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Assessing the Costs and Benefits of Renewable Portfolio Standards: A Guide for Policymakers

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Executive Summary

More than half the states have renewable portfolio standards in place requiring certain and growing percentages of electricity to come from specified sources. Are these policies providing society with measurable benefit? Are they too costly for what they provide? In an attempt to answer this fundamental question, the National Renewable Energy Laboratory and Lawrence Berkeley Laboratory published a survey of estimates from the state regulatory agencies and utilities entitled *A Survey of State-Level Costs and Benefits of Renewable Portfolio Standards*. Unfortunately, the *Survey* failed to assess the quality of the estimates and ends up potentially misleading policymakers. The *Survey* has a number of structural and conceptual problems:

- Cost estimates include only direct costs to utilities. Other market participants and non-participants carry much of the cost of renewable portfolio standards. Further, the *Survey* counts the costs for only two years (2010–2012), while counting the benefits for 30 years or more.
- Neither costs nor benefits occur in a consistent manner over time. The *Survey*'s selection of the time-frames magnifies the false impression that benefits are near equal to, or exceed, costs.
- The *Survey* is incomplete with respect to the cost of integration of intermittent and volatile generation sources. Specifically it ignores the cost of backup capacity and the lost efficiency of power plants required to balance the output of intermittent and volatile generation. (With wind energy, "backup" is required to operate during periods when the wind is

not blowing; “balancing” is required during periods when the wind is blowing but not at a very constant speed.)

- The *Survey* does not include environmental impacts that create non-monetized costs, such as noise pollution and avian mortality. Increased noise pollution, in addition to its own health impact, reduces the aesthetics of neighborhoods with renewable installations, thus reducing property values and property taxes to local governments.
- Higher electricity rates caused by RPS lead to reduced discretionary income for ratepayers, which in turn may lead to premature mortality. This phenomenon is especially regressive (that is, it harms poor people more than wealthy people).
- The *Survey* ignores the cost associated with causing prematurely “stranded” assets in the existing fleet of power plants due to lowered capacity factors. RPS effectively wastes useful and serviceable power plants (and the embodied energy and emissions that went into building them), because they will no longer be used at the capacity for which they were designed.
- The *Survey* ignores costs for backup and balancing of intermittent and volatile renewables that are shifted to neighboring states.
- Similarly, the *Survey* ignores the very expensive Production Tax Credit that shunts almost half of the cost of wind installations onto taxpayers (many of whom realize zero benefit from wind installations) made even worse by special tax depreciation available only to certain renewables.
- The *Survey* is silent on lost opportunity. There are commercially available technologies that can achieve the same or better primary objectives (price stability, environmental improvements, etc.) than the specified favored renewables included in RPSs.
- The *Survey* assumes that all renewables installed during the period in which RPSs have been in place were the result of the RPSs and that without the RPSs there would have been zero new renewables. This is clearly an error, as renewables were in fact installed prior to any RPS, when market participants found specific installations cost-effective. In some states, there was as much renewable generation, in percentage terms, prior to imposing the RPS as there was after.
- Some benefits noted in the *Survey,* including inflated benefits and incomplete netting, are speculative and self-fulfilling rather than meaningful. For example, one RPS benefit claimed is an increase in diversity, even if that supply diversity provides no price hedging,

reduction of emissions or other actual benefit. It presumes diversity is a goal and benefit in and of itself.

- The benefit estimates also suffer from double counting. Double counting is especially prevalent with emission reductions, as those benefits (and their costs) have already been accounted for in such regulatory programs as Clean Air Act Regulations. The majority of the dollar benefits from emission reduction cited in the *Survey* are from reductions of carbon dioxide "priced" at the EPA's highly controversial "social cost of carbon."

Some renewable energy technology installations conserve resources and some don't: some are efficient and some are not. Renewable portfolio standards (further exacerbated by various federal tax treatments and local subsidies) fail to recognize this distinction and foster the development of inefficient installations, thereby discouraging the use of more efficient and environmentally effective facilities. For example, most of the compliance with state-level RPSs has come in the form of wind energy. Wind energy is unpredictable and volatile, leading to lower value and imposing significant costs on others. Advocating for RPS reveals the belief by proponents that the market would not otherwise embrace cost-effective, resource-conserving installations of renewables. History proves otherwise.

Even more unfortunate is that some advocates are citing the *Survey* in efforts to extend or expand such policies. The *Survey* has already been inappropriately cited, such as in congressional testimony, to justify extending and expanding renewable portfolio mandates, including at the national level.[1] Doing so would further harm our economies and negatively impact public health. The *Survey* should not be used to formulate or justify policy in any state or federal legislation.

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Introduction

More than half of U.S. states have renewable portfolio standards (RPS) in place. These policies require utilities to buy a certain percentage of renewable energy from certain "qualified" sources (which then pass most of the associated additional costs on to their customers). These policies, in combination with federal tax preferences such as the Production Tax Credit, have been major contributing factors in the construction of approximately 46,000 MW of new renewable energy capacity in the U.S. through the end of 2012. Most of that capacity is in the form of wind turbines.

The premise underlying state RPS schemes is that they benefit society. Most state-level RPS policies have been in place for five or more years, so it should be possible to undertake at least a first pass analysis of their costs and benefits. The National Renewable Energy Laboratory (NREL), along with Lawrence Berkeley National Lab (LBNL), recently released a survey of state-level RPS cost and benefit estimates (hereinafter "the NREL *Survey*" or "*Survey*") that purports to represent such an analysis.[2]

This review uses examples from various states to evaluate the NREL *Survey*. Most of the examples use wind energy, because that is the dominant technology used to satisfy RPSs thus far. Part 1 provides a summary of the *Survey*. Part 2 describes general methodological shortcomings of the *Survey*. Part 3 discusses missing cost elements, while Part 4 discusses overestimated and double-counted benefits. Finally, Part 5 provides conclusions and recommendations.

Part 1

Summary of NREL Report

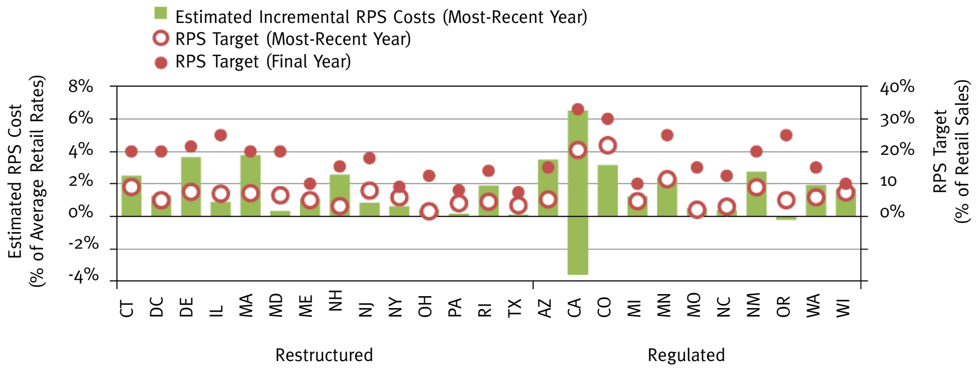
The NREL *Survey* poses the following key findings with respect to RPS costs:

- Over the 2010–2012 period, average estimated incremental RPS compliance costs in the United States were equivalent to 0.9% of retail electricity rates when calculated as a weighted average (based on revenues from retail electricity sales in each RPS state) or 1.2% when calculated as a simple average, although substantial variation exists around the averages, both from year-to-year and across states. Focusing on the most recent historical year available, estimated incremental RPS compliance costs were less than 2% of average retail rates for the large majority of states (see Figure 1).
- Among restructured markets, estimated incremental compliance costs ranged from 0.1% to 3.8% of retail rates. Expressed in terms of the cost per unit of renewable energy required, estimated incremental RPS compliance costs in these states ranged from $2–$48/MWh.
- Variation among those states reflects differences in RPS target levels, Renewable Energy Certificate (REC) pricing, the composition of RPS resource tiers, and other factors.
- Among traditionally regulated states (excluding California), estimated incremental compliance costs varied from -0.2% (i.e., a net savings) to 3.5% of average retail rates. Variation among these states partly reflects differences in RPS procurement levels. In addition, relatively high estimated costs for a number of states are associated with the presence of distributed generation set-asides, for which compliance costs tend to be front-loaded. The estimated incremental costs of meeting general RPS obligations (i.e., excluding distributed generation or solar set-asides) ranged from -$4 to $44/MWh of renewable energy procured.
- Methodological differences contribute to observed variations in these compliance cost estimates, especially among regulated states. For example, in California, two different methodologies yield derived

incremental compliance cost estimates ranging from a net savings equal to 3.6% of retail rates to a net cost of 6.5%, as shown in Figure 1.

- Utilities in eight states assess surcharges on customer bills to recoup RPS compliance costs. These utility-reported surcharges, which represent the costs borne directly by customers, ranged in 2012 from about \$0.50/month to \$4.00/month for average residential customers, and on a statewide average basis, equate to roughly 0.5% to 4% of average retail electricity rates. These customer surcharges may differ from the estimated compliance costs borne by the utility for a variety of reasons, such as differences in the timing or type of costs that can be passed through to customers.
- Estimated incremental RPS compliance costs over the historical period of the *Survey*'s analysis reflect the RPS targets applicable during those years (the open circles in Figure 1).

Figure 1: Estimated RPS Costs Compared to Recent and Future RPS Targets



*For most states shown, the most-recent year RPS cost and target data are for 2012, exceptions are CA (2011), MN (2010), and WI (2010). MA does not have single terminal year for its RPS; the final-year target shown is based on 2020. For CA, high and low cost estimates are shown, reflecting the alternate methodologies employed by the CPUC and utilities. Excluded from the chart are those states without available data on historical incremental RPS costs (KS, HI, IA, MT, NV). The values shown for RPS targets exclude any secondary RPS tiers (e.g. for pre-existing resources). For most regulated states, RPS targests shown for the most-recent historical year represent actual RPS preocurement percentages in those years, but for MO and OR represent RFC retirements (for consistency with the cost data).

Source: NREL Survey Figure ES-1

Under current policies, RPS targets are scheduled to increase significantly, eventually reaching levels represented by the closed circles. Whether and the extent to which incremental RPS costs rise in tandem depend on many factors: renewable energy technology costs trends, natural gas prices, federal tax incentives and environmental regulations, among others.

Future RPS compliance costs are limited by cost containment mechanisms built into most RPS policies, such as “Alternative Compliance Programs” or ACPs. ACPs allow utilities to pay for other favored programs like energy efficiency, at administratively set dollar amounts, when renewable costs are high. Among those states relying principally upon an ACP mechanism for cost containment, RPS costs are effectively capped at roughly 6–9% of average retail rates in most cases. Cost caps in most other states are considerably more stringent, often limiting compliance costs to 1–4% of average retail rates. Compliance costs in several of those states have already reached or are approaching the respective caps.

- The *Survey* notes that several states use input-output models or simplified approaches to estimate gross jobs, which do not account for shifts in employment that may occur, as opposed to new *net* jobs.
- A number of the studies examined economic development benefits annually or over the lifespan of the renewable energy projects, with benefits on the order of $1–$6 billion, or $22–30/MWh of renewable generation.
- Estimates of [emission] benefits ranged from roughly tens to hundreds of millions of dollars on an annual basis depending on the state and scenario. These estimates translate to approximately $4–23/MWh of renewable generation, depending on the study and the cost value assumed for CO_2.

By way of comparison, the wholesale cost of traditional generation ranges from about $25–35/MWh, or perhaps $60/MWh during high use hours, when more expensive plants are utilized.

Part 2

General Methodological Criticisms

There are numerous problems with the methodology adopted in the *Survey*, of which the following are among the most serious:

1. The states do not use consistent methods or underlying assumptions in estimating costs and benefits. For example, benefit estimates in some states, like Michigan, count only project-related jobs, while in others, like Connecticut, economic modeling is done to estimate broader and long-term effects.
2. Not all costs are included: only costs experienced directly by a subset of the marketplace (e.g., utilities or load-serving entities) are included; this is particularly problematic for technologies that have been successful in offloading costs to others.
3. In some cases, costs may have been double counted. The authors of the *Survey* assert, "Our analysis focuses specifically on the incremental cost of meeting RPS targets, i.e., the cost above and beyond what would have been incurred absent the RPS, over the 2010–2012 period." For some states (depending on the restructured or regulated nature of the state's electricity market), the incremental cost was calculated from a baseline of day-ahead market clearing prices. This itself may create a situation of double counting as day-ahead markets are inherently volatile, yet price stability is considered a benefit in the *Survey*. Achieving price stability using any of a number of hedging mechanisms would use long-term arrangements, not day-ahead markets.

Establishing what would have happened but for the RPS (the counterfactual) is itself a monumental task of conjecture and likely results in an underestimate of incremental cost, by setting too high a cost for the "no-RPS" case. Further, many of the *Survey's* underlying reports from the states occurred prior to the dramatic decrease in natural gas prices, and consequently electricity prices, from the expansion of hydraulic fracturing.

The *Survey*'s authors acknowledge some of these serious methodological shortcomings and note that the reported values may differ from those derived through a more consistent (or comprehensive) analytical treatment:

> *First and foremost, the comparisons across states are imperfect, given the varying methods and assumptions used (especially among regulated states). Second, the data presented most closely correspond to the costs borne by utilities or other load serving entities; they do not represent net costs to society, nor do they necessarily represent the costs ultimately borne by ratepayers, such as in cases where ACPs or financial penalties are not passed through to rates or differences in the timing of when costs are incurred and recovered in rates. Third, depending upon the state and particular methodology used, the cost data may omit certain costs incurred by utilities (e.g., integration costs), as well as possible benefits.*

In other words, the *Survey*'s authors acknowledge some of the short-comings of their methodology. This is commendable, but the question then becomes whether this lack of accuracy renders the *Survey* useless to policymakers. The reality is that these fundamental methodological problems mean that not one of the *Survey*'s findings is generalizable, nor are any applicable to future discussions about renewable portfolio standards specifically, let alone renewable energy policy in general.

Part 3

Missing Cost Factors

This section details the main costs that are omitted from some or all of the assessments of the costs of RPSs included in the *Survey*.

