User's Guide for ACEEE's Energy Efficiency and Pollution Control (EEPC) Calculator

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Abstract

Over the next decade, a host of federal air regulations will impose restrictions on the emissions of multiple pollutants from stationary sources such as power plants and industrial facilities. These air regulations create a demand for low-cost and rapidly deployable emissions reduction measures and energy efficiency proves to be the least-cost resource when compared with new generation. However, quantifying the emissions benefits from energy efficiency is not straightforward and the multi-pollutant and energy savings benefits from efficiency is often overlooked. To help with this issue, American Council for an Energy-Efficient Economy (ACEEE) Energy Efficiency and Pollution Control Calculator (EEPC) is intended to help policymakers, state governments, utility operators, and other stakeholders estimate the multi-pollutant air quality benefits of energy efficiency policies and compare both the benefits and the costs with more traditional approaches to reducing pollution. The results provided by this tool are high-level estimates intended to provide the user with an idea of the magnitude of the costs and the impacts of these options on energy use and pollution.

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Introduction

Over the next decade, a host of federal air regulations will impose restrictions on the emissions of multiple pollutants from stationary sources such as power plants and industrial facilities. Many of these regulations have near-term obligations with overlapping compliance deadlines. The regulations include: mercury restrictions; limitations on the emissions of nitrogen oxides (NOx); limitations on the emissions of sulfur dioxide (SO_2); standards limiting the emissions of particulates through updated air quality standards; and greenhouse gas limitations.[1] These air regulations create a demand for low-cost and rapidly deployable emissions reduction measures.

Compliance with federal air regulations is estimated to cost the power sector as much as $275 billion through 2035, creating a strong incentive to reduce compliance costs (EPRI 2012).[2] Fortunately, most of these regulations provide the electric power sector with an opportunity to reduce the costs of compliance through end-use energy efficiency. Energy efficiency proves to be a least-cost resource when compared with new generation, costing on average 2.5 cents per kilowatt-hour (kWh) (Friedrich et al. 2009). In comparison, new fossil fuel generation sources can range from 6 to 23 cents per kWh (Lazard Ltd. 2012). Energy efficiency reduces energy demand, offsetting the amount of electricity that must be generated by utilities and simultaneously eliminating emissions from multiple regulated air pollutants.

While there are many opportunities for energy efficiency to play a role in federal air regulations, calculating the multiple air quality benefits from energy efficiency can be challenging. Emissions reductions from end-use efficiency are based on the energy saved by the project or end-use efficiency program and the air quality impacts of energy savings are not measured in the same way as pollution control technologies. This is largely because it's not possible to trace electricity back through the electric grid to its exact source. Rather, electricity is generated from multiple sources simultaneously and distributed as needed throughout an entire network of consumers. This process makes it impossible to determine exactly which power plant changed its operation at any given moment due to energy savings by a single consumer.

Energy efficiency reduces all air pollutants at the same time, but the air quality planning process in many states doesn't comprehensively address multiple pollutants simultaneously. Therefore, when evaluating options for reducing pollution, states may not be comprehensively evaluating the full costs and benefits of energy efficiency options.[3] Furthermore, utilities and plant managers are making

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[1] Some examples of regulations are State Implementation Plans (SIP) and Mercury Air Toxics Standards (MATs), and some pending obligations include the revised Cross-State Air Pollution Rule (CSAPR) and 111(d) of the Clean Air Act.
[2] These costs are a higher end estimate. Brattle Group estimates that scrubbers and selective catalytic reduction (SCR) (for 187 GW coal capacity) needed to comply with the Environmental Protection Agency (EPA) mandates would cost between $70-130 billion as well as an additional $30-50 billion if cooling towers are also mandated.
[3] The Regulatory Assistance Project (RAP) has a model process, titled the Integrated Multi-Pollutant Planning for Energy and Air Quality (IMPEAQ) model, which states, local agencies, and EPA can apply to comprehensively and simultaneously reduce all air pollutants: criteria, toxic, and greenhouse gases. For more information see: http://www.raponline.org/document/download/id/6326.

decisions about air emission controls amid significant uncertainties including anticipated future pollution regulations, technology costs and availability, and the price of natural gas.

