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Energy Efficiency Resource Standards

Economics and Policy

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RESOURCES
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Energy Efficiency Resource Standards: Economics and Policy

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Abstract

Twenty states in the United States have adopted energy efficiency resource standards (EERS) that specify absolute or percentage reductions in energy use relative to business as usual. We examine how an EERS compares to policies oriented to meeting objectives, such as reducing greenhouse gas emissions, correcting for consumer error in energy efficiency investment, or reducing peak demand absent real-time prices. If reducing energy use is a policy goal, one could use energy taxes or cap-and-trade systems rather than an EERS. An EERS can be optimal under special conditions, but to achieve optimal goals following energy efficiency investments, the marginal external harm must fall with greater energy use. This could happen if inframarginal energy has greater negative externalities, particularly regarding emissions, than energy employed at the margin.

Key Words: energy efficiency resource standards, energy efficiency, electricity, conservation

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Introduction

Twenty states have adopted energy efficiency resource standards (EERS), broadly regarded as standards or policies that require a minimum reduction of energy use, particularly through energy efficiency (EE) programs (Palmer et al. 2012). Some, including Maryland, specify not just reductions in overall electricity use, but also reductions in peak demand (Maryland Energy Administration 2008). EERS programs can cover natural gas and electricity; we focus here primarily on the latter. These programs vary greatly in their percentage reductions, dates by which they would nominally be achieved, and baselines or reference cases—what energy use would have been absent the EERS. They can also differ in a number of aspects of implementation, including the identification of responsible parties, methods of verification, incentives, and penalties for noncompliance.

Because an EERS is typically a target for reductions, and not a cap on use, the choice of the reference case becomes crucial. One cannot look only at how much electricity is used by a target year to see if an EERS is effective; one must have some way to estimate what the use would have been if the supporting EE programs had not been in place to see whether the absolute or percentage reduction goals were met. The energy savings that count are those that can be attributed to the EE programs rather than to independent factors, such as mild weather, economic downturns, or higher energy prices.[1] One can estimate the reference case either by making an

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[1] An example based loosely on the Maryland policy may make this clear. Suppose that energy use in 2007 is 100. An EERS requiring electricity use to fall to 85 percent of 2007 levels by 2015 would cap energy use in that year at 85. However, in general, an EERS would only require energy use to be 15 percent less than it would have been in 2015 absent policy interventions. So if energy use in 2015 would have been 110, the EERS would cap energy use at 95 (110 – 15), not 85 (or 15 percent less than the 2007 level). If use in 2015 would have been 120, then use under the EERS would be 105, exceeding the 2007 level. Different observed levels of energy use may be consistent with an EERS; to know whether the standard is satisfied, one needs to know the reference case from which reductions are calculated.

independent estimate of what energy use would have been absent the policies or by attributing energy savings to the policies directly (e.g., determining that X megawatt-hours of annual energy savings can be attributed to each subsidized compact fluorescent light bulb).

A broad question is whether an EERS is itself a policy, or a guidepost by which other policies are measured. Whether in fact an EERS is a "policy" alternative or an aspirational goal depends on whether the EERS has independent penalties for failure to comply. If it does, those charged with compliance will treat the EERS as a policy in and of itself; if it is a goal, then the primary focus should be on the policies that an EERS engenders, rather than the EERS itself.

One way to understand this "policy or goal" question is to consider whether an EERS is a substitute for, or a complement to, alternative policies. If it is a substitute, this implies that the EERS is a policy unto itself that takes the place of other policies. For example, were a cap-and-trade program in place, states might be less likely to adopt an EERS, believing that the goals of the EERS are being addressed in another way. An EERS is a goal, rather than a policy, if other policies are complements in that having an EERS in place increases the demand for them. For example, if having an EERS makes it more likely that a utility, state agency, or other entity will adopt policies, such as energy efficiency equipment subsidies or cap-and-trade mechanisms, to meet the EERS, then the EERS is a complement to those policies, not a substitute for them. Viewed in this light, an EERS would appear to be more of an aspirational goal for direct policy interventions to meet, rather than a policy itself.

Justifications for EERS programs usually appeal to factors beyond energy use directly; these include mitigating emissions and reducing electricity use during expensive peak demand periods. States may also institute EERS programs to encourage energy efficiency investments when the benefits from reduced spending on energy exceeds their up-front costs, but consumers nevertheless fail to take advantage of them. Other rationales include promoting economic development and employment ("green jobs") and addressing energy security (Palmer et al. 2012).

We begin by examining how an EERS compares to policies designed to address those specific justifications. We then turn to how an EERS would be designed if energy use reductions were the objective, to reach the level of energy use where its marginal value—willingness to pay less marginal cost—equals its marginal external harm. Using that framework, we identify conditions under which an EERS, specified by an absolute amount of energy reductions or an amount based on a percentage of business-as-usual (BAU) use, could lead to an optimal amount of energy use reductions as the underlying demand for energy changes. When the change in underlying demand is the result of increased investments in energy efficiency, the resulting reduction in the elasticity of demand for energy implies that an EERS leads to an optimal outcome only if the marginal external harm falls the more energy is used. This may well be the case when, for example, marginal megawatt-hours of electricity are generated using natural gas, which pollutes less than using coal to generate inframarginal megawatt-hours.

Rationales for EERS

As noted above, the rationales offered by states for EERS policies focus on improving the environment, reducing the need for new generation and transmission, helping consumers realize the benefits of energy efficiency investments, encouraging economic development and green jobs, and promoting energy security. For each rationale, we look at how an EERS might perform compared to policies specifically designed to address it.

Environmental Benefits

One of the leading concerns motivating policies to reduce energy use involves reducing the emissions of harmful pollutants that accompany the generation of electricity. This is not a new concern; federal policies going back more than two decades have addressed small particulates associated with an increased risk of heart or lung disease and premature death; sulfur dioxide, which can affect respiratory and cardiovascular functions and can create habitat-threatening acid rain and fine particles; nitrous oxides associated with smog and ozone as well as particulate creation; and mercury, which can cause renal and neurological problems, particularly in developing fetuses, when people eat fish from contaminated waters (Brennan, Palmer, and Martinez 2002, 161–62). More recently, an additional air pollution concern associated with electricity generation—emissions of carbon dioxide and an increase in the likelihood and severity of global climate change—has become more prominent.

Air effects are not the only environmental harms associated with electricity generation. Electricity generation generally requires copious amounts of water, as most forms of large-scale electricity generation (other than wind and combustion turbines) involve heating water to create the steam that drives turbines to produce power. Water is also used to cool the plumbing and machinery involved in generation. The conversion of surface or groundwater to steam and the return of warm water to lakes and streams can harm aquatic habitats. Nuclear power raises unique concerns associated with the risks of radioactive emissions following plant failures and, over the longer term, the disposal of radioactive waste fuels and materials from decommissioned plants. Wind power, although free of air and water effects, is associated with adverse effects such as noise, flickering light, the deaths of migrating birds and local bats, and in some celebrated cases, the degradation of otherwise desirable views (Rosenberg 2008, 640–41).

All sources are not equal when it comes to emissions. As alluded to above, electricity is generated using a wide variety of fuels; coal, natural gas, hydroelectric dams, nuclear reactors, wind, and other biofuels are the leading sources of energy. The wide variety of fuels and technologies arises because of differences in location; for example, not every electricity user is near a river amenable to damning for hydropower or a site with reliable wind currents. Further, some types of electricity, most notably nuclear and coal, are characterized by high fixed costs relative to fuel and operating costs, making them relatively economical for continuous baseload operation. Natural gas combustion turbines, on the other hand, can be produced at smaller scales and designed to come on and off in response to variations in demand.

