Utility Investments for Market Transformation

How Utilities Can Help Achieve Energy Policy Goals

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AUTHORS

Jeremy Fisher, PhD
Melissa Whited
Tim Woolf
Danielle Goldberg

Synapse Energy Economics, Inc.

485 Massachusetts Avenue, Suite 2
Cambridge, Massachusetts 02139

617.661.3248 | www.synapse-energy.com

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1. INTRODUCTION

The currents of electricity that flow over transmission lines, through the distribution grid, and into our electrical devices are shaped by many different actors, both regulated and unregulated. For example, the electricity itself might be generated by an independent power producer and sold into the wholesale market, which is then purchased by the electric utility and sent over miles of transmission and distribution lines to the final customer. The customer then flips a switch and a light bulb brightens a dark room. This apparently simple feat is achieved through the efforts of a complex ecosystem consisting of light bulb manufacturers, local electricians, electric utilities, power plant owners, fuel companies, fuel transportation systems, emissions control developers, regulators, other government agencies, and many others.

Electric utilities play a central role in this ecosystem, not only through providing retail electricity, but also by influencing how that electricity is generated and consumed. Electricity generation and consumption has far-reaching implications for our society, ranging from environmental and health impacts to economic growth and development. Achieving energy policy goals, such as reduced air pollution and enhanced customer equity, thus requires a multi-pronged approach – one in which electric utilities are often a key player. Achieving energy policy goals may involve direct utility investments or other interventions in unregulated markets related to energy services to help overcome market failures or reduce market barriers to new technologies and services.

This paper explores the role that utilities can play in supporting market transformation or new technology adoption in the electricity landscape. We review cases where utility investments were specifically geared towards these goals and discuss how utility ownership or leadership affected the growth of the market.

2. UTILITY INVESTMENTS TO ACHIEVE ENERGY POLICY GOALS

The electric industry has long been recognized to be "affected with the public interest" in a way that other industries are not.[1] Electricity is vital for the economy and for individual households, but its production and delivery can also have profoundly negative impacts on public health and the environment. Further, many aspects of electricity production and consumption are subject to market failures, which prevent the market from functioning optimally. Because of this, electric utilities have long been regulated by the public sector.

As a regulated industry, electric utilities are frequently on the frontlines of implementing programs to achieve energy policy goals, such as cleaner air and energy affordability. To be successful, these

[1] This concept was first discussed by the United States Supreme Court in *Munn v. Illinois*, 94 U.S. 113 (1876).

programs often require interventions in markets related to electricity, such as the market for efficient light bulbs or emissions controls. Utility interventions in these markets may serve a variety of purposes, including:

1. **Research and development**: Utility-funded research and development (R&D) can be a key mechanism for bringing new technologies to market where a public benefit has been identified but the technology lacks a clear source of funding. Utility R&D provides a foundation to study currently out-of-market options while also enabling utilities to "learn by doing." Emissions controls, transmission and distribution system improvements, modeling software, and large projects like post-combustion carbon capture and sequestration pilots all represent utility-funded R&D geared towards driving innovation and technological progress.

2. **Market acceleration**: Utilities can play a role in helping to accelerate the adoption of new or emerging technologies where cost is still a barrier. The development and adoption of many energy efficiency products falls into this category, including compact florescent lightbulbs, efficient refrigerators, smart thermostats, and heat pumps. In each of these cases, the benefits from the mature technology are clear, but the early version of the technology was too expensive to generate sufficient demand. Weak demand in turn delayed cost reductions through large-scale production. Utility programs helped to reduce the costs to customers, thereby spurring market demand.

3. **Filling a market gap:** Certain segments of the population face unique challenges that make it difficult for them to take advantage of new technologies. For example, low-income customers may be unable to pay an up-front price premium for rooftop solar or an energy efficient product in order to realize longer-term monetary savings. This results in serious equity concerns, as the population who would benefit most from the energy savings is least likely to attain them. To fill these market gaps, some utilities offer programs where customers can pay down the costs over time through bill savings (rather than up-front expenditures).

4. **Fixing a market failure**: Utility investments can address market failures, achieving public benefits that may otherwise be unreachable through the market alone. Emissions controls represent one such technology: the market for clean air and water is diffuse and difficult to monetize because these are classic examples of "public goods." Clean air policies requiring emissions controls work to internalize the costs of pollution, and utility investments pass this cost through to ratepayers, aligning the costs of clean air with the demand for emissions reductions. As another example, many benefits of the "smart grid" (more efficient grid operation and improved reliability) are also public goods, and will thus be under-provided by the market. Utility investments in advanced metering infrastructure (AMI) are designed to overcome this market failure to provide benefits to all customers.

In the following sections, we discuss examples of utility investments geared towards market transformative effects and the impacts on markets and vendors. We focus on five example sectors: super-efficient refrigerators, offshore wind, compact fluorescent lighting, advanced metering infrastructure, and emissions controls.

3. CASE STUDY: SUPER-EFFICIENT REFRIGERATORS

Interventions: Research and Development and Addressing a Market Failure

By providing funding for research and development, utilities can drive innovation for beneficial technologies. In this case, utilities sponsored a competition to drive market innovation and reduce technology costs for a technology that provides environmental benefits (a public good).

