Regulating U.S. Electric Utilities to Improve Energy Efficiency

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To make meaningful cuts in carbon emissions, the United States electric power sector must improve its energy efficiency. One opportunity to slash emissions is by reducing "upstream" energy losses that occur in transit between generators and customers. Utilities can use existing infrastructure to help minimize these network losses. Utilities could, for example, invest in capital equipment that saves energy and ratepayer funds while fortifying grid stability. However, traditional utility regulations do not provide utilities with the necessary incentives to achieve this end. This report examines regulatory alternatives for electric utilities in the United States and finds that traditional rate-of-return regulation discourages energy efficiency. Incentive regulation, on the other hand, may motivate network modernization and improve energy efficiency by rewarding firms for desired performance, rather than for past costs. Based on lessons learned from initial evidence of incentive regulation for U.S. utilities, the author recommends a performance-based incentive regulation mechanism that combines a revenue cap based on statistical benchmarking with targeted incentives for quality of service and network energy losses. There are economic and environmental opportunities associated with improving upstream energy efficiency, and incentive regulation can provide regulators with the tools they need to seize it.

INTRODUCTION

The electric power sector has produced nearly 40 percent of total carbon dioxide emissions in the United States since 1990, a larger contribution than any other single sector. In light of the deep carbon reductions considered necessary to avert disastrous impacts of climate change, we must use the electric power sector to achieve a corresponding proportion of emissions cuts.

The U.S. power sector now faces a markedly more demanding environment than it has encountered at any time in its history. When electric utilities came into existence, they owned and operated all aspects of power systems—large centralized power plants as well as the equipment to transport and deliver the energy they produced to often-remote cities and towns. Regulations that governed these early utilities aimed to ensure reliability, i.e., that supply exactly equals demand for all those who wish to use power at any moment, and to prevent price gouging.

Utilities now face new challenges. In order to help reduce carbon emissions and stave off the worst effects of climate change, utilities now must also reduce the greenhouse gas emissions associated with energy services. To meet this challenge, the power sector must incorporate decentralized renewable resources into their operations. They must invest in energy efficiency improvements while ensuring the power stays on and customers do not face exorbitant rates. The way utilities are regulated can shape a new business model for the industry that takes into account these newer objectives of energy services.

This energy transition would entail significant economic and technological demands. Alternative energy production technologies, for example wind and solar, are a potential solution to this challenge, particularly as they continue to become more efficient and less expensive. However, because storage technologies that would cost-effectively deploy this power are not market-ready, it is unlikely that alternative energy production technologies can sufficiently reduce emissions on their own.

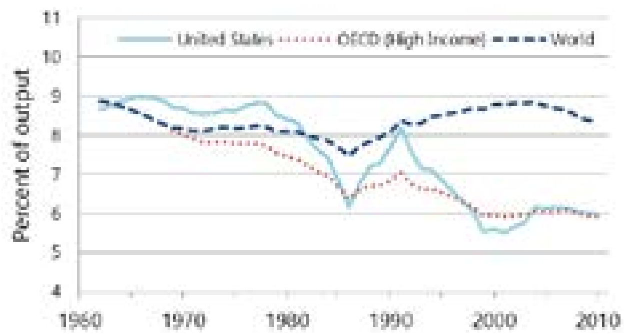
On the other hand, energy efficiency is already a cost-effective means of reducing the electric power sector's carbon emissions. Utilities have successfully employed this tactic since the 1970s to reduce carbon emissions. In short, energy efficiency reduces the amount of electricity needed to deliver a service, "getting more performance from less electricity."

Demand-side management (DSM) provides the most visible examples of energy efficiency. DSM usually includes measures that reduce demand for electricity at the point of consumption, such as building weatherization and incentives for more energy-efficient appliances. Similar opportunities for energy efficiency exist further upstream, before electricity reaches the point of consumption. These opportunities include modernized electric power systems that use advanced technologies to reduce losses of electricity occuring during the course of transmission and distribution (T&D) as electricity courses through wires and poles. These technologies can reduce the amount of generation, and associated carbon emissions, required to supply a unit of electricity.

