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Renewable Electricity Standards, Energy Efficiency, and Cost-Effective Climate-Change Policy

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It is important to define an energy efficiency standard carefully. If energy efficiency is defined relative to a baseline level of consumption, it is critical that the baseline be permitted to grow at an appropriate rate over time. Otherwise, the requirements to use renewable generation will be less flexible than under a pure renewable electricity requirement.

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I. Introduction and Summary

Congress is in the process of writing major climate change legislation. Current bills include both a cap-and-trade program to curb greenhouse gas (GHG) emissions and a nationwide renewable electricity standard (RES). Some proposals permit a portion of the renewable electricity requirement to be satisfied by adopting energy efficiency measures, while others include a separate efficiency requirement. Assuming that the goal is cost-effective reduction of GHG emissions, an important question is whether these various approaches fit together in a coherent manner.

It is now generally accepted that cost-effective environmental regulation uses market mechanisms in order to leave choices about the least-cost ways of achieving policy goals to individual producers and consumers. In the context of reducing GHG emissions, more than 2,500 economists (including nine Nobel laureates) endorsed the ''Economists' Statement on Climate Change'' (Arrow *et al.*, 1997), which stressed that ''The most efficient approach to slowing climate change is through market-based policies... The United States and other nations can most efficiently implement their climate policies through market mechanisms, such as carbon taxes or the auction of emissions permits.''

Cost-effective regulation of GHG emissions, through a tax or a cap-and-trade program, puts a price on GHG emissions and provides an incentive to control those emissions up to the point that the marginal cost of doing so is equal to the price. If the goal becomes more stringent, the cap can be reduced or the tax increased. Both methods give producers and consumers the incentive to find the least-cost ways to reduce GHG emissions.

An RES represents the opposite of a market-oriented approach. An RES mandates that a prescribed percentage of the electricity produced be from a specific set of renewable resources.[1] Rather than prescribing a goal and allowing the market to choose least-cost technologies, an RES prescribes technologies regardless of cost and establishes no emissions-reduction goal.[2] If Congress adopts a cap-and-trade program, an RES is unnecessary to achieve GHG emissions-reduction goals. Moreover, an RES will reduce the economic efficiency advantages, perhaps significantly, of a cap-and-trade program and raise the cost of achieving any given level of GHG emissions reduction.[3]

An RES can be made more market oriented by allowing energy efficiency to count toward its requirements.[4] Expanding the range of ''qualifying resources'' to include energy efficiency, as the most recent RES proposals do, moves an RES closer to a performance standard.[5]

An RES can be made more market oriented by allowing energy efficiency to count toward its requirements.

In this article, I discuss some of the costs associated with substantially expanding the portion of electricity generated by renewable resources, as called for by RES proposals, and the benefits of incorporating energy efficiency into an RES. Incorporating energy efficiency—defined as a reduction in consumption—into any RES would likely reduce its costs significantly.[6] A recent Resources for the Future study found that the costs of an RES increase sharply for renewable penetration levels in excess of 15 percent. Moreover, the same study found that at high levels of penetration renewable resources substitute for nuclear generation, thereby negating any GHG benefits (Palmer and Burtraw, 2005).

Wind and solar generation entail substantial costs beyond the cost of building new generation. They require tens of billions of dollars of investment in transmission to move the power from where it is produced to consumers, which would be on top of dollars needed to upgrade the existing transmission network and build the smart grid. Because of their seasonal and intermittent nature, generation from wind and solar sources also must be backed up by more reliable forms of fossil-fuel generation.

Incorporating energy efficiency into an RES would give utilities a stronger incentive to promote a variety of measures, including the smart technologies now available for businesses and consumers to control their electricity usage. Incorporating energy efficiency also gives utilities a stronger incentive to implement dynamic pricing programs that would make those technologies more effective and would reduce consumption during periods of high demand when the marginal cost of generation is high. Enhancing the demand side of the market would make electricity markets work better generally and make them less susceptible to the exercise of market power.[7]

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It is also important to correctly specify the baseline against which reductions in consumption should be measured. If the baseline is not specified correctly to reflect the trend growth in electricity consumption, utilities may need to make even larger investments in renewable generation than under a "pure" RES that does not incorporate energy efficiency.

