Energy Efficiency in the Regional Greenhouse Gas Initiative: How Much Can Efficiency Contribute to a Carbon Cap-and-Trade Program?

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ABSTRACT

The authors, as stakeholders in the Regional Greenhouse Gas Initiative (RGGI), a seven-state regional power sector carbon cap-and-trade policy in the Northeastern United States, developed a set of energy efficiency resource characterizations for the RGGI modeling process. Using the IPM power-sector resource optimization model, and the REMI regional economic model, the modeling process simulated a range of scenarios to test RGGI's impacts on the region. We used a 2003 New York state efficiency potential study, plus other regional data sources, to develop an aggregated set of efficiency potential data formatted to fit IPM's input requirements. Working with the modeling team, we helped work out methods for constraining efficiency resources within the model to keep model outputs within a reasonable range. IPM results showed that energy efficiency would have strong positive effects on the RGGI program: load growth would fall by up to two-thirds, reducing electricity prices and carbon allowance prices, reducing emissions "leakage" (increased emissions from regional power imports), and reducing consumer energy bills by over $100 annually. The REMI modeling results showed that higher efficiency investment levels produced greater economic benefits. The authors recommended that, based on these modeling results, the RGGI states should both allocate more than 25% of emission allowances to energy efficiency and other public benefits, and should also set energy efficiency resource targets for their states, to achieve RGGI's carbon emission reduction goals with maximum economic benefit to the region.

Background

This paper summarizes the results of a ground-breaking effort to calculate the effects of increased energy efficiency investment in a carbon cap-and-trade policy framework. While it is generally accepted that energy efficiency reduces carbon emissions and can cut the cost of a carbon-reduction policy, there has been little quantitative analysis of specific levels of efficiency investment in a defined carbon policy context. Some climate policy analyses have projected negative economic impacts from carbon caps; however, they have generally not addressed energy efficiency explicitly as a resource in achieving climate goals. The analysis covered in this report is thus an important advance in the climate policy sphere: it is the most specific study yet conducted of energy efficiency's impacts on such important factors as allowance prices, energy prices, and economic growth.

The analysis focuses on the Regional Greenhouse Gas Initiative (RGGI), a nine-state effort to develop a regional carbon cap-and-trade system. At the invitation of New York Governor Pataki in 2003, the governors of Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, New Jersey, and Delaware committed to developing a model carbon cap-and-trade rule for the region's power sector by 2005. A state agency working group composed of staff from participating state agencies, a stakeholder group composed of generators, customer groups, and environmental groups, and other mechanisms were set up to develop the model rule. As a core part of the rule's development, the working group conducted extensive modeling of the regional power sector using the ICF Consulting *Integrated Planning Model* (IPM) [1] linear programming model, and the Regional Economic Models, Inc. (REMI), *20/20 Insight*™ regional economic model to assess RGGI's potential impacts. Part of the IPM and REMI modeling effort was dedicated to simulating the impact of accelerated energy efficiency deployment scenarios.

Seven of the RGGI states signed a Memorandum of Understanding (MOU) in December 2005, largely embodying the policy attributes that were studied in the modeling process described in this paper. The RGGI Model Rule was issued for comment in March 2006, and will be finalized in summer 2006. States will then conduct processes for implementation of the model rule. As currently designed, the first compliance period will begin in 2009

Methodology

IPM is an electric power generation model that characterizes the acquisition, operation and retirement of resources to meet market demand for electric power. This model is used nationally by U.S. EPA for many of its air quality policy analyses, and is also widely used by states in their air quality and climate policy analysis, and by utilities and utility regulators as a utility generation planning tool. IPM is a linear programming model designed to simulate an economically optimum power sector resource scenario, given basic inputs such as electricity demand, fuel prices, resource capital costs, emission constraints, and other factors.

IPM comprises several modules that reflect different elements of an electric power market: a resource stock module that compiles available generation resources; a resource acquisition module that procures new generation assets to meet future market demands for power; and a dispatch module that selects which generation assets are operated to meet demand. IPM also has a demand side management (DSM) module, which characterizes efficiency as pre-set decrements on electric power demand; this module does not dynamically respond to price changes or allow energy efficiency resources to compete with generation in the resource acquisition module.

