Clean Energy States Alliance

Evaluating the Benefits and Costs of a Renewable Portfolio Standard

A GUIDE FOR STATE RPS PROGRAMS

Prepared for the

State-Federal RPS Collaborative

by

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About This Report

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Disclaimer

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Report Abstract

This report explains some of the issues associated with RPS evaluation and makes suggestions for how states may want to proceed with an evaluation.

It begins with an explanation of why RPS costs and benefits are so difficult to quantify. It then presents four approaches to RPS evaluation that vary in their complexity and cost, as well as in the precision of their quantitative results. The report explains the advantages and disadvantages of each approach. The four approaches are:

1. ***Description of costs and benefits***. This is the easiest, least expensive program evaluation method. Although some specific costs and specific benefits may be quantified, the evaluation does not attempt to produce a net total and does not try to quantify all costs and benefits. Instead, each particular category of benefit or cost is described and explained in detail.

2. ***An electricity rate impact study***. Public utility commissions and legislatures often wish to know specifically how an RPS is impacting electricity rates. While that is important information, it only gives a partial picture of the RPS, because it does not quantify important non-rate benefits and costs.

3. ***Building blocks.*** Each of the different types of costs and benefits covered in the descriptive method (approach one) is quantified separately. The evaluator identifies the most appropriate data source and calculation method for each of the benefit and cost categories. Because different data sources are used for different pieces of the calculation, this approach yields approximate results. There are both basic and more elaborate ways to quantify the various building blocks. This report presents a relatively simple, low-cost method for a state with a modest budget for RPS evaluation.

4. ***Economic modeling***. This approach uses a single econometric and input/output model to calculate all the direct and indirect economic impacts. Ideally, a dynamic, multi-faceted model is used. A static input-output model could also be used, but the results will be less robust.

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Introduction

Many people are interested in knowing the actual benefits and costs of state renewable portfolio standards. RPS program administrators often seek the results of an RPS evaluation in order to know what the program is accomplishing and to determine whether the RPS regulation or its implementation needs to be modified. Legislators, utility commissioners, and government leaders are often interested in comparing an RPS's financial costs to its financial benefits so that they can judge whether public funds are being used cost effectively. Advocates for the technologies supported by an RPS may seek to demonstrate that public incentives for clean energy technologies are in the economic interest of the state's citizens. Critics of those technologies or of public support for clean energy may try to prove that an RPS is expensive and undesirable.

Interest in RPS cost-benefit evaluation has increased significantly in recent years, not only because the share of electricity that is required to come from renewable energy has been increasing, but also because of the weak economy. In today's climate, businesses and consumers are sensitive to anything that imposes a cost on them, while policymakers tend to view almost all state actions through an economic development lens. All are keenly interested in whether an RPS will help create jobs and greater economic activity in the state, or whether it will impose extra costs that indirectly reduce the number of jobs.

Although it is logical and appropriate that many people want to know whether an RPS is a net economic winner or loser for a state, it is usually quite difficult to produce definitive answers to that question. Depending upon how an RPS is structured, the data needed to evaluate it can be incomplete or difficult to obtain. Moreover, the traditional evaluation approaches for comparing costs to benefits of a government program can be quite expensive when applied to an RPS and can exceed an RPS program's evaluation budget.

This report explains some of the issues associated with RPS evaluation and presents four options for how states may choose to proceed:

1. Description of costs and benefits
2. An electricity rate impact study
3. Buildings blocks
4. Economic modeling

These four approaches vary in their complexity and cost, as well as in the precision of their quantitative results. As an alternative to following one of these pure models, states can take a hybrid approach and combine aspects of two or more models. Sample RPS evaluations completed to date—which include both pure and hybrid approaches—are listed in Appendix B.

This report begins with an explanation of why RPS costs and benefits are so difficult to quantify, and then goes on to explain the advantages and disadvantages of each approach.

Why RPS Evaluation Can Be So Difficult

A full RPS evaluation, like any other thorough evaluation of a public program's costs and benefits, needs to consider the complex direct and indirect ways in which the program interacts with the economy. For example, when an RPS causes a renewable energy facility to be built in a state, the jobs associated with that facility need to be counted as a benefit of the RPS, as do multiplier effects created when the workers at that facility spend money in the state. On the other hand, if the money spent by utilities or competitive energy suppliers to purchase renewable energy certificates (to demonstrate RPS compliance) leads to higher electricity prices, the evaluation should also count the lost economic activity and job losses caused by ratepayers having less money to spend on things other than electricity.

Further heightening the degree of difficulty for an RPS evaluation, it can be hard to pin down even the direct costs of an RPS. Unlike government programs in which a portion of tax revenues are appropriated and spent for a particular purpose, an RPS imposes an obligation on certain market participants such as utilities or energy suppliers. In most cases, these entities fulfill their obligation by purchasing and retiring renewable energy certificates (RECs). RECs are purchased using a variety of contracting mechanisms, including short-term and long-term, bundled with energy and unbundled. Each purchase is negotiated bilaterally with customized pricing, often in transactions invisible to regulators. It is therefore very difficult for the administering regulatory agency to maintain an accurate accounting of REC prices and to quantify the direct costs of the program.

Even in a regulated utility system, in which utilities need to disclose their costs, it may be difficult to tease out the price of RECs. This is because the utilities may have paid a bundled price for the power and RECs from a clean energy generator under a contract that does not specify the assumed allocation of total cost. In bundled purchases of RECs and electricity for a single price, the portion attributable to RECs is arbitrary.

Moreover, even if the cost of the RECs is determined, it is still not necessarily easy to assess the total costs of the RPS. That is due to the complexity of electricity rate structures. Depending upon its location, a new renewable energy development can lead to either reductions or increases in transmission and distribution costs. In some cases, installing more renewable energy generation can suppress electricity prices for all generation during particular hours (see the discussion of price suppression on page six below).

With respect to economic benefits, RPS administrators rarely have systems in place to capture all the relevant financial information about the facilities that were built in the state, such as the cost of those facilities, production, and employment. If a detailed REC tracking or compliance reporting system does not exist, research may be required to establish an accurate list of which renewable energy facilities were used for RPS compliance.

Further complicating the evaluation, evaluators need to do more than collect data about the past. To quantify the return on investment for an RPS program, they may need to make reasonable projections about future fuel prices, energy demand, production costs for various energy technologies, and other variables. As the forecast horizon is extended, it becomes increasingly difficult to predict the future.

These factors—and others—make it very difficult to quantify the precise economic costs and benefits of an RPS. One should be wary of any evaluation that claims to have easily and quickly come up with a precise bottom-line result.

To illustrate the way in which costs can vary based on the many decisions involved with complying with an RPS, we can look at recent filings by Minnesota utilities. State law requires the utilities to submit reports to the state's legislature and to the Public Utilities Commission on the rate impacts of the RPS. Although most of the 14 utilities produced results that suggested that the RPS had led to a very small increase in rates, there was still considerable variation among the utilities. Xcel Energy found that its renewable energy purchases had actually reduced prices by 0.7%. On the other extreme, Minnkota Power Cooperative's RPS purchases led to a nearly 16% rate increase.[1] These variations came only from looking at direct costs and did not consider indirect costs and benefits.