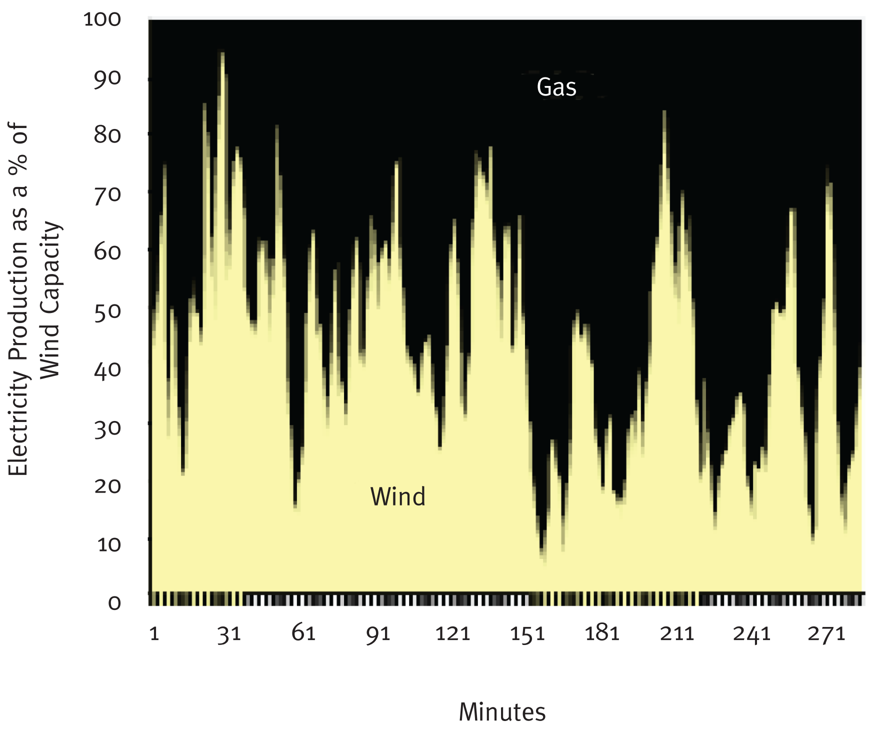
A. Costs Related to Intermittent Supply

The most significant sources of cost omitted in the *Survey* are those associated with the inherently intermittent nature of energy supplied from wind (and solar) installations. In the United States, most electricity is supplied to end users via a "grid," which comprises the wires and associated apparatus, along with management, communications and control systems between the generators and the electrical service line.[3] Electrical power created by any specific generating facility connected to the grid can supply the power demanded from any point on the grid. However, the high variability of supply from intermittent sources such as wind means that such sources cannot be relied upon to meet demand at any particular point in time.[4] As a result, it is necessary always to have alternate sources available.

To ensure electricity generation (supply) in the grid equals demand on a second-by-second basis, independent system operators (ISOs), also known as "balancing authorities," increase and reduce generation as needed, often using automated generation control.[5]

When demand increases (or other supplies become unavailable), the ISO directs a generating facility operator to "ramp up" its generation. When demand drops, the ISO directs a "ramp down" in generation. Prior to the significant growth of wind generation, these ramp ups and ramp downs reflected daily life and followed a predictable and relatively smooth schedule. By contrast, when intermittent sources such as wind are introduced, second-by-second changes in wind velocity (or, for solar, the movement of clouds) results in the need for saw-tooth ramping to balance the variation in grid-connected intermittent generation. Figure 2 shows how reliable generation sources, in this example gas-fired, must be ramped up and down to account for the variation in wind energy.[6]

Figure 2: Intermittent Energy from Wind Balanced with Gas-Fired Generation



Source: Jon Boone, "Overblown: Windpower on the Firing Line (Part 1)" 2010

When wind speed increases (but remains below the maximum speed allowed by the turbines), generation companies curtail generation from other sources, known as "intermediate load units," sufficient to accommodate the wind power. Intermediate load units are usually natural gas powered generators, but, as discussed below, must on occasion be slow-to-respond coal-fired units. When the wind subsequently slows, generation from the intermediate load units is increased or otherwise brought back on line as needed. The process by which generation is ramped up and down at a plant due to wind or any other factor is called cycling. Integrating erratic and unpredictable wind resources with established coal and natural gas generation resources requires the electricity generators to cycle their intermediate load coal and natural gas-fired units. This wind-energy-caused cycling results in significantly less efficient performance of fossil fuel facilities.[7] The net result is increased emissions and fuel use, with attendant costs. These costs are not always paid for by utility or load-serving entity customers, and thus are excluded from the *Survey*. These costs increase, per kWH, at a rate faster than the growth in wind generation.

B. State RPSs Impose Costs on Neighboring States

In all contiguous states of the Union, companies that sell retail electricity draw from an interstate grid and thus participate in interstate commerce (the only partial exception is Texas, where the majority of power is produced and consumed within a separate grid). For example, the electricity grid in Colorado is a portion of the Western Interconnection, which is managed by multiple entities. The Western Electricity Coordinating Council (WECC) helps manage the Western Interconnection and is a regional forum for promoting regional electric service reliability in Western Canada and the Western United States.[8] Various "balancing authorities" within the WECC maintain precise balance between electrical supply and demand every moment, while managing frequency and voltage, by telling power plants to run more or less (i.e. ramp up or down).

RPSs in one state may, therefore, affect the cost of electricity in another state. For example, North Dakota sets a voluntary goal of generating 10% of its power from renewable sources. Across the border, under its 2007 Next Generation Energy Act, Minnesota requires 31.5% of Xcel Energy's power be generated by wind and other renewables.[9] For years, Xcel has spread the cost of Minnesota's renewable energy standard to the utility's customers in five neighboring, interconnected states. Meanwhile, North Dakota officials grudgingly looked the other way as Minnesota regulators continued to approve more renewable energy projects. Those projects increased the utility bills of Xcel's 80,000 customers in North Dakota by an estimated $5.7 million a year. The system-wide cost for ratepayers in all states served by Xcel is about $92 million per year.[10]

Finally, the state of North Dakota was moved to take legal action to address what it claimed was a violation of the Commerce Clause of the U.S. Constitution, bringing a case against the Minnesota PUC, whose chairperson is Beverly Heydinger. On April 18, 2014, a Minnesota federal district court issued a decision in *State of North Dakota et. al. v. Heydinger et al.*, concluding that the Minnesota Act inappropriately reached beyond the state's borders to regulate activity in neighboring states.

Colorado's retail electricity utilities connected to the PSCo-managed grid draw power from a grid that crosses state boundaries,[11] so those utilities, like those in North Dakota and Minnesota, participate in interstate commerce. In order to maintain balance, the balancing authority may direct a power plant to ramp up or down in a state other than the state with an RPS. This imposes a cost in that other state, just as in North Dakota and Minnesota.

The *Survey* does not include the costs imposed on grid-connected electricity consumers in states outside those with state RPSs.