In addition, each of these fuels has a different pollution profile, although one often finds considerable variation within fuel types as well. Coal is often regarded as the dirtiest, but emissions can be controlled through the use of low-sulfur coal, scrubbers to remove emissions of SO_2 and other technologies to remove emissions of nitrogen oxides or mercury. Still in the prototype stage are technologies to capture carbon dioxide emissions from coal and natural gas plants and store them underground so they do not exacerbate atmospheric greenhouse effects. In addition, the production of coal, particularly strip mining, raises environmental concerns.[2] Natural gas is typically cleaner than coal, though with variation among the different gas generation methods. For example, combined cycle plants produce more electricity for a given level of heat and thus have lower emissions per kilowatt-hour compared to boilers or simple gas turbines.[3] Moreover, natural gas (methane) in the environment is itself a potent greenhouse gas, raising concerns about leakage. Methane emissions potential, along with alleged effects on groundwater quality and other land use issues, has raised concerns regarding hydrofracturing ("fracking") methods for extracting natural gas from shale deposits deep underground.

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[2] Coal mining also raises the possibility of other potential market failures. In particular, miners may not be informed of the risks, such as mine accidents and post-mining respiratory diseases, and they may not be compensated for such accidents or diseases. Although important, these risks to miners can, at least in principle, be addressed through safety standards and information programs.

[3] U.S. Environmental Protection Agency, Natural Gas, http://www.epa.gov/cleanenergy/energy-and-you/affect/natural-gas.html (last accessed November 16, 2011).

Although an EERS can reduce these assorted environmental harms by reducing energy use, it is a very crude instrument for doing so. Its essential shortcoming is that an energy use reduction target treats reductions from all energy sources equally. In general, one would expect that an EERS would eliminate the least valuable uses of energy, that is, those uses for which the value of the electricity to users, less the sum of the cost of generation and the cost of investments or technologies to reduce energy use, is the smallest.[4] This need not match the change in the portfolio of electricity generation methods that would be optimal were one targeting emissions directly.

This may be seen most easily by noting that, leaving aside variations in how much consumers might value electricity or in the cost of energy efficiency investment, an EERS will lead to a reduction in the most expensive source of generation, which may not be the source with the highest emissions. For example, an EERS could result in reduced electricity use when natural gas is the marginal fuel, but a policy directed at reducing greenhouse gases or particulate emissions might instead reduce the use of coal and increase use of natural gas. In the extreme, electricity use could be reduced when the generation source is hydropower or nuclear, where greenhouse gas emissions are not relevant. One avoids this outcome with policies directed specifically at emissions. We show below that if the target of the policy is limited to energy use, with the effect on emissions only indirect, having marginal harm fall with greater electricity use is necessary for an EERS to optimally reduce energy use when demand for electricity changes as a result of energy efficiency investments.

In principle, the most economically efficient method for getting sellers and buyers to incorporate the cost of pollution into their production and purchase decisions is to institute some means of pricing pollution directly. The two broad categories of policies with which to do this are taxes on emissions (e.g., a price on emitting a ton of carbon dioxide) and marketable permit programs. A tax will influence the cost, and thus the price, of electricity based on the amount of

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[4] This relationship won't hold if electricity prices do not match generation cost, as is the case when users pay the same price for electricity at peak demand times, when electricity generation can be very expensive, as they do at off-peak times when it is cheap. If prices do not conform to cost, users are already not maximizing the value of electricity, because they use too much when it is expensive and not enough when it is cheap. A second complication is that part of the cost of generation is typically covered through capacity markets, in which generators receive payments for having capacity in reserve and as compensation when, because of price controls, electricity prices would generate insufficient revenues to cover capital costs. We discuss EERS policies that address these complications below, but they can safely be ignored to understand why an EERS is not designed to reduce emissions in an economically efficient way.

emissions used by the technology for generating it. A carbon tax, for example, would differentially affect those fuels that emit more carbon dioxide, correcting for the “it’s all the same” aspect of an EERS. A marketable permit program, which allows producers to collectively emit up to a given amount, will have the same differential effect, such that the price of a permit to emit a ton of carbon dioxide will be incorporated into the generation cost just as would the tax.[5] Despite this fundamental similarity, tax and marketable permit programs differ in some ways; we discuss these differences below when we address them as alternative means of reducing energy were a state to decide to focus on energy reduction rather than emissions reduction.

Reduce Use of Expensive Electricity during Peak Demand Periods

A second leading motivator for EERS policies is to reduce the need for generation and transmission capacity. This is most crucial at peak periods. Because electricity, once produced, generally cannot be stored,[6] it has to be produced to meet demand on a virtually minute-by-minute basis. This means that the capacity to produce or deliver the largest amount of electricity that could be demanded has to be in place at all times. If demand for electricity were nearly constant over time, this would not be problematic. However, system loads can vary greatly depending on the time of day, day of the week, season of the year, and variations in weather conditions during any of those times.

In many regions of the United States, particularly where weather-driven demand can be highly variable, the largest peaks in demand may occur during only a few hours of the year, such as on hot and humid summer afternoons on weekdays when commercial and business demand is

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[5] Emitting one more ton of the pollutant either requires the purchase of a permit at the permit price or forces the polluter to forgo the opportunity to sell a permit that it would not otherwise need. Whether by increasing expenses on permits or reducing revenues from their sale, the cost of generating electricity that results in an additional ton of emissions will increase by the price of the permit.

[6] The one large-scale exception is pumped storage, where electricity produced during off-peak periods can be used to pump water into reservoirs, which can then be drained through turbines to produce electricity during peak periods. Pumped storage is limited (a) to regions with hydroelectric facilities and (b) by the volume of the reservoirs and the capacity of the hydroelectric facilities to generate electricity. As an example of a smaller-scale way to store electricity, some large-building cooling systems rely on the creation of ice or dry ice when electricity is inexpensive, during the evenings, and then use that ice to cool air and provide air conditioning during the day when electricity would be expensive. In addition to being limited in applicability, pumped storage and smaller-scale storage methods incur considerable costs, both in terms of the facilities needed to bring about the storage and the inevitable fact that the energy that comes out of storage will be less than the energy that went in.

also high. In Maryland, the top 15 percent of capacity comes into play less than 60 hours per year, less than 1 percent of the 8,760 hours in a year. If the price of electricity has to be high enough to cover, in those 60 hours, the full cost of that capacity, then the price can be orders of magnitude greater during those 60 hours than during nonpeak baseload times.[7]

For this reason, programs that shave demand on peak can have large benefits in avoided costs of constructing generation and transmission capacity just to meet demand during those few critical peak hours. The usual method for getting users attuned to costs throughout the economy is to charge prices reflecting that costs so users elect to purchase something only when its value to them exceeds its cost. For electricity, this would entail effective means for imposing real-time prices that vary to reflect the costs, particularly during the critical peak hours.[8] A similar alternative considered in some states, including Maryland, is to pay consumers for reducing use at critical peak times (Sergici and Faruqui 2011).[9]

For such programs to be effective, one needs more than new meters that allow the measurement of electricity use by time (rather than just the total over a month); users also need some way to know when high critical peak prices or payment programs are in effect and how to control their energy use in response to those incentives. Absent effective pricing methods, high peak-period costs may warrant adoption of less direct alternatives, such as setting a quantity target through a peak demand EERS and using a combination of centralized energy use controls (e.g., cycling off air conditioners during peak periods), subsidizing the use of high-efficiency appliances used during critical peak periods (again, air conditioners), and other attempts to

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[7] Because of concerns regarding these high prices and the potential for generators to take advantage of the system operating at its limits by withholding energy and driving up prices even more, many wholesale markets employ a combination of ceiling prices on energy. Because ceiling prices limit cost recovery, these wholesale markets also typically have (a) capacity markets to cover remaining costs and to provide for the capacity needed to meet peak demand and (b) reserves in place in case of unexpected demand surges or equipment failures. However, the payments for this capacity eventually have to be incorporated in the prices users pay for electricity.