II. The Costs of Renewables

In 2007, renewable energy sources accounted for less than 9 percent of U.S. electricity generation (**Table 1**). The bulk of renewable energy came from existing hydroelectric generation, which generally does not count toward RES requirements. Renewables that satisfy RES requirements accounted for 2.5 percent of generation in 2007. Wind, which accounted for 0.8 percent, is the only renewable resource that has materially increased its share of electric generation capacity in this decade (EERE, 2008). Solar electricity accounted for 0.02 percent of the total.

The main reason adoption of renewables has proceeded slowly is that the costs of these technologies are usually not competitive with the costs of generation from fossil fuels. Electricity from wind, the fastest-growing renewable resource, can be generated for an unsubsidized cost of 8–8.5 cents/kWh, which is comparable to the costs of fossil fuel generation. However, the added transmission cost of bringing wind-generated electricity to consumers may double its cost. In addition, wind-generation costs are likely to rise as wind's share of generation expands, because less attractive, more remote wind resources will have to be utilized (Apt *et al.*, 2008).

Table 1: Generation Mix.

Generation Source	2005	2006	2007
Percentages of Net U.S. Energy Generation by Source			
Coal	49.6%	49.0%	48.5%
Petroleum	3.0%	1.6%	1.6%
Natural gas	18.8%	20.1%	21.6%
Nuclear	19.3%	19.4%	19.4%
Conventional hydroelectric	6.5%	7.0%	5.8%
Renewable	2.2%	2.4%	2.5%
Percentages of Renewable Energy Generation by Source			
Biomass (Wood)	44.5%	40.2%	37.1%
Waste	17.7%	16.7%	15.7%
Geothermal	16.8%	15.1%	13.9%
Wind	20.4%	27.5%	32.7%
Solar and PV	0.6%	0.5%	0.6%

Source: U.S. Energy Information Administration Electric Power Annual 2007.

Renewable generation sources, such as wind and solar, are located far from most consumers. Wind resources are primarily located in the plains and mountain states, including North and South Dakota, Kansas, Montana, Nebraska, Wyoming, Oklahoma, Minnesota, Iowa, Colorado, and New Mexico. Of the most populous states, only Texas has significant wind energy resources. The entire Southeast is devoid of opportunities for land-based wind generation (Piwko *et al.*, 2007).

Using wind power to meet a 20-percent RPS has been estimated to require a $60 billion investment in transmission (AEP-AWEA, undated). Even in Texas, which has good resources located relatively close to population centers, integrating wind resources to comply with the state's RES will require billions of dollars of transmission investments.[8] These "green" transmission projects will compete for capital and other resources with investments otherwise needed to expand transmission capabilities, as well as to develop the smart grid.

In order to encourage solar adoption, many state RES programs include specific set-asides for solar technologies. However, the costs of solar generation can be a full order of magnitude larger than other sources. Current photovoltaic electric generation has a nonsubsidized cost of 33–61 cents/kWh, almost 10 times the cost of the current electric power generation mix. Pennsylvania's requirement that 0.5 percent of electricity be generated by solar by 2020 is projected to add 6 percent to the average electricity bill (Apt *et al.*, 2008).

The best solar resources are concentrated in the Southwest, also far from most consumers. Among the nation's largest major metropolitan areas only those in Southern California and Phoenix have high potential for solar generation. Solar energy is the resource least likely to make any meaningful contribution to RES targets in virtually the entire Northeast and Midwest (Apt *et al.*, 2008).