Energy is inevitably lost in transit from generators to end-users, typically as a result of resistance along the poles and wires (see Figure 1). These losses represent units of energy that today's investor-owned utilities (IOUs) purchase from generators but cannot sell to customers. T&D losses currently comprise about 6 percent of delivered power in the United States, on par with loss rates in high-income member nations of the Organization for Economic Cooperation and Development (OECD)). The average global T&D loss rate is much higher, likely owing to prevalent power theft in much of the developing world.

However, even in countries without the threat of power theft, more efficient T&D equipment can still significantly reduce energy losses. For example, a 2007 assessment of more efficient distribution transformers by the U.S. Department of Energy (DOE) projected that more efficient T&D equipment could reduce the amount of energy production needed from the nation's power plants each year by up to 2 percent. The DOE determined that several higher-efficiency distribution transformers could offset the up-front costs with lower operating costs—i.e., lower energy losses—in less than ten years, and, in some cases, less than three years. Despite these potential energy and cost savings, the DOE estimated that 25 percent of purchasing decisions for this equipment do not factor in the costs associated with energy losses.

Figure 2. Transmission and distribution losses in the U.S. relative to OECD high-income and world averages, 1962-2010 (percentage of delivered electricity, five-year centered moving average; data source: World Bank—World Development Indicators)



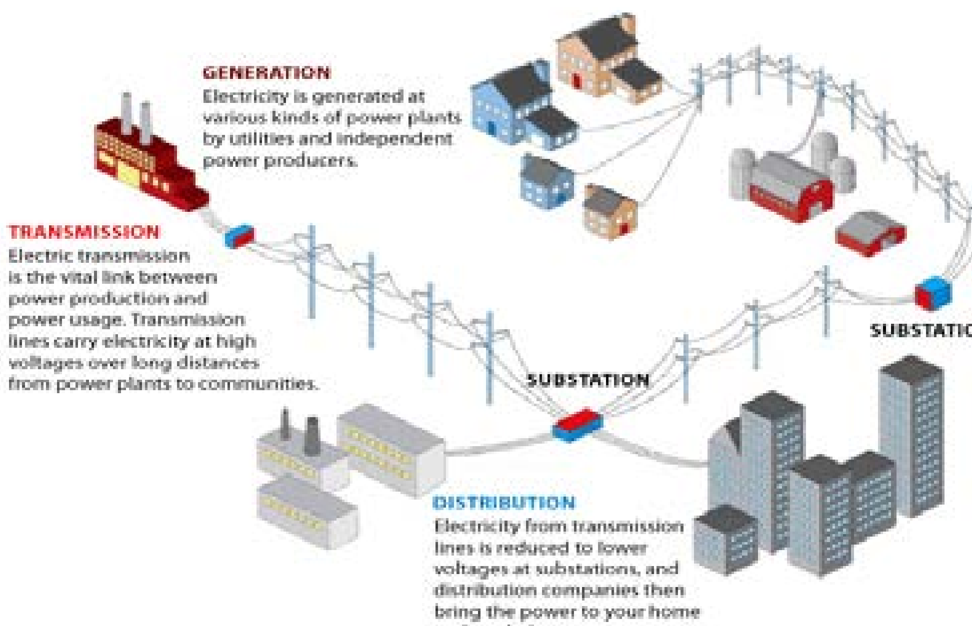


Figure 1. Power systems have three main components: generation, where power is produced, transmission, where power is transported over large distances at high voltage to reduce resistive losses, and distribution, where power is delivered to end-users at lower ("utilization") voltage (source: U.S. Department of Energy).

Utilities are likely to purchase more energy-efficient equipment if they determine it is in their financial interest to do so. However, the above example illustrates that an appreciable number of utilities use only purchase price to make these decisions, rather than some method of weighing future benefits against incremental upfront costs. This constitutes a formidable barrier to utilities adopting more advanced T&D equipment.[5]

The U.S. government recently tightened federal energy efficiency standards for distribution transformers as more efficient designs have become technologically feasible, but these new standards leave considerable potential energy and cost savings on the ground. Current regulatory incentives are simply insufficient to compel utilities to prioritize upstream energy efficiency.