The international Montreal Protocol of 1987 set a target of reducing chlorofluorocarbons (CFCs), a powerful ozone-depleting substance used in refrigeration and chilling, to zero by the end of 1995. Recognizing that the operating efficiency of existing refrigerators would be penalized by the phase-out of CFCs, in 1993 a coalition of utilities created a unique incentive structure to develop and bring to market a "super-efficient" refrigerator without the use of CFCs at or below the cost of existing refrigeration technology.

The program was organized, administered, and funded by 24 utilities, collectively serving over 20 percent of U.S. households.[2] The Super Efficient Refrigerator Program (SERP) provided a $27 million prize to be awarded to a manufacturer able to exceed U.S. Department of Energy (DOE) standards at a competitive price with existing comparable refrigerators.[3] SERP was one of the first wide-spread prize-based energy incentive programs, known as a Golden Carrot, offered in the United States.

Fourteen manufacturers submitted proposals to SERP. Whirlpool and Frigidaire competed as finalists, with Whirlpool ultimately securing the contract in July 1993. As part of the contract, Whirlpool was provided both the direct incentive of the prize and a guaranteed first mover advantage as specifications and design were kept confidential. To collect the full prize, the manufacturer had to meet strict specifications, sell at or below cost, and produce 250,000 super-efficient refrigerators by July 1997.[4]

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[2] Eckert, "The Super Efficient Refrigerator Program: Case Study of a Golden Carrot Program."

[3] Feist et al., "Super Efficient Refrigerators: The Golden Carrot from Concept to Reality."

[4] Davis and Davis, "How Effective Are Prizes as Incentives to Innovation? Evidence from Three 20th Century Contests."

Broadly, the program was a success. CFC emissions were reduced substantially,[5] making great strides towards meeting the Montreal Protocol commitments,[6] and the 2001 efficiency standards reduced average refrigerator energy consumption by nearly 20 percent.[7]

However, falling electricity prices through the mid-1990s and a delay in United States efficiency standards from 1998 to 2001 led to a lower-than-expected adoption of the efficient refrigerators. As a result, Whirlpool reportedly pulled out of the program before the full distribution was complete.[8] Yet Whirlpool and its competitors did successfully develop new efficient refrigeration techniques based on the technologies developed in the SERP program, and the market for efficient refrigeration has remained robust.

Despite awarding SERP to Whirlpool, other manufacturers have thrived in the refrigeration market. In 2016, Samsung (a new market entrant since SERP) held the largest market share of new household refrigerators.[9]

Lessons Learned

The SERP program was designed to help utilities and equipment manufacturers accelerate technology to ease the transition to new regulatory regimes – the Montreal Protocol and anticipated 1998 efficiency standards. Efficient refrigerators might have ultimately found a niche without utility involvement, but were brought to market more effectively and broadly through direct utility participation.

Effective use of incentives

One of the critical features of SERP was its ability to harness manufacturers' desire to be first to market. First movers can establish brand loyalty, capture wider market share, and improve second generation products. SERP awarded only one manufacturer, provided an exclusive marketing and distribution opportunity through 24 large utilities, and offered brand promotion on a national scale. That incentive proved to be powerful, even if the monetary prize was relatively small.

Further, the adoption of a centralized, efficient refrigeration program provided a level of certainty to the organizing utilities. The direct-to-manufacturer rebate eliminated many problems associated with utility-

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[5] Hu et al., "Considerable Contribution of the Montreal Protocol to Declining Greenhouse Gas Emissions from the United States."

[6] Gareau, "A Critical Review of the Successful CFC Phase-out versus the Delayed Methyl Bromide Phase-out in the Montreal Protocol."

[7] DiMascio, "How Your Refrigerator Has Kept Its Cool over 40 Years of Efficiency Improvements."

[8] Davis and Davis, "How Effective Are Prizes as Incentives to Innovation? Evidence from Three 20th Century Contests."

[9] Jin-young, "Biggest Player In US: Samsung Electronics Beats Whirlpool, GE in US Consumer Electronics Market."

to-customer rebate programs, including free-ridership, inconsistency with the level of offered rebate, and market uncertainty.[10]

Award did not exclude competitive market entry

Although SERP only awarded a single manufacturer, other market participants were not excluded from entering the market for efficient, CFC-free refrigerators. Indeed, shortly after Whirlpool developed the SERP model, General Electric, Amana, and Frigidaire all began to produce – and roll out – competitive products. Utility engagement should not preclude competitive market entry – either in utility-sponsored programs or those that compete with utility programs.

Adverse impacts of a winner-take-all approach

During the SERP, Whirlpool's competitors were concerned enough by the potential value of the first-mover advantage that they worked with the American Home Appliance Manufacturers trade group to successfully lobby for a delayed adoption of the 1998 refrigeration standards, over the objections of Whirlpool. This delay obviated much of the market advantage of being a first mover.

