Co-benefits
Experience and lessons from the US electric sector

Co-bénéfices
Expérience et enseignements tirés du secteur électrique des États-Unis

Bruce BIEWALD*, Lucy JOHNSTON*, Jeremy FISHER*

Abstract

Past experience in the US indicates that a focus on reducing individual types of pollutants can result in success for the targeted pollutants, yet allow continued growth in other pollutants, most notably CO_2. The electric industry has demonstrated the capacity to make large investments in controlling emissions, as well as in developing new generation sources. In the absence of multi-pollutant regulations, investments in specific emissions controls may subsequently prove non-useful as new pollutants are regulated. The most effective approach to achieving co-benefits is to anticipate future regulatory constraints and invest in non-polluting technologies and energy efficiency. However, estimating the emissions avoided due to energy efficiency is not straightforward. In the United States, "displaced" emissions are spatially and temporally non-uniform due to the distribution of energy production and energy market dynamics. Emissions data exist to understand this variation and may be used to target programs. Analysis of program results reveals that energy efficiency programs exhibit economies of scale. The case of Southwest Connecticut provides an example of a co-benefits approach to addressing conflicting results of several policies. Efficiency programs have a high potential to reduce both carbon emissions as well as other pollutants. Significant consideration must be given to techniques to account for the emissions benefits of these programs.

Introduction

In the past decade, European nations have focused on reducing greenhouse gas emissions. It has proven challenging to design greenhouse gas reduction programs that, at a minimum, do no harm *via* other pollutants, and it appears even more difficult to achieve multi-pollutant reductions. In the United States there is a converse problem: in the past, the regulatory focus has been on other pollutants, such as SO_2 and NO_x, with no explicit regulation of CO_2. Therefore, while there have been significant improvements in air quality, greenhouse gasses have not been abated and cost-effective opportunities such as energy efficiency investments, that would simultaneously reduce multiple pollutants, have been missed. In this paper, we touch on research exploring the potential for efficiency to achieve multi-pollutant reductions economically, a method for estimating emissions reductions from efficiency and renewable energy, and a case study in the Northeast United States. The term "co-benefits", as we use it here, refers to achieving secondary benefits from a program or regulation with a different primary target.

The US electric power sector
A major player in CO_2 emissions

The electric power plant fleet in the United States is a tremendous source of air pollution. Its CO_2 emissions amount to 2.4 billion metric tons of CO_2 per year, which is about 40 percent of the US total CO_2 emissions, and amounts to about 7 percent of the world's total CO_2 emissions from fossil fuel**. Clearly, any effective approach to address global climate change will require CO_2 emissions reductions from the US electric sector.

* *Synapse Energy Economics – Cambridge – Massachusetts, US – bbiewald@synapse-energy.com*

** *Data for US electric sector and US Total from EIA Emissions of Greenhouse Gases Report 2007, December 2008; Data for World from EIA International Energy Annual 2006, December 2008.*

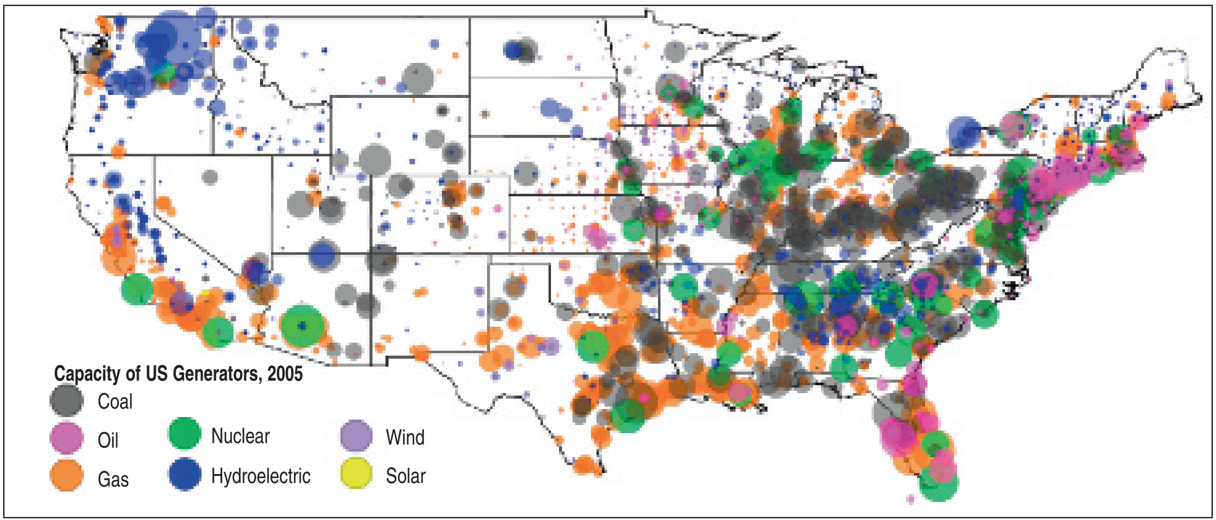

Figure 1.
Map of power plants in the United States.
(Data from US EPA eGRID, 2007)

The power plants in the US are shown in the map in Figure 1, color coded by fuel type, and sized in proportion to annual electricity generation. The coal-fired power plants, depicted in grey, contribute about over 80% of the 2.4 billion metric tons of CO_2 emitted by the entire fleet*. This share of emissions is so large because coal is the most carbon-intensive fossil fuel, and because coal-fired units produce roughly one half of the total electricity generated**. Large concentrations of coal-fired plants are located along the Mississippi and Ohio Rivers, but they are also found in other regions of the country, particularly in the Eastern States.

