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Rate Design as a Compliance Strategy for the EPA's Clean Power Plan

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The Clean Power Plan (CPP), promulgated by the Environmental Protection Agency under Section 111(d) of the Clean Air Act, will require significant reductions in carbon dioxide (CO_2) emissions from the electric power sector. Specific reduction obligations vary by state, but overall reflect approximately a 32 percent reduction from 2005 emission levels. States can meet this obligation using a multitude of tools, including shifting generation from coal to natural gas power plants, developing low-carbon generating resources (e.g., hydro, nuclear, wind, solar, etc.), and making energy efficiency investments that reduce total required generation.[1]

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This paper discusses one often-overlooked way to reduce CO_2 emissions from the electric power sector: electricity rate design. Rate designs that encourage wise use of electricity can help states meet a significant portion of their CPP obligation, while rate designs that result in higher use can hinder—or significantly increase the cost of—state compliance with the CPP.

Emissions are Not Linear with Generation

Emissions are not linear with respect to electricity consumption. Utilities use what is called "economic dispatch" to determine which power plants are used to meet customer electricity demand at different times, based primarily on the variable operating costs per kilowatt-hour. Renewable resources and nuclear units normally operate as much as they are able, providing low-carbon energy with low variable operating costs. The most efficient thermal power plants generally also run as much as they are able to, with swings in electricity demand met primarily by less-efficient generating units. When customer electricity usage increases, utilities tend to dispatch remaining, lower-efficiency power plants to provide the incremental energy required, and their emissions are normally higher than average. Where utilities are able to shape customer usage into particular hours of the day, they can meet a larger share of total customer usage with either variable renewable resources or with high-efficiency generating units.

Therefore, a relatively small reduction in customer usage can produce a much larger than average reduction in total emissions. For example, a system that is supplied one-fourth with carbon-free resources (renewables and nuclear), one-fourth with high-efficiency natural gas units (with carbon emissions of 800 lb/MWh), one-fourth with low-efficiency natural gas units (1,200 lb/MWh), and one-fourth with coal units (2,000 lb/MWh) will have average emissions of 1,000 lb/MWh. However, if it reacts to reduced electricity demand by reducing dispatch of its low-efficiency natural gas and coal units, it will avoid 1,200–2,000 lb/MWh of CO_2 emissions, resulting in average emissions lower than 1,000 lb/MWh during those periods.

There are exceptions to this general set of principles. Solar and wind resources operate on their own schedules, and utilities must adapt the use of their dispatchable power plants to fill the remaining need. Hydro resources may have seasonal power production and are limited by the

1 For more detail on available options, see: National Association of Clean Air Agencies (NACAA). (2015). *Implementing EPA's Clean Power Plan: A Menu of Options*. Retrieved from www.4cleanair.org/sites/default/files/Documents/NACAA_Menu_of_Options_LR.pdf

amount of water in the river or impoundment, but given available water supply can often be operated during high-cost hours to avoid running expensive peaking units. On many systems with high levels of coal generation, coal-fired units are often the incremental generating resource during off-peak periods. On these systems, shifting load into low operating-cost hours may result in higher emissions. All of these factors may influence the ideal rate design for a specific utility, depending on the mix of resources it has available.

Basic Rate Design and Residential Usage

Utilities employ a variety of current rate designs that apply to residential, commercial, and industrial customers. Historically, most electric utilities have applied monthly fixed charges to recover billing and collection costs, and recovered all power supply and distribution costs in per-unit charges for energy consumption. More recently, many utilities have introduced time-varying rates that provide strong incentives for consumers to shift electricity usage into low-cost hours. Some have introduced "critical peak pricing" or "peak-time rebates" that provide very powerful price signals for a few key hours per year. Others have sought regulatory approval for changes that increase the fixed charge component of rates (i.e., monthly customer charges), and reduce the per-kilowatt-hour charges.

Customers use less electricity when their incremental cost per kilowatt-hour is higher, following an economic principle known as "elasticity of demand."[2] Therefore, rate design choices have multiple impacts on utility sales levels and generating needs. These include:

- Higher fixed charges, which result in lower per-kWh prices, reduce customer incentives to pursue energy efficiency and on-site renewable energy development, and may cause price-responsive customers to consume additional utility-supplied power, thereby increasing emissions.
- Inclining block rates, which increase the price of power as usage increases (i.e., price discretionary usage at higher per-kWh prices to reflect system long-run marginal costs) encourage customers to be frugal in energy usage, and also drive them to install energy efficiency measures (either funded through utility-run programs or self-financed). This will decrease emissions.
- Time-varying rates can cause customers to shift usage into low-cost hours. If this results in an ability to meet more load with variable renewable resources or high-efficiency natural gas combined-cycle units, this likely results in lower emissions; conversely, if it results in higher off-peak demand that is met with increased coal generation, then emissions would increase.