The remainder of this report will look at the four primary approaches to estimating RPS costs and benefits. The report does not presume to prepare readers to be professional evaluators, but instead aims to provide them with information they need to decide which type of evaluation they want to commission and to select an appropriate evaluator.

Approach One:
Description of Cost and Benefits

After recognizing the difficulties associated with a full quantitative cost-benefit evaluation of an RPS, a state may decide to take a non-quantitative, descriptive approach. This is the easiest, least expensive program evaluation method.

With this approach, the evaluator—either agency staff or an external consultant—describes all of the various known or reported costs and benefits of the RPS. This can help policymakers, the media, stakeholders, and the general public to understand some of the ways in which the RPS impacts the state. It can be useful for enlightening stakeholders on the full range of direct and indirect costs and benefits. It can also help them understand the complexity of cost-benefit calculations and see why there may not be a simple way to carry a full cost-benefit study leading to a single bottom-line number.

This approach can include the quantification of some specific costs and specific benefits, but it does not attempt to produce a net total and it does not try to quantify all costs and all benefits. Instead, each particular category of benefit or cost is described and explained in detail. This type of evaluation should be accompanied by a disclaimer that states its limited purpose and points out unmeasured areas of cost and benefit.

Benefits

A cost-benefit evaluation of an RPS will inevitably focus primarily on *economic* costs and benefits, but it is important to describe the wide range of benefits of the RPS, including non-economic ones. After all, most RPSs have been established for reasons that extend beyond economic development. It is useful to remind policymakers and stakeholders of those other benefits and to describe them in ways that are tangible and meaningful. To the extent that an RPS ends up imposing some net economic costs on the state, those costs are often, in effect, purchasing future economic benefits (such as lower power costs or a larger clean energy industry cluster), hard-to-measure economic benefits (such as reduced negative global warming impacts), and non-economic benefits (such as reduced pollution or nuclear accident risk) that the state considered to be significant when it established the RPS.

Here are some of the benefits, both economic and non-economic, that can be described:[2]

More Renewable Energy

Presumably, the initial impetus for a renewable portfolio standard is to change the electricity supply by adding certain quantities of renewable energy, as well other electricity from nonrenewable clean energy technologies if they are allowed as part of the portfolio standard. A description of this benefit of the portfolio standard should describe what is actually being achieved in terms that can be understood by people other than energy professionals.

Energy policymakers generally talk about megawatts of renewable energy capacity and megawatt-hours of electricity produced. Although it is important to quantify results using those basic metrics, most people—including most legislators, reporters, and other stakeholders—have difficulty envisioning the meaning and implications of those terms. A descriptive evaluation of an RPS should therefore translate those results into more accessible terms that people can understand. There are two ways in which this can be done:

1. ***A visualization of the energy produced.*** The description can and should use something like the following formulation: "The electricity from renewable energy that was produced because of the RPS during the past year was enough to supply all the electricity needs of XX thousand households in the state."

2. ***A visualization of the electricity generating facilities installed.*** This can be a little more difficult to describe simply, but can be done with reference to average-sized installations. Here is a sample formulation: "Last year, because of the state's RPS, 150 megawatts of wind power, 10 megawatts of biomass, and 5 megawatts of solar were installed. Although the size of the systems and facilities varied, this was equivalent to 100 wind turbines averaging 1.5 megawatts each, one wood gasification facility of 10 megawatts, 8 large commercial solar installations averaging 250 kilowatts in size, and 750 residential solar installations averaging four kilowatts." To further help readers visualize this point, pictures of the average-sized installations can be included. The evaluation report should, of course, acknowledge that this is merely a representative illustration of what the RPS achieved and that the actual results were different and more varied but equivalent.

Improved Environment

Most states have identified environmental improvement as one of the goals and benefits of developing renewable energy. To remind policymakers and the public of those benefits, a descriptive evaluation can discuss the various ways in which substituting clean energy technologies for fossil fuels reduces air pollution, water pollution, water use, thermal pollution of waterways, and greenhouse gas emissions.

Ideally, a general description of these benefits should be supplemented by some simple quantitative analysis. That can be difficult because it is generally hard to know exactly which generation is displaced when new clean energy projects come online. An exact accounting is not necessary, however, as long as an evaluation report is clear that it is presenting an approximation and it expresses the results as a range (e.g., "In 2010, the state's RPS reduced carbon dioxide emissions from electricity generation by approximately 400,000 – 500,000 metric tons."). Because results expressed as tons of CO_2 or NO_x mean little to most people, it is useful to translate them so they will be more meaningful. One frequent formulation is to explain: “The state’s RPS reduced greenhouse gas emissions as much as taking XX thousand cars off the road.” And percentages can be useful: “Because of the RPS, greenhouse gas emissions from electricity are Y percent lower than they would otherwise be.”

The US Environmental Protection Agency (EPA) has published *Assessing the Multiple Benefits of Clean Energy: A Resource for States*, a helpful report that can used to figure out how to quantify the greenhouse gas, air quality, and health benefits of implementing clean energy.[3] It offers both relatively simple and more advanced methods for estimating those benefits. For most descriptive RPS evaluations, the simpler methods should be sufficient.

Reduced Near-Term Electricity Prices from Price Suppression Effects

There are two primary ways in which the addition of renewable energy generating units can reduce electricity prices in the short run, even if the cost of running those units is currently higher than the cost of operating conventional fossil fuel facilities.

First, if a large amount of renewable energy is added to the system, it can reduce demand for natural gas, which fuels the marginal generating units in many regions of the country. As with any commodity market, with lower demand, the marginal price for natural gas should drop. When natural gas prices were high in the mid-2000s, this demand-reduction effect was probably significant.[4] However, given current low natural gas prices and excess supply capacity, it is unlikely that renewable energy development is causing a significant suppression of natural gas prices, although there is likely some small impact.

A second type of price suppression effect can be much more significant. In most competitive wholesale markets and a few regulated ones, the addition of renewable energy generators can reduce reliance on high-priced units that set prices—the so-called “bid-stack effect.” In those competitive markets, wholesale electricity prices in any given hour are determined by the bid price of the generating unit on the margin during that hour. For that reason, the operator of the regional electricity system first uses the lower-priced generators before calling on ones that offer power at higher prices.

Because some clean energy facilities, like wind farms, do not use fuel, they are able to offer their power at the lowest price, since there is no additional cost for operating them during a particular hour. Renewables effectively push the most costly fossil fuel unit that would have otherwise been dispatched off the top of the bid stack, reducing the marginal electric energy clearing price in that hour. The effect is most pronounced when renewables produce at times of peak electricity demand when costly and inefficient peaking plants would otherwise be called upon.