The staff working group decided to go beyond IPM's DSM module approach of treating efficiency as an exogenous demand decrement. Because the RGGI states expected energy efficiency to play a significant role in RGGI, staff wanted to explicitly model energy efficiency resources in the IPM-simulated policy analysis scenarios. ACEEE was invited to work with staff and consultants to develop the necessary input data on efficiency resource potential for the RGGI region and incorporate this potential into IPM. With support from the Energy Foundation, we developed a strategy to model energy efficiency in IPM and compile data in a format suitable for

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[1] IPM provides integration of wholesale power, system reliability, environmental constraints, fuel choice, transmission, capacity expansion, and all key operational elements of generators on the power grid in a linear optimization framework. The model utilizes a Windows™-based database platform and interface that captures a detailed representation of every electric boiler and generator in the power market being modeled.

The fundamental logic behind the model determines the least-cost means of meeting electric generation energy and capacity requirements while complying with specified constraints, including air pollution regulations, transmission constraints, and plant-specific operational constraints. The versatility of IPM allows users to specify which constraints to exercise and populate IPM with their own datasets. Versions of IPM have been used to support the U.S. Environmental Protection Agency's (EPA) analyses of utility air emissions, and the recent Federal Energy Regulatory Commission (FERC) benefit-cost analysis of Regional Transmission Organizations (RTO).

incorporation into IPM. Since the DSM module does not dynamically model energy efficiency, we proposed using the resource acquisition module as the vehicle to consider energy efficiency. Energy efficiency resources would be considered as an alternative to conventional generation technologies, and would compete on a cost basis to meet future generation demands. This approach can be envisioned as virtual energy efficiency power plants competing with new natural gas and coal power plants to serve future load.

Our first challenge was to characterize efficiency resources in an IPM-usable format. The primary data source was a 2003 efficiency potential study conducted for NYSERDA (NYSERDA 2003). The NYSERDA analysis was the most complete and detailed study available in the region, and thus provided the fullest basis for this analysis. ACEEE was part of the analytical team for that study, and so was able to straightforwardly manipulate the data sets into formats compatible with IPM input. We also checked the NYSERDA data against other potential studies conducted in the RGGI region, in states like Connecticut, Massachusetts, and Vermont. We found that the potential data were very consistent across the various states, and thus felt confident in extending the NYSERDA data characterizations across the region.

Using the NYSERDA data sets, we characterized efficiency potential data for the residential, commercial, and industrial sectors in the form of generation resources. Because IPM calls for resource availability in peak and off-peak periods, we subdivided the residential and commercial resources into peak and off-peak categories. Each sector's potential was based on quantified savings from a wide range of efficiency technologies, including both economically viable technologies that are commercially available now and emerging technologies considered likely to be commercialized within the 20-year study horizon.

Defining Efficiency Potential

For the purposes of this analysis, we define three types of potential calculations: technical, economic, and achievable potential.

- **Technical potential** is based on engineering and technology assessment; for a given end-use, such as residential lighting or commercial air conditioning, it typically determines the differential between the average efficiency of equipment currently in place, and the highest-efficiency equipment that is currently available, and that is likely to be available during the study period. Technical potential then becomes a function of the energy savings from best-available equipment instantaneously replacing existing equipment in all affected end-use applications.
- **Economic potential** is derived as a subset of technical potential, based on calculation of the monetized costs and benefits of a given efficiency measure type, typically expressed on a Total Resource Cost (TRC) basis. In simple terms, TRC compares the net present value (NPV) of the total costs and benefits of a given measure type or efficiency program.
- **Achievable potential** is defined as the efficiency resource amount than can be delivered in a defined time period, given realistic assumptions on the limits of markets, program funding, and other constraints. While defining achievable potential is the least precise of the three types of potential analysis, it is important to conduct because failing to do so could produce unrealistic modeling results, which could damage the credibility of this kind of analysis. If the economic levelized cost per saved kWh were low enough, IPM

could "build" the entire efficiency resource in as little as a single year. Many analysts would not find such results credible.