In addition to the location mismatch between consumers and producers of wind and solar power, there is also a timing mismatch between when wind and solar power can be generated and when consumers need it. The timing mismatch is particularly problematic for wind energy, which is available more during the spring and fall than during the winter and summer, and more at night than during the day. Consequently, wind will make a disproportionately small contribution to meeting spikes in electricity demand on hot summer days. The timing mismatch also means that an increase in generation from wind and solar sources will need to be accompanied by additional fossil-fuel generation facilities to meet demand during high-use periods. Many of these fossil-fuel facilities would be operated for only a few hours annually, and at high marginal costs.

Increasing the share of renewable electricity also raises reliability issues. Because of inherent fluctuations in wind and solar resources, output from these facilities is subject to substantial and often unpredictable fluctuations. These variations also mean that conventional power generation facilities must either continue to operate concurrently with the renewable plants (e.g., if the baseload generation is from coal-fired or nuclear plants) or be available to come online on a rapid-start basis (e.g., fast-ramping natural gas generators). In either case, once the renewable output picks up after a fluctuation, electricity generation will exceed demand until the conventional plants can adjust, and the excess electricity will be "spilled," or not used. A somewhat counterintuitive consequence of establishing a national RES will therefore be to increase the proportion of electricity generation that is wasted.

There is also a timing mismatch between when wind and solar power can be generated and when consumers need it.

III. Proposals for a National Renewable Electricity Standard

RES legislation specifies the categories of generation that comply with the requirement and a schedule for reaching specified targets. A national RES would place a floor under state RES targets, which have been enacted by 28 states.

Up until recently, the major proposals were for a national RES in the 20 to 25 percent range. Some proposals allowed a portion of the requirement to be met with efficiency savings and some did not.[9]

The two major national RES proposals currently under consideration are Senator Bingaman's bill (S. 1462), and the Waxman-Markey bill (H.R. 2454) reported by the House Energy and Commerce Committee. The Bingaman bill counts electricity generated from solar, wind, geothermal and ocean energy, biomass, landfill gas, and incremental hydropower as renewable electricity. Utilities would be required to attain annual renewable electricity percentages building from 3 percent of total generation in 2011 to 15 percent by 2021. The Waxman-Markey bill incorporates a similar definition of renewable electricity and would require it to constitute 6

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percent of generation in 2012, growing to 20 percent by 2020.

The Bingaman proposal would permit up to 26.67 percent (4 percentage points) of the requirement to be met by energy efficiency. Energy efficiency includes a reduction in electricity use by consumers relative to a base year or, in the case of new facilities, relative to equipment of average energy efficiency.[10] The Waxman-Markey bill would permit up to 25 percent (or 40 percent on petition of a state) of the requirement to be met by efficiency improvements.

IV. Including Energy Efficiency in an RES

Allowing energy efficiency to count as a "qualifying resource" expands the range of tools and technologies that can be utilized to achieve the goals of the RES and therefore allows those goals to be achieved at lower cost. Thus, there should be no cap on the amount of energy efficiency allowed to satisfy the RES. If the cap is binding, its effect will be to raise costs to consumers, as well as to make the standard less effective at achieving its goals.

A Resources for the Future study (referred to above) of renewable electricity policies found that RES costs rise sharply at penetration levels between 15 and 20 percent (Palmer and Burtraw, 2005). The study also found that renewable sources of generation generally replaced natural gas, but as their share approached 20 percent they began to substitute for nuclear generation. In fact, natural gas generation was greater at a 20-percent renewable share than at somewhat lower levels, thereby limiting its GHG-reduction benefits. By lowering the share generated by renewable sources, including energy efficiency can reduce both costs and emissions and improve cost-effectiveness.

Even if the price signals are correct, consumers may underinvest in energy efficiency if they don't have sufficient information to make cost-effective choices.

