools, this policy will result in a greater number of student training opportunities both in technical and business industrial environments. Given the success of university programs that provide students with real-world applications of classroom learning objectives, it is anticipated universities will be supportive of the policy. ISS would also benefit the U.S. workforce by increasing the level of training and size of a management workforce capable of promoting and facilitating energy-efficient savings in industry.

Consumer groups, as a subset of the general public, may withhold support of federal funding to incentivize industrial energy efficiency since industrial firms will directly reap the energy saving benefits of increased energy efficiency. If emphasized, the public benefits of lower economy-wide energy consumption and reduced emissions from CO_2 and criteria pollutants may be utilized to gain consumer group support.

Utilities and regulators. Since the efficiency improvements enabled by this policy would reduce natural gas and electricity sales, utilities in states where profits are coupled to sales will generally not be supportive. Even though utilities may face a reduction in costs facilitated by industrial energy efficiency, the reduction in revenue from sales are larger, thereby negatively affecting the utility's balance sheet (ACEEE, 2011). However, in states where utilities do not experience revenue erosion when their sales decline, support for this policy may be neutral.

Energy service companies (ESCOs). We expect creating ISS within the IAC program will receive mixed support from ESCOs. ESCOs have traditionally not had a significant penetration into the industrial sector (Elliot, 2002). However, since ISS utilize existing working relationships between engineering firms, financial institutions, and industrial facilities to create a pseudo-ESCO solution, its acceptance and industrial sector penetration may be more successful. Additionally, industrial firms may be more willing to allow access to ISS, since they are a part of the federal IAC program. Therefore, ESCOs may be supportive of the ISS model because of its potential to demonstrate the benefits that the ESCO model can bring. However, ESCOs may see ISS as a direct competitor and as a result offer resistance to their establishment.

Local, state and federal government. ISS can coordinate across multiple government agencies to present industrial facilities with the best available implementation assistance by working with such programs as Save Energy Now, Manufacturing Extension Program, Clean Energy Application Centers, and local State Energy Offices. This level of synergistic coordination should increase the overall impact of these energy-efficiency programs. With this in mind, we expect positive support. However, because ISS is an additional federal program, it will have to compete for finite federal resources with other energy-efficiency programs, such as the aforementioned. Consequently, there may be resistance from these programs for fear of a negative funding impact on their organizations. Furthermore, this program could be viewed as duplicative with these existing programs, even though it provides assistance to increase the implementation rate of IAC assessments, a targeted purpose not currently being addressed.

Table 3.10. Stakeholder Assessment of ISS

Stakeholder	Pros	Cons	Dominant Position
Industrial Firms and Manufacturers	Will provide additional assistance to help reduce energy bills and production costs	Possible reluctance to allow access to processes and products	Favorable
Environmentalists	Through helping firms achieve increased energy efficiency, ISS will improve the environmental performance of participating facilities.	None	Favorable
General public and consumer groups	ISS and additional IAC funding will increase the practical workforce training of engineering and business students in energy efficiency.	Consumer groups may resist federal funding to incentivize industrial energy efficiency since industrial firms directly reap the energy savings.	Favorable
Utilities and regulators	States with decoupling will not see a threat to revenue and profits.	Without decoupling, energy efficiency can negatively affect balance sheets.	Unfavorable
Energy Service Companies	ISS can demonstrate the benefit of the ESCO model in industry.	ESCOs may see ISS as a direct competitor to their business model.	Favorable
Local, State, and Federal Government	Prospects of increasing industrial productivity through energy efficiency would lead to policy support by many government agencies.	Other federal agencies may perceive ISS as a funding competitor.	Favorable

3.2.6 Policy Evaluation

Appropriateness of the federal role. Because of the public nature of energy use and the benefit of energy consumption reduction by the industrial sector, it is appropriate for the federal government to act in the manner described by this policy. Since 1976, the federal government has invested in the IAC program to identify energy-efficient opportunities in industrial sites while providing “hands-on” training to next-generation engineers. Increasing funding to the IAC program will facilitate additional energy consumption reductions from implemented energy saving assessment measures to an expanded number of industrial facilities. This will in turn help the U.S. achieve its goal of supporting industries as they pursue a 2.5% reduction in their energy intensity each year through 2016 (EPAct, 2005).

Additionally, the creation of ISS further enhances the energy saving capabilities of an existing DOE program by increasing the implementation percentage of energy saving recommendations from IAC energy audits. As the overall energy demand decreases due to more efficient energy use, all U.S. citizens will feel the positive economic impact of lower energy prices.

In funding the IAC program since 1976, DOE has demonstrated a commitment to workforce development, particularly with regard to industrial energy efficiency. The ISS described in this policy option is consistent with that commitment by providing training in industrial energy efficiency to business students. In synergy with the IAC program's current success in training next-generation energy engineers, the ISS will facilitate the development of next-generation industry managers with an understanding of how to efficiently use energy.

Broad applicability. Energy savings assessments are currently conducted at large industrial facilities by DOE Energy Experts through SEN and at small- to medium-sized facilities by IACs. As greater funding is allotted to the IAC program, a greater number of assessments can be completed thereby leading to an expanded reach of the IAC energy impact. Because ISS will initially work directly with IACs, their applicability will be concentrated in medium-sized firms. However, ISS can foster increased implementation of energy saving measures in both large and mid-sized industries. As a result, the long term effect of this policy proposal would be to have broad applicability across medium to large sized facilities within the industrial sector that consume 93% of the sector's energy. Smaller facilities with high investment risk due to a reduced confidence in the facility's operational stability through the life of the energy savings payback period are less likely to directly benefit from this policy. Such high investment risk may preclude engineering firms and financial institutions from entering financial and energy performance contracts that are based on a facility's operations and mid- to long-term process stability.

Significant potential benefits. Analysis of IAC plant energy assessment and post-assessment survey results from the Save Energy Now (SEN) program from 2006-2009 (Wright and Nimbalkar, 2010) were used to estimate ISS potential benefits (see Appendix E for details). From 2000-2009, approximately 37% of Btu source energy savings identified in IAC assessments were implemented (IAC database, 2010). From the SEN survey analysis of reasons industrial firms did not implement energy saving recommendations, 23% were rejected due to financial reasons. Additionally, approximately 39% of measures not implemented from SEN energy saving assessments were in the in-planning phase, but had a simple payback of less than two years. Because ISS would work with financial institutions to reduce economic barriers, while also engaging engineering firms to provide manpower and expertise, these two categories of recommended energy savings will likely be significantly impacted. Accordingly, we estimate that half of these measures will be implemented as a result of ISS. This facilitates an increase in the total IAC implementation rate from 37% under business-as-usual (BAU) reference case to 58%.

The impact of increasing IAC funding to $16 million was modeled to facilitate an average of 1,300 energy saving assessments annually (twice the funding and therefore twice number of assessments completed in 2000), in contrast to the reference case of 312 energy saving assessments each year. As a result, from 2011-2035, the total number of energy savings assessments forecasted to be completed by the IAC program was increased from a business-as-usual reference case of 7,800 to 31,734. With an estimated 43,300 medium-sized firms (as defined in Chapter 1 of this report), this policy will support the assessment of approximately 74% of these facilities from 2011-2035. A second scenario was also examined as a policy sensitivity where the funding was only increased to the 2000 level of $8 million to support 650 energy assessments. This policy sensitivity results in a total number of 16,134 energy saving assessments forecasted (38% of medium-sized firms) to be completed from 2011-2035.

The potential incremental benefits of increased IAC assessments along with a higher implementation percentage of recommendation energy saving measures are significant and are summarized in Table 3.11. The benefits shown are in addition to the reference case of 7,800 IAC assessments completed through 2035 with an implementation rate of 37% (i.e. only the impact of increasing the number of assessments and augmenting the implementation rate is shown). The quantitative benefits of energy savings and emissions reduction are presented in the table. However, the additional benefit of providing the industrial workforce with business students trained in how to effectively generate bottom-line savings from energy reductions will also be significant but are not monetized and evaluated in our benefits and costs analysis. Also, since ISS is a new program, we model a two year pilot period. During this period, we assume that only two pilot ISS will be established; however, we estimate full deployment from 2013-2035. Lastly, in our analysis, we assume all facilities that receive an IAC recommendation, will allow an ISS follow-up. The authors believe that since other successful energy-efficiency programs have employed implementation assistance to generate energy savings, the IAC program will be able to do the same. However, it is possible that all firms will not welcome the additional assistance and will thereby reduce the overall added benefit of ISS.

Table 3.11. ISS Impact from the Industrialists' Perspective*

Year	BAU Energy Consumption**	Annual Energy Savings			Cumulative Energy Savings***		Annual Private Cost	Cumulative Private Cost
	Trillion Btu	Trillion Btu	$M (2008)	%	Trillion Btu	$M (2008)	$M (2008)	$M (2008)
2011	27,000							
2020	29,800	96	325	0.3%	506	2,000	107	1,230
2035	30,800	144	192	0.5%	2,500	6,140	39	2,210
2055	---	---		---	3,410	7,030	---	2,210

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

** Reference case industrial energy consumption excludes refining

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

While BAU annual industrial energy consumption is forecasted to grow by an average of 0.5% annually from 27,000 TBtu in 2011 to 30,800 TBtu in 2035, (an increase of 3,770 TBtu,), the annual energy saved under the principal policy scenario would reduce this anticipated increase by 144 TBtu (a 3.8% reduction). The forecasted energy savings in 2035 account for 0.5% of the total industrial energy consumption. Cumulatively, more than 3.4 quads of energy are projected to be saved from 2011 to 2055 in a cost positive manner. For comparison, the second policy scenario (IAC funding at 2000 levels) is projected to result in cumulative energy savings of 1.4 quads with a total private cost of $914 million.

Technology readiness. This policy is intended to result in an increased implementation rate of energy assessment recommendations, which focus on energy-efficient technologies that are currently available in the marketplace. As more efficient technologies emerge in the industrial sector, recommended measures will improve and the cost-effectiveness of the policy will improve.

Cost effectiveness. The benefits and costs of this policy are shown in Table 3.11 and 3.12. The principal policy (IAC funding at twice 2000 levels) is expected to generate $4.4 billion in cumulative energy savings from private investments of $2.2 billion that are leveraged from approximately $0.5 billion in federal funding. Moreover, these public expenditures lead to energy savings of approximately 3.4 quads. This yields an energy leveraging ratio of 7 TBtu/million $2008 or MMBtu/$2008. In the policy sensitivity case (IAC funding at 2000 levels), $0.2 billion in public investments generate $1.8 billion in cumulative energy savings. This also yields an energy leveraging ratio of 6.7 TBtu/million $2008 or MMBtu/$2008.

Table 3.12. Leveraging of Energy Savings from Cumulative Public Investments in ISS

	Public Costs*				Cumulative Energy Savings	Leveraging Ratio*
	Million $2008				TBtus	MMBtu/$
Year	Annual Administration Cost	Annual Investment Cost	Total Annual Costs	Total Cumulative Costs		
2020	22.5	---	22	217	506	
2035	14.4	---	14	485	2,500	
2055	---	---		485	3,410	7

*Ratio of cumulative energy savings in MMBtu to cumulative public costs in $2008. Present values of public costs were calculated using a 3% discount rate.

Table 3.13 presents the ability of the public sector to leverage carbon dioxide savings in the industrial sector through ISS. In 2035, public expenditures lead to CO_2 savings of 6 metric tons, representing 0.5% of the business-as-usual CO_2 emissions in the industrial sector that year. Over the lifetime of the equipment installed by 2035 as a result of this policy change, 157 metric tons of CO_2 emissions are avoided, yielding a carbon-dioxide leveraging ratio of 0.3 metric tons per dollar. For the policy sensitivity, a cumulative of 65 metric tons of CO_2 are avoided through 2055 via leveraging of 0.3 metric tons per dollar of public investment.

Table 3.13. Leveraging of CO_2 Emission Reductions Cumulative Public Investments in ISS

Year	Public Costs	CO_2 Emission Reductions			Leveraging Ratio*
	Million $2008	Million Metric Tons CO_2			
	Cumulative Costs	Annual MMT Saved	% Annual Emissions	Cumulative MMT Saved	Metric Tons/$
2020	217	5	0.3%	24	
2035	485	6	0.5%	116	
2055	485			157	0.3

*Ratio of cumulative emission reductions in million metric tons to cumulative public costs in $2008. Present values of public costs were calculated using a 3% discount rate.

Figure 3.7 shows the leveraging ability of public expenditures in the principal policy case ISS coupled with IAC funding at twice the 2000 level (shown with solid markers) compared with the sensitivity case where IAC funding is at the 2000 level (shown with open markers). The leveraging of energy savings per public dollar is shown on the left and the leveraging of carbon dioxide emission reductions is shown on the right.

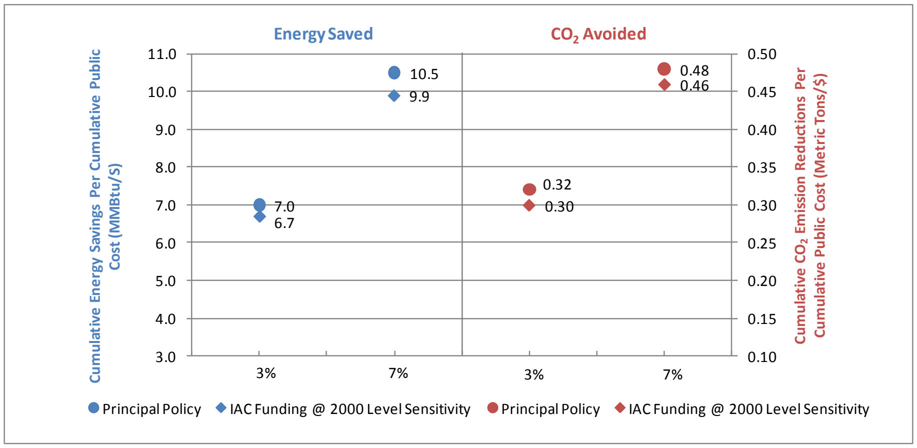

Figure 3.7. Energy and CO_2 Leveraging for ISS*

Cumulative CO_2 emission reduction per cumulative public cost for principal policy and policy sensitivity are both equal to 0.2 Metric Tons/$

Additional benefits from avoided air pollution damages due to the combustion of less fossil energy are also a significant benefit. Estimates of the reduction of criteria pollutant emissions are shown in Table 3.14 and Figure 3.8. These benefits are classified as public since the effects are distributed throughout society, and are discounted using a 3% rate. Of the four criteria pollutants considered, SO_2 emission reductions deliver the greatest human health and environmental benefits, totaling $4.1 billion in avoided damages through the year 2055, as the policy. Similarly, $1.67 billion in avoided damages from SO_2 occur in policy sensitivity case.

Table 3.14. Value of Avoided Damages from Criteria Pollutant Emissions* (Billions $2008)

	NO_x		SO_2		PM_{10}**		$PM_{2.5}$	
	Annual	**Cumulative**	**Annual**	**Cumulative**	**Annual**	**Cumulative**	**Annual**	**Cumulative**
2020	0.02	0.10	0.14	0.80	0.00	0.00	0.01	0.08
2035	0.02	0.38	0.12	2.91	0.00	0.02	0.01	0.28
2055	---	0.53	---	4.05	---	0.02	---	0.39

* Values are based on the National Research Council report estimating damages from energy production and consumption in the U.S. (NRC, 2010). Excludes pollutant damages from petroleum and coal for industrial heat. Present values of avoided damages were calculated using a 3% discount rate.
** Excludes PM_{10} from the production of industrial heat.

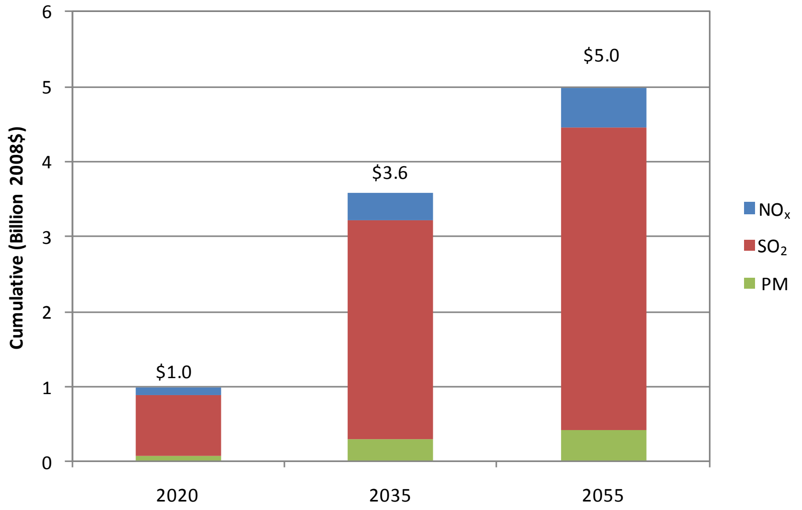

Figure 3.8. Value of Avoided Damages from Criteria Pollutants for ISS

We determined the financial value of reduced CO_2 emissions in each year by multiplying the decrement in emissions by the “social cost of carbon” (SCC) for that year. The SCC is defined as an estimate of the monetized damages caused by each incremental ton of CO_2 emitted. The SCC used in this analysis are central value estimates of the U.S. Government Interagency Working Group on the Social Cost of Carbon (EPA, 2010a). In this report, the central value SCC estimates ranged from $23/metric ton of CO_2 in 2011 to $34/metric ton and $47/metric ton in 2030 and 2050, respectively (all values are in $2008). Cumulatively, the principal policy option described in this report facilitates a present value of $3.0 billion in avoided CO_2 costs, while $1.2 billion in avoided CO_2 costs are achieved in the policy sensitivity. Considering the benefits of avoided CO_2 and damage from criteria pollutants in pollution reduction along with cumulative energy savings, the total discounted benefits derived from the primary policy through 2055 are $21 billion (Table 3.15a). The social benefit/cost ratio is approximately 5.6 with an estimated net societal benefit of $17.3 billion. In the case of the policy sensitivity, there are approximately $7.1 billion in net societal benefits with a social benefit/cost ratio of 5.5. Table 3.15b shows the discount rate sensitivity of the total social benefits and costs monetized in this report for the principal policy. Even in this higher discount rate case, the social benefit/cost ratio is approximately 4.5 with an estimated net societal benefit of $8.8 billion.

Table 3.15a. Total Social Benefit/Cost Analysis of Cumulative Public Investments in ISS

	Cumulative Social Benefits (Billions $2008)				Cumulative Social Costs (Billions $2008)			Benefit/Cost Analysis	
Year	Energy Savings	Value of Avoided CO_2	Value of Avoided Criteria Pollutants	Total Social Benefits**	Public Costs	Private Costs	Total Social Costs**	Social B/C Ratio	Net Societal Benefits (Billions $2008)
2020	2.5	0.5	1.0	4.0	0.22	1.48	1.7		
2035	10.3	2.3	3.6	16.2	0.49	3.29	3.8		
2055	13.0	3.0	5.0	21.0	0.49	3.29	3.8	5.6	17.3

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

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

Table 3.15b. Total Social Benefit/Cost Analysis of Cumulative Public Investments in ISS (7% Discount Sensitivity)

	Cumulative Social Benefits (Billions $2008)				Cumulative Social Costs (Billions $2008)			Benefit/Cost Analysis	
Year	Energy Savings	Value of Avoided CO_2	Value of Avoided Criteria Pollutants	Total Social Benefits**	Public Costs	Private Costs	Total Social Costs**	Social B/C Ratio	Net Societal Benefits (Billions $2008)
2020	2.0	0.4	0.8	3.2	0.18	1.23	1.4		
2035	6.1	1.4	2.2	9.7	0.33	2.21	2.5		
2055	7.0	1.6	2.7	11.4	0.33	2.21	2.5	4.5	8.8

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

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

Table 3.16 shows a range of benefit/cost ratios for both the primary policy and the policy sensitivity under alternative discount rate scenarios of 3% and 7%. In the first scenario, all cost and benefits are evaluated at 3% (i.e. private costs, energy savings, value of emission savings, and public costs). Similarly all costs and benefits are evaluated at 7% for the second scenario. As seen in the table, both the primary policy and the policy sensitivity have highly favorable benefit/cost ratios and net societal benefits.

Table 3.16. Social Benefit/Cost Analysis of Policy and Discount Rate Sensitivities

		Alternative Discount Rates	
		3%	7%
ISS with IAC funding at twice the levels in 2000	Benefit/Cost Ratio	5.6	4.5
	Net Societal Benefits (Billions $2008)	17.3	8.8
ISS with IAC funding at 2000 levels	Benefit/Cost Ratio	5.5	4.4
	Net Societal Benefits (Billions $2008)	7.1	3.6

Administrative feasibility. The administration of increased funding to the IAC program should be straightforward and no significant barriers are anticipated. Increased Congressional appropriation could be applied to ITP's "Industrial Technical Assistance". However, a challenge may arise from the need to create and fund more IAC centers (roughly twice the present number) to complete the increased number of energy assessments described by this policy. Additionally, small to moderate administrative barriers exist for the creation and support of ISS. ISS will be a new extension within the established IAC program; therefore, initial development will require a higher level of administration than currently present. ISS will operate in a mirror approach to IACs, in that both will work with regional industrial facilities and both will employ university students along with energy professionals to train a next-generation workforce competent in energy efficiency. Whereas the current IAC program provides energy saving assessments as a technical service to industrial facilities, ISS will primarily provide economic and business development assistance to local financial institutions and engineering firms to facilitate implementation of energy-efficient projects. The authors note that potential inefficiencies could exist in the handoff of IAC recommendations to ISS implementation staff. Therefore to minimize operational friction, the program could be designed to integrate the ISS business students in part of the assessment phase and the engineering students in part of the implementation phase. Because ISS is a new extension, it should first be established as a pilot program to determine operational best practices that can be implemented at to full deployment.

Additionality. ISS will have a positive impact on the other policies described in this report. As noted by the market progress evaluation of the Northwest Industrial Efficiency Alliance (Rock et al., 2009), continuous energy improvements such as those promoted by Superior Energy Performance (SEP) are likely to face implementation difficulty due to the lack of available staff and funding in industrial facilities. Therefore, the ability of ISS to bring together the necessary parties to provide funding and technical personnel will support and foster the industrial energy-efficiency efforts of other polices outlined in this report. This policy addresses the same market as SEP and Property Assessed Clean Energy (PACE) policies and therefore duplication of benefits and costs may exist.

3.2.7 Summary

Energy saving assessments conducted in industrial facilities have generated considerable reductions in U.S. energy consumption. The DOE ITP has facilitated much of the energy use reduction through successful industrial programs such as Save Energy Now and Industrial Assessment Centers. The federal action described by this policy option is to increase the appropriation applied to ITP's "Industrial Technical Assistance" to increase the funding level of the IAC program to enable a higher number of completed energy assessments. Also included in the increased appropriation would be funding to establish and support ISS. By leveraging existing relationships between industrial facilities, local financial institutions, and engineering firms, ISS would increase implementation of energy saving measures by providing additional technical and business support subsequent to initial IAC energy assessments. Because ISS would utilize business students from local universities, similar to the successful model employed by IAC to work with engineering students, this policy would support education and provide business graduates with a better understanding of energy and energy efficiency.

Key strengths and weaknesses of this policy are summarized in Table 3.17. ISS will have some challenges, such as resistance to additional ITP funding and reluctance of industrial facilities to utilize ISS, but in turn there is considerable long-term potential societal benefit. While we estimate approximately 3.4 quads and $17.3 billion of net social benefits will be fostered by ISS from 2011 through 2055, the non-monetized benefit of additional engineering and business students educated in energy efficiency is most significant. With a total present value of approximately $3.8 billion in federal and private investments, this policy has significant potential social benefits that outweigh societal costs.

Table 3.17. Overall Assessment of ISS

	Strengths	Weaknesses	Time Horizon*
Implementation Support Services	Appropriateness of the Federal Role; Workforce Development; Leverages an Existing Program	Potentially Duplicative with Exiting Programs, Low Societal Benefit/Cost Ratio	Short to Medium

*Time horizons when significant energy savings begin: short (5 years or less), medium (5 to 10 years), and long (more than 10 years).

3.3 Small Firm Energy Management

Policy Option: Authorize and appropriate funding for the Department of Energy (DOE) to implement a program to provide small manufacturing firms (five to 49 employees) with energy management software tools to build in-house capacity to manage energy use and identify potential energy savings opportunities, and to increase the participation of small firms in the Industrial Assessment Center (IAC) program.

3.3.1 Policy Summary

DOE has implemented industrial energy-efficiency programs since 1976, with the creation of the IAC Program.[55] IACs are oriented to conduct energy management audits and recommend energy-efficiency improvements in small and medium-sized plants. This program has conducted more than 14,000 assessments and has yielded more than 100,000 energy-saving recommendations. Over $4.5 billion in IAC identified energy savings have been implemented. While the IAC program is oriented to small and medium-sized facilities, only about 13% of industrial assessments to date have been conducted in firms with five to 49 employees. The U.S. has approximately 160,000 small manufacturing firms, representing 48% of the total manufacturing firms. These small firms consume 7% of U.S. industrial energy use and 21% of the energy used by the IAC target population (i.e., small and medium firms) (EIA, 2006).[56] Thus, the 13% rate of participation in the IAC program is low relative to the 21% of energy use that small firms represent in the IAC target market.

The Small Firms Energy Management (SFEM) policy would fill this gap in energy management assistance. The SFEM will offer training and support to small firms to manage their energy consumption, and explore potential energy-efficiency opportunities that would allow them to become a priority target for subsequent IAC assessments.

3.3.2 Elements of the Recommended Policy Approach

Four elements comprise the recommended policy approach:

- **Provide appropriate funding to the DOE Industrial Technologies Program (ITP) –** to implement workshops, create web tools for support, and increase funding for the IAC program to increase the number of assessments oriented to small firms.

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[55] http://www1.eere.energy.gov/industry/bestpractices/about_iac.html

[56] The data for these statistics are based on manufacturers categorized within NAICS codes 31-33. These manufacturers do not include refining, agriculture, or construction. Information on the number of firms with respect to different sizes based on the number of their employees can be found in: U.S. Census Bureau Office (2007) http://censtats.census.gov/cgi-bin/cbpnaic/cbpsel.pl. Data on the energy consumption by firms of different sizes can be found in: MECS (2006) http://eia.doe.gov/emeu/mecs/mecs2006/2006tables.html.

- **Organize IAC workshops and training programs** – to target 10 energy-intensive industry groups with a high proportion of small firms.[57]
- **Select small firms to participate in IAC assessments** – After participating in the energy management workshops and utilizing web-based tools, small firms will be able to benefit from an IAC assessment, followed by implementation of energy-efficiency recommendations.
- **Benchmark current industrial processes for small firms** – to improve the design of the targeted program activities and improve the effectiveness of their implementation at the state level.

3.3.3 Policy Experience

Between 2007 and early 2011, a total of approximately 206 IAC assessments have been conducted in small manufacturing firms. This represents 12.9% of the 1,593 assessments conducted in total during that period. Over the course of the entire program, small firms have represented 13.2% of participating sites. Based on total energy consumption as previously noted, this limited number of small firm assessments suggests an under-representation of small firms as participants of this energy-efficiency program.[58]

The average annual energy cost of small firms participating in the IAC program between 2000 and 2009, is approximately $509,000 per facility. The IAC assessments have identified an average of 7.7 billion Btu of annual energy saving opportunities for each participating small firm, which would reduce their energy consumption by 14.4%.[59]

The lack of knowledge in energy management of many small firms is one of the reasons for their minimal participation in the IAC program. Thus, improving small firm capacity and knowledge of energy management is a crucial step. DOE through the ITP has developed training programs that can be used as a platform to design new programs targeted to small firms. Some of the current ITP training programs, such as improving the efficiency of compressed air, motor, pump, steam, process heating systems, and data centers, can be easily adjusted to the requirements of small industrial firms.

The ITP also offers a collection of free software tools to help industrial plants identify and analyze energy system savings opportunities (Table 3.18).

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[57] Industry groups are defined by 4-digit North American Industry Classification System (NAICS) codes.

[58] Source: Analysis of the IAC database, accessed in May, 2011, conducted by authors (http://iac.rutgers.edu/database/).

[59] Source: Analysis of the IAC database, accessed in May, 2011, conducted by authors (http://iac.rutgers.edu/database/). IAC recommendations were matched with assessments for NAICS codes 31-33 in years 2006-2011. By focusing on these three codes, we eliminate the inclusion of agriculture, construction, and mining. This results in a subset of 263 assessments.

Table 3.18. Software Tools Sponsored by DOE's ITP

Plant-wide
- Industrial Facilities Tool Suite
- Quick Plant Energy Profiler/Integrated Tool Suite

Motor-Driven
- AirMaster+
- Fan System Assessment Tool
- MotorMaster+
- MotorMaster+ International
- Chilled Water System Analysis Tool
- Pumping System Assessment Tool

Steam
- Steam System Tool Suite

Process Heating
- Combined Heat and Power Application Tool
- NO_x and Energy Assessment Tool
- Process Heating and Survey Assessment Tool

Data Centers
- DC Pro Software Tool Suite

Source: DOE/ITP (2010b)

The Industrial Facility Tool Suite (IFTS) is designed to help owners and operators of industrial sites find ways to reduce energy use and costs, lower emissions, boost productivity, and increase the energy efficiency of their facilities. The IFTS has two components designed by ITP oriented to industrial plants: Industrial Facility Score Cards and the Industrial Facilities Systems Assessment Tool. The customization of the information provided is a key component of these tools. Required information includes the total annual electricity and fuel/steam consumption by process (envelope, lighting, heating and cooling, and ventilation), and the energy cost of each plant's building. These tools help to identify potential energy savings (electricity and fuel/steam) based on the energy information provided by plant owners and managers.

Most of the ITP Software tools that have been developed for the industrial processes described in Figure 3.9 are designed for industrial plants with high energy intensity uses (over 26 billion Btu) such as combined heat and power systems, boilers, and steam systems that are not frequently used in small industrial plants. Thus, there is an opportunity to augment existing software tools to facilitate their applicability to industrial processes more commonly used in small firms and by personnel who do not necessarily have sufficient knowledge to manage efficient-energy systems.

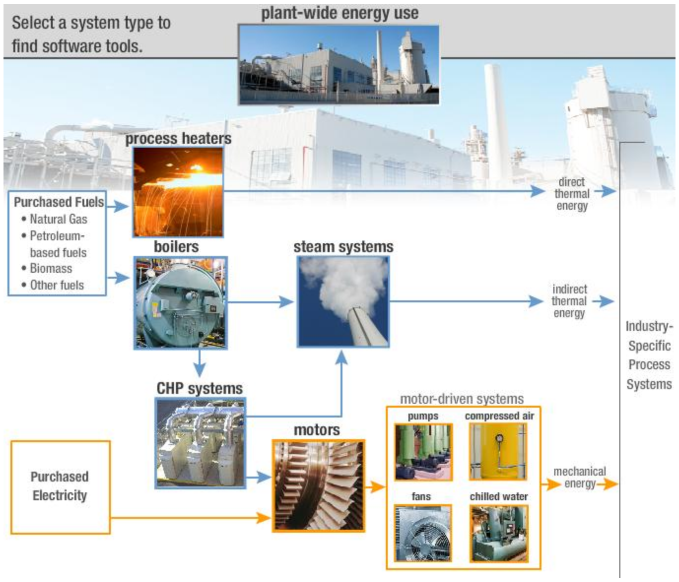

Figure 3.9. ITP Diagram of Software Tools for Different Types of Industrial Processes
Source: DOE/ITP (2010b)

A good example of adjusting specific programs to help small firms foster industrial building energy efficiency is the ENERGY STAR Program conducted by the U.S. Environmental Protection Agency (EPA). This program provides small firms with relevant information to conduct plant upgrades implemented with limited or no technical support. SFEM policy takes into consideration the limited knowledge and capital constraints faced by small firms. These barriers tend to limit actions to low-risk and high-return investments to save energy, such as replacing lighting with energy-efficient devices and programming annual maintenance of air conditioning and heating equipment (EPA, 2007b). ITP can work together with other federal agencies such as EPA and the Manufacturing Extension Program (MEP), which already have experience working with small firms in order to increase the adoption rate of this policy by small firms and ensure success.

ITP's energy management software tools currently designed for medium and large firms will need to be revised and adjusted to simplify their use by managers of small manufacturing firms, who typically lack energy management knowledge. Therefore, it will require a greater effort to reduce the energy management knowledge gap through the implementation of workshops by industry group. The implementation of specific training programs by industry will permit a focus on the particular requirements of small firms with similar production processes and equipment.

3.3.4 Policy Rationale and Description

DOE's ITP offers a range of additional energy-efficiency programs, such as the Save Energy Now (SEN) program, that are oriented to large energy-intensive industrial firms (more than 500 Billion Btu annual energy consumption). In addition, the IAC Program focuses on medium and moderately small facilities (between 70 to 499 Billion Btu). However, small firms with annual energy consumption lower than 70 Billion Btu (or those with five to 49 employees) have more limited program participation opportunities. These firms represent 48% of the total industrial sites in the U.S., although they account for only 7% of energy use (see Chapter 1 for more information about the population of industrial firms by employment size and energy consumption).

Due to rising prices for electricity, natural gas, and petroleum – the three principal sources of energy used by the industrial sector – energy consumption is having an increasingly negative impact on industry's bottom line. This negative effect also is hurting small firms. Historically energy has not been considered a critical cost element for small businesses, but it is increasingly perceived as an opportunity for cost reduction.

Often, energy savings are larger for small firms than for large firms, because in many energy-intensive small firms the energy costs represent a much higher proportion of the variable costs compared with process inputs. Small firms face more barriers than medium and large firms, such as lack of knowledge, lack of financing, and insufficient time to adopt energy management and energy-efficiency programs. Thus, it is important to generate programs especially designed for small energy-intensive firms, which consider and help overcome these particular barriers.

The SFEM program is conceived to fill the gap in availability of energy programs for the entire industrial sector. Due to the existence of more than 160,000 small firms, the program could be designed to target a limited number of industrial subsectors (Table 3.19). This targeting will not only reduce the number of potential clients (to approximately 102,000), but it could also concentrate the resources in the 10 subsectors with the highest potential for savings energy.

As shown in Table 3.19, the top ten industry subsectors of small firms include “fabricated metal production” and “nonmetal mineral production,” which have the largest total annual energy consumption among small firms, averaging 13 Billion Btu for each firm in fabricated metal production, and 36 Billion Btu for each firm in nonmetal mineral production. Other small firms with high levels of energy consumption come from the pulp and paper industry and the petroleum industry. On average, each of the 103,000 small firms in these ten industry subsectors consumes 21 Billion Btu of energy annually, compared with 15 Billion Btu for the total population of nearly 165,000 small firms.

Table 3.19. Top Ten Small Industrial Subsectors Based on Annual Energy Consumption

Industry Subsector	Average Energy Consumption per Small Firm (BBtu)	Number of Firms (5 to 49 employees)	Total Annual Energy Consumption (TBtu)
332 Fabricated Metal Production	13	31,680	408
327 Nonmetal Mineral Production	36	9,910	358
325 Chemical Manufacturing	42	6,640	279
311 Food Products	22	12,380	278
321 Wood Products	31	8,700	272
333 Machinery Manufacturing	11	13,790	155
322 Paper Manufacturing	63	2,140	136
323 Printing & Related Support Activities	6	14,970	94
324 Petroleum & Coal Production	70	1,130	79
313 Textile Mills	39	1,260	49
Other Manufacturing Industries	7	62,160	437
Subtotal: Top Ten	21	102,600	2,110
Total Small Firms	15	164,800	2,540

Source: IAC database (2010)

The design of workshops for each of these 10 industrial subsectors will help to provide owners and plant managers with an introduction to the best practices and cost-effective actions to reduce energy consumption and identify potential energy-efficiency opportunities. Additionally, new software tools, which consider the particularity of each industry subsector, will be required. The organization under each industrial subsector will facilitate the design of these software tools to leverage the lessons they share. The incorporation of this segment of small firms into successful practices of energy management will permit them to be ready to undergo IAC assessments and increase their rate of implementation of the effective recommendations.

SFEM policy is oriented to small firms; in the U.S. more than 160,000 companies fit this category (70% of the total population). Due to the large number of small firms it is necessary to reduce the scope of the SFEM policy to coincide with those small firms other than the energy-intensive industries. With this selection criterion, we assume a participation rate of 40% of the small firms in the 10 most energy-intensive small firm subsectors of the U.S. – resulting in 40,000 companies participating in the policy implementation, while also focusing on the largest opportunities for energy savings. Table 3.20 shows the top 10 small industrial subsectors (five NAICS code industries) that would be prioritized for SFEM.