Constraining Efficiency Potential Within IPM

Applying these constructs to the RGGI IPM modeling process, it became apparent that while we had developed robust estimates of economic potential, it would also be necessary to constrain this potential within the model for each model run year, to establish a reasonable proxy for achievable potential. We used the fact that IPM allows the amount of any resource available in a year to be constrained as a way of approximating a realistic achievable potential estimate. We considered three ways to constrain the efficiency resource data within the model:

- **Straight-line diffusion.** This uses a very simplified version of a market diffusion model. It involves dividing the resource potential by the number of years in the study period, and assuming that that fraction of the total resource potential is the maximum that would be achievable in a given year. For example, if the total potential is 100 million kWh, and the study period is 20 years, the assumption would be than no more than 5 million kWh is achievable in any given model year.
- **Percent of load growth.** Data is available from states that have been aggressively pursuing energy efficiency over several years, on the net effect of these programs on total growth in electricity sales. This makes it possible to constrain the IPM data sets in terms of total impact on load growth. For example, if the reference case shows an average load growth of 1% per year, the model could constrain efficiency resources to reduce load growth by no more than 0.5% or 1% per year. Leading states are showing efficiency program impacts in that range.
- **Available funding.** The third constraint approach is to assume a maximum annual funding level available for efficiency programs, and to then apply an average cost per first-year saved kWh to estimate the level of efficiency resource that could be "bought" by the assumed level of program funding. For example, if the maximum available funding is assumed to be $1 billion per year, and the average program cost per first-year saved kWh is 10 cents, the achievable potential would be capped at 10 billion kWh for that year.

ACEEE recommended that the RGGI working group use two methods to constrain IPM's ability to deploy efficiency resources: the diffusion approach and the available funding approach. After a series of consultations among staff working group members and stakeholders, the modeling subgroup staff decided to focus on available funding as the operant constraint. The details of this process are explained below.

Characterizing the IPM Efficiency Inputs

The NYSERDA study characterized the performance of individual or grouped sets of efficiency technologies in detail. Because of the limitations of IPM, we had to significantly aggregate this data to fit within the model's calculation constraints. Thus, from hundreds of measure combinations, we developed a total of 15 "bins" of efficiency potential data. These were defined as residential peak, residential off-peak, commercial peak, commercial off-peak, and industrial, with three cost tiers within each end-use bins. So, for example, the model was able to select from low, medium, and high-cost resource bins in each of the five end-use categories. While this aggregation limited the "granularity" of the data, it was the maximum number of variables the model could handle, given that the resources also had to be allocated to 12 sub-regions within the RGGI region, and that the model calculates 6 run years. In total, the IPM model considered 1,080 combinations of energy efficiency potential data in this analysis (15 bins x 12 sub-regions x 6 years = 1,080 combinations).

The structure of the input data set is summarized in Table 1.

Table 1. Energy Efficiency Resource "Bins" for IPM Input

Customer Sector	Time Period	
	Peak	Off-Peak
Residential	High cost	High cost
	Medium cost	Medium cost
	Low cost	Low cost
Commercial	High cost	High cost
	Medium cost	Medium cost
	Low cost	Low cost
Industrial	High cost	High cost
	Medium cost	Medium cost
	Low cost	Low cost

IPM employs these data sets in its resource development module. Its core operations center on selecting an optimal set of resources for a given model run year, based on the demand forecast and a set of assumptions about resource costs, fuel prices, financial parameters, and other factors. In the RGGI process, as with most analyses of this kind, IPM's operators first run a reference case. They then run a series of policy scenarios, based on various policy assumptions, and also run a number of sensitivity cases, based on alternative assumptions about key variables such as fuel prices.

In the aggregate, the economic potential represented in all bins combined ranges from 27% to 31% of the electric sales in the reference case forecast. These numbers are consistent with other recent assessments of efficiency potential (Nadel, Shipley and Elliott 2004). The IPM reference forecast shows total growth in electricity sales over the study period of 21%, with an average annual growth rate of just under 1%. Assuming that the economic potential study were to be constrained on a straight-line diffusion basis, i.e. about 5% per year, it would be possible to keep electricity sales virtually flat over the study period. It is important to remember, however, that achievable potential as discussed in the Nadel (2004) paper averages 67% of economic potential. Also, the model selects resource bins sequentially, taking the lowest-cost resources first. In some cases, it may not select the highest-cost bins of efficiency resource. So the economic aggregate potential serves only to define an upper bound for the analysis.