The American Council for an Energy-Efficient Economy (ACEEE) Energy Efficiency and Pollution Control Calculator (EEPC) is intended to help policymakers, state governments, utility operators, and other stakeholders estimate the multi-pollutant air quality benefits of energy efficiency policies and compare both the benefits and the costs with more traditional approaches to reducing pollution. Whether energy efficiency is a means of direct compliance or a complementary tool to reduce the cost of compliance, energy efficiency can help find the lowest cost approach to cleaning the air.

Purpose and Uses

The purpose of EEPC is to provide policymakers and stakeholders with a rough estimate of some of the costs and benefits of using energy efficiency to meet air quality goals in a selected state. The tool compares the costs and some of the benefits[4] of specific energy efficiency policies with some standard air quality control measures. The results provided by this tool are high-level estimates intended to provide the user with an idea of the magnitude of the costs and the impacts of these options on energy use and pollution. This calculator can be used by state regulators and policymakers to obtain a first-order estimate of what the costs and emissions benefits from energy efficiency could be in a state and to illustrate the magnitude of efficiency's potential. In addition, this tool is meant to help stakeholders make informed decisions about the efficiency opportunities in their states and the ability to use efficiency to meet their air quality goals. The calculator is also meant to assist advocacy organizations that are working to convey the importance of energy efficiency in reducing pollution.

The results provided by this tool are dependent on several assumptions about costs, power plant sizes, efficiency potential, and more as described in the upcoming sections. We have made efforts to use accurate, reasonable, and conservative assumptions to give the user an approximate comparison of the multiple pollution benefits of energy efficiency. However, this tool is a first-order estimate and more accurate estimates of the impacts of these measures can be obtained and should be pursued in states considering implementation of any of the measures or policies addressed in EEPC. The energy efficiency policies included in this tool are:

- Annual Energy Savings Target (standard)—A statewide energy efficiency savings goal of 1% electricity savings per year through 2025;
- Annual Energy Savings Target (lite)—A statewide energy efficiency savings goal of 0.5% electricity savings per year through 2025;
- Building Codes—Adoption of 2010 ASHRAE 90.1 and 2012 International Energy Conservation Codes for commercial and residential sectors (respectively);
- Combined Heat and Power—100 megawatt (MW) of waste heat recovery systems are installed; and

[4] Energy efficiency has many additional benefits not included here. For more information, see slide 12 here: http://www.raponline.org/document/download/id/6326

- Behavior Programs—A residential feedback program saving 2% of residential energy consumption annually from program participants.

These energy efficiency policies are compared with installation of the following emissions control measures on a representative 500 MW coal-fired power plant operating at 85% capacity:

- Selective Catalytic Reduction—An emissions control technology used to reduce emissions of NO_x by 90%;
- Flue-Gas Desulfurization—An emissions control technology used to reduce emissions of SO_2 by 95%;
- Activated Carbon Injection—An emissions control technology used to reduce emissions of mercury by 90%;
- Fuel Switching from Coal to Natural Gas—A retrofit of an existing coal-fired power plant to burn natural gas; and
- Carbon Sequestration—A post-combustion carbon dioxide (CO_2) capture and storage technology.

Limitations of this Tool

The estimated costs for each of these policies and measures are based on a number of assumptions. While the results are provided for individual states, the assumptions are often based on national or regional-level data. For example, estimates of NO_x, SO_2 and CO_2 emission reductions are provided by state for each of the energy efficiency measures. However, these estimates come from the Environmental Protection Agency's Power Plant Emissions Calculator (P-PEC), which uses a capacity factor to estimate emission reductions due to energy savings in each FERC subregion. The assumptions and data sources relied on by this tool are discussed in the Assumptions and Data Sources section of this document.

This tool is not intended to provide a detailed analysis of the costs of different options to control emissions at an individual power plant or the costs and benefits of a policy or measure at a given point in time. More specifically, while estimates are provided at specific points in time (2013, 2018, and 2025), these estimates are average annual estimates. In reality, many policies and measures require an initial "ramp-up" period before the annual benefits are fully realized. Similarly, the benefits of many of the policies and measures included here may extend well beyond the thirteen-year period covered by this tool. Our goal was to make a fair comparison of the costs and benefits of different approaches to reducing emissions from the power sector during a finite time period. Therefore, we have estimated only the pollution and energy impacts that occur in the thirteen-year period covered by this tool (2013-2025). We include the full upfront costs incurred (such as construction of combined heat and power facilities or installation of scrubbers), but any ongoing operation and maintenance costs, including fuel-related costs, are estimated only for the thirteen-year period covered by the tool. It should also be noted that a number of other "real world" factors can impact the costs and benefits associated with these policies and measures. For example, installation of pollution controls on a power plant can take years. In states that adopt building energy codes, enforcement of those codes can vary widely. These are factors that users should consider and account for in order to more accurately evaluate a state's policy options.