4. CASE STUDY: OFFSHORE WIND

Interventions: Market Acceleration and Addressing a Market Failure

Utilities can play a role in helping to accelerate the adoption of new or emerging technologies where cost is still a barrier. Utility procurements of off-shore wind through long-term PPAs have provided developers with the revenue and certainty required to undertake offshore wind projects. These procurements also provide environmental benefits (a public good).

With high, predictable, and sustained windspeeds relatively close to large load centers, offshore wind offers a highly attractive renewable energy profile to states interested in expanding renewable uptake, and to utilities concerned with predictability and intermittency. Offshore wind, however, requires specialized equipment to install and maintain and has traditionally been expensive relative to other renewable options. It is in an early development stage in the United States, with only one operational wind farm, Deepwater ONE, off the coast of Rhode Island. Nonetheless, the enabling regulations leading to contemporary offshore wind projects are explicitly designed to foster a new competitive industry, and the emergence of new players suggests that developers are willing to meet demand. Today there are eight developers engaged in twelve commercial-scale offshore wind projects in various stages of

[10] Eckert, "The Super Efficient Refrigerator Program: Case Study of a Golden Carrot Program."

development.[11] In every case, the developers have only been able to proceed by securing exclusive long-term power purchase agreements (PPAs) from utilities, enabled through statute or regulation.

The legislation and regulations enabling offshore wind procurement by U.S. utilities are notable because they identify a need for utility action to spur development. In Massachusetts, enabling legislation states that utility action is required "to facilitate the financing of offshore wind energy generation,"[12] while in Maryland the public service commission (PSC) identified that allowing the new wind projects would position the state as "a frontrunner in both economic and climate initiatives, striving to lead by example."[13] The PSC stated that Maryland "must develop a project that warrants investment in both infrastructure and jobs in order to realize a return on our ratepayers' investment in this nascent industry."[14]

Overall, the identified potential for offshore wind is large, yet untapped due to relatively little experience in the United States. Offshore wind developers face a substantial market and public perception barrier to entry. Investment in early projects is needed to ease public concerns, allow developers to gain necessary experience, and support the acquisition of the specialized equipment required to install offshore wind at reasonable costs. DOE has identified more than 24 gigawatts (GW) of active or planned offshore wind activity in twelve U.S. states.[15] As of this writing, Maryland had approved the sale of specialized "offshore renewable energy credits" (ORECs) from two separate projects from competing providers (US Wind and Skipjack Offshore), totaling 368 megawatts (MW) of capacity.[16] Massachusetts utilities have issued a request for proposals for up to 1,600 MW and expect offers from at least three prominent bidders,[17] including one paired with battery storage.[18]

Importantly, in both states, offerors are expected to invest heavily in the local upstream economy. In Maryland, the $1.4 billion US Wind project is expected to invest $100 million in industrial and manufacturing facilities in Baltimore County, redeveloping aging port and abandoned industrial areas.

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[11] Musial et al., "2016 Offshore Wind Technologies Market Report."

[12] MA Act 4568 §83C.

[13] Public Service Commission of Maryland, "Order No. 88192."

[14] Public Service Commission of Maryland, 88192.

[15] Musial et al., "2016 Offshore Wind Technologies Market Report."

[16] American Wind Energy Association, "Maryland Becomes an Offshore Wind Contender with OREC Decision."

[17] Serreze, "Massachusetts Utilities Release First Offshore Wind RFP under New State Energy Law."

[18] Deepwater Wind, "Deepwater Wind Proposing World's Largest Offshore Wind, Energy Storage Combination."

Lessons Learned

The infrastructure required for developers to successfully bring an offshore wind project to completion requires substantial near-term investments. Overcoming this high initial cost is necessary to make incremental projects more cost-effective.

The twelve states planning for offshore wind projects have opted to employ utility resource procurement as a vehicle for spurring further development of offshore wind and driving down long-term costs. The early movers amongst these states have opted to seek projects at above-market rates to encourage first movers.[19] In addition, these states have opted for a competitive framework in which multiple suppliers could ultimately be selected, encouraging a robust market.

Value of competition

Both Massachusetts and Maryland have recognized the value of competition in fostering a resilient marketplace for offshore wind. In both cases, the states set up mechanisms to seek relatively cost-effective bids without guaranteeing exclusivity. While developers in Massachusetts have expressed concerns that a bidder could monopolize the first-round RFP through an excessively-sized bid, the size of the developable tract virtually guarantees that multiple bidders will have access if the offers are attractive.

State regulator engagement in RFP process

In Massachusetts, regulators were deeply engaged in the development of the mandated utility RFPs for offshore wind, while in Maryland, regulators provided a detailed evaluation of each bid and supporting studies through a contested proceeding. In both cases, the process engages utilities, but does not exclusively rely on, the utilities in bringing offshore wind projects to fruition.

[19] Or in the language of Massachusetts Act 4568, projects should be "cost effective to electric ratepayers in the commonwealth over the term of the contract taking into consideration potential economic and environmental benefits to the ratepayers."