[8] Because the critical peak hours are generally not predictable long in advance, and because so few of them occur throughout a typical year, softer methods of charging for electricity on the basis of the time of day or season of the year will not be sufficiently responsive to send the price signals necessary to get electricity users to conserve electricity or to shift the time of use to avoid these very high critical peak costs.

[9] Revenues to cover the cost of these reductions could come from selling the ability to reduce demand during critical peak periods—*demand response*—in capacity markets. An important consideration here, as elsewhere, is estimating the reference case from which use reductions would be measured. For a critical peak pricing experiment in Anaheim, California, Wolak (2006) found that paying a rebate for reductions in consumption from a reference level of demand that occurs on noncritical peak days can result in an increase in demand on those days.

persuade consumers to shift use away from peak periods (e.g., by running dishwashers and clothes dryers at night).

In considering these proposals, one should keep two things in mind. First, although the potential to avoid high costs by attenuating peak demand is considerable, the amount of energy saved by reducing peak demand is typically a small fraction of total energy use. For example, if electricity use in 60 critical peak hours is double the average use, and EERS reduces use in those peak periods by 15 percent, the total electricity use reduction would be only about 0.2 percent of the total, or just over 1 percent of the reductions needed to meet an overall 15 percent energy use reduction goal. Second, the most cost-effective energy use reductions, if timed optimally, will be a very small portion of total energy use, suggesting that states might want to focus an EERS primarily, if not exclusively, on peak demand rather than on total use; currently about half of the states with an EERS focusing on overall electricity use also have an EERS focusing on peak demand (Palmer et al. 2012).[10]

Correct for Market Error in Energy Efficiency Investing

A third leading justification for EERS programs is that consumers fail to make energy efficiency investments that would make them better off, in the sense that the reduced spending on energy (discounted at reasonable rates) would more than offset the up-front cost of the energy efficiency investments. These private returns to energy efficiency investments are in addition to any other benefits to the public at large from reduced energy use, such as from reduced harms due to emissions of greenhouse gases or other pollutants. This justification for EERS is something of a puzzle in economic terms, as it seems to say that people fail to optimize.

This is not a new concern; Hausman (1979) found that the implicit discount rate for savings from energy efficiency in the purchase of room air conditioners ran from about 9 percent for middle-income purchasers up to 39 percent for low-income purchasers. Hausman treated these as accurate representations of time preference, suggesting that energy efficiency standards that prevented low-income people from buying less expensive, less efficient air conditioners would make them worse off. Gately (1980) found that the corresponding discount rates for

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[10] A related possibility is that, in proposing EERS as a means to reduce expenditures on energy, a state could be in a position not only to avoid costs resulting from an inability to set the right prices, but also to drive use down so prices fall below competitive levels—in other words, the state might exercise monopsony power against energy sellers. Such tactics would benefit consumers but reduce the overall economic efficiency of energy markets. The circumstances under which a state could exercise monopsony power appear fairly limited (Brennan 2011a).

energy purchases ran as high as 300 percent, which he found sufficiently implausible to be represent actual time preference; more likely, he said, this indicated that “the calculations were difficult or impossible because of ignorance of the monthly operating costs” (Gately 1980, 374).

Gillingham, Newell, and Palmer (2009) surveyed a number of reasons why consumers may fail to make these investments. Among these are difficulty in borrowing to finance the up-front costs of such investments, an inability to reconcile incentives in rental properties between the landlords who would pay for more-efficient appliances and the tenants who would be saving the money on their electricity bills, and failure to recapture the undepreciated cost of energy efficiency investments when houses are sold. As a public good, information on the benefits of energy efficiency may not be freely available. Gillingham, Newell, and Palmer also noted that one source of the problem may be *behavioral failures*—that is, cognitive limitations or biases that keep people from taking actions that would be in their own self-interest.

The problem with using EERS to address this issue is that the usual presumption in economic policy design is that consumers make choices in their own interest. Because this presumption may not be accurate, policies intended to address the apparent consumer failure might be used first to improve the information they have. Vendors of high-efficiency appliances have an incentive to inform consumers of the benefits of such appliances over time, but perhaps this is inadequate in light of consumers’ difficulty in verifying advertising claims. Electric utilities lack incentives to provide this information if their profits are based on how much electricity consumers use (Brennan 2010). A second set of policies could help people overcome information problems that prevent them from borrowing money at reasonable risk-adjusted rates to finance energy efficiency investments.[11]

Whether correcting for information failures would lead to consumer choices that meet an EERS is an empirical question. As a matter of policy design, it would make more economic sense to fix the information failures rather than induce changes through subsidy programs. With improved information, whatever electricity reductions we see would be presumptively those consumers choose that benefit them directly (i.e., absent other market failures based on the environmental or pricing issues described above). Designing policy without a presumption that appropriately informed consumer choices are the correct ones becomes more difficult. The

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[11] See Palmer et al. (forthcoming) for a discussion of private markets for energy efficiency finance and the role of government policy.

policymaker is now in the position of having to decide what a consumer would do if she did what the regulator or legislature regards as correct. To some degree, one could put this within the realm of conventional economic policy evaluation by treating it as a rational delegation of authority from consumers to policymakers, allowing consumers to avoid the time and trouble of having to think through the decision of whether to invest in energy efficiency. Otherwise, the evaluation of these policies requires additional information beyond what consumers reveal about their willingness or reluctance to spend now on energy efficiency to reduce electricity expenditures later.

Economic Development and Green Jobs

Some states view EERS programs as instruments to promote economic development in green sectors of the economy—those associated with reduced emissions. Many state policymakers and economic planners hold the view that this is a growing international sector, and that economic benefits would flow to their state if they got a head start in the market. Requiring that consumers use less energy would increase demand for energy-saving technologies and retrofits of the existing building stock. This increased demand would lead firms to start up or locate in the state. This, in turn, would provide jobs to workers in those green sectors and facilitate entrepreneurial initiative and innovation that would make the state an economic leader in this sector.

Ultimately, this is an empirical question. Because EERS programs are new, data to confirm that they promote green economic development and employment are not available. However, economic principles lead us to be somewhat skeptical of these claims. First, markets for energy efficiency devices and appliances are likely to be national if not international. Thus, stimulating demand through an EERS is not likely to generate supply-side benefits within the state, with the possible exception of construction jobs associated with building retrofit and equipment installation. In addition, policies to conserve electricity use will reduce the demand for new energy sources, and thus may inhibit growth in sectors devoted to the development of green energy alternatives. A notable example is that an EERS could inhibit growth in the use of plug-in hybrid or all-electric vehicles if the added electricity use they entail would make it harder overall to meet a use reduction target. More generally, reduced spending on energy will reduce demand for labor in those sectors. Another example is renewable energy development. In many states, renewable investment is driven by a renewable portfolio standard requiring that a minimum percentage of electricity sales come from qualified renewables. EERS policies that reduce growth in electricity use reduce renewable energy development.

This last point leads to a more general reason for skepticism regarding EERS as an instrument to promote job growth. An EERS may well change the composition of consumer spending, partly toward energy-efficient technologies, partly away from energy itself and, depending on net expenditures, toward or away from other goods and services. When the economy is working well overall, this change in the composition of jobs is not likely to affect employment overall. The story may be quite different in a recession, when many people are willing to work at prevailing wages and salaries but cannot find positions. In that context, the jobs question becomes whether promoting energy conservation is a better way to stimulate a local economy than other methods intended to encourage the hiring of those who are unable to find adequate work.