This report reviews how the profit opportunities historically permitted by utility regulators have generally discouraged efforts to address upstream energy efficiency and explores whether newer regulatory approaches may offer improved incentives for utilities to modernize and reduce energy losses.

The remainder of this report is structured as follows: Section two details the traditional regulation of utilities and some of the issues associated with this arrangement; Section three reviews regulatory innovations that have attempted to address these historical shortcomings, namely decoupling and incentive regulation; Section four discusses how regulators in the United States can improve the effectiveness—in terms of energy efficiency—of incentive regulation for electric utilities; Section five concludes.

BACKGROUND: STRUCTURES & REGULATIONS OF THE U.S. ELECTRICITY INDUSTRY

Restructuring Electricity Services into Competitive and Regulated Segments

Vertically integrated power companies that control all aspects of service—including generation, transmission, distribution, and sales—have traditionally purveyed electricity services in the United States. These companies were regarded as natural monopolies, since it is more efficient for a single firm to make the large investments required to provide the service in a given area. To prevent these large monopolies from charging exorbitant prices for electricity services, independent utility regulators in each state regulated the rates they were able to charge in accordance with what constitutes a "fair" return on their investments.

In recent years regulators have realized that competition can improve the efficiency of the service in certain segments of the industry. Accordingly, regulatory bodies have restructured electricity markets in the United States through a series of reforms that consist of:

- Unbundling vertically integrated utilities into separately owned and operated component business;

-Introducing compeititon in the generation component (wholesale market); and

-Introducing competition in the supply component (retail market).

The literature offers no consensus on the effectiveness of introducing competition in wholesale and retail markets for electricity. Markiewicz et al. (2004) find that the introduction of market-based structures improved the economic efficiency of generation plants. However, competitive wholesale markets may be vulnerable to market power, which was suspected to have precipitated California's energy crisis of 2000-2001 (Borenstein and Bushnell, 2000; Friedman, 2009). At the opposite end of the value chain, a number of states introduced retail choice to varying levels of success; in most states, relatively few customers switched from incumbent power providers to new market entrants, which limited the realization of economic benefits (Joskow, 2006).

However, both the wholesale and retail components of the electric industry still depend on physical T&D infrastructure—power lines, poles, transformers—that retain natural monopoly properties. As such, T&D networks continue to be tightly regulated segments of the electricity sector, even where competition thrives in both wholesale and retail markets. Though traditional rate-of-return regulation is the predominant form of regulation for T&D utilities, the regulatory theory literature has suggested that incentive regulation may offer improved efficiencies. I discuss both of these regulatory approaches in greater detail in coming sections.

Regulating the Natural Monopoly: Rate-of-Return Regulation

Without regulation, natural monopolies are likely to ration their services in order to charge higher prices and maximize profits, resulting in potentially large economic inefficiency. To reduce this inefficiency, regulators have traditionally restricted the returns that natural monopolies can earn. Rate-of-return regulation (henceforth "RORR") ensures that utility profits are "just sufficient to compensate the firm for its investment in plant and equipment," with periodic rate adjustments.[11*]

However, RORR uses firm-reported costs as the basis of returns, creating incentives that are inconsistent with efficient performance. Some of these inefficiencies arise from the limited information regulators have about firm costs. For example, if true firm costs are below reported costs, approved rates, and profits, are too high. On the other hand, the guarantee of returns on approved costs gives firms with high costs little incentive to operate more efficiently.

Other inefficiencies of RORR result from regulatory lag. Rates are only renegotiated during rate cases, which occur once every few years. As a result, rates cannot continuously adjust in response to changes in realized costs. This allows even inefficient firms to profit from technological improvements that reduce costs below rates until regulators realign them.

For electric utilities operating under RORR, regulatory lags create especially perverse incentives. RORR sets average rates equal to the ratio of approved income to forecasted sales, and then fixes those rates until the next rate case. Between rate cases, however, a utility can collect in excess of the revenue requirement by surpassing the sales forecast. This means that regulatory lag presents a formidable disincentive to conserve energy. As long as utility revenues are directly tied to sales of electricity, energy efficiency programs that reduce sales are unlikely to flourish.