Renewable generating capacity is relatively small, and vast opportunities for energy efficiency remain untapped. The US Department of Energy's current reference case scenarios for the future, which assume no carbon restrictions, continue past trends and emphasize fossil fuel (a mix of coal and gas) capacity additions to the electric power system***.

1. Emissions regulation – individual success, combined waste?

The US has not yet tackled carbon emissions from the electric sector, but has made major strides in reducing certain types of emissions from the electric power sector. US emissions regulations have focused on reducing emissions that contribute to acid rain and health impacts. While individual states and regions have begun to mandate greenhouse gas reductions, greenhouse gas emissions remain unregulated by the Federal Government. An emissions dataset from 1996 shows significant reductions in SO_2 and NO_x emissions from the power plant fleet as Clean Air Act requirements went into effect. The most notable reductions are in 1995 and 2000, associated with deadlines in the 1990 Clean Air Act Amendments. These trends are shown in Figure 2, along with the CO_2 emissions over time.

The results are clear in the reductions depicted in Figure 2. A large portion of criteria pollutant reductions have been achieved at existing coal-fired power plants by adding emission controls – flue gas desulfurization ("scrubbers") for SO_2 and selective catalytic reduction and front end burner modifications for NO_x. The choice to equip an existing power plant with a control technology represents an investment decision to continue operating the plant. These decisions may have anticipated a cost recovery over a period of years or decades, an assumption which may be rendered invalid once the economic implications of greenhouse gas emissions become clear with the implementation of a greenhouse gas reduction policy.

While many countries which signed the Kyoto protocol have achieved reductions or have at least slowed CO_2 emissions, the US has been on a steady trajectory of increased CO_2 emissions over time. Air quality programs have been effective in reducing SO_2 and NO_x, but lacking a multi-pollutant regulatory approach in the electric sector, the United States has missed an opportunity to anticipate and achieve GHG co-benefits. Had costs of carbon emissions been included in resource decisions over a decade ago, investment decisions may have led to different results. Failure to take a multi-pollutant approach, and the resulting focus on only a subset of pollutants, has likely led to ratepayer-funded investments that will not be useful in a carbon-constrained economy.