Apart from employment, a state government may be interested in increasing or exploiting a state's potential to become a substantial presence in green technology–related markets. If so, public policies directly targeting that end may be more effective. Although we are not experts in local economic development, we imagine that such policies may include tax credits to induce firms to relocate to the state, fostering collaborations between universities and entrepreneurs, and increasing subsidies for educating students in areas related to these technologies. Whether the benefits of such policies exceed their costs is outside our bailiwick.

Energy Security

Although difficult to quantify, the energy security concern arises from the view that an economy would be better off if it reduced imports of energy from other countries. Some of this is to avoid potential price volatility; another motivation is the geopolitical instabilities that could leave the economy vulnerable to a sudden unavailability of imports or induce military measures to maintain access to those energy supplies.[12]

Important as those concerns may be, they are not immediately significant for electricity generation (Brennan 2007). The energy security concern is almost exclusively about oil, and in the United States, almost no electricity is generated with oil. Electricity generation may be indirectly affected, however, because electricity may be a substitute for oil products as an energy source for particular services. Home heating is one example. If electric-powered vehicles become more important, it is conceivable that long-run concerns about the security of oil supplies may

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[12] For a discussion of the energy security externalities associated with imported oil, see Brown and Huntington (2010).

increase demand for electric vehicles and, ultimately, the electricity to power them. An EERS could be viewed as a way to increase reserve electricity generation capacity were a situation like this to arise. However, we cannot say that these indirect effects are sufficiently likely to justify any intervention in electricity markets on national security grounds.

Policies To Reduce Energy Use

As just discussed, a wide variety of policies could directly and more efficiently address the prominent goals justifying EERS policies. However, if reducing energy use—or, here, electricity use—remains a policy goal, the effects of direct policies other than an EERS to do so should be considered.[13] We want first to see how one might apply to energy use these more standard approaches for regulating externalities. We then examine the conditions under which the approaches taken in typical EERS programs could lead to optimal outcomes. This section concludes with a discussion of whether an EERS program might be inappropriate because the sources of electricity likely to be withheld might pollute less than those sources that are likely to remain in use. In that context, the level of electricity use for which the marginal harm equals its marginal value could minimize rather than maximize net economic benefit. [14]

At the top of the list of standard regulatory approaches are specific mandates to take actions with predictable reductions in energy use. Such policies are typically referred to as *command-and-control* (CAC) mechanisms. One example would be requirements to install high-efficiency appliances or lighting. Another would be a requirement to bring a house up to a prevailing energy efficiency code for new homes prior to sale or, slightly more flexibly, a mandate that each household or firm reduce its electricity use by a specified amount or percentage. A potential advantage of a CAC policy is that it may be easier to monitor compliance (e.g., to inspect businesses and households to see if they have installed mandated equipment. The cost of a CAC, however, is its inflexibility. In the short run, a CAC prevents reallocation of the burden of meeting an overall reduction from those who could cut energy use only at high cost to

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[13] Harris et al. (2008) argue for a greater focus on energy conservation—that is, reduced consumption of energy services—in energy policy. They suggest tying efficiency standards to levels of use, such as building size, as opposed to a direct cap. So, for example, larger houses would face stricter efficiency standards than smaller houses.

[14] The marginal value of electricity is the difference between the willingness of consumers to pay for the benefits brought about by that marginal megawatt-hour and the marginal cost of generating that marginal megawatt-hour (not counting externalities). This value can increase if the demand for electricity increases or the marginal cost of generating electricity falls and vice versa.

those who could do so at relatively low cost. In the long run, CAC policies that involve technology mandates can lock in potentially obsolete equipment and discourage innovation and adoption of new devices that could provide greater reductions at lower net costs.

For these reasons, economists have long advocated policies that provide appropriate incentives to make the desired reductions, but allow producers and consumers to collectively find the least cost means to do so and maintain an atmosphere conducive to innovation. The two leading types of incentive-based policies are taxes and marketable permits, frequently known as cap-and-trade programs. The usual context involves pollution. A tax on emissions will lead sellers and buyers to factor in the costs of emissions in their supply and purchase decisions, providing appropriate incentives for abatement or reducing the production or use of goods and services that lead to extra emissions. Under cap-and-trade, a decision that leads to the emission of one more unit will either require one to purchase a permit to do so at the permit market price, or to forgo the opportunity to sell a permit at that price. Either way, emissions lead to higher costs, which again will encourage abatement or reductions of goods or services associated with greater emissions. Both taxes and marketable permit programs create incentives to come up with innovative technologies and methods to reduce abatement expense or to minimize the costs of reducing the use of these goods and services.

In the EERS context, the analogue to an emissions tax would be a tax on energy use meant to encourage users to take into account the supposed external costs of using energy that the market price of electricity does not incorporate. An example of a marketable permit program would be to allocate a fixed quantity of “rights to purchase energy” coupons among energy suppliers, households, and businesses—perhaps requiring any or all of them to purchase coupons from the government—and then let them buy and sell coupons from and to each other so those who get the highest economic value from electricity use are able to do so. The analogue to abatement would be investing in energy-efficient equipment that allows the production of services (heating, cooling, lighting, and communication) with less energy. An example of reduced use of goods and services under an EERS would be setting the thermostat at a higher temperature during the summer to reduce the use of air conditioning.

In principle, the choice of whether to use taxes or marketable permits depends on a variety of economic and political factors. On the economic side, permits tend to be better when going beyond a target level of the bad activity, in this case energy consumption, creates very large harms to be avoided at almost any cost. Taxes tend to be better when the harm from an additional use of a unit of energy (e.g., a megawatt-hour) is relatively constant regardless of the number of units used (Weitzman 1974). A second issue is that the costs of a tax or permit program may be exacerbated if piled onto preexisting taxes, and could be beneficial only if the revenues from the new tax or permit program are used to reduce those preexisting taxes. This, in particular, is an argument for the government selling permits, rather than giving them away, so it has revenues it can use for this purpose (Oates and Parry 2000).

This last point leads to political arguments that cut the other way. Under a permit program, the government can give the permits away to different groups in the economy to secure different ends. First, it can give the permits to politically powerful entities that would be worse off if energy use was reduced, and thus mitigate their opposition to the program. Second, allowing energy prices to rise through a tax or permit program enough to induce a desired level of conservation may be hard on the budgets of many households, and permits could be allocated to those households, particularly low-income households, to reduce the burden on them (Blonz, Burtraw, and Walls 2011).[15]

A last point to be made is that a cap on electricity use could be counterproductive from the perspective of environmental protection. The most prominent example would be getting gasoline-fueled vehicles off the road and instead using plug-in hybrids or all-electric vehicles. If cars, trucks, and buses charged from the electric grid were to become widespread, the electricity to charge them either might not be forthcoming under an electricity cap or would require reductions of electricity uses highly valued by consumers. Another example could be the substitution of electricity in home heating for gas, propane, or oil heat that might take place if reducing emissions rather than electricity use were the goal.[16] To avoid these outcomes, a cap would need to be adjusted because the optimal amount of electricity use will vary as opportunities expand to substitute it for fossil fuels as an energy source in transportation, heating, and perhaps other sectors.

Are EERS Programs Ever Optimal?

In the United States, no EERS program makes use of a tax mechanism or allows for the trading of credits between entities, such as utilities. Two states, however, allow for energy

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[15] Conceptually, the government could do the same thing with tax revenues, although practically it might be harder to give away revenues than permits.