C. Federal Tax Preferences Also Impose Costs

Federal tax preference for wind turbines also shifts costs to neighboring states. The Federal Production Tax Credit (PTC) and accelerated depreciation schedules, available only to wind, transfer significant parts of the cost of facilities to taxpayers, many of whom reside in states neighboring those with an RPS. Combined, the PTC and accelerated depreciation represent 30–40% of the cost of wind energy. Estimating the transfer from non-participating states to RPS-participating states would require significant tax flow analysis. Recipient states likely consider (but do not quantify) this as a benefit, while non-RPS states should consider it a cost. Overall, federal tax preference, just in the form of the Production Tax Credit, shifts approximately $13 billion from non-participants to participants. Of course, not all, or even most, ratepayers in RPS states receive this benefit as it goes primarily to project developers. The *Survey* did not consider these costs at all, but the benefit to recipient states is included in some state reports.

D. Not All Costs Are Paid for by Utilities or Load-Serving Entities

A general distinction is made between sources of electricity that can be dispatched by balancing authorities and those that cannot. The "costs" of dispatchable technologies, such as natural gas and coal, cannot be compared to those of non-dispatchable technologies, such as wind energy. The Energy Information Administration (EIA) recognizes that dispatchable technologies are fundamentally different from non-dispatchable technologies (they have different value), and lists each subset separately to reinforce this concept.[12] According to the EIA:

> *Since load must be balanced on a continuous basis, units whose output can be varied to follow demand (dispatchable technologies) generally have more value to a system than less flexible units (non-dispatchable technologies) or those whose operation is tied to the availability of an intermittent resource. The levelized costs for dispatchable and non-dispatchable technologies are listed separately in the tables, because caution should be used when comparing them to one another.*[13]

Further, the EIA acknowledges that its presentation of levelized cost reflects cost only to plant owner/developers, not the broader costs to electricity consumers that result from wind plant operators off-loading their costs to others involved in maintaining adequate and reliable service.

The cost of wind electricity has been greatly understated in most published reports, simply because this difference in value is ignored. Putting wind on a comparable value basis requires the addition of capacity resources and other factors, such as increased transmission, tax treatment and maintenance. Six factors increase the total cost of wind electricity from the 8 cents per kilowatt-hour that the EIA reported to at least 15 cents/kWh, if wind were backed up and balanced with natural gas, and 19 cents/kWh if wind were combined with coal.[14] These factors, which are not adequately accounted for in the *Survey*, are as follows:

1. The expected life of massive turbine structures and gearboxes have a significant impact on actual (as opposed to anticipated) costs. The unit production cost of a technology that is effectively 100% capital is far greater if it only lasts 10 years than if it lasts 20 years. Recent experience suggests that a major overhaul of the gearbox may be required—at a cost approaching 40 to 50% of the total installed cost—after just 7–10 years.

2. Wind generation reduces the average level of generation (capacity factor) of the backup and balancing plants but does not reduce the need for keeping those plants in operation, so part of wind's cost responsibility includes the costs of capital, operations and maintenance of those plants.

3. Wind generation also imposes inefficiencies on those primary balancing plants, and requires additional reserves in order to maintain system reliability. As a result, wind does not save 100% of the fuel that would "otherwise" have been consumed for those kilowatt hours. This shortfall has not been counted in most cost of electricity tables, although it has been reported as a "cost of intermittency" in studies on the cost of wind integration.

4. The best locations for wind generation are remote from major cities, so it requires new transmission lines that are much longer than average. These have lower capacity factors (owing to wind's lower capacity factor) and have higher transmission losses (due to their length).

5. The Production Tax Credit as described above.

6. Accelerated depreciation as described above.

The Cost of Extra Transmission for Renewable Energy in Texas

In 2005 the Texas Legislature approved a major transmission project, the Competitive Renewable Energy Zones (CREZ), to transmit wind energy generated in West Texas and the Panhandle to load centers in Houston and Dallas/Fort Worth. The project was forecast to cost less than $5 billion but increased to more than $6.9 billion for the nearly 3,600 miles of transmission lines and dozens of substations.

Consumers will pay for CREZ lines carrying wind energy for 15 to 20 years and the Texas PUC estimates that residential customers will pay roughly $5 to $7 per 1,000 kWh used. Based on the average household's electricity use, that will cost $70 to $100 per year. An official with the Electric Reliability Council of Texas (ERCOT), the electric grid operator, told the PUC in August 2014 that further expansion of the West Texas transmission grid could cost an additional $2 billion.

Additionally, different definitions result in inconsistent accounting of costs. For example, the definitions established in the Colorado statute are not identical to those used under the Northeastern United States and Eastern Canada's "Regional Greenhouse Gas Initiative" (RGGI),[15] nor are they the same as California's Renewable Portfolio Standard.[16] Of the 28 states with renewable portfolio mandates, there is no standard definition of qualifying renewable technologies. Renewable energy credits (RECs) are one method states use to control cost for complying with their RPS. RECs are an attempt to monetize environmental attributes of renewable energy, but still be from qualifying technology. The inconsistent treatment of RECs from state to state imposes two additional costs not covered by the *Survey*: it creates a "thinner" market for RECs as they are limited to that state's list of qualifying technologies. This drives up costs, and it creates a more volatile market, which drives up risk.

RECs are an ineffective method of monetizing environmental externalities. RECs homogenize environmental attributes and effectively assign a single value to a diverse set of benefits. A hog farm that uses manure digestion reduces odors in the region, but this is not accounted for in RECs. Thus, the value of odor removal from the hog farm is assigned a zero value.

California has passed legislation that recognizes these additional costs. AB2363[17] directs the Public Utility Commission to include the costs of integration of intermittent technologies when evaluating the renewables procurement plans of the utilities.

Meanwhile, outside the U.S., the German government recently acknowledged the offloading of some costs to others. Federal Environment Minister Peter Altmaier (CDU) and North Rhine Westphalia's Prime Minister Hannelore Kraft (SPD) have agreed on a change in cost treatment for RWE and E.on, (the controlling grid operators for much of Europe). Peter Terium and John Teyssenhave adopted a new policy that places the burden of capacity cost onto the renewable power plant developers. [18]

E. Reliability Degradation Is Excluded from the Survey

Electricity generation supplied to an interstate electrical grid must equal the electricity demand from the grid on a second-by-second basis. When demand exceeds supply (including back-up spinning reserve), the voltage and frequency drop, increasing loss-of-load probability. Loss of load implies blackouts and/or brownouts. Even small changes in frequency or voltage (either positive or negative) can significantly increase the loss-of-load probability. In some cases, to prevent such contingencies from cascading into more widespread and unmanageable outages, the balancing authorities will impose crisis management protocols, which might include disconnecting some customers from a localized distribution network under established "Demand Side Management" programs.

Blackouts, brownouts and other system excursions are most disruptive to industrial and commercial operations. Brownouts reduce the available voltage, causing instability and/or failure of electronic equipment, for example, and can cause protective devices to "trip", shutting down industrial and commercial equipment. So-called "high-tech" commercial and industrial facilities are especially prone to equipment damage and financial harm from voltage or frequency disruptions of even sub-cycle (less than 1/60 of a second) disruption. Blackouts and brownouts can have severe consequences to homeowners as well. For instance, refrigerator compressors can fail with either.