This price suppression effect can be substantial. Two different studies of the price suppression effect caused by the New York RPS—one by the New York State Department of Public Service in 2008 to project likely future price suppression impacts and the other by consulting firm Summit Blue in 2010 assessing the RPS during the mid-2000s—found that this one economic benefit was greater than the entire extra cost of the renewable energy certificates from the facilities built to meet the RPS.[5] The Massachusetts Department of Energy Resources reached a similar conclusion for the impact of that state's RPS.[6] Although the Summit Blue results may have been somewhat overstated, these studies suggest that an RPS can occasionally be a net economic winner for ratepayers based on this one factor alone. Even when price suppression does not outweigh the direct costs of an RPS, it certainly counterbalances some of those costs in markets where it plays a role. It is therefore useful to describe and explain this benefit.[7]

It is important to keep three caveats in mind about the price suppression effect:

1. It does not necessarily translate immediately into visible savings on ratepayers' bills on a one-to-one basis. That is because it can only be measured relative to what wholesale electricity prices would have been in the absence of the RPS (and can therefore only be calculated via modeling, never measured). Over time, however, the lower prices will be reflected in retail rates.

2. While price suppression is definitely a benefit to ratepayers, it is, in effect, a transfer payment from producers of electricity to consumers. Some market participants therefore do not benefit from price suppression.

3. Some analysts have concluded that the price suppression effect from a particular renewable energy development declines in magnitude over time as other resource expansion decisions are made and the electricity system adjusts to the increased capacity.

Increased Long-Term Rate Stability

A virtue of certain renewables—especially solar, water, and wind—is that they do not require fuel. Once a project gets installed, the future price of the electricity from that project is predictable and considerably more stable than from facilities that need to purchase fuel. In the case of some other renewable energy technologies—landfill gas, farm digesters, and geothermal—fuel is used, but its ongoing supply and cost is relatively predictable at the time the project is built.

All these renewable technologies make electricity rates less subject to swings in fossil fuel prices and make the system less vulnerable to shortages in the supply of fossil fuels.[8] But this benefit is different from most other renewable energy benefits in that cost savings are not guaranteed until fossil fuel prices exceed certain levels. In this case, renewables only lead to cost savings when the price of fossil fuels rises beyond the cost of the renewable energy generation. The price of the renewables remains stable but may be higher or lower than market prices for conventional generation at different points in the future.

Most fossil fuel price forecasts assume prices, including for natural gas, will rise in the long run. But even if those prices do not increase, there is still a value to the price and supply stability of renewables. The best way to think of this benefit is as insurance against the ***risk*** of high fossil fuel prices. As with any insurance, the condition insured against may not come to pass, but it is worth something to reduce the risk—especially when there is a high probability associated with it.

In-State Spending and Jobs

A renewable portfolio standard generally produces a range of in-state economic benefits that are distinct from any impacts on electricity rates. The various benefits should be included in a descriptive evaluation. Case studies of particular renewable energy projects or renewable energy businesses can be used to illustrate these benefits.

Although the benefits vary depending upon the structure of an RPS and conditions in a particular state, they generally include:

- ***Jobs connected to constructing, operating, and maintaining facilities***. Without trying to quantify all the jobs produced by the RPS, it can be useful to show how many people were directly required for one or more specific projects.

- ***Other jobs in the clean energy industry***. An RPS may cause businesses to locate or expand manufacturing facilities in the state in order to supply equipment and materials for renewable energy projects. There can also be jobs in other stages of the supply chain, including ones related to project development or equipment transportation. More broadly, an RPS may indirectly lead to increased jobs serving the clean energy industry, including ones related to financial, legal, research, and consulting services.

- ***Indirect economic impacts of in-state spending.*** To the extent that an RPS causes more money to be spent in the state, the spending causes multiplier effects that ripple through the economy. The businesses and individuals that receive the initial spending on renewables take the money and spend it on other things, some of which is spent in the state. That increases the level of economic activity in the state.

- ***Assistance to specific industries.*** Many RPSs have technology requirements or carve-outs that are designed in part to help particular industries that are important to the state. For example, the inclusion of biogas digesters may be part of a strategy to assist farmers. Any such efforts that are a part of an RPS can be described.

Reduced Transmission and Distribution Costs

Locally sited renewable energy projects can reduce the need for electricity companies to expand or upgrade the electricity transmission and/or distribution system because the locally produced distributed generation can eliminate the need to bring in additional power from outside the locality or region.[9] This economic benefit is real, but its size varies. It is greatest when utilities explicitly consider distributed generation in transmission and distribution planning, and when renewable energy installations are consciously placed in specific locations likely to lead to deferrals in transmission and distribution upgrades. When that is not done, the economic benefits can be small on a kilowatt-hour of generation basis. In any case, the economic benefits are difficult to quantify because it is necessary to calculate or estimate what would have happened without the renewable energy addition.

Other Benefits

There can also be other benefits of renewables, some of which may be specific to a particular state or region. For example, millions of trees in Colorado and other parts of the west have been killed or damaged by pine beetles, creating an increased risk of destructive and costly forest fires. Expanded use of wood for electricity generation can help with clearing the dead and dying trees, thereby reducing the risk of fire.

Costs

When using a description of costs and benefits approach, it is important to accurately describe potential RPS program costs, which may include the following:

Higher Electricity Prices

In many cases, it costs electricity suppliers more money to procure electricity from renewable energy facilities than from fossil fuel power plants, at current prices and taxation regimens. Most quantitative evaluations up to now have shown these costs to be small but real in the near term. An RPS evaluation should consider this impact.

Even if no detailed quantitative analysis is carried out, an evaluation can give a general sense of the possible impacts of the RPS. This can be done by referring to quantitative analysis from comparable states or by showing a range of possible outcomes. In many cases, just doing the latter can be reassuring because it will demonstrate that an RPS cannot possibly have had a significant impact on electricity rates. It is useful to point out that an RPS usually applies only to a small percentage of the electric load, thereby limiting its potential rate impact.

To illustrate this, let's take an example of a state that has required an additional 5% of electricity to come from renewables. And let's assume that half the retail cost of electricity is related to the electricity supply, with the remaining associated with system costs such as maintaining the transmission and distribution system. The increased cost of the renewable energy supply is spread out over the entire electricity service for which consumers pay. If electricity from renewable energy costs anywhere between 10% and 100% more than new fossil fuel generation, the range of possible impacts on average retail rates is anywhere from 0.25% to 2.5%. For a household with a monthly bill of $100, that means an extra near-term expense ranging from 25 cents to $2.50. Even using such gross estimation methods, most states would be able to come up with a narrower range of possible initial cost results than provided in this example.

In those states where there may be price suppression effects, it is, of course, very important to explain that price suppression may partially or fully cancel out the additional costs spent on procuring electricity supply from renewable energy facilities. And, if fossil fuel prices rise over time as discussed above, longer-term savings would begin to accrue.

Job Losses

Just as an RPS leads to some job gains, it may also lead to some job losses. There are two different ways in which this may happen:

- ***Jobs connected to abandoned conventional generation.*** To the extent that an RPS causes in-state conventional generating stations to close or reduce their operations, jobs may be lost related to operating, maintaining, and supplying those facilities. However, in a state where overall electricity demand is rising, an RPS may satisfy additional demand without causing any conventional generating stations to close.