We acknowledge that this tool has limitations, but it is our hope that it will help users understand some of the benefits and tradeoffs of different ways of reducing pollution from the power sector. In particular, we wanted to create a resource that will help users assess the multiple air quality benefits of energy efficiency policies and compare both those benefits and the costs with more traditional approaches to reducing pollution.

How to Use the Tool[5]

Step 1. Begin in the tab labeled "Start—Inputs." Click on the cell next to "Select State" at the top of the page, and then choose desired state from drop-down menu.

Step 2. In the cell next to "Select Energy Efficiency Measure," choose up to three energy efficiency policies to evaluate from the drop-down menus (Step 2a – 2c). The results from the selected policies are cumulative and the user may select the same policy more than once.

Step 3. In the cell next to "Select Emissions Control Measure," choose up to three emission control measures to evaluate from the drop-down menus (Step 3a – 3b). The results from the selected policies are cumulative and the user may select the same policy more than once.

Step 4. View the combined results for all policies and measures selected by clicking the tab labeled "Results." The pink summary box at the top of the page contrasts the costs, pollution reductions, and energy savings in 2025 of the selected energy efficiency policies with those of the selected emissions control measures. This box provides a quick assessment of the relative air quality impacts of energy efficiency policies and more traditional approaches to reducing pollution.

The "Results" tab also includes blue and green tables that expand on the summary box by detailing the costs, pollution reductions, and energy savings for the selected efficiency policies and pollution control measures in the years 2013, 2018, and 2025.

Step 5. View the detailed results for each of the selected energy efficiency policies by selecting the tab labeled "Detailed EE Results." This tab breaks out the total cost, cost per kilowatt-hour, and energy savings for each of the selected efficiency policies. In addition, the dollars per ton costs of selected options are included here for energy efficiency policies and emission control measures.

Assumptions and Data Sources

This section outlines the assumptions and data sources used to develop this tool. The section begins by discussing the efficiency policies and then addresses the emissions control measures. We have attempted to be clear and transparent with our approach, but if users have questions about the assumptions or data sources used in the tool or they would like to see the full spreadsheet and calculations, they should contact Sara Hayes at shayes@aceee.org or Rachel Young at ryoung@aceee.org.

[5] Instructions for using the EEPC can also be found in the "Introduction" tab of the spreadsheet.

EFFICIENCY POLICIES

The assumptions and data sources relied on for the energy savings and costs estimates of the energy efficiency policies are described for each policy below. The method for estimating emissions reductions for energy efficiency policies is derived primarily from the approach used in a tool developed by U.S. Environmental Protection Agency (EPA) called the Power Plant Emissions Calculator (P-PEC). Sources used to calculate air emission reductions from energy efficiency, including P-PEC, are addressed first rather than repeated in the discussion of each policy. All dollars are reported in 2012$.

Emission Reductions from Energy Efficiency

Emission reductions for all energy efficiency policies for NO_x, SO_2 and CO_2 rely on the same methodology as used in P-PEC. P-PEC calculations are based on data from EPA's Emissions and Generation Resource Integrated Database (eGRID), which contains detailed information on capacity factors, location, generation, and emissions for almost all power plants in the United States (EPA 2012b). P-PEC uses data from eGRID 2012, the most recent year for which eGRID data is available (EPA 2012c).[6] P-PEC relies on the assumption that a reduction in demand is most likely to reduce generation by power plants with the lowest capacity factors.[7] An estimate of how much a particular plant's generation can be displaced by energy efficiency, a "percent displaceable" figure, is calculated based on a plant's capacity factor. For example, if a plant's capacity factor is less than 0.2, it is assumed that the plant is very likely to be among the first to reduce generation when demand decreases, so it is given a "percent displaceable" value of 100%. Plants with capacity factors greater than 0.8 are considered to be "base load" plants and very unlikely to reduce generation, so they are assigned a "percent displaceable" value of 0%. P-PEC assumes a linear relationship to assign "percent displaceable" values to all power plants with capacity factors that lie between 0.2 and 0.8.