A. Energy efficiency incentives for utilities and consumers

Incorporating energy efficiency into an RES will give utilities a greater incentive to make and promote consumer investments in saving energy, both through lower consumption and the adoption of more energy efficient technologies. This would help address concerns that energy efficiency investments are not being made even when they are cost-effective.[11] Consumers may not make cost-effective efficiency investments for several reasons. They may face a price of electricity that is lower than its marginal cost, at least some of the time, because regulated prices don't reflect real-time generation costs. Even if prices accurately reflect the costs of generation, those prices don't include the external costs associated with GHG and other emissions. If the price of electricity is less than its marginal cost, including its marginal externality costs, then even well-informed, utility-maximizing consumers will underinvest in efficiency.[12]

Moreover, even if the price signals are correct, consumers may underinvest in energy efficiency if they don't have sufficient information to make cost-effective choices. Some evidence suggests that consumers fail to make investments that would be privately beneficial—i.e., that would pay off in a reasonable period of time with a reasonable discount rate.[13]

Utilities could be a source of information about efficiency investments for their customers, but they may not have the appropriate incentive to provide such information.[14] Utilities' incentives to promote efficiency instead of additional sales depend on the profitability of those sales. Under average-cost pricing, prices will be above marginal cost at some times and below marginal cost at other times. If the price is above marginal cost—as it may be during off-peak periods—utilities will have an incentive to sell more electricity. On the other hand, when the price is below marginal cost—as it may be during peak periods—utilities will have an incentive to reduce demand.

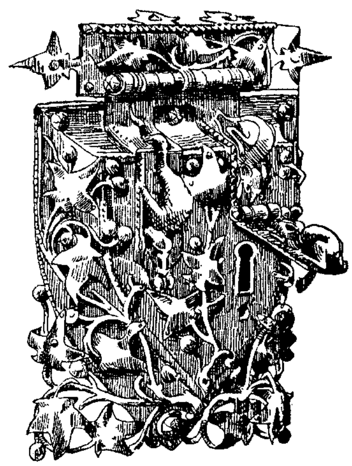
If utilities increase generation from renewable sources that have a higher-than-average cost, consumers who face the average cost of electricity will lack the appropriate incentive to invest in energy efficiency. If consumers faced the marginal cost of generation from renewable sources, they would have a stronger incentive to invest in efficiency.

Utilities, however, do face the marginal cost of renewable generation under an RES. If energy efficiency is included, utilities will have an incentive to substitute efficiency for generation whenever the former is less costly. Thus, incorporating efficiency into an RES will improve the incentives that utilities have to promote efficiency, because it will often be less costly than the marginal cost of additional generation from renewables.

There are (at least) two ways utilities can promote energy efficiency.[15] First, they can provide information, directly promote, and perhaps even subsidize the adoption of efficiency measures by their customers. To finance these measures, utilities may have to raise the price of electricity, which would also promote efficiency. Second, utilities can implement dynamic pricing plans, which better reflect variations in generation costs and thereby provide better incentives to customers to modify their consumption patterns.

B. New technologies

Many technologies can help consumers save electricity, but a whole new group of smart technologies—including smart meters and automated systems that control individual appliances, HVAC, lighting systems, and even entire buildings—is now available.



These technologies can give consumers the ability to adjust their consumption in response to changes in price and other factors. These technologies also reduce utilities' operating costs by facilitating more efficient meter reading and billing, and increase power reliability and quality. The benefits accruing to utilities themselves go a long way toward justifying the required investment.

Broadening the definition of measures that can be used to meet RES targets would provide important support for more rapid deployment of smart grid technologies. Among the most important of these is advanced metering infrastructure (AMI) that permits automated exchange of information about electricity supply and pricing conditions between utilities and their customers; commercial building and home "gateways" that allow for pre-set or remotely controlled changes in equipment operation in response to this information; and smart HVAC equipment, lighting, and appliances that respond to the directions of these centralized controllers. More rapid deployment of these smart technologies, along with more traditional improvements in energy efficiency and conservation measures, could make a greater contribution toward meeting GHG-reduction goals than increased reliance on renewable energy sources.

