Regulatory Reform to Promote Clean Energy: The Potential of Output-Based Emissions Standards

Matt Cox and Marilyn Brown Georgia Institute of Technology
Roderick Jackson, Oak Ridge National Laboratory[1]

ABSTRACT

Barriers to industrial energy-efficient technologies hinder their use. A number of EPA analyses and industrial experts have found that the utilization of input-based emissions standards (measured in parts-per-million or pounds/MMBtu) in the Clean Air Act creates a regulatory barrier to the installation and deployment of technologies that emit fewer criteria pollutants and use energy more efficiently. Changing emission management strategies to an output-based emissions standard (measured in tons of pollutant emitted) is a way to ameliorate some of these barriers. Combined heat and power (CHP) is one of the key technologies that would see increased industrial application if the emissions standards were modified. Many states have made this change since the EPA first approved it in 2000, although direction from the Federal government could speed implementation modifications.

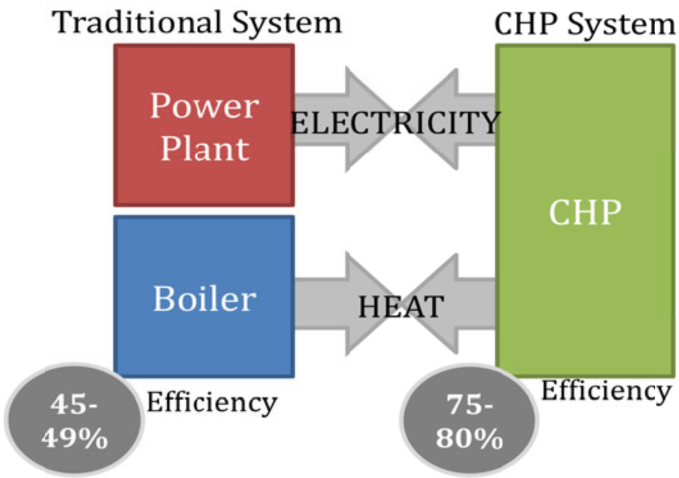
To analyze the national impact of accelerated state adoption of output-based standards on CHP technologies, this paper uses detailed National Energy Modeling System (NEMS) and spreadsheet analysis illustrating two phased-in adoption scenarios for output-based emissions standards in the industrial sector. Benefit/cost metrics are calculated from a private and public perspective, and also a social perspective that considers the criteria and carbon air pollution emissions. These scenarios are compared to the reference case of AEO 2010 and are quite favorable, with a social benefit-cost ratio of 16.0 for a five-year phase-in scenario. In addition, the appropriateness of the Federal role, applicability, technology readiness, and administrative feasibility are discussed.

Overview of Combined Heat and Power

Combined heat and power (CHP) refers to a group of technologies that produce electricity and useful thermal energy in a single integrated system. CHP uses otherwise-wasted energy streams and is more efficient than separate heat and power systems. Shipley et al. 2008 state that separate systems operate at 45% efficiency, but a CHP system can be up to 80% efficiency. The US Environmental Protection Agency estimates are more conservative; the estimates from these two sources are combined in Figure 1.

[1] Support for this research was provided by the U.S. Department of Energy's Office of Policy and International Affairs, Climate Change Policy and Technology Program.

Figure 1. CHP Process Flow Diagram



(Source: modified from http://www1.eere.energy.gov/industry/distributedenergy/chp_basics.html)

While the benefits from CHP are large from both an industrialist's perspective and society as a whole, numerous barriers halt the widespread deployment of such technologies (CCCSTI, 2009). Of particular interest to this paper is a regulatory barrier imposed by the use of input-based emissions standards in the Clean Air Act as applied to CHP installations. Following the policy theories that emphasize the incremental nature of policy change [including the advocacy coalition framework, institutional analysis and development, and punctuated equilibrium theory – see Sabatier (2007) for a description of each], this analysis focuses on a minor adjustment to Clean Air Act implementation by moving to output-based emissions standards.