5. CASE STUDY: COMPACT FLUORESCENT LIGHTING

Interventions: Market Acceleration, Filling a Market Gap, and Addressing a Market Failure

Utilities can help to accelerate the adoption of new or emerging technologies where cost is still a barrier, while ensuring that underserved populations also benefit. Utilities have played a key role in the development of efficient lighting through working with manufacturers on specifications, providing manufacturer buy-downs and performance incentives, offering consumer rebates, conducting advertising and marketing, and working with retailers. Utilities have also helped to reach low-income customers and underserved populations by focusing promotions on discount and ethnic grocery stores, and discount general merchandise stores. Energy efficiency investments also serve to reduce emissions, thereby providing a public good.

Compact fluorescent lightbulbs (CFLs) have been available since the mid-1980s, but were a fringe—and expensive—item until around 2006.[20] By 2007, however, CFLs commanded a 20 percent market share, and the cost had plummeted from $20 per bulb to $3 per bulb.[21] The story of the widespread adoption of modern CFLs has the fingerprints of numerous parties and drivers on it, including electric utilities and their energy efficiency program administrator counterparts.

CFLs were first introduced at a commercial scale in the early 1980s, but were generally not considered reasonable substitutes for standard incandescent bulbs. CFLs had problems with flicker and durability, had poor design and color, and were expensive.[22] Expectations for sales were low, so bulb manufacturers had little incentive to improve the technology. However, In the late 1990s, concerted efforts by efficiency organizations working with bulb manufacturers started to result in substantial technology improvements and lower prices.[23]

Beginning in the late 1990s, several factors conspired to push CFLs into the mainstream. In 1999, the Department of Energy set the first national standards for CFLs, improving product quality and increasing customer satisfaction.[24] Then in the West, the California utilities joined together to overhaul the ways that CFLs were marketed and sold to customers. Efforts included cooperative advertising programs, training of sales representatives, and promotions at retail outlets. The utilities also poured significant funding into up-stream incentives for manufacturers. Through manufacturer buy-down programs, the

[20] Bickel, "CFL Market Overview."

[21] D&R International, "CFL Market Profile 2010."

[22] Sandahl et al., "Compact Fluorescent Lighting in America: Lessons Learned on the Way to Market."

[23] Interview with Steven Cowell of Conservation Services Group (CSG), August 2017

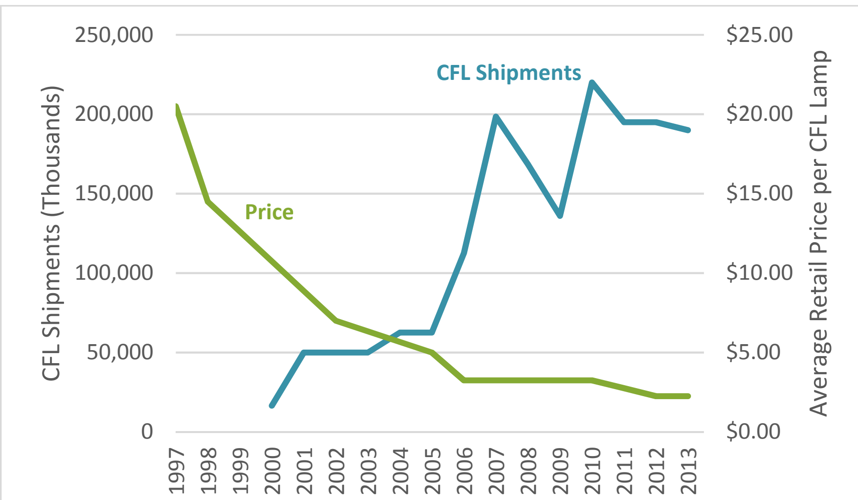
[24] Smith, Wei, and Sohn, "A Retrospective Analysis of Compact Fluorescent Lamp Experience Curves and Their Correlations to Deployment Programs."

price that a consumer paid for a CFL could be made less than or equal to the price of an incandescent bulb.[25] Importantly, the funding for manufacturers was competitive so that the manufacturers who were able to sell their products more quickly could obtain additional allocations from their less successful competitors.[26]

The 2000-2001 California energy crisis spurred an increased interest in rapid efficiency gains and energy efficient products.[27] In 2001, a nationally-coordinated lighting promotion called "Change a Light, Change the World" increased customer awareness of the benefits of CFLs.

CFL prices plummeted, falling from $19 per bulb in 1996 to $6 or less by 2003.[28] In 2006, Walmart made a commitment based largely on a sustainability initiative to sell 100 million CFLs.[29] Walmart's efforts and resulting market research, coupled with utility programs to subsidize and distribute new CFLs, contributed to even faster uptake of the lighting systems in 2006 and 2007, as shown in the figure below.[30]

Figure 1. CFL Shipments and Price



Source: Kelly and Rosenberg, 2016; Navigant Consulting, 2015

25 Manufacturer buy-downs were also used in other regions, including the Pacific Northwest and the Northeast.

26 Calwell et al., "2001—A CFL Odyssey: What Went Right?"

27 Moran et al., "CFL Program Strategy Review: No Programmatic "Silver Bullet"."

28 Sandahl et al., "Compact Fluorescent Lighting in America: Lessons Learned on the Way to Market."

29 U.S. Environmental Protection Agency, "Product Retrospective: Residential Lighting."

30 Kelly and Rosenberg, "Some Light Reading: Understanding Trends Residential CFL and LED Adoption"; Navigant Consulting, "Residential End Uses: Area 1: Historical Efficiency Data."