The Colorado Energy Forum, Colorado's Electricity Future, 2006, reports that 355,120 commercial and industrial Colorado customers (28% of all such customers) suffered economic losses of $1.8 billion due to blackouts in a single year. Untold additional costs arise from brownouts.[19]

Outage costs tend to be driven by the frequency rather than the duration of reliability events. Momentary power interruptions, which are more frequent, have a stronger impact on the total cost of interruptions than sustained interruptions.[10] The costs of lost reliability are not included in the *Survey.*

Modeling of blackouts and brownouts indicates that the higher the percentage of wind power on the grid, the greater the unreliability of the grid and the greater the likelihood of blackouts and brownouts.[20] This risk increases exponentially, not linearly, with increasing levels of wind generation.

Real world experience in the United Kingdom, Germany, Denmark and California demonstrates the reliability problems created on electrical grids that depend on increasing levels of wind generation. In the United Kingdom, a recent study published by the John Muir Trust found that over a period of 26 months, there were 124 separate occasions from November 2008 till December 2010, when total generation from the wind farms metered by the National Grid was less than 20MW. [21] (The installed capacity over the period averaged in excess of 1600MW.) The study further found that the average frequency and duration of a low wind event of 20MW or less between November 2008 and December 2010 was once every 6½ days for a period of five hours. At each of the four highest peak demand periods of 2010, wind output was less than 6% of capacity. In addition, during March 2011 there were six instances of a five-minute rise in output in excess of 100MW, the highest being 166MW, and five instances of a five-minute drop in output in excess of 100MW, the highest being 148MW. This is equivalent to the instantaneous loss (or gain) in the operation of a large thermal plant, but of course would be worse with higher levels of installed wind.

F. Higher Costs of Renewables Lead to Spill-Over Costs

The price of wind power is generally higher, in many cases significantly higher, than current prices for market-based alternatives.[22] States that had adopted an RPS program subsequently experienced a 0.35% larger annual increase in average retail prices than those that did not adopt an RPS. The analysis reporting these outcomes includes the years from 1990 through 2005, controlling for natural gas prices, coal prices and the generation mix for each state, thereby filtering out these other price effects, allowing identification of the specific effect due to RPS.[23] More recently, Heartland Institute senior fellow James Taylor has analyzed electricity prices in states with high levels of wind generation compared to average states. Taylor found that from 2008 to 2013 electricity prices rose an average of 20.7% in the top 10 wind power states, which is seven-fold higher than the national electricity price increase of merely 2.8%.[24] Further, these increases do not include other costs, such as the added cost of additional interstate transmission lines needed by wind facilities and others as discussed above.[25]

One reason retail prices in RPS mandate states have grown is the increased use of natural gas generation, which is better able to adapt to the cycling required due to intermittent and erratic wind generation. In many cases this has required the installation of new gas-fired power generation, and resulting recovery of capital costs. In addition, until recently the cost per megawatt-hour (MWh) of natural gas was higher than for existing coal plants (but lower than wind). When coupled with the higher cost of the wind generation itself, this explains why prices have generally been higher in the RPS mandate states.[26]

In addition, the effect of cycling itself causes generation inefficiencies that increase costs and hence prices. Coal-fired and combined cycle natural gas electricity generating facilities are not designed to rapidly cycle up and down. Analysis of the operational effects of wind-caused cycling of coal plants showed that it took more fuel to generate a kWh of electricity than had no wind generation been present. A detailed study of plant operations over two days found that coal consumption at one Colorado plant was actually 22 tons greater than if the plant had not been cycled and generation had remained stable. The same is true for combined-cycle natural gas-fired electricity generation facilities.[27] To date, most of the wind integration studies—and thus the *Survey*—have ignored these additional costs.

Unpriced impacts further increase the costs of RPSs

The erratic and highly variable nature of wind power has been found to increase rather than decrease emissions of several common pollutants regulated under the Clean Air Act. This occurs because the cycling of coal and natural gas plants results in inefficient operation of both the combustion processes and the pollution control processes, as well as from the increases of fuel used to produce a kWh of electricity.

The two most significant pollutants regulated under the federal Clean Air Act and emitted by fossil fuel electricity generation units are sulfur dioxide (SO_2) and nitrogen oxides (NO_x). Another emission now being controlled under the Clean Air Act is the greenhouse gas carbon dioxide (CO_2).[28]

A 2010 analysis by Bentek Energy quantified the increase in these emissions for the state of Colorado.[29] By netting out the emissions associated with the coal-fired generation that were avoided by using wind, the analysis showed that due to wind generation, SO_2 and NO_x emissions were actually higher (23% and 27%, respectively) than they would have been if the coal plants had not been cycled to compensate for wind generation. In addition, more CO_2 (2%) was emitted than if the erratic variability of wind had not caused the plants to be cycled.[30]

Professor Gordon Hughes of Edinburgh University undertook a similar analysis of the UK's Renewable Obligation (its analog to an RPS) and concluded:

> *Indeed, there is a significant risk that annual CO_2 emissions could be greater under the Wind Scenario than the Gas Scenario. The actual outcome will depend on how far wind power displaces gas generation used for either (a) base load demand, or (b) the middle of the daily demand curve, or (c) demand during peak hours of the day. Because of its intermittency, wind power combined with gas backup will certainly increase CO_2 emissions when it displaces gas for base load demand…the Wind Scenario will reduce emissions of CO_2 relative to the Gas Scenario by 23 million metric tons in 2020–2.8% of the 1990 baseline – at an average cost of £270 per metric ton at 2009 prices. The average cost is far higher than the average price under the EU's Emissions Trading Scheme or the floor carbon prices that have been proposed by the Department of Energy and Climate Change (DECC)…*[31]

Meanwhile, Charles Frank of the Brookings Institution has found that replacing coal with modern combined-cycle gas turbines cuts 2.6 times more emissions than using wind. [32] Frank used conservative assumptions about the energy consumed for balancing and cycling.

Frank's analysis and that of Gordon Hughes are consistent with an analysis by Bill Korchinski published by Reason Foundation, which showed the significant degradation of wind's contribution as the proportion of wind energy increases.[33]

In addition to increases in emissions of common air pollutants and CO_2 due to the variability in wind power generation, renewable energy mandates cause other environmental problems. Wind resource areas often coincide with critical habitat and/or migratory flyways. Many of these conflicts are for protected, threatened and endangered species. Wind energy development has long had significant issues with avian and bat mortality, even given the relatively few wind turbines installed to date. More wind turbines will pose greater threats. For example, in California's Altamont Pass area, one of the nation's oldest wind energy development areas, 40 to 120 golden eagles are slaughtered each year.[34] Research by raptor experts for the California Energy Commission indicates that the facility's turbines kill more than 1,000 birds of prey from 40 different species each year, violating federal and state wildlife protection laws such as the

Bald Eagle and Golden Eagle Protection Act, the Migratory Bird Treaty Act, and several California Fish and Game Code provisions. Further, the additional transmission lines necessary to serve wind development areas pose special threats to birds as well.[35]

Similar avian risks exist in every state with an RPS. For example, Colorado is an important part of both the Pacific Flyway and Central Flyway for migratory birds, with thousands of migratory birds transiting to and through the state.[36] For Colorado and other northern tier states, violations of the Migratory Bird Treaty are more likely as more wind development occurs, due to the international nature of bird migration.[37] None of these impacts on species are accounted for in the *Survey*.