Table 3.20. U.S. Small Firms in High Priority Industries for the SFEM Policy

NAICS Code	Industry	5 to 9 employees	10 to 19 employees	20 to 49 employees	Total Small Firms
31111	Animal Food Manufacturing	316	430	438	1,184
31121	Flour Milling and Malt Manufacturing	43	66	125	234
31151	Dairy Product (except Frozen) Manufacturing	112	141	217	470
31181	Bread and Bakery Product Manufacturing	1,904	1,643	1,089	4,636
31191	Snack Food Manufacturing	84	73	94	251
31331	Textile and Fabric Finishing Mills	206	145	135	486
32111	Sawmills and Wood Preservation	730	760	750	2,240
32121	Veneer, Plywood, and Engineered Wood Product	183	326	498	1,007
32222	Paper Bag and Coated and Treated Paper	101	125	178	404
32223	Stationery Product Manufacturing	74	85	88	247
32229	Other Converted Paper Product	82	114	159	355
32221	Paperboard Container Manufacturing	178	256	592	1,026
32222	Paper Bag and Coated and Treated Paper	101	125	178	404
32229	Other Converted Paper Product Manufacturing	82	114	159	355
32412	Asphalt Paving, Roofing, and Saturated Materials	403	244	164	811
32419	Other Petroleum and Coal Products	74	73	81	228
32518	Other Basic Inorganic Chemical	106	108	159	373

NAICS Code	Industry	5 to 9 employees	10 to 19 employees	20 to 49 employees	Total Small Firms
32519	Other Basic Organic Chemical	121	99	234	454
32561	Soap and Cleaning Compound	257	224	195	676
32599	All Other Chemical Product and Preparation	370	365	389	1,124
32711	Pottery, Ceramics, and Plumbing Fixture	139	92	77	308
32712	Clay Building Material and Refractories	79	98	152	329
32721	Glass and Glass Product Manufacturing	311	221	235	767
32732	Ready-Mix Concrete Manufacturing	1,164	1,550	1,259	3,973
32739	Other Concrete Product Manufacturing	430	453	434	1317
32799	All Other Nonmetallic Mineral Product	613	694	538	1,845
33242	Metal Tank (Heavy Gauge) Manufacturing	85	114	186	385
33243	Metal Can, Box, and Other Metal Container	73	59	102	234
33272	Turned Product and Screw, Nut, and Bolt Manufacturing	621	790	845	2,256
33281	Coating, Engraving, Heat Treating, and Allied Activities	1,155	1,256	1,278	3,689
33299	All Other Fabricated Metal Product Manufacturing	909	833	837	2,579
33313	Mining and Oil and Gas Field Machinery Manufacturing	144	155	184	483
33321	Sawmill and Woodworking Machinery Manufacturing	54	51	49	154
33329	Other Industrial Machinery Manufacturing	488	562	563	1,613
33331	Commercial and Service Industry Machinery Manufacturing	370	379	360	1,109
33399	All Other General Purpose Machinery Manufacturing	620	626	678	1924
	TOTAL	12,782	13,449	13,699	39,930

Source: U.S. Census Bureau, 2007

3.3.5 Stakeholders and Constituencies

Small industrial firms. The SFEM policy will facilitate the inclusion of small firms into effective energy management and energy-efficiency programs. The relatively small size of building firms usually does not allow them to take in consideration aspect of energy-efficiency in their building design and technologies (DOE/ITP, 2008a). These small industrial firms have been ignored from previous energy-efficiency governmental programs due to their lower energy-savings potential relative to large industrial facilities and firms. With the establishment of an SFEM policy, it will be possible to help these enterprises increase their energy efficiency, thereby reducing production cost and improving competitiveness of a particular U.S. industrial subsector. The program will likely improve the knowledge of energy-efficiency practices at small scale and over time refine the industrial characterization by subsector requirements and barriers to invest in energy efficiency.

Local, state and federal government. SFEM will work with different agencies to identify and bundle other available implementation assistance from state and federal agencies, such as EPA, the Office of Small Business Development Centers (SBDC) from the U.S. Small Business Administration (SBA), and IAC from DOE. Because SFEM promotes collaboration, allied state and federal programs should support the creation of SFEM, unless it is perceived to be duplicative.

Equipment suppliers. Given the increased level of energy assessments and higher implementation at a small scale, a greater number of energy-efficient retrofits especially designed for small firms and facilities are needed. This will create opportunities for suppliers to invest in small business energy innovations that can be developed in conjunction with other government supports programs such as the "*i6* Green Challenge program" launched recently by DOE in collaboration with the U.S. Commerce Department's Economic Development Administration (EDA) and its Office of Innovation and Entrepreneurship to promote clean energy innovation and economic growth. This program will consider funding to support energy innovation in small firms (DOE, 2011). Consequently, equipment suppliers will be supportive of this policy unless they currently engage in the energy performance market and are not receptive to additional competition from engineering firms and financial institutions.

General public. The general public will probably experience better air quality, which may have tangible health benefits. In industries where efficiency upgrades are made, consumers may also see reduced prices of products. The SFEM policy could also positively impact total U.S. employment, since manufacturing cost reductions could help retain jobs in small firms, which are historically responsible for a high proportion of industrial employment growth (SBA, 2011).

Gas and electric utilities. The response of traditionally regulated gas and electric utilities to this policy will be mixed. Since the efficiency improvements enabled by this policy would reduce natural gas and electricity sales, utilities in states where profits are coupled to sales will generally not be supportive. However, in states where utilities do not experience revenue erosion when their sales decline, support for this policy might be favorable.

Table 3.21. Stakeholder Assessment of SFEM Policy Implementation

Stakeholder	Pros	Cons	Dominant Position
Small Industrial Firms	Will reduce energy bills and possibly reduce production costs.	Small firms and facilities present significant barriers to adopting energy-efficiency measures that could reduce active participation in this program.	Favorable
Local, State, and Federal Government	SFEM does not require a huge amount of funding and the benefits are very important to small firms, which have high relevance with respect to employment rates and effects in local economies.	Higher impact of programs such as IAC and SEN for medium and large firms could reduce the incentive to conduct SFEM at smaller firm size levels.	Favorable
Equipment Suppliers	Potential to develop new products for small firms and take advantage of governmental programs that support R&D in energy efficiency.		Favorable
General Public/Consumers	Favorable general public opinion of SFEM due to its improvement of air quality, economic development, and employment rates.	If the benefits of this program are not well understood by the public, support by the general wane.	Favorable
Gas and Electric Utilities	Energy efficiency may erode utility revenues; however, its positive impact on the competitiveness of small firms would be appreciated by utilities.		Mixed

3.3.6 Policy Evaluation

Appropriateness of the federal role. Because of the numerous negative externalities associated with the consumption of fossil energy and the benefits of reducing the energy consumed by the industrial sector, it is appropriate for the federal government to act in the manner described by this policy. Bringing opportunities to small firms can improve their ability to manage their energy use. By building better bridges to small firms, the federal government can encourage them to be more active participants in energy-efficiency programs like IAC. Such participation can improve firm profitability. Reducing industrial energy consumption and environmental impacts, including carbon emissions and local pollutants from energy production, is another rationale for federal involvement.

Small firms make a significant contribution to economic growth. States with higher proportions of small firms show higher growth in productivity and Gross State Product than states with a lower proportion of small firms. Moreover, very small firms contribute to reduced wage inflation and rates of unemployment (Robbins et al., 2000). Other studies show an important contribution of small firms in entrepreneurship and innovation, two factors that promote economic development (Carree and Thurik, 2003). Given the important role that small firms play in the U.S. economy, providing methods and training on how to efficiently manage energy consumption in order to increase firm competitiveness is appropriate for federal action.

Broad applicability. This policy targets the 10 industrial subsectors of small firms that have the most energy-intensive operations. This program can also provide spin-off benefits to the rest of the industrial sector that face lower – but still significant – potential for energy savings through the development of energy management software tools that can be applied more broadly across small firms in different industries. These benefits, while potentially quite significant, are not monetized in this analysis.

Significant potential benefits. Full implementation of this policy is anticipated to result in a participation rate of 40% of the small firms in the 10 most energy-intensive small firm subsectors of the U.S. (i.e., 40,000 small firms). A rate of penetration of 60% of total potential energy-saving recommendations obtained with the use of software tools is also assumed. Such a policy scenario could save 21 TBtu of natural gas and electricity in the year 2020 and 38 TBtu of energy in 2035.[60] The latter is equivalent to the energy used by 1,800 small firms in the top 10 (small firm) industries in 2006 (i.e., 21 Billion Btu per small firm).

The energy savings of this program accrue from 2011 through 2055 and lead to cumulative energy savings of nearly 945 TBtu (Table 3.21). Although this represents less than 1% of the business-as-usual industrial energy consumption in that year (29,785 TBtu in 2020 and 30,763 TBtu in 2035, excluding refining), it nevertheless would save meaningful amounts of energy for each participating firm.

Also, among the 40,000 small firms participating in the SFEM policy, those that document a higher-than-average potential for energy savings would be encouraged to apply to be part of the IAC assessment program. The benefits of this recruiting function – with subsequent energy savings – are not included in our analysis.

These energy savings come at a private investment cost of $20 million in 2020 and $10 million in 2035, the last year of the SFEM policy. Cumulative private investment costs from 2011 through 2055 are $450 million (in $2008). These costs are considerably less than the value of the energy saved ($945 million in cumulative energy savings), suggesting a highly positive NPV from the industrialists' perspective.

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[60] Savings of other fuels such as coal and petroleum are not considered.

Sensitivity analysis was applied to evaluate the impact in energy savings of this policy with the same 40% participation rate, but with a lower (40%) rate of penetration of recommended measures. If only 40% instead of 60% of the measures recommended in the SFEM program are implemented, the energy savings would be reduced by 34% (e.g., from 20.9 to 13.8 TBtu in 2020). Cumulative energy savings of the program would drop from 945 to 624 TBtu, and from $2,450 to $1617 million in savings. These energy savings are small relative to the size of the entire industrial sector's energy usage, but still helpful to the participating firms. In addition, they remain considerably less than the cumulative private investment of $450 million, once again suggesting that the policy would be attractive from the industrialists' perspective.

Table 3.22. SFEM from the Industrialists' Perspective

Year	BAU Energy Consumption*	Annual Energy Savings			Cumulative Energy Savings		Annual Private Cost	Cumulative Private Cost
	Trillion Btu	Trillion Btu	$M (2008)	%	Trillion Btu	$M (2008)	$M (2008)	$M (2008)
2011	26,995							
2020	29,785	20.9	110	0.04	124	890	20	270
2035	30,763	37.6	60	0.06	587	2,140	10	450
2055	--	--	--	--	945	2,450	--	450

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

** Reference case industrial energy consumption excludes refining. These Business-as-Usual (BAU) estimates are output from the GT-NEMS industrial module. They differ slightly from the *AEO 2010* (EIA, 2010) published estimates, which are produced from a fully integrated NEMS analysis.

*** The percentages refer to the percent of energy use and carbon dioxide emissions from industrial energy use.

****Investments stimulated from the policy occur through 2035.

Broad applicability. Energy savings assessments are currently conducted at large industrial facilities by DOE energy experts through SEN and at medium-sized facilities (and some small firms) by IACs. The implementation of energy management targeted to small firms will allow filling this gap in energy management for all the different industrial sizes. The SFEM policy goal is cover 40,000 firms during the period 2011-2035. However, this policy will not be exclusive to this group of 10 energy intensive industries, because the ITP's energy management software tools will be free of cost available for the other 120,000 small companies. These additional benefits are not included in the monetized benefits estimates in our cost-benefit analysis.

Cost-Effectiveness. Assumptions regarding investment and potential benefit will be made based on small firms (five to 49 employees). This includes increasing appropriations of ITP "Industrial Technical Assistance" funds.

The public costs include the administrative cost required to implement the SFEM policy during the period 2011-2035. The estimated administrative cost is $6,000 per small firm. The total potential number of small firms participating in this program is about 40,000 during 2011 to 2035. In year 2020 the federal Government will incur administration costs of $10 million.

Table 3.23 estimates the ability of the public sector to leverage energy savings in the industrial sector using the SFEM policy. Cumulative energy savings through 2055 amount to 945 TBtu. Through 2035, cumulative public expenditures are estimated at $240 million using a 3% discount rate. This yields an energy leveraging ratio of 3.94 TBtu/million $2008 or 3.94 MMBtu/$2008.

Table 3.23. Leveraging of Energy Savings from Cumulative Public Investments in SFEM

	Public Costs*				Cumulative Energy Savings	Leveraging Ratio*
	Million $2008				TBtu	MMBtu/$
Year	Annual Administration Cost	Annual Investment Cost	Total Annual Costs	Total Cumulative Costs		
2020	9.6	0	9.6	96	124	--
2035	9.6	0	9.6	240	587	--
2055	--	--	--	240	945	3.94

*Ratio of cumulative energy savings in MMBtu to cumulative public costs in $2008. Present value of public costs were calculated using a 3% discount rate.

Table 3.24 presents the ability of the public sector to leverage carbon dioxide savings in the industrial sector using the SFEM policy. In 2020, public expenditures lead to CO_2 savings of 1.12 million metric tons, and this rises to 2.03 million metric tons in 2035, representing a fraction of a percent of the total CO_2 emissions from industry in those years. Over the lifetime of the equipment installed by 2035 as a result of this policy change, 40.3 million metric tons of CO_2 emissions are avoided, yielding a carbon-dioxide leveraging ratio of 0.17 metric tons per public dollar.

The estimated energy and carbon dioxide leveraging ratios are shown in Figure 3.10. These ratios are higher when public costs are discounted at a 7% real rate. They are also one-third higher with a 40% participation rate and a 60% rate of penetration of recommended measures (the assumptions of the “principal policy”) than with the 60% participation/40% penetration sensitivity case.

Table 3.24. Leveraging of CO_2 Emission Reductions from Cumulative Public Investments in SFEM

Year	Public Costs	CO_2 Emission Reductions			Leveraging Ratio*
	Million $2008	Million Metric Tons CO_2			
	Cumulative Costs	Annual MMT Saved	% Annual Emissions	Cumulative MMT Saved	Metric Tons/$
2020	96	1.12	0.07	6.67	--
2035	240	2.03	0.13	31.5	--
2055	240	--	--	40.3	0.17

*Ratio of cumulative emission reductions in million metric tons to cumulative public costs in $2008. Present value of the public costs was calculated using a 3% discount rate.

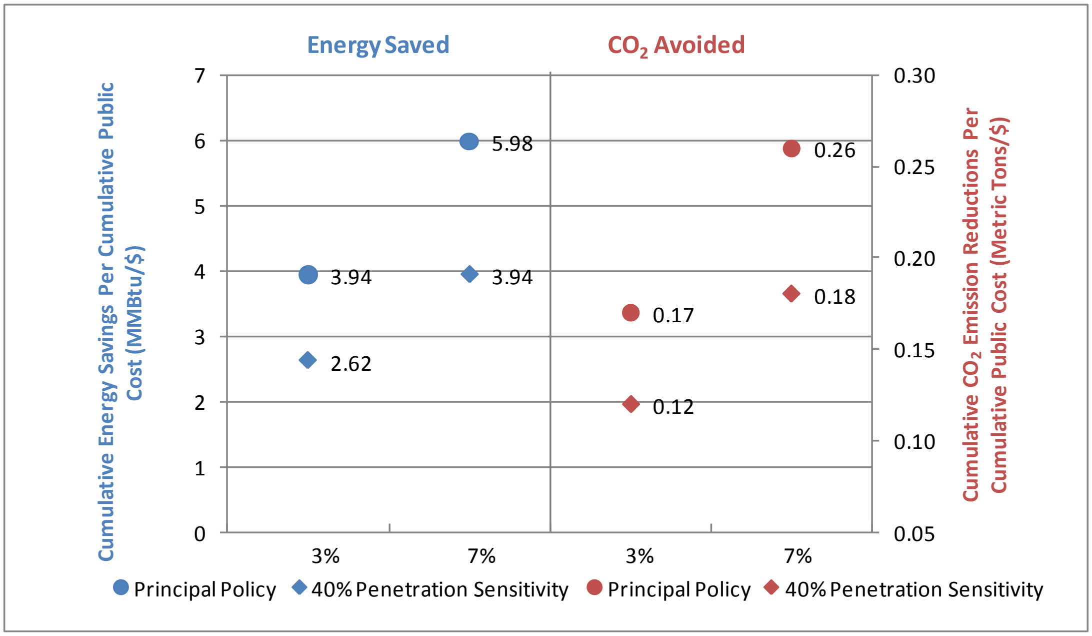

Figure 3.10. Energy and CO_2 Leveraging for SFEM

Further benefits accrue to society as a whole from increased energy efficiency in the industrial sector and reduced energy consumption from the electricity sector. Estimates of the reduction of criteria pollutant emissions are shown in Table 3.25 and Figure 3.11. Of the four criteria pollutants considered, SO_2 emission reductions deliver the greatest human health and environmental benefits, at $624 million cumulatively through 2055. The avoided costs of NO_x, SO_2, PM_{10}, and $PM_{2.5}$ due to the energy-efficiency measures are calculated in this table using a 3% discount rate. These emissions reductions represent additional significant benefits of the output-based approach, with savings of almost $800 million for the principal policy.

Table 3.25. Value of Avoided Damages from Criteria Pollutant Emissions (Billions $2008)

	NO_x		SO_2		PM_{10}**		$PM_{2.5}$	
	Annual	**Cumulative**	**Annual**	**Cumulative**	**Annual**	**Cumulative**	**Annual**	**Cumulative**
2020	0.003	0.02	0.018	0.121	0.0	0.0	0.002	0.012
2035	0.004	0.08	0.021	0.429	0.0	0.002	0.002	0.043
2055		0.113		0.624		0.003		0.063

*Values are based on the National Research Council report estimating damages from energy production and consumption in the U.S. (NRC, 2010). Excludes avoided pollutant damages from petroleum and coal for industrial heat. Present value of avoided damages were calculated using a 3% discount rate.
**Excludes PM_{10} from the production of industrial heat.

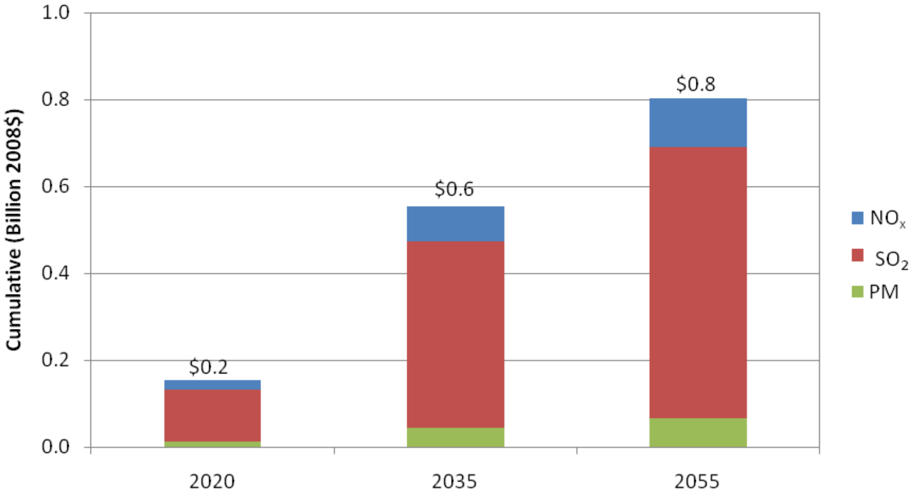

Figure 3.11. Value of Avoided Damages from Criteria Pollutants for SFEM Policy

This policy is cost-effective with a high rate of return on investment assuming a 40% participation rate and a 60% rate of penetration of recommended measures. Gains in efficiency of industrial processes reduce the emissions of the industrial and electricity sectors. We estimate the financial value of reduced CO_2 emissions in a particular year by multiplying the decrement in emissions by the "social cost of carbon" (SCC) for that year. The SCC is defined as an estimate of the monetized damages caused by each incremental ton of CO_2 emitted. The SCC used in this analysis are central value estimates of the U.S. Government Interagency Working Group on the Social Cost of Carbon (EPA, 2010a). In this report, the central value SCC estimates ranged from $23/metric ton of CO_2 in 2011 to $34/metric ton and $47/metric ton in 2030 and 2050, respectively (all values are in 2008 dollars). These reductions produce significant societal benefits from targeting the energy-efficiency potential of small firms, as shown in Table 3.26a. Including the social value of these emissions benefits as well as the energy savings results in a social B/C ratio of 7.95 for this policy option, using a 3% discount rate.

Table 3.26a. Total Social Benefit/Cost Analysis of the SFEM Policy

	Cumulative Social Benefits (Billions $2008)				Cumulative Social Costs (Billions $2008)			Benefit/Cost Analysis	
Year	**Energy Savings**	**Value of Avoided CO_2**	**Value of Avoided Criteria Pollutants**	**Total Social Benefits****	**Public Costs**	**Private Costs**	**Total Social Costs****	**Social B/C Ratio**	**Net Societal Benefits (Billions $2008)**
2020	1.27	0.14	0.15	1.57	0.10	0.35	0.45		
2035	5.06	0.63	0.55	6.24	0.24	0.88	1.12		
2055	7.22	0.88	0.80	8.90	0.24	0.88	1.12	7.95	7.78

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

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

The same analysis using a 7% discount rate is shown in Table 3.26b. The present value of the cumulative social benefits from SFEM are nearly cut in half with the higher discount rate, while the present value of the cumulative social costs decline less because they generally occur earlier. As a result, the social B-C ratio and the net social benefits are slightly lower when a 7% discount rate is used, compared to using a 3% rate to devalue costs and benefits over time. Net societal benefits are estimated to be approximately $47.8 billion. Its cumulative public costs of $1.1 billion are much smaller than its total societal benefits of $8.9 billion.

Table 3.26b. Total Social Benefit/Cost Analysis of the SFEM Policy (7% Discount Rate)

	Cumulative Social Benefits (Billions $2008)				Cumulative Social Costs (Billions $2008)			Benefit/Cost Analysis	
Year	**Energy Savings**	**Value of Avoided CO_2**	**Value of Avoided Criteria Pollutants**	**Total Social Benefits****	**Public Costs**	**Private Costs**	**Total Social Costs****	**Social B/C Ratio**	**Net Societal Benefits (Billions $2008)**
2020	1.03	0.12	0.13	1.27	0.08	0.30	0.38		
2035	3.01	0.37	0.34	3.71	0.16	0.58	0.74		
2055	3.70	0.43	0.44	4.56	0.16	0.58	0.74	6.20	3.82

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

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

The benefit-cost ratio of the sensitivity case is slightly lower than the main policy case because the lower penetration rates reduce the potential energy savings obtained with the implementation of this policy (Table 3.27).

Table 3.27. Social Benefit/Cost Analysis of Policy and Discount Rate Sensitivities

		Alternative Discount Rates	
		3%	**7%**
Policy Case	Benefit/Cost Ratio	7.95	6.20
	Net Societal Benefits (Billions $2008)	7.78	3.82
Sensitivity	Benefit/Cost Ratio	5.45	4.39
	Net Societal Benefits (Billions $2008)	4.98	2.49

Technology readiness. This policy focuses on removing information barriers to energy efficiency. It is not selecting technologies, only enabling their selection. As more efficient technologies emerge in the industrial sector, more of them should be implemented in industry as a result of the SFEM program.

Administrative feasibility. This policy can be administered by the ITP, which currently administers the IAC and SEN programs. The addition of the SFEM policy could complement the work conducted in the industrial sector. Because small firms face similar challenges to larger entities, these firms should be encouraged to collaborate with the SBDC, which currently is working with small firms and has a good understanding of the barriers and specificities of small enterprises.

The implementation of this policy involves three steps.

- First is the development of workshops for each of the 10 industries, using a webinar format. These webinars must be broadly advertised among small firms, with the objective of warranty their participation.
- The second step involves the creation of the internet platform which will be the contact point between ITP and the SFEM users. This platform must have a simple design that facilitates use by small firm managers that do not necessarily have expertise in energy management. This homepage will support the database generated by users. This information will be very relevant to determine future energy-efficiency potential in small firms. Each user should have a user name and password to enter to this service, and all the information should be registered in a database. Among the services offered by this platform are: best practices, energy audit, financial information, benchmarking.
- The third step is oriented exclusively to those small firms that utilized the software tools and determine significant potential energy savings. These firms could be offered audit services by the IAC program to determine recommendations for saving energy.

Additionality. SFEM will also have a positive impact on the other policies described in this report. In particular, this policy complements the IAC program that could be used to assess the energy-efficiency potential of these small firms. It could also facilitate the participation through information dissemination on the motor rebates program and encourage them to become an engine of energy-efficient job growth.

3.3.7 Summary

Small Firms Energy Management is a policy intended to fill the gap in energy management among small industrial plants (five to 49 employees). SFEM will allow small firms to build on-site capacity to manage energy use, and identify potential energy savings opportunities, which will qualify these firms to be part of IAC assessments. A full implementation of this policy with a penetration rate of 60% could save 76 TBtu annually, which is equivalent to the energy use of 1,000 small firms. Moreover, federal and private expenditures of $39.82 per metric ton of avoided CO_2 are projected. Table 3.28 summarizes the strengths and weaknesses of the Small Firms Energy Management policy. This program is applicable to the ten most energy intensive IACs industries. SFEM policy is cost-effective as each dollar invested in this policy will yield $3.53 of directly measurable benefits. Moreover, considering the environmental benefit of reduction in GHG emissions, the benefit-cost ratio could reach 5.8. SFEM can effectively contribute to reduced energy consumption by industry, thereby reducing production cost and improving the competitiveness of U.S. small firms.

Table 3.28. Overall Assessment of SFEM

	Strengths	Weaknesses	Time Horizon*
SFEM	Use of Information Technology, Appropriateness of the Federal Role, Additionality, Cost-Effectiveness	Broad Applicability, Administrative Feasibility, Lack of Financial Incentives to Implement	Medium

*Time horizons when significant energy savings begin: short (five years or less), medium (five to 10 years), and long (more than 10 years).

4 Policy Options to Address Financial Challenges

4.1 Tax Lien Financing

Policy Option: Allow municipalities to establish clean energy taxation districts, which can issue tax-free bonds for certified energy-efficiency and alternative energy projects, through federal enabling legislation. Authorize DOE to offer federal loan guarantees to provide security for the bond purchasers and provide a standardized format for the application process.

4.1.1 Policy Summary

Allowing municipalities to establish clean energy special taxation districts to enable upgrades for property owners (commonly referred to as Property Assessed Clean Energy (PACE) tax districts and liens) would facilitate financial options for industrial firms to invest in energy efficiency. To implement this policy option nationally, the federal government must pass enabling legislation and could offer loan guarantees to provide security and standardization for municipal bonds. Municipalities would, however, retain the primary responsibility for these activities, with flexibility to implement clean energy special taxation districts to meet local challenges and achieve local goals. While this policy option would allow property owners in all building sectors to access financing for energy upgrades, this report focuses on the potential of tax lien financing within the industrial sector.

This policy option would allow for the low-cost deployment of industrial energy-efficiency upgrades. Stand-alone financing insulates alternative energy and energy efficiency from competing with other maintenance and upgrade projects for funding, while maintaining transparency in the accounting system. The financing would support energy efficiency in industrial applications, as renewable energy installations are not as cost-effective in the industrial sector. Small and medium-sized industrial installations are likely to be the major beneficiaries of this effort, as large firms may prefer to self-finance rather than enter into special taxation agreements.

The approach involves the following elements, as outlined in Figure 4.1:

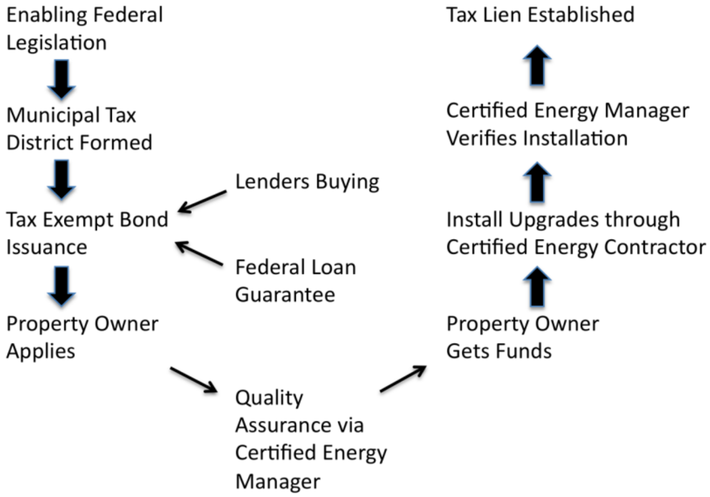

Figure 4.1. Elements of Clean Energy Tax Lien Financing

- **Pass enabling federal legislation allowing municipal governments to establish clean energy special taxation districts.** Such language is contained in the American Clean Energy and Security Act of 2009, which passed the House of Representatives in June 2009.
- **Municipality special taxation district formation.** This is the first step in bond issuance, allowing the municipality to find bidders and investors.
- **Municipal bond issuance with federal loan guarantee backing and tax-exempt status.** Federal loan guarantees provide stability and security for investors and signals the creation of a standardized bond product. The loan guarantee lowers market risks and information barriers to investment. Tax-exempt status for the loans is also a critical element to the program, as it disconnects these bonds from market fluctuations and allows for a stable rate of repayment.
- **Property owner applies for funds.** A Certified Energy Manager must approve the project and verify proper installation after project completion as a quality assurance measure. Municipal governments should also verify that the owner has a good tax payment history.
- **Certified energy contractor installs the efficiency upgrades.** The list of certified contractors available for such upgrades could be established by State Energy Offices or through a federal certification program.
- **Tax lien established and funds repaid over 20 years.** The marginal increase in property taxes would repay the bond funds issued for the upgrades. Additional activities could complement clean energy tax lien financing and address barriers to industrial energy efficiency. A federal training and certification program to ensure quality of efficiency service providers would develop a workforce capable of providing auditing, installation, and verification services. Incentivizing Superior Energy Performance

Standards (Chapter 3.1) would also lead to more firms looking to make efficiency upgrades to facilities, which PACE programs could help finance.

Clean energy special taxation districts can help property owners finance energy-efficiency upgrades through transparent means without making these upgrades compete with other projects for capital. Rates of repayment are established by municipalities, but are generally 20-year terms. These taxation districts also allow the efficiency measures to pay for themselves through energy savings, addressing the high upfront costs of upgrades. The incremental cost of repayment is usually offset or overcome through the energy savings, making projects cash-flow positive.

4.1.2 Policy Experience

As shown in Figure 4.2, 24 states have passed enabling legislation allowing municipal bond financing. All of these enabling laws passed in the last few years, with California the first to authorize PACE in 2008. Despite the short history, there are already several municipalities that have implemented clean energy special taxation districts as a means to finance energy-efficiency and renewable energy upgrades. The Database of State Incentives for Renewables and Efficiency (DSIRE) maintained by North Carolina State University lists 32 localities that have enabled PACE financing options[61]. Fuller, Kunkel, and Kammen (2009) reviewed three municipalities' – Palm Desert, California; Boulder County, Colorado; and Babylon, New York – experiences with this mechanism.

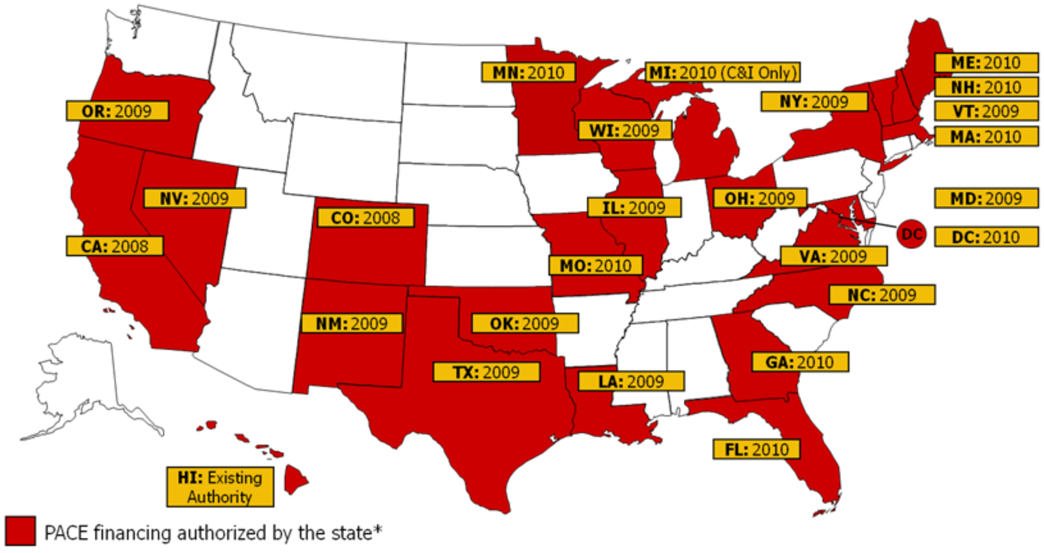

Figure 4.2. Clean Energy Financing Legislation

Source: DSIRE[62]

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[61] http://www.dsireusa.org/incentives/index.cfm?EE=1&RE=1&SPV=0&ST=0&searchtype=PTFAuth&sh=1

[62] http://www.dsireusa.org/solar/solarpolicyguide/?id=26

Table 4.1. Municipal Policy Experience

PROGRAM LAUNCHED	**PALM DESERT, CALIFORNIA**	**BOULDER COUNTY, COLORADO**	**BABYLON, NEW YORK**
	Oct 2008	April 2009	August 2008
POPULATION DENSITY HOUSING UNITS % RENTAL UNITS	51,000 pp 1,600 pp/sqmi 33,500 units 34% rental units	300,000 pp 400 pp/sqmi 123,000 units 34% rental units	220,0000 pp 4,1000 pp/sqmi 74,000 units 20% rental units
MEDIAN FAMILY INCOME	$70K	$64K	$84K
SOURCE OF CAPITAL	City's general fund for Phase I, then Redevelopment Agency bonds, now seeking a financing partner for Phase III	County issue bonds	Municipal solid waste revolving fund
FINANCING MECHANISM	Assessment (AB 811)	Assessment (HB 08-1350)	Assessment (amended solid waste code)
COLLECTION MECHANISM	Property tax bill	Property tax bill	Separate bill, transfers to property tax bill if delinquent
ELIGIBLE MEASURES	Energy efficiency, solar thermal, solar PV	Energy efficiency and variety of renewables	Energy efficiency, solar thermal, solar PV
CREDIT REQUIREMENTS	Clear title & good property tax payment history	Clear title & good property tax payment history	Clear title & good property tax payment history
SECURITY	Senior lien on property	Senior lien on property	Senior lien on property
RATE TERM MAX AMT	7% Up to 20 years No max	Varies (6.68% for 1st round) 15 years $50,000	3% term varies $12,000
WHO PROCESSES APPLICATION?	City staff	County staff with third party support	City staff
LOCAL GOVT STAFF	1.5 FTE	1-2 FTE	3 FTE
RESULTS AS OF AUGUST 2009	206 projects $36,000 ave/per $7.5 committed	393 projects $19,000 ave/per $7.5M committed	169 projects $7100 ave/per $12M committed

Modified from Fuller, Kunkel and Kammen, 2009

Palm Desert selected a unique approach from the other municipalities. The city initially chose to self-finance PACE liens through its general fund. There was public opposition to this approach and it did not have the full support of the city council. The second phase of the program uses bonds under the management of a city agency. Palm Desert also has a minimum cost associated with entering the program of $5,000 for the retrofit to qualify. There is no maximum limit to the funding for a project, but certain thresholds trigger oversight by officials in city government. With no cap, Palm Desert generally finances larger and more expensive upgrades than the other municipalities.

Boulder County offers tax-exempt bonds, which dramatically lowers the interest rates. The city has targeted the tax-exempt bonds to those citizens making less than 115% of median income. The remainder of Boulder's available funding is not tax exempt nor income restricted and has a cap of $50,000 per project. The first round of financing received 393 applications and approved $7.5 million towards these clean energy projects.

Babylon had a different approach to establishing their financing mechanism. Babylon reclassified carbon dioxide as a type of solid waste, which allowed the city to use its solid waste fund to finance projects that reduce carbon dioxide emissions. This fund now acts as a revolving loan program for PACE projects. Babylon is also unique in that instead of immediately assessing the lien to the property, it issues a separate bill to the owner. In cases of default, the debt is placed on the property.

The focus of these programs has been the residential sector, but there is an opportunity to expand the efforts to include industrial and commercial upgrades. Raising or eliminating the maximum values of upgrades would allow for further participation from industrial firms. There is also a significant opportunity for standardization in this process that would allow for a large-scale national effort. Caldwell et al. (2009) likened this program to curbside recycling; once municipalities and people are acquainted with the program, it could become a standard municipal service provided by communities nation-wide.

It should be noted that in July 2010, the Federal Housing Financing Agency (FHFA) issued a statement that has effectively halted most residential PACE programs and a number of lawsuits are currently in process (Lines and Supple, 2010). However, commercial and industrial PACE programs fall outside the FHFA's purview and have not been affected in the same way. While there are only 4 commercial and industrial PACE programs nationally, their number is increasing, with 13 more in the planning and design stages (LBNL, 2011).

4.1.3 Policy Rationale and Description

There are numerous barriers that lead to fewer investments in efficiency and renewable energy projects, as projects compete for limited capital financing within a business (examples include high hurdle rates within businesses and capital depreciation schedules for tax purposes). The federal response to corporate accounting scandals at Enron, Tyco, and Worldcom in the early 2000s has had the unintended consequence of creating a regulatory barrier for energy-efficiency and renewable energy upgrades. The Sarbanes-Oxley Act, which became law in 2002, addresses complex and off-balance-sheet accounting practices for publicly traded companies through information disclosure. Companies traditionally completed clean energy installations through off-balance-sheet financing and now have to finance these projects in competition with other costly measures (Lines and Supple, 2010). In addition, high transaction costs related to energy-efficiency and renewable energy projects and finding qualified and competent installers of these technologies is a challenge for industrial facilities.

Clean energy tax liens can provide solutions to these barriers. Financing clean energy upgrades through tax liens creates a transparent system for investors and property owners, while meeting the regulatory guidelines of Sarbanes-Oxley. The policy establishes available capital for industrial property owners to access, and creates security and standardization through federal loan guarantees. This can drastically reduce transaction costs for bond investors and property owners. Some initial difficulties are transferred to municipal governments like administrative and transaction costs previously handled by the industrial sector. However, ultimately, the property owner receiving the funds pays these costs.

Clean energy tax districts are special taxation districts, so municipal governments establish them but require enabling legislation from the state or federal government. The clean energy taxation district issues a master bond (preferably, a tax-free bond, like a private allocation bond) to generate funds, backed by a federal loan guarantee. Individual property owners apply for these funds to install a clean energy project. Creditors consider the funding as a property tax lien, senior to other debt on the property, and generally repaid over 20 years. The lien stays with the property and is visible to all involved parties at the time of a sale. The long, cash-flow-positive payback period, avoided complexities of multiple government bureaucracies, and local program administration make this approach potentially more attractive than other similar efforts, such as grant programs and revolving loan funds.

4.1.4 Stakeholders and Constituencies

Property owners (manufacturers, industrialists, generally small and medium sized companies). There are many advantages to the property owner with this type of financing. First, no upfront capital is required to begin retrofitting sites. Second, in the case of efficiency upgrades, savings can outpace the taxation surcharge, and thus creates positive cash-flows from the outset.

With a property sale, the lien stays with the property. However, if property-ownership changes and the new use of the property is unrelated to previous activities, the former owner may sell the property at a lower value because of the lien. The salvage value of the equipment may offset these concerns.