IPM Modeling: Further Input Modifications

As mentioned above, the final decision was to constraint the level of efficiency resources for a given model run year on the basis of maximum available funding. This required an additional step: converting cost-of-saved-energy (CSE) data, on a levelized cost per lifetime kWh, into a first-year cost per saved kW. This amounted to estimating an imputed capacity cost for energy efficiency resources. Because it is designed to select from among power generation resource options based on their combined capital and operating costs, the IPM model selects resources based on capacity (capital) costs plus fixed and variable operating and maintenance costs. To conform to this data convention, the energy efficiency data was revised accordingly. Working group staff imputed capacity costs for the efficiency resource data bins using both historical program results from RGGI states, and average measure-life estimates. This imputed capacity cost was then converted to average cost per kWh by assuming zero operation and maintenance costs. This approach yielded per-kWh cost averages that were very close to those in the original data set; any small differences were estimated not to alter the model results significantly.

To complete the funding-constrained resource estimate for IPM input purposes, it was also necessary to establish an upper limit for available funding in the region. Currently, the 9 RGGI states spend an average of about one and one-half mills ($0.0015) per kWh on public-benefits efficiency programs. The highest spending level is currently about 3 mills. Total dollar spending for the region is about $630 million. The working group established two levels of funding for purposes of constraining efficiency resource availability within IPM: (1) continuing efficiency program results assuming maintenance of current spending levels, and (2) doubling current spending, with proportional results. The working group also allowed the model, in one run, to select all available economically cost-effective efficiency resources.

The modeling staff and consultants made additional modifications in applying the energy efficiency inputs as they finalized the IPM modeling process. For the initial policy scenario runs, they applied the efficiency resource data as planned in the resource module, in order to select the economically correct levels of efficiency resources. However, they also encountered an anomaly involving other aspects of IPM, stemming from the issue of capacity payments as simulated in the model. After IPM selects a resource portfolio and dispatches resources, it also allocates payments to the various sources of capacity and energy. This led to a computational problem, in that efficiency resources would be acquired through parallel markets, not through the regional power market directly, so including energy efficiency created price distortions in the capacity payment allocation routines.

To work around the capacity payment issue, the staff using the DSM module option, and using the efficiency savings levels selected in the resource module as a demand decrement. After trying this approach, the team found that it produced the same overall results in terms of electricity sales, electricity prices, carbon prices, emissions leakage, as would have been generated using the original modeling process.

This "learn-by-doing" experience suggests a few lessons:

- Characterize efficiency data inputs in terms of first-year capacity cost, not levelized cost of saved energy, because the model has its own algorithms for deriving levelized cost. This will typically need to be an imputed cost, but the mathematics is straightforward and defensible.
- Use the IPM resource module to calculate the economically-optimal level of efficiency resource acquisition. IPM appears to correctly calculate these numbers if the inputs are correctly characterized.
- Complete the IPM model runs using the DSM demand-decrement module. This is needed to work around the capacity-payment problem.

Economic Modeling Using the REMI Model

The RGGI staff working group selected the Regional Economic Models, Inc. (REMI) 20/20 Insight™ model[2] to assess the impacts of the RGGI program on the 9-state region. REMI, an input-output model based on matrix algebra like most mainstream economic policy models, has been widely used by state and other government agencies to simulate the economic effects of various policy regimes. Like IPM, REMI creates a reference case for the region, using current conditions and other known factors to generate a business-as-usual regional economic future. REMI, however, uses IPM's outputs to assess the economic impacts of different policy scenarios. Changes in energy prices, power sector inputs and outputs, and related variables are mapped into REMI's input formats.

For the IPM runs involving energy efficiency investments, working group staff mapped additional data into REMI's input formats. For example, increased investment in sectors stimulated by efficiency investments were mapped into specific REMI sector input vectors. Increased employment in sectors where efficiency investment created new jobs was also mapped into REMI, as were the effects of money saved on energy bills generating added spending in other sectors.

In this regard, REMI provides a more robust characterization of energy efficiency's economic impacts than do many other economic models. Some models treat energy efficiency impacts as simply a drop in energy sales, which shows up as entirely negative economic impacts as growth in energy-sector revenues, investment, and employment shrinks. However, because efficiency generates capital investment, additional employment, and frees up dollars otherwise spent on energy bills, it can create economic benefits that more than outweigh any economic losses in energy supply sectors. In today's increasing national and global energy markets, the economic impacts of energy supply flow increasingly outside of state and regional economies. Efficiency investments, which tend to generate more local investment in retail, construction, services, and other sectors, can be a net economic winner for state and regional energy policymakers and consumers.

