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The importance of marginal cost electricity pricing to the success of greenhouse gas reduction programs

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ABSTRACT

The efficient reduction of GHG emissions requires appropriate retail pricing of off-peak electricity. However, off-peak electricity for residential consumers is priced at 331% above its marginal cost in the United States as a whole (June 2009). Even for the 1% of residences that are on some form of time-of-use (TOU) rate schedule, the off-peak rate is almost three times higher than the marginal cost. A barrier to marginal-cost based TOU rates is that less than 9% of U.S. households have the "smart" meters in place that can measure and record the time of consumption. Policies should be put in place to achieve full deployment. Another important barrier is consumer concern about TOU rate design. Two TOU rate designs (baseline and two-part tariff) are described that utilize marginal-cost based rates, ensure appropriate cost recovery, and minimize bill changes from current rate structures. A final barrier is to get residences on to these rates. Should a marginal-cost based TOU rate design remain an alternative for which residences could "opt-in," or become the default choice, or become mandatory? Time-invariant rates are a historical anachronism that subsidize very costly peak-period consumption and penalize off-peak usage to our environmental detriment. They should be phased out.

1. Introduction

Most of the world's science and policy communities have come to accept both that the globe is warming and that this is largely caused by the emissions of greenhouse gases (GHGs) as byproducts of human commerce. Furthermore, there is recognition that any increase of more than 3 degrees centigrade by the next century poses a severe danger, perhaps catastrophic, to the world's ecosystems. Many nations are struggling to design and implement policies to prevent such an increase. To achieve this, something like a 50–80% global GHG reduction from the 1990 level is necessary by 2050. The problem is greatly complicated by its nature as a global public good: reductions in any one country do not work to cool that specific country's climate, but are a general cooling force throughout the globe. Thus the willingness of one nation to undertake costly reductions depends on the willingness of others to contribute as well. The focus here is on one important way to make the reductions less expensive—indeed, a way that is in the self-interest of countries acting autonomously. Taking up this opportunity lowers the overall reduction costs, and increases the likelihood that the reductions can be achieved within the necessary time frame.

GHG emissions are negative externalities, and corrective policies should effectively internalize them. Because the sources of these emissions are so varied, market-based policies like a carbon tax or a GHG cap-and-trade program are typically centerpieces of the recommended corrective efforts. As important as these policies are, the politics of creating such systems at more global levels have at least temporarily stalled further progress. The U.S. is a leading outlier among highly developed nations with no firm reduction goals or national cap-and-trade programs to achieve them currently under serious consideration. Nor have the extensive international efforts to forge a reduction agreement beyond the 2012 targets and 37 countries of the Kyoto Protocol yet borne fruit.

The analysis of this paper identifies a different problem that has not yet been a focus of policy debate in the GHG context, but is also crucial to the success of GHG reduction efforts. The problem is the proper pricing of electricity, apart from how its price may be affected by internalizing the GHG externality (as with cap-and-trade programs).[1] In the usual analysis of negative externality problems, the initial price of one activity (emitting GHGs) is too low relative to all other prices. But the other prices are generally assumed to be set appropriately. However, that is not the case with electricity. Electricity prices to its consumers are almost never equal to the

[1] The latter is also an important issue, but will not be the focus of this paper. Retail electricity prices should rise by the marginal cost of GHG allowances necessary to generate the electricity. However, most retail rates are set at average cost rather than marginal cost, and if electricity distribution companies effectively receive revenue to offset allowance costs (e.g. by free distribution of the allowances to them, or by earmarking some portion of auctioned allowance revenue to them), then even their average costs may not rise by the full value of the allowances.

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marginal costs of providing it, and are often multiples away from the appropriate marginal cost. Failure to fix this problem can seriously impair efforts to reduce GHG emissions. The politics of such fixes are quite different, and perhaps more favorable to action, than those of global GHG agreements. Put plainly, it is in the self-interest of nations to fix this part of the problem.

A simple example can suggest the seriousness of the mispricing. One of the most promising new technologies for reducing GHGs is the electric vehicle. In California, it has been estimated that compared to conventional gasoline, using electricity to power the vehicle and move it an equivalent distance reduces GHG emissions by about 60%.[2] Since transportation is responsible for about 40% of all California GHG emissions, it is possible to achieve very substantial overall reductions simply through vehicle electrification. Of course if the cost of using electricity is much more expensive than gasoline then few consumers would choose to use it.[3] Based on current technology, several researchers have estimated "break-even" prices—for a given gasoline price, the electricity price that makes the marginal cost per mile the same. For example, Kammen et al. (2008) estimate that gasoline at $5.00 per gallon is equivalent to electricity at $.10 per kilowatt-hour (kWh), at (high) battery prices of $1300/kWh.