[16] We note that some states have EERS programs directed toward natural gas as well.

savings that exceed the state's given year's goals to be banked.[17] Instead, the EERS plans typically take one of two forms. The leading form, as described at the outset, is that the EERS is not a cap or tax on energy use, but a requirement that the amount of electricity used be a fixed quantity—X percent of the amount used in some base year—below the BAU amount (i.e., below the amount that would have been used absent a policy). When the base year is the current year, the EERS takes the form of a fixed percentage reduction in the amount of electricity used. The second form is that the target of an EERS be calculated as a percentage of what would have been used had no policy been in place.

This introduces the question of whether EERS approaches could achieve optimal results. The question arises because under an EERS approach, an exogenous change in electricity demand changes the amount of electricity use that an EERS program permits. A change in demand also can change the amount of electricity for which the marginal external harm equals the marginal value of electricity use. If no exogenous change in demand is expected, no difference need arise; the EERS can be targeted to allow the optimal quantity of energy use. If demand can change, however, the change in use permitted by the EERS, whether a constant or percentage reduction, need not equal the change in the optimal amount of energy use; we describe some likely exceptional cases in which an EERS would produce an optimal outcome in the face of changing demand.

- If the marginal external harm from electricity use is constant, the marginal value function is linear, and a change in demand increases or decreases the marginal value by a constant amount for each megawatt-hour—a parallel shift in willingness to pay for electricity or the marginal cost of making it—then the optimal reduction of electricity use below BAU will be unchanged. This would justify an EERS mandating a fixed reduction in electricity use.
- If the marginal external harm from electricity use is constant, the demand and marginal cost curves for electricity are linear, and the change in the marginal value of electricity reflects a constant change in the slopes of either or both of those curves, then the optimal

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[17] In the European Union, however, *white certificate* programs designed to promote energy efficiency—mentioned in the conclusion below—have aspects of a marketable permit program. In particular, the white certificate programs in the United Kingdom, France and Italy, described above, allow for the creation and trading of energy savings certificates, although very little trading has occurred in the United Kingdom (Giraudet et al. 2011).

reduction of electricity use below BAU will remain a fixed percentage of BAU use. This would justify an EERS mandating a fixed percentage reduction in electricity use.

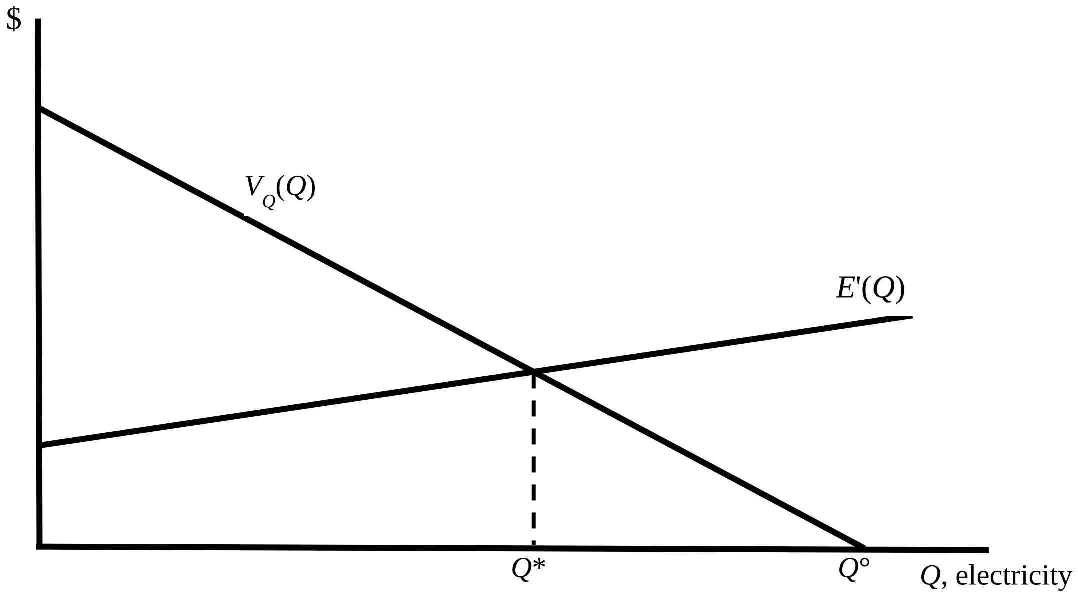
- If changes in the marginal value of electricity are only inframarginal, leaving the marginal value of the last unit of electricity used under BAU at zero, then an EERS with either a fixed absolute or fixed percentage reduction will produce the optimal outcome if marginal harm becomes infinite beyond the efficient level of energy use.

These need not be the only settings in which an EERS achieves optimal results; on the other hand, there is no reason to believe that any of these settings or any others need hold.

To examine the optimality of EERS programs that reduce electricity use, let Q be the quantity of electricity used, $B(Q)$ be the benefit consumers get from using electricity, and $C(Q)$ be the marginal cost of generating that electricity. Define $V(Q) = B(Q) – C(Q)$ as the value of electricity. To allow $V(Q)$ to change from outside factors, rewrite it as $V(Q, \theta)$, where θ is a parameter reflecting exogenous changes in the benefit or cost functions. Let $E(Q)$ be the external harm associated with electricity generation; to keep matters simple, assume that the external harm from generation (e.g., marginal greenhouse gas effects) is independent of θ, the parameter affecting V.

Assuming no market failures associated with a significant lack of competition or asymmetric information, in the absence of policy, electricity will be used up to the point where $V_Q(Q, \theta) = 0$. Let $Q°$ be the value of Q where this holds. If external harms are taken into account, net economic benefit $V(Q, \theta) – E(Q)$ is maximized at the level of electricity use where $V_Q(Q, \theta) – E'(Q) = 0$; let Q^* be the level of electricity where this holds. The optimal reduction in electricity use is $Q° – Q^*$; this difference will depend on θ. Figure 1 depicts this framework.

Figure 1. Business-as-Usual and Optimal Electricity Use



If a fixed-quantity EERS is in place, it will achieve the optimal level if it equals $Q^\circ - Q^*$ and that difference is constant for all θ

$$\frac{d\left(Q^\circ - Q^*\right)}{d\theta} = 0.$$

The conditions defining Q° and Q^* imply that

$$\frac{dQ^\circ}{d\theta} = -\frac{V_{Q\theta}^\circ}{V_{QQ}^\circ}, \frac{dQ^*}{d\theta} = -\frac{V_{Q\theta}^*}{V_{QQ}^* - E''^*},$$

where the superscripts ◦ and ∗ indicate that these second partial derivatives are calculated at Q° or Q^* respectively. For $Q^\circ - Q^*$ to be constant,

$$\frac{d\left(Q^\circ - Q^*\right)}{d\theta} = -\frac{V_{Q\theta}^\circ}{V_{QQ}^\circ} + \frac{V_{Q\theta}^*}{V_{QQ}^* - E''^*} = 0,$$