Input- and Output-Based Emissions Standards

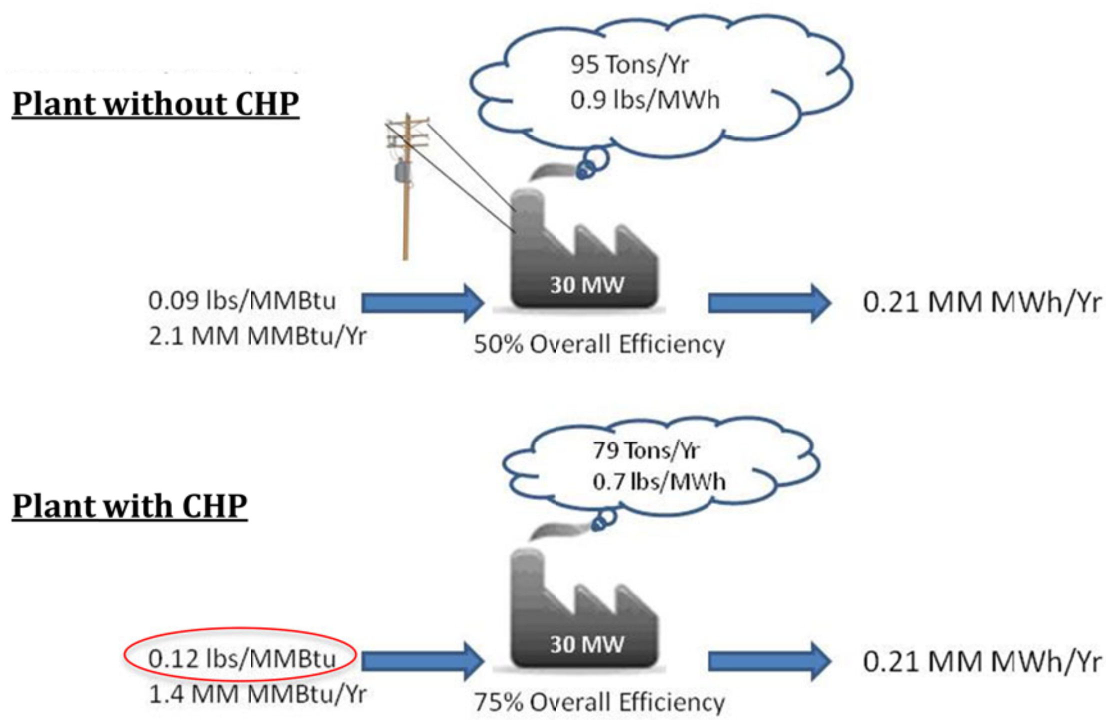
States submit State Implementation Plans to the US EPA to ensure compliance with the Clean Air Act. These regulations are historically input-based, that is, determined on a parts-per-million or MMBtu input-heat basis. These standards generally do not recognize the multiple energy outputs of CHP or account for the efficiency of the technology used at a facility, both critical for properly characterizing the benefits of CHP. With these aspects lacking in input-based emissions standards, many efficiency upgrades are foregone since they may not be compliant.

On the other hand, output-based emissions standards are determined on gross tons per year or pounds per MWh bases. The EPA (2008) recommends that the factory-owner be given credit for avoided emissions that would have been released by separately producing electricity and useful thermal energy. This takes into account the overall emissions reductions from the factory and power plants, and thus more fully captures the benefits of CHP technologies.

The US EPA recognized the benefits that a regulatory change would have, and in 2004, published *Output-Based Regulations: A Handbook for Air Regulators* to assist states in establishing output-based emissions standards. The EPA noted that output-based emissions standards could also reduce regulatory burden on industry and decrease overall emissions. However, since input-based approaches are still compliant with the Clean Air Act, the EPA has limited authority to demand output-based emissions standards. States may be wary to adopt OBES due to the regulatory inertia 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 equally with other means of reducing pollution (EPA, 2004).

Experience with the output-based approach has produced increases in the installation of efficient technologies and net decreases in pollution. This can be partly attributed to the change in regulatory framework: on average, states see 82% more installations of CHP in all sectors during the three years following the regulatory change than during the three years preceding it (ICF International, 2009). Not all of the increase in installations can be attributed to output-based emissions standards due to other policy changes in these same states (like renewable portfolio standards). Figure 2 shows why an output-based emissions standard allows more CHP projects.