Description of the IPM Runs

The IPM modeling process explored increased energy efficiency investment scenarios in five different model runs outlined below (note that the final RGGI model rule has modified some

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[2] REMI 20/20 Insight™ is a model for fiscal and economic analysis at the local level. 20/20 Insight allows city, county, and municipal decision makers understand the total economic and fiscal effects of proposed policy changes, permits for housing or new business, and many other changes that will affect the local areas in question. 20/20 Insight incorporates a year-by-year forecast of local spending and projected revenues expressed in fiscal years, as well as a detailed population forecast by age and gender, and a complete economic forecast expressed in calendar years.

REMI designed 20/20 Insight to help county and municipal decision makers answer such questions as:

- How much total revenue will be generated by a giant retailer opening a local store?
- How much will the town's expenditures on sewers, police, fire, and schools increase due to new proposed residential development?
- What are the total effects of increasing local property taxes?

20/20 Insight is a fully customized product, incorporating county, city, or municipal fiscal data with the comprehensive power of REMI's economic and demographic forecast model. The simplified user interface provides access to necessary economic and fiscal variables in a clear, manageable system (REMI 2006).

of the specifics assumed in these model runs). The reference case assumes no RGGI program in place; for efficiency, it assumes current programs run through their current authorizations and then terminate. Some effects from current programs may also be embedded in the reference case, though because of differences in how the three Independent System Operators (ISOs) prepare forecasts, we were unable to discern those effects with precision.

1. **The RGGI "policy package" case**. The policy package included a phased-in carbon cap that begins to take effect in 2009, reaching maximum reductions by 2020. It allows for emission targets to be met by a limited number of offsets. It assumes an allocation of 25% of carbon allowances for public goods, including energy efficiency, and allocates 5% of allowances to a strategic carbon fund to support key carbon reduction options. It also assumes that current levels of energy efficiency spending and program results continue through the modeling period.
2. **The package case with doubled efficiency**. This run simply doubled the assumed level of funding available for energy efficiency program support during the modeling period.
3. **The reference case with continued efficiency spending**. This run used all reference case assumption, but assumed that current efficiency spending levels and program impacts continue through the modeling period.
4. **The reference case with doubled efficiency spending**. This run used the reference case assumptions, but allowed efficiency spending to double during the modeling period.
5. **The reference case with all economic efficiency resources**. This run simply removed the annual funding constraint for efficiency programs, and assumed that all cost-effective measures would be implemented.

Results

IPM's outputs showed that doubling the current level of energy efficiency spending in the RGGI region would have several very favorable effects on the carbon cap-and-trade system:

- **Electricity load growth—**Figure 1 shows that doubling efficiency would cut load growth by about two-thirds in 2024 compared to the reference case, from about 20% to about 6% above 2006 levels.
- **Generation capacity additions—**the doubled-efficiency scenario reduces 2024 capacity additions by about 8,000 MW compared to the reference case, or about 25% of the reference case forecast for new capacity.
- **Carbon emissions—**Figure 2 shows that the efficiency scenario keeps carbon emissions virtually flat through 2024, compared to about 15% growth in the reference case.
- **Energy prices—**doubling efficiency reduces energy price growth to almost nothing; no significant prices impacts occur until after 2020, when they show a less-than-1% impact on wholesale power market prices.
- **Carbon allowance prices—**Figure 3 shows that allowance prices are also substantially lower with increased energy efficiency investment, falling by about one-third to less than $2/ton in 2024.