Municipalities. From the municipality's perspective, there is little credit or obligation risk, as the obligation is only for those who opt in to the tax district and the lien stays with the property, not the owner. The municipality could benefit from additional employment and GHG reductions due to retrofit projects. Implementing a mechanism for improving properties within a municipality, at no cost to those who choose not to participate, should help local economies. The municipality will incur the upfront costs of establishing the program and administering it, but these costs will be reimbursed over time and many municipalities are familiar with the process of establishing special taxation districts. The National League of Cities and the National Association of Counties have voiced strong support for PACE programs (NLC, 2010)

Federal government. This program would have significant job creation benefits and would rapidly advance national energy security and GHG emission reduction goals. The federal loan guarantee program should have low fiscal costs and high benefits, with the public cost burden at the local level. According to a preliminary analysis by Johnson Controls (2009), tax-exempt bonds could actually yield greater tax revenues, due to an expansion of job-related taxes, which outweighs the lost bond taxes. Enabling language was passed in the American Clean Energy and Security Act of 2009, but is not currently contained in active legislation in the Senate.

Bond investors. PACE investments are very secure, since property taxes are senior to all other debts on the property. Thus, in the case of a default, this debt is the first repaid. With a federal loan guarantee providing standardization and greater security, investors can become familiar with this type of bond issuance, similar to the American Municipal Bond Assurance Corporation and the Municipal Bond Insurance Association. Bond investors are buying an ownership interest in a revenue stream that can come from multiple projects as well, which then can act like a dividend and reduce risk.

National politicians. National politicians, specifically in the industrial Southeast and Midwest, might be particularly supportive of this type of program, as it expands industrial investment and job creation, without a significant expansion of federal authority. Fourteen senators (five from the South/Midwest) and 65 congressional representatives (12 from the South/Midwest) have expressed support for PACE programs[63].

Energy Service Companies (ESCOs) and integrated efficiency package designers. These service providers stand to gain business and expand their industries with this type of policy. ESCOs and integrated efficiency package designers would likely prefer certification to maintain quality in the industry.

Environmental groups. Influential groups such as the Sierra Club and National Resources Defense Council have expressed support for PACE financing, and both groups are now suing the Federal Housing Finance Agency, claiming the FHFA is effectively prohibiting PACE programs.[64] Its environmental benefits should help encourage other groups to support this activity as well.

Existing mortgage lenders. Mortgage lenders, a politically powerful group, may (and do) initially oppose this policy because a new debt is becoming senior to the existing debt. Fannie Mae and Freddie Mac have both publicly opposed this type of financing in the commercial and residential sector for this reason.[65] However, in the case of efficiency upgrades, Amory Lovins (among others) has argued that existing mortgage lenders should be supportive if provided with a project summary (Caldwell et al, 2009). This is because the returns on an efficiency investment often generate positive cash flow, thus decreasing the risk of default on the mortgage. The value of the property will also probably increase with newer and more efficient technology. Legally, the issue of placing a new senior debt on the property may be problematic, since many loan notes may require consent of the lender in order to do so. The more the

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[63] http://pacenow.org/blog/2010/09/endorsements/

[64] http://action.sierraclub.org/site/MessageViewer?em_id=183284.0; http://www.nrdc.org/media/2010/101006.asp

[65] http://www2.eere.energy.gov/wip/pace.html

municipal policy is designed as a standard special tax, the firmer the legal standing is for not requiring consent. Boulder, for example, does not require consent because they have structured their policy in a similar manner to other special taxes. Many municipalities appear uncomfortable with that approach, however, so lender notification is common. Fannie Mae/Freddie Mac could also develop a standard clarification or exemption form for PACE financing.

Shareholders. Shareholders may have concerns with this type of financing, should the investments not be rapidly cash flow positive, as the business may have invested resources elsewhere. On the other hand, if cost-effective efficiency investments are made, this should improve the overall financial situation of individual businesses and improve profitability.

Utilities and utilities commissions. Utilities, another politically powerful group, may be supportive of increased energy efficiency in the industrial sector, especially efficiency upgrades that do not also represent forms of distributed generation. The National Association of Regulatory Utility Commissioners have made it especially clear that they support PACE programs in the residential sector, urging the FHFA to rescind or substantially amend current practices that incapacitate existing PACE programs (NARUC, 2011). The NARUC argument in favor of residential PACE programs (efficiency is cost-effective and aids public health goals, amongst others) could easily be extended to the industrial sector, suggesting this group would view industrial PACE programs favorably as well.

A graphical analysis of the level of support each stakeholder group is anticipated to provide is found in Table 4.2 below.

Table 4.2. Stakeholder Assessment

Stakeholder	Pros	Cons	Dominant Position
Property Owners	Cash-flow positive efficiency upgrades	Increased property taxes	Very favorable
Municipalities	Increased local economic activity, improved environmental conditions, potential tax revenues	Programmatic start-up costs and on-going administrative costs, cost of 0% interest rate programs	Favorable
Federal Government	Job creation, energy security, emissions reductions, tax revenues	Costs of loan guarantee program	Favorable
Bond Investors	New market of secure investments	None	Very Favorable
National Politicians	Job creation, energy security, emissions reductions, tax revenues	None	Favorable
ESCOs	Increased customer base	None	Very favorable
Environmentalists	Decreased emissions of criteria pollutants and GHGs	None	Very favorable
Mortgage Lenders	Increased ability of program participants to repay loans	Loss of senior debt status	Unfavorable
Shareholders	Improvement in financial situation of company	Increased tax burden of company	Slightly favorable
Utilities	Reduction in energy consumption through cost-effective means	If distributed generation also increases, utilities may be less supportive	Favorable

4.1.5 Policy Evaluation

Appropriateness of the federal role. The House of Representatives passed enabling legislation in the form of the American Clean Energy and Security Act of 2009 (HR 2454), allowing the establishment of special taxation districts as well as the ability for the federal government to provide loan guarantees. DOE is extremely experienced with loan guarantees and operates other programs offering this option. While clean energy special taxation district formation is still a municipal-level decision, and enabling legislation typically comes from the state government, the federal enabling legislation would expedite the adoption of this policy option. Furthermore, the American Recovery and Reinvestment Act of 2009 provided funding for these types of programs.

Broad applicability. Allowing clean energy tax liens provides a cross-cutting, low-cost option for efficiency upgrades across all parts of U.S. industry. This policy option would incentivize firms to improve the efficiency of their manufacturing equipment and processes. A federal loan guarantee could provide standardization to the application process nationally, as well as provide greater security to bond purchasers.

Significant potential benefits. The potential benefits of this program for all sectors are substantial, and could begin almost immediately after the program is established. Fir Tree Partners (2009) estimates that the market for such a program would grow to $500 billion in 10 years after inception. Tax revenues five years after inception are estimated at $1.75 billion per year (Johnson Controls, 2009). Johnson Controls, in an analysis focused on energy retrofits to commercial buildings, also estimates $2 billion per year energy savings, a 22% reduction in commercial-sector GHG emissions, and 200,000 jobs created five years after inception.

Our analysis for the industrial sector also shows significant savings. We collected data from the Industrial Assessments Centers and Save Energy Now programs and analyzed those activities to determine implementation rates and the reasons for rejecting a recommendation. Looking at the rejections, we established an estimate of the recommendations that might be implemented and industry might finance through PACE programs. This percentage was multiplied by the energy expenditures of the small, medium, or large firms (from the 2002 *Manufacturing Energy Consumption Survey* [EIA, 2002]) and then multiplied by the overall efficiency improvement available in industry (22%) (from Nadel et al., 2004; and the *America's Energy Futures* study from The National Academies [2009a]). This determined annual savings for each industrial firm size, and summing this number provided an estimate of the potential savings. In the "Fast" case, it is assumed that it will take five years for all municipalities to offer PACE liens. A sensitivity analysis ("Slow") was performed with lower available efficiency improvements (14%) and a 20-year adoption period, the results of which are shown in Figure 4.3. All firms interested in PACE programs are assumed to utilize PACE financing the first time it is offered in their municipality in all scenarios. A complete description of assumptions and discussion is in Appendix G of this report.

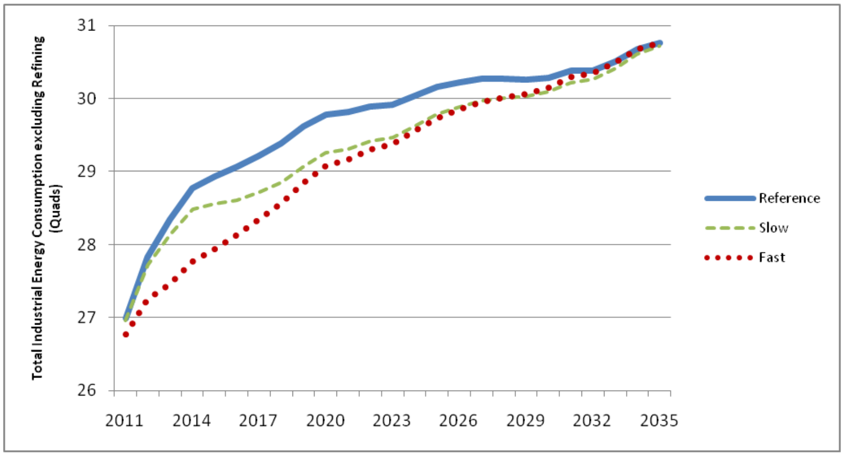

Figure 4.3. Industrial Energy Consumption Scenarios through 2035

The analysis shows that the greatest impacts from PACE financing are likely to occur early in the program's life, as the energy savings are not sustained throughout the entire 25-year period. This is largely the result of an assumption in the analysis that no firms would re-invest in PACE financing options after their original 20-year lien has been repaid and the expiration of the efficient equipment installed; as such, Figure 4.3 only represents the energy savings of PACE if the program can only be utilized once per interested facility and the program attracts no new interested firms. The greatest savings in the fast scenario occur in 2014; the greatest savings occur in 2019 for the slow scenario.

Table 4.3 presents the results of the analysis in terms of energy consumption and energy expenditures from the perspective of industrialists, utilizing a 7% discount rate. For the Fast PACE policy scenario, it is estimated that 638 TBtus of energy would be saved in 2020, representing 2.4% of the business-as-usual industrial energy consumption in that year. Over the lifetime of equipment installed through 2035, there would be 10,700 TBtus of energy saved. These energy savings come at a cost of $6.2 billion ($2008), but result in $33.2 billion in savings over the lifetime of the installed equipment. In the Slow PACE policy scenario, roughly 8,000 TBtus are saved, representing about $22 billion in savings over the lifetime of the installed equipment. See Appendix G for more information.

Table 4.3. Fast PACE Policy Option from the Industrialists' Perspective*

Year	BAU Energy Consumption**	Annual Energy Savings			Cumulative Energy Savings***		Annual Private Cost	Cumulative Private Cost
	Trillion Btu	Trillion Btu	$M (2008)	%†	Trillion Btu	$M (2008)	$M (2008)	$M (2008)
2011	27,000							
2020	30,000	638	1,680	2.4	7,010	26,500	323	4,620
2035	30,800	0.00	0.00	0.0	10,720	33,200	0.00	6,210
2055	--	--	--	--	10,720	33,200	--	6,210

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

**Reference case industrial energy consumption excludes refining

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

†Percent of annual industrial energy consumption

PACE financing clearly enables significant and rapid energy savings for the industrial sector. However, these savings are not sustained without additional efforts, due to equipment degradation.

Technology Readiness. This policy option focuses on addressing regulatory and fiscal barriers to implementing currently existing efficient technologies and is not dependent on new technologies entering the marketplace. As new, more efficient technologies become available, this policy option could increase their adoption rate, as it would be less expensive for firms to invest in these technologies.

Cost effectiveness. This policy option has proven attractive enough that municipalities are voluntarily providing this service. Federal actions could greatly expand the market and availability of clean energy special taxation districts for retrofit financing. The federal loan guarantees associated with the establishment of a national clean energy tax lien policy are historically secure investments, with a default rate of roughly 1% per year in states such as California on property taxes. With liens being the senior debt on a property, it is extremely unlikely that such loan guarantees will result in a loss of funds. The larger initial cost to the federal government would come from making the bonds tax-exempt. However, analysis by Johnson Controls suggests tax revenues from increased jobs in the energy services sector would offset the decrease in tax revenues from bonds (Johnson Controls, 2009). Noting the environmental, energy, and cost savings, as well as the legal structure, costs to the federal government should be minimal while benefits should be quite large.

Due to the repayment of the lien by the PACE user, the annual investment costs for the public sector rapidly become negative, representing income for local governments. However, since the PACE financing is modeled with 0% interest, local governments do not recover the full cost of the program through servicing the issued debt. Jurisdictions anticipate these losses will be recovered by employment, property, and sales taxes where this has been implemented (like Boulder County) and in multiple analyses (Fir Tree Partners, 2009; Colorado Legislative Council Fiscal Note, 2011; and California State Senate Majority Caucus, 2010).

Table 4.4 presents the ability of government to leverage energy savings in the industrial sector in the Fast PACE scenario. Through 2035, public expenditures are estimated at $3.6 billion with a 3% discount rate, and lead to energy savings of 10,700 TBtus. This yields an energy leveraging ratio of 3.00 TBtu/$million (2008 $) or 3.00 MMBtu/$. In the Slow PACE scenario, the energy leveraging ratio is 3.77 MMBtu/$ (see Appendix G for more information).

Table 4.4. Leveraging of Energy Savings from Cumulative Public Investments in Fast PACE

Year	Public Costs*				Cumulative Energy Savings	Leveraging Ratio*
	Million $2008				TBtus	MMBtu/$
	Annual Administration Cost	Annual Investment Cost	Total Annual Costs	Total Cumulative Costs		
2020	8.80	-584	-575	9,100	7,010	--
2035	0.00	0.00	0.00	3,580	10,720	--
2055	--	--	--	3,580	10,720	3.00

*Ratio of cumulative energy savings in MMBtu to cumulative public costs in $2008. Present value of public costs were calculated using a 3% discount rate.

Table 4.5 presents the ability of the public sector to leverage carbon dioxide savings in the industrial sector in the Fast PACE scenario. In 2020, public expenditures lead to CO_2 savings of 34 million metric tons, representing 2% of the business-as-usual CO_2 emissions in the industrial sector that year. Over the lifetime of the equipment installed by 2035 as a result of PACE, 570 million metric tons of CO_2 emissions are avoided, yielding a carbon-dioxide leveraging ratio of 0.16 metric tons per dollar or $6.30/ton. In the Slow PACE scenario, 380 million metric tons of CO_2 are avoided, corresponding to a carbon dioxide leveraging ratio of 0.18 metric tons per dollar or $5.60/metric ton.

Table 4.5. Leveraging of CO_2 Emission Reductions from Cumulative Public Investments in Fast PACE

Year	Public Costs	CO_2 Emission Reductions			Leveraging Ratio*
	Million $2008	Million Metric Tons CO_2			
	Cumulative Costs	Annual MMT Saved	% Annual Emissions	Cumulative MMT Saved	Metric Tons/$
2020	9,100	33.6	2.09	374	--
2035	3,580	0.00	0.00	566	--
2055	3,580	--	--	566	0.16

*Ratio of cumulative emission reductions in million metric tons to cumulative public costs in $2008.

Figure 4.4 shows both the energy and CO_2 leveraging ability of the Fast and Slow PACE scenarios at 3% and 7% discount rates. The ratios are higher for the Slow scenario due to the slower policy adoption rate pushing investments further into the future than in the Fast scenario. Combined with the discount rate, this yields improved ratios although net energy and CO_2 savings are lower.

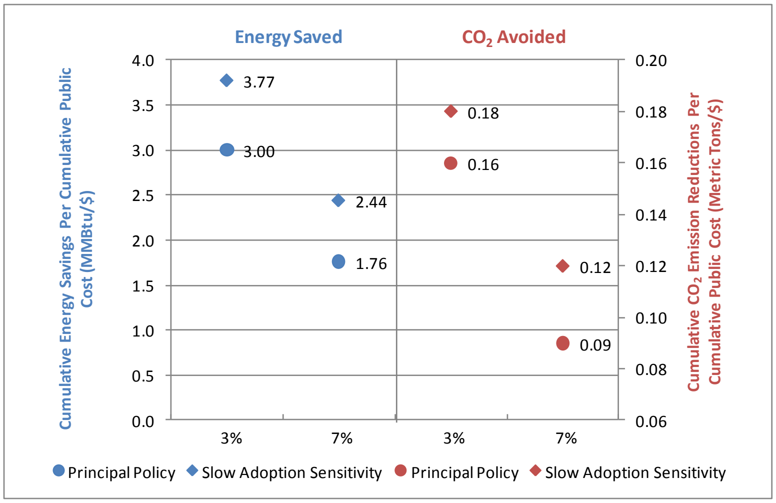

Figure 4.4. Energy and CO_2 Leveraging for PACE

Gains in the efficiency of industrial processes reduce emissions from the electric sector and from some combustion processes in industry. These emissions reductions represent additional significant benefits of the PACE approach, with savings in the tens of billions of dollars for both Fast and Slow scenarios (refer to Appendix G for more information). Estimates of the reduction of criteria pollutant emissions for the Fast scenario are shown in Table 4.6 and Figure 4.5, with SO_2 providing the greatest economic benefit at $18 billion cumulatively through 2055. The avoided costs of NO_x, SO_2, PM_{10}, and $PM_{2.5}$ due to the energy-efficiency measures are shown using a 3% discount rate.

Table 4.6. Value of Avoided Damages from Criteria Pollutants Emissions in Fast PACE Scenario (Billion $2008)*

	NO_x		SO_2		PM_{10}**		$PM_{2.5}$	
	Annual	**Cumulative**	**Annual**	**Cumulative**	**Annual**	**Cumulative**	**Annual**	**Cumulative**
2020	0.13	1.62	1.02	13.0	0.01	0.07	0.10	1.22
2035	0.00	2.26	0.00	18.0	0.00	0.10	0.00	1.70
2055		2.26		18.0		0.10		1.70

*Values are based on the National Research Council report estimating damages from energy production and consumption in the U.S. (NRC, 2010). Excludes avoided pollutant damages from petroleum and coal for industrial heat. Present value of avoided damages were calculated using a 3% discount rate.
**Excludes PM_{10} from the production of industrial heat.

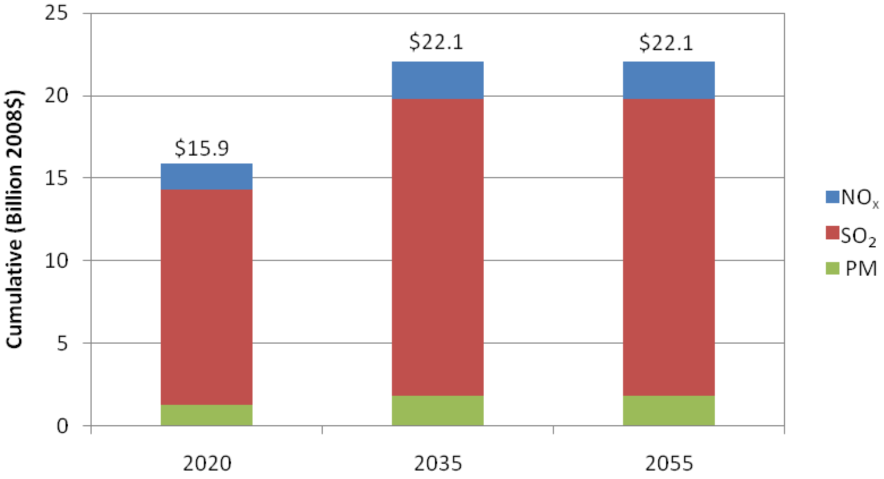

Figure 4.5. Value of Avoided Damages from Criteria Pollutants for Fast PACE

Gains in efficiency of industrial processes reduce the emissions of the industrial and electricity sectors. These reductions represent significant societal benefits for the PACE approach, as shown in Table 4.7a. Including the social value of these emissions benefits as well as the energy savings results in a social B/C ratio of 5.81 for the Fast PACE scenario, using a 3% discount rate. The same analysis using a 7% discount rate is shown in Table 4.7b, providing a sensitivity estimate.

Table 4.7a. Total Social Benefit/Cost Analysis of Fast PACE Scenario

	Cumulative Social Benefits (Billions $2008)				Cumulative Social Costs (Billions $2008)			Benefit/Cost Analysis	
Year	**Energy Savings**	**Value of Avoided CO$_2$**	**Value of Avoided Criteria Pollutants**	**Total Social Benefits****	**Public Costs**	**Private Costs**	**Total Social Costs****	**Social B/C Ratio**	**Net Societal Benefits (Billions $2008)**
2020	35.7	8.16	15.9	59.8	9.09	5.56	14.7		
2035	51.5	12.1	22.1	85.7	3.58	11.2	14.7		
2055	51.5	12.1	22.1	85.7	3.58	11.2	14.7	5.81	71.0

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

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

Table 4.7b. Total Social Benefit/Cost Analysis of Fast PACE Scenario (7% Discount Sensitivity)

	Cumulative Social Benefits (Billions $2008)				Cumulative Social Costs (Billions $2008)			Benefit/Cost Analysis	
Year	Energy Savings	Value of Avoided CO_2	Value of Avoided Criteria Pollutants	Total Social Benefits**	Public Costs	Private Costs	Total Social Costs**	Social B/C Ratio	Net Societal Benefits (Billions $2008)
2020	30.0	6.84	13.4	50.2	9.24	4.62	13.9		
2035	39.5	9.20	17.1	65.8	6.09	7.82	13.9		
2055	39.5	9.20	17.1	65.8	6.09	7.82	13.9	4.73	51.9

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

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

Table 4.8 provides a summary of the social benefit/cost ratios for the Fast and Slow PACE scenarios, analyzed at both the 3% and 7% discount rates. This sensitivity analysis highlights the net social benefit of more rapid adoption, but shows promise at either rate.

Table 4.8. Social Benefit/Cost Analysis of Policy and Discount Rate Sensitivities

		Alternative Discount Rates	
		3%	7%
Fast PACE Adoption Scenario	Benefit/Cost Ratio	5.81	4.73
	Net Societal Benefits (Billions $2008)	71	52
Slow PACE Adoption Scenario	Benefit/Cost Ratio	6.03	4.87
	Net Societal Benefits (Billions $2008)	44	29

Administrative feasibility. DOE has administered many large federal loan guarantee programs. However, the current Loan Guarantee program is oriented to nuclear, clean coal, and other large projects and has not been implemented at the smaller scale of numerous and more idiosyncratic energy-efficiency programs. Administrative issues may also occur at the municipal level, as each municipal government chooses how to specifically implement their program. However, experience with special taxation districts is widespread throughout municipal governments, and is unlikely to pose new difficulties. Measurement and verification, quality assurance aspects of the programs, and development of the certified workforce to install and approve efficiency upgrades would pose a challenge, but establishment and standardization should foster long-term success. Some programs in the commercial sector prove that these obstacles can be overcome (DOE/WIP, 2011).

Additionality. This policy option addresses very specific regulatory issues and concurrently addresses market barriers to industrial energy efficiency. Other programs, such as workforce training and certification programs, would assist in the ability of this policy option to finance energy-efficiency upgrades. It is also important to note that without awareness-building, this program is likely to be underutilized. DOE and local governments could leverage their relationships with industry to promote PACE. Expanding the scope and scale of this policy option will assist in establishing programs nation-wide. Increased implementation experience will also lower administrative costs at the local level. Clean energy special tax liens are compatible with a number of other policy options discussed in this report like an energy portfolio standard, but would also be compatible with other approaches, including training programs and industrial benchmarking requirements.

4.1.6 Summary

Clean energy tax liens offer the ability to implement many of the economically achievable efficiency upgrades that currently are untapped within industry due to financial constraints. The federal government could promote this policy option through enabling legislation, and DOE could assist with the market appeal by offering loan guarantees. This policy addresses significant financing and regulatory barriers that prevent manufacturers from making energy upgrades to their facilities. Enabling and promoting nation-wide adoption of clean energy tax lien approaches could lead to large energy savings and spur job development.

Table 4.9. Overall Assessment of Tax Lien Financing

	Strengths	Weaknesses	Time Horizon*
Tax Lien Financing	Broad Applicability; Significant Potential Benefits; Cost-Effectiveness; Additionality	Administrative Feasibility	Short to Medium

4.2 Energy Efficient Industrial Motor Rebates

Policy Option: Authorize and appropriate funding for DOE to implement a program to provide industrial firms and motor manufactures with rebates for purchases of certified high-efficiency motors of 25 to 500 horsepower that replace pre-EPACT-92 motors to accelerate adoption of EISA standard motors. Give priority and additional technical assistance to companies that include motor upgrades as part of a system-wide optimization of their facilities and promote further efficiency measures.

4.2.1 Policy Summary

The Energy Independence and Security Act of 2007 (EISA) upgraded standards on all new motors sold in the U.S. from requirements laid out in the Energy Policy Act of 1992 (EPACT-92) to National Electrical Manufacturers Association (NEMA) Premium® certified levels, but does not offer incentives to encourage firms to replace functional motors that predate EPACT-92 standards with more efficient models. In fact, an unintended consequence of the new standards policy could be that industrial firms choose to repair instead of replace older, inefficient motors rather than pay the additional costs of new motors under the new regulations (Elliot, 2007).

The Energy Efficient Industrial Motor Rebates (IMR) Program would provide industrial firms with the capital resources to replace motors that are a continual drain on operating budgets and quickly promote energy-efficiency upgrades. It could be modeled after the Motor Efficiency Rebate Program authorized in Section 245 of the American Clean Energy and Security (ACES) Act, as passed in the House of Representatives, which included an $80 million authorization for the first year of a program, and $270 million over the four years thereafter. Section 228 of the Senate's proposed American Clean Energy Leadership Act (ACELA) includes the same legislative language. Both bills would provide rebates to industrial enterprises that purchase a NEMA Premium® certified motor at $25 per each unit of nameplate horsepower. The manufacturers of the efficient motors would also receive $5 per unit of nameplate horsepower for efficient units that they sell.

Although not currently in the Congressional proposals, in order to facilitate the removal of the most inefficient motors, this policy option would incentivize motor replacement and recycling for 25 to 500 horsepower (hp) that pre-date EPACT-92 standards. Even efficient motors of that vintage will have undergone degradation in their energy saving mechanisms (Brown et. al., 1996). While firms readily replace smaller motors when they break down, they often decide to repair and rewind a larger motor in spite of higher electricity costs (Nadel et al., 2002). The federal government could also prioritize rebates for firms that incorporate the new motor into an optimization strategy for system performance and actively pursue energy efficiency beyond the replacement. The program would run through DOE's Industrial Technologies Program (ITP). ITP would devote training and technical resources on motor management and innovation to foster greater energy savings through this policy option. Congress can consider these rebates along with tax credits, such as the Variable Speed Motor Tax Credits, to further improve the nation's motor stock. These rebates would serve as a policy bridge towards greater implementation of the more stringent energy-efficiency standards industry-wide on motors.

Since motor replacement will likely be a part of any energy-efficiency upgrade, the rebates, also known as the National Crusher Credit Incentive Program, could complement any proposed industrial policy option, particularly the Superior Energy Performance program.

The policy’s design involves the following features:

- Authorization through ACES, ACELA, or another energy/climate bill and associated appropriations would initiate the program. DOE would then issue application guidance. A Central Processing Center (CPC), under the direction of the ITP, would administer the rebate to firms and manufacturers on a system similar to the Car Allowance Rebate System.
- DOE’s rebate program would give priority to companies that are engaged in comprehensive energy-efficiency activities or programs, such as Superior Energy Performance, Save Energy Now Leaders, or other similar programs. Firms will need to certify that they are replacing motors with new equipment of the same horsepower (or smaller) and are using the new equipment for a system-wide optimization. Firms will also need to verify that they recycled their motors and that the replaced devices will not return to the electric grid.
- ITP would provide training and technical resources to firms on motor management in order to encourage the best operational practices of the new motors and facilitate innovation in the design and efficiency of electric motor systems. ITP would work with energy managers to facilitate system optimization with the replacement motor. Firms would receive assistance in combining the motor replacement with other energy-efficiency improvements and financing options.
- DOE would leverage this program with public relations opportunities that encourage adoption of short, medium, and long-term industrial efficiency measures and inform the general public about the potential for savings in this sector.

Motor replacement is the first step toward any systems optimization and improved manufacturing processes. Combining this policy option with innovative financing programs could allow for further investment in energy-efficient systems throughout industrial facilities. The rebates are an effective first step toward the improved use of energy in any firm, particularly in the high motor energy process industries. Half of motor system energy use occurs in less than 2% of the nation’s industrial facilities, and chemicals, steel, aluminum, pulp and paper, water supply and wastewater, and mining are the primary users of industrial motors (Xnergy, 2002).

With effective planning and implementation, ITP could expand and enhance its existing and proposed activities in concert with the Energy Efficient IMR Program. The automotive and appliance programs have brought issues of efficiency in those areas to the forefront of national consciousness. The benefits and attention derived from this effort can facilitate a slate of future policies that will make American industry more competitive in the current economy and even better prepared for a potential cap on GHG emissions.

During consideration of the Energy Independence and Security Act of 2007, energy-efficiency advocates estimated that requiring all electric motors to meet NEMA standards could save 9,800 GWh per year (Elliott, 2007). The incentive program itself is a small policy but would be a useful tool for improving the reach, impact, and effectiveness of the new standards. Improved maintenance and rewinding of motors is a useful method for low-cost improvements, but wider deployment of NEMA-certified new motors could lead to an 11% to 18% decrease in motor electricity use (Xnergy, Inc., 2002). In addition, the program could encourage “free drivers,” or companies that elect not to participate in the rebate program directly, but decide to replace pre-EPACT-92 motors, or even EPACT-92 standard motors, with NEMA Premium® equipment. Some firms that receive rebates may also choose to upgrade additional motors that are ineligible for rebates, which are another type of “free driver” or positive spillover effect (NAPEE, 2007b).

4.2.2 Policy Experience

Motor rebate programs have been and continue to be successful in the Northeast and the West. Industrial leaders recognized the need for the efficient use of motors in facilities in the wake of the energy challenges of the 1970s. Energy intensive industries voluntarily improved their electric motor systems throughout the 1970s and 1980s. The EPACT-92 required Motor Efficiency Performance Standards across the industrial sector, and EISA mandates further improvements, but there are no regulations requiring the shutdown of pre-EISA or pre-EPACT machinery.

The Motor Challenge Program was initiated in 1993 as a voluntary effort of DOE that operated primarily through partnerships, technical assistance, and software applications. The expanded partnerships facilitated the growth of the efficient motors market, resulting in nearly $25 million in annual energy savings by the end of that decade (Xnergy, 2000). NEMA and the Consortium for Energy Efficiency (CEE)[66] aligned their specifications for 1-200 hp motors in 2001 to be equivalent to the NEMA Premium® efficiency level (Emanuele, 2010).

On a regional level, the Northeast Energy Efficiency Partnership and New York State Energy Research and Development Authority began to encourage efficient motor deployment. The Northeast states used ratepayer funding to provide rebates on NEMA certified motors. Pacific Gas and Electric in California also used a combination of upstream rebates (to motor manufacturers) and downstream rebates (to motor purchasers) to encourage sales of the energy saving technologies (Elliott, 2007). In the Pacific Northwest, the Northwest Energy Efficiency Alliance also developed motor programs (Eaton Consultants Inc. and Xnergy Inc., 1999). These rebates, however, have not reached the entire population of industrial facilities and, as this federal program is relatively small, could still successfully operate in conjunction with this effort.

4.2.3 Policy Rationale and Description

Approximately two-thirds of industrial electricity consumption is used to operate motors and, over the life of a motor 96% of the expenditure is for electricity, with initial purchase and

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[66] CEE operates Motor Decisions Matter (2010), “a national public-awareness campaign sponsored by a consortium of electric utilities, industry trade associations, and others. MDM and its sponsoring organizations provide support for companies interested in motor management.”

maintenance accounting for a small fraction of the cost (DOE/ITP, 2008b). Motor replacement is a long-term endeavor, with an estimated time frame of 15 to 20 years for a 90% turnover in the market (Xnergy Inc., 2002). Building on the successful energy-efficient rebate model should drive demand towards cost-effective technologies and encourage the development and production of premium electric motors. Among the barriers to deployment of NEMA certified motors are financing and a lack of understanding on the part of the industrial sector leadership to the saving opportunities (Eaton Consultants Inc. and Xnergy Inc., 1999). Through funding and information dissemination in this policy, significant savings are possible.

The economics of energy-efficient motor deployment rest on the decisions of firms to repair or replace. The challenge of the standards regulations that go into effect in December 2010 is that NEMA Premium motors cost 10% to 30% more than EPACT standard motors (EIA, 2010), changing the equation as firms decide how to handle a breakdown for their oldest equipment. This policy will reduce prices 35% to 40%, helping to ensure that the new standards do not undermine the intent of those who advocated for the EISA requirements.

The transportation and residential sector energy-efficient rebate programs of the American Recovery and Reinvestment Act have laid the groundwork for the industrial program. “Cash for Clunkers” improved the entire fuel economy of all American automobiles on the road by 0.17% (Brown, 2009). While this may not have been a groundbreaking total, the attention helped to spur interest and demand in fuel efficiency. The “Cash for Appliances” program has also increased energy-efficient product sales and helped improve consumer awareness in ENERGY STAR labeled products (Plautz, 2010).

This policy can become law as part of a climate or energy bill, or as stand-alone legislation. Implementation should occur as part of the ITP budget in the appropriations process. The Executive Branch, with oversight from Congress, can use its administrative resources to ensure transparency and legitimacy in the financial transactions of these incentives.

4.2.4 Stakeholders and Constituencies

Important stakeholders include the motor manufacturers, industrial firms, utilities, the federal government, policy-makers, and the general public. Support or objection from these groups is likely to depend on the benefits each group might accrue, as well the desirability of public expenditures on energy efficiency in industry.

Motor manufacturers. Motor manufacturers, an industry that produces more than half of its output domestically (IMPLAN, 2008), will benefit from increased sales of their products and the direct upstream rebate of $5 per horsepower on every motor they sell. Although that $5 per horsepower will primarily cover the paperwork and other processing requirement of the rebates, the motor market should experience a boost as industrial firms take advantage of this policy to upgrade their systems. While this market transformation may require changes to motor manufacturers’ current operations, the deployment of energy-efficient products will help expand

and improve the industry. The rebates will also help alleviate any decline in sales from the implementation of the new standards.

From conversations with staff on Capitol Hill, motor manufacturers have been the most vociferous advocates of the rebates. In fact, many of the champions of this program in Congress hail from states and districts with motor manufacturing companies. The rebates will help these firms to increase sales and continue to produce advanced motor systems.

Industrial firms. Industrial firms in need of motor replacement will find that this policy should meet the cost premium of efficiency on all motors of greater than one horsepower (Nadel et. al., 2002). While firms will need to certify that they meet the program criteria, these rebates will have short term and long-term benefits to their economic futures. Many companies will likely seek the opportunity of the Energy Efficient IMR Program, although limited resources may not allow for replacement of motors for all interested parties.

From discussions with stakeholders, industrial firms may be reluctant to replace a working motor due to the potential risk of that machine on its production process. In addition, this may not be the preferred equipment for an energy-efficient replacement for many firms. This voluntary program, however, would have significant financial benefits at a lower cost to participating firms.

Utilities. As a result of the energy savings from the energy-efficient electric motors, utilities will see a small decline in electricity sales. Additionally, from communications with stakeholders, utility program managers may also see this program as a challenge to their own energy-efficiency rebates. The rebates, however, could also serve as a leveraging opportunity and help maintain large customers in a utility service area.

Federal government. This investment in American industry will further expand the deployment efforts of ITP and the federal government. To complement ITP's transformative R&D and targeted education and technical assistance in the industrial sector, these additional resources would allow the Office of Energy Efficiency and Renewable Energy to directly fund industrial energy efficiency. This would provide for an expanded role for the federal government in this sector.

Policy-makers. The popularity of this program with industry could help garner the support of politicians and policy-makers. This authorization has already passed the House of Representatives through ACESA and but failed to move through the Senate in the last Congress. Senator Blanche Lincoln was the leading proponent of this proposal in her chamber before leaving office in January. With opposition to the expansion of the federal budget and national debt, however, some national leaders may resist the additional $350 million on taxpayers, particularly representatives of non-industrialized constituencies.

General public. Unlike the automotive and appliance rebate programs, individual consumers will not see direct and immediate benefits from these rebates. However, the longer term effect should be to lower manufacturing costs, which could translate into lower prices of finished products to consumers in competitive markets. The externalities of this program will all improve the public good – as it could reduce pollution and expand economic opportunities in the industrial sector. As a result, this policy would likely garner the support of environmental and business advocacy groups; however, it could also receive opposition from taxpayer groups and those opposed to additional public sector spending. A significant fraction of the rebates would go to large companies, potentially leading to complaints about spending taxpayer funds on big business.

Table 4.10. Stakeholder Assessment

Stakeholder	Pros	Cons	Dominant Position
Motor Manufacturers	Will help boost motor sales and drive the market towards new more efficient motors	None	Very Favorable
Industrial Firms	Will allow firms to upgrade and improve their motor systems at a discounted price.	Risk and uncertainty from the new equipment or may prefer rebate on a different product	Favorable
Electric Utilities	Will open opportunities to leverage utility programs to support large customers	Will reduce sales and could overshadow utility rebate programs for industry.	Unfavorable
Federal Government	Will expand the role of ITP and allow DOE to promote the new standards and other programs	Will require significant administrative support.	Favorable
Policy-makers	Will support American industry and American motor manufacturing firms	Significant costs to the federal government.	Mixed
General Public	Will reduce emissions, support domestic industry, and facilitate economic growth.	High public expenditures with most of the financial benefits for business.	Mixed

4.2.5 Policy Evaluation

Appropriateness of the federal role. The federal government is responsible for the promulgation of the new standards in EISA. As this specific policy relates to those new standards and its extension of the broader policy context, it is appropriate for the federal government to participate in this manner. In addition, the American Recovery and Reinvestment Act included popular energy-efficiency replacement programs – including "Cash for Clunkers" and ENERGY STAR Appliance Rebates – to drive investment in new products and remove outdated equipment with relatively higher emissions rates (DOE, 2010b). The House of Representatives passed enabling legislation in the form of the American Clean Energy and Security Act of 2009 (HR 2454), which authorized the creation of this approach. Through the

"Cash for Clunkers" and "Cash for Appliances" programs, DOE is well prepared to manage a "Cash for Crushers" program of this form and magnitude.