** US EIA, Emissions of Greenhouse Gases, Report #: DOE/EIA-0573(2007). Released Date: December 3, 2008. Table 11.*

*** Data for 2007 from US EIA, Electric Power Monthly, released January 15, 2009.*

**** US EIA, Annual Energy Outlook 2009 (AEO2009) reference case Early Release. Released December 17, 2008.*

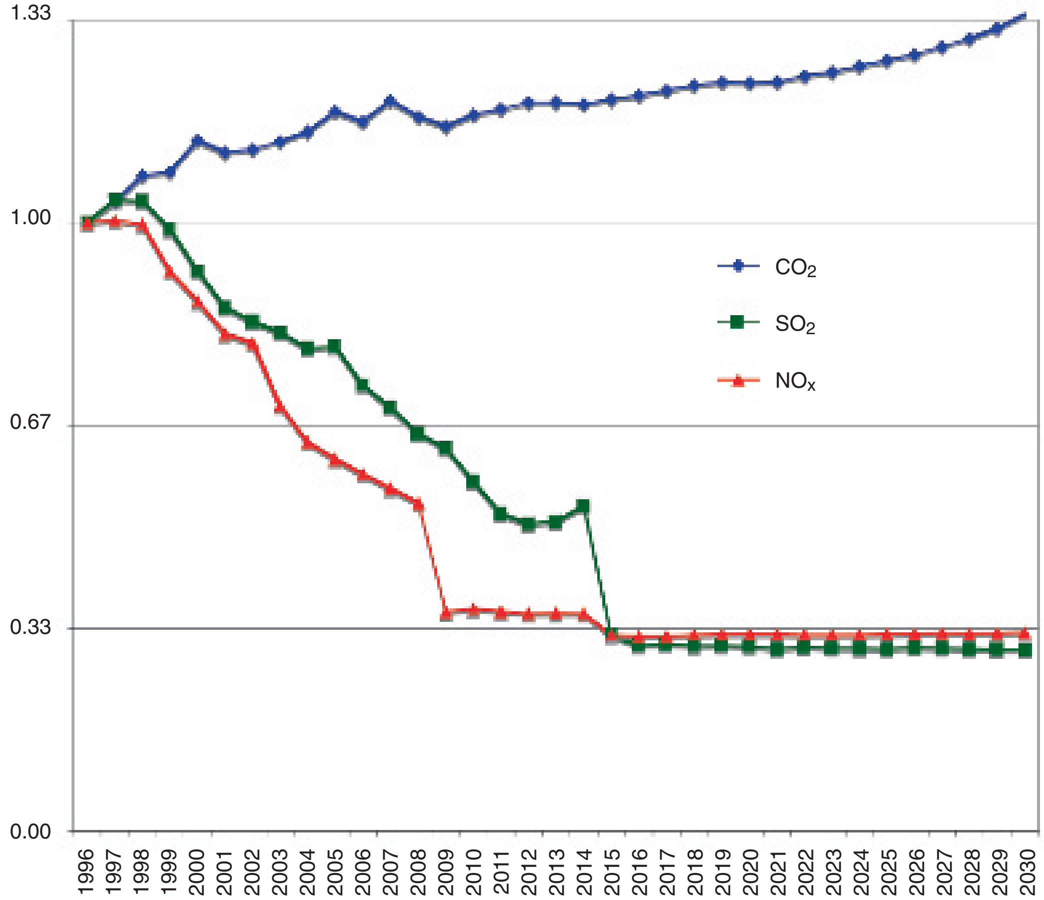

Figure 2.
Electric power sector CO_2, SO_2 and NO_x emissions trends (indexed with 1996 emission levels = 1.0). (Source: US Energy Information Administration, data tables for "Electric power annual 2007" (for actual emissions) and "Annual energy outlook preliminary release 2009" (for projections)).

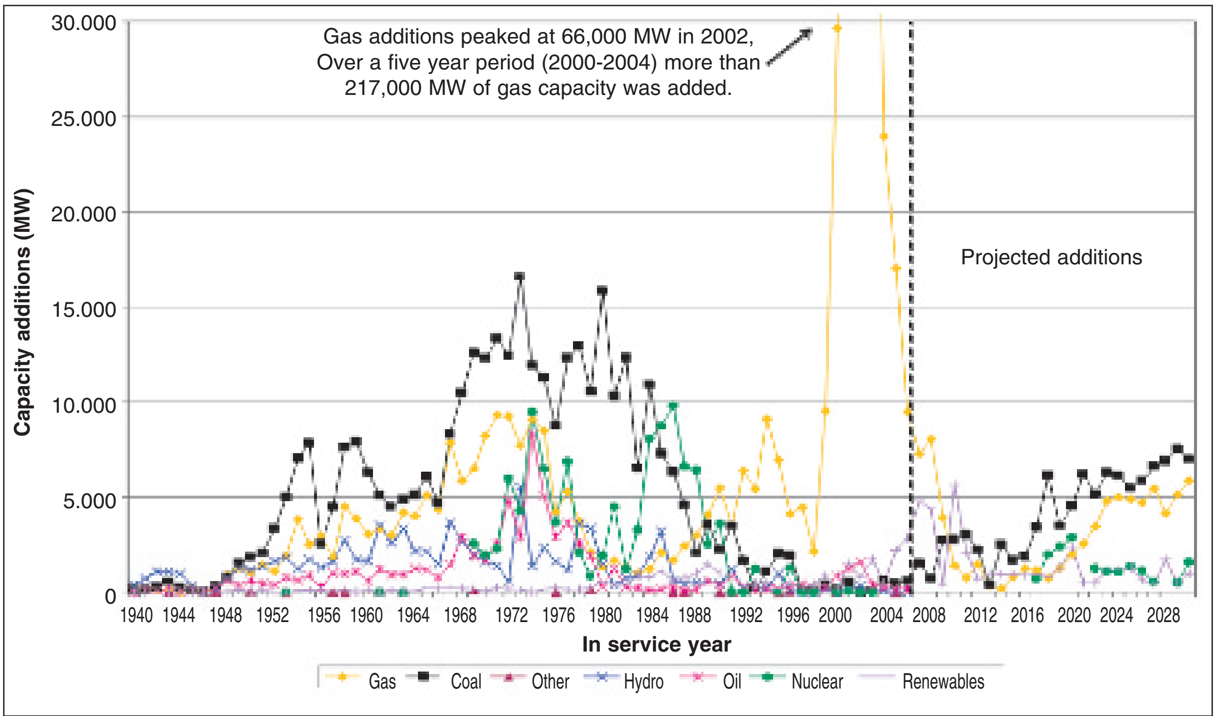

Figure 3.
US generating capacity by vintage and fuel type.