Figure 2. Energy and Environmental Benefits from Output-Based Emissions Standards for Industry



(Source: Modified from EPA 2004)

Figure 2 represents the same plant before and after the installation of a CHP system that was enabled by an output-based emission standard for NO_x. In the "before" scenario, there is a CHP opportunity, but it would result in raising the lbs/MMBtu from 0.09 to 0.12. The higher combustion temperatures that achieve greater energy efficiency and result in overall pollution reduction also create more NO_x emissions per fuel input. If the input-based emission standard for NO_x were established at 0.10 lbs/MMBtu, then such a CHP installation would not be compliant with the State Implementation Plan. However, with the regulatory change, a more efficient CHP system that produces less pollution per year can be installed, with the overall emissions decreasing from 95 to 79 tons/year in the Figure 2 example.

Method for Estimating the National Impact of Output-Based Emissions Standards on CHP

Using the national energy modeling system (NEMS). NEMS is the principal model used by the Department of Energy and the Energy Information Administration (EIA) to forecast US energy markets. It has supply-side and demand-side modules as well as exogenous, conversion, and integrating modules. NEMS is used to forecast energy, environmental and economic policy impacts for energy sources and end-use sectors. Reference case projections are published yearly in the *Annual Energy Outlook* (AEO) and reflect the current regulatory state and viewed as a reliable resource in the field. Alternative energy policy scenarios are frequently analyzed using NEMS by many federal agencies and research laboratories. Because we have modified the input assumptions of NEMS, we relabeled it the Georgia Tech – National Energy Modeling System (GT-NEMS).

The Industrial Module contains a number of "levers" to modify, including a section explicitly focused on industrial CHP. Assumptions about the cost of CHP systems, the rate of market penetration (determined by installations), and the efficiency of systems are some of the modifiable aspects for industrial CHP systems. In this analysis, the rate of market penetration and the efficiency of CHP systems are modified within the industrial module.

From the CHP Database, it was determined that in the three years after adopting an output-based emissions standard, 82% more industrial CHP systems were installed than in the three years before in these states. However, this result is limited in scope to twelve states. Also, the states are not adopting output-based emissions standards in the same way; some use distributed generation rules, other adjust allowance allocation and allow trading of pollutants, others still produce pollutant limits. Thus, in choosing a market penetration rate to model, a 20% annual adoption rate was modeled as the principal policy assumption, and a 10% sensitivity was modeled to evaluate a slower pace of adoption; these correspond to 5 years and 10 years for all states to have adopted output-based emissions standards, respectively (referred to as 5- and 10-year adoption). The GT-NEMS reference case uses a 5% market penetration rate of CHP.

A moderate CHP R&D program was also modeled, representing a $10 million dollar annual expenditure over 10 years. This was modeled by increasing the efficiency of CHP systems 0.7% annually over the period without increasing the installation cost. All equipment is anticipated to last 20 years and degrade in performance 5% annually, so equipment installed in 2035 will be taken out of service in 2055 and no longer present any benefit.

Emissions calculations. The GT-NEMS results provide information about the energy savings and the cost of the installations, but not about the public health and environmental benefits that may accrue due to reduced emissions of criteria pollutants and carbon dioxide. To account for these, carbon dioxide intensities of various fuel types used in industry are derived from the EPA (2007) (measured in MMT CO_2 per quad). The AEO 2010 reference case estimates the fuel consumption by source and the energy sources for electricity generation out to 2035. This allows the output from the GT-NEMS modeling of the 5- and 10-year adoption scenarios to be compared to the AEO 2010 reference case.