Residential Rates

In a previous RAP publication, we examined the amount of load reduction that a shift in residential rate design can achieve.[3] That examination suggested that:

- An inclining block residential rate with a low customer charge, like those in California and Massachusetts, can achieve about an *8 percent decrease* in residential consumer usage compared with a flat rate.
- A high-fixed-charge rate design, like those proposed by utilities in Ohio, Illinois, and Wisconsin, can result in about a *7 percent increase* in residential consumer usage compared with a flat rate.

Table 1

Comparison of Illustrative Rate Designs

Rate Designs	Flat Rate	Inclining Block Rate	Straight Fixed/Variable Rate
Customer charge $/month	$5.00	$5.00	$30.00
First 500 kWh/month	$0.085	$0.070	$0.060
Next 500 kWh/month	$0.085	$0.100	$0.060
Over 1,000 kWh/month	$0.1085	$0.140	$0.060

2 Elasticity varies over time; short-run elasticity is typically estimated at -0.1 to -0.3, while long-run elasticity—over a period of time when customers replace equipment such as heating and cooling systems—is higher. Elasticity will likewise vary from utility to utility and region to region. We have used a conservatively low estimate to illustrate the effect.

3 Lazar, J. (2013). *Rate Design Where Advanced Metering Infrastructure Has Not Been Fully Deployed.* Montpelier, VT: Regulatory Assistance Project. Retrieved from www.raponline.org/document/download/id/6516

The vast majority of residential usage is by customers who use in excess of the first block of a multi-block rate; these customers have an incentive to constrain usage in response to a higher price. A much smaller portion of usage—typically less than 20 percent—is by customers who limit their use to the first block; while these customers have an incentive to use more, the amount is very small.

Taken together, the difference between the inclining block rate design and the high fixed charge rate can represent as much as a 15 percent swing in residential customer usage. Thus, a utility with a progressive rate design that moves to a high-fixed-charge rate design may experience a significant increase in generation and emissions, making compliance with the CPP more difficult. Conversely, a utility that moves toward lower fixed charges and inclining block rates may meet much of its CPP compliance obligation through these changes alone.

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Carbon Impacts of Time-Varying Rates

Many utilities have deployed time-varying rates in order to encourage customers to shift usage to lower-cost periods, and to recover appropriate costs from those that cannot do so. Some utilities have made time-varying rates mandatory for larger commercial and industrial customers, but many have not. And while a few utilities and their regulators are moving towards default time-of-use (TOU) rates for residential consumers, at this time nearly all residential TOU rates are optional and have very low participation rates. Nearly all TOU rates are based on the variable fuel costs at different times of the day, plus the capital required to meet incremental demands.

To date there has been little consideration of carbon impacts in designing TOU rates, except where carbon carries a price (such as in California or the Northeastern member states of the Regional Greenhouse Gas Initiative). In many states, regulatory commission decisions on electricity prices are exempt from state environmental review applicable to other government administrative actions.

To examine the carbon impact of TOU rates, we consider three different utilities, all of which are simplified examples of the much more complex resource mix typical of real utilities and the electricity grids in which they buy and sell power. In each case, we measure the hypothetical effect of a change from a flat rate of $0.10/kWh to a simple TOU rate that is $0.13/kWh during on-peak hours, and $0.07/kWh off-peak. Consistent with the analysis applied to the inclining block rate design, we assume a modest elasticity of -0.2, meaning that the amount of consumption changes (up or down) by 20 percent of the percentage change in price over time as customers adapt to the new prices. We stress that these are very simplified examples, but they illustrate the impact.

Utility 1 (see Table 2 below) has only natural gas generation, a mix of high-efficiency and low-efficiency units. Any change in on-peak usage requires dispatch of a low-efficiency gas unit, while any change in off-peak usage is met with dispatch of a high-efficiency gas unit. Under our simplified assumptions, this utility experiences a 1.2 percent reduction in carbon emissions from implementing the TOU rate design.