Many of the key technologies have already been developed and commercialized on a large scale. New buildings increasingly incorporate infrastructure to regulate electricity use in response to fluctuations in electricity grid conditions and prices, as well as internal usage conditions such as the presence of occupants in specific areas of the building. Smart meters and two-way communication systems are increasingly being installed to serve not only larger commercial and industrial users, but also residential consumers and small businesses. Deployment of these technologies is expanding rapidly. In 2007, advanced meters constituted about 4.7 percent of all meters in the United States—up

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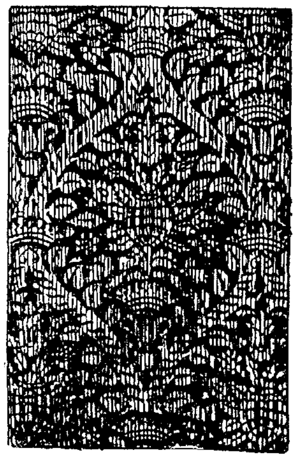
from less than 1 percent in 2006 (FERC, 2008).

Installing these technologies requires much shorter lead times and less capital than building new generation and transmission capacity. A McKinsey report (2007) estimates that rapid action to implement available "negative-cost" energy conservation options would yield capital cost savings of as much as $300 billion (in 2005 dollars) by 2030 from avoided construction of new generation facilities.

In contrast to increasing reliance on wind and solar generation, increasing energy efficiency would reduce the burden on the transmission grid rather than require new construction. Scarce investment dollars could instead be used to accelerate development and deployment of the smart grid. These investments typically have relatively short payback periods.[16]

Upgrading the existing transmission network would also produce direct electricity savings. Reduced transmission losses represent another potentially large source of benefits from a more reliable, more visible grid system. During the most recent year for which data are available, nearly 3 percent of the total electricity transmitted was lost in distribution (EIA, 2008). At the average retail price of 8.7 cents per kWh in 2006, this translates to an annual cost of $20.7 billion. A significant portion of "normal" transmission losses is attributable to deteriorating or failing network components, which can be detected, serviced, and repaired more readily with the automatic sensing and communications components of a smart grid. Improvements in electrical reliability, reductions in transmission losses, and operational cost savings can in some cases be large enough to



justify the required investment (EEI-Plexus, 2006).

Opportunities to improve efficiency and reduce electricity consumption are not dependent on regional endowments of specific renewable energy sources. For example, the Southeast has little by way of usable wind and solar power resources, but could exploit many conservation opportunities. The magnitude of these opportunities has been demonstrated by a highly successful real-time pricing (RTP) program which Georgia Power & Light has aggressively marketed for more than a decade to a broad group of commercial and industrial customers. The program allows the utility to realize savings from avoided electricity generation during peak periods due to reduced demand from 80 percent of the load in these customer categories (FERC, 2008).

C. The importance of the baseline

Legislation that includes energy efficiency as a "qualified electricity savings" will need to define the baseline against which the savings are to be measured. For example, the Bingaman Discussion Draft (partially) defines the savings as a reduction in end-use electricity as compared to consumption in a base year, although the draft does not define the base year. It is important that the base be defined correctly. If the baseline is incorrectly defined, incorporating efficiency into an RES can reduce rather than increase flexibility in meeting environmental goals.

For example, a 20-percent RES requirement incorporating energy efficiency can be defined as follows:[17]

$$R + (X - Y) = 0.20Y, \qquad (1)$$

where R = renewable generation, Y = electricity consumption, $(X - Y)$ = savings relative to a base level of consumption, X

Thus, the equation says that renewable generation plus efficiency should equal 20 percent of consumption. Rewriting equation (1) shows the importance of defining the base

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properly:

$$R = 1.20Y - X \quad (2)$$

If the base (X) is constant, then a one-unit increase in consumption (Y) requires a 1.20 unit increase in renewable generation—one unit to make up for the foregone savings and 0.20 of a unit to meet the RES target. Thus the requirement on renewable generation is more stringent than under a simple RES that does not include efficiency.