Utilities have, and continue to, play a key role in the rollout of CFL and other efficient lighting. Utilities work with manufacturers on specifications to increase uptake, provide direct-to-manufacturer buy-downs and performance incentives, offer consumer rebates, conduct advertising and marketing, perform direct installations during on-site visits, and even work with retailers to increase exposure and sales.[31] In some cases, utilities have also helped to reach low-income customers and underserved populations by focusing CFL promotions on discount and ethnic grocery stores, and discount general merchandise stores.[32]

From 1999-2004, the number of manufacturers producing Energy Star qualified CFLs grew by an order of magnitude from approximately 10 manufacturers to nearly 100.[33] By 2010, the market was producing 1,600 unique CFL products.[34]

And while some manufacturers have now transitioned to other types of lighting (particularly LEDs), the industry appears to be strongly committed to efficient products. Utility engagement in the distribution of CFLs helped create a burgeoning efficient lighting industry, competing for price, design, and quality.

Lessons Learned

Existing technology, hypothetical demand

Once CFLs matured, there was a clear demand for the efficient lighting technology. Had CFLs rolled onto the market at their current price point, quality, and options, the potential consumer savings might have been more apparent. Hypothetically, consumers should orient towards the superior product and savings. However, anecdotal evidence from manufacturers suggests that utility programs were key for disseminating information and mobilizing customers in large market regions.

Successful programs have multiplier effects

The success and rapid uptake of efficient lighting has been instrumental in the ability of utility-run efficiency programs to obtain low-cost savings. Indeed, the CFL is the poster-child for countless efficiency programs and acts as a driver of immediate savings for programs with home audits, product giveaways, rebates, and trade-ins. The widespread availability of the bulbs and diversity of retailers has allowed utilities to experiment with different forms of rebates, marketing, and distribution, providing many opportunities to learn from experience. In addition, newly formed utility efficiency programs, buoyed by low-cost lighting savings, invest in other efficiency measures, spreading incentives across multiple industries, from manufacturers to contractors and installers.

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[31] Rosenberg, "Measuring Spillover and Market Transformation Effects of Residential Lighting Programs."

[32] Joint California Utilities, "Statewide Lighting Market Transformation Program Report."

[33] D&R International, "CFL Market Profile 2010."

[34] D&R International.

Retailers and utilities can provide complementary services

Utility efficiency programs offered rebates and customer savings for CFLs, but evaluative research suggested that these rebates did not fundamentally change end-user consumer behavior.[35] However, competitive pricing, combined with long-term marketing and consumer education, a focus on value rather than price, and a shift towards better displays, and site visits produced lasting results in consumer behavior. Contracts and commercial customers, more directly responsive to price incentives, continue to benefit from "upstream lighting" or direct-to-distributer rebates provided by utilities. Utilities have persistent marketing opportunities through bills and direct consumer access, which allows them to compliment efforts at local retailers.

6. Case Study: Advanced Metering Infrastructure

Interventions: Addressing a Market Failure

Benefits of the smart grid, including improved system efficiency and improved reliability, are shared across all customers, and no customer can be excluded from the benefits. The market tends to under-provide such public goods, due to the difficulty in ensuring that the recipients of the benefits also help pay for its costs. This is particularly true for emerging, innovative, or risky initiatives. With the help of federal funds, numerous electric utilities took the plunge in investing in smart grid technologies.

Certain technological advancements, particularly those meant to modernize an industry, often cannot be adequately modeled on a small scale. To determine merit, these projects must sink or swim after implementation, making them especially risky investments. The United States sought to accelerate the adoption of AMI and other smart grid technologies with the 2007 Energy Independence and Security Act, which called for federal matching of smart grid investments, and the 2009 American Recovery and Reinvestment Act (ARRA) which allocated $4.5 billion in federal dollars to the Smart Grid Investment Grant (SGIG) and Smart Grid Demonstration Program (SGDP).[36] SGIG was specifically geared to modernize transmission and distribution systems with the federal government supporting up to half of utility costs. SGDP was designed to help utilities test integrated smart grid systems.[37]

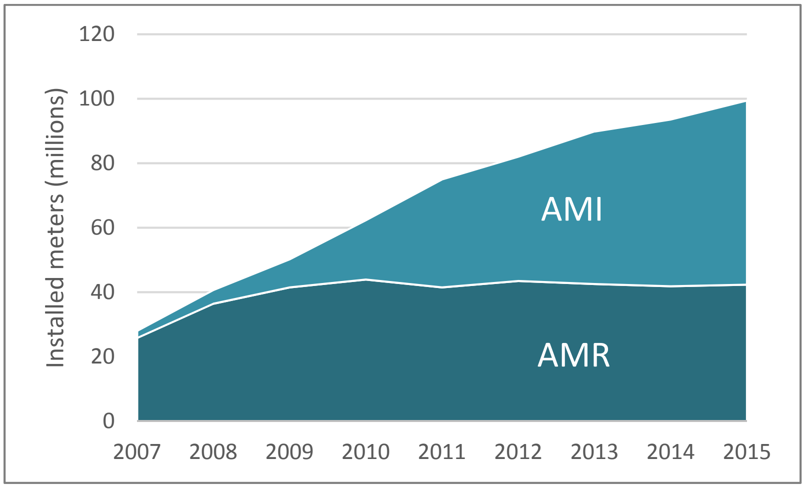
[35] Sandahl et al., "Compact Fluorescent Lighting in America: Lessons Learned on the Way to Market."