implying

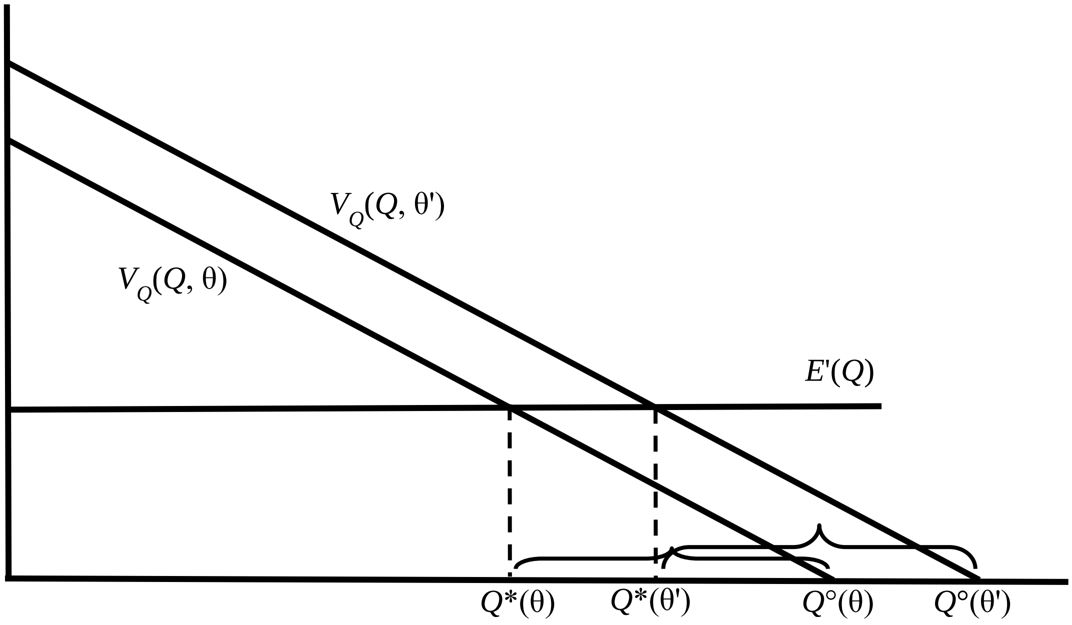
$$\frac{V_{Q\theta}^\circ}{V_{QQ}^\circ} = \frac{V_{Q\theta}^*}{V_{QQ}^* - E''^*}$$

and thus

$$E''\left(Q^*\right) = \frac{V^\circ_{Q\theta} V^*_{QQ} - V^*_{Q\theta} V^\circ_{QQ}}{V^\circ_{Q\theta}}. \tag{1}$$

If marginal external harm is constant, $E'' = 0$. If the effect of θ on V_Q is constant for all Q, $V^\circ_{Q\theta} = V^*_{Q\theta}$. If the marginal value function is linear, $V^\circ_{QQ} = V^*_{QQ}$. If all of those hold, (1) is satisfied implying the above derivative is zero and an EERS with a constant electricity reduction requirement would be optimal for all θ. Figure 2 depicts this setting where θ indicates the initial marginal value and θ' the value curve following a change; the distance between Q^* and Q° is the same for θ and θ′, as indicated by the brackets.

Figure 2. Potential Optimality of a Fixed-Quantity EERS



If an EERS limits electricity use to a fixed percentage below BAU, then the optimal reduction in electricity use $Q^\circ - Q^*$ will need to equal kQ°, a constant fraction k of BAU use. This implies that $Q^*/Q^\circ = 1 - k$ must stay constant for all θ. For this to hold,

$$\frac{d\left(\frac{Q^*}{Q^\circ}\right)}{d\theta} = 0,$$

which requires that

$$Q^{\circ}\frac{dQ^{*}}{d\theta}-Q^{*}\frac{dQ^{\circ}}{d\theta}=0.$$

This holds when

$$\frac{Q^{*}V_{Q\theta}^{\circ}}{V_{QQ}^{\circ}}=\frac{Q^{\circ}V_{Q\theta}^{*}}{V_{QQ}^{*}-E''^{*}}$$

or

$$E''\left(Q^{*}\right)=\frac{Q^{*}V_{Q\theta}^{\circ}V_{QQ}^{*}-Q^{\circ}V_{Q\theta}^{*}V_{QQ}^{\circ}}{Q^{*}V_{Q\theta}^{\circ}}. \tag{2}$$

An example of when (2) would hold with changes in the net value of electricity is when $E'' = 0$ and the value function is

$$V(Q, \theta) = aQ - \theta bQ^2,$$

which gives a linear marginal value of electricity with varying slope

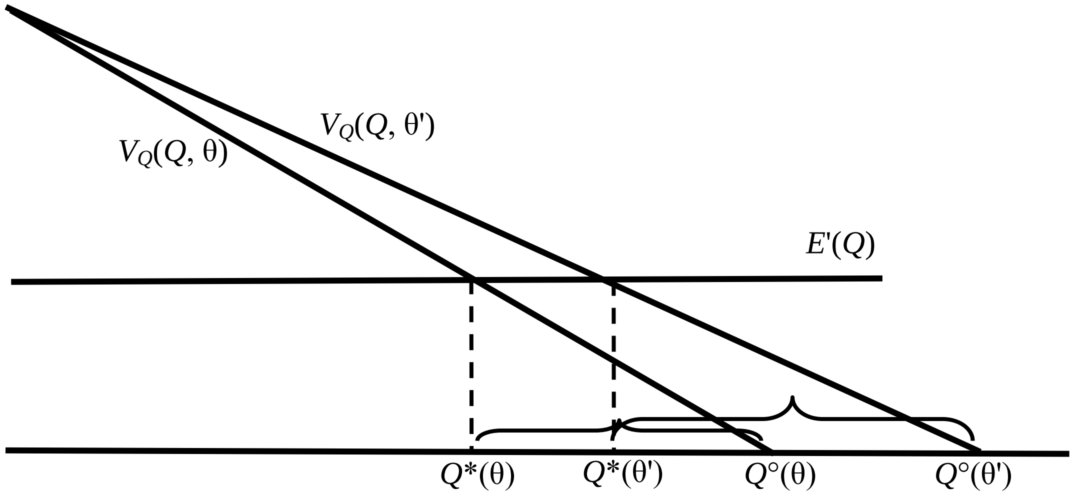
$$V_Q = a - 2\theta bQ,$$

a relationship where the quantity of electricity with any particular marginal value changes in equal proportion as θ changes. For this function, $V_{Q\theta} = -2bQ$ and $V_{QQ} = -2b\theta$. Inserting these values into condition (2) shows that the condition for a fixed-percentage EERS to produce optimal results is satisfied when

$$E''\left(Q^{*}\right)=\frac{4b^{2}\theta Q^{*}Q^{\circ}-4b^{2}\theta Q^{\circ}Q^{*}}{-2bQ^{*}Q^{\circ}}=0.$$

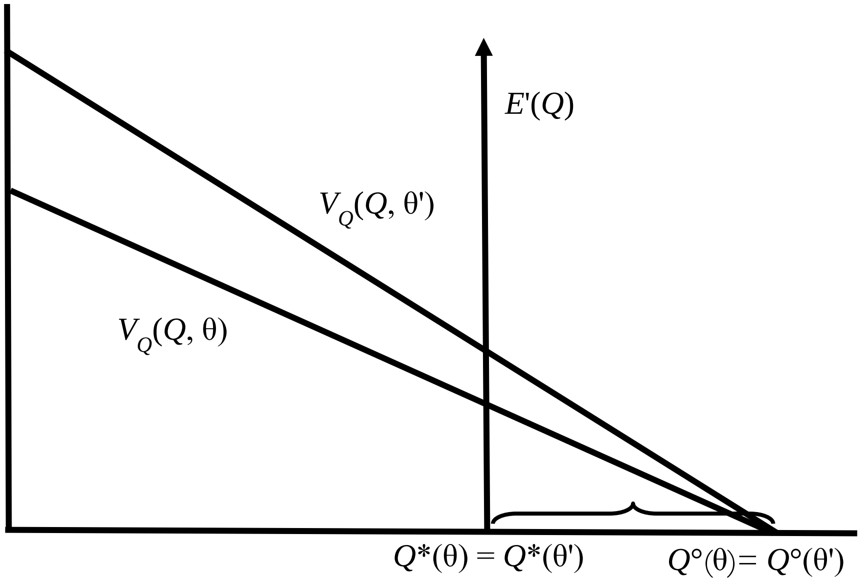
Figure 3 below illustrates this case, where the brackets indicate that the difference between Q^* and Q° increases proportionally with Q°.