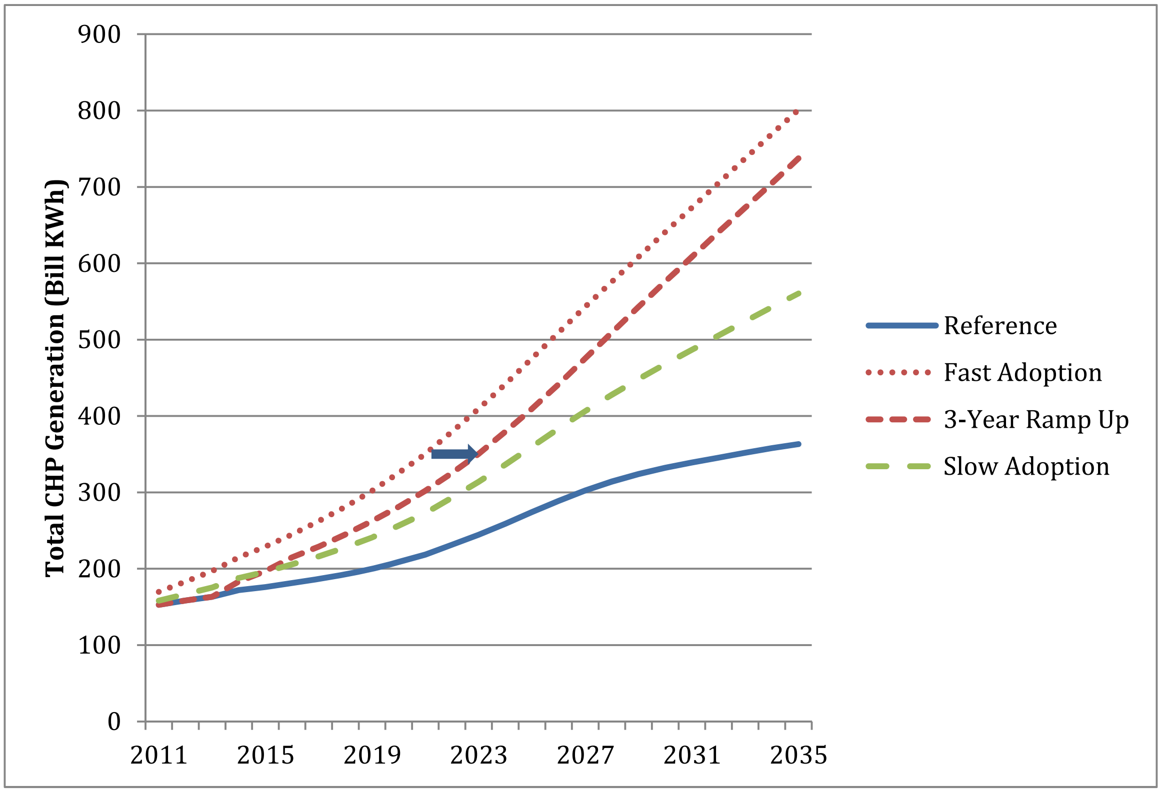
The benefit of reduced CO_2 emissions are estimated by subtracting the emissions in the reference case from the policy scenario and then multiplying by the social cost of carbon, an estimate of the damages caused by a ton of CO_2 in a given year. The social cost of carbon used in this analysis is the central value of the US Government Interagency Working Group of the Social Cost of Carbon (EPA 2010), which ranges from $23/metric ton in 2011 to $47/metric ton in 2050 (in $2008). This analysis projects savings out to 2055, and assumes the social damage per ton from 2050-2055 remains constant.

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 reference case.

Results and Discussion

The AEO 2010 reference case shows roughly a doubling of 2010 CHP generation by 2035. The GT-NEMS analyses of the 10-year and 5-year adoption scenarios respectively show 1.5 to 2 times the amount of CHP generation in 2035 than the reference case (Figure 3). This corresponds with the installation of 27 to 61 GW of CHP beyond the reference case by 2035.