In the absence of a federal carbon limit, CO_2 reductions might be considered a "co-benefit" of policies that are aimed at other objectives. There have been efforts to foster CO_2 emissions reductions through the implementation of air pollutant emission reduction requirements. For example, an emphasis on electrical output-based emissions standards would favor efficient generation, thus resulting in lower emissions for each unit of useful electrical output. The expansion of pollution concerns to include CO_2 is a promising, indeed essential, direction for US energy and environmental policy. However, efficiency at the generator alone will not achieve the targets believed to be necessary to curb global warming, and moving to a carbon constrained economy will pose a significant challenge in the US, which relies on domestic coal for half of electricity generation (50.2% in 2007)*.

2. Generation capacity by vintage

In addition to investment in emission controls, the power sector in the US electric sector has, over the last decade, made considerable investment in new generating capacity. This new capacity is almost entirely gas-fired. Figure 3 shows the additions of new generating capacity by year for the period since 1940. The peak period for new coal units entering service was the 1970s, and so the current fleet of existing coal units has an average age of about 40 years.

Three main points emerge from a review of the existing generating capacity in the US:

- Aging coal plants present a clear and inescapable challenge in a carbon constrained world, yet addressing their CO_2 emissions presents an opportunity to obtain co-benefits in other pollutants.
- The enormous investment in new natural gas (on the order of 200 billion dollars) indicates the magnitude of collective investment that the electric industry has made in the past and can make in the future. It should be noted that not all of these investments were well considered, and numerous companies made poor financial decisions investing in new gas; any new build-out should be shaped by a thoughtful and comprehensive approach.
- Coal continues to be alluring to the US electric industry, as indicated by the point farthest to the right on the chart above for the coal line under "projected additions".

3. Reducing emissions – geography and timing matter

As planners consider the challenge of meeting future energy needs while satisfying increasingly tighter environmental constraints, they should consider a wide range of resource options and the implications of each upon all of the different categories of air emissions, including NO_x, SO_2, CO_2 and other pollutants. One consequence of a focus on maximizing co-benefits is that it quickly becomes apparent that energy efficiency is a particularly effective solution that can achieve reductions across all pollutants. It bears emphasis that estimating avoided emissions is a complex task, since the emissions profile of displaced electricity varies by time and place. Understanding what is displaced on the grid is challenging. Most importantly, the grid is interconnected, so a program in only one state will typically affect generation in a larger region, not just the state (and in some cases may affect the state minimally). Secondarily, the timing of efficiency measures matters: programs targeted towards peak periods will impinge on a very different cohort of generators than programs which reduce demand during off-peak hours. Generation and emissions patterns, both spatial and temporal, lend important insight into potential avoided emissions. It is worthwhile dissecting these patterns to optimize the benefit of avoided electricity generation. In the US emissions from large stationary sources are monitored for compliance with air regulations; these public datasets have yielded a wealth of information on plant emissions and behavior.

Continuous emissions monitoring data is available for each power plant at hourly (and even finer) intervals over the course of each year. Analysis of average and marginal emissions for electrical subregions highlights the challenge of achieving and assessing co-benefits from reducing generation in particular times and places**. In this paper, we show hourly average emissions of NO_x and CO_2 for a selected subset of the regions, shown in the circled area of the map below. For the EPA and this research, each region is considered a semi-autonomous power control area, although there are strong transmission linkages across the regions.

Figures 5 and 6 show regional and temporal variations in hourly average emissions rates for NO_x (lbs/MWh) and CO_2 (tons/MWh), respectively, in 2005. Each horizontal bar shows the average emissions in a particular electric subregion (designated by a four letter acronym) over the course of a year. The bars in the figures correspond to regions progressing east to west down the page. Within each bar hours in the day are on the y-axis; thus the top begins with midnight, progresses through morning, noon (in the middle of the graph), through evening, and ends at 11 pm. The x-axis represents the day of the year, it progresses left to right from January to December. The color indicates the fossil-based emissions rate at any given hour, where blue indicates a lower emissions rate and red indicates a high emissions rate. The bounds of this color graph where chosen to highlight the variations seen in these regions and do not represent an absolute maximum or minimum.

** US EIA, Net Generation by Energy Source, Table 1.1. Released February 13, 2009.*

*** Hausman, Fisher and Biewald;* Analysis of Indirect Emissions Benefits of Wind, Landfill Gas, and Municipal Solid Waste Generation; *report for the US Environmental Protection Agency; Synapse Energy Economics. July 23, 2008. Available at: http://www.synapse-energy.com/Downloads/SynapseReport.2008-07.EPA.EPA-Indirect-Emissions-Benefits.06-087.pdf*