Wind turbines sited too close to human dwellings may also impose direct health and safety risks to the public that are not accounted for in the *Survey*. The tip speed of modern wind turbines approaches 200 MPH when operating. Ice and blade throw, from the top of a 300-foot tower, while infrequent, poses serious safety risks to the public within about ¾ of a mile. Further, the noise from wind turbines can cause health effects, as documented by Dr. Nina Pierpont and others.[38] Industrial wind turbines produce significant amounts of audible and low-frequency noise. Dr. Oguz A. Soysal, professor and chairman of the Dept. of Physics and Engineering at Frostburg State University in Maryland, measured sound levels over half a mile away from the Meyersdale, Pennsylvania 20-turbine wind farm. Typical audible (A-weighted) sound pressure levels were in the 50–60 decibel (dB) range, and audible plus low-frequency (C-weighted) sound pressure levels were in the 65–70 dB range. The 65–70 dB range equals that of a washing machine, vacuum cleaner or hair dryer at close range. A difference of 10 dB between A and C weighting represents a significant amount of low-frequency sound by World Health Organization standards. The noise produced by wind turbines has a thumping, pulsing character, especially at night, when it is more audible (due to lower background noise). It has been documented to disturb residents 1.2 miles away from wind turbines in regular rolling terrain, and 1.5 miles away in Appalachian valleys.[39] Higher levels of noise disturb sleep and produce a host of effects on health, well-being and productivity. Effects of noise-induced sleep disturbance include fatigue, depressed mood or well-being, decreased performance, and increased use of sedatives or sleeping pills.

If the argument for greater use of the often more expensive alternative energy is to benefit society, it must address cost. The deployment of more-expensive power generation technologies in order to comply with the RPS reduces disposable income of residents and, consequently, imposes significant local costs—possibly including premature deaths. [40] The U.S. Environmental Protection Agency notes that: “people's wealth and health status, as measured by mortality, morbidity, and other metrics, are positively correlated. Hence, those who bear a regulation's compliance costs may also suffer a decline in their health status, and if the costs are large enough, these increased risks might be greater than the direct risk-reduction benefits of the regulation.”[41]

Using EPA methods, this author estimated that in Colorado, an additional 50 to 250 premature deaths of citizens might occur due to the RPS in 2015, with larger rates of death to come as RPS quotas and loss of disposable income increase in future years.[42]

The *Survey* did not account for any of these additional costs.

G. The *Survey* Did Not Account for the Impact of RPSs on Property Values and Taxes

As wind farms spread, local opposition to the massive towers (some over 400 ft tall) is growing (and is beginning to impact state regulation). Residents not only oppose the turbines for aesthetic reasons, they also worry about the effect of wind farms on property values. *Values in the Wind: A Hedonic Analysis of Wind Power Facilities* used data on 11,331 property transactions over nine years in northern New York State to explore the effects of new wind facilities on property values.[43] The study found that nearby wind facilities significantly reduce property values in two of the three counties studied.

Kurt C. Kielisch, president and senior appraiser with Appraisal Group One, used a survey of realtors and an impact study (using sales of properties affected by wind turbines compared to those that were not) to show that prices of properties sold within the wind turbine area were lower than comparable sales outside of the turbine area. [44] In addition, there were substantially fewer sales within the wind turbine area than outside of it. The impact of the wind turbines on vacant residential land was estimated to be in the range of -19% to -40%. These costs associated with lost property values were not included in the *Survey*.

H. Renewable Mandates Reduce Economic Activity

Recent economic analysis of electricity generation indicates that renewable energy generation causes a net reduction in economic activity,[45] just as the use of more land for capturing renewable energy flows has a similar negative effect on long-run economic growth.[46]

A detailed study on the effect of a mandate for wind energy, which is the practical effect of RPS, demonstrates that above-market wind energy costs have the harmful effects of reshuffling consumer spending and increasing the cost of production for businesses. Increased costs for households and employers reduced the otherwise positive employment impacts of renewable energy capital investment and ongoing operational repair and maintenance activities.[47]

I. The Bottom-Line Goals of RPSs Can Be Achieved at Lower Cost, While RPSs "Strand" Otherwise Useful Assets

All power technologies require some level of backup. Most can also provide their own backup–but wind cannot. This has a detrimental impact on operational reliability (security). With respect to planning level reliability (adequacy), the National Electricity Reliability Corporation had this to say about Texas's reserve margin, in its most recent (May 2013) summer assessment:

> *ERCOT's summer planning reserve margin is projected to be below the NERC Reference Margin Level…Generation capacity in ERCOT has not kept pace with load growth and has resulted in diminishing planning reserve margins… Delays in generation development are a result of low market prices (due to low natural gas prices and significant wind generation development); reduced availability of capital for financing; and uncertainty associated with changing environmental regulations.*[48]

And in a special report with the California Independent System Operator, NERC said this:

> *Integrating large quantities of variable energy resources (VERs) (predominantly wind and photovoltaic (PV) solar) into the North American bulk power system (BPS) requires significant changes to electricity system planning and operations to ensure continued reliability of the grid.*[49]

Renewables are viewed by some as a mechanism to hedge (i.e. insure against) future price volatility. But there are much less expensive ways to achieve the same objective. For example, a utility that must buy natural gas or coal can lock in a future price using a financial instrument, such as an option or a futures contract. Utilities frequently use such mechanisms, which are considerably less expensive than long-term, fixed-price renewable contracts.

Options and futures contracts incur an insurance premium, but one that is considerably less than the nearly two-times cost of wind compared to new natural gas-fired power generation facilities. Renewables are heavily capital-intensive, while fossil-fired generation is less capital-intensive. Investing heavily in capital-intensive technologies converts a risk (uncertainty of future price increase) that can be hedged inexpensively into an expensive certainty (legal and contractual obligation for capital recovery payments, regardless of actual fuel price.)

“Regulators should expect utilities to realize small losses from hedging in most years because hedging is, after all, an insurance policy against severe price spikes, and insurance is not costless,” said Ken Costello, natural gas principal with the National Regulatory Research Institute, an arm of the National Association of Regulatory Utility Commissioners.[50] “Almost all regulatory commissions allow gas utilities to hedge with financial instruments. A much smaller number require them to do so,” he said. They are considered prudent expenditures.

Since the early 2000s, state regulatory commissions have told gas utilities that buying at the market or spot prices may no longer be acceptable—that is, it may be imprudent. It is also the nature of hedging that a utility and its customers could pay above-market prices if the market for the physical commodity falls below the price that is hedged.

Natural gas and electricity futures contracts were introduced in the early and mid-1990s. Today, there are approximately 250 electricity and 300 different types of natural gas futures, options and cleared swaps contracts available to market participants from both the New York Mercantile Exchange and the Intercontinental Exchange. These cover various delivery points, quantities and time spans.

Regulators began taking a serious look at utility hedging after a series of particularly severe natural gas price spikes. Prices went to a then-record of $10 per million British thermal units (MMBtu) in late 2000 and again in 2003, then ran up to an all-time high of $15/MMBtu in 2005 after Hurricane Katrina, and spiked again at more than $13 in 2008.