This problem can be solved by allowing the base in the legislated formula to grow at a trend rate over time. What is the correct trend rate? As we demonstrate in the appendix, if the trend rate of growth of the base is the same as the trend rate of growth of electricity consumption, then the RES with energy efficiency will maintain a constant level of stringency. If the base is defined to grow more slowly than consumption, then the standard will run into the problem illustrated above, with renewable generation being required to supply an ever-increasing portion of consumption over time. If, on the other hand, the base is defined to grow more rapidly than consumption, then the pressure on utilities to use renewables will diminish over time.

It is therefore important to estimate the trend rate of growth of consumption accurately and, since any estimate will not precisely reflect the growth in actual consumption, to adjust the base (including its growth rate) at regular intervals.

V. Conclusion

Incorporating energy efficiency into an RES is a second-best solution designed to expand the range of technologies that can be used to meet the standard. The most cost-effective way to regulate GHG emissions is to rely on a market-based system such as a cap-and-trade program or a tax that allows the market to choose the least-cost technologies.

Incorporating energy savings into an RES has the benefit of increasing utilities' incentives to promote efficiency whenever it is less costly than generation from renewable sources, which is likely to be the case at least some of the time. Energy efficiency is the ultimate "green" source of energy, lowering GHG and other emissions even more than generation from renewable sources. Many energy efficiency improvements are the "low-hanging fruit" of GHG emissions reduction. They can achieve the goals of an RES at lower cost than expanding renewable energy generation with its associated higher transmission costs.

This analysis demonstrates the importance of defining an energy efficiency standard carefully. If energy efficiency is defined relative to a baseline level of consumption, it is critical that the baseline be permitted to grow at an appropriate rate over time. Otherwise, the requirements to use renewable

Upgrading the existing transmission network would also produce direct electricity savings.

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generation will be less flexible than under a pure renewable electricity requirement.

Appendix A: Importance of Baseline Growth Rate

This appendix shows why it is important for the baseline against which energy savings are measured to grow in line with electricity consumption.

The Renewable Electricity Standard is defined as:

$$(X_t - Y_t) + R_t = 0.20Y_t \qquad \text{(i)}$$

where X_t = baseline electricity consumption at time t; Y_t = actual electricity consumption at time t; R_t = production from renewable at time t.

Rearranging terms:

$$R_t = 1.20Y_t - X_t \qquad \text{(ii)}$$

Assume that actual consumption grows at rate g and baseline consumption grows at rate n:

$$Y_t = Y_0 e^{gt} \qquad \text{(iii)}$$

$$X_t = X_0 e^{nt} \qquad \text{(iv)}$$

Then, from Eqs. (ii) to (iv) the growth rate of renewable generation is:

$$\frac{\dot{R}_t}{R_t} = \frac{1.20Y_0 g e^{gt} - X_0 n e^{nt}}{1.20Y_0 e^{gt} - X_0 e^{nt}} \qquad \text{(v)}$$

From Eq. (v) we can show that

$$\frac{\dot{R}_t}{R_t} \gtrless \frac{\dot{Y}_t}{Y_t} \quad \text{as } n \lessgtr g \qquad \text{(vi)}$$

From Eqs. (v) and (iii), we have

$$\frac{\dot{R}_t}{R_t} = \frac{1.20\,Y_0 g e^{gt} - X_0 n e^{nt}}{1.20\,Y_0 e^{gt} - X_0 e^{nt}} \gtrless g = \frac{\dot{Y}_t}{Y_t} \qquad \text{(vii)}$$

Rearranging terms:

$$1.20\,Y_0 g e^{gt} - X_0 n e^{nt} \gtrless g(1.20 Y_0 e^{gt} - X_0 e^{nt})$$

or:

$X_0 e^{nt}(g - n) \gtrless 0$, which is true as $n \lessgtr \omega g$.