- ***Indirect economic impacts of higher electricity prices.*** To the extent that an RPS causes electricity prices to rise, that has negative economic impacts. The businesses and people who are paying the higher prices have less money to spend on other things in the state. In the longer run, businesses that are energy-intensive will tend to locate in lower-cost states.

System Costs of Increased Renewable Energy Use

While renewable energy development provides some benefits to the electricity system (e.g., deferral of distribution upgrades), it can also impose some costs that may not be paid for by the renewable energy generators. These may vary depending upon the state, but they should be discussed and can include:

- ***Transmission upgrades.*** When renewable generating facilities are built in remote or distant locations, it may require the construction of additional transmission lines. Sometimes the cost of transmission is paid for by the renewable energy developer or otherwise included in the price of the electricity from the facility. If that is not the case and the cost of the added transmission is included in the base cost for the electricity system, it needs to be acknowledged as an extra cost and considered separately.

- ***Integration costs.*** There are two ways in which renewable energy can make it more complicated for independent system operators and utilities to manage the electricity system. First, generation from wind and solar facilities is variable and uncertain, and that requires additional planning and perhaps operational changes. Second, to the extent that renewables increase the number of small distributed generation installations coming online, they can increase the transaction costs for utilities to handle interconnection and the ongoing integration of those installations into the system.

- ***Planning and operating reserves.*** In terms of planning reserves, as the amount of variable generation, such as wind and solar, gets added to the electricity system, it is possible that more peak-power units or more natural gas projects will be needed in the system portfolio in order to maintain reserve requirements. In addition, at any given time, system operators may need to have a greater amount of operating reserve either available or online to be able to handle the incremental variability of the difference between instantaneous load and generation. The National Renewable Energy Laboratory (NREL) has done considerable research into integrating large quantities of variable wind energy into the electricity system and has produced many relevant publications, some of which include data on the projected costs of reserves for integrating different amounts of wind and solar into the electricity supply in particular regions.[10]

Approach Two:
An Electricity Rate Study

When states have tried to quantify the costs and benefits of an RPS, they have most frequently focused on its impact upon electricity rates. That is partly because there is often solid data for calculating this impact, but also because public utility commissions and legislatures are concerned about the effect of their policies on rates.

This was the approach required by the Minnesota state legislature for the filings that were described earlier in this report. The Michigan Public Service Commission also took this approach in a report earlier this year.[11]

How to determine the rate impacts depends upon the state. In the case of competitive markets, there will either be full, partial, or only suggestive data on the price that electricity suppliers paid for renewable energy certificates. In regulated markets, cost information may be available in rate requests and other filings to the public utility commission. Alternatively, as in the case of Minnesota, the public utility commission can ask utilities to make special filings providing cost data. In all cases, there should be some assessment of whether or not there were any price suppression effects, because that could be an important factor influencing net rate impacts. Ideally, a rate impact study should include a reference case for comparison. This would show what would have happened in the absence of the RPS.

Because an RPS should not ultimately be judged solely on its near-term impact on rates, it is best to supplement a rate study with some additional information—even if only descriptive—covering other benefits and costs of the RPS, including likely longer-term cost savings. In that way, to the extent that there is a negative initial rate impact, policymakers, stakeholders, and the general public will be reminded of the specific benefits the state will receive over time from having the RPS.

Approach Three: Building Blocks

The simplest, least expensive way to quantify the total economic benefits and costs of an RPS is to use a building block approach. With this method, each of the different types of costs and benefits covered in the descriptive method (approach one) is quantified separately.

When taking this approach, the evaluator identifies the most appropriate data source and calculation method for each of the cost and benefit categories. Because different data sources are used for different pieces of the calculation, this approach yields approximate results.

There are both basic and more elaborate ways to quantify the various building blocks. A relatively simple, low-cost method is outlined below for a state with a modest budget for RPS evaluation. If more funding is available, professional evaluators can use more sophisticated methods for some of the building blocks.

The Building Blocks

Benefits	Costs
Improved environment	Higher near-term electricity prices
Price suppression effects	Job losses
In-state spending and jobs	System integration costs
System benefits	

Improved Environment

When taking the building blocks approach, a state needs to decide whether or not to assign monetized values to the environmental improvements achieved by the RPS. Certain audiences will be more comfortable with an assessment that includes the economic implications of environmental actions, while other audiences will not. Environmental advocates and some legislators may be unhappy if environmental impacts are ignored, but other legislators or business groups may feel that it is inappropriate to count reduced pollution as a quantifiable economic benefit.

A state that decides to place dollar numbers on the positive environmental impacts of an RPS should acknowledge the difficulty of this task and the limitations associated with any methodology. It might proceed by first quantifying the emission reductions caused by the RPS, using one of the methods described in the EPA report mentioned above. It would then place a dollar value on the reductions.

One common, relatively simple method for doing so is to estimate the "health benefit value per ton of emissions" (also referred to as the "benefit per ton") and then multiply that value for each ton of emissions reduced. EPA has produced estimated values for various air pollutants.[12]

That method can work well for toxic air pollutants such as particulates, carbon monoxide, and sulfur dioxide. It cannot be applied to carbon dioxide, for which immediate health impacts are not easily measured and are not the biggest concern. Instead, for carbon dioxide, a building blocks study could determine the marginal cost of controlling those emissions or apply a frequently used value, such as $20 per ton.

A variant on this method is to use the trading value of any allowances or credits associated with the pollutants. A recent Illinois RPS cost-benefit study used this approach and valued nitrogen oxides at $10,000 per ton and carbon dioxide at $5 per ton.[13]

Reduced Electricity Prices from Price Suppression Effects
There are several different ways in which this can be calculated, if it is a relevant factor in a particular state. The conventional approach is a relatively straightforward comparative run of production cost models with and without the additional renewables.[14]

In some cases, state regulators or evaluators have already determined the price suppression effect for energy efficiency programs. Those calculations can be used as the basis for determining any price suppression from renewables brought online by an RPS.[15] To account for the variability of certain technologies, the impact of renewables would need to be weighted for season and time of day. Solar, which tends to generate much of its electricity at or near peak times, has an enhanced price suppression effect, while wind turbines, which generate more of their power off-peak, have a reduced price suppression effect.

If price suppression has not been previously calculated for a state's efficiency programs, it may be possible to build on data from a nearby state that has made such calculations, assuming that the state is part of the same regional electricity system.

In-State Spending and Jobs
To quantify the economic benefits to the state from constructing and operating renewable energy facilities, it is first necessary to determine how much generation was built in the state because of the RPS. How to do that will vary depending upon the way the RPS is structured. In the case of the two states with a central procurement model—Illinois and New York—the procuring agency knows exactly which facilities it supported. For New York, developers seeking RPS support are required to submit detailed information about direct economic benefits, including the number of jobs they expect to create when constructing and operating their facilities.