Figure 1. Electricity Generation

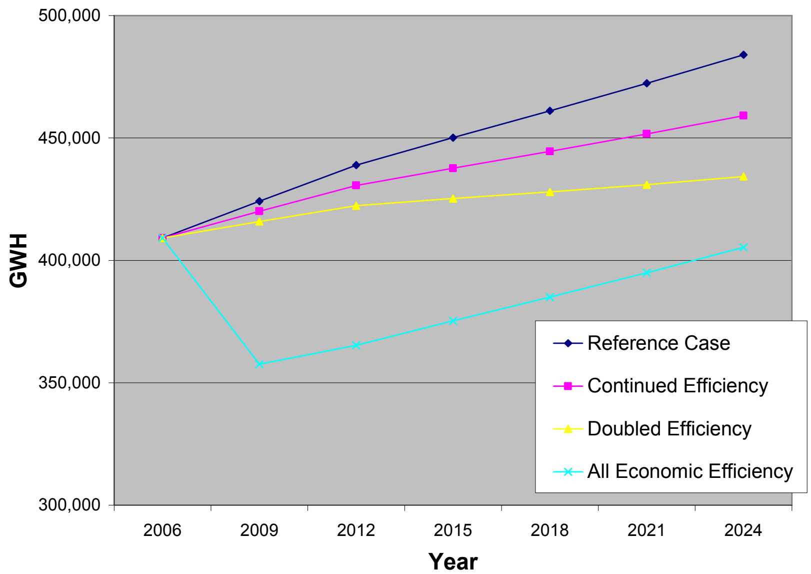
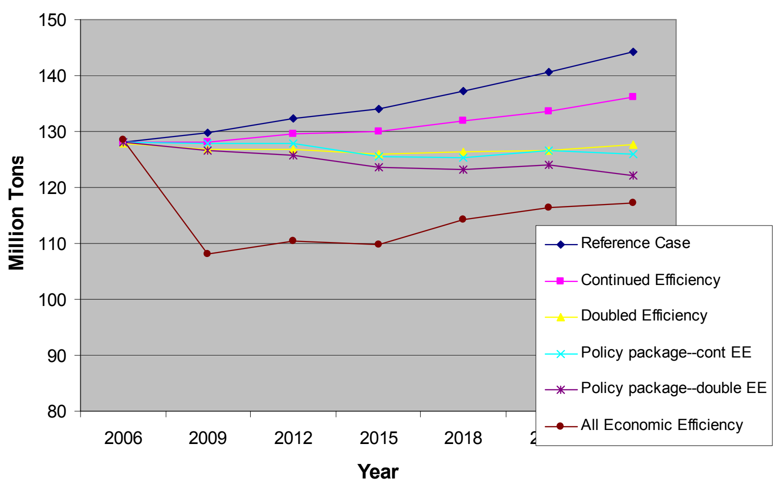
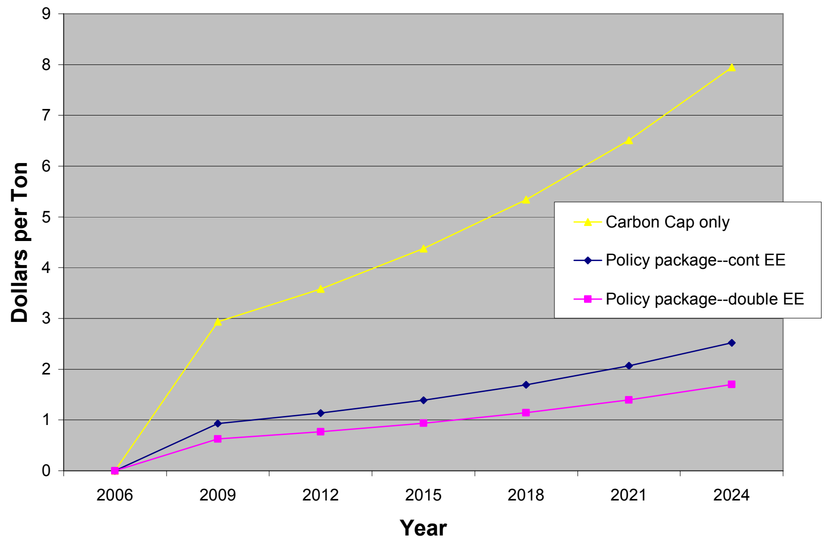


Figure 2. CO_2 Emissions



- **Power imports or "leakage"**—Because increased efficiency reduces power imports to levels lower than the reference case, it is a key factor in avoiding one of the biggest concerns about RGGI, that it would cause increased emissions from plants selling power into the region, thus causing emissions "leakage" that could largely offset the impacts of the RGGI carbon cap. IPM modeling results showed that increased efficiency investment tended to reduce projected leakage effects, mainly by reducing wholesale power price increases in the region and thus reducing the economic motivation for outside generators to increase sales into the region. While many factors, including transmission constraints, fuel prices, and plant locations also affect leakage, a strong commitment to efficiency