However the actual marginal cost of using off-peak electricity to recharge a vehicle in California is only on the order of $.03/kWh, based on recent off-peak market wholesale prices. Even ignoring improving battery technology, consumers should be indifferent between using electricity and gasoline at a gasoline price of $1.50 per gallon. Since gasoline is about $4.00 per gallon at the time of this writing, off-peak electricity charging of vehicles should seem like a great bargain compared to gasoline. One problem is that virtually all residential customers are on rate schedules in which prices are the same throughout the day, and far above off-peak marginal cost. According to a FERC survey discussed in more detail later, less than 1% of California's residential consumers are on rate schedules that vary prices within a day (called here time-of-use or TOU schedules, encompassing not just simple time-of-day pricing but also more dynamic variants like real-time pricing or critical peak pricing).[4] The rates that California residences face are tiered and increase with consumption, and even the average residential rate in the year ending May 2009 was about $.15 per kWh, five times greater than the marginal cost.[5] Many of these customers face actual marginal rates of well over $.30 per kWh, or prices more than 10 times higher than a marginal cost price.[6]

To put this in a pocketbook perspective, assume a compact plug-in hybrid electric vehicle (PHEV) is driven 1000 miles per month and that half of that or 500 miles is powered by electricity. With current technology the PHEV gets about 4 miles/kWh, or it will need 125 kWh of electricity each month. On Tier 3 of our representative rate schedule, this is $47.33 extra on the monthly electricity bill or $568 annually, whereas the off-peak marginal cost of providing it is only $3.75 per month or $45 annually. The difference in the attractiveness of these two amounts to consumers, and therefore their willingness to consider purchasing plug-in hybrids, is obvious. Huang et al. (2011) show empirically that the high tiered electricity prices in California will act as a substantial deterrent to PHEV adoption, even relative to its existing TOU rates that are still well above marginal cost.

A number of questions can and should be raised about this illustrative example. Is it true that the off-peak marginal cost is only about $.03 per kWh? Would not consumers simply switch to a TOU rate schedule? This paper gives more detailed answers to these questions in the U.S. context, although the answers remain as disturbing as the example and other nations likely have similar situations.

The paper proceeds as follows. In Section 2, the historical argument for marginal cost pricing is reviewed (Section 2.1), then evidence is presented about actual off-peak marginal costs throughout the U.S. (Section 2.2), and actual available rate structures (Section 2.3). This evidence suggests that, under status quo policies, there is substantial reason to be concerned about the gap between actual consumer rates and off-peak marginal costs. Then in Section 3, obstacles to marginal cost off-peak pricing are considered. Information from a useful set of surveys undertaken by FERC is reviewed (Section 3.1) and utilized in two important dimensions. One dimension is metering issues that impede the use of TOU rate schedules, especially the important role of advanced meters and policies to speed up their deployment (Section 3.2). Such meters make it feasible to administer TOU rates, but do little by themselves to cause consumers to want to be on these rates. Thus the second dimension concerns TOU rate design barriers (Section 3.3), with focus on two aspects. The first aspect is the feasibility of designs that make rates closer to marginal costs and are perceived as fair by consumers, and two methods to achieve these are discussed (Section 3.3.1). The second aspect is to consider the question of consumer options: whether an appropriate marginal-cost based TOU rate structure should be an available alternative if a residence chooses to "opt-in", the default alternative unless the residence "opts out," or mandatory (Section 3.3.2). Finally, Section 4 provides a summary and conclusions.

2. Is there really a U.S. problem of mispriced off-peak electricity?

2.1. The historical argument for marginal cost electricity pricing

Long before global warming became a known issue, economists have pointed out the inefficiency caused by the mismatch between electricity's rates and the highly variable marginal cost of providing it. The 20th century argument was usually in the

[2] The reduction would not be as great for jurisdictions relying primarily upon coal-fired electricity, but it would still be significant. The 60% reduction figure is the average of two calculations using the approved "carbon intensities" and "energy economy ratio" for electricity of the California Air Resources Board as of February 2011. According to it, gasoline has a carbon intensity of 95.86 gCO_2e/MJ. Electricity has an energy economy ratio of 3, meaning one MJ of it will move a passenger vehicle 3 times the distance than if the MJ was generated by a gasoline engine. Average electricity including imports from out-of-state coal-fired plants had a carbon intensity in 2005 of 124.10 and thus if used to power vehicles would reduce emissions by 57% (=100*[95.86–124.10/3]/95.86). However, "marginal electricity" in California comes from natural gas and renewables that have a lower carbon intensity of 104.71 gCO_2e/MJ, and vehicles powered by these sources will reduce emissions by 63% (=100*[95.86–104.71/3]/95.86). See California Air Resources Board, (CARB) (2009).

[3] Some who value the GHG reduction highly might use it anyway, for the same reasons that some people voluntarily provide support for other public goods.

[4] The survey we are referring to is the December 2010 Assessment of Demand Response and Advanced Metering by the Federal Energy Regulatory Commission. It reports fewer than 25,000 residential customers of more than 11 million served by the state's three investor-owned utilities as on any form of TOU rates. The California off-peak marginal cost is estimated by using the average off-peak price of $.028/kWh reported by the California Independent System Operator (CAISO) for April–June 2009.

[5] The California Energy Commission has a table on its website "Average Retail Price of Electricity to Ultimate Customers by End-Use Sector, by State (EIA)" in which it is reported that California residential customers had an average rate of $.1464 per kWh in the year ending May 2009. Because most consumers use amounts beyond the first-tier (baseline) quantity, their marginal rates exceed their average rates.

[6] For example, customers of PG&E on the most common residential rate schedules (E-1, EM, ES, ESR, ET) have an average rate of $.17643, but those customers who are between 201% and 300% of the baseline quantity pay a marginal rate of $.37866 and those 300% above or more pay a marginal rate of $.44098. These rates are from the schedule on the PG&E website described as in effect from March 1, 2009 through September 30, 2009.