States that do not have as much specific, detailed information about individual projects are still generally able to identify the amount of RPS-eligible electricity that was generated in the state and the types of technologies that were used to generate that electricity. But they cannot necessarily take credit for all the facilities that generated the electricity, since some may have been in existence before the RPS was established. The RPS should only count jobs created at new facilities constructed after the start of the RPS, unless there is clear evidence that some of the earlier facilities would have closed down or reduced operations without the RPS.

Once a state has determined the amount of in-state generation that can be directly attributed to the RPS, it can use representative capacity factors to translate generation data into numbers of installations by technology. That information then needs to be translated into the number of direct jobs linked to that generation and further to the indirect economic benefits from creating those jobs and spending money in-state.

The National Renewable Energy Laboratory has created Jobs and Economic Development Impact (JEDI) models which are designed to do precisely this task. NREL offers models for biofuels, concentrating solar, photovoltaics, wind, and marine and hydrokinetic power. JEDI models estimate project development and onsite labor impacts; local revenue and supply chain impacts; and induced impacts from increased spending as the money that goes to the renewable energy facility ripples out into the local economy.

To the extent that RPS evaluators have project-specific data on costs (i.e., construction costs, equipment costs, maintenance costs, and financing costs for RPS-supported renewable energy projects), they can substitute that data for the default values in JEDI. They can also adjust the proportion of project spending that is purchased locally in order to reflect local realities.

The JEDI models are available for free on the NREL website and are easy to use. These simple tools will not give as comprehensive an analysis as more complex, multi-faceted economic models, and they cannot calculate negative impacts from higher electricity prices, but they can be useful to a state that wishes to carry out a building blocks evaluation on a modest budget.[16]

Higher Electricity Prices

A generic input-output model, such as RIMS II or IMPLAN,[17] can be used to quantify some of the economic impacts of any higher or lower electricity rates caused by an RPS for a specific time period. Those models supply "multipliers," which show how changes (jobs, earnings, or sales) in one industry ripple through other industries in a regional economy at a fixed point in time.

These models can be used to estimate some of the economic effects of changes in household income and spending caused by higher electricity rates (or of lower rates if an RPS leads to overall price reductions). It is harder to determine the impact of changes in commercial and industrial rates, because different industries have different multipliers, reflecting the fact that some industries spend more of their money within a state than others do. Without doing a full economic modeling study of the state, an evaluator can use an average multiplier that is determined by first finding the multipliers for a range of relatively important industries and commercial sectors in the state.

A recent evaluation of the Maine RPS used an interesting variant on this method. The researchers from the firm of London Economics International used RIMS II for households, but then included case studies of two important local industries—tourism and paper and pulp manufacturing. This allowed them to discuss the complicated ways in which higher prices might affect those industries. For example, in the case of paper mills, competition with global competitors may make it difficult for them to pass on the higher rates to customers, but the higher electricity prices could cause them to curtail production or take steps to make their operations more energy efficient. [18]

Both RIMS II and IMPLAN are limited to measuring economic impacts at a specific point in time, which can be a serious drawback when modeling costs and benefits that can extend 20 or 30 years into the future. This limitation prevents these models from measuring full feedback loops from changes in the economy that can influence longer-term business investment due to regional energy price differentials.

Job Losses

Some of the job losses from higher electricity prices would be captured by the above use of a simple input-output model that includes both direct and indirect economic impacts of higher electricity prices. Job losses associated with reduced production from conventional electricity generators need to be assessed separately.

The first step is to determine whether the RPS caused any in-state conventional generators to close or reduce operations. If that is the case, the evaluator can perhaps find out the exact number of jobs that were lost or can make an estimate of the extent to which income has declined for those facilities. The industry code for "electric power generation, transmission, and distribution" can then be used in RIMS II or IMPLAN to calculate the number of lost jobs and some of the other negative economic effects.

System Benefits and Costs

The various system costs and benefits (e.g., integration costs, lower transmission and distribution costs) are likely to be smaller economic factors than the other costs and benefits already discussed in this section. For an evaluation that is being carried out on a modest budget, it is reasonable to assume that the various system benefits and costs balance out. Or an evaluation can use studies in other locations to develop a range of estimated costs and benefits.

For a more elaborate evaluation or if there is reason to believe that a particular system benefit or cost is especially significant, it may be necessary to carry out special analyses that include such costs and/or benefits.

The Bottom Line

After all the building blocks have been quantified, it should be possible to tally up the individual totals to get a bottom-line net result for the RPS.

When considering whether or how to undertake a building blocks study, it is good to keep the following in mind:

- Choose an experienced evaluator who has conducted previous cost-benefit studies for satisfied clients. This will increase the likelihood that you will get a sound report that can withstand critical scrutiny. In your search for an experienced evaluator, you may discover one who has already done some related analysis of the state's economy. That could reduce the amount of new work, thereby holding down the cost of the evaluation.

- Make sure you understand the research methods the evaluator will use. Ask the evaluator to explain the advantages and limitations of those methods.

- Because the study will produce approximate results with a considerable margin of error, it is important to avoid implying that the findings are more accurate and precise than they are. It is best to present the results as an approximation or a range. For example, rather than state that the RPS raised electricity rates by 1.16%, provided $20,126,322 in economic benefits, and created 1,412 jobs, a study might indicate that the RPS increased rates by slightly more than 1%, provided about $20 million in economic benefits, and created between 1,200 and 1,600 jobs.

Past versus Future

Some quantitative cost-benefit evaluations of an RPS look only at those costs and benefits that have occurred up to the time of the evaluation (or up to some logical date in the recent past). Other evaluations also consider the future. Sometimes a legislature or RPS governing authority wants to project how much the RPS will cost in coming years. In addition, because the facilities constructed because of the RPS will last for a long time, it can be appropriate to assess the impacts on the state's electricity system and economy over the entire life of those facilities. Often, the greatest benefits will occur in the future, when fixed-price renewable energy becomes less expensive than rising fossil-fuel-powered generation.

Any consideration of the future complicates the evaluation, however, because it is difficult to predict far into the future with accuracy. It is notoriously challenging to predict future electricity prices and it may even be hard to pinpoint the amount of generation that will come from the installed renewable energy, because the specific equipment may not have a long enough track record to predict performance degradation or maintenance needs.

When considering these important complicating factors, it can be useful to do the following:

- Have the evaluator specify and justify key predictions of the future, involving such factors as fuel prices, electricity rates, electricity consumption, and equipment performance. Make sure that you believe that those assumptions are reasonable and defensible.
- Ask the evaluator to assess more than one scenario. Even if you agree that a certain set of assumptions about the future represents the most likely scenario, there remains considerable possibility that future events will prove those assumptions wrong. You should therefore encourage the evaluator to consider and produce results for other plausible scenarios (e.g., different natural gas prices). Primary benefits of using more robust economic models, such as the ones discussed below under Approach Four, are their ability to consider changes over time and their ability to develop alternative scenarios using a range of economic assumptions.