Another possible inefficiency of RORR is that firms may overinvest in capital infrastructure because their capital stock forms the basis of their returns. Though this tendency ostensibly favors expensive investments such as advanced network equipment, regulators have the discretion to deem expenditures "imprudent" if they consider them unnecessary or excessively costly. Regulators may avoid approving efficient but expensive technologies that would cause short-term rate increases, even if they reduce average rates in the long term. The regulator may even review past expenditures and revise the approved rate of return downward if it deems past practice to be imprudent. This uncertainty may discourage regulated utilities from making occasionally large capital investments, such as more advanced network equipment.

In sum, although RORR emerged as a viable way to manage natural monopolies in the interest of society, it creates perverse incentives that inflate expenses and boost sales, but discourage utilities from investing in new technology.

REGULATORY ALTERNATIVES: DECOUPLING AND INCENTIVE REGULATION

Revenue Decoupling: Unlinking Utility Revenues from Sales

As outlined above, electric utilities under RORR have an incentive to maximize sales, regardless of whether additional energy can be supplied more cheaply through energy efficiency. Recognizing these misaligned incentives, regulators in many states have introduced "decoupling" mechanisms that unlink utility revenues from sales. These mechanisms continually adjust to keep utility revenues at precisely the authorized amount, thereby removing the utility's incentive to maximize sales since it can no longer keep the excess profits. Decoupling also insulates the regulated utility from risk associated with unfavorable sales fluctuations, making it more attractive to the utility. Furthermore, ongoing rate adjustments between rate cases can remove some of the price inefficiencies associated with regulatory lag.

In many instances these utility-sponsored efficiency campaigns are cost-effective. For example, Eto et al. find in a study of 20 large-scale utility programs for commercial lighting improvements that all programs were achieved at lower cost than the power they conserved. By dissolving the link between revenues and sales, decoupling removes disincentives to utility programs that improve energy efficiency at the point of use.

Incentive Regulation: Encouraging Economic Efficiency

While decoupling represents a critical step toward encouraging more efficient electricity end-use technologies, it has had little direct implication for the efficiency of electricity network components. Specifically, decoupling reduces a utility's incentive to boost sales to earn a better return, but does not address inefficiencies "upstream" or before the point of energy use. As outlined in Section two, RORR also poses structural impediments to network modernization investments that keep system losses greater than necessary.

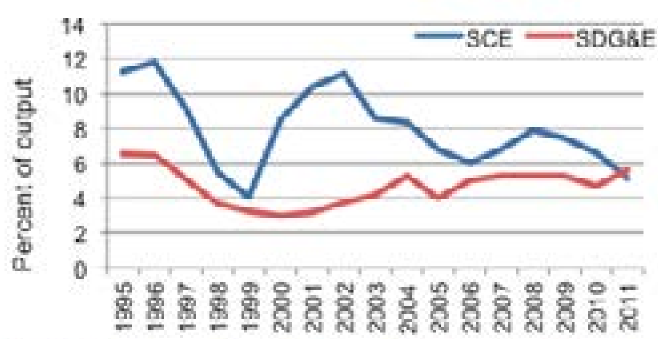


Figure 3. Network energy losses for SCE and SDG&E, 1995-2011 (percentage of total output, three-year centered moving average; data source: FERC).

Incentive regulation provides one solution to this problem. Incentive regulation may be an efficient alternative to RORR that simulates competitive market outcomes. The telecommunications industry, and to a lesser extent the electricity industry, have already used this type of regulation throughout the world.

Price caps that are invariant to firm behavior and firm-specific costs commonly characterize incentive regulation. Rather than regulating profits, incentive regulation promotes firm efficiency by letting firms keep the difference between their costs and the price cap. This encourages greater managerial effort toward low-cost operation.