[36] U.S. Department of Energy, "Smart Grid Investment Grant Program."

[37] Wiranowski, "Competitive Smart Grid Pilots: A Means to Overcome Incentive and Informational Problems," 361.

The vast majority of AMI and customer system projects funded by SGIG were led by utilities. Utilities led 67 of such projects, while vendors or service providers led only 3.[38] One SGIG recipient was the Pacific Northwest Smart Grid Demonstration Project.[39] The project encompassed five states in the Northwest, requiring collaboration from private developers, utilities, power suppliers, and customers. The purpose of the project was to lay the groundwork for a smart grid system in the Northwest. The system would enhance grid communication and control; ease the addition of demand response, distributed generation, and small-scale storage; and evaluate the costs and benefits of smart grid investments.[40] Through this project, more than 30,000 AMI smart meters and $80 million of technology and equipment were installed. While the project faced many challenges, it also provided developers with abundant feedback and lessons.[41]

Figure 2. AMI deployment post-2007 (residential meters only)[43]



By and large, these efforts on behalf of the federal government, utilities, and industry partners were successful at transforming the market. Prior to AMI, the dominant new meter technology was automated meter reading (AMR), allowing meter readers to remotely access meter records but neither real-time nor bi-directional. AMI deployment ramped quickly after 2007, doubling every year through 2011, and then increasing steadily thereafter as shown in Figure 2. Utilities broadly ceased rolling out new AMR by 2010, and AMI had surpassed AMR as the dominant residential metering technology by 2013.

Under the SGIG and SGDP programs, utilities issued merit-based requests for proposals to AMI vendors. While no single utility used more than one major vendor, the large number of participating utilities drove substantial growth—and competition—in the AMI industry.[42]

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38 U.S. Department of Energy, "Advanced Metering Infrastructure and Customer Systems: Results from the Smart Grid Investment Grant Program," 9.

43 Energy Information Administration, Electric Power Annual 2016, Table 10.10 Advanced metering count by technology type.

Lessons Learned

Benefits accrue with adoption

Smart grid technologies require extensive infrastructure to provide the promised electric sector benefits, such as enabling distributed energy resources to play an active role in providing energy services. Success requires coordinated information flows among customers, utilities, system operators, and often third-party developers. Projects of this magnitude require funding, multi-sector cooperation, and patience. Immediate benefits are unlikely. While the networks provide the opportunity for improved services by enabling better data analysis and controls, the full benefits are rarely realized in the early years.

Utility and third-party involvement

In the Pacific Northwest Smart Grid Demonstration Project, utilities played a vital role. Utilities have ample information about their customer base, are a natural point of contact for participants, have experience with program design, and have knowledge of the importance of grid reliability and safety.[44]

While the value provided by utilities to Smart Grid programs is undisputed, there has been a drawback from utility engagement. Utilities habitually avoid risky investments. In the case of Smart Grid infrastructure, the unproven benefits led utilities to overbuild programs to ensure returns, rather than optimize system-wide benefits.[45] Utility programs are scrutinized for cost-effectiveness to ensure customer protection, motivating the utility to err on the side of caution rather than face the negative implications of program failure. To overcome this drawback, utilities can partner with third parties who have significant smart grid infrastructure expertise and experience, thereby reducing the risk that the project will go awry.

Compatibility and flexibility

One of the key issues plaguing Smart Grid projects is compatibility across vendors and technologies. A lack of forward planning leads to expensive integration costs later in the project, which could be avoided with predetermined interoperability standards.[46] Flathead Electric, an electric cooperative participating in the Pacific Northwest Smart Grid Demonstration Project, noted that its main challenge was the

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[40] Battelle Memorial Institute, 4.

[41] Battelle Memorial Institute, 2.

[42] Neichin and Cheng, “2010 U.S. Smart Grid Vendor Ecosystem: Report on the Companies and Market Dynamics Shaping the Current U.S. Smart Grid Landscape.”

[43] Energy Information Administration, Electric Power Annual 2016, Table 10.10 Advanced metering count by technology type.

[44] Wiranowski, “Competitive Smart Grid Pilots: A Means to Overcome Incentive and Informational Problems.”

[45] Wiranowski.

[46] Battelle Memorial Institute, “Pacific Northwest Smart Grid Demonstration Project Technology Performance Report,” 28.

integration of communications technology. The speed at which the platforms advanced was faster than the utility's ability to process the changes.[47]

The flexibility of a system extends beyond software or technological points of connection. Central Maine Power, an investor-owned utility that rolled out full scale AMI implementation to its 600,000 customers, faced a unique issue with network integration. The terrain in Maine is hilly and forested, causing the need to replace existing technology for more robust equipment. Each redesign proved challenging to integrate into the network, as the system has not been designed for flexibility.[48]

The important takeaway is that each program confronts obstacles that are territory-specific, and planning for complications is useful and economical. The larger the project, the more problems tend to be amplified. Building in flexibility where possible can help to overcome these challenges.