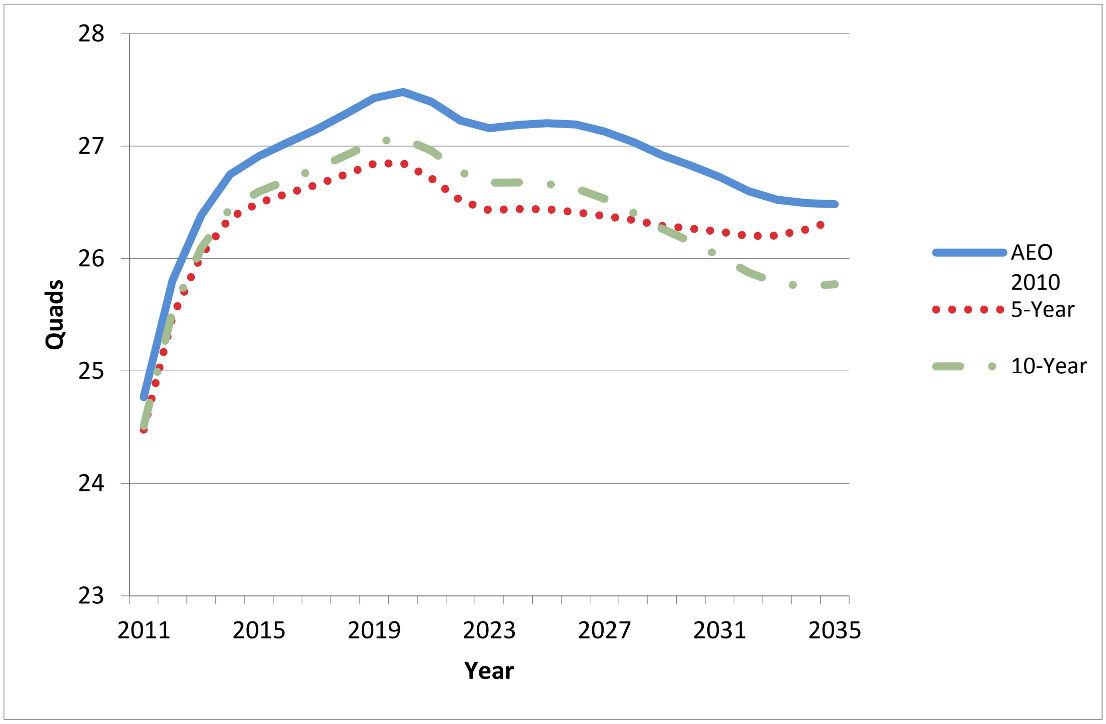
Figure 3. Total Industrial CHP Generation as a Result of Output-Based Emissions Standards



The results presented in Figure 3 may be slowed by the long lead times needed to bring new CHP systems online, 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.

Overall industrial energy consumption declines in both scenarios in comparison to the *AEO 2010* reference case forecast. In the last five years of the 5-year adoption scenario, industrial energy consumption begins to increase due to the value of grid-sales driving an increase in CHP electricity generation (Figure 4). The GT-NEMS analysis shows industries like pulp and paper and bulk chemicals significantly expanding their generation of electricity for grid sales starting between 2022 and 2031, depending on the adoption scenario.

Figure 4. Industrial Energy Consumption



The energy savings are substantial, with 30 to 53 quads saved over the lifetime of the equipment installed through 2035. In the 5-year adoption scenario, the combined savings from the industrial and electricity sectors are 2.4 quads in 2035, but as Figure 4 shows, the bulk of those savings are from the electricity sector. A hefty private-sector investment is needed to general these savings ($23 billion), but it produces $223 billion in energy savings over the modeled lifetime of the equipment, as seen in Table 1.

Table 1: Energy Savings from a 5-Year 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	939	4,850	3.42	6,090	36,000	1,020	9,930
2035	26,480	2,380	8,850	8.98	30,900	139,000	639	22,600
2055	--	--	--	--	53,500	223,000		22,600

*Using a 7% discount rate.
**Reference case industrial energy consumption excludes refining.
†Percent of annual industrial energy consumption.

Since the bulk of CHP systems use natural gas, overall emissions of carbon and criteria pollutants fall as gas displaces more emissions-intensive fossil fuels used on-site or in the electricity sector. This results in social benefits beyond the energy savings that accrue to the industrialist group. The greatest benefit comes from reduced emissions of SO_2, with $51.8 billion to $28 billion in avoided damages using a 3% discount rate in the two adoption scenarios. This represents roughly 88% of the avoided damages from criteria pollutants. The avoided damages from reduced CO_2 emissions outweigh the total avoided damages from criteria pollutants, as summarized in Table 4. These avoided damages total almost $60 billion in the 5-year adoption scenario and $32 billion in the 10-year adoption scenario for criteria pollutants.

Table 2. Value of Avoided Damages from Emissions for the 5-Year Adoption Scenario (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

For policymakers, it may be interesting to understand the ability of the public sector to leverage energy and CO_2 savings in the industrial sector using output-based emissions standards. Through 2035, public expenditures include the R&D program and the administrative costs of training regulators on output-based emissions standards. For the 5-year adoption scenario, this yields an energy leveraging ratio of 595 MMBtu/$ and a carbon dioxide leveraging ratio of 35 $MMTCO_2$/$. The 10-year adoption scenario yields lower energy and carbon dioxide leveraging ratios (333 MMBtu/$ and 19 $MMTCO_2$/$), underscoring the value of accelerating the adoption of OBES. The results for the 5-year adoption scenario are presented in Table 3.