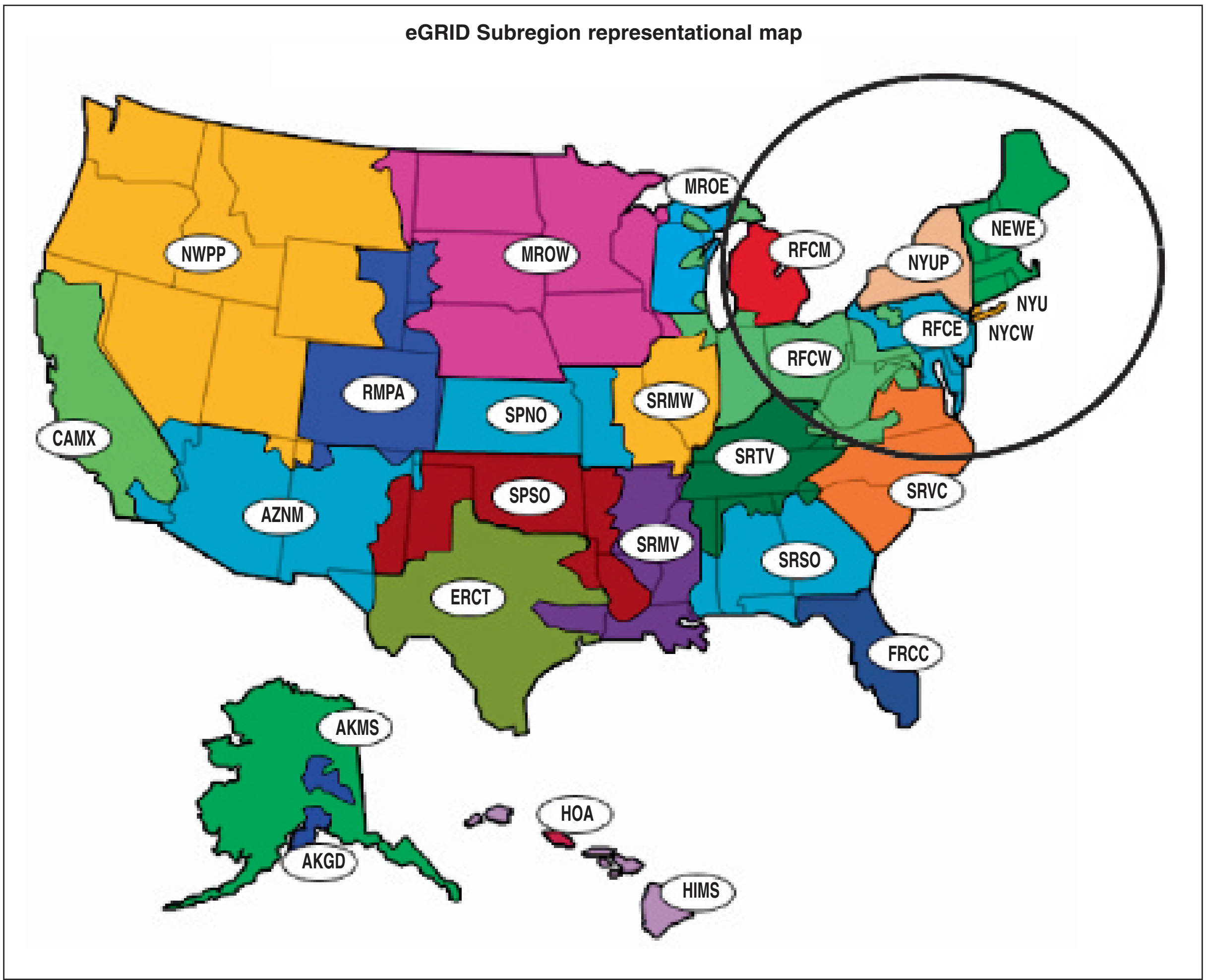

Figure 4.
Map of electric subregions.

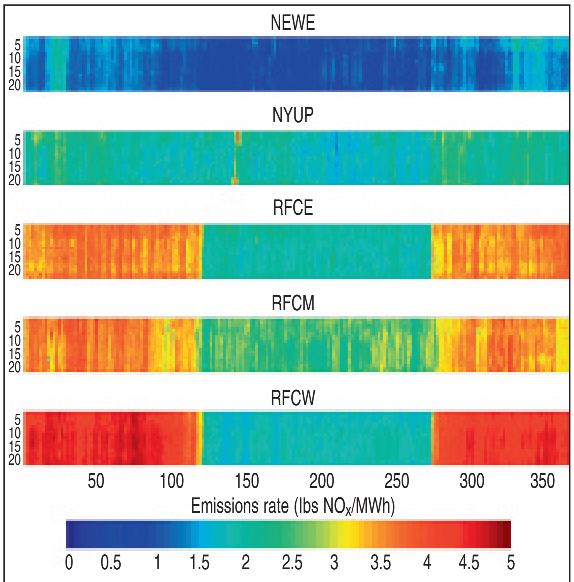

Figure 5.
Hourly average NO_x emissions rates
for five eastern US electric regions, 2005.