7. CASE STUDY: EMISSION CONTROLS

Interventions: Research and Development, Addressing a Market Failure

Clean air is a classic example of a public good that can be jeopardized if left unregulated and subject only to market forces. Utilities were a key player in the development of pollution emissions control technologies, as they provided important operational experience feedback to technology developers and hired chemical engineers to improve the operation of the technology.

Since the passage of the Clean Air Act (CAA) in 1963, the federal government has striven to improve air quality through "end of pipe" technology improvements, with some of the most substantial requirements and standards impacting emissions of sulfur dioxide (SO_2). Through the early 1950s and 1960s, the federal government funded various programs to develop scrubber technologies to reduce SO_2 emissions, but these technologies were not widely adopted until the CAA amendments of 1970. The Clean Air Act, which formed the Environmental Protection Agency (EPA) and required states to meet air quality standards, created the first competitive markets for flue gas desulfurization (FGD) technology. By the early-1970s, the EPA was funding prototypes and sponsoring commercial-scale demonstration projects.

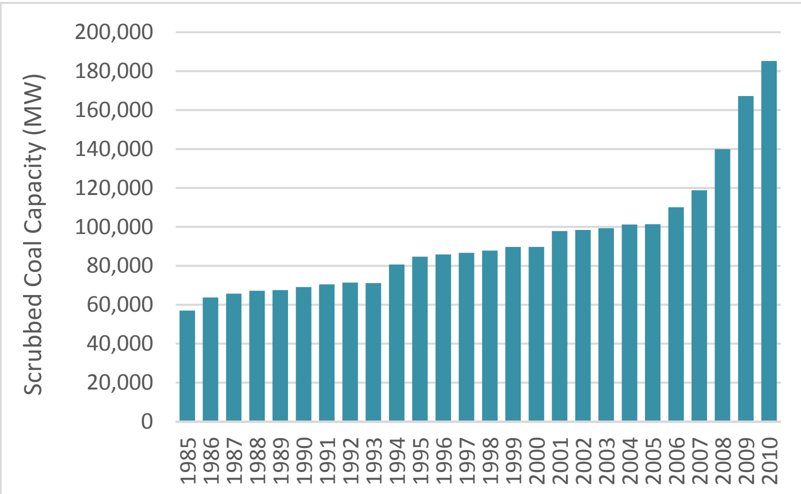
Broad-scale utility engagement in the development of emissions controls began with the Tennessee Valley Authority (TVA) in 1971 when the federally-chartered utility built prototype FGDs at its Colbert

[47] Battelle Memorial Institute, 15.

[48] U.S. Department of Energy, "Advanced Metering Infrastructure and Customer Systems: Results from the Smart Grid Investment Grant Program," 34.

and Shawnee plants. EPA's national standards-based rule required utilities to start reducing SO_2 emissions, and by 1976 had created a robust market for FGD technologies. [49] By the 1986, more than 60 GW of coal was scrubbed—but then adoption stagnated until the 1990s, as shown in Figure 3.

Figure 3. Capacity of Coal Generation with FGD 1985-2010



Source: EIA, Annual Energy Review, Table 11.6, Annual Energy Review, September 2012

The plateau in saturation of FGDs is attributed to a change in EPA's guidelines in the 1977 CAA Amendments that set strict requirements for 90 percent removal at all emissions sources, but allowed states to relax guidelines on a case-by-case basis – which they did.[50]

EPA guidance became stricter in 1987[51] and 1994 saw a substantial increase in utility investments in SO_2 controls across the United States.[52] The CAA amendments of 1990 introduced tradable allowances, and researchers estimate that by 1995, only half of emissions reductions were achieved through scrubbers, while the other half were achieved by fuel switching to low-sulfur fuels.[53]

Innovation and the proliferation of scrubber technology followed EPA's requirements. Patents for SO_2-related controls quickly grew from 1967 to 1975 before plateauing thereafter. Researchers have noted that the setting of a strict standard for SO_2 first led to a rapid expansion in research and development, and once the industry had started operation, helped drive down costs.[54] Some researchers have shown evidence that the 1990 CAA Amendments, by implementing a market cap on emissions, led to new innovations, such as fuel switching and partial controls (such as dry sorbent injection).[55]

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[49] Taylor, Rubin, and Hounshell, "Control of SO2 Emissions from Power Plants."

[50] Plant owners regularly sought to demonstrate that emissions controls would lead to job losses or other economic hardship, and thus were relieved of obligations. *See:* Popp, "Pollution Control Innovations and the Clean Air Act of 1990."

[51] In 1987, EPA eliminating the economic out clauses invoked by utilities and states.

[52] Taylor, Rubin, and Hounshell, "Control of SO2 Emissions from Power Plants."

[53] Ellerman et al., "Emissions Trading Under the U.S. Acid Rain Program: Evaluation of Compliance Costs and Allowance Market Performance."