However, incentive regulation has its own imperfections. First, it may encourage reductions in service quality, since it is a convenient way to cut costs. This concern is particularly relevant for regulated monopolies, since they are not under threat of losing dissatisfied customers. Second, the effectiveness of price cap regulation depends on the price level that regulators set. For example, to allow for the possibility that regulated firms are truly high-cost operations, regulators may set relatively high price caps that would allow firms to profit handsomely without providing strong incentives for lean operation. Third, price caps may discourage utilities from sponsoring DSM programs if the cost of such programs pushes costs closer to the price cap and erodes profits. Finally, price caps may penalize utilities for implementing successful DSM programs that reduce sales.

However, other forms of incentive regulation exist that lie somewhere between pure price caps, as described above, and RORR. In fact, Joskow (2008) notes that the most efficient regulatory form "will lie somewhere between these two extremes." These alternative incentive schemes include:

-Profit sharing mechanisms, in which utilities and their customers split revenue surpluses or shortfalls;

-Banded rate-of-return regulation, in which the regulator sets a range through which a utility's returns may vary;

-Benchmark (yardstick) regulation, whereby the regulator sets targets for utility rates on performance based on an analysis of comparable firms; and

-Sliding-scale contracts, in which utilities choose from a menu of contracts that trade off stricter performance targets with greater approvals for capital expenditures.

Some of these incentive regulations have been employed for utilities, primarily in Europe. Jamasb and Pollitt and Giannakis et al. detail the data and methods European regulators use to determine the relative efficiency of individual firms' operating costs, quality of service, and system losses relative to a comparable peer group of firms. These benchmarking exercises help to determine price caps that encourage inefficient firms to approach maximum efficiency. However, Jamasb and Pollitt and Giannakis et al. find that benchmarking results are highly sensitive to the particular data and methods employed, which makes it difficult to rely on benchmarking.

The United Kingdom has realized similar efficiency improvements from incentive regulation. The United Kingdom's Office of Gas and Electricity Markets (OFGEM) initiated a series of incentive measures to target reductions in operating and capital expenditures and improve network energy losses for its electricity distribution network operators. Subsequent distribution rates reflected deviations from targets in expenditures rates, while deviations from network energy loss targets resulted in specific rewards or penalties. In addition, OFGEM has offered a sliding-scale menu of contracts that effectively allows distribution network operators to trade greater capital expenditures for lesser rewards, along with an explicit allowance for investments aimed at network modernization. Over the period of reform, distribution rates dropped by roughly 50 percent for nonresidential consumers and total national distribution energy losses declined from above 7.5 percent of delivered electricity to roughly 6 percent, without increasing service interruptions.

These results clearly show the success of incentive regulation of British distribution network operators. In large part, we should credit this success to the policy's design. By instituting a set of multi-faceted incentive measures, the OFGEM regulations made comprehensive reform possible. As Joskow and Schmalensee point out, "a regulated firm will act in its own self-interest and try to improve only the performance measure on which it is graded, at the expense of other dimensions of performance." By targeting not only operating expenditures, but also capital expenditures, quality of service, and network losses, OFGEM ensured that improvements in any one of those dimensions were not achieved to the detriment of the others.

Performance-based regulation in the United States

Despite its successes abroad, incentive regulation has not fully spread to the electric industry in the United States. Evidence from the U.S. telecommunications industry shows that various forms of incentive regulation have reduced operating costs and customer rates and sped network modernization.

If incentive regulation has led to success for electric utilities abroad and for domestic telecommunications providers, why have electricity regulators been slow to adopt it? Two convincing arguments exist to answer this question. The first possibility is that the investment profiles of the telecommunications industry and the electric industry are inherently different. While capital investments for telecoms are roughly continuous and ongoing, investments in new equipment or capacity for electric utilities are discrete and "lumpy." In these cases, periodic spikes in capital costs may have large, if temporary, effects on rates. This means that RORR may be better suited to creating predictable and stable rates in industries with discrete capital decisions. The second possibility is that the complexities of the capital stock in the electricity sector cause regulators to know far less than firms about true capital costs and investment opportunities.