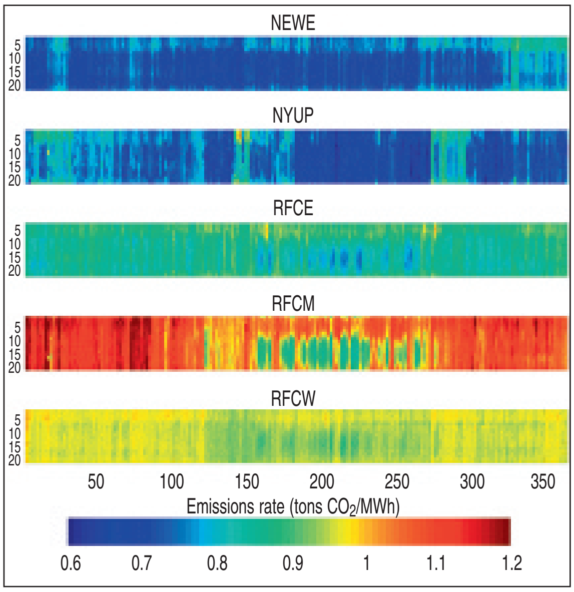

Figure 6.
Hourly average CO_2 emissions rates
for five eastern US electric regions, 2005.

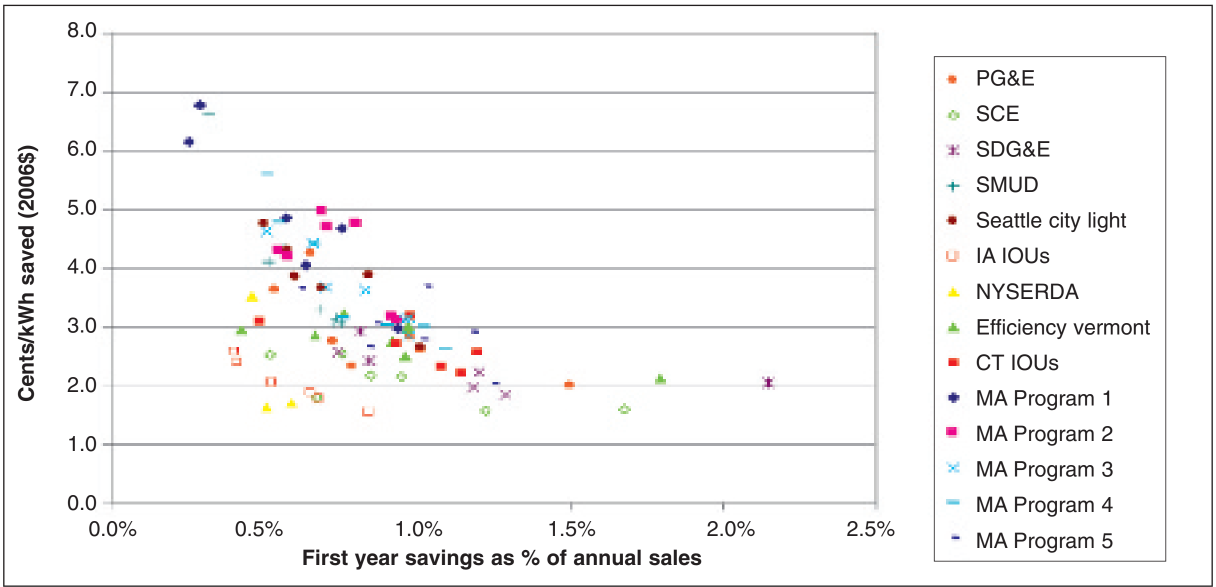

Figure 7.
Cost of saved energy in relation to program annual savings.

The color variation between bars shows that the electric sector emissions profile varies among regions and across time. The eastern-most regions (New England and New York, NEWE and NYUP, respectively) have a fairly low NO_x emissions rate throughout the year, varying primarily by the amount of oil used in a largely gas-fired region. In the western regions (Reliability First region, east, mid, and west, RFCE to RFCW, respectively) power is increasingly coal-derived, and the emissions rates are significantly higher. In the western regions, a summer ozone control season forces generators to utilize NO_x emissions controls, primarily on coal-fired generators. In the westernmost region (RFCM), NO_x emissions drop by more than half. Emissions of CO_2 do not vary significantly over the course of the year, both because the fossil-fired resources all have emissions rates between ~ 0.6 and 1.2 tons CO_2/MWh and because there are no analogous control technologies for CO_2. One of the most dramatic patterns in this series occurs in RFCM, where during summer months large amounts of gas generation comes online to meet peak load, reducing the average hourly emissions rate from over 1.2 t CO_2/MWh do about 0.85 t CO_2/MWh. Even though the emissions rate decreases, increased demand drives up overall emissions during these hours.

To estimate the emissions reductions feasible from a demand reduction program, one would clearly not want to use an average national emissions rate, or even a regional average annual emissions rate, because the rates vary dramatically across geography and time. In this case, we use the hourly average emissions rate in these figures for illustrative purposes only: an efficiency program or renewable energy program would likely displace a mix of marginal generators, not the average generation mix. Techniques for identifying the mix of displaced generation (and air emissions) are discussed in the report for US EPA, and elsewhere.