Annual energy savings estimates from the EEPC serve as inputs to P-PEC, which then estimates emissions savings for NO_x, SO_2, and CO_2 in the eGRID subregion where the state is located. These estimates are provided in the "Results" tab of the EEPC. Additional detail is available in EPA's P-PEC Draft User Manual (EPA 2012b).

P-PEC does not estimate the emissions reductions for mercury and a similar tool is not currently available. In order to estimate the impact of energy efficiency measures on mercury emissions, we applied a statewide emission rate for mercury based on the mercury content of the type of coal primarily used in the selected state. We use data from EPA's Integrated Planning Model (IPM) and the Energy Information Administration (EIA) (described in detail in the discussion of Activated Carbon Injection) to estimate total mercury reductions in pounds based on the amount of energy saved. This statewide emission rate is multiplied by the energy savings of the selected measure(s) to determine the total amount of mercury that would be reduced. The same approach is used to estimate

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[6] eGRID 2012 relies on 2009 data.

[7] The capacity factor is the ratio of the electrical energy produced by a generating unit for the period of time considered to the electrical energy that could have been produced at continuous full power operation during the same period.

the mercury emissions reductions impacts of the Activated Carbon Injection option and other pollution control measure options as applicable.

Annual Energy Savings Targets

POLICY There are two options that may be selected that represent implementation of an Annual Energy Savings Target. The "Standard" option assumes an annual savings target of 1% per year through 2025; while the "Lite" option assumes an annual savings target of 0.5% per year through 2025. These amount to total cumulative savings goals of 13% by 2025 and 6.5% by 2025, respectively. Users may vary these goals by selecting the Annual Energy Savings Target option up to three different times from the drop-down menus in the "Start" tab (e.g., if you select the "Standard" option for Step 2a and the "Lite" option for Step 2b you will be effectively selecting a 1.5% savings target).

Annual savings targets generally consist of a variety of measures, some which are included in this calculator. Statewide annual savings targets can be met through a variety of measures and programs. Some common examples include air sealing insulation for residential and commercial buildings, appliance rebate programs, partnerships with business to reduce energy costs, and upgrades to public buildings and fleets. The annual target option in this calculator assumes that all savings are achieved outside of any additional programs or policies that are selected by the user (e.g., if you select the Annual Energy Savings Target option for Step 2a and then select the Behavior option for Step 2b, the behavior programs will be counted on top of the Annual Energy Savings Target, not as part of it).

Many states have energy savings targets in place. The results of our calculator are estimated independent of these actual goals, but we mention the existence of these policies in the "Notes" that appear to the immediate right of a selected policy, as a reference for the user. For states that have energy savings targets in place, EEPC estimates cost and savings in lieu of any existing savings.

ENERGY SAVINGS State-specific energy savings are extrapolated from current energy consumption by state (EIA 2012a) and a forecasted growth rate is applied (EIA 2012b). Savings reported are an annual average of the total cumulative savings that would be obtained from this policy assuming a 13-year life of energy efficiency measures. This means that the estimates provided by this tool include all costs for all years of the policy (everything is fully paid for by 2025) while the savings reported are an annual average of savings that would be generated by those investments across the life of the measures.

COST The costs of the two options for annual energy savings targets that we model here are based on an average dollar per kilowatt-hour cost of utility-operated energy efficiency programs in 10 states. This data comes from utility filings in state rate cases for efficiency programs in 2009-2011 and the average first-year cost used here is $0.22.[8] This is consistent with past ACEEE research on the costs of energy efficiency measures incurred by utilities or other program administrators (i.e., costs do not include additional customer costs for efficiency measures) (Friedrich et al. 2009). Costs assume the policies operate for thirteen years and all measures implemented in those years are paid for by the end of

[8] This includes costs to utilities only. Program participants may incur additional costs; for example, a utility incentive program provides a $100 rebate to a consumer for purchasing a new high-efficiency appliance. The calculation of the cost of the efficiency only includes the cost to the utility (the $100) and not the cost of the appliance.

2025. Costs are assumed to be paid over the number of policy years remaining, so for measures implemented in Year 1 of the policy there is a thirteen-year payback period. Measures implemented in Year 13 of the policy have only a one -year payback period. A 4% weighted average cost of capital[9] is assumed.

Building Codes

POLICY The results provided for the Building Codes option in EEPC are based on state adoption of the residential 2012 International Energy Conservation Code (IECC) and commercial ASHRAE 90.1-2010 codes in 2013.