Although the State Energy Offices operated "Cash for Appliances" with federal funds, DOE could have the most impact if it does not cede control of this effort to the local level. A consistent nation-wide effort will serve the needs of industrial facilities without creating an additional layer of administrative complexity and ensuring the most effective distribution of resources. Since not all regions and states have familiarity with industrial rebates, the federal government can ensure that facilities that have not yet been eligible to receive these funds will benefit through this program. The ITP, through its administration of programs and partnerships with national labs, universities, and other relevant entities can support the technical assistance aspects of this program.

Broad applicability. Any industrial facility looking to upgrade its infrastructure for energy efficiency will be able to participate in this program. Only companies that cannot certify that they are seeking improved technologies and practices beyond just replacing their motors may be ineligible for rebates. This program should drive the long-term marketplace towards the use of more efficient motors, even after its expiration, via cost/price competition. As noted, however, the motor population is concentrated in larger firms in the most energy intensive industries, limiting the opportunities for many businesses.

Significant potential benefits. This program could save industry millions of dollars, with an initial federal investment of $350 million. On average for eligible motors, using EIA (2010) assumptions, the new motors will cost approximately $1,120 more than fixing old machinery. Using data from the American Council for an Energy-Efficient Economy (Nadel et. al., 2002), this program will lead to an estimated replacement of 259,000 motors (11.3 million hp) over the total 5-year period, and the incentives will cover the full cost differential between a premium and inefficient new motor for companies replacing their systems. As indicated in Table 4.12, the number of motors replaced is based on the total number of horsepower available for replacement, annual sales ratio by size, and the average size of the motors within the categories. The rebates will reduce the cost of premium motors by 35% to 39% of their list price depending on the size of the motor (EIA, 2010). Table 4.11 shows the average savings to the private sector in motor price by the horsepower of the motor.

Table 4.11. Motor Replacement by Size

Horsepower	Percentage of Sales for All Sizes	Estimated Motors Replaced by Size Under Rebate Program	Percentage of Average Premium Efficiency Motor Cost Discounted with Rebate
25 to 50	8%	215,000	36%
51 to 125	4%	40,000	39%
126 to 500	1%	4,000	35%

Source of Percentage of Sales: Nadel et al. (2002)
Source of Price Data: EIA (2010)

Based on previous studies (Elliott, 2007), we have assumed that firms would voluntarily purchase efficient motors 20% of the time without the incentives, and thus, 20% of firms are assumed to be free riders of this policy. The energy savings, investment costs, and public costs of these free riders are not counted in the principal policy analysis of the IMR program; however, we do conduct a sensitivity analysis of the program's societal costs and benefits when the public costs of free riders are included in the overall policy assessment.

Figure 4.6 is the savings formula for motors as outlined by Jordan (1994) and applied for this analysis. Over 60% of those replaced motors will be 25 to 50 horsepower based on the sales ratio, while almost 8% will utilize over 125 horsepower (Table 4.11). The *Motor Master* + software from DOE provides facilities and researchers decision-making tool for motor purchases.

$$\mathrm{S=hp \times 0.746} \left[\frac{1}{\eta_1} - \frac{1}{\eta_2}\right] \mathrm{H \times C}$$

Savings= Horsepower * 0.746 kW/HP * (1/ Efficiency of Inefficient Motor-
1/Efficiency of Efficient Motor) * Annual Hours of Operation * Cost of Electricity

Figure 4.6. Annual Savings Formula for Energy-Efficient Motors

The analysis of the program runs under two different scenario assumptions. The policy case assumes that firms will purchase new standard motors five years earlier than would have otherwise occurred without the rebate. Instead of repairing a motor to last another five years, the firms replace motors right away. The sensitivity assumes that firms will purchase rather than fix new standard motors ten years earlier than would have otherwise occurred without the rebate.[67] Both scenarios replace the same amount of motors, which is roughly equivalent to 1% of the current U.S. motor stock (Xnergy, 2002), and thus have the same savings for the first five years of the program. After five years in 2016, the motors replaced in 2011 under the 5-year acceleration scenario are no longer achieving the savings as a result of this particular policy and thus, are not included in the calculations (those savings could be attributed to EISA). The 10-year acceleration sensitivity includes greater savings not because it replaces more motors, but because the assumption is that it replaces motors that otherwise might have come off the grid in later years.

Table 4.12 analyzes this policy's potential benefits in terms of the present value of its energy savings and energy expenditures from the perspective of industrialists, utilizing a 7% discount rate. Under the assumption of a 5-year acceleration of the purchase of efficient motors, the benefits of this program accrue from 2011 through 2019 and lead to cumulative energy savings of nearly 67 TBtu. This represents less than 1% of the business-as-usual industrial energy consumption in that year (26,910 TBtu, excluding refining), but it would save meaningful amounts of energy for each participating facility.

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[67] These assumptions were developed in consultation with industry and program evaluation experts. Unlike the other policy scenarios, this sensitivity is more optimistic than the principal policy being evaluated.

Table 4.12. The Industrial Motor Rebate from the Industrialists' Perspective*

Year	BAU Energy Consumption**	Annual Energy Savings***			Cumulative Energy Savings****		Annual Private Cost	Cumulative Private Cost
	Trillion Btu	Trillion Btu	$M (2008)	%	Trillion Btu	$M (2008)	$M (2008)	$M (2008)
2011	24,770							
2015	26,910	13.9	184	0.05	41.9	613	32.4	219
2025	27,200	0	0	0	66.8	908	--	219

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

** Reference case industrial energy consumption excludes refining. These Business-as-Usual (BAU) estimates are output from the GT-NEMS industrial module. They differ slightly from the *AEO 2010* (EIA, 2010) published estimates, which are produced from a fully integrated NEMS analysis.

*** The percentages refer to the percent of energy use and carbon dioxide emissions from industrial energy use.

****Investments stimulated from the policy occur through 2015. Energy savings accrue only through 2019.

Under the sensitivity assumptions of a 10-year acceleration in motor replacement, the savings would last through 2024 and yield larger cumulative energy savings of 115 TBtu. Again, these savings are small relative to the size of the entire industrial sector's energy usage, but still helpful to the participating firms.

These energy savings come at a private investment cost of $32 million in 2015, the last year of the IMR stimulus program, and $219 million in cumulative program costs from 2011 through 2019. These costs are considerably less than the value of the energy saved ($908 million in cumulative energy savings), suggesting a highly positive net present value from the industrialists' perspective.

Technology readiness. NEMA Premium® Motors are already widely available in the marketplace. Proven technologies can reduce industrial motor energy use by 11% to 18%. Additional R&D and learning curves from increased mass production could lead to further improvements, but simply using widely available technology with improved practices could have a significant impact.

Cost effectiveness. Energy efficiency, in general, helps to stretch available energy resources while providing retail electricity price relief to manufacturers and consumers (Ellliott, 2007).

Table 4.13 presents the ability of the public sector to leverage industrial energy savings with the IMR policy. Public costs include the rebates, which are equal to the incremental costs of the more certified high-efficiency motors purchased by participating firms. Through 2015 (the last year of the IMR program), public expenditures are estimated at $332 million with a 3% discount rate, and lead to cumulative energy savings of 67 TBtus. This yields an energy leveraging ratio of 0.2 MMBtu per dollar of public expenditure.

Table 4.13. Leveraging of Energy Savings from Cumulative Public Investments in the IMR Program

Year	Public Costs*				Cumulative Energy Savings	Leveraging Ratio*
	Million $2008				TBtus	MMBtu/$
	Annual Administration Cost	Annual Investment Cost	Total Annual Costs	Total Cumulative Costs		
2015	1.83	57.7	59.5	332	41.9	--
2025	0	0	0	332	66.8	0.20

*Ratio of cumulative energy savings in MMBtu to cumulative public costs in $2008. Present value of public costs was calculated using a 3% discount rate. Program benefits end in 2019.

Table 4.14 presents the ability of the public sector to leverage carbon dioxide savings in the industrial sector with the IMR program. In 2015, public expenditures lead to CO_2 savings of 2.3 million metric tons, representing less than 1% of the business-as-usual CO_2 emissions in the industrial sector that year. Over the lifetime of the equipment installed by 2019 as a result of this policy change, 3.7 million metric tons of CO_2 emissions are avoided, yielding a carbon-dioxide leveraging ratio of 0.01 metric tons per pubic dollar expended.

Table 4.14. Leveraging of CO_2 Emission Reductions from Cumulative Public Investments in the IMR Program

Year	Public Costs	CO_2 Emission Reductions			Leveraging Ratio*
	Million $2008	Million Metric Tons CO_2			
	Cumulative Costs	Annual MMT Saved	% Annual Emissions	Cumulative MMT Saved	Metric Tons/$
2015	332	0.76	0.14	2.32	--
2025	332	0.0	0.0	3.68	0.011

*Ratio of cumulative emission reductions in million metric tons to cumulative public costs in $2008. Present value of the public costs was calculated using a 3% discount rate. Program benefits end in 2019.

Figure 4.7 shows the leveraging ability of the IMR policy with an assumed 5-year accelerated purchase of certified high-efficiency motors (shown with solid markers) compared with the sensitivity case of the EPS with a 10-year investment tax credit ending in 2020 (shown with open markers). The leveraging of energy savings per public dollar is shown on the left and the leveraging of carbon dioxide emission reductions is shown on the right. For both the energy and CO_2, and using both a 3% and a 7% discount rate, the leveraging metrics are greater with the assumption of a 10-year acceleration, reflecting its lower level of free ridership per dollar of public expenditure.

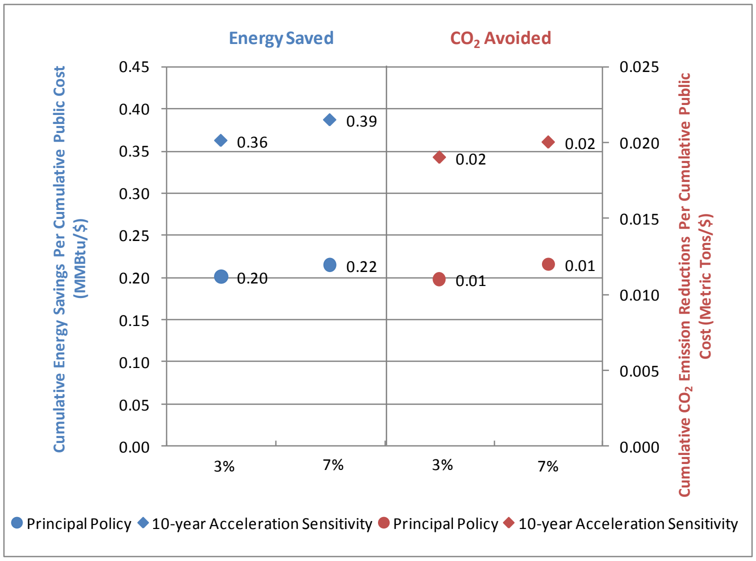


Figure 4.7. Energy and CO_2 Leveraging for an IMR Policy

Further benefits accrue to society as a whole from the increased efficiency of motors in the industrial sector, resulting in lower electricity consumption. Estimates of the reduction of criteria pollutant emissions are shown in Table 4.15 and Figure 4.8. Of the four criteria pollutants considered, SO_2 emission reductions deliver the greatest human health and environmental benefits of the IMR policy, totaling $108 million in avoided damages through the year 2019. There is also an $11.2 million dollar reduction in damages from nitrogen oxides and a total of $10.7 million in avoided damages from decreases in the emissions of particulate matter. In total, these emissions reductions represent additional significant benefits of an IMR policy, with savings of more than $127 million. These avoided damage costs of NO_x, SO_2, PM_{10}, and $PM_{2.5}$ due to the energy-efficiency measures are calculated using a 3% discount rate. The present value of avoided damages for all four local pollutants drops to $106 million using a 7% discount rate.

Table 4.15. Value of Avoided Damages from Emissions of Criteria Pollutants from an IMR Program (Billion $2008)*

	NO_x		SO_2		PM_{10}**		$PM_{2.5}$	
	Annual	**Cumulative**	**Annual**	**Cumulative**	**Annual**	**Cumulative**	**Annual**	**Cumulative**
2015	0.002	0.008	0.022	0.07	0.0	0.0003	0.002	0.007
2025	0.0	0.012	0.0	0.108	0.0	0.0006	0.0	0.009

*Values are based on the National Research Council report estimating damages from energy production and consumption in the U.S. (NRC, 2010). Excludes avoided pollutant damages from petroleum and coal for industrial heat. Present value of avoided damages was calculated using a 3% discount rate. Program benefits end in 2019.

**Excludes PM_{10} from the production of industrial heat.

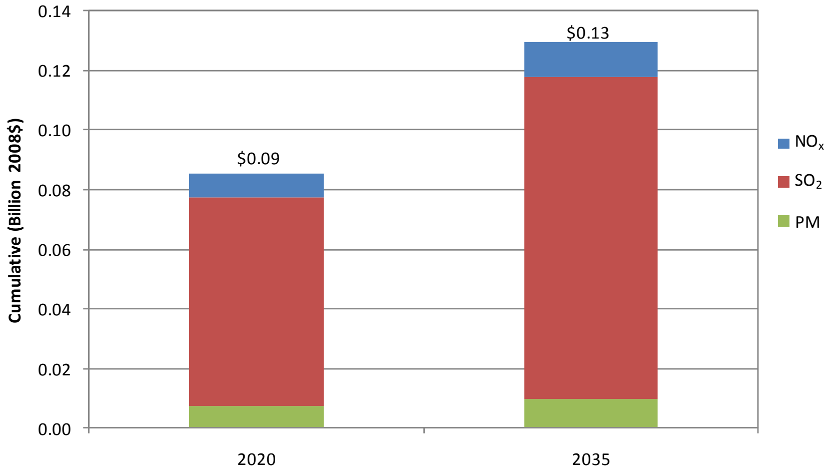


Figure 4.8. Value of Avoided Damages from Criteria Pollutants for an IMR Policy

Next we estimate the B/C ratios when the value of avoided damages from CO_2 and the four criteria pollutants are included (Tables 4.16a and 4.16b). We determine the economic value of reduced CO_2 emissions in each year by multiplying the decrement in emissions by the “social cost of carbon” (SCC) for that year. The SCC is defined as an estimate of the monetized damages caused by each incremental ton of CO_2 emitted. The SCC estimates used in this analysis are the central value estimates of the U.S. Government Interagency Working Group on the Social Cost of Carbon (EPA, 2010a). In this report, the central value SCC estimates ranged from $23/metric ton of CO_2 in 2011 to $34/metric ton and $47/metric ton in 2030 and 2050, respectively (all values are in $2008).

Consideration of these emissions benefits raises the B-C ratio for this policy to 2.21 with a 3% real discount rate and 2.04 with a 7% real discount rate (Table 4.16b). The economics look less attractive with the higher discount rate because the investment and pubic costs occur early in the program, while the energy savings benefits and associated pollution and carbon dioxide emission reductions occur through 2019. It should be noted that these estimates do not include mercury pollution reduction, increased productivity, grid reliability, water quality impacts, and other non-monetized benefits.

Table 4.16a. Total Social Benefit/Cost Analysis of an IMR Policy*

	Cumulative Social Benefits (Billions $2008)				Cumulative Social Costs (Billions $2008)			Benefit/Cost Analysis	
Year	**Energy Savings**	**Value of Avoided CO_2**	**Value of Avoided Criteria Pollutants**	**Total Social Benefits****	**Public Costs**	**Private Costs**	**Total Social Costs****	**Social B/C Ratio**	**Net Societal Benefits (Billions $2008)**
2015	0.676	0.050	0.082	0.809	0.332	0.234	0.566		
2025	1.05	0.078	0.127	1.25	0.332	0.234	0.566	2.21	0.684

* Present value of costs and benefits were calculated using a 3% discount rate. Program benefits end in 2019.

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

Table 4.16b. Total Social Benefit/Cost Analysis of an IMR Policy*
(7% Discount Sensitivity)

	Cumulative Social Benefits (Billions $2008)				Cumulative Social Costs (Billions $2008)			Benefit/Cost Analysis	
Year	**Energy Savings**	**Value of Avoided CO_2**	**Value of Avoided Criteria Pollutants**	**Total Social Benefits****	**Public Costs**	**Private Costs**	**Total Social Costs****	**Social B/C Ratio**	**Net Societal Benefits (Billions $2008)**
2015	0.613	0.044	0.072	0.728	0.310	0.198	0.53		
2019	0.908	0.066	0.106	1.08	0.310	0.198	0.53	2.04	0.55

* Present value of costs and benefits were calculated using a 3% discount rate. Program benefits end in 2019.

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

Table 4.17 provides a summary of the social benefit/cost ratios for the IMR program assuming a 5-year acceleration and the same program with a 10-year acceleration, analyzed at both the 3% and 7% discount rates. This sensitivity analysis highlights the greater societal benefits of the 10-year acceleration.

Table 4.17. Social Benefit/Cost Analysis of Policy and Discount Rate Sensitivities

		Alternative Discount Rates	
		3%	**7%**
IMR 5-Year Acceleration	Benefit/Cost Ratio	2.21	2.04
	Net Societal Benefits (Billions $2008)	0.68	0.55
IMR 10-Year Acceleration	Benefit/Cost Ratio	3.70	3.20
	Net Societal Benefits (Billions $2008)	1.43	1.08

Further efforts to educate motor consumers in proper motor management could expand the savings outlined in Table 4.16a and Table 4.16b. It is important to note that these savings are in addition to other benefits from the EISA standards and only account for the equipment benefits and not opportunities for improvement in motor management and workforce development. The majority of the burden of this program primarily falls on the public sector with $332 million in present value costs, but the private sector must invest additional resources because the motor replacement will still cost more upfront than fixing and rewinding old equipment. The cumulative social benefits from this program would be $0.8 billion by 2015, rising to $1.25 billion by 2019 under the 5-year acceleration scenario and more than $1 billion in the sensitivity scenario. It is anticipated that additional net benefits could be achieved with additional investment, but we would also expect marginal returns to decline, both to industry and society, as additional motors, and/or earlier replacements occur with an expanded program.

Other benefits of this policy include maintaining the U.S. motor market and domestic jobs. The motor industry employs 11 Americans per million dollars of investment and generates $1.15 towards the Gross National Product for each dollar of productivity. By comparison, the electricity sector only generates six jobs per million dollars (IMPLAN, 2009). Policies that promote higher efficiency motor purchases could lead to net employment growth, as was concluded in an assessment of industrial energy-efficiency policies in the South (Brown, et al., 2010b).

This policy is attractive from the industrialists’ perspective because government subsidies cover the incremental costs of certified high-efficiency motors. And it is highly attractive from society’s perspective because of its significant energy, carbon dioxide, and pollution reduction benefits. Despite these benefits, IMR could drive industry towards business decisions that do not achieve optimal efficiency or savings with its specific focus on motors. An expansion of the policy could include rebates on other equipment that could encourage energy efficiency. Additional controls and behavioral changes could further improve the effectiveness of this policy. This program would seem to fit well (possibly with expanded coverage eligibility) within the broader frameworks outlined in earlier sections (such as the Superior Energy Performance program).

Administrative feasibility. This program is significantly smaller than the $2 billion automotive rebate program and occurs over a longer period of time. The federal government managed that program with less than 3% of the costs devoted to administration (O'Keefe, 2010) and should be able to achieve the same results with $10 million of the $350 million (less than 3%) of the appropriation for the incentive for overhead and processing. ITP, through the Central Processing Center, should have limited difficulty ensuring that firms receive their correct rebates in a timely manner after properly purchasing their new equipment and recycling their old motors.

Additionality. Electric motors are a critical component in the optimization of industrial systems and processes. Combining this program with efforts towards improved maintenance and management would deliver increased benefits to the industrial sector. The majority of the savings potential may be in the use of the motor rather than the particular technology. Since motor replacement will likely be a part of any energy-efficiency upgrade, the rebates, also known as the National Crusher Credit Incentive Program, could complement any proposed industrial policy option, particularly the Superior Energy Performance program.

4.2.6 Summary

Electric motors represent the largest end use category of electricity in the nation, roughly 23% of all electricity in the U.S. (DOE/ITP, 2008b). The program will foster improvement to this consumptive part of the industrial infrastructure. Replacement of the oldest motors is an effective starting point for any effort to reduce the climate impacts of the industrial sector, while helping firms remains competitive in the global marketplace.

Table 4.18 summarizes the strengths and weaknesses of the motor rebate policy option. The program is broadly applicable and uses readily available technology to enhance energy efficiency in manufacturing. It will save industry $822 million to $1.2 billion in present value, depending on how quickly the sector may have otherwise replaced its motors and will reduce environmental impacts associated with energy consumption. It uses readily available technology and alleviates a flaw in the design of the new standards policy that could limit the effectiveness of the EISA goals, the flaw being the attenuated retention of inefficient motors when standards escalate the cost of a replacement unit by requiring increased efficiencies. Through free drivers, who do not directly participate in the program but adopt the more efficient motors as a positive reaction to the program, it will encourage firms to make additional upgrades to their facilities. The benefits of this positive spillover effect are not captured in our analysis of societal benefits and costs. It is, however a program with significant public costs and is open to free-ridership. In addition it could distort the market both through encouraging motor upgrades where other opportunities for equipment replacement may be more effective and by rewarding firms who were laggards in replacing pre-EPACT-92 motors. Finally, it is a small program that covers a small segment of the efficiency potential.

Table 4.18 Overall Assessment of Motor Rebates

	Strengths	Weaknesses	Time Horizon*
Motor Rebates	Technology Readiness; Mitigation of Unintended Consequences; Positive Spillover from Free-Drivers; Additionality	Public Costs; Free Riders; Market Distortion; Small Size	Short

*Time horizons when significant energy savings begin: short (five years or less), medium (five to 10 years), and long (more than 10 years).

The EISA standards on motors will have a significant impact on U.S. industry. Rebates on motors can drive the industrial sector towards greater efficiencies by improving the economics of new motor purchases and maintaining the competitiveness of the motor manufacturing industry. This equipment replacement would be most successful if firms change their behavior towards energy when they change out their motors. Financing motor replacement is a step towards a culture of energy efficiency in the American industrial sector. This program is a sales-pitch for energy efficiency through discounts that could lead to broader improvements across industries.

5 Policy Synergies and Conclusions

This report has developed and evaluated a set of seven federal policy options that could motivate industrial enterprises to invest in improving the energy efficiency of their facilities, processes, and practices. Each of these seven policy alternatives received an individual assessment, assuming that one of them might be added to the current federal policy mix. In reality, several of these policy options could be implemented simultaneously, in which case potential policy synergies, complementarities, conflicts, and overlapping effects need to be considered.

5.1 Policy Synergies

Figure 5.1 shows how the seven policies might operate together, addressing three key barriers to industrial efficiency improvements: regulation, information/work force training, and financing. The figure also reflects the fact that any new policy initiatives must be fit into the landscape of current policies (illustrated by the left-hand boxes).

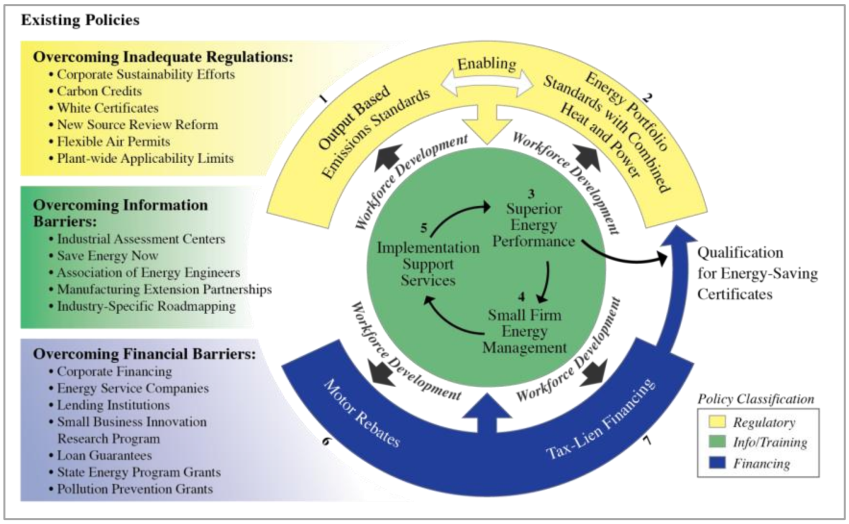


Figure 5.1. Policy Synergies

The regulatory policies enable and motivate efficiency investments by eliminating regulatory obstacles (which is the intent of Output-Based Emissions Standards [OBES]) and by using regulations to promote greater energy efficiency (a goal of Energy Portfolio Standards [EPS] with CHP). The Implementation Support Services (ISS) and Small Firm Energy Management (SFEM) program help develop the workforce required by the Superior Energy Performance (SEP) program, EPS, and generally support industrial efficiency. Finally, the two financing policies help underwrite the investments needed to bring industrial energy efficiency to "scale." In addition, the EPS/CHP policy includes a financial incentive, and SEP seeks to qualify energy-efficiency credits for trading in carbon markets. As a set, these policies allow individual firms and entire industries to enhance efficiency through multiple opportunities and programs.

Figure 5.2 characterizes the potential impacts of the full portfolio of policy options described in this report. The regulatory, information, and financial impacts of these policies stretch across manufacturing sectors, with four of the options impacting non-manufacturing industrial facilities. The policies, however, are diverse in the size of the firms that they impact. Motor rebates are applicable to firms of all sizes, while the regulatory policies and the SEP program apply principally to large firms. The SFEM program only applies to small firms, while Implementation

Support Services can assist both large- and medium-sized companies. The impacts of the policies also vary across time frames.

This analysis does not include a geographic assessment of where such policies will likely have the greatest impact. Geographic content is part of the underlying analysis. For instance, GT-NEMS evaluates CHP opportunities individually for each of nine census districts. In addition, the IAC analysis that underpins the SFEM estimates of energy-savings potential utilities state-specific data for 3-digit NAICS codes. Further, the assessment of the avoided pollutant damages is based on a study by the National Research Council that considers the location of electricity generating plants relative to populations at risk of health consequences (NRC, 2010). In contrast, our spreadsheet assessment of carbon dioxide emission reductions from energy savings is based on national averages of the carbon content of different fuels, using the *AEO Outlook* "business-as-usual" projection of the fuels generating electricity over the next twenty-five years (EIA, 2010).

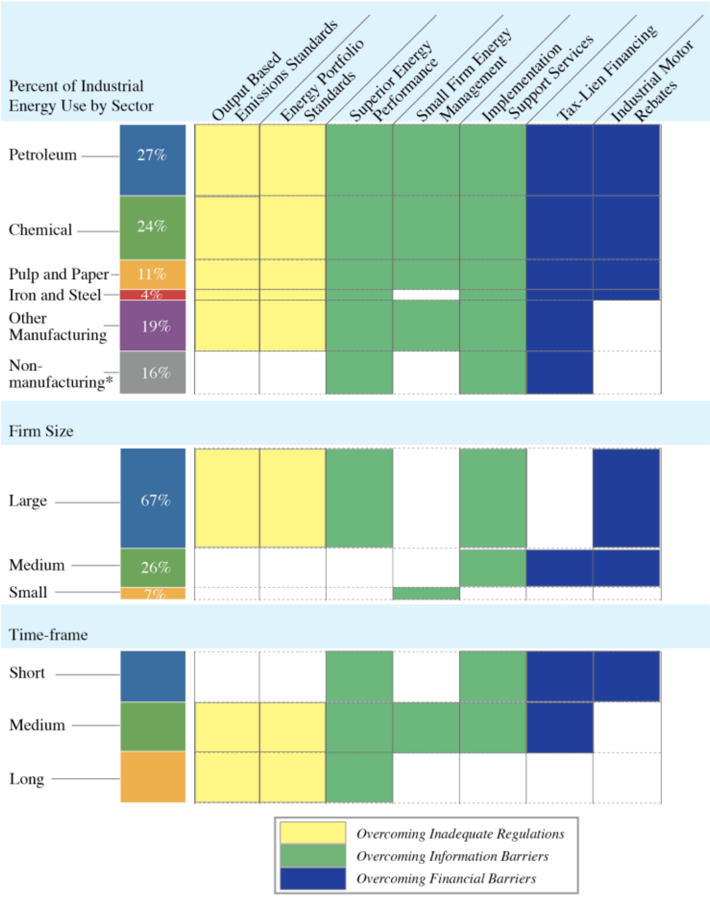


Figure 5.2. Portfolio of Industrial Policy Options by Sector, Size, and Time Frame
*Non-manufacturing is only included in the analysis of SEP, ISS, and Tax-Lien Financing

The seven federal policy options to promote industrial energy efficiency are likely to target and attract different program participants depending on their levels of capacity to manage their plant energy (see section 1.5 for a description of the three-tiered typology of energy management capacity).

- *Highly sophisticated manufacturers* as a group are good candidates for participating in the SEP, because they are likely to have the benchmarking capacity to verify energy performance improvements and management practices, which is a requirement of participation. They are also likely to have the regulatory expertise and technology sophistication needed to understand the complexities of CHP systems and to use OBES to qualify them. Finally, they are good candidates for both financing policies – to adopt tax-lien financing, since their CFO is likely able to manage its sophisticated application processes and to be well aware and to take advantage of government rebates.

- Manufacturers with *basic energy management experience* are excellent candidates for the ISS (because they would tend to recognize their need to better understand financial options and the business case for energy efficiency). Utilizing an investment tax credit to support CHP systems as part of an EPS program would similarly be of interest, given their accounting expertise relative to reducing tax liabilities. And they would be good candidates to upgrade their motors to certified high-efficiency models using an industrial motor rebate because without a subsidy, they might be inclined to prolong the lives of their existing equipment.
- Manufacturers with *little or no knowledge of energy management* are just beginning to learn about managing energy in their plants and facilities. Many of these will be small enterprises and would therefore be appropriate participants for the SFEM program. They might also find it easy to participate in the IMR program, and some might also be inclined to participate in Property Assessed Clean Energy (PACE) financing and ISS.

The alignment of policy options with energy management capacity is illustrated in Figure 5.3. The distinct position of each policy underscores their additionality as well as their potential policy synergies.

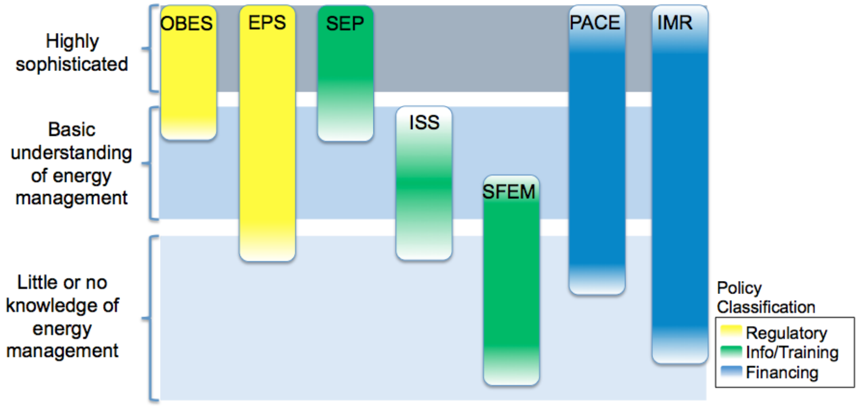


Figure 5.3. Alignment of Policy Options with Energy Management Capacity

5.2 Stakeholder Assessment

Critical stakeholder analysis brings three important benefits. First, it can jumpstart dialogue and facilitate discussions among previously disconnected actors, making it an important component of democratic decision making and also revealing power asymmetries between stakeholders (De Leon and Varda, 2009; Dryzek and Tucker, 2008; Hendriks and Carson, 2008). Second, the process of identifying stakeholder interests can promote a common understanding of key agendas and help incentivize collaboration. Conversely, it can identify zero sum tradeoffs and incommensurable or irresolvable views among stakeholders that must be resolved for consensus to occur (Weible, Sabatier, and McQueen, 2009). Third, by making some stakeholders and their power relations more visible, critical stakeholder analysis can improve social responsibility and force desirable change. Numerous examples abound of organizations and stakeholders being forced to alter their practices in response to stakeholder analysis and participation (Heidrich, Harvey, and Tollin, 2009; Brown and Sovacool, 2011, Chapter 6).

By collecting and analyzing data on stakeholders, one can develop an understanding of – and possibly identify opportunities that influence – how decisions are made in a particular context

(Dunn, 2008). Table 5.1 summarizes the stakeholder assessment of these seven policies for parties that are relevant to multiple policy options, as evaluated in this report.

The direct beneficiaries of these policies – the industrial firms and companies that will provide equipment and support the upgrades – are all likely to be strongly in favor of their creation. The public sector stakeholders should also find their improved role in supporting industrial energy efficiency to be consistent with their civic-minded goals. The general public may not support the upfront financial burden of some of these efforts, but they will receive long-term economic and environmental benefits from implementation. Environmentalists will likely support the reduction in greenhouse gas and criteria pollutant emissions, although they may have some reservations about regulatory changes, particularly amending the Clean Air Act to legislate OBES.

The utility sector will have mixed views of these policy options, because they could negatively impact the profits of many electric utilities, particularly in the 40 states without decoupling. Even in decoupled states (where profits are not coupled only to the retail sales of energy), these federal efforts may cut into utility revenues: they will be selling less energy to industrial customers and may not be able to act in providing them the efficiency services that could offer a return on the utility's investment. Utilities with good management and "modern" business models have moved into energy-efficiency services as a revenue part of their business – partly in response to regulatory pressure but also from recognition that energy-efficiency services can be "good business."

The outlook will vary for each policy option based on the utility's ownership (investor-owned or public), primary fuel supply (natural gas utilities will support CHP policies, which would expand their market share), expected load growth and need for capacity expansion (some utilities may prefer the economics of avoiding construction of new generation due to lower load growth, while others may be seeking the opportunity to build), and state regulatory environment. Distributed generation through CHP may be viewed with particular skepticism by electric utilities, as they will not receive revenue from grid sales, but natural gas retailers could see an expansion of demand for gas-generated cogeneration systems. On the other hand, utilities may also see benefits in supporting industry and helping energy-intensive companies in their service territory become more competitive and expand their levels of production through these policies.

Table 5.1. Summary Stakeholder Assessments of Industrial Policy Options

Stakeholder	Pros	Cons	Dominant Position
Industrial Firms	Will reduce energy bills and production costs	Possible reluctance to allow access to processes and products; facilities without tax liabilities would not benefit as much	Very Favorable
Manufacturers of Energy-Efficient Equipment	Will generate increased sales and develop new business and products, particularly for high-efficiency motors and CHP systems	None	Very Favorable
Energy Service Companies	ESCOs could increase their industrial sector business	None	Very Favorable
Federal, State and Local Government	Economic development, job creation, energy security, and emissions reductions are all public goals promoted by these policies	Emphasis on debt reduction will cause scrutiny of proposals to expand subsidies; other programs may perceive these policies as competitors; may require significant administrative support	Mostly Favorable
General Public and Consumer Groups	Workforce training, economic development, improved air quality are all consumer issues	Federal debt will cause skepticism; public expenditures will primarily benefit industry	Mixed
Environmentalists	Increased energy efficiency will improve the environmental performance of industrial facilities	Local effects from CHP systems in nonattainment regions could be an issue	Mostly Favorable
Electric Utilities	States with decoupling will not see as big a threat to revenues and profits; even in these states, utilities may see revenue shortfalls if they do not participate in providing energy-efficiency services to the industrial sector	In the 40 states without electric decoupling, these policies would erode utility profits	Mostly Unfavorable
Natural Gas Utilities	Will support CHP policies, because they would gain market share	May not support other policies, because they could erode natural gas sales and hence profits	Mixed
Public Utility Commissions and other Regulators	Will likely be most supportive in the 10 states with decoupling	Will likely be most unfavorable in the 40 states without decoupling	Mixed

5.3 Cost-Effectiveness

When viewed in light of their positive net societal benefits, all seven policy options are judged to be favorable approaches to reducing industrial energy use and limiting the emission of greenhouse gases and criteria pollutants. Four economic metrics are shown in Table 5.2: the social benefit-cost ratio, the net societal benefit and the total cost of policy (both measured in billions of $2008), and a measure of public resource leverage, derived by dividing the cumulative energy savings of a particular policy by the cumulative public costs of the policy (in MMBtu/$2008).

Table 5.2. Cost-Benefit Analysis of the Seven Policy Options (Million $2008)

	Social Benefit-Cost Ratio*	Net Societal Benefits (Billions $2008)*	Total Cost of Policy (Billions $2008)**	Public Resource Leveraging: Cumulative Energy Savings Per Cumulative Public Cost (MMBtu/$2008)
Policy Options to *Overcome Inadequate Regulations*				
Output-Based Emissions Standards	16.0	542	424	595
Federal Energy Portfolio Standard with Combined Heat and Power	15.3	283	206	3.0
Policy Options to *Overcome Information Gaps*				
Superior Energy Performance Program	14.3	255	146	23
Implementation Support Services	5.6	17.3	9.2	7.0
Small Firm Energy Management	8.0	7.8	6.1	3.9
Policy Options to *Overcome Financial Challenges*				
Tax Lien Financing (PACE)	5.8	71	37	3.0
Motor Rebates	2.2	0.68	0.48	0.2

*Present values of costs and benefits were calculated using a 3% discount rate. Cumulative social benefits include energy savings, avoided CO_2, and avoided criteria pollutants. Cumulative social costs include the private sector investment, the public sector investment, and the public administrative costs.

** Total Cost of Policy” refers to the present value of cumulative private and public investment and administrative costs minus the present value of cumulative energy savings. The value of pollution and carbon dioxide emission reductions are not included in the “Total Cost of Policy.”

Based on these benefits and costs, each of the seven policies has a benefit-cost ratio greater than one. With net societal benefits and a social benefit-to-cost ratio of $542 billion and 16, respectively, the OBES is the most favorable policy option from an economic perspective. As can be seen in the table, both policy options to overcome an inadequate regulatory environment have high net societal benefits and social benefit-to-cost ratios. A distinctive difference between OBES and EPS with CHP is the magnitude of public resource leveraging. The principal cost of the OBES policy is its regulatory and technical assistance activities; it does not offer subsidies to industry. EPS with CHP, on the other hand, combines regulation with financial assistance and therefore has a much lower leveraging ratio (595 vs 3 MMBtu per dollar of public cost).