Table 2

Illustration of Emissions Impact of TOU Rate for All-Gas Utility

Time of Usage	Usage Before TOU (MWh)	CO_2 Emissions Rate (lb/MWh)	Emissions (Tons)	Initial Rate ($/kWh)	TOU Rate ($/kWh)	% Change in Price	Assumed Elasticity	Change in Usage (MWh)	Change in Emissions (Tons)
On-Peak	100,000	1,200	60,000	$0.10	0.13	30%	-0.2	(6,000)	(3,600)
Off-Peak	100,000	800	40,000	$0.10	0.07	-30%	-0.2	6,000	2,400
Total			100,000						(1,200)
Emission Reduction (-) or Increase (+)									-1.2%

Utility 2 (see Table 3 on next page) has a mix of coal and solar resources. It has so much solar installed on its system that it defines "off-peak" to mean 10 a.m. to 4 p.m., when it is often forced to curtail some solar output. Any shift

Table 3

Illustration of Emissions Impact of TOU Rate for Coal/Solar Utility

Time of Usage	Usage Before TOU (MWh)	CO_2 Emissions Rate (lb/MWh)	Emissions (Tons)	Initial Rate ($/kWh)	TOU Rate ($/kWh)	% Change in Price	Assumed Elasticity	Change in Usage (MWh)	Change in Emissions (Tons)
On-Peak	100,000	2,000	100,000	$0.10	0.13	30%	-0.2	(6,000)	(6,000)
Off-Peak	100,000	-	-	$0.10	0.07	-30%	-0.2	6,000	-
Total			100,000						(6,000)
Emission Reduction (-) or Increase (+)									-6.0%

of load to those hours will have zero carbon impact, and any reduction of use during the on-peak hours will reduce coal usage. Under our simplified assumptions, this utility will experience a 6 percent reduction in carbon emissions from implementing the TOU rate that moves usage from high-emission resources to zero-emission resources—even without a change in total consumption.

Utility 3 (see Table 4 below) has a mix of gas and coal resources. During the day, the coal plants run at full capacity, and incremental needs are met with natural gas. During night-time hours, its coal generation is not fully utilized, so a shift of load from on-peak to off-peak means less use of gas and more use of coal, saving fuel costs and justifying a TOU rate differential. Because shifting load to the off-peak period means a shift from gas to coal, this utility experiences a 1.5 percent increase in carbon emissions from implementing the TOU rate.

We do not consider any of these simple illustrations to be representative of any utility anywhere, but used these three examples to illustrate the point that a TOU shift can have significant carbon benefits if it results in a shift to low-carbon resources, and an adverse carbon impact if it enables higher levels of coal plant dispatch.

Commercial and Industrial Rates and Carbon Regulation

Rates applied to commercial and industrial customers generally take a different form than residential rates; they commonly include a "demand charge" that measures the customer's highest usage during any hour of the month. This charge often collects up to one-third of total utility revenue from commercial and industrial customers, with the balance recovered in per-kWh energy charges. A typical rate for a large commercial customer class may have the rate form described above in Table 5.

Table 5

Basic Rate Design For Large Commercial Customer

Rate Element	Price
Customer Charge $/month	$20.00
Demand Charge $/kW/month	$10.00
Energy Charge $/kWh	$0.08

For most utilities in the United States, the highest

Table 4

Illustration of Emissions Impact of TOU Rate for Gas/Coal Utility

Time of Usage	Usage Before TOU (MWh)	CO_2 Emissions Rate (lb/MWh)	Emissions (Tons)	Initial Rate ($/kWh)	TOU Rate ($/kWh)	% Change in Price	Assumed Elasticity	Change in Usage (MWh)	Change in Emissions (Tons)
On-Peak	100,000	1,200	60,000	$0.10	0.13	30%	-0.2	(6,000)	(3,600)
Off-Peak	100,000	2,000	100,000	$0.10	0.07	-30%	-0.2	6,000	6,000
Total			100,000						2,400
Emission Reduction (-) or Increase (+)									1.5%

100 hours of usage often represent the only period when its generation and distribution capacity is stressed. During these hours, the lowest-efficiency and most polluting power plants are often called into service.

One option is to apply the demand charge only during these key hours; this is known as a "coincident peak demand charge" because it reflects the extent to which the customer's highest demand occurs coincident with the system peak. If the customer can reduce its electricity usage during these limited peak hours, it can avoid a significant cost and also help reduce generation and emissions from low-efficiency power plants.