Ex-Colorado Public Utilities Commissioner Matt Baker has said the agency looks at risk aversion starting with the planning process. “We’re trying to get utilities to create enough fuel diversity between coal, gas, wind, and energy efficiency and demand response, so that consumers have protection if one commodity gets out of line. On the gas side, we’ve encouraged our utilities to enter into long-term, fixed-price physical contracts.”[51]

He noted that one utility recently signed a 10-year contract pegged at $5.15/MMBtu. “We looked at how much we were spending on hedges and what the value of that was. What we’re trying to do is purchase some stability. There’s probably a little bit of a premium on it, but over the 10-year life span, we think this will be in the best interest of the ratepayers, even though gas is $2.50 now.”

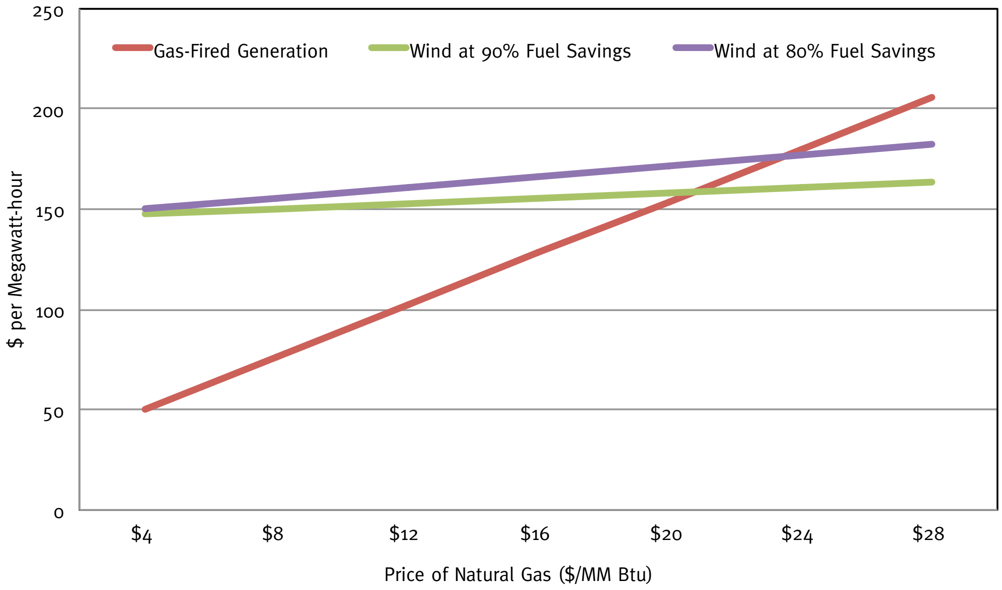
Furthermore, hedging as a mechanism should isolate, to the extent possible, the hedge-taker from the event being hedged against. In other words, a hedge against, say, natural gas price volatility should isolate the hedge-taker from natural gas price increases. As discussed above, wind does not isolate the electric utility from natural gas prices but in fact ties the utility more tightly to natural gas, for balancing and backup, and thus natural gas prices. Adding wind to the grid necessitates adding natural gas to the grid, making wind an ineffective hedge.

Finally, signing long-term contracts for wind as a “hedge” against fossil fuel prices reduces the opportunity to take advantage of fossil fuel prices that turn out less than forecast when the contract was signed. Imagine entering a futures contract at a strike price of, say, $5.00/mmbtu, with an embedded premium of $0.50/mmbtu, and then being faced with an actual market (spot) price at the time the contract matures of $3.50/mmbtu. You’d be overpaying, compared to the market, by $1.50/mmbtu. By contrast, if you had purchased a call option at the same price, $5.00, and paid $0.50 for the option, then if the spot price turns out to be $3.50, you can simply buy in the market, saving a net $1.00 compared with the futures contract. Twenty- and 30-year renewable power contracts signed in say, 2006 or 07 when natural gas prices were forecast to continue rising now look very expensive. Natural gas prices would have to quadruple in price for wind to represent an effective hedge. Significant expansion of natural gas supply and reductions in price have occurred, making actions predicated on those forecasts ill-conceived in hindsight, illustrating the need to avoid lost opportunities by flexible and diverse hedging strategy, with few if any long-term, fixed-price contracts.

J. The Goal of Reduced CO_2 Emissions Can Be Accomplished at Lower Cost

Substituting natural gas generation for coal generation provides a CO_2 emission reduction of about 40–50% for every kilowatt-hour.[52] Using the cost of new, efficient gas generators and the cost of wind generation, Figure 3 shows that wind electricity would not reach breakeven with gas-fired electricity unless the delivered price of natural gas were about $20 per million Btu. At either point, both wind and gas generation would be far more expensive than nuclear generation, and perhaps more expensive than coal with carbon capture and storage.

Figure 3: The Cost of Wind Electricity vs. Gas-Fired Electricity, Relative to the Price of Natural Gas ($/MM Btu)



Source: George Taylor and Thomas Tanton, *The Hidden Cost of Wind Electricity,* (Washington, D.C.: Energy and Environment Legal Institute, 2012). Available at: http://eelegal.org/wp-content/uploads/2013/09/Hidden-Cost.pdf

Part 4

Overestimated, Incomplete and Double Counted Benefit Estimates

There are a few assumed benefits that are generally considered foundations for RPS, and are referenced in the *Survey*:

- Reduced Emissions and Associated Health Impacts
- Job Creation and Economic Development
- Supply [Fuel] Diversity
- Price Stabilization
- Water Savings

In addition to the structural differences noted in the *Survey* (benefits are estimated for the life of the project, while costs are for a limited time period) each of these benefit categories, as reported, suffers from some fatal flaws. The most serious flaw, affecting all benefit estimates, is the embedded assumption that renewables would not develop save for the RPS. Three areas serve to illustrate problems with the *Survey's* compilation of benefits.

A. Reduced Emissions and Associated Health Impacts

The criteria pollutants SOx, NOx and Particulate Matter (PM) are all regulated by a variety of national- and state-level regulations designed to protect human health and other goals. The establishment of those regulations already "counts" human health impacts, and to also include them as a benefit of RPS double counts those benefits. Further, assuming those regulations are effective in achieving the low pollution levels that protect human health (the basis of the regulations), further reductions pose no additional health benefit.

With respect to reduced CO_2 emissions, the *Survey's* value estimates of the "social cost of carbon" (SCC) are highly speculative and subject to intense debate. By its very nature the SCC is an arbitrary number, which is completely malleable in the hands of an analyst who can make it very high, very low, or even negative, simply by adjusting parameters, such as the damage function and discount rate (especially so for the very long time horizon.) In a peer-reviewed article, MIT Professor Robert Pindyck writes that computer-generated SCC estimates are "close to useless" for guiding policymakers, and that the "damage functions" embedded within the computer models are "arbitrary," having no basis in either economic theory or empirical observation.[53] Further, the rate at which future damages are discounted to present-day monetary terms has an enormous impact on the estimated SCC. For example, in the May 2013 Working Group update, the SCC in the year 2010 was reported as $11/ton at a 5% discount rate, but $52/ton at a 2.5% discount rate. In other words, cutting the discount rate in half caused the reported SCC to more than quadruple. The problem is that the choice of discount rate is not something that can be settled objectively through technical analysis.