Table 3. Leveraging Energy and CO_2 Savings from Public Investments

Year	Public Costs* (Million $2008) Total Annual Costs	Public Costs* (Million $2008) Total Cumulative Costs	Cumulative Energy Savings (TBtus)	Leveraging Ratio* (MMBtu/$)	Cumulative CO_2 Savings ($MMTCO_2$)	Leveraging Ratio** (Tonnes/$)
2020	7.75	89	6,092	--	345	--
2035	0.012	90	30,900	--	1,790	--
2055	--	90	53,500	595	3,140	34.9

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

The emissions reductions and energy savings that output-based emissions standards could provide represent significant societal benefits. Including the social value of the emissions benefits as well as the energy savings results in a social benefit/cost ratio of 16.0 with a 3% discount rate for the 5-year adoption scenario. Using a 7% discount rate lowers the social benefit/cost ratio to 12.5. For the 10-year adoption scenario, a 3% discount rate yields a social benefit/cost ratio of 15.6, while a 7% discount rate yields a social benefit/cost ratio of 12.7. Net social benefits range from $542 billion in the 5-year adoption scenario with a 3% discount rate to $119 billion in the 10-year adoption scenario with a 7% discount rate. A summary of the 5-year adoption scenarios using a 3% discount rate is provided in Table 4.

Table 4. Total Social Benefit/Cost Analysis of Output-Based Emissions Standards Using a 3% Discount Rate

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

While these potential savings are large, the estimates only include savings from CHP technologies. Output-based emissions standards could enable a number of other equipment upgrades, such as boilers and turbines. This analysis also does not include savings to firms from reduced regulatory burdens or the expansion of CHP systems into the refining industries.

Also, as with all assumptions, there is uncertainty in this analysis. For example, roughly half of US industry is based in the South, which is largely lacking output-based emissions standards. Thus, while the CHP database is a great resource, the impact of an output-based emissions standard on the South cannot be definitively determined from current data. This may lead to fewer or more CHP installations, depending on the type of laws the States choose to implement and the effectiveness of supporting efforts.

Conclusion

Output-based emissions standards have a proven track record of cost-effectively increasing the efficiency of US industrial energy consumption and benefiting society overall. Administratively, this regulatory change is not onerous and the US EPA has written handbooks to assist with implementation and design (EPA 2004, 2008). While states already have the option to make this change, a Federal-level incentive for the adoption of output-based emissions standards may provide the catalyst for accelerating this regulatory modification, enabling economic, energy, and public health gains.

References

Committee on Climate Change Science and Technology Integration (CCCSTI). 2009. *Strategies for the Commercialization and Deployment of Greenhouse Gas Intensity-Reducing Technologies and Practices*. Washington, DC: U.S. Department of Energy, DOE/PI-0007. http://www.climatetechnology.gov/Strategy-Intensity-Reducing-Technologies.pdf

Energy Information Administration (EIA). 2010. *Annual Energy Outlook 2010*. http://www.eia.doe.gov/oiaf/aeo/index.html

ICF International. 2009. "Combined Heat and Power Installation Database." http://www.eea-inc.com/chpdata/index.html

National Research Council. 2010. *Hidden Costs of Energy: Unpriced Consequences of Energy Production and Use.* Washington, DC: The National Academies Press.

Sabatier, Paul. 2007. *Theories of the Policy Process*. Westview Press.

Shipley, Anna, Anne Hampson, Bruce Hedman, Patti Garland, and Paul Bautista. 2008. *Combined Heat and Power: Effective Energy Solutions for a Sustainable Future"* (Oak Ridge, TN: Oak Ridge National Laboratory), ORNL/TM-2008/224.

U.S. Environmental Protection Agency (EPA). 2004. *Output-Based Regulations: A Handbook for Air Regulators*. http://www.epa.gov/chp/documents/obr_final_9105.pdf

U.S. Environmental Protection Agency (EPA). 2007. Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2001. Annex B. Washington, DC: U.S. EPA. http://www.eia.doe.gov/oiaf/1605/coefficients.html

U.S. Environmental Protection Agency (EPA). 2008. *Output-Based Environmental Regulations: An Effective Policy to Support Clean Energy Supply*. http://www.epa.gov/chp/documents/output_based_regs_fs.pdf

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