Beyond regulatory policies, incentives to encourage the adoption of SEP also have significantly appealing economic metrics. In contrast, the motor rebate policy has the smallest benefit-to-cost ratio and net societal benefits of all policies. This can primarily be attributed to the assessment of benefits that do not include energy savings generated from the Energy Independence and Security Act of 2007, coupled with the high level of free riders. Even the least beneficial of the seven policies (the motor rebate policy), has benefits that outweigh their costs based on the monetized benefits and costs included in our analysis, suggesting the cost-beneficial nature of it and all seven policies.

To emphasize the variable results produced by different sensitivity analyses, Figure 5.4 shows a range of four social benefit-cost ratios for each of the seven studies. These include sensitivities around discount rates (3% versus 7%), key policy features (e.g., the duration of subsidies in the energy portfolio standard), and variable assumptions about impacts and participation rates (e.g., a five-year versus a 10-year adoption period for OBES). In each case, benefits include the social cost of carbon abatement and reduced criteria pollution.

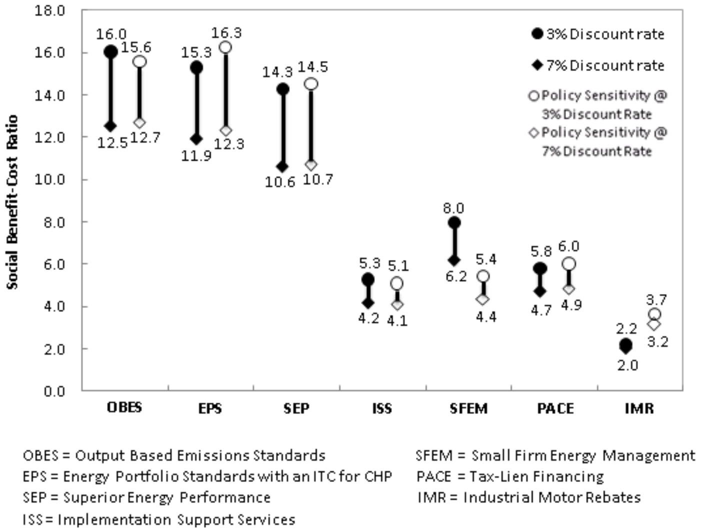


Figure 5.4. Social Benefit-Cost Ratios for Each Policy and Its Sensitivities

The results show that the benefits of each of these policies would likely outweigh their costs of implementation, even in the scenario with the higher discounting of energy savings over time and the less favorable assumptions about policy design and participation. The IMR policy has the lowest social benefit-cost ratios (ranging from 2.0 to 3.5). At the other extreme, the OBES and EPS with CHP have the highest ratios (both ranging from 12 to 16).

Figure 5.5 characterizes the overlapping benefits of these policies. The area of each circle is relative to the total energy savings of each category of policy. These areas and the overlap areas are approximate and are based on the analysis described in previous chapters. The federal EPS with CHP and OBES will capture similar benefits, since they both support industrial combined heat and power. SEP, ISS, and SFEM, on the other hand, will reach distinct efficiency market segments. The latter, in particular, is the only one of the seven policies that focuses on enterprises with 5-49 employees. Some firms may finance the purchase of a rebated motor through PACE tax-liens instead of the IMR, but Tax Lien Financing will enable a large array of additional technology upgrades, large and small, and is examined as an enduring financial policy compared to the stimulus nature of the IMR, which would provide subsidies for only five years.

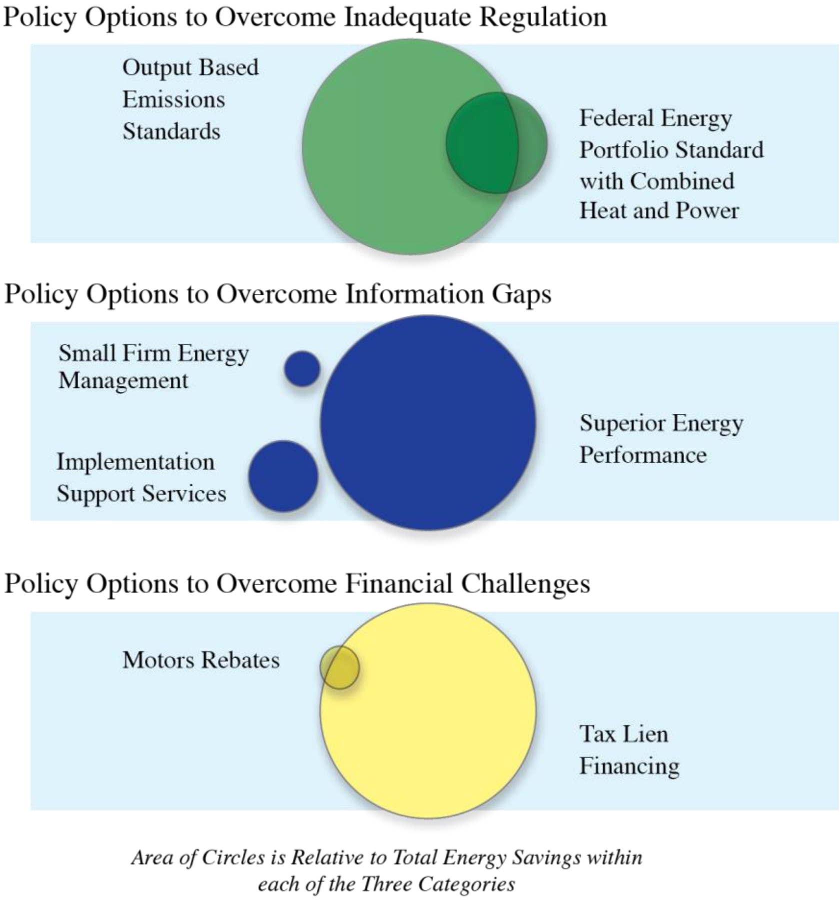


Figure 5.5. Conceptual Venn Diagrams of Policy Benefits Overlap

The policy performance analysis was not performed on a composite basis. That is, we were unable to assess how the aggregate of the policies would perform. However, given the overlapping markets and the multiple policies targeted at similar types of barriers (regulatory, information/training, and financial) as described above, we assume that the composite of the policies would likely to be less than the sum of the seven individual policies.

Firms will have opportunities to implement multiple forms of assistance from the portfolio of seven policies. A hypothetical small paper company in the Northwest might participate in the SFEM program and could use local PACE resources to have these trained employees install and optimally utilize new high-efficiency equipment, assuming that their energy management staff become certified installers. A medium-size chemical firm in the Northeast might sign up for ISS, purchase new motors with rebates, and see the benefits of a federal EPS as making CHP installation a worthwhile venture. A large refinery operation in the Gulf might decide to adopt SEP, contract with an ESCO, and install a CHP system because of the OBES, possibly leading to valuable Energy Savings Certificates. Maximizing such participation in these policies could enable and assist firms in the development of sustainable corporate strategies for energy efficiency and carbon reductions.

5.4 Cost of Carbon Dioxide Emission Reductions

Overall, these seven policy options appear to offer appealing opportunities for significant low-cost CO_2 mitigation. Figure 5.6 compares the net total cost of each policy with the million metric tons of CO_2 avoided over the same timeframe. For this chart, we calculated net total costs by subtracting the present value of the energy savings from the present value of the private and public costs. We do not include the value of criteria pollution abatement, similar to Granade et al. (2009). The result for each of the seven policies is a negative net total cost, meaning that the present value of the energy savings benefits exceeds the present value of the private and public costs.

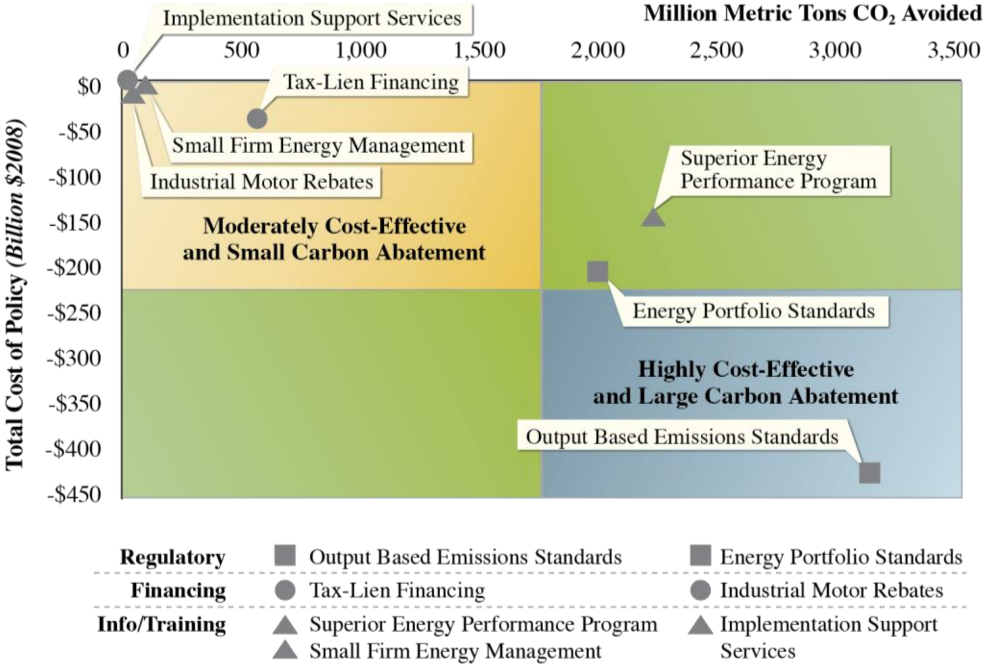


Figure 5.6. Net Costs and Carbon Abatement from Seven Industrial Energy-Efficiency Policies*

*"Total Cost of Policy" refers to the present value of cumulative private and public investment and administrative costs minus the present value of cumulative energy savings. The value of pollution and carbon dioxide emission reductions are not included in the "Total Cost of Policy."

Four of the seven policies are situated in the upper left-hand quadrant, characterized by small carbon abatement impacts (ranging from 4 to 566 million metric tons of CO_2 abated over the 2011-2055 evaluation period) and modest cost-effectiveness (ranging from $1 to $37 billion of negative costs). At the other extreme, OBES is the only policy that is situated in the lower right-hand quadrant described as highly cost-effective (at $424 billion of negative costs) with large carbon abatement (more than three billion metric tons of CO_2). The remaining two policies (the SEP program and a federal EPS with CHP) offer large carbon benefits (each avoiding approximately two billion metric tons of CO_2), but they are less cost-effective (at $146 to $206 billion of negative costs).

5.5 Avoided Damages from Criteria Air Pollutants

Estimates of the value of reduced emissions of criteria pollutants are shown in Figure 5.7 for all seven policies, where each policy is evaluated on its own, and not as a portfolio. For all of these policies, SO_2 emissions reductions provide the greatest benefit. Summing across all of the pollutants, these policies avoid cumulative costs that range from $130 million to $38 billion through 2035 (in $2008).

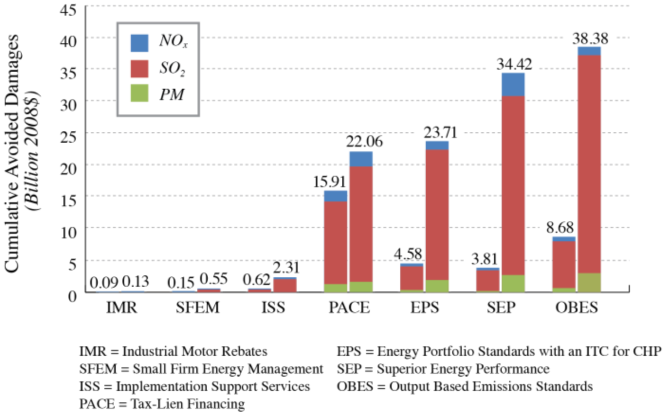
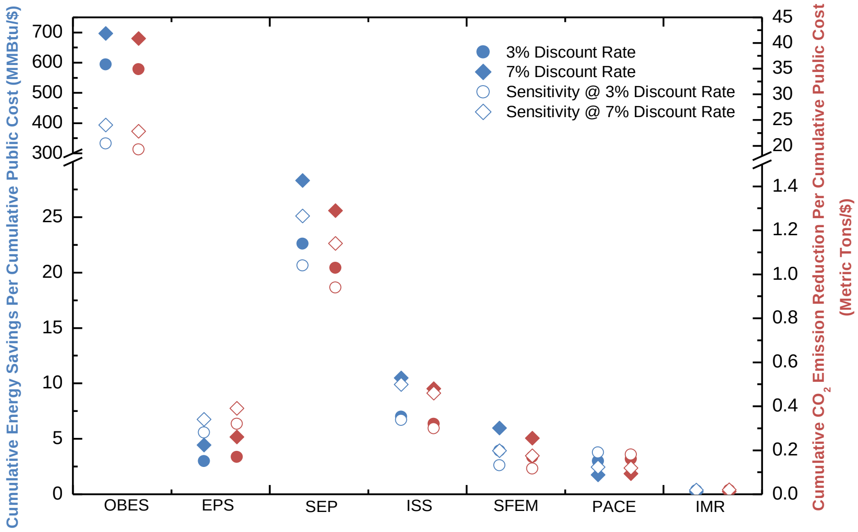


Figure 5.7. Value of Avoided Damages from Criteria Pollutants*
*The left bar refers to 2020 estimates and the right bar refers to 2035 estimates.

5.6 Resource Leveraging

Each policy offers a significant amount of leveraging in terms of saved energy per public costs and the ratio of avoided CO_2 emissions per public cost. OBES has the highest leveraging ratios for both energy saved and CO_2 displaced; a public dollar spent on OBES, for example, would generate nearly 600 MMBtu of saved energy. The SEP program also offers substantial public leveraging of energy savings and CO_2 mitigation, with the second highest ratios. The leveraging ratios are smallest for PACE and the IMR policy, with ratios for CO_2 ranging from 0.01 to 0.16 MMBtu of saved energy per public dollar invested.



OBES = Output Based Emissions Standards
EPS = Energy Portfolio Standards with an ITC for CHP
SEP = Superior Energy Performance
ISS = Implementation Support Services
SFEM = Small Firm Energy Management
PACE = Tax-Lien Financing
IMR = Industrial Motor Rebates

Figure 5.8. Leveraging Ratios:
Energy Savings and CO_2 Emissions Reductions per Public Dollar Invested

5.7 Conclusions

The energy-efficiency gap in the U.S. industrial sector is large; at the same time, this sector is responsible for more than one-third of the nation’s energy-related carbon dioxide emissions. If key barriers that impede investments in energy-efficient technologies and practices could be removed, U.S. industry could become a more significant part of the solution to the global climate challenge and remain competitive in the global marketplace.

These policies all help American industry to shrink the energy-efficiency gap. Table 5.3 summarizes the strengths and weaknesses of the various options. The policies operate on different time horizons. For example, the motor rebates provide a short-term stimulus to expand premium efficient motors sales; the federal EPS creates both a short- and long-term regulatory environment for the expansion of CHP technology in industrial firms. In general, the policies are cost-effective, offer economic and environmental benefits, primarily utilize available technologies, and are within the scope of federal involvement.

Several of the policies have challenges to adoption, administration, and implementation. Creating a new framework for industrial energy efficiency will require action in federal agencies, Congress, and at the state and local level. Experience with the American Recovery and Reinvestment Act should improve the immediate scaling up of new and enhanced programs. Policy-makers and program managers will need to meet the challenges of interagency work at multiple levels of government and establishing public-private partnerships to ensure these policies meet, or exceed, their projected successes.

Table 5.3. Summary Assessment of Policy Options

	Strengths	Weaknesses	Time Horizon*
Policy Options to *Overcome Inadequate Regulations*			
Output-Based Emissions Standards	Significant Potential Benefits, Cost-Effectiveness, Leveraging of Public Resources, Additionality	Narrow Focus on Single Technology	Short to Long
Federal Energy Portfolio Standard with Combined Heat and Power	Broad Applicability, Cost-Effectiveness, Significant Potential Benefits	Free Riders; Need to develop M&V Protocols; Stricter Standards Require Improved Technologies	Short to Long
Policy Options to *Overcome Information Gaps*			
Superior Energy Performance Program	Significant Potential Benefits; Cost-Effectiveness, Market Transformation; Measurement and Verification	Public Costs; Dependence on Energy-Efficiency Credits	Short to Long
Implementation Support Services	Appropriateness of the Federal Role, Significant Potential Benefits, Cost-Effectiveness	Implementation Challenges from Rapid Expansion	Short to Medium
Small Firm Energy Management	Use of Information Technology, Appropriateness of the Federal Role, Additionality, Cost-Effectiveness	Broad Applicability, Administrative Feasibility, Lack of Financial Incentives to Implement	Medium
Policy Options to *Overcome Financial Challenges*			
Tax Lien Financing	Broad Applicability; Significant Potential Benefits; Cost-Effectiveness; Additionality	Administrative Feasibility	Short to Medium
Motor Rebates	Technology Readiness; Mitigation of Unintended Consequences; Positive Spillover from Free-Drivers; Additionality	Public Costs; Free Riders; Market Distortion; Small Size	Short

*Time horizons when significant energy savings begin: short (five years or less), medium (five to 10 years), and long (more than 10 years).

The seven federal policy options evaluated in this report would require sustained public commitment and resources, and their success would require substantial capital, time, and effort by industrial facilities. In turn, they could deliver significant energy, environmental, and economic benefits and help American industry meet the challenges of a low-carbon economy.

These seven policies would bring important benefits to all regions of the country, but would have the greatest impact in manufacturing-heavy regions, such as the South and Midwest where energy-intensive industrial activity is concentrated. These are not the only means to build a low-carbon industrial sector; however, the detailed analysis using rigorous and fully documented analytic methods show that this portfolio offers a significant opportunity for policy-makers to help industry reduce their consumption of energy resources, become more competitive, and protect the environment. This report concludes that these seven federal policy options are cost-effective, offer substantial economic and environmental benefits, primarily utilize available technologies, and are within the scope of federal involvement.

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Appendices

Appendix A

Background on Overall Methodology and Analysis Approach

Summary of the "Policy Options Workshop: Energy Efficiency in the Industrial Sector"

The U.S. Climate Change Technology Program, led by the Department of Energy, held a workshop on September 30, 2009, in Washington, DC. to discuss barriers to industrial energy efficiency and to develop policy options the federal government could pursue to increase the implementation of industrial efficiency measures. The facilitated roundtable with experts from academia, national laboratories, corporations, trade associations, and government agencies elicited six important themes that could be developed into policy options.

7. Industrial plants as power plants
8. Benchmarking of energy and CO_2 intensity
9. "Set-point"-driven technology deployment
10. Market-determined price for carbon
11. Revenue-side (vs. tax-side) incentives for clean energy
12. Industrial clean energy tax lien financing

Industrial plants as power plants. Policies that allow industrial processes with significant heat generation to generate electricity and integrate with the grid were highlighted. Smart-grid policies and integrated planning were particularly emphasized. Utilities have partnered with industry to shed load and manage the grid during peak demand, but industry has been discouraged from exploiting waste heat and CHP potentials due to restrictive permitting processes, counterproductive incentives for utilities, excessive financial and capital risks, among other reasons. Encouraging industrial facilities to be more active in power generation may alleviate some of the need to build additional generation capacity and assist currently strained grid resources, particularly during peak hours. Realizing the potential of CHP may also limit the amount and unit cost of industrial energy.

Benchmarking of Energy and CO_2 Intensity. These policy options expand existing benchmarking programs, increase Federal support for data collection, and leverage the data. The Federal government collects energy and greenhouse gas emissions data from industry; benchmarking policy options could allow the industry, the government, and the public to better understand energy consumption and greenhouse gas emissions.

Many industries lack reliable information of their greenhouse gas emissions, the emissions of their competitors, or of their sector. Benchmarking policy options will allow these companies to understand their relative positions and target investments in these areas. Additionally, the Federal government could identify sectors that perform poorly and recognize efficient sectors and industries.

Carbon “Set-Point”-Driven Technology Deployment. The federal government could coordinate a state-approved carbon/CO_2 set point credit for investments in new energy production systems. Those that operate under the set point could receive waivers and greater incentives in the short term, buying down the cost of efficient technology like CHP. A phased or step down process could be incorporated over a designated time period. Streamlined permitting at the state and local levels would be key; current permitting processes represent barriers to successful implementation of this policy option.

Market-Determined Price for Carbon. Cap-and-trade legislation under consideration (at the time of the workshop) included price ceilings on CO_2 allowances. This policy option would remove such ceilings and fully allow the market to set the price, increasing economic efficiency and reducing government intervention. Policymakers have been concerned about the additional burden on energy-users, and economic modeling revealed a wide range of possible prices, but other cap-and-trade programs have largely resulted in allowance prices lower than *ex ante* predictions. Additionally, higher prices would increase incentives for industrial efficiency investments.

Shift to Revenue-Side versus Tax-Side Incentives for Clean Energy. Many companies are able to reduce their tax burdens significantly, to the point where additional tax-based incentives, like investment tax credits, may not provide a strong incentive for energy-efficiency investments. Direct payments to companies demonstrating energy efficiency improvements would address this problem. Non-profits and companies not posting profits would also benefit whereas with a tax-side incentive they do not.

Industrial Clean Energy Tax Lien Financing. Many energy-efficiency investments are burdened by upfront capital costs. Tax lien financing would enable the funding of these investments through property taxes through the bond market, with funds collected by the local municipal tax authority. While this approach would require significant coordination between lenders, municipalities, and industry, it would retain the transparency required by the Sarbanes-Oxley Act of 2002. Other advantages include: debt seniority, low risk, and no effect on the corporate debt-equity ratio, and therefore no effect on stock ratings.

A list of the workshop participants is provided in Table A.1.

Table A.1. List of Workshop Participants

(N=39)

Name	Affiliation
Lindsay Brumbelow	DOE-PI
Scott Hutchins	DOE EE
Douglas Kaempf	DOE EE
Henry Kelly	DOE EE
Robert Marlay	DOE-CCTP
Daniel Shapiro	DOE
Masood Akhtar	Clean Tech Partners
Jorge Arinez	General Motors
Andrew Aulisi	EPA
Marilyn Brown	Georgia Institute of Technology
Brian Castelli	Alliance to Save Energy
Sean Casten	Recycled Energy Development
Stephen DeCanio	University of CA
Krish Doraiswamy	DuPont
Neal Elliott	ACEEE
Peter Gorog	Houghton Cascade Holdings, LLC
Michael Greenman	Glass Manufacturing Industry Council
David Hitchings	Northrop Grumman
Larry Kavanagh	American Iron and Steel Institute
David Mann	McKinsey & Company
Clay Nesler	Johnson Controls, Inc.
Michael Parr	DuPont
Chris Payne	Lawrence Berkeley National Lab
Joe Roop	Pacific NW National Lab
Eric Stuart	Steel Manufacturers Association
Paul Stern	The National Academies
Tom Tyler	EPA
Mark Wagner	Johnson Controls, Inc.
Tony Wright	Oak Ridge National Lab
Matt Antes	Energetics
Grayson Bryant	Energetics
Matt Cox	Georgia Institute of Technology
Ted Fox	Oak Ridge National Lab
Charlotte Franchuk	Oak Ridge National Lab
Roderick Jackson	Oak Ridge National Lab
Burt Koske	Idaho National Lab
Melissa Lapsa	Oak Ridge National Lab
Joan Pellegrino	Energetics
Laura Wagner	Oak Ridge National Lab

The Social Cost of Carbon

Our cost-benefit analysis uses estimates of the "social cost of carbon" from the following report:

U.S. Environmental Protection Agency (EPA). 2010. *Technical Support Document: Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866*. http://www.epa.gov/otaq/climate/regulations/scc-tsd.pdf

The social cost of carbon (SCC) is an estimate of the monetized damages associated with an incremental increase in carbon emissions in a given year. It is intended to include (but is not limited to) changes in net agricultural productivity, human health, property damages from increased flood risk, and the value of ecosystem services due to climate change.

Three integrated assessment models (IAMs) are used to estimate the SCC in the EPA (2010) report: the FUND, DICE, and PAGE models[1], which combine climate processes, economic growth, and feedbacks between the climate and the global economy into a single modeling framework. The general approach to estimating SCC values is to run the three models using the following inputs agreed upon by the interagency group:

- A distribution for the climate sensitivity parameter bounded between 0 and 10 with a median of 3°C and a two-thirds probability of a cumulative probability between 2 and 4.5°C.
- Five sets of GDP, population and carbon emissions trajectories.
- Constant annual discount rates of 2.5, 3, and 5%.
-

For each of the three models, the basic computational steps for calculating the SCC in a particular year t are:

1. Input the path of emissions, GDP, and population from the selected EMF-22 scenarios, and the extrapolations based on these scenarios for post-2100 years.
2. Calculate the temperature effects and (consumption-equivalent) damages in each year resulting from the baseline path of emissions.
3. Add an additional unit of carbon emissions in year t. (The exact unit varies by model.)
4. Recalculate the temperature effects and damages expected in all years beyond t resulting from this adjusted path of emissions, as in step 2.

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[1] The DICE (Dynamic Integrated Climate and Economy) model by William Nordhaus evolved from a series of energy models and was first presented in 1990 (Nordhaus and Boyer 2000, Nordhaus 2008). The PAGE (Policy Analysis of the Greenhouse Effect) model was developed by Chris Hope in 1991 for use by European decision-makers in assessing the marginal impact of carbon emissions (Hope 2006, Hope and Newberry, 2008). The FUND (Climate Framework for Uncertainty, Negotiation, and Distribution) model, developed by Richard Tol in the early 1990s originally to study international capital transfers in climate policy, is now widely used to study climate impacts (e.g., Tol, 2002a, and b; Anthoff et al., 2009, Tol, 2009).

5. Subtract the damages computed in step 2 from those in step 4 in each year. (DICE is run in 10-year time steps, FUND in annual time steps, while the time steps in PAGE vary.)
6. Discount the resulting path of marginal damages back to the year of emissions using the agreed upon fixed discount rates.
7. Calculate the SCC as the net present value of the discounted path of damages computed in step 6, divided by the unit of carbon emissions used to shock the models in step 3.
8. Multiply by 12/44 to convert from dollars per ton of carbon to dollars per ton of CO_2.

The interagency group selected four SCC values for use in regulatory analyses. Three values are based on the average SCC from three IAMS, at discount rates of 2.5, 3, and 5%. The fourth value, which represents the 95th percentile SCC estimate across all three models at a 3% discount rate, is included to represent higher-than-expected impacts from temperature change further out in the tails of the SCC distribution.

The Hidden Cost of Energy

Our cost-benefit analysis uses estimates of the damage costs of three criteria air pollutants from the following report:

National Research Council. 2010. *Hidden Costs of Energy: Unpriced Consequences of Energy Production and Use.* Washington, DC: The National Academies Press.

The Hidden Costs of Energy defines and evaluates key external costs and benefits that are associated with the production, distribution, and use of energy, but are not reflected in market prices. The damage estimates reflect damages from air pollution associated with electricity generation, motor vehicle transportation, and heat generation. The report also considers other effects not quantified in dollar amounts, such as damages from climate change, effects of some air pollutants such as mercury, and risks to national security.

The report estimates that pollution damages totaled $120 billion in 2005, excluding damages from climate change, effects of mercury, impacts on ecosystems, and other difficult-to-monetize damages. The total costs are dominated by human health damages from air pollution associated with electricity generation and vehicle transportation. Also included in the estimates are damages sustained by grain crops and timber yields, buildings, and recreation. Altogether, non-climate damages from coal power plants are estimated to exceed $62 billion annually. These damages average 3.3 ¢/kWh in $2008.

Natural gas use in the industrial sector also generates significant human health and environmental externalities when combusted to produce heat. NO_x emissions are particularly high. In contrast, natural gas used for industrial feedstocks (as in the chemicals industry) has much lower NO_x emissions.

Coal. The NRC used the APEEP model developed by Muller and Mendelsohn (2006) for each of the 406 coal fired plants in 2005. Only SO_2, NO_x, PM2.5, and PM10 were analyzed. Since other pollutants are not estimated, the full "social" cost of pollution is underestimated. CAMR and CAIR both attempted to address additional pollutants, but both were vacated or remanded by the court system.

The calculation involves translating the emissions into changes in air quality, using concentration-response functions to calculate health and environmental impacts, and valuing the health and environmental impacts. APEEP accounts for the spatial component of emissions and the dilution effects in a county-by-county basis. It cannot, however, model episodic events because it uses annual and seasonal averages.

The PM numbers are obtained from Pope et al. (2002), which might be lower than recent EPA estimates.

Ecosystem damages are listed as a limitation. Acid rain damage to fish and tree canopies were not monetized. Likewise, eutrophication from nitrogen deposition was also not monetized.

$PM_{2.5}$ plays a central role in the Value of a Statistical Life (VSL) discussion – they used $6M US$2000 as the VSL.

$PM_{2.5}$ is associated with premature death and visibility impairments. Both $PM_{2.5}$ and PM_{10} are associated with chronic bronchitis and respiratory or cardiovascular hospital admissions. Ozone impacts crop and timber yields, and SO_2 emissions damage building materials.

The NRC approach compares currently installed technologies to the damages and does not include potential installations of scrubbers or fuel switching that could eliminate most of the impact. This implies that the damages calculated at each plant are an upper bound to the benefits from additional pollution controls.

APEEP also calculates ammonia and ozone damages, but NRC does not include these in the analysis due to missing emissions data for roughly 25% of coal plants. With regard to dropping ammonia damages, NRC reports that for 95% of plants, ammonia emissions represent less than 1% of damages. In the remaining plants, it accounts for up to 14% of damages per kWh. Since higher emissions of ammonia only occur in a small fraction of plants, NRC purports that including ammonia would change the reported damages very little. No explanation is given for dropping ozone.

Direct emissions of $PM_{2.5}$ do have high damages, but the vast majority of this comes from natural sources or construction, and not power production (NRC, 2010 p. 88).

The map below (Figure A.1) shows the distribution of monetized impacts across all power plants. Large damages are concentrated along the Ohio River valley, in the middle Atlantic, and the South.

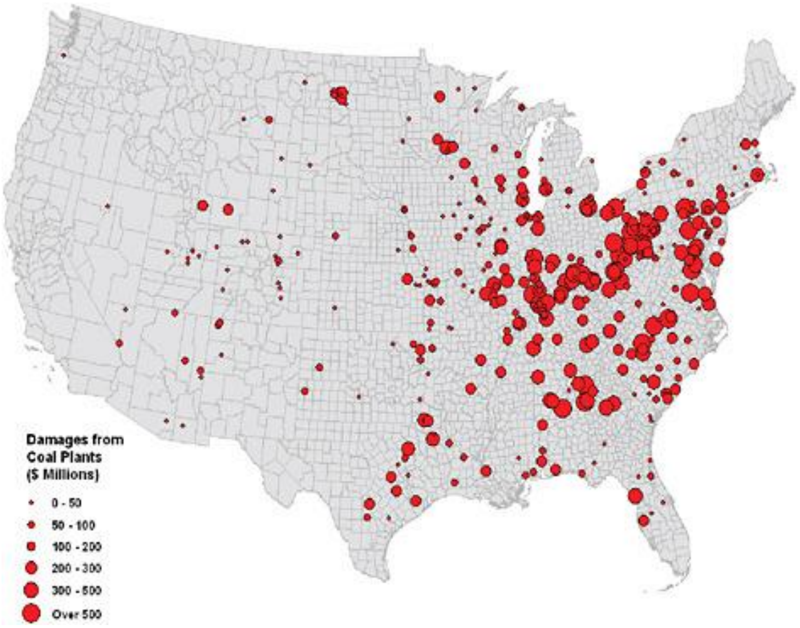

Figure A.1. Air-pollution damages from coal generation for 406 plants, 2005
(2007 U.S. dollars) (Source: NRC, 2010, Figure 2-6, p. 90)

Interestingly, distribution is less important for SO_2 damages than the raw emissions, suggesting the dilution factor is not very strong.

Premature mortality represents 94% of the reported damages. Approximately 59.5% of coal fired power plants are not subject to NSPS, which represents 66% of NO_x emissions and 76% of SO_2 emissions. This impedes some of the regulatory power (NRC, 2010, Table 2-10, pp 95-95).

The EPA modeling of CAIR (CMAQ) shows higher benefits than the NRC report because of differences in the air quality model, which estimates nearly twice as much premature mortality and predicts a greater impact than the APEEP model. NRC acknowledges the CMAQ model is more detailed than the APEEP model they employ, but they also criticize that it has an upwards-estimation bias when compared to sample locations. However, this does not fully represent the difference between the two model outputs. APEEP does better with spatial representations than CMAQ, but there is still uncertainty – a model with better spatial resolution may find different results.

2030. NRC made an estimate of damages in 2030 using *AEO 2009* (EIA, 2009). EIA forecasts SO_2 and NO_x emissions, and PM emissions were imputed from the *AEO 2009* estimates. Using the NERC region outputs, regional multipliers were created and the siting of plants was assumed to not change. Thus, NRC assumptions are consistent with *AEO 2009*, and were deliberate since their charge was meant to ignore policy changes.

AEO 2009 reports that SO_2/MWh would decrease from 10.1 lbs in 2005 to 3.65 in 2030 and NO_x would decrease from 3.42 to 1.90. The NRC used APEEP to model these changes. No adjustment for an older population in the VSL calculation was conducted, though an adjustment for a larger population from census estimates was included. The NRC report assumed VSL increases by 27% due to higher incomes and VSL elasticity. This leads to an increase in damages per pollutant of about 50% per ton, but this varies greatly by county.

All of this leads to monetized air pollution damages of about $38B in 2030, even though net generation is 20% higher. This is because lbs/MWh of SO_2 falls 64% and NO_x and PM emissions fall 50%, counteracting the increase in damages per ton. In the end, NRC projects from this methodology that the externality per ton of electricity will be 1.7¢/kWh by 2030, about half of what is currently the case (3.2¢/kWh). Neither a complete tracking of costs nor a complete set of pollutants is provided by NRC.

Gas. A comparable analysis is conducted for the nearly 500 natural gas plants in the U.S. Results are similar, although the distributional impacts are of greater importance for gas than for coal (dilution factors are more important). PM is also higher, due to distributional emissions.

It appears the NRC analysis was conducted before the increase in shale gas, since the NRC report assumes that the prospects of shale gas might be limiting and that liquid natural gas (LNG) and synthetic natural gas (SNG) are more likely to be supplies for natural gas.

EIA projects a 9% increase in natural gas usage by 2030, a 19% decrease in NO_x, a 32% decrease in PM, and a 51% decrease in SO_2. The projected damages per ton increase like the case of coal. Overall, damages fall from $0.74B in 2005 to $0.65B in 2030 (from 0.16 ¢/kWh to 0.11¢/kWh).

GT-NEMS Analysis of Policy Options

Table A.2 describes the parameters and levers in the NEMS software that were identified as possible mechanisms for modeling the seven industrial energy-efficiency policies.

Table A.2. NEMS Policy Levers

Models	Levers/ parameters/ codes	Description	Location
Overall Technologies	Unit Energy Consumption (UEC)	Energy use per dollar of shipments (Energy use per ton of throughput at a process step)	Itech.txt
	Technology Possibility Curve (TPC)	Future path of energy intensity change	Itech.txt
CHP Technology	Market Penetration Rate (a)	Quantify the relationship between the economics of cogeneration and its adoption over time	Ind.f (source code)
	Installation cost (b)	Overall cost for CHP equipment installation	Indcogen.xml
	Technology profile (c)	Heat rate/ efficiency	Indcogen.xml
Investment Tax Credit for CHP	(a), (b) and (c) + duration of policy	Existing investment tax credit is modeled with variations in (a), (b), and (c)	Ind.f (source code)
Motor Master Inputs	Unit Energy Consumption (UEC)	Energy use per dollar of shipments (Energy use per ton of throughput at a process step)	Itech.txt

We attempted to evaluate four of the seven policies by changing the technology possibility curves (TPC) in the GT-NEMS model. The amount of energy to produce a unit of output, or unit energy consumption (UEC), is derived by GT-NEMS based on the given TPC. We determined TPCs via assumptions made about the impact of a given policy on the relative energy intensity (REI) in each industrial sector. The REI is defined as the ratio of energy use in 2035 compared to 2002 average energy use, while the rate of change between energy consumption in the first year and last year is given as the TPC. REI, UEC, and TPC are related as follows:

$$\mathrm{REI} = \frac{\mathrm{UEC}_{2035}}{\mathrm{UEC}_{2002}} = \left(1 + \mathrm{TPC}\right)^{2035-2002}$$

However, we faced significant challenges with incorporating TPC changes into the 2010 revised bulk chemical industry module. Since the bulk chemical industry comprises more than 20% of total industrial consumption, these challenges precluded our use of GT-NEMS to evaluate these policies. Instead, we used a spreadsheet analysis where the *AEO 2010* (EIA, 2010) forecasted energy consumption was used as a reference for policy impacts to be determined.

We also could not manipulate the motor module to account for a short-term rebate policy under our policy design. While we incorporated information (including Motor Master Inputs) and analysis from the software and module input into our spreadsheet work, we did not run this policy in GT-NEMS.

In contrast, CHP technology characteristics and the investment tax credit parameters were used to evaluate output-based emissions standards and a federal energy portfolio standard qualifying combined heat and power. In the end, only these two policies could be successfully modeled by GT-NEMS. The other five policies were assessed with customized spreadsheets.

Table A.3 itemizes some of the policy levers in the NEMS industrial module that could theoretically be used to analyze the costs and benefits of industrial policy options.