Despite these barriers, in recent decades, regulators have conducted isolated experiments to test whether incentive regulation is applicable to U.S. utilities. In the United States, regulators have implemented incentive regulation under an alias of "performance-based regulation (PBR)," though there is no important distinction in its approach or objectives. To date, PBR schemes have been used for electric utilities in at least twelve states, most of which have at least partially restructured electricity markets.

In recent decades, California made a substantial attempt to formalize PBR as a fixture in the electric industry structure. In December 1995, with restructuring of California's electricity markets underway, the California Public Utilities Commission (CPUC) released a decision that indicated a shift away from cost-of-service regulation and toward PBR. Two of California's three principal utilities implemented PBR in the 1990s—San Diego Gas & Electric (SDG&E) in 1994 and Southern California Edison (SCE) in 1997. The SCE program was better conceived and run than that of SDG&E, which could explain why it was associated with greater improvements in network energy efficiency. It is difficult to assert causality in this case, since energy efficiency was not explicitly targeted by either PBR scheme.

SDG&E applied for a PBR scheme under the premise that market forces would reduce the regulatory inefficiency that arises from traditional regulation. The scheme they proposed consisted of a revenue baseline requirement, a profit-sharing mechanism, a quality control mechanism, specific pass-throughs, and targets for DSM programs. From 1994-1996, SDG&E reduced operations and maintenance costs by $15-19 million below the authorized level, accounting for more than 50 percent of excess returns. Over the same period, SDG&E also surpassed targets for quality control and increased DSM expenditures by 50 percent. However, this scheme was wildly profitable for SDG&E without encouraging significant cost reductions, and accordingly, regulators terminated the program at the end of 1998.

SCE's PBR program began toward the end of the initial review period of SDG&E's program. SCE's scheme incorporated a price cap and other incentive mechanisms, such as an incentive for service quality. Regulators set SCE's initial price using 1996 rates and built in a graduated schedule of price reduction. Significant cost savings in the first year of the program saved ratepayers $40 million in 1997. The regulation also benchmarked incentives for service quality and customer satisfaction using targets, and deviations from these targets resulted in corresponding rewards or penalties.

In contrast to the SDG&E PBR program, which retained cost-of-service characteristics, the SCE program implemented a price cap to improve efficiency without concern for excess profits. The SCE program also set a fairly large number of targeted incentives for desired outcomes and thus does not sacrifice quality of service as a means of reducing costs. The SCE PBR program still appears to be in effect today.

REGULATING NETWORK LOSSES FOR DISTRIBUTION UTILITIES

While the above case studies of PBR in the United States cover a standard set of incentive types—cost reduction, profit sharing, and several measures of service quality—they did not specifically aim to address network energy losses. Even without explicitly targeting them, however, it is worth examining whether or not these PBR reforms had a noticeable effect on energy losses.

Figure 3 presents annual energy loss data submitted by SCE and SDG&E to the Federal Energy Regulatory Commission (FERC) on the Electric Energy Account schedule of its Electric Utility Annual Report. To adjust for volatility, Figure 3 presents three-year moving averages of network energy losses as a percentage of total output (delivered electricity).While network losses for SDG&E remained relatively constant over the period, SCE losses declined from nearly 12 percent in the mid-1990s to meet SDG&E at less than 6 percent by 2011. One interpretation is that SDG&E was already at or near some efficiency frontier before California introduced PBR, and as a result, we would not expect to see further reductions in network losses. Another possibility is that the more comprehensive and effective PBR for SCE brought about network-wide efficiency improvements that reduced its network losses. By contrast, SDG&E sustained a several-year period with losses below 4 percent of output, but that figure has been on the rise since about 2000.

While this sample size is too small to draw firm conclusions about a trend, California's experience may indicate that better incentive design leaves room for greater network energy efficiency. Without specifically targeting energy losses as an area of interest, however, we may prioritize other criteria at the expense of network energy efficiency. For instance, if the only incentives are a price cap and a profit-sharing arrangement, then a firm may choose to contain costs by deferring retirement of relatively inefficient equipment.