Figure 3. Potential Optimality of a Fixed-Percentage EERS



Turning to the case where E'' is infinite at Q^*, the marginal harm of going beyond that point is infinite, making Q^* the target regardless of the size of demand; conditions (1) and (2) are both satisfied if $V°_{Q\theta} = 0$. The set of potential changes in the willingness to pay for electricity or its marginal cost of generation and delivery would have inframarginal effects but no effect on the quantity of electricity used absent an EERS. Under those conditions, an EERS that reduces electricity use by a fixed amount or fixed percentage relative to BAU would be optimal. As illustrated by Figure 4, this holds simply because these two conditions imply that both BAU electricity use and the optimal level of electricity use are independent of variations in the marginal value of electricity.

Figure 4. Potential Optimality of a Fixed-Percentage or Fixed-Amount EERS with Infinite Marginal Harm at *Q**



Energy Efficiency and the EERS

Although some energy efficiency investments may be the result of utility or state government efforts in response to an EERS, some investments may be undertaken outside those policies. Recall that a rationale for these policies is that they produce net benefits for consumers apart from environmental improvements, so one might expect the market to advertise these gains and consumers to make these investments without utility or state government assistance. In addition to EERS policies, some federal appliance standards and local building codes will increase the level of energy efficiency investments over time. Lastly, an EERS requirement based on consumption in recent years will be imposed on an economy with a different marginal value of electricity than would otherwise be in place had earlier energy efficiency investments not been made.

Accordingly, a last point to consider is the compatibility between energy efficiency investments and the form of an EERS. Greater energy efficiency will change the position of the marginal value curve for electricity, given by V_Q. Following such a shift, the question becomes whether an EERS defined by a fixed absolute or percentage reduction of use from the reference case following such a policy would give the efficient level of electricity use. Even with energy efficiency in place, whether adopted to meet EERS targets or privately chosen in light of energy savings or altruistic motives to reduce greenhouse gas emissions, energy use will still have marginal harms. If so, a policy to reduce use would still have added benefits even after the energy efficiency reductions are put in place.[18]

To model this effect, using the same notation as above, let Q be electricity use as above and θ an index of energy efficiency. Assume further, as in some of the illustrative examples above, that the marginal value curve for electricity is a straight line. Let $1/\theta$ be the normalized quantity of electricity demanded where the price of electricity is zero, with θ units of energy efficiency in place; increased energy efficiency reduces the quantity of electricity that satiates demand. To keep the presentation simple, assume that the marginal cost of generation is zero; assuming a positive constant marginal cost has no effect on the qualitative results. In that case, if energy efficiency neither reduces nor enhances the quality of services generated from electricity, the total gross value of the services provided using electricity up to that point of satiation would be constant at a level K. If the value of the service with no electricity used is zero, the area under the straight line has to be constant, equal to K, regardless of θ. This implies that the maximum willingness to pay for electricity must equal $2K\theta$ for the area under the line to equal V.[19] Setting the slope of the marginal value curve to be $2K\theta^2$ so $V_Q = 0$ when $Q = 1/\theta$, the marginal value curve $V_Q(Q, \theta)$ is

$$V_Q(Q, \theta) = 2K\theta - 2K\theta^2 Q$$

and the marginal value line pivots as θ increases.[20] Figure 5 displays this outcome, and shows how the marginal value line changes when energy efficiency increases from θ to θ'.

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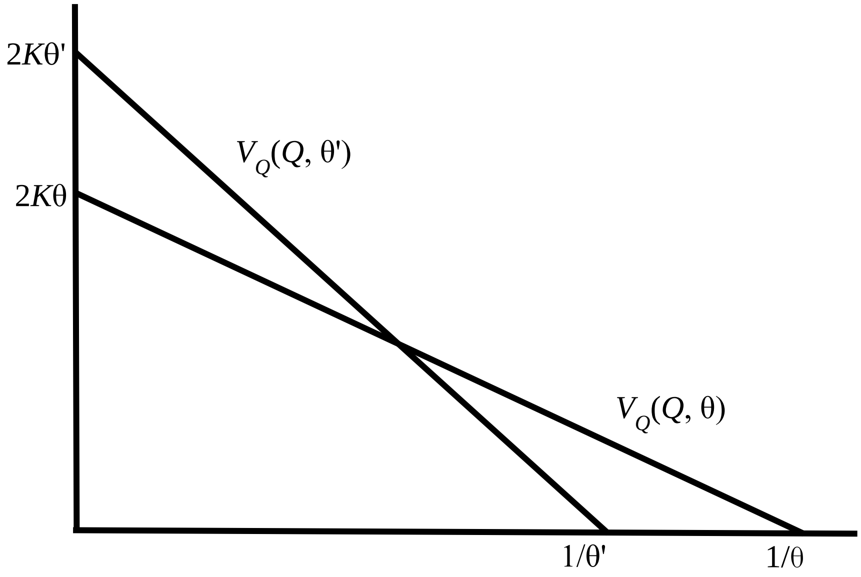
[18] For a discussion of potential paradoxes or puzzles that arise in assessing environmental policies based on consumers internalizing external costs in other ways, see Brennan (2006).

[19] The area under the line will be $\frac{1}{2}[2K\theta][1/\theta] = K$.

[20] For a general argument that increased energy efficiency leads the demand curve for energy to pivot rather than fall, see Brennan (2011a, b). An implication is that if energy prices are sufficiently high, increased energy efficiency will increase, rather than reduce, demand for energy because increased energy efficiency increases the marginal willingness to pay for energy at low quantities of energy use.

Figure 5. The Effect of Energy Efficiency on Marginal Value



The above expression for the marginal value line $V_Q(Q, \theta)$ gives

$$V_{QQ}(Q, \theta) = -2K\theta^2$$

and

$$V_{Q\theta}(Q, \theta) = 2K - 4K\theta Q.$$

Substituting these into the condition for when a fixed-quantity EERS is optimal, from (1), gives

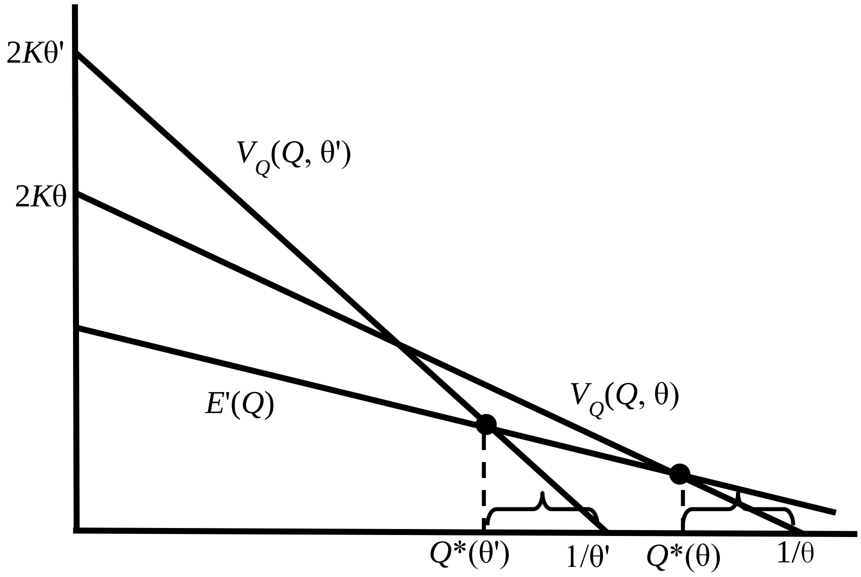
$$\frac{2K - 4K\theta Q^\circ}{-2K\theta^2} = \frac{2K - 4K\theta Q^*}{-2K\theta^2 - E''^*}.$$

This expression can be simplified considerably. Recall that, by construction, $Q^o = 1/\theta$, so the right-hand side equals $1/\theta^2$. This allows us to calculate that, at Q^*

$$E'' = -4K\theta^2 + 4K\theta^3 Q^* = 4K\theta^2 \left[\theta Q^* - 1\right].$$

Because $Q^* < Q^o = 1/\theta$, the expression in the brackets is negative. For a constant-reduction EERS to be optimal in the face of energy efficiency programs, the marginal harm from electricity use must be negative. Figure 6 depicts this result.