ENERGY SAVINGS The energy savings estimates used in the tool are provided by the Building Codes Assistance Project (BCAP) Code Savings Estimator (Nils 2012). The BCAP Code Savings Estimator is a tool that estimates energy savings based on adoption of a specified building code scenario relative to one of two possible baselines. The baseline selected for the Calculator reflects a more conservative estimate of energy savings as it factors in likely technological improvements that will occur over time, reducing the energy savings that can be attributed to the model codes. This baseline option is referred to in the BCAP tool as "current practice" case (2010 version). While current practice isn't likely to continue unchanged even in the absence of stronger codes, this comparison allows us to see what benefits can be reaped from codes that might increase construction cost. The current practice baseline assumes that those aspects that are impacted by codes (shell, lighting, etc.) don't improve beyond their 2010 efficiency levels. Other factors that aren't impacted by codes (i.e., residential HVAC, water-consuming appliances, etc.) do change as projected by the *Annual Energy Outlook*, so current practice refers only to those components where codes make a difference.

Current energy use is based on the Residential Energy Consumption Survey (RECS) and the Commercial Building Energy Consumption Survey (CBECS) (EIA 2012d, 2012c). Energy savings due to improved building codes are relative to current energy consumption in similar buildings as reported by RECS and CBECS. Codes savings estimates are the difference in energy consumption between codes currently in place and the new codes; therefore savings estimates do not include achievements resulting from codes already in place. In addition, savings reported are for new construction only. We were unable to obtain cost estimates for code upgrades to existing buildings, so we also excluded the savings from those upgrades. This means that the estimated energy savings and costs provided for the Building Codes option are lower than what they might be if implemented.

The BCAP Code Savings Estimator provides individual state estimates of energy savings that can be achieved if national model building codes are adopted using a range of data sources and assumptions including construction data, energy use intensity, the end-use breakdown by census region in RECS and CBECS (EIA 2012d, 2012c), and state-specific heating degree days and cooling degree days. While the BCAP tool allows users to vary assumptions, we opted to rely on BCAP's default assumptions unless otherwise noted. The savings reported assume building codes are required

[9] The weighted average cost of capital (WACC) is the rate that a company is expected to pay on average to all its security holders to finance its assets.

through 2025 and are an annual average of savings that would be achieved from this policy assuming a 13-year measure life for energy efficiency technologies.

COST Cost estimates of building codes are based on ACEEE data. Estimates of the costs of these policies by state are not readily available, so we relied on a number of resources to extrapolate estimates. For example, to estimate the state-specific costs of residential codes we relied on forecasted new construction (BCAP 2010) and estimates of the added costs of codes in an average house in the same climate region where the state is primarily located (BCAP 2012a).

Cost estimates for commercial buildings are based on forecasted new construction by state (BCAP 2010) multiplied by an estimate of the additional cost per square foot of constructing a new building to code. This $2.00 per square foot figure is an average of the additional costs of high-efficiency buildings for a number of different building types (NBI 2012). Unfortunately, these cost estimates are not readily available by building type or relative to current code so we used this rough estimate for all buildings and all states. These costs reflect upgrades for new buildings that are more stringent than the model codes and are therefore likely at the high end of potential costs.

Combined Heat and Power

POLICY The Combined Heat and Power (CHP) policy option represents construction and operation of 100 MW of waste heat recovery facilities[10] in the selected state. If you believe your state has more potential, you may select the CHP policy multiple times (e.g., selecting CHP for Step 2a and 2b will estimate costs and benefits for 200 MW of waste heat recovery in the results).

ENERGY SAVINGS Energy saving estimates for the CHP option represent installation of 100 MW of waste heat recovery facilities operating 7,500 hours per year and are reported as average annual estimates (EPA CHP 2012).

COST The costs of this policy include upfront capital of $3,000,000 per MW and operation and maintenance costs of $12.50 per MWh (EPA CHP 2012). The total costs to install CHP systems include the costs associated with the waste heat recovery equipment (boiler or evaporator), the power generation equipment, power conditioning, and interconnection equipment. It also includes the soft costs associated with designing, permitting, and constructing the system. Costs represent a range of project sizes (<400 kW to > 5 MW) and site complexity. The operation and maintenance (O&M) costs are based on the middle of a range of possible costs from $0.005 to $0.020/kWh (EPA CHP 2012). There are no fuel costs for true waste heat to power projects (i.e., no supplemental fuel use). These costs assume a thirteen-year payoff with a weighted average capital cost of 4%, but these types of facilities typically operate for more than thirteen years. This means that the cost estimates included here include all upfront capital costs, but not all of the benefits this policy is likely to produce.