Another alternative is to eliminate the demand charge entirely, and implement very high per-kWh rates during the extreme hours. Such critical peak pricing rates, which result in "peak shaving" of loads, reflect the very high cost of building generating plants and distribution capacity that is utilized for only a few hours per year.[4] This approach has the benefit of providing substantial cost savings to the customer for every hour it can reduce electricity usage during the critical periods.

Either of these options will tend to reduce usage of oil-fired generation and low-efficiency natural gas units, with emissions of 1,200 to 1,600 lb/MWh, and shift usage to higher-efficiency natural gas units with emission levels below 1,000 lb/MWh. The compelling economic reason to use coincident peak demand charges or critical peak energy pricing is to avoid investment in peaking generation units and associated distribution system capacity, but the emission savings are a significant co-benefit that can help address CPP compliance obligations.

However, because only about 100 hours/year (~1 percent of the hours) involve these extreme loads, and because the high-efficiency generators still provide the vast majority of power during those hours, the total amount of carbon emissions avoided is relatively small. As an illustration of the possible effect, the table below shows the effect of a 5 percent shift in the peaking resources used during the highest hours from a low-efficiency natural gas unit to a high-efficiency unit, completely eliminating usage of the low-efficiency unit.

Table 6

Effect of Peak Shaving Displacing Low-Efficiency Power Plant

	Incremental Emissions (lb/MWh)	MWh Before Load Shaving	Tons Before Load Shaving	MWh After Load Shaving	Tons After Load Shaving
High-Efficiency	800	195,000	78,000	200,000	80,000
Low-Efficiency	1,200	5,000	3,000	-	-
Total			81,000		80,000
Emission Reduction (-) or Increase (+) (Tons)					(1,000)
					-1.2%

Conclusion

One of the primary concerns raised by parties fearful of the impacts of EPA's CPP rule is the cost that states—and their electricity ratepayers—may incur to comply with its requirements. In order to address this concern, EPA has provided substantial flexibility for states to tailor cost-effective compliance options for their specific circumstances. Energy efficiency, due to its low or even negative costs over time and the multiple other benefits it provides, is expected to enjoy widespread adoption as a CPP compliance measure. Like energy efficiency, effective electric rate design can reduce energy consumption, yet rate design has thus far been overlooked as a CPP compliance option. This paper illustrates that rate design is a readily available CPP compliance step that utilities and public utility commissions can implement at little or no cost. Equally important, regulators who have proposals before them to change rate design to implement higher fixed charges need to be aware that doing so will compound the challenges of CPP compliance.

The scale of rate design's contribution to overall state CPP compliance will vary, of course, depending on the opportunity to redesign each utility's existing rate structure, and the utility's contribution to the state's power sector CO_2 emissions. But it could easily be as high as 15 percent, almost half the national average required CPP CO_2 reduction. Very few compliance measures offer a more cost-effective or easily adopted solution. Alternatively, states that adopt rate designs with higher fixed charges and demand charges, offset by lower per-kWh prices that result in increased usage, will increase their compliance costs and compound the challenges they face under the CPP.

4 For a detailed discussion of this approach, see: Faruqui et al. (2012). *Time-Varying and Dynamic Rate Design.* Montpelier, VT: Regulatory Assistance Project. Retrieved from www.raponline.org/document/download/id/5131

Related Resources

Smart Rate Design for a Smart Future

http://www.raponline.org/document/download/id/7680

The electric utility industry is facing a number of radical changes, including customer-sited generation and advanced metering infrastructure, which will both demand and allow a more sophisticated method of designing the rates charged to customers. In this environment, traditional rate design may not serve consumers or society best. A more progressive approach can help jurisdictions meet environmental goals and minimize adverse social impacts, while allowing utilities to recover their authorized revenue requirements. In this paper, RAP reviews the technological developments that enable changes in how electricity is delivered and used, and sets out principles for modern rate design in this environment. Best practices based on these principles include time-of-use rates, critical peak pricing, and the value of solar tariff.