Table A.3. Cross-Walk of Energy-Efficiency Policies and Possible NEMS Policy Levers

Levers/ parameters/ codes	OBES	Federal EPS with CHP	SEP Program	ISS	SFEM	Tax Lien Financing	Motor Rebate
CHP: Market Penetration Rate	✓						
CHP: Installation cost		✓					
CHP: Technology profile	✓	✓					
CHP: Investment Tax Credit		✓					
Unit Energy Consumption (UEC)			✓	✓	✓	✓	
Technology Possibility Curve (TPC)			✓	✓	✓	✓	
Motor Master Input							✓

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Appendix B

Background for Analysis of Output-Based Emission Standards (OBES)

Regulatory barriers to industrial energy-efficient technologies hinder their use. Reducing or removing these barriers is critical to effectively harness the best instincts of the sector. Small changes in the implementation of the Clean Air Act at the federal or state level can have a major impact on the installation rates of these technologies. A number of EPA analyses and industrial experts have found that the dominant usage of input-based emissions standards creates a regulatory barrier to the installation and deployment of technologies that emit less and use energy more efficiently (EPA, 2004, 2009; Casten, Mullarkey, and Casten, 2010). Combined heat and power (CHP) is one of the key technologies that would see increased industrial application if the emissions standards were modified. We have developed this policy scenario to address this regulatory barrier. To assess the impact of the policy scenario, we have assumed two key policies: first, a linking of Federal funding to the states where the presence of an OBES increases grant scoring, and; second, an accelerated learning curve that improves the performance of CHP technologies over time, as greater CHP capacity is installed.

Modeling the Impact of an Output-Based Emissions Standard

Two policies were modeled concurrently in GT-NEMS, the result of which was compared to the *AEO 2010* (EIA, 2010) reference case. The first policy increased the market penetration of CHP technologies at the national level to approximate the adoption of OBES by all states within five years of the federal grant incentive (the “policy case” or the “fast” case).

The second policy modeled expanded R&D activities for improving the performance of CHP systems. We assumed that the programs could increase the overall efficiency by 0.7% annually and raise the average efficiency level up to 83% by 2030 without any additional increase in installation cost. Table B.1 shows that the overall efficiency values for the EIA’s reference case and those for our study. We assumed that the grant program would spend $10 million over 10 years annually to cost share the R&D of research entities. CHP system performance and cost information from EIA were used to quantify energy savings and financial costs.

A sensitivity where the regulatory modifications take 10 years was also carried out, with the same improvement in CHP performance (the “slow” case).

Table B.1. Overall Efficiency by CHP System (Size)

		Reference*			Policy**	
System	**Size (kilowatts)**	**2006**	**2020**	**2035**	**2020**	**2035**
1 Internal Combustion Engine	1,000	0.71	0.75	0.75	0.76	0.86
2 Internal Combustion Engine	3,000	0.71	0.74	0.75	0.77	0.86
3 Gas Turbine	3,000	0.69	0.71	0.72	0.74	0.82
4 Gas Turbine	5,000	0.71	0.72	0.72	0.76	0.84
5 Gas Turbine	10,000	0.71	0.72	0.73	0.76	0.84
6 Gas Turbine	25,000	0.71	0.72	0.74	0.76	0.84
7 Gas Turbine	40,000	0.72	0.73	0.74	0.77	0.85
8 Combined Cycle* **	100,000	0.70	0.73	0.74	0.75	0.84

* Industrial CHP Technology Performance Data used for EIA's *AEO 2010* projections (EIA, 2010)

** We increased the overall efficiency of each CHP system by 0.7% annually and raised the efficiency level up to 83% by 2030.

***Two 40 MW Gas Turbine & 20 MW Steam

The GT-NEMS runs showed an increase in the installed capacity and generation in every industrial sector. The largest gains were found in bulk chemicals, pulp and paper, and the food industries. The food industries comparison is shown in Figure B.1 below.

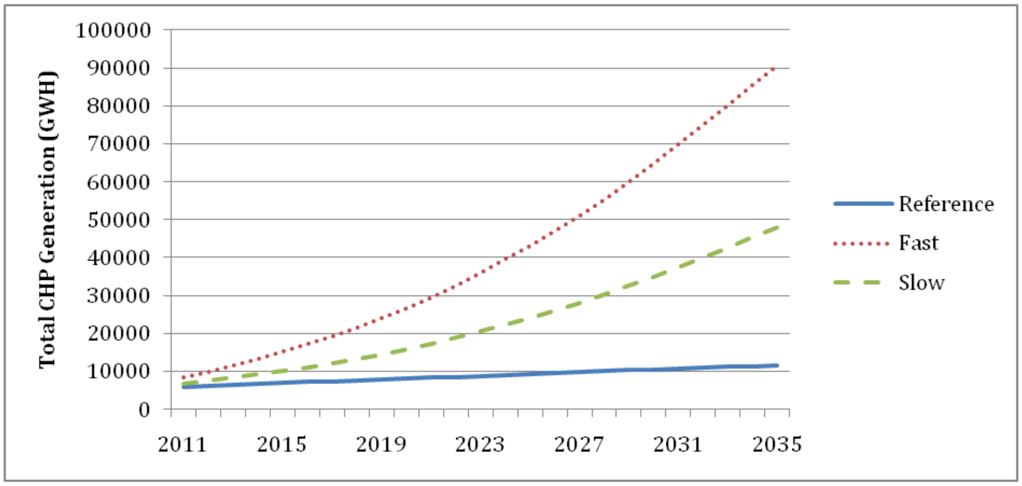

Figure B.1. Food Industry CHP Generation

The GT-NEMS runs also showed interesting trends in the ways industries would use the energy provided by the CHP. The bulk chemicals industry shows the trend for the largest users of CHP, where the model projects a rise in own-use of electricity generation. Eventually, GT-NEMS projects these industries will start to provide power to the grid, as grid sales increase and own-use levels off. This is shown in Figures B.2 and B.3.

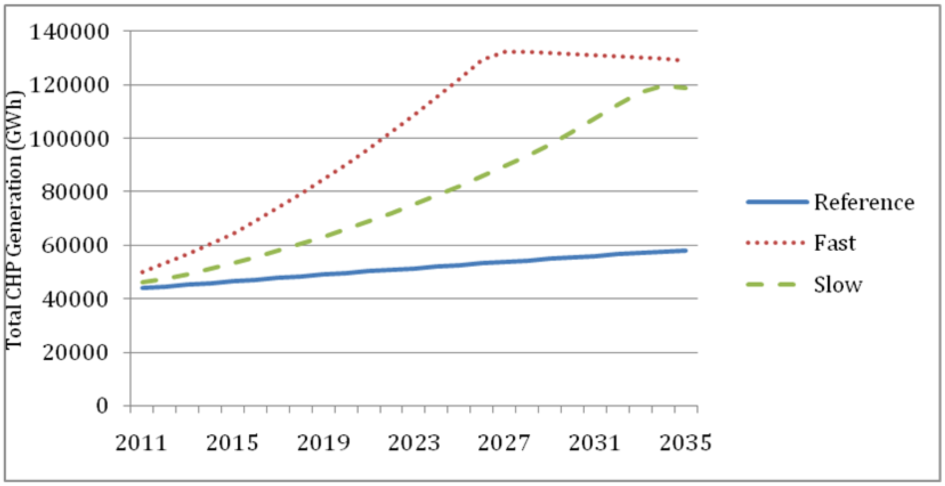

Figure B.2. Bulk Chemicals CHP Generation for Own-Use

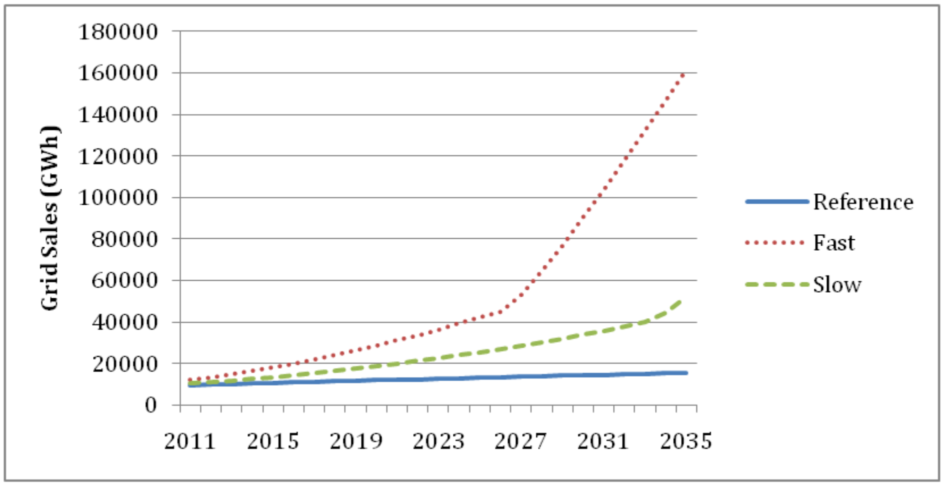

Figure B.3. Bulk Chemicals Generation for Grid Sales

The take-off in grid sales coincides with the year that generation for own-use plateaus and begins to decline, suggesting an economic tipping point for grid sales. This increase in sales to the grid represents an offsetting of generation by the electric sector in the projection.

The graphs of industrial CHP utilization are indicative of the GT-NEMS analysis savings by fuel type. The greatest savings in the sector are from purchased electricity, however there is an increase in natural gas consumption, especially towards the end of the modeled scenarios, as shown in Figure B.4. The result is the cessation of energy savings in the fast adoption scenario, when industrial CHP begins to sell electricity back to the grid.

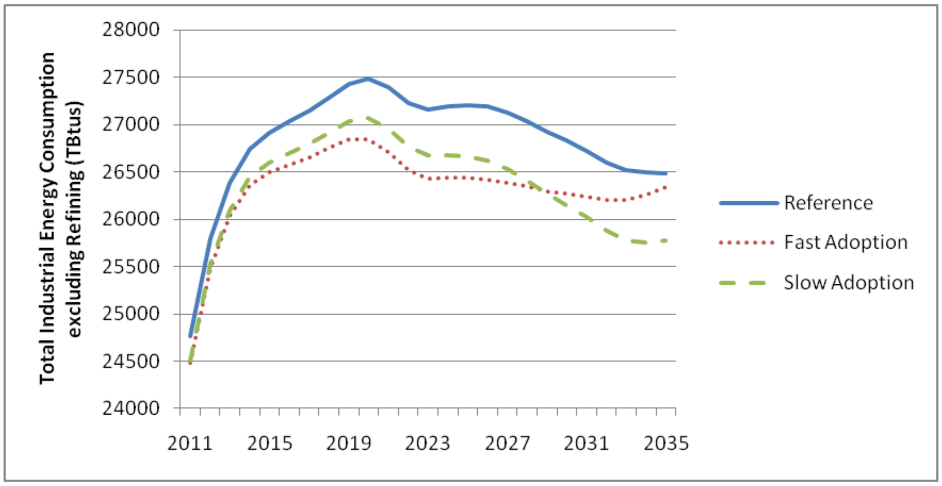

Figure B.4. Industrial Energy Consumption

From the model runs, we could also anticipate the regional distribution of increased CHP generation from 2010 through 2035 by census region. This suggests an increase in the trends in *AEO 2010* (EIA, 2010) with relatively minor proportional differences (the Northeast and West gain and the South and Midwest decline in terms of percent of national CHP generation; for example, the Northeast represents 14% in the policy case compared to 11% of the reference case). These results are shown in Figure B.5.

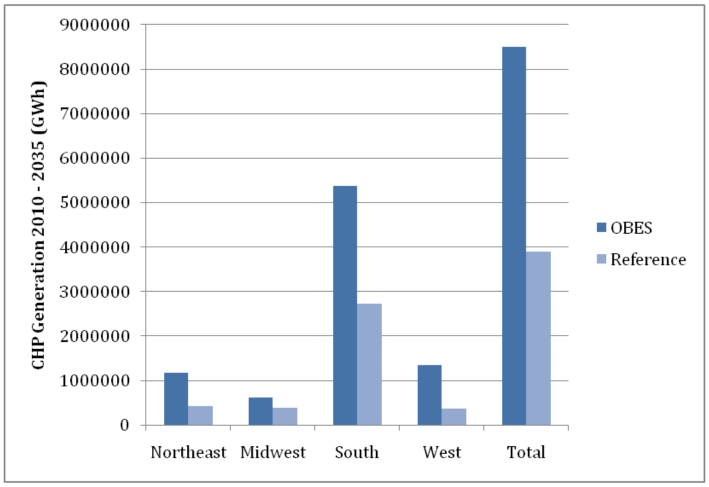

Figure B.5. CHP Generation by Census Region, 2010-2035

The OBES has low public investment costs, since little funding is associated with the policy modification. There is a $10 million per year R&D program (2008 $) that is assumed to create the 0.7% increase in CHP efficiency modeled, and there is funding for re-training state regulators on the ins-and-outs of an OBES. To estimate this cost, the 2011 budget request of related training programs offered by the National Enforcement Training Institute[1] were summed. This yields a training program costing $200,000 per year until all states have adopted an OBES,

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[1] https://www.netionline.com/Default.asp

at which point funding declines by 10% per year (therefore the training expenditure is greater and over a longer duration in the 10-year adoption case). Since no subsidy is being offered for CHP installations, free riders are not a part of this analysis. Other economic costs, like installation costs and the benefits of emission reductions, are described in Chapter 1 of this report.

Results of 10-Year OBES Adoption Scenario

Table B.2 presents the results of the analysis in terms of energy consumption and energy expenditures from the perspective of industrialists, utilizing a 7% discount rate. For the 10-year adoption scenario, it is estimated that 1,300 TBtus of energy would be saved in 2035, representing 5% of the business-as-usual industrial energy consumption in that year. Over the lifetime of equipment installed through 2035, there would be 30,000 TBtus of energy saved. These energy savings come at a cost of $10 billion, but result in $95 billion of savings over the lifetime of the installed equipment.

Table B.2. 10-Year OBES Adoption Scenario from the Industrialists' Perspective*

Year	BAU Energy Consumption**	Annual Energy Savings			Cumulative Energy Savings***		Annual Private Cost	Cumulative Private Cost
	Trillion Btu	Trillion Btu	$M (2008)	%†	Trillion Btu	$M (2008)	$M (2008)	$M (2008)
2011	24,770							
2020	27,480	536	2,448	1.95	3,909	20,338	453	4,169
2035	26,480	1,322	3,318	4.99	17,766	63,643	310	10,055
2055	--	--	--	--	30,306	95,168	--	10,055

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

** Reference case industrial energy consumption excludes refining

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

†Percent of annual industrial energy consumption

Table B.3 presents the ability of the public sector to leverage energy savings in the industrial sector with the 10-year adoption scenario. Through 2035, public expenditures are estimated at $90 million with a 3% discount rate. This yields an energy leveraging ratio of 335 MMBtu/$.

Table B.3. Leveraging of Energy Savings from Cumulative Public Investments in a 10-Year OBES Adoption Scenario

Year	Public Costs				Cumulative Energy Savings	Leveraging Ratio*
	Million $2008					
	Annual Administration Cost	Annual Investment Cost	Total Annual Costs	Total Cumulative Costs	TBtus	MMBtu/$
2020	0.15	7.66	7.81	89.6	3,909	--
2035	0.02	0	0.02	90.5	17,766	--
2055	--	--	--	90.5	30,306	335

*Ratio of cumulative energy savings in MMBtu to cumulative public costs in $2008. Present value of public costs was calculated using a 3% discount rate.

Table B.4 presents the ability of the public sector to leverage carbon dioxide savings in the industrial sector in the 10-year adoption scenario. In 2020, there are CO_2 savings of 30 million metric tons, representing 2% of the business-as-usual CO_2 emissions in the industrial sector that year. Over the lifetime of the equipment installed by 2035, 1,760 million metric tons of CO_2 emissions are avoided, yielding a carbon-dioxide leveraging ratio of 19.4 metric tons per dollar or $0.05/metric ton.

Table B.4. Leveraging of CO_2 Emission Reductions from Cumulative Public Investments in a 10-Year OBES Adoption Scenario

Year	Public Costs	CO_2 Emission Reductions			Leveraging Ratio*
	Million $2008	Million Metric Tons CO_2			
	Cumulative Costs	Annual MMT Saved	% Annual Emissions	Cumulative MMT Saved	Metric Tons/$
2020	89.6	29.8	1.9	216	--
2035	90.5	78.1	5.2	1,015	--
2055	90.5	--	--	1,757	19.4

*Ratio of cumulative emission reductions in million metric tons to cumulative public costs in $2008. Present value of public costs was calculated using a 3% discount rate.

Further benefits accrue to society as a whole from increased energy efficiency in the industrial sector and reduced energy consumption from the electricity sector. Estimates of the reduction of criteria pollutant emissions are shown in Table B.5, with SO_2 providing the greatest economic benefit at $28 billion cumulatively through 2055. The avoided costs of NO_x, SO_2, PM_{10}, and $PM_{2.5}$ due to the energy-efficiency measures are shown in Table B.5 using a 3% discount rate.

Table B.5. Value of Avoided Damages from Criteria Pollutant Emissions from 10-Year OBES Adoption Scenario (Billions $2008)*

	NO_x		SO_2		PM_{10}**		$PM_{2.5}$	
	Annual	**Cumulative**	**Annual**	**Cumulative**	**Annual**	**Cumulative**	**Annual**	**Cumulative**
2020	0.05	0.47	0.51	2.89	0.00	0.01	0.05	0.28
2035	0.06	1.37	1.19	16.69	0.01	0.09	0.11	1.56
2055		1.89		28.03		0.15		2.60

*Values are based on the National Research Council report estimating damages from energy production and consumption in the U.S. (NRC, 2010). Excludes avoided pollutant damages from petroleum and coal for industrial heat. Present value of avoided damages was calculated using a 3% discount rate.

**Excludes PM_{10} from the production of industrial heat.

Gains in efficiency of industrial processes reduce the emissions of the industrial and electricity sectors. These reductions represent significant societal benefits for the 10-year OBES adoption scenario, as shown in Table B.6. Including the social value of these emissions benefits as well as the energy savings results in a social B/C ratio of 15.6 for this policy option, using a 3% discount rate. The same analysis using a 7% discount rate is shown in Table B.7, providing a sensitivity estimate.

Table B.6. Total Social Benefit/Cost Analysis of a 10-Year OBES Adoption Scenario*

	Cumulative Social Benefits (Billions $2008)				Cumulative Social Costs (Billions $2008)			Benefit/Cost Analysis	
Year	**Energy Savings**	**Value of Avoided CO_2**	**Value of Avoided Criteria Pollutants**	**Total Social Benefits ****	**Public Costs**	**Private Costs**	**Total Social Costs ****	**Social B/C Ratio**	**Net Societal Benefits (Billions $2008)**
2020	24.6	4.70	3.65	33.0	0.09	5.03	5.12		
2035	109	20.3	19.71	149.5	0.09	16.2	16.3		
2055	188	34.0	32.67	254.8	0.09	16.2	16.3	15.6	238

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

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

Table B.7. Total Social Benefit/Cost Analysis of a 10-Year OBES Adoption Scenario (7% Discount Rate Sensitivity)*

	Cumulative Social Benefits (Billions $2008)				Cumulative Social Costs (Billions $2008)			Benefit/Cost Analysis	
Year	**Energy Savings**	**Value of Avoided CO_2**	**Value of Avoided Criteria Pollutants**	**Total Social Benefits****	**Public Costs**	**Private Costs**	**Total Social Costs ****	**Social B/C Ratio**	**Net Societal Benefits (Billions $2008)**
2020	20.3	3.90	2.94	27.2	0.08	4.17	4.25		
2035	64	11.9	11.16	86.7	0.08	10.1	10.1		
2055	95	17.4	16.36	128.9	0.08	10.1	10.1	12.7	119

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

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

Key Assumptions and Uncertainties with the OBES GT-NEMS Analysis

The most important assumption related to the OBES analysis is the selection of a market penetration rate, as the differences between the 5-year and 10-year adoption scenario show. These were modeled as a 20% and 10% market penetration rate, respectively.

In comparing CHP installations in states three years before and three years after the adoption of an OBES, we see an increase in installations of 82.1% in states that adopted an OBES before 2006. Since GT-NEMS' market penetration rate is determining the speed at which economically-viable CHP is installed, this suggests a high number for the market penetration rate might be justified. However, there are plenty of reasons for caution with a figure as high as 82%.

First, there is uncertainty in comparing all of the states – many of them chose unique applications and implementation methods for OBES. Second, as can be seen in Figure B.6, the regional distribution of industrial CHP generation focuses on the South, where there is scant OBES adoption (Texas and Maryland being the sole exceptions). Thus, there is little empirical evidence of how the rest of the South will respond to OBES. Lastly, it is unclear with this nascent policy option how prolonged the increased installation rate will be maintained. Such a pronounced projected increase in CHP in the South as a result of the policy, coupled with the uncertainty about the comparability of the states in the CHP database and the sustainability of the installation rates, 20% was determined to be a more conservative and appropriate market penetration rate for a 5-year adoption scenario. A 10% market penetration rate was chosen to provide an appropriate estimate for the longer 10-year adoption scenario. These market penetration rate selections yield results that match very closely with other reports on potential future CHP capacity (such as Shipley et al., 2008).

To attempt to understand the impact of OBES on the utilization of CHP more completely, some statistical modeling was performed. This information was not used in the modeling of the policy option, instead utilized *only* to provide more quantitative support for the positive impact of an OBES on CHP installations and capacity. The increase in CHP installations and CHP capacity after the adoption of an OBES can be seen in the CHP Database (owned by DOE, maintained by ICF International [ICF, 2009]), which attempts to catalog every instance of CHP technology deployment in the country (Figure B.6). On average, states that have implemented an OBES have seen the installation of more CHP in the three years following the regulatory change than the three years prior. These same states, on average, see an increase of roughly 37% in the capacity of total installed CHP. The direction of the increase is not universal. Some states see an increase in capacity but not installations, or vice versa, or see no change at all.

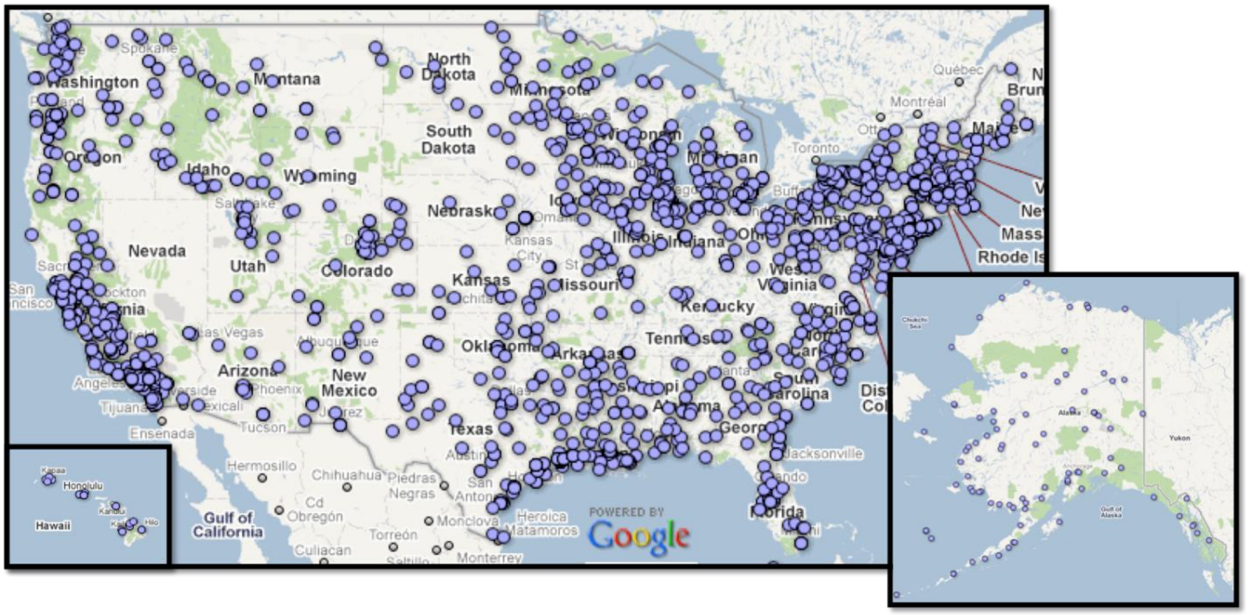

Figure B.6. Distribution of U.S. CHP Systems

Source: Derived from ICF, 2009

Data were collected from the CHP Database (ICF, 2009), State Permitting Issues for Distributed Generation (owned by EPA, maintained by ICF International [ICF, 2008]), the State Energy Data System (EIA, 2009), the Regional Economic Accounts (from the Bureau of Economic Analysis, 2010), the Database of State Incentives of Renewables and Efficiency (owned by DOE, maintained by North Carolina State University [DSIRE, 2010]), and the State, Citizen, and Government Ideology Database (Berry et al., 2007). The information from these databases was combined to measure CHP installations for every state in each year from 1995 through 2006 (state-year as the unit of analysis), controlling for the presence of an OBES, the year, gross-state product (GSP), the presence of a renewable portfolio standard that included CHP technology (RPS), state industrial energy consumption, state energy expenditure, state industrial energy expenditure, state energy expenditure/gross state product (SEE/GSP), state industrial energy expenditure/state energy expenditure (IE/SE), and the political liberalism of the state. Each of these variables could impact the number of CHP installations in a given state in a given year. Table B.8 below describes these variables in more detail.

Table B.8. Explanation of Regression Variables

Variable	Description
OBES	Dummy variable indicating an OBES is present
GSP	Gross State Product
RPS	Dummy variable indicating an RPS with CHP is present
State Industrial Energy Consumption	Energy consumed by industry in a given State
State Energy Expenditure	State spending on energy across all sectors
State Industrial Energy Expenditure	State spending on energy in the industrial sector
SEE/GSP	The proportion of GSP spent on energy across all sectors
IE/SE	The proportion of energy spending industry is responsible for
Political Liberalism	Political leanings of state citizens

To try and determine whether CHP technologies are installed more frequently due to an OBES, a fixed effects regression model (with robust standard errors) was used to compare the installation of CHP units and the installed capacity of CHP before and after the implementation of an OBES, using data from 1995 through 2006, providing 600 state-year observations (the first instance of an OBES was in 2000). As a result of using the fixed-effects model for the OBES, the impact of an OBES is only being captured for its first year, which may limit its effectiveness in capturing the impact of an OBES on overall CHP installations due to an inability to segregate new CHP orders from backlogged projects. It also bears repeating that the different policies adopted at the same time as the OBES and the changing Federal policy landscape (i.e., the Publuc Utility Regulatory Policy Act and the Energy Policy Act of 2005) also affect the business decision to purchase CHP and add to uncertainty in the regression analysis. However, we still find that concurrent with the implementation of OBES, there is a significant increase in the number of CHP installations nationally.

The results of these two regressions are important. Table B.9 shows the significant variables for both regressions. The explained variance for each regression model is also included.

Table B.9. Significant Variables for CHP Capacity and Installations in a State-Year

	OBES	RPS	GSP	IE/SE	R^2
Capacity	106**	91**	-.052	700**	0.446
Installations	0.82	- 0.01	0.00003**	14.9*	0.623

*signifies significance at $p < 0.1$ level
**signifies significance at $p < 0.05$ level
All “Capacity” units are MW, except GSP, which is KW

From these regressions, OBES have a significant impact on the installed capacity of CHP, but not on the gross number of CHP installations. It may be that OBES are enabling larger CHP installations in large industrial operations, with the increased savings in emissions and energy cost that follows such additional investment. It may also be that these are the installations most-easily adopted in the OBES regulatory environment, since the impact is only being captured for the first year of an OBES. The presence of a renewable portfolio standard allowing CHP has a slightly smaller similar impact.

For a state where industry represented 100% of the economy, CHP capacity could be expected to increase by 700 MW per state-year over the 12-year period, holding all other variables constant. Since no state economy is so dominated by industry, this number is likely much smaller (i.e., Alabama 2006 IE/SE = 0.25 [calculation from State Energy Data System information], so the expected installation would be 175 MW).

The number of observations in the time period of interest limits doing a similar analysis strictly on industrial CHP installations. After adoption of an OBES, on average, more installations and increased capacity of CHP are seen. However, this is not to say that CHP installation rates are guaranteed to increase everywhere with the adoption of an OBES. Massachusetts, Maryland, and Ohio have seen no change in implementation rates between the three years preceding implementation and the three years following it, although Ohio and Massachusetts experienced increases in annual installed capacity. Some other examples:

- In California, the number of CHP installations across all sectors increased roughly 50% annually after the implementation of an output-based emissions standard (from 10.7 to 15.7 annual installations).
- Indiana’s annual industrial CHP installation rate remained constant, while overall CHP installations increased substantially within the three-year window.
- Texas experienced a decrease in new industrial installations when comparing before-and-after industrial applications (13 installations before contrasted with nine installations after).

Another assumption is the 0.7% annual increase in CHP system efficiency due to the 10 year/$100 million R&D program, although this had less of an effect than the market penetration rates. This assumption increases the energy savings projected by GT-NEMS by less than 1% through 2035, but this is not a true picture of the impact of the R&D program. The R&D program instead appears to be accelerating the pace at which industry, through CHP, becomes a supplier of electricity back to the grid. This increases industrial energy consumption while lowering overall energy consumption – hence the increase in energy consumption shown in OBES scenario in Figure B.7.

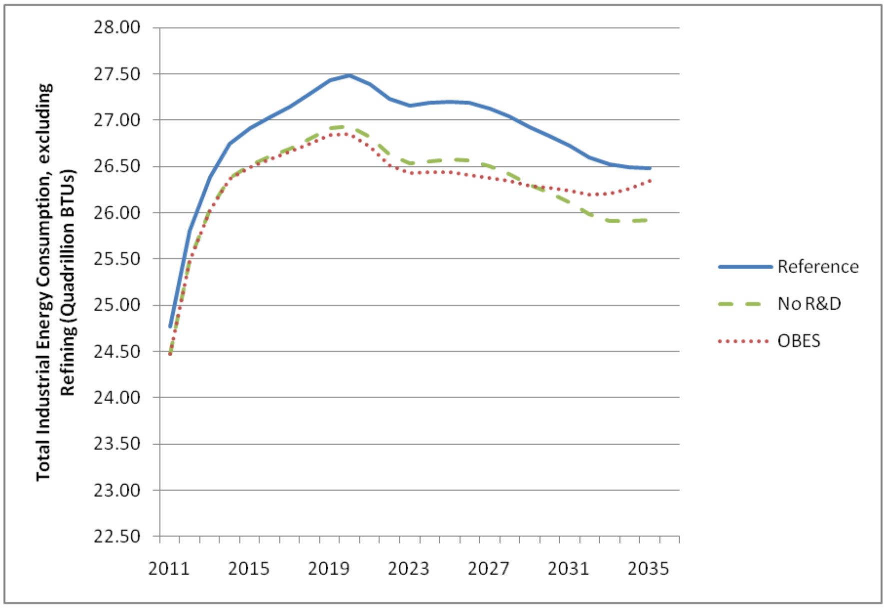

Figure B.7. R&D Contribution to OBES' Industrial Energy Consumption

Remaining uncertainties and assumptions are not unique to the OBES modeling, and relate to GT-NEMS modeling of power purchase agreements with utilities for CHP (and other economic choices made by GT-NEMS), with unquantified benefits and damages related to emissions, for example, or future energy prices. These are shared uncertainties and assumptions, equally applicable to other policy options in this document.

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Appendix C

Background for Analysis of a Federal Energy Portfolio Standard Qualifying Combined Heat and Power

C.1 GT-NEMS Analysis

To motivate plant owners to install more CHP equipment, policy makers must address several technology barriers. Two key parameters that influence economic viability are operating costs (driven by efficiency and fuel price) and capital costs (driven by initial installation costs) (Brown et al., 2008). We have developed a policy scenario to address these two factors. To assess the magnitude of cost-effectiveness and achievable energy-efficiency improvements from CHP proliferation, we have assumed adoption of a set of transformative energy policies: 1) extension and expansion of the duration of the existing federal tax credit programs and 2) an accelerated learning curve that improves the performance of CHP technologies over time, as greater CHP capacity is installed.

The first policy was modeled in GT-NEMS by extending the duration of the current Investment Tax Credits (ITC). In this study, we assumed that policymakers would extend the duration of the ITC through 2035. In addition, we implemented a 30% subsidy policy for accelerating additional installation of CHP equipment. In sum, we assume that 30% of the total investment cost for new CHP systems would be supported by the federal government. As noted in Chapter 2, the 30% ITC has been proposed in prior legislation and has been studied by at least one group. The extension of the ITC through 2030 is consistent with the “No Sunset” policy sensitivity evaluated by EIA (2010) in its *AEO 2010*.

We also modeled expanded R&D activities for improving the performance of CHP systems. We assumed that the programs could increase the overall efficiency by 0.7% annually and raise the average efficiency level up to 83% by 2030 without any additional increase in installation cost. Table C.1 shows that the overall efficiency values for the EIA’s reference case and those for our study. We approximated that the grant program would spend $10 million annually to cost share the R&D of research entities. CHP system performance and cost information from EIA were used to quantify energy savings and financial costs.

Table C.1. Overall Efficiency by CHP System (Size)

		Reference*			Policy**	
System	**Size (kilowatts)**	**2006**	**2020**	**2035**	**2020**	**2035**
1 Internal Combustion Engine	1,000	0.71	0.75	0.75	0.76	0.86
2 Internal Combustion Engine	3,000	0.71	0.74	0.75	0.77	0.86
3 Gas Turbine	3,000	0.69	0.71	0.72	0.74	0.82
4 Gas Turbine	5,000	0.71	0.72	0.72	0.76	0.84
5 Gas Turbine	10,000	0.71	0.72	0.73	0.76	0.84
6 Gas Turbine	25,000	0.71	0.72	0.74	0.76	0.84
7 Gas Turbine	40,000	0.72	0.73	0.74	0.77	0.85
8 Combined Cycle* **	100,000	0.70	0.73	0.74	0.75	0.84

* Industrial CHP Technology Performance Data used for EIA's *AEO 2010* projections (EIA, 2010)

** We increased the overall efficiency of each CHP system by 0.7% annually and raised the efficiency level up to 83% by 2030.

***Two 40 MW Gas Turbine & 20 MW Steam

(1) End year of ITC: To extend the duration of ITC, *CapCostMultEnd* is changed from 2008 to 2035.

(2) Installation Cost: To implement a 30% subsidy for installation, the installation cost by system is reduced by 30%.

(3) Overall Efficiency: To implement a rapid technological development in CHP performance, the overall efficiency is increased by 0.7% annually.

Table C.2. CHP Installation Cost by System Type and Year

	Internal Combustion Engine		**Gas Turbine**					**Combined Cycle***
Total Installed Cost (2005$/KW)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
2010	**1277**	**1058**	**1451**	**1096**	**1060**	**892**	**782**	**831**
2011	885	737	1011	762	739	622	546	580
2012	876	734	1006	757	735	619	545	578
2013	867	730	1001	753	732	616	543	576
2014	858	727	996	748	728	613	542	574
2015	848	723	991	743	725	610	540	572
2016	839	720	986	738	721	608	539	570
2017	830	716	981	733	718	605	538	568
2018	821	713	977	728	714	602	536	566
2019	812	709	972	723	711	599	535	564
2020	804	704	964	721	707	596	534	564
2021	793	699	956	718	704	593	532	563
2022	782	693	948	714	700	590	531	561
2023	771	687	940	711	697	587	529	560
2024	760	682	932	707	693	585	528	559
2025	748	676	925	704	690	582	526	557
2026	737	671	917	700	686	579	525	556
2027	726	665	909	697	683	576	524	554
2028	715	659	902	693	679	573	522	553
2029	704	654	894	690	676	571	521	552
2030	692	650	886	685	671	569	520	551
2031	692	650	886	685	671	569	520	551
2032	692	650	886	685	671	569	520	551
2033	692	650	886	685	671	569	520	551
2034	692	650	886	685	671	569	520	551
2035	692	650	886	685	671	569	520	551

*Two 40 MW Gas Turbine & 20 MW Steam

C.2 Benefit/Cost Calculations

The spreadsheet assessment of cost-effectiveness involved the following six steps.

1. Baseline forecast of energy consumption and CHP penetration
2. Estimation of market penetration of CHP using NEMS 2010
3. Estimation of savings from NEMS analysis by industry and type of fuel
4. Incremental investment cost of policy scenario from spreadsheet analysis
5. Free riders from baseline CHP facilities built after 2010.

6. Sensitivity analysis: assessment of a policy that limits the investment tax credit to 10 years.

C.3 Details of Sensitivity Analysis

The following tables provide an analysis of the policy sensitivity case, which assumes that the investment tax credit for CHP ends on 2020 instead of 2035.

Table C.3. SFEM from the Industrialists' Perspective (10-Year ITC Sensitivity)

	BAU Energy Consumption*	Annual Energy Savings			Cumulative Energy Savings		Annual Private Cost	Cumulative Private Cost
Year	**Trillion Btu**	**Trillion Btu**	**$M (2008)**	**%**	**Trillion Btu**	**$M (2008)**	**$M (2008)**	**$M (2008)**
2011	24,770							
2020	27,480	619	4,314	2.25	4,306	29,110	314	3,114
2035	26,480	1072	8280	4.05	17,153	108,411	378	8,994
2055	--	--	--	--	27,323	164,910	--	8,994

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

** Reference case industrial energy consumption excludes refining. These Business-as-Usual (BAU) estimates are output from the GT-NEMS industrial module. They differ slightly from the *AEO 2010* (EIA, 2010) published estimates, which are produced from a fully integrated NEMS analysis.

*** The percentages refer to the percent of energy use and carbon dioxide emissions from industrial energy use.

****Investments stimulated from the policy occur through 2015. Energy savings accrue only through 2019.

Table C.4. Leveraging of Energy Savings from Cumulative Public Investments in Small Firm Energy Management (10-Year ITC Sensitivity)

Year	Public Costs Million $2008				Cumulative Energy Savings	Leveraging Ratio*
	Annual Administration Cost	**Annual Investment Cost**	**Total Annual Costs**	**Total Cumulative Costs**	**TBtus**	**MMBtu/$**
2020	10.1	514	524	4375	4,306	--
2035	0.00	0.00	0.00	4913	17,153	--
2055	--	--	--	4913	27,323	5.6

Table C.5. Leveraging of CO_2 Emission Reductions from Cumulative Public Investments in Small Firm Energy Management (10-Year ITC Sensitivity)

Year	Public Costs	CO_2 Emission Reductions			Leveraging
	Million $2008	Million Metric Tons CO_2			Ratio*
	Cumulative Costs	Annual MMT Saved	% Annual Emissions	Cumulative MMT Saved	Metric Tons/$
2020	4375	34.7	2.2	240	--
2035	4913	62.9	4.2	977	--
2055	4913	--	--	1,575	0.32

*Ratio of cumulative emission reductions in million metric tons to cumulative public costs in $2008. Present value of the public costs was calculated using a 3% discount rate.