Regulators have discretion over incentive schemes' criteria. The first component of regulation for improved upstream energy efficiency is to improve regulatory awareness of the opportunities that currently exist for modernized T&D networks. The regulator can then apply pressure to regulated firms to respond to performance incentives in the areas of emphasis.

An example of a potentially effective incentive scheme is a revenue cap. Regulators would set these caps using statistical benchmarking and pair them with targeted incentives, not only for quality of service, but also system losses—similar to what OFGEM has implemented in the United Kingdom.

There are three advantages of revenue caps. First, a revenue cap, rather than a price cap, would align a utility's incentives with DSM programs that cut energy demand in buildings and thereby decrease the amount of network energy losses. Second, a revenue cap may also retain the properties of price caps that are conducive to network modernization and more timely replacement of outdated equipment, which could encourage faster uptake of more efficient technologies. Finally, targeted incentives would provide a concrete incentive to achieve desired service quality and energy loss targets while introducing more information into the marketplaces by identifying the best network configurations for both service quality and energy efficiency. This information can set into motion a virtuous cycle in which faster adoption of advanced technologies fuels technological innovation.

CONCLUSION

In order to meet ambitious, but important, emissions reduction goals, the United States must rely heavily on its most culpable sector—the electricity industry—to introduce sweeping reforms that substantially reduce the carbon intensity of electricity generation and provision. While the general consensus is that renewable sources of generation and energy efficiency are two promising resources that we should aggressively pursue in order to meet environmental targets, the electricity sector has been slow to seize these opportunities.

Network energy efficiency presents another possible opportunity for significant emissions reductions. In this report, I have discussed the possible structural causes of electric utilities' slow uptake of network energy efficiency. I attribute this slow uptake, in part, to lagging regulations. Although the structure of the utility industry has changed greatly in most states in recent decades, regulation has not kept pace. In most states, rate-of-return regulation still governs the profit opportunities for electric utilities, but provides them with inadequate incentives for energy conservation and network modernization—both of which are essential to the development of low-carbon power systems.

Incentive regulation is generally a preferable, if imperfect, alternative to RORR for utilities. Incentive regulation attempts to minimize the efficiency problems associated with RORR by allowing firm-specific performance to determine profits.

While variants of incentive regulation have precipitated successful reforms in electricity sectors abroad, and even in the U.S. telecommunications sector, the electricity sector in the United States has been slow to adopt substantial incentive regulation schemes. Now that there has been more trial-and-error with performance-based regulation for numerous utilities in the United States, however, regulators are beginning to learn how to structure incentive mechanisms that help them capture the advantages associated with incentive regulation.

Still, regulators seem unaware of the large potential to improve upstream energy efficiency by modernizing capital equipment. If regulators awaken to this opportunity to address emissions reduction goals while saving energy and money, incentive regulation can provide the tools they will need to seize it.

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GLOSSARY

CPUC	California Public Utilities Commission	*independent utility regulator for the state of California*
DNO	distribution network operator	*electric distribution utilities in the U.K.*
DSM	demand-side management	*consists of measures or programs that reduce demand for energy*
FERC	Federal Energy Regulatory Commission	*federal agency that sets rates for transmission and receives regulatory data from investor-owned utilities*
IOU	investor-owned utility	*private utilities, owned by shareholders and subject to regulation by public utilities commissions (PUCs)*
OFGEM	Office of Gas and Electricity Markets	*nationwide utility and energy market regulator in the U.K.*
PBR	performance-based regulation	*a form of incentive regulation that offers rewards or penalties according to designated performance metrics*
PUC	public utilities commission (public service commission)	*independent state agencies that provide oversight and regulation of utility services including those of electric utilities*
RORR	rate-of-return regulation (also known as rate base regulation)	*method of regulating natural monopolies by allowing a fair rate of return on approved capital investments*
SCE	Southern California Edison	*one of three major investor-owned utilities in California, servicing parts of Southern California including Los Angeles*
SDG&E	San Diego Gas & Electric	*one of three major investor-owned utilities in California, servicing the greater San Diego area*
T&D	transmission and distribution	*components of electricity networks that transport and deliver electricity from generators to end-users*

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