Designing Distributed Generation Tariffs Well

http://www.raponline.org/document/download/id/6898

Improvements in distributed generation economics, increasing consumer preference for clean, distributed energy resources, and a favorable policy environment in many states have combined to produce significant increases in distributed generation adoption in the United States. Regulators are looking for the well-designed tariff that compensates distributed generation adopters fairly for the value they provide to the electric system, compensates the utility fairly for the grid services it provides, and charges non-participating consumers fairly for the value of the services they receive. This paper offers regulatory options for dealing with distributed generation. The authors outline current tariffs and ponder what regulators should consider as they weigh the benefits, costs, and net value to distributed generation adopters, non-adopters, the utility, and society as a whole. The paper highlights the importance of deciding upon a valuation methodology so that the presence or absence of cross-subsidies can be determined. Finally, the paper offers rate design and ratemaking options for regulators to consider, and includes recommendations for fairly implementing tariffs and ratemaking treatments to promote the public interest and ensure fair compensation.

Incorporating Environmental Costs in Electric Rates: Working to Ensure Affordable Compliance with Public Health and Environmental Regulations

http://www.raponline.org/document/download/id/4670

The purpose of this paper is to give utility regulators an appreciation for the breadth of issues that may cause cost impacts on fossil-fuel power plants over the coming decades. The paper begins with a brief recital of major forthcoming public health and environmental regulations for power plants. It identifies some of the costs of compliance with these existing and potential regulations. It then turns to how these costs will likely be presented to utility regulators and discusses how regulators should evaluate them.

Driving Energy Efficiency: Applying a Mobile Source Analogy to Quantify Avoided Emissions

http://www.raponline.org/document/download/id/7501

Energy efficiency is a cost-effective, multi-pollutant strategy for addressing air quality, but is rarely utilized to meet air quality standards in the United States. This policy brief provides state air quality regulators and the U.S. Environmental Protection Agency (EPA) with an innovative approach to quantifying efficiency-related emissions reductions with sufficient rigor to meet regulatory standards and without being so onerous as to discourage the use of efficiency in air quality plans. The 'mobile source analogy' suggests that the same approaches used to quantify emissions from the country's cars, buses, and trucks can also be used to quantify the emissions avoided by energy efficiency programs. In addition, the authors offer three complementary approaches EPA could take to connect the dots between energy saved and emissions avoided. Under a "deemed emissions approach", EPA would establish default emissions reductions for a host of well-established efficiency measures with well-documented outcomes. A second approach suggests that EPA extend its existing AP-42 approach for establishing acceptable emission factors to include acceptable emissions reductions from energy efficiency measures. A third approach would utilize modeling to determine location-specific emissions reductions when important for meeting ambient air quality standards. Regardless of the approach taken, the authors see great potential for energy efficiency as an air quality strategy and encourage EPA to provide the necessary guidance to states to maximize its use.

Quantifying the Air Quality Impacts of Energy Efficiency Policies and Programs

http://www.raponline.org/document/download/id/6680

In recent years, more and more regulators view energy efficiency as a viable air quality improvement strategy. While no regulator should expect to solve all air quality challenges through one strategy alone, efficiency has distinct advantages over pollution control methods. This report is premised on the belief that regulators should employ energy efficiency as a first step toward air quality improvement rather than as a last resort. The report provides an introduction for air quality regulators to the rationale and opportunities for using energy efficiency as an air quality improvement strategy, identifies useful data sources, and outlines four basic steps for quantifying the air quality impacts of energy efficiency policies and programs. In addition, the paper explores opportunities to work with energy agencies to communicate air regulators' energy efficiency data priorities, including ways to improve the data.

Integrated, Multi-pollutant Planning for Energy and Air Quality (IMPEAQ)

http://www.raponline.org/document/download/id/6440

IMPEAQ is RAP's initial effort to develop a model process that states, local agencies, and EPA can apply to comprehensively and simultaneously reduce all air pollutants, including criteria, toxic, and greenhouse gases (GHGs). IMPEAQ seeks to identify least-cost pathways to reduce emissions of multiple pollutants by adhering to Integrated Resource Plan (IRP) principles. In doing so, IMPEAQ also seeks to minimize electric reliability impacts and other system impacts.

"Skate Where the Puck Is Going to Be"

http://www.raponline.org/featured-work/skate-to-where-the-puck-is-going-to-be

States (and utilities) are in hot pursuit of least-cost strategies for Clean Power Plan compliance, and many observers believe the simplest and cheapest solution is to increase natural gas-fired capacity and generation. A careful assessment, however, reveals that this is a myopic focus. Looming in the background are a host of other rules, initiatives, and market trends that are forcing other changes on electric utilities. Instead of "playing where the puck is today," utilities and states would do well to revamp their resource planning processes to ensure that they acquire a portfolio of resources able to serve customers well in light of all these trends. RAP's IMPEAQ process provides a good guideline for this reassessment.

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