Approach Four: Economic Modeling

This approach is a variation on the building blocks approach, but it uses a single econometric and input/output model to calculate all the direct and indirect economic impacts. Ideally, a dynamic, multi-faceted model such as REMI,[19] REDYN,[20] or a comparable state-specific model, would be used. A static input-output model like IMPLAN could also be used, but the results will be less robust, in part because it will not reflect changes over time and does not include important feedback loops that are included in the more complex models.

There are two factors to consider when deciding whether to use this approach:

1. **Cost.** A comprehensive regional economic modeling study of RPS impacts can cost from $20,000 to as much as several hundred thousand dollars. Among the variables affecting this cost are whether there is an existing economic model of the state that is available to the evaluator, whether there is an economic modeling study focused on the electricity system in the state that is available to the evaluator, and the extent to which accurate local data is available to be used as critical models inputs. If the evaluator has to purchase a relatively expensive model, such as REMI, extensively modify it for use in measuring RPS impacts, and generate accurate local input data, the project is usually much more expensive.

2. **Data quality.** The results generated by an economic model will only be as good as the data that goes into it. If there are significant uncertainties in the input data, it will not justify undertaking an intensive economic modeling study. Often, more than 90% of the effort involved in a comprehensive economic analysis is spent on researching, collecting, and creating high-quality data for input into an econometric and/or input-output model. The data includes the annual rate impacts of the RPS (as reflected in REC prices or utility contracts, and including any price suppression effects), the quantity and type of generation built or expected to be built in the state as a direct result of the RPS, and annual flows of local labor and materials used in the construction, maintenance, and operation of this additional generation capacity. Considerable detail regarding all of these data inputs (e.g., rate impacts by ratepayer type; exact specifications for existing or anticipated new generation facilities, including all interconnection expenditures; types of jobs, expected salaries, and detailed operational and construction expenditure data; and the local manufacturing potential that exists in a state or region for production of demanded components) are required in order to have high-quality model output.

In some cases, the data may be provided by the RPS administrator or other public sources. If the economic modeling expert is required to develop the data, it can add substantially to the cost. In the most detailed energy demand models, hourly system dispatch models are used in conjunction with the economic models in order to measure energy prices and thus rate impacts with a high degree of precision.[21] This is especially important in evaluating variable electricity generation sources, such as wind and solar.

When considering whether or how to undertake an economic modeling study, it is good to keep the following in mind:

- Any quantitative model that tries to replicate real-life phenomena in something as complicated as a state economy will have inherent limitations and imperfections. Unless considerable effort is expended in developing high-quality data inputs, the ensuing analysis may yield results with a considerable margin of error. Nevertheless, quantitative analysis using complex models of the economy remains the best way to approximate likely impacts under various sets of assumption and thereby understand likely "real world" impacts. Unsurprisingly, the more thorough and comprehensive the model, the more expensive it will be. When high-quality output and analytic integrity are critical to an RPS study, it can be worth the added expense.

- As with a building blocks study:
  - It is best to choose an experienced evaluator who has conducted previous cost-benefit studies for satisfied clients. If you have access to a particular state or regional economic model, you would likely want to look for an evaluation firm that has experience with it. Or you can look for an evaluator who already has a subscription to a relevant regional economic model so that you would not have to pay for that as part of the cost of the evaluation.[22] And you may be able to find an evaluator who has already done related analysis of the state's economy.
  - Make sure you understand the advantages and limitations of the research methods the evaluator will use.
  - Avoid implying that the results are more accurate than they are and present the results as a range or set of ranges associated with various model input assumptions.

- Compare the findings to those from RPSs in other nearby or comparable states. If the findings are significantly different, make sure that the evaluator can provide a logical explanation for the differences.

Appendix A: Description of Models Used in Cost-Benefit Evaluations

This appendix discusses four models that evaluators frequently use in studies of renewable energy's impact on the economy—IMPLAN, RIMS II, JEDI, and REMI. Other models have been developed for particular states, such as ILREIM for Illinois, but they tend to be similar in approach to one of the models discussed below. All of the models attempt to apply mainstream (neoclassical) economic theory using mathematical equations and economic data. In some cases, customized regional economic models may also be developed for specific analytic applications. Firms that perform such customized contract work include Moody's Analytics and IHS Global Insight.

IMPLAN

IMPLAN is an input-output model that was developed by the US Forest Service and is now marketed as a commercial software package by an independent company, the Minnesota IMPLAN Group.[23] Input-output analysis is a useful analytical approach for measuring most economic impacts.[24]

Like other input-output models, IMPLAN divides the economy into a large number of industry and commodity sectors, in this case the 528 standard industrial classifications. It then tracks the flow of money—inputs and outputs—between them. A portion of the input (i.e., purchases) of one industry will appear as an output (i.e., sales) of another industry. For example, steel is an input of the wind industry, but is also an output of the steel industry. The input-output model measures how a change in one part of the economy will ultimately affect other parts based on these purchasing and selling relationships.

The main source data for all such models in the United States is the Industry Economic Accounts, especially the Annual and Benchmark Input-Output Accounts, produced by the Bureau of Economic Analysis (BEA), which in turn depends on data from other federal agencies. BEA produces tables that summarize at the national level which industries produce and consume which commodities and services. BEA updates its national accounts every five years.

These tables are then "regionalized" using each region's own industry mix and other information. This regionalization would ideally be based on a survey that asked every individual business about its suppliers and major clients. The responses would then be added up by industry. Because such a survey is not practical, IMPLAN and the other input-output models use non-survey techniques that rely on various regional data sources, including its industry mix.[25]

IMPLAN calculates local "multipliers," which show how changes (jobs, earnings, or sales) in one industry ripple through other industries in a regional economy. For example, a jobs multiplier of 2.1 for the photovoltaic industry in a state means that a change of 100 jobs in the PV industry would lead to a total change of 210 jobs (2.1 x 100) in the whole regional economy

IMPLAN is relatively inexpensive and is easy to work with. But as a model of a regional economy it has considerable limitations, especially when trying to measure changes extending into the future. Most importantly, simple input-output models are static and do not consider the inherent changes over time in a dynamic economy. For example, IMPLAN assumes that there are no supply constraints and that the relationship between industries is constant. In other words, the model would not have projected the mid-2000s situation where increased demand for photovoltaic panels led to rapidly rising silicon prices. The model also simplifies geographic differences by using national data that assumes that products are made the same way in all regions, even though such factors as wage rates, land costs, energy prices, transportation costs, and water scarcity could encourage a particular industry to use different inputs in one part of the country than another. In addition, the model looks at a state or region as a whole and places impacts either entirely inside or outside the region, even though there could be significant variations. For example, the model does not recognize that more of the money spent on home construction in a border community may slip out of state than in a town in the center of the state.[26]

RIMS II

The Regional Input-Output Modeling System (RIMS II) is similar to IMPLAN, but is somewhat less sophisticated. It uses the Bureau of Economic Analysis's input-output tables and is available from the Bureau for a nominal cost. As an example of how it is simpler than IMPLAN, it uses only one household type rather than nine. In addition, users cannot directly access the database; they can only generate and use multipliers. However, for some projects, simply having and using the multipliers is sufficient.[27]