4. Electric Utility Energy Efficiency Costs – new findings on program costs

For energy efficiency efforts, the benefits include the avoided power plant construction and operation costs, as well as the important, but difficult to estimate, multi-pollutant reductions discussed above. On the cost side for energy efficiency, one of the key challenges at this time is figuring out how the costs of current efforts will change as the scale of efficiency investments is ramped up. Conventional wisdom is that there is an inclining "supply curve" for conservation measures. That is, as the size of the effort is expanded the cost per kWh saved is generally expected to increase. To test this idea, Synapse examined actual data for specific electric utilities and charted program savings vs. program expenditures per kWh saved*. Actual program data showed that instead of increasing, the curve is flat or decreasing.

The overall cost per kWh saved for a utility program in a particular year turns out to be lower for the more ambitious programs. We found that the CSE ranges from about 1.5 cents to close to 7 cents per kWh saved, with the average of 2.4 cents/kWh and the median of 3 cents/kWh saved based on 90 data points.

** Details of the analysis are found in Doug Hurley, Kenji Takahashi, Bruce Biewald, Jennifer Kallay, Robin Maslowski 2008.* Costs and Benefits of Electric Utility Energy Efficiency in Massachusetts: *Synapse Energy Economics, Inc. For references and other information related to this analysis, contact Doug Hurley at Synapse Energy Economics (dhurley@synapse-energy.com).*

Among all of the datasets that we have collected, all of the slope coefficients of the linear trend lines are negative. This strongly suggests that per-unit cost of energy efficiency (EE) decreases as the amount of EE savings increases. It is important to emphasize that this finding contradicts the generally accepted theory that costs of EE increase when EE savings amounts increase.

The fact that the coefficient is negative in every case is particularly striking. While it is possible that unit costs might begin to increase at much higher levels of EE program savings, this evidence suggests that current program savings levels have not yet approached any such point. Possible reasons for the decreasing cost trends include:

- economies of scale are at work (e.g., allocating marketing and administration costs over more savings, achieving lower unit costs for program inputs);
- more economies of scope are at work at larger scale of energy savings relative to annual sales (e.g., exploiting synergies among different measures such as reducing the cost of site visits per measure by implementing multiple efficiency measures at one time);
- administrators become more organized in designing and developing effective EE programs (including appropriate level of incentives to promote customer participation);
- administrators have more credibility or more resources available for quality program design and development.

Our conclusion is that energy efficiency programs appear to have economies of scale, perhaps at an even greater extent than do power plants. There is a great deal of untapped energy efficiency potential – an aggressive program/effort will reap the greatest benefits. As entities in the US ramp up the programs that are offered, in part due to the consideration of co-benefits, they may see significant reductions in the unit cost of saved energy.

5. A Case Study: Achieving emissions reductions on High Electricity Demand Days

Individual policy goals, each desirable on their own, can interact to produce an undesirable outcome. Recent experience in southwest Connecticut illustrates the complexities that can arise through the interaction of circumstances and policy initiatives. In this region, it has proven particularly difficult to achieve multiple policy goals without adverse results.

The state of Connecticut, like other states in the US, must demonstrate compliance with National Ambient Air Quality Standards (NAAQS). Achieving the NAAQS for ozone has proved particularly difficult for eastern states like Connecticut due to pollutant transport from states to the west. At the same time that the environmental regulators continue efforts to comply with emissions standards, developments in the electricity sector have made the task more difficult. Southwest Connecticut suffers from transmission constraints and congestion. As a result, in order to achieve reliability standards, several generating plants operate outside of economic dispatch order (known as RMR, "Reliability Must Run", units). Simultaneously, there has been a considerable push for demand response – with its energy, capacity, and reliability benefits – as a regional tool but also one that is particularly suited to the circumstances of Southwest Connecticut. Unfortunately, demand response which includes small customer-site diesel generation can overwhelm emission reductions achieved through controls on regulated electric generators. Synapse evaluated how various energy efficiency and regulatory scenarios could reduce NO_x emissions in Southwest Connecticut in two phases through 2020*.

Analysis revealed that the state environmental regulator's goal to achieve a specific emission reduction commitment by 2009 cannot be met through a business as usual approach (even when all new generation is as clean as possible) or through a program that relies solely on existing levels of energy efficiency. Instead, the most effective reductions result from a combination of at-stack emissions reductions and intensive energy efficiency programs. Connecticut's energy efficiency initiatives are fairly aggressive compared with some other states. Further investment in efficiency is justified by economies of scale observed in efficiency programs.

Figure 8 shows the outcome of a displaced emissions analysis tailored to the needs of the State of Connecticut. In a baseline demand-growth scenario, new requirements are met with clean generators, and net emissions do not decrease. If non-economic, highly polluting RMR units are compelled to introduce control technologies, reductions occur, but state targets are not met. Similarly, a 2% annual efficiency program results in significant reductions, but also does not meet air quality targets. However, either ambitious 3% annual EE or a highly viable program of 2% EE and at-stack reductions results in the target being met in out-years.