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[10] Waste heat recovery systems are a subset of CHP technologies. The calculation of savings and costs for other types of CHP technologies would be different. For example, some CHP technologies include onsite power generators that require additional fuel and produce a surplus of electricity that can be sold back to the electric grid. A waste heat recovery unit uses wasted heat to produce electricity. We make no assumptions about where the electricity is used, i.e., transmission and distribution losses (and savings) are not calculated.

Behavior Program

POLICY The Behavior Program option models an enhanced billing program that provides residential customers with additional energy usage data as an addendum to their monthly utility bills, often referred to as a "residential feedback program."

ENERGY SAVINGS Estimated savings assume 80% of residential customers participate in the program and achieve 2% annual savings for the first 6 years of the program. These savings are calculated as a percentage of current forecasted consumption by state, using the same methodology that was used to estimate the baseline for the Annual Savings Target options (EIA 2012a, 2012b). Both the savings and costs are listed in the results as average annual amounts spread over a thirteen-year period. For example, if a residential feedback program saves 100 MWh per year for six years, the calculator will list those savings as 600 MWh ÷ 13 years, or 46.2 MWh per year. Although we recognize that this is not an accurate representation of how savings will actually occur, it allows us to contrast this type of program with other efficiency programs and pollution control measures, based on the constraints of the P-PEC model.

Further, this is likely a conservative estimate of total savings as the effects of residential feedback programs may continue beyond six years due to persistence of changed behavior beyond the end of the program target. A larger savings estimate has not been used here because experience with these programs is generally limited to fewer than six years, and so there is little data we can use to reliably estimate the level of savings that will occur in later years of the program.

COST The dollar per kilowatt-hour cost of such a program was provided by Opower based on an average of the programs they have operated (Opower 2012).

EMISSION CONTROL MEASURES

Below is a description of the assumptions that went into the emissions savings and cost calculations for the pollution control measures. These measures are the most common kinds of controls that utilities use to comply with air regulations. In addition, we selected fuel switching as a control option since many power plants are likely to use natural gas instead of coal due to the current low price points and the lower emissions rates. The results for all of these options are based on a 500 MW coal-fired power plant operating at 85% capacity. The results from the selected policies are cumulative and the user may select the same policy more than once. If a user selects multiple controls, the controls are thought to be applied to multiple power plants, not the same one (e.g., if a user selects Selective Catalytic Reduction for Step 3a and Flue-Gas Desulfurization for Step 3b, the total affected power plants would be two 500 MW plants, or 1000 MW of power plants).

Selective Catalytic Reduction

TECHNOLOGY The Selective Catalytic Reduction option represents NOx reduction in an SCR system that takes place by injecting ammonia (NH_3) vapor into the flue gas stream where the NOx is reduced to nitrogen (N_2) and water (H_2O) abetted by passing over a catalyst bed typically containing titanium, vanadium oxides, molybdenum, and/or tungsten.

Cost Capital costs for this technology are $197 per kW (2012$); fixed operating and maintenance costs are $0.87 per kwh (2012$); and variable operating and maintenance costs are $0.001373 ($1.373 mills) per kWh (2012$) (EPA 2012a). The technology is assumed to reduce emissions of NO_x by 90%.

Capital investments are repaid over a 13-year period. A weighted average capital cost of 4% is applied.

Emissions savings The results for this option are based on a power plant burning bituminous coal in the FERC subregion where the state is located. These reductions are calculated using the average emissions rate of coal-fired power plants with greater than 100 MW capacity and an emissions rate of at least 0.15 lb per MMBtu operating in the FERC subregion where the selected state is primarily located. The emissions and costs reported reflect a 0.56% capacity penalty incurred by installation of the SCR technology.

Flue-Gas Desulfurization (FGD)

Technology The technology is assumed to remove 95% of SO_2 emissions, which is deducted from the average per megawatt emissions rate of coal-fired power plants greater than 100 MW and with an emissions rate greater than 0.60 lb/MMBtu operating in the FERC subregion where the selected state is primarily located. Mercury co-benefits are assumed to be 58% removal of mercury from inlet mercury concentrations. Inlet mercury concentrations come from the process described below for the Activated Carbon Injection option.