Figure 6. Optimal Fixed-Amount EERS with Energy Efficiency Implies Declining Marginal Harm from Energy Use



A similar result holds for this straight-line case when the EERS involves a constant percentage reduction. From (2), a constant–percentage reduction EERS is optimal in this setting if

$$\frac{Q^*\left\lfloor 2K - 4K\theta Q^\circ \right\rfloor}{-2K\theta^2} = \frac{Q^\circ\left\lfloor 2K - 4K\theta Q^* \right\rfloor}{-2K\theta^2 - E''^*}.$$

Because $Q^o = 1/\theta$, we can rewrite this condition as

$$\frac{Z}{\theta^2} = \frac{2K - 4KZ}{-2K\theta^2 - E''^*},$$

where $Z = Q^*/Q^o = Q^*\theta < 1$. This equality will hold at Q^* when

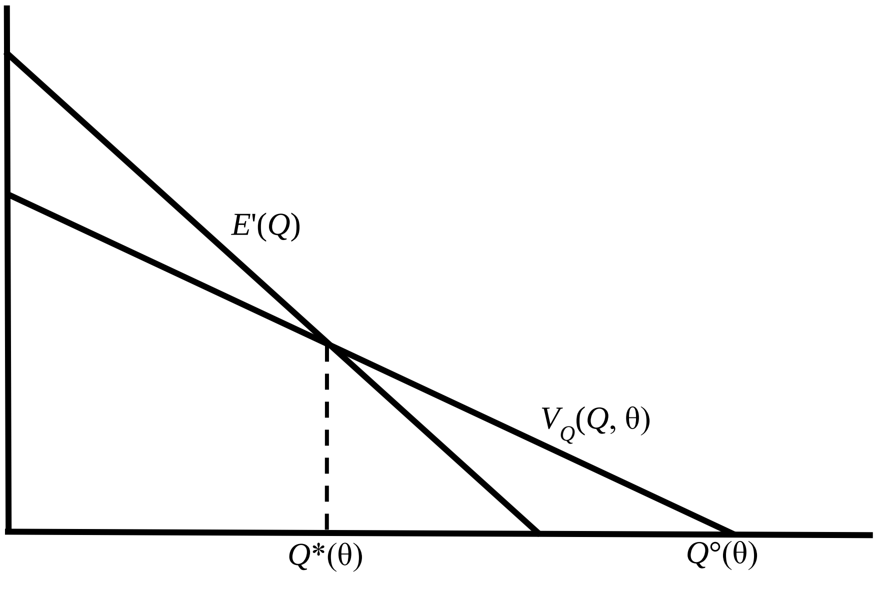
$$E'' = \frac{2K\theta^2[2Z - 1 - Z]}{Z} = \frac{2K\theta^2[Z - 1]}{Z} < 0.$$

Again, the marginal external harm curve has to be downward sloping for a constant-percentage EERS to produce optimal results following investments in energy efficiency; the illustration resembles Figure 6.

These last two results invite consideration of whether any of these “marginal value equals marginal external cost” points are appropriate targets. This condition usually holds because we can safely assume that the marginal value of a polluting activity falls the more of it is done, and the marginal harm from the pollution is constant or increases; these conditions together guarantee that equating marginal value to marginal external cost maximizes net economic benefit. However, in the case of electricity, the marginal external cost may fall with electricity use. Sources that are excluded as a result of an EERS may pollute less per megawatt-hour than sources that would remain in use. The standard example would be that reducing electricity use could reduce the generation of electricity from wind, solar, or relatively clean natural gas, while leaving coal emissions unaffected.

Downward-sloping marginal harm complicates determination of the target level of electricity use. A downward-sloping marginal harm curve could intersect the marginal value curve at a number of points. If the marginal external value of electricity falls faster with output than the marginal external harm, then the quantity of electricity use where they are equal will produce less economic welfare than at other levels of output.

Figure 7. *Q Minimizes Welfare if Marginal Harm Falls Faster Than Marginal Value**



If the sources of electricity excluded from the market are sources with no emissions, then the marginal value of electricity beyond this intersection point will exceed the marginal external cost. This suggests that, on externality grounds, the optimal electricity use reduction would be zero under an electricity-targeted program. In other words, the best EERS would be none.

This is an extreme example of the point made earlier that an EERS is an inferior way to address emissions externalities because it targets clean and dirty sources equally. It creates no incentives to switch from dirty sources to clean ones, and could reduce incentives to adopt clean sources if those would be supplying the marginal units of electricity. If controlling emissions is the rationale for an EERS, that goal would be better served by direct tax or cap-and-trade programs directed at those emissions.

Conclusions

As noted at the outset, twenty U.S. states have adopted EERS programs to reduce energy use. Three countries in the European Union have tradable *white certificate* programs, in which those who can exceed energy-reduction targets at low cost can sell certificates to others who find energy reductions more expensive,. States that have implemented EERS programs have offered a number of rationales, but each of those rationales might be addressed more effectively and at lower cost by policies specifically targeted to address them rather than by focusing on gross percentage electricity use reductions. If energy policymakers believe that energy use reductions should be the objective, they could address those through direct policies such as energy use taxes or permit programs.

To the extent that an EERS is employed, it need not produce optimal energy use reductions, with varying demand for energy, except under special conditions related to the slopes of the marginal harm curve, marginal value of energy, and how the latter may change in response to factors affecting how much users are willing to pay for electricity or the marginal cost of generating it. If the shift in the marginal value of energy results from energy efficiency investment, these conditions are satisfied only if inframarginal units of energy are more harmful than marginal units, although policies directed at emissions rather than electricity use will be able to target inframarginal electricity sources and lead to a more economically efficient outcome. Decreasing marginal damages from generation can happen if marginal units of electricity are produced with less emissions-intensive fuels and technologies, but it raises a possibility that the optimal EERS would be to have none at all if it excludes only less-polluting energy sources.

The cost-effectiveness of an EERS policy at achieving a particular goal, whether environmental or related to energy use, will depend on how the policy is designed. One way to maximize cost-effectiveness might be to allow trading as well as banking and borrowing of energy savings credits among utilities and others who have obligations to demonstrate energy savings under the EERS policy. Experience in Europe suggests that trading of energy saving credits can work; however, experience is limited and the size of the gains from credit trading and the main factors that influence those gains are unclear. Credit trading and banking also require the development of standard protocols for measuring energy savings attributable to the EERS and for how those approaches would evolve over time. Future research is needed to understand how best to design cost-effective EERS policies that take advantage of cost-effective opportunities for trading, banking, and borrowing.

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