In other words, if the baseline is defined in such a way that it grows more slowly than electricity consumption over time (i.e., if n is less than g) then renewable generation will be required to account for an increasing percentage of total consumption over time. Such a standard will be more restrictive than if it did not incorporate efficiency as an option.■

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Endnotes:

1. For reviews of this issue, see Apt, Lave and Pattanariyankool (2008) and Michaels (2008).

2. Proponents argue that an RES has additional goals, such as energy independence. These goals also involve reducing fossil-fuel generation and so the analysis would be similar. Some RES proponents may argue that promoting renewables is an end in itself. As a general matter, technologies should be adopted as a way of achieving socially worthwhile goals, not as ends in themselves.

3. In principle a cap-and-trade system should lead to cost-effective emissions reduction. This does not necessarily mean that it is justifiable on cost-benefit grounds. See Feldstein (2009).

4. Lave (2009) and Michaels (2008) also make this point.

5. An RES still would suffer in comparison to purer market-based approaches and performance standards that put all emissions-reducing technologies, including nuclear and carbon sequestration, on an equal footing. Performance standards typically apply to a firm and allow it to reach an emissions-reduction goal at least cost. Market-based approaches that put a price on emissions provide incentives for firms that can cut emissions at lower cost to do so, and therefore for society as a whole to reach its emissions-reduction goals at least-cost.

6. A reduction in the amount of energy consumed is sometimes referred to as energy "conservation," while energy "efficiency" denotes a reduction in the amount of energy required to produce a given amount of energy services, such as air conditioning, refrigeration, lighting,

etc. (e.g., Gillingham, Newell and Palmer, 2009). In this discussion, as in the legislative proposals, energy efficiency generally includes both components.

7. Making demand more price-responsive alleviates market power problems. See Blumsack, Apt and Lave (2006), and Rassenti, Smith and Wilson (2003).

8. Citing an ERCOT report, Michaels (2008, p.13) notes that "integrating 10,000 MW of renewable (nearly all wind) to comply with Texas' 2005 RPS will require between $1.7 and $3.0 billion in new transmission."

9. A Jan. 2009 Bingaman Discussion Draft specified a 20 percent renewable requirement, with efficiency permitted to satisfy up to a quarter of the requirement. The Markey-Platts bill in the House (H.R. 890) required a renewable share of 25 percent and did not permit efficiency to count towards the requirement. Markey has introduced separate legislation requiring a 15-percent reduction in energy use (H.R. 889). The Senate bill introduced by Sens. Mark Udall (D.-Colo.) and Tom Udall (D.-N.M.) (S.433) established renewable targets similar to those proposed in the Markey-Platts bill.

10. The Bingaman bill's energy efficiency provisions also include credit for reducing distribution system losses and installing combined heat and power systems.

11. Gillingham, Newell and Palmer (2009) catalogue a range of potential market failures, including externalities, average-cost pricing, capital market failures, and information problems that may account for underinvestment in energy efficiency. They also point to consumer behavior that may be inconsistent with utility maximization. Brennan (2009a) also discusses these issues.

12. Of course, under average-cost pricing, consumers will sometimes face prices that are greater than marginal cost.

13. For example, the McKinsey report (2007) argues that consumers expect many household investments to have a short, two- or three-year payback period, which implies a discount rate of nearly 40 percent. Other reasons it cites for underinvestment in energy efficiency measures include limited access to financing, divergence of owner and occupant interests for rental properties, and poor information about the performance benefits of efficiency-enhancing technologies.

14. Conservation advocates suggest that this problem can be alleviated by "decoupling" utility profits from sales. This major change in utility regulation is now being actively debated. For a discussion of decoupling, see Brennan (2009b).

15. See, generally, DOE (2006).

16. For example, SAIC estimated that the costs of implementing a comprehensive program in the San Diego area could be recouped in about seven years (SAIC, 2006).

17. This section owes much to discussions with Tim Brennan.

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