JEDI

Jobs and Economic Development Impact (JEDI) is based on IMPLAN and focuses specifically on energy projects. There are JEDI models for wind, concentrating solar, PV, biofuels, coal, natural gas, and marine and hydrokinetic power projects. These models were developed by the National Renewable Energy Laboratory (NREL) as "user-friendly tools that estimate the economic impacts of constructing and operating power generation and biofuel plants at the local and state levels."[28]

For each project, JEDI estimates the number of in-state construction jobs and looks at three categories of economic impacts: (1) project development and onsite labor impacts; (2) local revenue and supply chain impacts, and (3) induced impacts, which are changes in household spending as income increases because of the renewable energy project.[29]

The models operate in Excel and are easy to use. They include default values that NREL chose based on interviews with project developers, state tax representatives, and others in the electric power industry. As NREL describes the methodology, "All JEDI models apply the same basic user interface. Users download the appropriate JEDI model and then enter basic information about a project, including the state, location, year of construction, and facility size. The model then estimates default project costs (i.e., static expenditure categories), and the economic impacts in terms of jobs, earnings (i.e., wages and salary), and output (i.e., value of production) resulting from the project."[30]

Users of the JEDI models have the option of replacing the default values with project-specific data on such things as construction costs, equipment costs, maintenance costs, and financing. They can also adjust the proportion of project spending that is purchased locally in order to reflect project-specific realities.

Although default JEDI estimates regarding typical expenditure flows by project type and region may be useful when no other source data exist, they rarely reflect actual project costs or local labor and materials costs. Where possible, users should determine these by examining specific expenditure flows from actual projects, supplemented with related research and survey-based data for determining local manufacturing input potential.

JEDI has the same limitations as other input-output models, but it is also limited to looking at the positive job and other economic impacts of projects. It cannot be used to analyze the negative impacts on the economy of ratepayer or taxpayer-funded financial incentives. In other words, JEDI can estimate benefits of a project, but not costs. For this and other reasons, JEDI is most useful for understanding the types of positive impacts a project or program will likely have and for making comparisons between projects or programs. It can also be used as one part of a building blocks approach to a cost-benefit study.

REMI

The REMI model is maintained and distributed by a private company, Regional Economic Models, Inc. It incorporates aspects of four major modeling approaches: input-output, general equilibrium, econometric, and new economic geography.

Each of these methodologies has distinct advantages as well as limitations when used alone. REMI's integrated modeling approach makes it more robust than an input-output model like IMPLAN. For example, the economic geography aspects of REMI incorporate the spatial dimension of the economy. That allows the model to consider such things as the different transportation costs and specialized labor costs for businesses in different locations. The general equilibrium properties of the model incorporate the relationships between such variables as tax policies, regional prices, and competitiveness. Of critical importance, REMI measures impacts and allows model inputs over specific time periods. The time dimension is often critical in examining RPS costs and benefits; impacts can vary significantly depending upon the time frame under consideration.

The REMI model is customized to each region of the country using historical economic data going back to 1990 provided by the US Bureau of Economic Analysis, the US Bureau of Labor Statistics, and the Census Bureau. Users can input changes to consumption, employment, output, income, productivity, fuel costs, production costs, wage rates, and other variables. The output variables include employment, compensation, wage and salary disbursements, relative cost of production, productivity, imports and exports, and output.

REMI consists of five blocks: (1) output and demand, (2) labor and capital demand, (3) population and labor supply, (4) compensation, prices, and costs, and (5) market shares.

Appendix B:
Sample RPS Evaluation Reports

Hicks, Liz et al. *New York Main Tier RPS Impact & Process Evaluation.* Burlington, MA: KEMA, 2009. Available at www.nyserda.ny.gov/Page-Sections/Energy-and-Environmental-Markets/Renewable-Portfolio-Standard/~/media/Files/EDPPP/Energy%20and%20Environmental%20Markets/RPS/RPS%20Documents/kema-rps-eval-090330.ashx.

Illinois Power Agency. *Annual Report: The Costs and Benefits of Renewable Resource Procurement in Illinois under the Illinois Power Agency and Illinois Public Utilities Act.* Springfield: Illinois Power Agency, 2012. Available at www2.illinois.gov/ipa/Documents/April-2012-Renewables-Report-3-26-AAJ-Final.pdf.

Kessler, Josh and Lisa Petraglia. *NYSERDA Main Tier RPS Economic Benefits Report.* Burlington, MA: KEMA, 2008. Available at www.nyserda.ny.gov/en/Page-Sections/Energy-and-Environmental-Markets/Renewable-Portfolio-Standard/~/media/Files/EDPPP/Energy%20and%20Environmental%20Markets/RPS/History/main-tier-rps-eco-benefits-rpt.ashx.

LaCapra Associates. *North Carolina's Renewable Energy Policy: A Look at REPS Compliance to Date, Resource Options for Future Compliance, and Strategies to Advance Core Objectives.* Boston: LaCapra Associates, Inc., 2011. Available at http://www.lacapra.com/downloads/NC_EPC_REPS_Report2011.pdf

London Economics International LLC. *MPUC RPS Report 2011 - Review of RPS Requirements and Compliance in Maine.* Boston: London Economics International LLC, 2012. Available at www.maine.gov/tools/whatsnew/attach.php?id=349454&an=1

Michigan Public Service Commission. *Report on the Implementation of the P.A. 295 Renewable Energy Standard and the Cost-Effectiveness of the Energy Standard.* Lansing: Michigan Public Service Commission, 2012. Available at www.michigan.gov/documents/mpsc/implementation_PA295_renewable_energy2-15-2012_376924_7.pdf.

Endnotes

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[1] For a summary of the utilities' reports, see Dan Haugen, "Mixed rate impact from MN renewable energy standard," *Midwest Energy News* (November 2, 2011). Available at www.midwestenergynews.com/2011/11/02/minnesota-utilities-report-mixed-rate-impact-from-renewable-standard. The utilities' reports are available on Minnesota Department of Commerce's eFiling at www.edockets.state.mn.us/EFiling/edockets/searchDocuments.do?method=eDocketsResult&userType=public.

[2] For a listing and discussion of common benefits that drive renewable energy policies, see Robert C. Grace et al., *When Renewable Energy Policy Objectives Conflict: A Guide for Policymakers* (Silver Spring, MD: National Regulatory Research Institute, 2011). Available at http://www.nrriknowledgecommunities.org/documents/317330/674ced16-69a0-46a1-8cd8-4ca2d5a15f41.

[3] US Environmental Protection Agency, *Assessing the Multiple Benefits of Clean Energy: A Resource for States* (Washington: US EPA, 2010), Chapter 4: "Assessing the Air Pollution, Greenhouse Gas, Air Quality, and Health Benefits of Clean Energy Initiatives," pp, 93-132 Available at www.epa.gov/statelocalclimate/resources/benefits.html.

[4] Ryan Wiser and Mark Bolinger, "Can Deployment of Renewable Energy Put Downward Pressure on Natural Gas Prices?" *Energy Policy* (December 27, 2005), pp. 295-306.