B. Job Creation and Economic Development

As discussed above, created jobs included in the *Survey* usually spring directly from building a facility in response to the RPS, either just the construction period or the life of the facility (depending on who is making the estimate.) What are usually not accounted for are the lost jobs caused by higher electricity costs. In study after study in Europe and in the U.S., more jobs are lost than created. In addition to harmonizing time periods of expenditures and job creation, benefit estimates should be calculated on a net basis, not cherry-picked from only those created by selected projects. The *Survey* fails to note the fallacy of calculating society-wide benefits but using only a subset (and a small one at that) of society in counting this benefit. Further, RPS acts to reduce productivity in capital and labor, exactly opposite to economic advancement.

Two published studies provide documentation of this net loss in employment: the first from Spain, and the second looking at Italy. Gabriel Calzada Álvarez of the University of King [Rey] Juan Carlos, Spain found that for every renewable energy job that the state manages to finance, Spain's experience (cited by President Obama as a model) reveals with high confidence, by two different methods, that the U.S. should expect a loss of at least 2.2 jobs on average, or about nine jobs lost for every four created.[54]

Carlos Stagnaro of the Institute Bruno Leoni found a similar tradeoff in Italy. Dr. Stagnaro and colleagues found that for every "green job" created, 4.8 "regular" jobs were destroyed.[55] Lost jobs represent an opportunity cost given that renewable energy subsidies divert money from other investment.

Similarly, the mal-investment of money spent on renewable energy in Germany was found to be very dear indeed:

> *To the contrary, the government's support mechanisms have in many respects subverted these incentives, resulting in massive expenditures that show little long-term promise for stimulating the economy, protecting the environment, or increasing energy security. In the case of photovoltaics, Germany's subsidization regime has reached a level that by far exceeds average wages, with per-worker subsidies as high as 175,000 € (US $ 240,000).*[56]

C. Supply Diversity and Price Stabilization

Supply diversity is good, but RPS predetermines the correct amount of diversity, rather than allowing a natural level of diversity to occur and change with changing circumstances. Further a single, government-imposed level of diversity assumes a single society-wide risk tolerance and perfect knowledge about the future (Will alternative fuels continue to increase in price, or will technological breakthroughs provide dramatic reductions? Will private investments bring about efficiency advances? Will unforeseen negative environmental impacts such as the slaughter of endangered species turn against the temporarily favored technology?).

Price stability is also good but only if the premium paid for that stability is reasonable. What we've seen is long-term power purchase agreements signed under RPS that are significantly above market price, imposing additional costs and for long periods. Price stability should not come at the expense of flexibility.

The *Survey* discusses the fact that in some wholesale electricity markets prices have gone down. What is not mentioned is that the commodity value has also gone down, leading in some cases to higher prices in capacity markets and the need to create capacity markets in others. No attempt to actually monetize the value of diversity or price stability was made. It suggests that if a little diversity or stability is good, more (increasingly expensive) is better. Monetization of different levels of diversity and stability is necessary to fairly compare with costs to achieve those different levels and account for the natural diversity in people's risk tolerance and choices. Different people view risk differently, which is why people carry different levels of insurance. "Valuing" the risk reduction of diversity should account for this.

Part 5

Conclusion and Recommendations

The *Survey* correctly notes that states have used disparate methods and assumptions to estimate costs and benefits of their RPS. The *Survey* also correctly notes that the *estimates of costs should not be compared to the estimates of benefits to derive a net benefits estimate.*[57] Thus it should not be used for policymaking. The *Survey* authors should make efforts to correct those who would abuse their report through such use.

The *Survey* incorrectly implies that future additions of renewables under the various states' RPSs will have costs and benefits comparable to the early installations. The unit impact of each installation, in total costs and total benefits, is highly divergent and non-proportional. For each new kWh of renewables generation the costs per kWh increase while the benefits decrease.

RPSs are likely to impose significant costs that exceed societal benefits. RPSs impose costs on neighboring states and on ratepayers, without attendant benefits. At the very least, RPSs are an inefficient means to achieve societal goals, as they preclude less expensive and more effective means of so doing. RPSs encourage the construction and operation of nonresource-conserving facilities while doing little for resource-conserving, cost-effective facilities. RPSs lock us into a future more dependent on natural gas than might otherwise be the case.

There is a persistent myth that renewables are cost competitive, environmentally benign, and can easily replace fossil fuels. Myths have consequences. Energy policy based on myths curtails our energy supply, drives up prices and harms the environment, all without any increase in energy security. On the other hand, energy policy based on facts stands the best chance of increasing our supply, lowering prices, trimming emissions and boosting our overall energy security. If that is their goal, policymakers, the media and the public should reject energy myths and stick to the path of facts and reality. That way alone leads to energy abundance and security for America.

Proponents of renewable portfolio standards (and other favoritism-bestowing policies such as the Production Tax Credit) argue that renewables need regulatory “certainty” and financial stability that can only come with government policy. They fail to understand that doing so would violate the very regulatory certainty promised utilities when building traditional power plants not so long ago. Utilities were guaranteed (typically) 30 years to recover capital costs and earn a reasonable return, in exchange for the obligation to serve. Requiring utilities to buy (and resell) certain percentages of renewables diminishes that guarantee, the same as if government reneged on its promise. What gives renewable proponents comfort that government won’t renege again sometime in the future, this time harming *them*?

More effort should go into accurately assessing the costs and benefits of renewables, developing true, market-oriented means for their competitive development, and recognizing the energy sector's inherent diversity. And far more attention should be paid to the end goals (cheaper, more stable, more robust, cleaner energy), while allowing the market to determine the means, be it renewables or advanced traditional technologies, or something yet unforeseen.

About the Author

Thomas Tanton is a senior fellow at Reason Foundation. He is also president of T^2 & Associates, a firm providing consulting services to the energy and technology industries, and director of science and technology assessment with Energy and Environment Legal Institute, a national non-profit energy think tank.

Mr. Tanton has 40 years' experience in energy technology and legislation. Until 2000, he was the principal policy advisor with the California Energy Commission (CEC) in Sacramento, California, having begun his career there in 1976. At the CEC, Tanton developed and implemented policies and legislation on energy issues of importance to California, the U.S. and international markets, including electric restructuring, gasoline and natural gas supply and pricing, energy facility siting and permitting, environmental issues, power plant siting, technology development and transportation. He completed the first assessment of environmental externalities used in regulatory settings. Mr. Tanton held primary responsibility for comparative economic analysis, environmental assessment of new technologies, and the evaluation of alternatives under state and federal environmental law.

As the general manager at the Electric Power Research Institute from 2000 to 2003, Mr. Tanton was responsible for the overall management and direction of collaborative research and development programs in electricity generation technologies, integrating technology, market infrastructure and public policy. From 2003 through 2007, Mr. Tanton was a senior fellow and vice president of the Houston-based Institute for Energy Research. He has also been a guest lecturer on the Master in Environmental Science program at California State University Sacramento (CSUS), lecturing on power plant and electric grid technologies and their comparative environmental impacts.

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