Cost Capital costs for this technology are $538 per kW (2012$); fixed operation and maintenance costs are $8.68 per kW-y (2012$); and variable operation and maintenance costs are 1.996 mills (2012$) (EPA 2012). The option assumes limestone forced oxidation, a "wet" technology, because removal efficiency of the alternative (lime spray dryer) varies considerably depending on the sulfur content of the coal.

The emissions and costs reported reflect a 1.67% capacity penalty incurred by installation of the flue-gas desulfurization technology.

Capital investments are repaid over a 13-year period. A weighted average capital cost of 4% is applied.

Activated Carbon Injection

Technology Installation of activated carbon injection (ACI) requires installation of a new fabric filter or "baghouse" to control particulates. The ACI technology is assumed to remove 90% of mercury emissions (EPA 2011a).

Cost The capital cost of installing this option is assumed to be $176 per kW; fixed operating and maintenance costs are assumed to be $0.67 per kW-y; and variable operating and maintenance costs are $0.0054 (0.54 mills) per kWh (EPA 2011a).[11] There is a heat rate penalty of 0.65%. A weighted average capital cost of 4% is applied.

[11] No adjustment for inflation was made to these numbers as the original source does not report the year of dollars.

EMISSIONS SAVINGS In order to calculate the emissions reductions of mercury, we had to first estimate the emissions at an uncontrolled coal-fired power plant. This data is not readily available. Mercury emissions at an uncontrolled plant are heavily dependent on the mercury content of the coal burned at the plant. We estimated the mercury content of coal that is likely to be used in each state by first identifying the state or region providing the largest amount of coal to each state (the "primary exporter") (EIA 2012a). Once the primary exporter was identified, a mercury content was assigned to the coal from that region using EPA data (EPA 2012). For example, Wyoming was identified as the primary exporter to Wisconsin, therefore the mercury content used to estimate emissions from coal burned in Wisconsin is an estimated midpoint from the range of mercury contents of subbituminous coal found in Wyoming. The mercury content of coal, even from the same location, is not uniform and states often import coal from multiple locations. Given this great degree of uncertainty we assigned broad estimates of 5, 10, or 15 pounds of mercury per trillion Btu of coal. Almost every state, including those with no data, was assigned a "5." Exceptions occur for certain coals that generally have higher contents including those from northern West Virginia, Mississippi, and Ohio. The states using primarily this coal and assigned a "10" include Connecticut, Mississippi, Ohio, and West Virginia. Coal from Pennsylvania was assigned "15" and only the states of New Hampshire and Pennsylvania use primarily coal from Pennsylvania. This approach is only an estimate based on limited data and interested parties wishing to understand the emissions and impacts of mercury in coal should pursue more detailed analyses. Once we have an emissions rate of coal, we are able to extrapolate the change in emissions at a straw 500 MW power plant operating at 85% capacity. Capital investments are repaid over a 13-year period.

Fuel Switching from Coal to Natural Gas

TECHNOLOGY The fuel switching option reflects a scenario where a coal-fired plant is retrofit to burn natural gas.[12]

COST The costs of this retrofit include:

- Capital costs estimated at $128.70 per kW.[13]
- Variable costs of operating coal plant with no mercury, SO_2, or NO_x controls of approximately $0.001766 (1.766 mills) per kWh ($2012) (EPA 2011b). This is reduced to 75% as the incremental variable operation and maintenance (VOM) costs of operating a coal plant retrofit to gas decrease by 25%.[14]

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[12] These cost assumptions are for conversion of the boiler of a pulverized coal plant to burn natural gas—not the addition of a turbine.

[13] See EPA 2011a, Table 5-11, Cost and Performance Assumption for Coal-to-Gas Retrofits. The incremental cost formula used is: 250*(75/MW)^0.35.

[14] See page 31, EPA 2011.

- Fixed costs of operating a coal plant with no mercury, SO_2, or NO_x controls of approximately \$44.29 per kW per yr (\$2012) (based on mid-range of plants from 20-30 years and 30-40 years old).[15] This is reduced by 33% if the plant is retrofit to burn natural gas.[16]

The cost of constructing new pipeline needed to transport gas to a facility can vary widely depending largely on the location of the facility. In order to provide a reasonable estimate of this, we took the average estimated cost of new pipeline for facilities between 400 and 600 MW in capacity (EPA 2011a).