[54] Taylor, Rubin, and Hounshell, "Control of SO2 Emissions from Power Plants."

[55] Popp, "Pollution Control Innovations and the Clean Air Act of 1990."

Since the 1990s, a series of new technologies have emerged at lower cost and higher effectiveness, generally targeted towards meeting the Mercury and Air Toxics (MATS) standards. Dry scrubbers, dry sorbent injection, and relatively unique technologies like the activated coke-based ReACT system[56] drove down compliance costs and allowed yet new market players into the emissions control industry.

Researchers have also noted that one of the most important elements of utility investments in emissions controls has been "learning by doing," where nascent technologies are improved through application, evaluation, and mid-course correction. Within the SO_2 emissions removal sector, early scrubbers experienced high levels of corrosion and plugging, which required substantial innovation by the operating utilities. Utilities began hiring and training specialized chemical operators to ensure efficient use of scrubbing technology.[57] Overall, investments from utilities driven by regulatory requirements resulted in robust emissions controls companies and implementation pipeline.

Today's emissions controls companies are refocusing efforts by applying utility technologies from large steam boilers to other industries, including refineries, chemical plants, and plastics manufacturing facilities.[58] In part, EPA's ability to apply standards to these non-utility sources has been bolstered by lessons learned and technology improvements at coal-fired boilers in the 1990s and 2000s. Emissions control companies are also re-orienting towards carbon capture and sequestration, in part banking on a future regulatory environment and continued investments. Indeed, some of the largest dollar projects in recent years have been utilities "learning by doing" at carbon capture facilities in Edwardsport and Kemper County. These projects stimulate the industry, provide substantial opportunities for research and development, and are the avenues for utilities to provide long-term public benefits through near-term large-scale investments.

Lessons Learned

Realization of public benefit

Clean air is a classic example of a public good that markets, operating by themselves, are unlikely to provide. Because emissions controls provide cleaner air for everyone, regardless of whether an individual pays for it, economic theory holds that public goods will be under-provided without government intervention. It is within this context that the Clean Air Act was enacted and the development of sulfur emissions control technologies began.

In order to provide clean air at a reasonable cost, however, the market for emissions controls had to be transformed. Government intervention, first in research and development and later through regulatory

[56] Weston 3 ReACT Emission Control Project. http://www.wisconsinpublicservice.com/environment/react.aspx

[57] Taylor, Rubin, and Hounshell, "Control of SO2 Emissions from Power Plants."

[58] Interview with Institute of Clean Air Companies, August 21, 2017.

requirements, helped foster and focus a new industry, and then provided robust market signals for the widespread commercialization of the technology.

Utilities were a key player in this transformation, as they provided important operational experience feedback to technology developers and researchers. Utility and technology developer interactions increased significantly between the implementation of the 1979 and 1990 regulations, leading to considerable advances in the technology over time. Both informal and formal gatherings helped support this collaboration, technology sharing, and competition of ideas. The government played an important role in this respect through its funding of the SO_2 Symposium.[59]

8. CONCLUSIONS

The case studies above span a wide range of utility actions, from purchase agreements to technology ownership, and from investments required by regulation to those which are grounded in policy initiatives. These utility investments have helped drive substantial market development in a wide variety of industries, from consumer end-use equipment (such as efficient refrigerators), to grid technologies (e.g., AMI and offshore wind), and environmental controls.

These case studies suggest that utility investment or ownership does not necessarily hinder competitive markets or create barriers to entry by competitors. Nonetheless, the case studies offer valuable lessons regarding future utility interventions in unregulated markets:

1. **Allow for competitive market entry.** Utilities should structure their programs to allow for competitive market entry both during solicitation phases as well as in parallel with the utility investments. When a utility seeks to fill a whole market gap through a single large purchase, it can drive away competition and risks investing in obsolete technologies.

2. **Seek to harness first-mover motivation, but not to the exclusion of competitive entry.** Manufacturers gain substantial market headway by being a first mover, and this fact can be a powerful motivator. However, first-mover status should not be harnessed to the exclusion of competitive market entry.

3. **Maintain meaningful regulator engagement.** Utility regulators provide a check on utility investments, ensuring that they remain in the public interest. Regulators can, and should, hold utilities responsible for ensuring that investments on behalf of customers provide net benefits and do not hinder competitive markets.

4. **Allow for learning-by-doing.** Every new technology will pose inevitable unforeseen problems to utilities, vendors, and consumers. A measured pace of adoption of the

[59] Taylor, Rubin, and Hounshell, "Control of SO2 Emissions from Power Plants."

new technology will allow for a process of learning, adjustment, and restructuring by utilities, regulators, vendors, and consumers. Utilities and regulators should design the procurement process around these inevitable problems, recognizing that continuous exposure and learning will eventually ease implementation.

5. **Build for flexibility and ongoing innovation.** One major risk of rapid technology deployment is that the rate of technological change can quickly lead yesterday's investments to be rendered obsolete and incompatible with new advancements. Several utilities engaged in AMI deployment complained that early models were incompatible with later communications software or did not have the ability to handle features later considered fundamental. Support for new technologies should specify compatibility requirements while allowing for innovation.