Table C.6. Value of Avoided Damages from Criteria Air Pollutant Emissions (Billion $2008) from Small Firm Energy Management (10-Year ITC Sensitivity)

	NO_x		SO_2		PM_{10}**		$PM_{2.5}$	
Year	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
2020	0.052	0.467	0.681	3.729	0.004	0.019	0.062	0.353
2035	0.064	1.344	0.988	16.764	0.005	0.089	0.092	1.555
2055		1.948		26.154		0.141		2.428

*Values are based on the National Research Council report estimating damages from energy production and consumption in the U.S. (NRC, 2010). Excludes avoided pollutant damages from petroleum and coal for industrial heat. Present value of avoided damages was calculated using a 3% discount rate.

**Excludes PM_{10} from the production of industrial heat.

Table C.7. Total Social Benefit/Cost Analysis of from Small Firm Energy Management (10-Year ITC Sensitivity)

	Cumulative Social Benefits				Cumulative Social Costs			Benefit/Cost Analysis	
	(Billions $2008)				(Billions $2008)				
Year	Energy Savings	Value of Avoided CO_2	Value of Avoided Criteria Pollutants	Total Social Benefits**	Public Costs	Private Costs	Total Social Costs**	Social B/C Ratio	Net Societal Benefits (Billions $2008)
2020	29.1	5.21	4.57	38.9	4.37	3.11	7.49		
2035	108.4	19.7	19.75	147.8	4.91	9.0	13.9		
2055	164.9	30.7	30.67	226.3	4.91	9.0	13.9	16.3	212

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

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

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Appendix D

Background for Analysis of Superior Energy Performance Program (SEP)

D.1 Policy Timeline

All policies scenarios are modeled to begin in 2011. The investments stimulated as a result of policy intervention are then extended out to 2035. The benefits are modeled to degrade at a rate of 5% after 2035, such that all benefits from the policy have ended by 2055. The degradation assumed is consistent with the literature (Brown et al., 1996).

D.2 Policy Scenarios

In the first policy scenario (PS1), 60% of facilities that comprise the large category, or about 5,760 sites, will adopt the Superior Energy Performance (SEP) standard. Sixty percent was selected because it is consistent with the adoption of energy management standards in countries with government sponsored strong incentives (McKane et al., 2005). The estimated number of sites is also consistent with the number of industrial sites that have adopted the internationally accepted environmental management standard, ISO 14000. As of 2006, 5,585 U.S. firms had received ISO 14000 certification. It is believed that sites that have demonstrated their commitment to a management standard focused on the environment will be likely candidates to pursue an energy management standard certification. In this scenario, we estimate that industrial facilities comprising approximately 40% of the total U.S. industrial energy consumption will adopt the SEP standard. In the second policy scenario (PS2), a lower penetration, 30% of large facilities, is estimated will become SEP certified to comprise approximately 20% of total U.S. industrial energy consumption.

For all policy scenarios, we predict that approximately 35% of facilities that become SEP certified will achieve a performance level of silver, while an additional 30% and 15% will achieve a performance level of gold and platinum, respectively. Descriptions of the requirements for certification for different performance levels are shown in Table D.1. Performance level estimations are based on a survey enquiring of executives the level of LEED certification their company would most likely seek (Turner Construction, 2008). LEED has a similar performance level structure, and insight with regard to the performance level executives would seek is a reasonable measure of future SEP performance level attainment.

Table D.1. Performance characteristics of silver, gold, and platinum level SEP facilities

Performance Characteristics		**Silver**	**Gold**	**Platinum**
Energy Performance Pathway	**Energy Performance Improvement**	Meets **5%** energy performance improvement threshold over the last 3 years.	Meets **10%** energy performance improvement threshold over the last 3 years.	Meets **15%** energy performance improvement thresholdover the last 3 years.
Mature Energy Pathway	**Energy Performance Improvement**	Demonstrates an energy performance improvement of **15%** or more over the last **10** years.	Demonstrates an energy performance improvement of **15%** or more over the last **10** years.	Demonstrates an energy performance improvement of **15%** or more over the last **10** years.
	Score on Best Practice Scorecard *Includes credits for energy management best practices and energy performance improvements beyond 15% over the last 10 years.*	• Meets a score of **at least 35 and up to 60** out of 100 total points for Best Practice Scorecard • Minimum of 25 points required for the energy management best practices.	• Meets a score of **at least 61 and up to 80** out of 100 total points for Best Practice Scorecard • Minimum of 25 points required for the energy management best practices and 10 for energy performance.	• Meets a score of **at least 81** out of 100 total points for Best Practice Scorecard • Minimum of 25 points required for the energy management best practices and 10 for energy performance.

Source: http://www.superiorenergyperformance.net/qualify.html

D.3 Implementation Costs

For our analysis, we estimate implementation costs of approximately $12 per MBtu/year of energy savings. This cost is based on average implementation costs from companies that participate in DOE's Save Energy Now and Industrial Assessment Centers.

D.4 Energy Savings Methodology

We estimate that every facility will initially become certified using the energy performance pathway. Every three years, plants will re-submit SEP documentation to renew certification. After the original certification, facilities that become certified at the silver level will subsequently renew certification utilizing the energy performance pathway the following two renewal periods.

After these two renewal periods, the SEP program will have been in place nine years and all further performance certifications will be achieved via the mature energy pathway (15% reduction over 10 years). However, plants that pursue gold and platinum certification will utilize the mature energy pathway for all certification renewals after the inaugural certification. This is because these gold and platinum facilities will have achieved sufficient savings in the first certification period so that they can achieve lower annual percent energy reduction in subsequent years and still renew their certification at the energy performance criterion of a 15% reduction over 10 years. Facilities that do not achieve higher performance level certification are characterized as basic and are modeled to achieve a 3% energy intensity reduction every three years (i.e. 1% per year). A reduction in energy intensity (i.e. energy per unit of production) is used to model energy performance improvements for each performance level and is shown in Figure D.1.

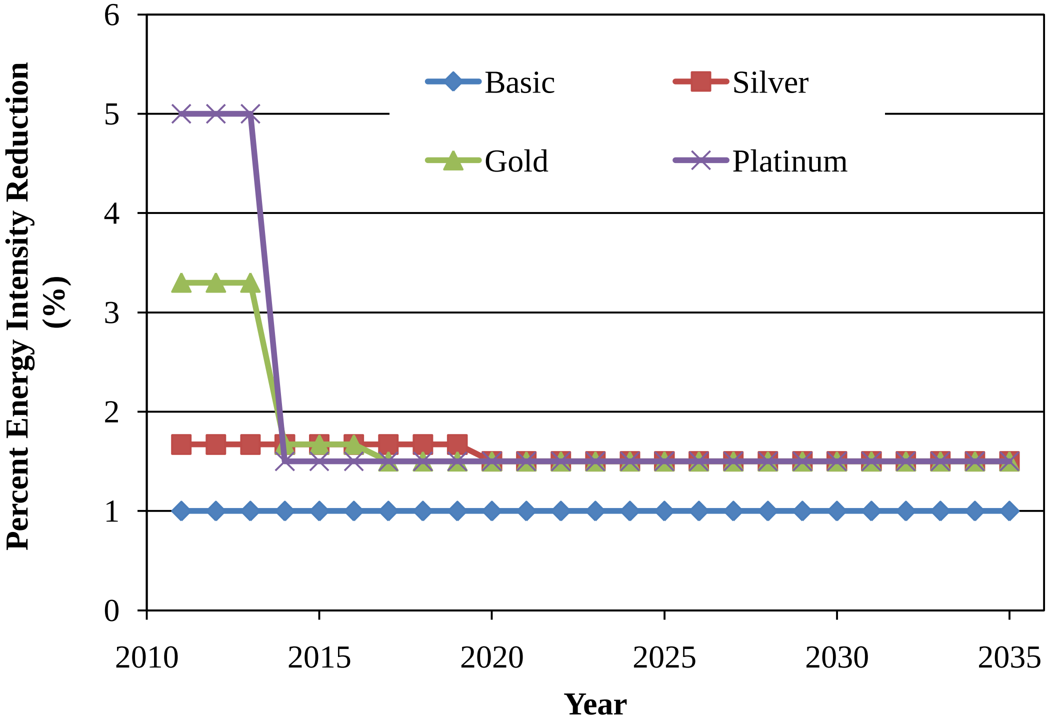

Figure D.1. Modeled Energy Reduction of SEP Facilities of as a Percentage of Total Energy Consumption

The reduction in energy use was determined by using the industrial energy consumption as projected by the Energy Information Administration's (EIA, 2010) *Annual Energy Outlook 2010* (*AEO*). This forecasted energy consumption contains factors such as structural changes in energy use, as well as variations in annual industrial production. Therefore, the reduction in energy consumption that would be achieved via the SEP prescribed decrease in energy intensity could be determined from *AEO* forecasted energy consumption. This is illustrated in Figure D.2. If the energy intensity was constant over the forecasted period, the energy consumption would increase at an average annual rate of 1.3%, which is equal to the *AEO* projected growth rate in value of shipments. However, *AEO* projects an overall decrease in energy intensity due to both structural changes and energy efficiency. Therefore, the *AEO* business-as-usual (BAU) forecast for industrial energy consumption is considerably lower, even though an average industrial growth rate is assumed. According to *AEO*, 82% of the reduction in industrial energy intensity is due to structural changes while the remaining 18% is due to energy-efficiency improvements. The impact on energy consumption can be seen in the figure.

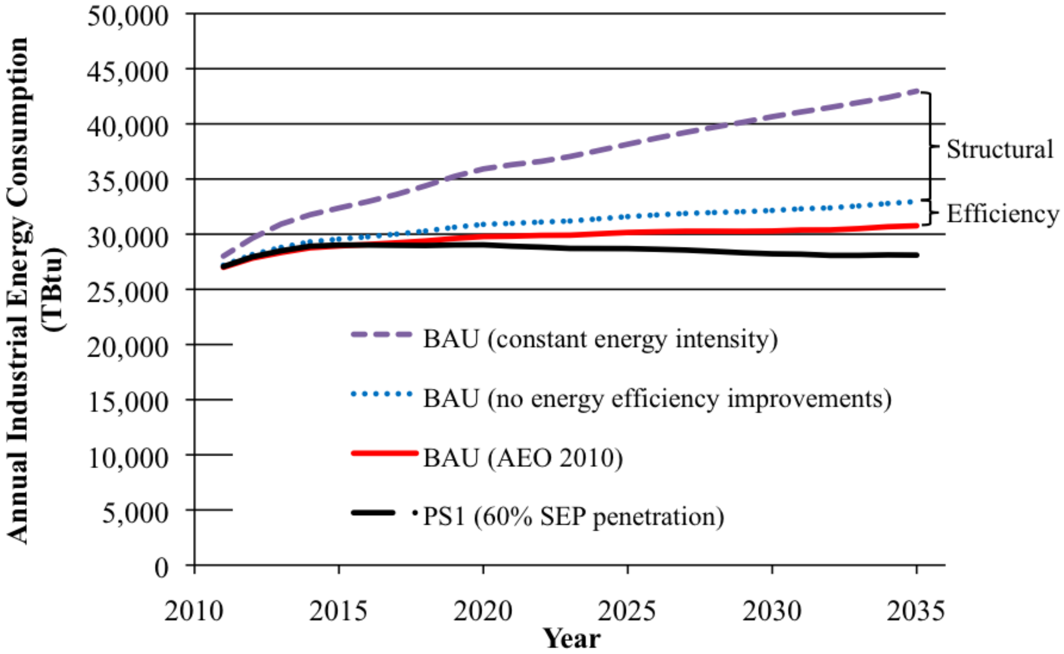

Figure D.2. Annual Industrial Energy Consumption of PS1 and BAU with Constant Energy Intensity, No Energy-Efficiency Improvements, and *AEO 2010* Forecast

The efficiency improvements prescribed by SEP are taken from a baseline case of BAU with no energy-efficiency improvements and are used to derive the impact of the different policy scenarios on facilities that become SEP certified. The total resulting industrial energy consumption is thereby derived by adding the energy consumption of SEP facilities to the energy consumption of the remainder of the industrial sector that would be projected by the *AEO*. The policy scenario representing a penetration of SEP certification into 60% large facilities is shown in the figure. The efficiency improvements projected in the *AEO* BAU model that would otherwise occur in the absence of the SPS policy are subtracted from the overall energy reductions for evaluation of the policy's associated benefits and costs.

The average energy savings of individual facilities in the manufacturing and mining sectors are presented in Table D.2 by varying performance levels. A SEP participating facility that does not achieve a higher performance level (i.e. silver, gold, or platinum) is estimated to generate six TBtu in cumulative energy savings from 2011 to 2035. In contrast, an industrial facility certified at a platinum performance level is projected to reduce annual energy consumption by 39% in the year 2035 and achieve 13 TBtu of energy-efficiency savings over the same period.

Table D.2. Average Energy Savings of Individual SEP Facilities

	Cumulative Energy Saved (2011-2035)	Present Value of Cumulative Energy Saved (2011-2035)	Annual Energy Savings over BAU in 2035
	Trillion Btu	Million 2008$	Percent
Basic	6	10	22
Silver	9	16	34
Gold	11	20	36
Platinum	13	25	39

D.5 Energy-Efficiency Credits

The impact of the energy-efficiency credits is not modeled to start until 2015 to allow time for a federal Energy Portfolio Standard to be established through which a system for renewable and efficiency credits may be traded. The efficiency credits are based on an average four year contract period of efficiency measures. Efficiency savings by all energy sources are eligible for trading, and an equivalent MWh was determined for all non-electricity sources for modeling in this report. An initial energy-efficiency value of $3.65/Mwh was assumed and indexed with the average price of energy as given by *AEO 2010* (EIA, 2010). The final value in 2035 was determined to be is $5.40/Mwh.

D.6 Free Riders

Based on the historical adoption rate of energy management standards in the U.S., in the absence of this policy we estimate that 5% of large facilities would become SEP certified and are modeled as “free riders”. The public costs of free riders are included in the analysis, however the private costs of free riders are not. While a firm may be able to be a free rider with regard to federal funding, all private costs are their own. The benefits of free riders are also excluded from the potential benefits of this policy as forecasted by this report.

D.7 Energy Prices

The reference case forecast of energy prices from the *AEO 2010* (EIA, 2010) provides the baseline for our policy analysis.

D.8 Results of the Sensitivity Analysis Assuming a Superior Energy Performance Program Penetration Rate of 20%

Table D.3 presents the results of the analysis in terms of energy consumption and energy expenditures from the perspective of industrialists, utilizing a 7% discount rate. For this policy scenario, it is estimated that 1,090 TBtu of energy would be saved in 2035, representing 3.5% of the business-as-usual industrial energy consumption in that year. Over the lifetime of equipment installed through 2035, there would be 22,900 TBtu of energy saved. These energy savings come at a cost of $4,780 million, but result in $35,800 million savings over the lifetime of the installed equipment.

Table D.3. SEP Program Impact from the Industrialists' Perspective* (20% SEP Penetration)

Year	BAU Energy Consumption**	Annual Energy Savings			Cumulative Energy Savings***		Annual Private Cost	Cumulative Private Cost
	Trillion Btu	Trillion Btu	$M (2008)	%	Trillion Btu	$M (2008)	$M (2008)	$M (2008)
2011	27,000							
2020	29,800	336	1,140	1.1	1,180	4,440	336	1,730
2035	30,800	1,090	1,460	3.5	12,510	26,800	99	4,780
2055	---	---		---	22,900	35,800	---	4,780

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

** Reference case industrial energy consumption excludes refining

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

Table D.4 presents the ability of the public sector to leverage energy savings in the industrial sector if 20% of industrial energy consumption adopted the Superior Energy Performance program. Through 2055, public expenditures are estimated at $1,110 million with a 3% discount rate, and lead to energy savings of 22,900 TBtu. This yields an energy leveraging ratio of 21 TBtu/million $2008 or MMBtu/$2008.

Table D.4. Leveraging of Energy Savings from Cumulative Public Investments in Incentives to Promote SEP in Industry

Year	Public Costs*				Cumulative Energy Savings	Leveraging Ratio*
	Million $2008					
	Annual Administration Cost	Annual Investment Cost	Total Annual Costs	Total Cumulative Costs	TBtus	MMBtu/$
2020	0.4	35	36	1,100	1,180	
2035	0.1	0	0.1	1,110	12,510	
2055	---	---	---	1,110	22,900	21

*Ratio of cumulative energy savings in MMBtu to cumulative public costs in $2008. Present value of public costs were calculated using a 3% discount rate.

Table D.5 presents the ability of the public sector to leverage carbon dioxide savings in the industrial sector if 20% of industrial energy consumption adopted the SEP program. In 2035, public expenditures lead to CO_2 savings of 49 metric tons, representing 3.5% of the business-as-usual CO_2 emissions in the industrial sector that year. Over the lifetime of the equipment installed by 2035 as a result of this policy change, 1,044 metric tons of CO_2 emissions are avoided, yielding a carbon-dioxide leveraging ratio of 0.9 metric tons per dollar.

Table D.5. Leveraging of CO_2 Emission Reductions Cumulative Public Investments in Incentives to Promote SEP in Industry

Year	Public Costs Million $2008	CO_2 Emission Reductions Million Metric Tons CO_2			Leveraging Ratio*
	Cumulative Costs	Annual MMT Saved	% Annual Emissions	Cumulative MMT Saved	Metric Tons/$
2020	1,095	16	1.1%	56	--
2035	1,113	49	3.5%	577	--
2055	1,113	--	--	1,044	0.9

*Ratio of cumulative emission reductions in million metric tons to cumulative public costs in $2008. Present value of public costs were calculated using a 3% discount rate.

Further benefits accrue to society as a whole from increased energy efficiency in the industrial sector and reduced energy consumption from the electricity sector. Estimates of the reduction of criteria pollutant emissions are shown in Table 4, with SO_2 providing the greatest economic benefit at $22.08 billion cumulatively through 2055. The avoided costs of NO_x, SO_2, PM_{10}, and $PM_{2.5}$ due to the energy-efficiency measures are shown in Table D.7 using a 3% discount rate.

Table D.6. Value of Avoided Damages from Criteria Pollutant Emissions* (Billions $2008)

	NO_x		SO_2		PM_{10}**		$PM_{2.5}$	
	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
2020	0.06	0.23	0.48	1.81	0.00	0.01	0.05	0.17
2035	0.12	1.75	0.91	13.45	0.01	0.07	0.09	1.31
2055	---	2.89	---	22.08	---	0.12	---	2.16

* Values are based on the National Research Council report estimating damages from energy production and consumption in the U.S. (NRC, 2010). Excludes pollutant damages from petroleum and coal for industrial heat. Present value of avoided damages were calculated using a 3% discount rate.

** Excludes PM_{10} from the production of industrial heat.

Gains in efficiency of industrial processes reduce the emissions of the industrial and electricity sectors. These reductions represent significant societal benefits if 20% of industrial energy consumption adopted the Superior Energy Performance program, as shown in Table D.7a. Including the social value of these emissions benefits, as well as the energy savings, results in a social B/C ratio of 14.5 for this policy option, using a 3% discount rate. The same analysis using a 7% discount rate is shown in Table D.7b providing a sensitivity estimate.

Table D.7a. Total Social Benefit/Cost Analysis of Cumulative Public Investments in Incentives to Promote SEP in Industry

	Cumulative Social Benefits (Billions $2008)				Cumulative Social Costs (Billions $2008)			Benefit/Cost Analysis	
Year	**Energy Savings**	**Value of Avoided CO_2**	**Value of Avoided Criteria Pollutants**	**Total Social Benefits****	**Public Costs**	**Private Costs**	**Total Social Costs****	**Social B/C Ratio**	**Net Societal Benefits (Billions $2008)**
2020	5.8	1.2	2.2	10.8	1.10	2.2	3.3		
2035	49.3	11.4	16.6	82.1	1.11	7.8	8.9		
2055	77.7	19.2	27.3	129	1.11	7.8	8.9	14.5	120

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

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

Table D.7b. Total Social Benefit/Cost Analysis of Cumulative Public Investments in Incentives to Promote SEP in Industry (7% Discount Sensitivity)

	Cumulative Social Benefits (Billions $2008)				Cumulative Social Costs (Billions $2008)			Benefit/Cost Analysis	
Year	**Energy Savings**	**Value of Avoided CO_2**	**Value of Avoided Criteria Pollutants**	**Total Social Benefits****	**Public Costs**	**Private Costs**	**Total Social Costs****	**Social B/C Ratio**	**Net Societal Benefits (Billions $2008)**
2020	4.4	0.9	1.7	8.2	0.90	1.7	2.6		
2035	26.8	6.1	9.1	45.0	0.91	4.8	5.7		
2055	35.8	8.6	13.4	60.9	0.91	4.8	5.7	10.7	55.2

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

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

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Appendix E

Background for Analysis of Implementation Support Services (ISS)

E.1 Energy Savings Methodology

A summary of energy savings identified in Industrial Assessment Center (IAC) assessments from 2000-2009 is shown in Table E.1. Approximately 32.4% of Btu source energy savings were implemented.[1]

Table E.1 Summary of recommended and implemented energy savings

Number of Assessments	Recommended Energy Savings		Energy Savings Implemented		Energy Savings not Implemented with a Simple Payback less than 2 years	
	Million $2008	TBtu	Million $2008	TBtu	Million $2008	TBtu
5,239	1,173	112	335	35	537	43.7

(IAC database, 2010)

Post-assessment survey results from the Save Energy Now (SEN) program from 2006-2009 were used to understand reasons that identified energy saving measures were not implemented (Wright and Nimbalkar, 2010). The SEN primarily focuses on large industrial firms, while the IAC program concentrates on medium sized firms. It is understood that a difference could exist between the decision making process and conclusions of large and medium sized firms. However, in the absence of a post-assessment analysis for the IAC program, the authors deemed it appropriate to use the SEN survey as a basis for estimating the ISS impact. As a point of comparison of the two programs, from 2006-2008, 33.7% of energy saving measures identified through SEN assessments were implemented (Wright et al., 2010),[2] which is similar to the 37% implementation rate of IAC recommendations.

From the SEN survey analysis, 23% of energy savings not implemented were rejected due to financial reasons. Additionally, approximately 39% of energy savings not implemented were in the in-planning phase, but had a simple payback of less than two years. Because ISS would work with financial institutions to reduce economic barriers while also engaging engineering firms to provide manpower and expertise, these two categories of recommended energy savings will likely be significantly impacted. Accordingly, we estimate that half of these measures will be implemented as a result of ISS. This facilitates an increase in the total IAC implementation rate from 37% to 58%.

From 2011 to 2035, the total number of energy savings assessments forecasted to be completed by the IAC program was increased from a business-as-usual reference case of 6,864

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[1] Source energy savings of 6.8 TBtu had an unknown implementation status and were not included in the percent estimation.

[2] SEN implementation rate includes measures implemented and measures in progress.

to 31,734. This increase raises the average number of assessments completed each year from 312 to 1,300. We modeled the increase over a period of two years, such that 534 assessments would be completed in 2011 and 1,300 in 2012. A similar approach was modeled in the second policy scenario where the total number of energy assessments was increased to 534 in 2011 and 650 in 2012.

E.2 Spreadsheet Analysis

Public costs to support additional IAC assessments were determined from the ratio of the current ITP funding and the total number of assessments. In FY2010, $4M was appropriated for 312 assessments. Given the similarities of the IAC program and ISS, we estimate a similar public cost per assessment to fund ISS. The private costs were estimated by assuming an average cost per MMBtu of implemented energy savings of $14.

E.8 Results of the Sensitivity Analysis with IAC funding at 2000 levels (~650 assessments per year)

Table E.2 presents the results of the analysis in terms of energy consumption and energy expenditures from the perspective of industrialists, utilizing a 7% discount rate. For this policy scenario, it is estimated that 59 TBtu of energy would be saved in 2035, representing 0.2% of the business-as-usual industrial energy consumption in that year. Over the lifetime of equipment installed through 2035, there would be 1,029 TBtu of energy saved. These energy savings come at a private cost of $914 million, but result in $2,902 million savings over the lifetime of the installed equipment.

Table E.2. ISS Impact from the Industrialists' Perspective*
(IAC funding at 2000 levels)

Year	BAU Energy Consumption**	Annual Energy Savings			Cumulative Energy Savings***		Annual Private Cost	Cumulative Private Cost
	Trillion Btu	Trillion Btu	$M (2008)	%	Trillion Btu	$M (2008)	$M (2008)	$M (2008)
2011	27,000							
2020	29,800	40	134	0.1	211	840	44	513
2035	30,800	59	79	0.2	1,029	2,537	16	914
2055	---	---		---	1,402	2,902	---	914

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

** Reference case industrial energy consumption excludes refining

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

Table E.3 presents the ability of the public sector to leverage energy savings in the industrial sector if funding for the IAC program remained at 2000 levels thereby permitting approximately 650 energy saving assessments per year. Through 2055, public expenditures are estimated at

$210 million with a 3% discount rate, and lead to energy savings of 1,402 TBtu. This yields an energy leveraging ratio of 6.7 TBtu/million $2008 or MMBtu/$2008.

Table E.3. Leveraging of Energy Savings from Cumulative Public Investments in ISS

	Public Costs*				Cumulative Energy Savings	Leveraging Ratio*
	Million $2008				TBtus	MMBtu/$
Year	Annual Administration Cost	Annual Investment Cost	Total Annual Costs	Total Cumulative Costs		
2020	9.7	---	10	95	211	
2035	6.2	---	6	210	1,029	
2055	---	---		210	1,402	6.7

*Ratio of cumulative energy savings in MMBtu to cumulative public costs in $2008. Present value of public costs were calculated using a 3% discount rate.

Table E.4 presents the ability of the public sector to leverage carbon dioxide savings in the industrial sector under this scenario. In 2035, public expenditures lead to CO_2 savings of 3 metric tons, representing 0.1% of the business-as-usual CO_2 emissions in the industrial sector that year. Over the lifetime of the equipment installed by 2035 as a result of this policy change, 65 metric tons of CO_2 emissions are avoided, yielding a carbon-dioxide leveraging ratio of 0.2 metric tons per dollar.

Table E.4. Leveraging of CO_2 Emission Reductions Cumulative Public Investments in ISS

Year	Public Costs	CO_2 Emission Reductions			Leveraging Ratio*
	Million $2008	Million Metric Tons CO_2			
	Cumulative Costs	Annual MMT Saved	% Annual Emissions	Cumulative MMT Saved	Metric Tons/$
2020	95	2	0.1%	10	
2035	210	3	0.2%	48	
2055	210			65	0.3

*Ratio of cumulative emission reductions in million metric tons to cumulative public costs in $2008. Present value of public costs was calculated using a 3% discount rate.

Further benefits accrue to society as a whole from increased energy efficiency in the industrial sector and reduced energy consumption from the electricity sector. Estimates of the reduction of criteria pollutant emissions are shown in Table E.5, with SO_2 providing the greatest economic benefit at $1.67 billion cumulatively through 2055. The avoided costs of NO_x, SO_2, PM_{10}, and $PM_{2.5}$ due to the energy-efficiency measures are shown in Table E.6 using a 3% discount rate.

Table E.5. Value of Avoided Damages from Criteria Pollutant Emissions* (Billions $2008)

	NO_x		SO_2		PM_{10}**		$PM_{2.5}$	
	Annual	**Cumulative**	**Annual**	**Cumulative**	**Annual**	**Cumulative**	**Annual**	**Cumulative**
2020	0.01	0.04	0.06	0.34	0.00	0.00	0.01	0.03
2035	0.01	0.16	0.05	1.20	0.00	0.01	0.01	0.12
2055	---	0.22	---	1.67	---	0.01	---	0.16

* Values are based on the National Research Council report estimating damages from energy production and consumption in the U.S. (NRC, 2010). Excludes pollutant damages from petroleum and coal for industrial heat. Present value of avoided damages was calculated using a 3% discount rate.

** Excludes PM_{10} from the production of industrial heat.

Gains in efficiency of industrial processes reduce the emissions of the industrial and electricity sectors. These reductions represent significant societal benefits IAC funding remain at 2000 levels, as shown in Table E.6a. Including the social value of these emissions benefits as well as the energy savings results in a social B/C ratio of 5.5 for this policy option, using a 3% discount rate. The same analysis using a 7% discount rate is shown in Table E.6b providing a sensitivity estimate.

Table E.6a. Total Social Benefit/Cost Analysis of Cumulative Public Investments in ISS

	Cumulative Social Benefits (Billions $2008)				Cumulative Social Costs (Billions $2008)			Benefit/Cost Analysis	
Year	**Energy Savings**	**Value of Avoided CO_2**	**Value of Avoided Criteria Pollutants**	**Total Social Benefits****	**Public Costs**	**Private Costs**	**Total Social Costs****	**Social B/C Ratio**	**Net Societal Benefits (Billions $2008)**
2020	1.1	0.2	0.4	1.7	0.09	0.61	0.7		
2035	4.3	1.0	1.5	6.7	0.21	1.36	1.6		
2055	5.4	1.2	2.1	8.7	0.21	1.36	1.6	5.5	7.1

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

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

Table E.6b. Total Social Benefit/Cost Analysis of Cumulative Public Investments in ISS (7% Discount Sensitivity)

	Cumulative Social Benefits (Billions $2008)				Cumulative Social Costs (Billions $2008)			Benefit/Cost Analysis	
Year	**Energy Savings**	**Value of Avoided CO_2**	**Value of Avoided Criteria Pollutants**	**Total Social Benefits****	**Public Costs**	**Private Costs**	**Total Social Costs****	**Social B/C Ratio**	**Net Societal Benefits (Billions $2008)**
2020	0.8	0.2	0.3	1.3	0.08	0.51	0.6		
2035	2.5	0.6	0.9	4.0	0.14	0.91	1.1		
2055	2.9	0.7	1.1	4.7	0.14	0.91	1.1	4.4	3.6

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

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

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Appendix F

Background for Analysis of Small Firm Energy Management (SFEM)

Analysis of Energy Savings Potential for Small and Medium-Sized Enterprises (SMEs)

The Department of Energy's Industrial Assessment Center (IAC) database is used to estimate the baseline of energy consumption for small- and medium-sized industrial sites (less than $2.5 million in energy consumption per year). These firms are characterized by source of energy (electricity, natural gas, LPG, fuel oil, coal and wood) and state. The IAC database includes information such as the North American Industry Classification System (NAICS) code, energy-efficiency recommendations, and potential energy savings (IAC database, 2010).

Data on the value of shipments, organized by establishment, are used to assess the size of industrial firms for this analysis. These data are collected from the Manufacturing Energy Consumption Survey (MECS) and are compiled by NAICS code (three digits) into four census regions (Northeast, Midwest, West, and South) in order to get an average baseline energy savings. Finally, with updated information on energy costs by state, it is possible to obtain the weighted-energy savings – by type of establishment – for small- and medium-sized industrial firms.

The DOE industrial assessments have an implementation rate of approximately 50%. This study assumed two different rates of penetration of recommended measures (60% and 40%) to obtain a sensitivity analysis to calculate the economic results of the implementation of our policies. This could be possible only if each state implements policies in support of the fulfillment of these recommendations by firms, through education, outreach, and financial assistance.

Table F.1. IAC Assessments to Date

Census Division	State	# of Assessments	Actions	Average Potential Payback of Recommended Actions (years)	Implemented Actions	Average Payback of Implemented Actions (years)	Rate (%)
New England	Connecticut	158	1,058	1.3	506	0.9	47.8
	Maine	197	1,575	1.3	761	1	48.3
	Massachusetts	333	2,134	1.5	1,058	1.2	49.6
	New Hampshire	102	755	1.6	347	1.3	46.0
	Rhode Island	43	267	1.5	133	1.1	49.8
	Vermont	29	214	1.2	123	0.9	57.5
Middle Atlantic	New Jersey	265	1,926	1	924	0.8	48.0
	New York	343	2,707	1	1,329	0.7	49.1
	Pennsylvania	376	3,309	1.1	1,530	0.9	46.2
East North Central	Indiana	320	2,632	1.5	1,009	1.4	38.3
	Illinois	749	6,748	1.3	2,473	1	36.7
	Michigan	409	2,809	1.3	1,138	1	40.5
	Ohio	890	6,309	1.1	3,133	1	49.7
	Wisconsin	297	2,305	1.1	892	1	38.7
West North Central	Iowa	331	2,708	1.1	1,355	1	50.0
	Kansas	378	3,162	1.1	1,507	0.9	47.7
	Minnesota	213	1,523	1.1	768	1	50.4
	Missouri	497	3,904	1.1	2,158	1.2	55.3
	Nebraska	108	917	1.2	460	1.1	50.2
	North Dakota	9	61	1.9	26	1.8	42.6
	South Dakota	40	270	1.6	123	1.3	45.6
South Atlantic	Delaware	47	393	1.3	129	0.8	32.8
	Florida	585	4,609	1.4	1,916	1.1	41.6
	Georgia	669	4,564	1.6	1,984	1.5	43.5
	Maryland	60	493	1	216	0.9	43.8
	North Carolina	514	3,658	1.2	1,795	0.9	49.1
	South Carolina	93	672	1.4	311	1.4	46.3
	Virginia	275	1,850	1.2	819	1.2	44.3
	West Virginia	117	1,225	1.6	661	1.8	54.0
East South Central	Alabama	147	1,105	1.5	460	1.3	41.6
	Kentucky	207	1,318	1.2	507	1	38.5
	Mississippi	325	2,110	1.1	774	0.9	36.7
	Tennessee	495	3,164	1	1,424	0.8	45.0
West South Central	Arkansas	300	2,131	0.9	1,215	0.8	57.0
	Louisiana	268	1,869	0.7	996	0.6	53.3
	Oklahoma	663	4,352	1.4	2,112	1.2	48.5
	Texas	858	6,447	0.8	3,615	0.6	56.1

Census Division	State	# of Assessments	Actions	Average Potential Payback of Recommended Actions (years)	Implemented Actions	Average Payback of Implemented Actions (years)	Rate (%)
Mountain	Arizona	411	3,400	1.6	1,292	1.5	38.0
	Colorado	549	4,247	1.4	2,394	1.1	56.4
	Idaho	30	173	1.7	66	1.1	38.2
	New Mexico	32	232	2	78	1.4	33.6
	Montana	6	44	1.2	18	0.9	40.9
	Utah	106	654	1.4	178	0.8	27.2
	Nevada	132	942	1.1	395	0.9	41.9
	Wyoming	19	148	1.4	77	1.1	52.0
Pacific	Alaska	8	81	0.8	47	0.6	58.0
	California	999	8,168	1.6	3,747	1.5	45.9
	Hawaii	8	61	1.5	37	1.2	60.7
	Oregon	398	2,590	1.5	1,375	1.3	53.1
	Washington	159	973	1.7	458	1.7	47.1

Source: DOE/EERE, 2009

Figure F.1 summarizes the information and process flows used to estimate the industrial potential Energy Savings based on results from IAC assessment. The U.S. South is used as an example of our modeling of the IAC assessments. This region is comprised of three Census division covering 16 States and the District of Columbia as defined by the U.S. Census Bureau.

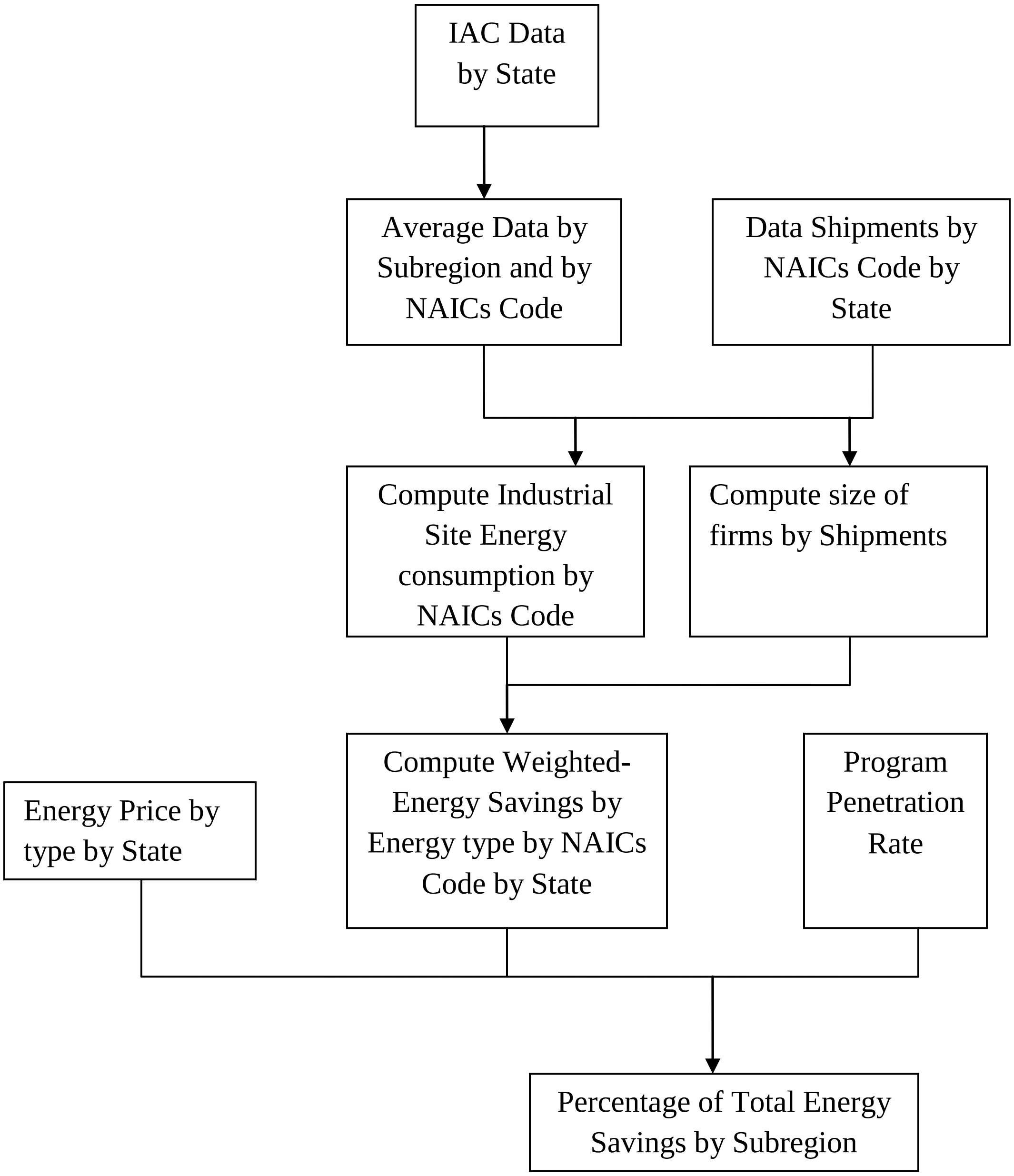

Figure F.1. Information and Process Flow Diagram of IAC Analysis

The projections of industrial assessments in the three Census divisions in the South are expected to have a significant increase during the first several years of the policy implementation. The South Atlantic will need to have 275 assessments in 2013, up from 150 in per year through 2009. The other two divisions require fewer assessments: going from 50 in 2009 in each division to 180 in 2013. The current university partners must provide all of these new assessments, which will require more personnel. Additionally, DOE could include other universities in the region with a capability to conduct these assessments (Figure F.2).