Figure 3. Carbon Allowance Prices



The regional economic impacts, as projected by the REMI input-output model, also showed positive impacts from increased efficiency investment. Like IPM, the REMI modelers first constructed a reference case that assumed no changes from current polices. The scenarios modeled are thus reported in terms of changes from the reference case. Kind findings included:

- **Consumer energy savings**—REMI showed that under the doubled-efficiency scenario, 2021 household electricity bills would be an average $109 lower than under the reference case.
- **Economic output**—doubling efficiency increases regional economic growth from virtually no impact to 0.6% positive in 2021, compared to reference case economic growth.
- **Personal income**—the doubled-efficiency scenario increases personal income by almost 1% in 2021 above the reference case.
- **Employment**—the increased efficiency future would increase private-sector job growth by 0.8% in 2021 above the reference case.

Policy Implications

The RGGI modeling results show that, based on the policy scenarios that continue efficiency spending at current levels or double it, an increased investment in energy efficiency results in the most positive set of economic impacts for the region. This puts a new premium on the value of increasing public commitments to efficiency in the RGGI states. With strong efficiency programs and policies in place, the region can enhance economic growth while cutting carbon emissions. This is good news for consumers and for policy-makers. The question that logically follows is: How can the RGGI states realize these benefits?

It is often assumed that cap-and-trade systems will create emission-reduction markets that will naturally select the most cost-effective resource available to meet emission-reduction targets at least cost. However, energy efficiency, at least in the electric power sector, cannot participate directly as an emission-reduction measure in emissions trading markets. Because it is an "indirect" kind of emission reduction measure, occurring not at the generation level but at customer facilities, there is no assurance that any marginal change in energy use will result in net emission reductions at the generation level for a given compliance period. The cap is on emissions and not on energy use, so if energy use is lower than expected, generators can adjust run times for various plants over the compliance period to marginally increase emissions up to the limits determined by emission allowances. For this reason, emissions traders have shied away from trading efficiency-based allowances or credits.

To overcome this inherent barrier to energy efficiency, policy-makers must either (1) carve out allowances from the cap specifically for efficiency-based emission reductions, or (2) pursue vigorous efficiency policies in parallel with the cap that will reduce the cost of meeting the carbon emissions targets. In the RGGI working group and stakeholder discussions, two major options have been discussed:

1. **A public-benefit allowance allocation**, in which a large fraction of carbon allowances would be allocated at the start of the program to public entities, which would then sell the allowances and use the proceeds to invest in public goods like energy efficiency. The RGGI MOU signed in December 2005 calls for allocating at least 25% of allowances in this way.
2. **A parallel commitment to achieving energy savings targets in the power sector**. Almost all of the RGGI states have some kind of public spending program for efficiency, known generically as public benefits programs. However, these programs' impacts are driven primarily by limitations on spending levels, rather than by savings targets. Some states, including CT and NJ, are developing quantitative targets as well as funding mechanisms. Known generically as Energy Efficiency Resource Standards (EERS), these mechanisms can be both simple and powerful ways to achieve desired results from efficiency programs. The MOU also encourages states to pursue these options.

The first option has the advantage of creating a defined pool of allowances, with monetary value, the proceeds from which can be used to increase energy efficiency investment. However, allowance prices are projected to be relatively low, less than $3/ton in most policy scenarios. Even if efficiency received all of the value of a 25% public benefit allocation, that would create perhaps $100 million/year in additional funding. Current spending in the region is over $600 million; so the direct allocation option seems unlikely to provide enough added funding to double efficiency resource results.

The second option may be more effective in achieving the doubled efficiency results that modeling results show to be desirable. States have already tested the approach of setting energy savings targets, and state program experience shows that aggressive efficiency programs can cut historic electricity demand growth by at least half. However, setting these more ambitious targets would involve policy action outside the RGGI regulatory structure. Moreover, funding this significant new investment could be challenging, be it through expanded public benefits funding or other mechanisms.

The authors recommend that the RGGI states pursue both options: use public benefits allowance allocation funds to invest in added energy efficiency resources, while also setting EERS targets to guide all power-sector efficiency programs toward the economically optimal goal.

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