To estimate the difference in fuel costs when burning natural gas instead of coal, we used an average of the forecasted price of coal (\$2.40 per MMBtu) and natural gas (\$4.90 per MMBtu) (EIA 2012e).

There is a 5% penalty for natural gas consumption due to a reduction in efficiency. This penalty appears as an increase in fuel consumed and increased emissions. Capital investments are repaid over a 13-year period. A weighted average capital cost of 4% is applied.

EMISSIONS SAVINGS Estimated emissions reductions of mercury and SO_2 assume that emissions of both pollutants are eliminated when burning natural gas. Estimated reductions in SO_2 emissions are based on the average emission rate by FERC subregion of coal-fired plants with a capacity greater than 100 MW (EPA 2012c). To estimate mercury emissions from an average 500 MW coal-fired power plant in each state, we used the same method as described under the Activated Carbon Injection option.

NO_x emissions are estimated at 50% of the average emissions of existing coal-fired power plants in the FERC subregion with a capacity greater than 100 MW (EPA 2012c).

To calculate the reductions of CO_2 that would be achieved, we used eGRID to determine the average emissions rate by FERC subregion of CO_2 from coal-fired power plants with a capacity greater than 100 megawatts. In order to compare this with the CO_2 emissions in a power plant retrofit to burn natural gas, we determined the average efficiency by FERC subregion of coal-fired power plants and applied a 5% efficiency penalty (see below) to determine how many Btus of natural gas would be needed to generate the same amount of electricity.[17] There is typically 117 lbs of CO_2 per million Btu of energy for natural gas (EIA 2012f). Using this information, we were able to determine the CO_2 reductions that would occur if a facility were retrofit from coal to natural gas.

Carbon Sequestration

TECHNOLOGY The Carbon Sequestration option represents retrofitting an existing pulverized coal-fired power plant with post-combustion technology to capture emissions of CO_2.

COST The capital cost of this technology is based on an upfront cost of \$2,184 (2012\$) per kW; fixed operating and maintenance costs assume a cost of \$3.32 (2012\$) per kw-y and variable operating and

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[15] See page 12 at http://www.epa.gov/airmarkets/progsregs/epa-ipm/docs/v410/Chapter4.pdf.

[16] See page 31 of IPM Supplemental documentation.

[17] In states where an average emission rate or efficiency by FERC subregion is unavailable, we used a national average.

maintenance costs are estimated at 2.60 mills (2012$) per kWh (EPA 2011c). The cost of transporting the captured CO_2 is $84,270,894 (2012$) annually and storage costs are based on a cost of $10.08 (2012$) per ton (a midpoint selected from a wide range of potential storage costs) (EPA 2011c). Carbon sequestration has a heat rate penalty of 33%, which has been included as increased emissions and fuel costs in the results. Carbon sequestration requires that SO_2 is removed from the flue gas prior to the capture and compression of CO_2. The costs included here assume that FGD technology has already been installed. Users may separately select FGD as an additional control measure to get a more accurate estimate of the costs of carbon sequestration on a facility that doesn't already have FGD installed and no additional investment is needed. Further, increased fuel costs due to the 33% efficiency penalty assume a price of coal of $2.40 per MMBtu (EIA 2012e). Capital investments are repaid over a 13-year period. A weighted average capital cost of 4% is applied.

EMISSIONS SAVINGS Emissions savings are based on the average CO_2 emissions rate from coal-fired power plants operating in the FERC subregion where the state is located. Calculations reflect a 33% increase in emissions that would be generated by 500 MW of existing capacity due to the increased energy needed to operate the carbon capture technology (EPA 2011c). Estimates reflect a 90% reduction of these total estimated emissions (EPA 2011c).

Conclusions and Next Steps

ACEEE intends to leverage the results of the EEPC Calculator to develop easy-to-understand resources for state policymakers and stakeholders. This research and discussions with the experts in the field have helped us identify several areas where additional research and work products will be helpful to states. In 2013 and 2014, ACEEE will develop resources and materials to help states understand and assess their options for using energy efficiency to meet their air quality goals. ACEEE will also provide specific technical assistance to states interested in pursuing their opportunities to employ energy efficiency.

For more information regarding the Energy Efficiency and Pollution Control Calculator or any of the other related projects stated above, see our dedicated web page at http://aceee.org/123-solutions. To speak to us directly or provide feedback on the Calculator, please contact:

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Rachel Young at ryoung@aceee.org, 202-507-4023.

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