Through an analysis of likely displaced generators under reduced demand, Synapse concluded that Connecticut DEP can meet its commitment to reduce NO_x emissions through a combination of reducing emissions from the units that operate for reliability, and continuing to have sustained performance from the state's energy efficiency programs. Achieving the

* *James and Fisher;* Reducing Emissions in Connecticut on High Electric Demand Days (HEDD) A Report for the CT Department of Environmental Protection and the US Environmental Protection Agency; *Synapse Energy Economics. July 25, 2008 Available at: http://www.synapse-energy.com/Downloads/SynapseReport.2008-07.EPA.CT-HEDD.08-020.pdf*

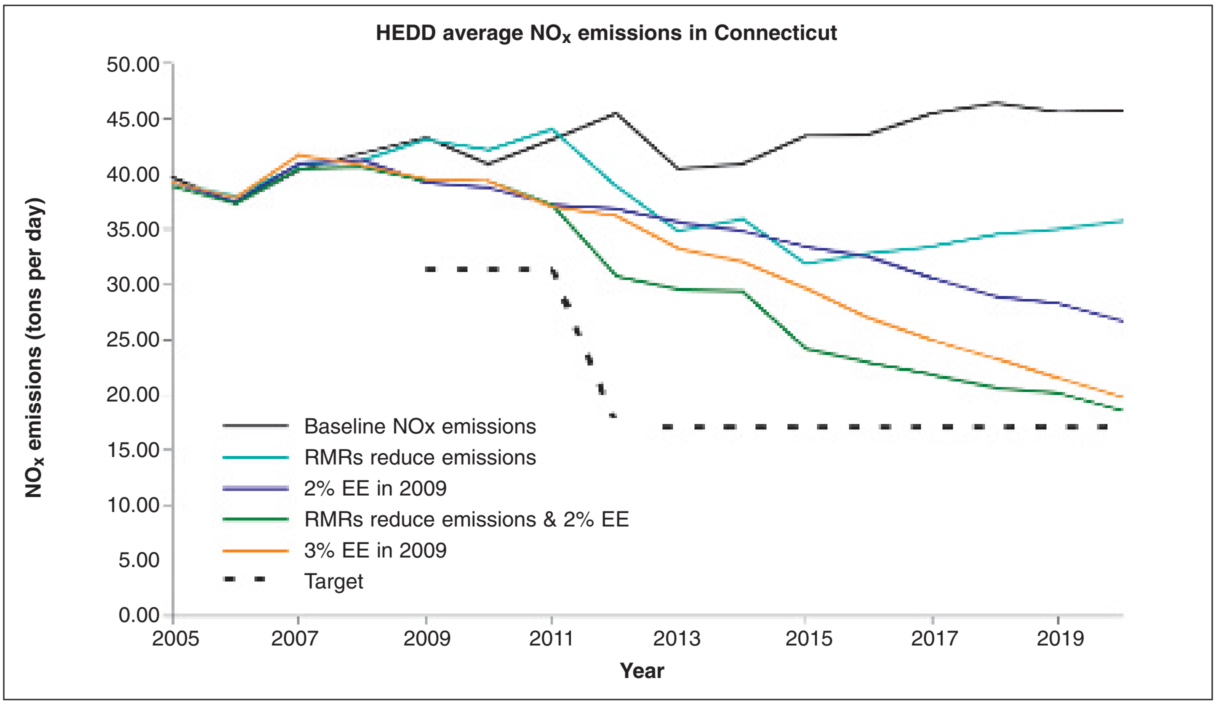

Figure 8.
Approaches to achieving an emission target.

second phase emission targets, with NO_x emissions decreasing a total of 50% from 2005 levels, will require additional reductions from the RMR units and ramping up energy efficiency programs to levels higher than 2008 in order to achieve these levels by 2020.

6. Conclusion

The US faces a variety of daunting challenges in achieving US carbon reductions in general; and, like in other countries, the challenge of achieving "co-benefits" is particularly difficult. These can, and must, be addressed through the application of good analytical techniques and creative policy solutions. The analytical toolbox should include models for understanding the impacts of energy efficiency investments upon the operation of the power grid, in other to appropriately quantify the emissions reductions, which can occur at power plants distributed over large regions, and can be dependant upon subtleties in the timing of demand reductions. The policy designs should establish mechanisms that encourage resource planners and investors to consider multi-pollutant benefits, which will lead to increased development of energy efficiency opportunities, and less reliance on power plant emissions control equipment. Experience in the US with pollutant-specific reduction mandates, and piecemeal policies, is not a model to emulate elsewhere or in the future for the US, but does offer useful lessons for developing the coordinated and comprehensive strategies that will be required to achieve the emissions reductions that will be required in the coming years.