[5] Frank Stern et al., *New York Renewable Portfolio Standard Market Conditions Assessment: Final Report* (Boulder, CO: Summit Blue Consulting, LLC, 2009), pp. 4-142 – 4-155. www.nyserda.ny.gov/en/Page-Sections/Energy-and-Environmental-Markets/Renewable-Portfolio-Standard/~/media/Files/EDPPP/Energy%20and%20Environmental%20Markets/RPS/RPS%20Documents/market-conditions-final-report.ashx

[6] Executive Office of Housing and Economic Development and Executive Office of Energy and Environmental Affairs, *Recent Electricity Market Reforms in Massachusetts: A Report of Benefits and Costs* (Boston: Executive Office of Housing and Economic Development and Executive Office of Energy and Environmental Affairs, 2011), pp. 23-24. Available at www.mass.gov/eea/docs/doer/publications/electricity-report-jul12-2011.pdf

[7] For a general but technical analysis of the price suppression effect, see Frank A. Felder, "Examining Electricity Price Suppression Due to Renewable Resources and Other Grid Investments," *The Electricity Journal* (May 2011), pp. 34-46.

[8] Compared to other renewables, facilities that use woody biomass have a greater connection to fossil fuel prices and supplies. For one thing, the demand for wood can go up when fossil fuel prices rise, since users switch to wood. Moreover, the cost of harvesting and transporting wood

goes up. The price and supply of wood are therefore partially but not fully linked to fossil fuel prices.

[9] For a general discussion of this topic, see Dana Hall et al., "Capturing the Value of Distributed Generation for More Effective Policymaking," paper presented at ASES National Solar Conference 2009. Available at http://www.law.pace.edu/energy/ASESfinalsubmission.pdf.

[10] For links to NREL's many publications on wind integration, go to: www.nrel.gov/wind/systemsintegration/publications.html#staff. For a good overview of the issues related to operating reserves, see a presentation by Michael Milligan of NREL: "Variable Reserve Generation Impact," presentation to the RMEL 2011 Spring Management, Engineering, and Operations Conference, May 17, 2011. Available at: www.nrel.gov/wind/systemsintegration/pdfs/2011/milligan_variable_impact_operating_reserves.pdf.

[11] Michigan Public Service Commission, *Report on the Implementation of the P.A. 295 Renewable Energy Standard and the Cost-Effectiveness of the Energy Standard* (Lansing: Michigan Public Service Commission, 2012). Available at www.michigan.gov/documents/mpsc/implementation_PA295_renewable_energy2-15-2012_376924_7.pdf.

[12] See, for example, the benefit per ton estimates for particulate matter 2.5 at www.epa.gov/air/benmap/bpt.html.

[13] Illinois Power Agency, *Annual Report: The Costs and Benefits of Renewable Resource Procurement in Illinois under the Illinois Power Agency and Illinois Public Utilities Act* (Springfield: Illinois Power Agency, 2012), pp. 22-23. Available at www2.illinois.gov/ipa/Documents/April-2012-Renewables-Report-3-26-AAJ-Final.pdf.

[14] For an example of this approach, see the November 2010 petition of National Grid to the Massachusetts Department of Public Utilities related to the Cape Wind project: www.env.state.ma.us/dpu/docs/electric/10-54/112210dpufnord.pdf.

[15] The consulting firm Sustainable Energy Advantage (SEA) used this approach when estimating the likely price suppression effect for a possible Vermont RPS. SEA started with the calculation of DRIPE (demand reduced induced price effects) in a 2011 study of avoided energy costs in New England, which was commissioned by the region's major utilities and energy efficiency program administrators. The SEA analysis is in Clean Energy States Alliance and Sustainable Energy Advantage, *Analysis of Renewable Energy Policy Options for Vermont: The SPEED Program and Renewable Portfolio Standard* (Montpelier: CESA, 2011), pp. 101-103. Available at www.cleanenergystates.org/assets/2011-Files/States-Advancing-RPS/NARUC-coverVT-SERCAT-final-rep-Sept-20111.pdf. For the avoided cost study, see Rick Hornby et al., *Avoided Energy Supply Costs in New England: 2011Report* (Cambridge: Mass.: Synapse Energy Economics, 2011). Available at www.synapse-energy.com/Downloads/SynapseReport.2011-07.AESC.AESC-Study-2011.11-014.pdf.

[16] Appendix A includes a more complete description of JEDI, as well as information about the ways in which it is similar to and different from other economic models used in cost-benefit studies of renewable energy.

[17] These models are described in Appendix A.

[18] The two Maine case studies are suggestive and the report includes a good description of its methodology for using RIMS II. See London Economics International LLC, *MPUC RPS Report 2011 - Review of RPS Requirements and Compliance in Maine* (Boston: London Economics International LLC, 2012), pp. 59-65. Available at www.maine.gov/tools/whatsnew/attach.php?id=349454&an=1

[19] REMI is described in Appendix A.

[20] REDYN is an excellent model that is considerably less expensive that REMI, but it does not offer nearly as extensive customer support. See www.redyn.com.

[21] See, for example, an analysis of alternative energy investment paths that was requested by the Vermont Legislature related to the possible closure of the Vermont Yankee nuclear power plant: Economic & Policy Resources, Inc. and Kavet, Rockler & Associates, LLC, http://www.leg.state.vt.us/jfo/envy/Economic%20Analysis%20-%20Executive%20Summary10.pdf

[22] In the case of REMI, it is not possible for an evaluator to use an existing license with one client for work with another. Each individual client must purchase the model. IMPLAN and RIMS II have much more flexible licensing arrangements and allow evaluators to purchase one geographical unit and use it with as many clients as they want.

[23] For more information about IMPLAN, see the company's website: www.implan.com.

[24] For an extended guide to input-output analysis, see M. Henry Robison, *Input-Output Guidebook: A Practical Guide for Regional Economic Analysis* (Moscow, ID: Economic Modeling Specialists Inc., 2009). Available at www.economicmodeling.com/wp-content/uploads/emsi-io-guide-1.pdf.

[25] *Ibid*., p. 7.

[26] Some of the limitations of IMPLAN are discussed in a presentation by Doleswar Bhandari and Jeffrey Mitchell, "Regional Economic Impact Analysis: Simplifying Assumptions to Manage a Complex Task" presentation at the University of New Mexico Bureau of Business and Economic Research Data Users Conference, November 6, 2008; available at http://bber.unm.edu/presentations/Mitchell.pdf.

[27] For more information about RIMS II, see the Bureau of Economic Analysis's website at www.bea.gov/regional/rims. For a comparison of RIMS II and IMPLAN, see http://implan.com/V4/index.php?option=com_multicategories&view=article&id=665:665&Itemid=10.

[28] NREL's JEDI website: www.nrel.gov/analysis/jedi; accessed April 29, 2012. The site includes information on the JEDI methodology and sample publications that have used the models. The models are available for free downloading.

[29] About JEDI models: www.nrel.gov/analysis/jedi/about_jedi.html; accessed April 29, 2012.

[30] Ibid.

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