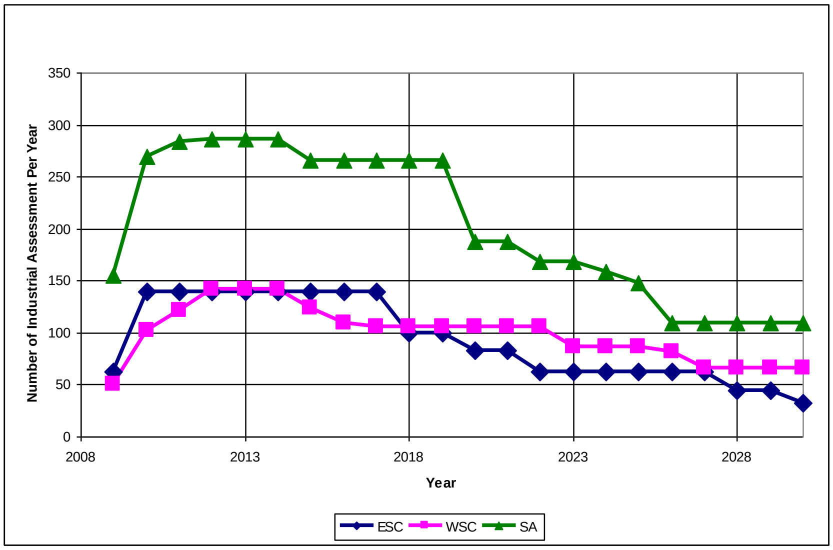

Figure F.2 Projection of IAC Assessments by Census Division in the South Region

The total energy savings expected from the IAC program in the South region is 208 TBtu in 2020. This program, which represents small and medium firms (with 50 to 249 employees), covers 30% of the total value of shipments of the manufacturing industry. The other 70% of shipments is represented by large industries with more than 250 employees (Table F.2).

Table F.2. Total Annual Energy Efficiency Potential Saving for SMEs Manufacturing Sector in 2035 (from 50 to 249 employees)

Census Region	Source Electricity Savings (TBTU)	NG Savings (TBTU)	Total Energy Savings (TBTU)	Electricity Investment Cost ($1000)	NG Investment Cost ($1000)	Total Investment Cost ($1000)
NORTHEAST REGION						
1. New England	12	7	19	233,090	96,909	329,999
2. Middle Atlantic	26	18	44	417,375	244,388	661,763
MIDWEST REGION						
3. East North Central	50	75	125	393,689	593,889	987,578
4. West North Central	19	20	40	169,574	189,942	359,516
SOUTH REGION						
5. South Atlantic	34	26	60			724,069
6. East South Central	36	10	46			422,392
7. West South Central	64	30	94			460,689
WEST REGION						
8. Mountain	8	10	18	63,704	90,299	154,003
9. Pacific	25	38	63	79,695	97,327	177,022
TOTAL	**274**	**234**	**508**	**1,357,000**	**1,313,000**	**4,277,000**

Source: IAC database (2010) and Team Analysis

Table F.3. SFEM from the Industrialists' Perspective (40% Penetration Sensitivity)

	BAU Energy Consumption*	Annual Energy Savings			Cumulative Energy Savings		Annual Private Cost	Cumulative Private Cost
Year	**Trillion Btu**	**Trillion Btu**	**$M (2008)**	**%**	**Trillion Btu**	**$M (2008)**	**$M (2008)**	**$M (2008)**
2011	26,995							
2020	29,785	13.9	136	0.05	83	873	35	352
2035	30,763	25.1	190. 4	0.08	391	3,471	35.2	879
2055	--	--	--	--	630	4,955	--	879

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

** Reference case industrial energy consumption excludes refining. These Business-as-Usual (BAU) estimates are output from the GT-NEMS industrial module. They differ slightly from the *AEO 2010* (EIA, 2010) published estimates, which are produced from a fully integrated NEMS analysis.

*** The percentages refer to the percent of energy use and carbon dioxide emissions from industrial energy use.

****Investments stimulated from the policy occur through 2015. Energy savings accrue only through 2019.

Table F.4. Leveraging of Energy Savings from Cumulative Public Investments in Small Firm Energy Management (40% Penetration Sensitivity)

Year	Public Costs*				Cumulative Energy Savings	Leveraging Ratio*
	Million $2008					
	Annual Administration Cost	Annual Investment Cost	Total Annual Costs	Total Cumulative Costs	TBtus	MMBtu/$
2020	9.60	0	10	96	83	--
2035	9.6	0	9.6	240	391	--
2055	--	--	--	240	630	2.62

*Ratio of cumulative energy savings in MMBtu to cumulative public costs in $2008. Present value of public costs were calculated using a 3% discount rate.

Table F.5. Leveraging of CO_2 Emission Reductions from Cumulative Public Investments in Small Firm Energy Management (40% Penetration Sensitivity)

Year	Public Costs	CO_2 Emission Reductions			Leveraging
	Million $2008	Million Metric Tons CO_2			Ratio*
	Cumulative Costs	Annual MMT Saved	% Annual Emissions	Cumulative MMT Saved	Metric Tons/$
2020	96	0.8	0.05	5	--
2035	240	1.35	0.08	22	--
2055	240	--	--	8.0	0.12

*Ratio of cumulative emission reductions in million metric tons to cumulative public costs in $2008. Present value of the public costs was calculated using a 3% discount rate.

Table F.6. Value of Avoided Damages from Criteria Air Pollutant Emissions (Billion $2008) from Small Firm Energy Management (40% Penetration Sensitivity)

	NO_x		SO_2		PM_{10}**		$PM_{2.5}$	
Year	**Annual**	**Cumulative**	**Annual**	**Cumulative**	**Annual**	**Cumulative**	**Annual**	**Cumulative**
2020	0.00	0.02	0.01	0.08	0.00	0.00	0.00	0.01
2035	0.00	0.05	0.01	0.29	0.00	0.00	0.00	0.03
2055		0.08		0.42		0.00		0.04

*Values are based on the National Research Council report estimating damages from energy production and consumption in the U.S. (NRC, 2010). Excludes avoided pollutant damages from petroleum and coal for industrial heat. Present value of avoided damages was calculated using a 3% discount rate.

**Excludes PM_{10} from the production of industrial heat.

Table F.7. Total Social Benefit/Cost Analysis of from Small Firm Energy Management (40% Penetration Sensitivity)

	Cumulative Social Benefits (Billions $2008)				Cumulative Social Costs (Billions $2008)			Benefit/Cost Analysis	
Year	**Energy Savings**	**Value of Avoided CO_2**	**Value of Avoided Criteria Pollutants**	**Total Social Benefits ****	**Public Costs**	**Private Costs**	**Total Social Costs****	**Social B/C Ratio**	**Net Societal Benefits (Billions $2008)**
2020	0.9	0.1	0.1	1.1	0.1	0.4	0.4		
2035	3.5	0.4	0.4	4.3	0.2	0.9	1.1		
2055	5.0	0.6	0.5	6.1	0.2	0.9	1.1	5.45	5.0

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

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

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Appendix G

Background for Analysis of Tax Lien Financing

Financial barriers can be a significant reason that firms do not select energy-efficient technologies. Selecting these technologies may provide benefits beyond that of the firm, such as reduced air and water pollutants. These financial barriers may be self-imposed or part of the traditional private-sector means of financing. To capture some of these benefits, the public sector can loan funds in such a way that efficient technologies are installed and maintaining fiscal solvency. One such policy option is Property Assessed Clean Energy (PACE) tax lien financing for industry, where firms could opt into special taxation districts to receive funding for efficient technologies. To assess the impact of the policy scenario, we have assumed a certain amount of available gains in efficiency and the number of firms that would participate in PACE financing, were it enabled by Federal legislation and implemented over a number of years (five, 10, and 20) by municipalities, with re-enrollment in the program disabled. That is unlikely to be the case for actual programs, assuming the PACE district still existed when the original lien was removed from the property, and may lead to this analysis being conservative if the other assumptions hold. The results of the analysis are below.

The percentage of energy used by firms of different sizes was derived from the Industrial Assessment Centers (IAC), the Save Energy Now (SEN), and Manufacturers Energy Consumption Survey (MECS) databases (EIA, 2002) to estimate total energy expenditures for small, medium, and large industrial firms (S, M, and L, respectively), labeled S_E, $M_{E,}$ and L_E.

Number of Firms at each size:

S_n = 228,383, responsible for 7% of total industrial energy use

M_n = 93,396, responsible for 26% of total industrial energy use

L_n = 9,576, responsible for 67% of total industrial energy use

Manufacturing spent $94.4B on energy in 2002 (2002 $), according to MECS.

Expenditures were multiplied by the proportion of energy investments that PACE financing options would directly assist, excluding free-riders (which are treated later) of the policy. These factors will be represented by σ, μ, and L, respectively.

The product of these variables equals the cumulative savings for S, M, and L that are currently available in the industrial sector. This cumulative number can then be multiplied by the efficiency savings available for the entire industrial sector as represented in Nadel, et. al. (2004), McKinsey and Company (Granade, et al., 2009), and America's Energy Future (The National Academies, 2009) (a 14-22% range). This provides a sensitivity sizing of the extant market.

Expenditures x available efficiency x percent of upgrades PACE assists = PACE impact. The available efficiency is assumed to be 14% for the lower bound and 22% for the upper bound. Symbolically:

S_E x σ = Σ S
Σ S x 0.14 = low bound for PACE financing in S industry = $0.409 B

" " x 0.22 = upper bound for PACE financing in S industry = $0.644 B

$M_{E\ x}$ μ = Σ M

Σ M x 0.14 = low bound for PACE financing in M industry = $1.22 B

" " x 0.22 = upper bound for PACE financing in M industry = $1.91 B

L_E x L = Σ L
Σ L x 0.14 = low bound for PACE financing in L industry = $0.868 B

" " x 0.22 = upper bound for PACE financing in L industry = $1.36 B

This potential, when summed across all industry sizes, corresponds to ~ 2.7 to 4.2% of annual industrial energy consumption.

Determining the Energy Savings Likely to Utilize PACE Financing

The energy savings from PACE financing depends largely on the opportunity for savings and a favorable view towards the financing option by firms. This analysis continues using the stratification of industry by size to determine what percent of upgrades PACE may assist. Table G.1 provides a summary of this information, explained in greater detail below.

Table G.1. Summary of Industrial Data

	Small	Medium	Large
Number of Firms	228,383	93,396	9,576
Total Consumption (TBtus)	1,582	5,876	15,142
Total Efficiency Potential (TBtus) (14-22%)	221-348	823-1,293	2,120-3,331
IAC/SEN % rejection rate	Unavailable	62.7%	29%
% of recommended upgrades assisted by PACE	44.3 (estimate based on medium firms)	35.4	9.9
% financial		21.3	5
% unsuitable return		10.3	2.1
% payback/other		3.8	2.7
Total Savings (2002 $B) (14-22%)	0.409 – 0.644	1.22 – 1.91	0.877 – 1.38
Total PACE Savings (TBtus) (14-22%)	148 – 232	438 – 688	313 – 492

Estimating 9.9% more implemented recommendations in large firms from PACE upgrade-assistance

Large firm savings are derived from the Save Energy Now (SEN) Assessments, as they relate to PACE financing in the largest industries. Since SEN recommends projects with both long- and short-term paybacks, this may be a fairly representative estimate of PACE financing opportunities in large industries. **29%** of recommendations made by SEN were rejected.

Table G.2 provides a summary of this information.
35% of the rejects were financial in nature. This means 10.15% of recommendations made by SEN were rejected due to financial constraints (F). Another 14.5% of rejected recommendations were rejected due to having an “unsuitable return on investment”, resulting in a total of 4.21% of the total SEN recommendations being unsuitable ROI (U).

0.29 (rejected) x 0.35 (financial) = 0.1015

0.29 (rejected) x 0.145 (unsuitable ROI) = 0.0421

Finally, 8.5% of planned projects had paybacks over four years, which means these projects are less likely to be implemented (P). 32% of all projects are planned, so this represents an additional 2.72% of recommendations.

0.32 (in-planning) x 0.085 (payback>4 yrs) = 0.0272

Industrial ESCOs (Energy Service Companies) are likely to receive some share of the 10.15%, so the total savings of F are not going to be financed through PACE (assuming an increase in industrial ESCO penetration). It is assumed that PACE will generally be a less attractive option to large firms than ESCO contracting for short-term projects, which dominate the SEN recommendations. This is due to ESCOs offering short-term contracts of three to five years (while PACE will use a 20 year lien), and both options being cash flow positive or cash flow neutral. However, for ESCOs to take a significant portion of these savings would require these companies to become much more active in the industrial sector. The ability to self-finance may also limit the impact of PACE in large, well-established firms, although the F projects were already rejected for self-financing. Also, PACE has the issue of being constrained by the size of the bond issued by the municipal government, which may not be large enough to finance major upgrades in large industrial sites. For those reasons, it is assumed that only 50% of F's savings will be financed through PACE liens.

This results in PACE's total share from F being **5%** of total available energy savings from SEN assessments, assuming that industrial ESCOs or ESCO incubators achieve significant penetration.

Of the Unsuitable ROI (U) group, the assumption is that 50% of these recommendations would become attractive investments with the option of PACE financing. As U represented 4.21% of overall available savings, this represents an additional **2.1%** of savings that PACE would finance. As these were unsuitable initially to the firm, it is assumed that ESCOs will not infringe upon these saving opportunities.

All of the available savings from the Extended Payback (P) group are assumed to be implemented through PACE financing, since these projects have paybacks beyond what ESCOs are likely to be interested in financing, and also longer than industry is likely to be willing to enter into a ESCO contract. This provides an additional **2.7%** of total savings that PACE financing can provide.

Thus,
L = 5%(F) + 2.1%(U) + 2.7%(P) = 9.9%

Table G.2. Summary of PACE Assistance for Large Firms

Financial Barrier	**%**
Rejected Recommendations	29%
Financial (F)	10% (35% of Rejects)
Unfavorable ROI (U)	4.2% (14.5% of Rejects)
Extended Payback (P)	2.7%
PACE Potential	**%**
Financial Opportunity After ESCOs	5% (50% of F)
Newly-Attractive ROI	2.1% (50% of U)
Enabled Planned Upgrades	2.7% (100% of P)
Total PACE Potential in Large Firms	**9.9%**

Estimating 35.4% more implemented recommendations in medium firms from PACE upgrade-assistance:

Medium firm assistance is derived from the Industrial Assessment Centers (IAC) database, compiled for the most recent four years of data, so as to reflect industry as it currently exists. However, IAC typically focuses on projects with short payback periods. Since PACE liens can finance projects with longer payback periods and higher up-front investments, these numbers are likely conservative estimates of the total possible efficiency investments assisted by PACE financing. Manufacturing during the study period in the United States has also been in decline, which may have led to decreased efficiency improvement measurements and an underestimate of total available savings if plants were not running at capacity or running at all.

Of 13,488 recommendations made by IAC in this period, 5,031 were implemented. This represents a 37.3% implementation rate. Conversely, this means 62.7% of projects have not been implemented.

From the 2000 Western Region Assessments IAC report, 34% of non-implemented projects were unimplemented due to financial constraints (F).

15% were not implemented due to unknown reasons (O). It was assumed that 40% of this 15% were likely financial in origin, from previous IAC reports, yielding an additional 6% of unimplemented projects that PACE could finance.

33% of unimplemented recommendations were rejected as unsuitable or currently unusable (U) in the 2000 IAC report. Under the same assumptions as in large firms, 50% of these recommendations could be implemented with PACE financing, providing an additional 16.5% of unimplemented projects enabled by PACE.

Thus,

$\mu = 0.627(F + O + U) = 0.627(0.565) = 0.354 = 35.4\%$

Table G.3. Summary of PACE Assistance for Medium Firms

Financial Barrier	**%**
Rejected Recommendations	62.7%
Financial (F)	34% of Rejects
Unknown Reasons (O)	6% of Rejects (after the 60% reduction)
Unsuitable (U)	16.5% of Rejects (after the 50% reduction)
PACE Potential	**%**
Financial Opportunity After ESCOs	21% (62.7% of F)
Newly-Attractive ROI	3.8% (62.7 of O)
Enabled Planned Upgrades	10.35% (62.7%% of U)
Total PACE Potential in Medium Firms	**35.4%**

Estimating 44.3% more implemented recommendations in small firms from PACE upgrade-assistance:

Small firm assistance is derived from μ, since there is little data on small industrial energy users. However, there are almost 230,000 of these firms nationwide, so there are a large number of potential users for PACE financing. It is assumed that ESCOs will not operate in this space, since these firms are often risky investments for ESCO contracting. It is also assumed that small firms face greater financing hurdles than medium-sized firms PACE ameliorates, which is why μ is multiplied by 1.25. Therefore, the savings generated in S will be a result of PACE financing. This factor includes the fact that there are disparate issues in accessing small firms with information, etc.

$1.25\ \mu = \sigma$

Thus,

$1.25 \times 0.354 = 0.4425$

σ = 44.3%

Further Analysis:

Additional analysis was performed to provide a sensitivity for PACE annual adoption rates by municipalities at 5, 10, and 20%. It is assumed that all interested industries will adopt in an adopting municipality in the year the municipality offers PACE financing. In the analysis, the 5% adoption with the 14% available-efficiency estimate was used as the low bound (5% Low), and the 20% adoption with the 22% available-efficiency estimate was the high bound (20% High).

In the following table and chart, “Low” signifies the 14% available-efficiency estimate and “High” signifies the 22% available-efficiency estimate. This projection also assumes 5% equipment degradation over the lifetime of new equipment.

Table G.4. Industrial Energy Consumption Scenarios With PACE

Industrial Energy Consumption Scenarios (Quads)	2020	2035
AEO 2010 Baseline	**29.78**	**30.76**
5% Low	29.25	30.72
5% High	29.39	30.28
10% Low	29.38	30.41
10% High	29.16	30.21
20% Low	29.25	30.45
20% High	29.08	30.76

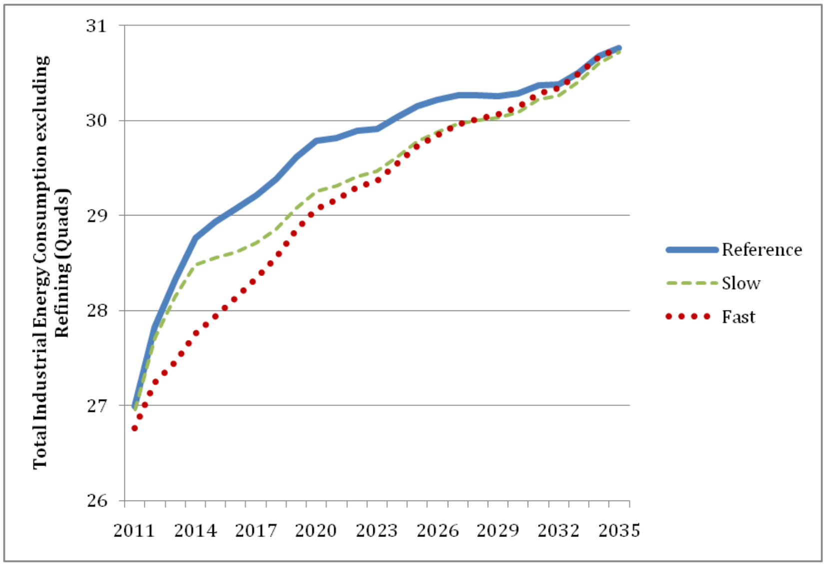

Figure G.1. Total Industrial Energy Consumption (excluding refining)

An economic analysis of energy consumption, savings, and costs (both public and private) was also made. To simplify this analysis, only the lowest (14% available-efficiency and 5% national penetration) and highest (22% available-efficiency and 20% national penetration) scenarios were compared to the baseline. The expenditures compare industrial sector energy expenditures under the different scenarios. The annual savings and costs are calculated with a number of different discount rates for public and private investment (as detailed in Chapter 1) and an assumption of 10% freeriders (whose savings have been eliminated from the total). Investment cost was calculated by proportioning the cost of energy savings from the IAC and SEN databases multiplied by the anticipated savings of PACE financing and applying the appropriate discount rates. Private costs were calculated as 5% of the cost required to finance the cost of the energy savings in a given year, due to the 20 year payback of the PACE policy being modeled. Public costs were the remainder of that cost, which is being financed through the bond issuance, plus an additional 1.5% for administrative costs, which is roughly double the administrative cost currently incurred by operating PACE programs in the country. Negative public cost is shown for 2020 and 2035, meaning industry is repaying more than is being lent through PACE bonds in this year. Table G.5 summarizes this information following this discussion. These projections assume that the program ceases to operate in 2035, so any remaining savings are projected through 2055 (when the equipment installed through PACE would no longer be yielding benefits). In the faster PACE scenario, all the savings have been captured and the debt repaid, so there are no savings beyond 2035.

Table G.5. Economic Summary of PACE and Sensitivity in 2020 and 2035

(Billions 2008$)

Year	2020	2035
Consumption (Reference)	**29.78**	**30.76**
Lowest PACE Adoption Consumption	29.25	30.72
Highest PACE Adoption Consumption	29.08	30.76
Reference Expenditures	185	209
PACE Expenditure Low	182	209
PACE Expenditure High	181	209
PACE Annual Savings Low (10% Freeriders)	3	0.26
PACE Annual Savings High (10% Freeriders)	4	0.00
PACE Investment Cost Low	0.32	0.00
PACE Investment Cost High	0.00	0.00
PACE Cumulative Savings Low (10% Freeriders)	19.2	42.4
PACE Cumulative Savings High (10% Freeriders)	41.2	64.7
Energy Savings – Investment Cost Low	2.65	0.26
Energy Savings – Investment Cost High	3.97	0.00
Private Cost Low	0.47	0.21
Private Cost High	0.76	0.00
Public Cost Low (including Admin)	0.074	-0.21
Public Cost High (including Admin)	-0.75	0.00

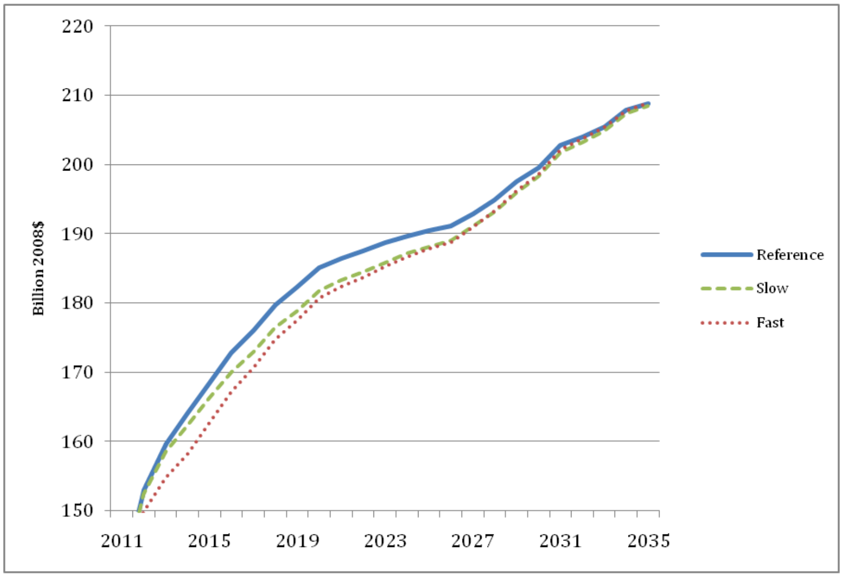

Figure G.2 Industrial Energy Expenditures

Analysis of the Slow PACE Scenario

Table G.6 presents the results of the analysis in terms of energy consumption and energy expenditures from the perspective of industrialists, utilizing a 7% discount rate. For the Slow PACE Policy Scenario, it is estimated that 43 TBtus of energy would be saved in 2035, representing 0.14% of the business-as-usual industrial energy consumption in that year. Over the lifetime of equipment installed through 2035, there would be 8,000 TBtus of energy saved. These energy savings come at a cost of $4.2 billion (2008 $), but result in $22 billion in savings over the lifetime of the installed equipment.

Table G.6. Slow PACE from the Industrialists' Perspective*

Year	BAU Energy Consumption**	Annual Energy Savings			Cumulative Energy Savings***		Annual Private Cost	Cumulative Private Cost
	Trillion Btu	Trillion Btu	$M (2008)	%[†]	Trillion Btu	$M (2008)	$M (2008)	$M (2008)
2011	26,995							
2020	29,785	531	1,617	1.78	3,567	12,974	258	1,882
2035	30,763	43	52	0.14	7,593	21,807	42	4,151
2055	--	--	--	--	8,002	21,970	--	4,213

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

** Reference case industrial energy consumption excludes refining

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

[†] Percent of annual industrial energy consumption

Table G.6 presents the ability of the public sector to leverage energy savings in the industrial sector with the Slow PACE Policy Scenario. Through 2035, public expenditures are estimated at $2.1 billion with a 3% discount rate. This yields an energy leveraging ratio of 3.77 MMBtu/$.

Table G.7. Leveraging of Energy Savings from Cumulative Public Investments in a Slow PACE Scenario

Year	Public Costs				Cumulative Energy Savings	Leveraging Ratio*
	Million $2008				TBtus	MMBtu/$
	Annual Administration Cost	Annual Investment Cost	Total Annual Costs	Total Cumulative Costs		
2020	5.44	-117	-112	6,102	3,567	--
2035	1.58	-105	-103	2,287	7,593	--
2055	--	--	--	2,122	8,002	3.77

*Ratio of cumulative energy savings in MMBtu to cumulative public costs in $2008. Present value of public costs was calculated using a 3% discount rate.

Table G.8 presents the ability of the public sector to leverage carbon dioxide savings in the industrial sector in the Slow PACE Policy Scenario. In 2020, there are CO_2 savings of 25 million metric tons, representing 1.6% of the business-as-usual CO_2 emissions in the industrial sector that year. Over the lifetime of the equipment installed by 2035, 380 million metric tons of CO_2 emissions are avoided, yielding a carbon-dioxide leveraging ratio of 0.18 metric tons per dollar or $5.55/metric tons.

Table G.8. Leveraging of CO_2 Emission Reductions from Cumulative Public Investments in a Slow PACE Scenario

Year	Public Costs	CO_2 Emission Reductions			Leveraging Ratio*
	Million $2008	Million Metric Tons CO_2			
	Cumulative Costs	Annual MMT Saved	% Annual Emissions	Cumulative MMT Saved	Metric Tons/$
2020	6,102	25.2	1.57	171	--
2035	2,287	1.94	0.13	358	--
2055	2,122	--	--	376	0.18

*Ratio of cumulative emission reductions in million metric tons to cumulative public costs in $2008. Present value of public costs was calculated using a 3% discount rate.

Further benefits accrue to society as a whole from increased energy efficiency in the industrial sector and reduced energy consumption from the electricity sector. Estimates of the reduction of criteria pollutant emissions are shown in Table G.9, with SO_2 providing the greatest economic benefit at $11 billion cumulatively through 2055. The avoided costs of NO_x, SO_2, PM_{10}, and $PM_{2.5}$ due to the energy-efficiency measures are shown in Table G.7 using a 3% discount rate.

Table G.9. Value of Avoided Damages from Criteria Pollutant Emissions from 10-Year OBES Adoption Scenario (Billions $2008)*

	NO_x		SO_2		PM_{10}**		$PM_{2.5}$	
	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
2020	0.10	0.72	0.76	5.73	0.00	0.03	0.07	0.54
2035	0.01	1.32	0.04	10.5	0.00	0.06	0.00	1.00
2055		1.37		10.8		0.06		1.03

*Values are based on the National Research Council report estimating damages from energy production and consumption in the U.S. (NRC, 2010). Excludes avoided pollutant damages from petroleum and coal for industrial heat. Present value of avoided damages were calculated using a 3% discount rate.
**Excludes PM_{10} from the production of industrial heat.

Gains in efficiency of industrial processes reduce the emissions of the industrial and electricity sectors. These reductions represent significant societal benefits for the Slow PACE Policy Scenario, as shown in Table G.10. Including the social value of these emissions benefits as well as the energy savings results in a social B/C ratio of 6.03 for this policy option, using a 3% discount rate. The same analysis using a 7% discount rate is shown in Table G.9, providing a sensitivity estimate.

Table G.10. Total Social Benefit/Cost Analysis of a 10-Year OBES Adoption Scenario*

	Cumulative Social Benefits (Billions $2008)				Cumulative Social Costs (Billions $2008)			Benefit/Cost Analysis	
Year	Energy Savings	Value of Avoided CO_2	Value of Avoided Criteria Pollutants	Total Social Benefits **	Public Costs	Private Costs	Total Social Costs**	Social B/C Ratio	Net Societal Benefits (Billions $2008)
2020	16.1	3.7	7.0	26.8	6.1	2.3	8.5		
2035	31.2	7.5	12.8	51.5	2.3	6.5	8.7		
2055	31.7	7.8	13.2	52.7	2.1	6.6	8.7	6.03	44.0

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

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

Table G.11. Total Social Benefit/Cost Analysis of a 10-Year OBES Adoption Scenario (7% Discount Rate Sensitivity)*

	Cumulative Social Benefits (Billions $2008)				Cumulative Social Costs (Billions $2008)			Benefit/Cost Analysis	
Year	Energy Savings	Value of Avoided CO_2	Value of Avoided Criteria Pollutants	Total Social Benefits **	Public Costs	Private Costs	Total Social Costs**	Social B/C Ratio	Net Societal Benefits (Billions $2008)
2020	13.0	3.0	7.0	23.0	5.4	1.9	7.3		
2035	21.8	5.2	12.8	39.8	3.3	4.2	7.5		
2055	22.0	5.3	13.2	40.5	3.3	4.2	7.5	5.41	33.0

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

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

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Appendix H

Energy Efficiency Industrial Motor Rebates

In determining the costs and benefits of the motor rebate program, we used the legislative text from ACES (which is the same as the language in ACELA). Funding amounts for the program authorized in these bills would be:

- $80 million in 2011
- $75 million in 2012
- $70 million in 2013
- $65 million in 2014
- $60 million in 2015
- Total Authorization (subject to annual appropriations) is $350 million

Over the five years, we assumed $10 million of those dollars would go towards program administration. At a cost of $30 per motor horsepower replaced, this program would impact 11.33 million hp of eligible industrial motors (dividing the total investment by the per horsepower investment) at between 25 and 500 hp per motor.

Table H.1 shows the sales ratio of industrial motors by size, based on figures from Nadel et al. (2002). Based on these figures, 61.5% (8/13) of eligible sales for the 11.33 million hp would be for motors at an average size of 33 hp, 20.8% of eligible sales would be for motors at an average size of 87 hp, with the remainder for sales of motors at an average size of 212 hp. Using these figures, we determined that the program would replace 259,000 motors over its lifetime.

Table H.1. Motors Replaced by Size

(Source: Nadel et al., 2002)

HP	Percentage of Sales	Average Size	Estimated Motors Replaced by Size
25 to 50	8%	33	215,000
51 to 125	4%	87	40,000
126-500	1%	212	4,500

The Department of Energy's Industrial Technologies Program (DOE/ITP, 2010), through the MotorMaster+ software, determined the difference in pre-EPACT efficiency for the motors by size and Nadel et al. (2002) indicated the average run times of motors by size. Table H.2 shows this data. These efficiencies and usage hours are critical components of the energy savings formula presented in the chapter.

Table H.2. Motor Savings Efficiencies and Annual Hours of Operation by Size

HP	Estimated Pre-EPACT Efficiency	Estimated Premium Efficiency (EISA Standard)	Average Annual Hours of Operation
25 to 50	89%	93.1%	3568
51 to 125	90%	94.7%	4163
126-500	93%	95.6%	4163

Table H.3 shows the results of the annual motor savings formula for the different efficiencies by size of motor in kilowatt-hours. In addition, the total potential site savings for each motor category, assuming full replacement and no free-ridership are included by motor size. The total value of this column shows 1.6 billion kWh in annual savings.

Table H.3. Total Potential Annual Savings of the Policy by Motor Class

HP	Average kWh Savings per Motor	Estimated Motors Replaced by Size	Total Potential Savings (in million kWh)
25 to 50	4,346	215,000	934
51 to 125	14,899	40,000	596
126-500	19,254	4,500	87
Total			1,617

Table H.4 shows calculations for determining the program costs. The total public costs came from the legislation as noted above. The average public costs are a result of multiplying the average motor size by the $30 rebate value. The difference in replacement cost by size is from EIA (2010). To determine private investment, this analysis subtracted the public investment from the cost differential of replacing instead of rewinding. The total undiscounted private costs of $247 million are proportioned by year in the same ratio as the public costs.

Table H.4. Motors Rebate Program by Size

HP	Difference in Rewind vs. Replace Cost	Average Public Investment Per Motor	Difference Between Cost to Replace and Rebates	Total Private Costs (Without Free Riders) (in million $2008)
25 to 50	$1,920	$990	$930	$160.0
51 to 125	$5,033	$2,610	$2,423	$77.5
126-500	$9,202	$6,360	$2,842	$10.2
Total				$247.7

The savings were distributed by year to determine the results. Both the policy and sensitivity case replace the same numbers of motors. For the first five years of the program, the savings are equal. After five years, however, the savings begin to expire for motors that would have otherwise been replaced under the 5-year acceleration scenario. The same is true after 10 years for the 10-year replacement acceleration. Thus, savings end in 2019 for the policy case and 2024 for the sensitivity scenario. After the program expires, the new motor savings are attributable to the EISA standard.

Table H.5. The Industrial Motor Rebate from the Industrialists' Perspective: 10-Year Acceleration*

Year	BAU Energy Consumption**	Annual Energy Savings***			Cumulative Energy Savings****		Annual Private Cost	Cumulative Private Cost
	Trillion Btu	Trillion Btu	$M (2008)	%	Trillion Btu	$M (2008)	$M (2008)	$M (2008)
2011	24,770							
2015	26,910	13.881	214.221	0.05	41.856	675.996	37.732	234.697
2019	27,200	0	0	0.00	115.742	1,726.895	--	234.697

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

** Reference case industrial energy consumption excludes refining. These Business-as-Usual (BAU) estimates are output from the GT-NEMS industrial module. They differ slightly from the *AEO 2010* (EIA, 2010) published estimates, which are produced from a fully integrated NEMS analysis.

*** The percentages refer to the percent of energy use and carbon dioxide emissions from industrial energy use.

****Investments stimulated from the policy occur through 2015. Energy savings accrue only through 2019.

Table H.6. Leveraging of Energy Savings from Cumulative Public Investments in the IMR Program: 10-Year Acceleration

Year	Public Costs*				Cumulative Energy Savings	Leveraging Ratio*
	Million $2008				TBtus	MMBtu/$
	Annual Administration Cost	Annual Investment Cost	Total Annual Costs	Total Cumulative Costs		
2015	1.83	57.7	59.5	332	41.9	--
2025	0	0	0	332	116	0.35

*Ratio of cumulative energy savings in MMBtu to cumulative public costs in $2008. Present value of public costs was calculated using a 3% discount rate.

Table H.7. Leveraging of CO_2 Emission Reductions from Cumulative Public Investments in the IMR Program: 10-Year Acceleration

Year	Public Costs	CO_2 Emission Reductions			Leveraging
	Million $2008	Million Metric Tons CO_2			Ratio*
	Cumulative Costs	Annual MMT Saved	% Annual Emissions	Cumulative MMT Saved	Metric Tons/$
2015	332	0.76	0.14	2.32	--
2025	332	0	0	6.33	0.02

*Ratio of cumulative emission reductions in million metric tons to cumulative public costs in $2008. Present value of the public costs was calculated using a 3% discount rate.

Table H.8. Value of Avoided Damages from Emissions of Criteria Pollutants from an IMR Program (Billion $2008) : 10-Year Acceleration *

	NO_x		SO_2		PM_{10}**		$PM_{2.5}$	
Year	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
2015	0.002	0.008	0.022	0.070	0.000	0.000	0.002	0.007
2025		0.019		0.177		0.001		0.016

*Values are based on the National Research Council report estimating damages from energy production and consumption in the U.S. (NRC, 2010). Excludes avoided pollutant damages from petroleum and coal for industrial heat. Present value of avoided damages was calculated using a 3% discount rate.

**Excludes PM_{10} from the production of industrial heat.

Table H.9. Total Social Benefit/Cost Analysis of an IMR Policy: 10-Year Acceleration *

	Cumulative Social Benefits (Billions $2008)				Cumulative Social Costs (Billions $2008)			Benefit/Cost Analysis	
Year	Energy Savings	Value of Avoided CO_2	Value of Avoided Criteria Pollutants	Total Social Benefits**	Public Costs	Private Costs	Total Social Costs**	Social B/C Ratio	Net Societal Benefits (Billions $2008)
2035	0.68	0.05	0.08	0.81	0.33	0.23	0.57		
2055	1.73	0.13	0.13	1.99	0.33	0.23	0.57	3.52	1.43

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

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