U.S. AND INTERNATIONAL EXPERIENCE WITH MARKET TRANSFORMATION

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White Paper

ACEEE
Smart Energy. Clean Planet. Better Lives.

Contents

About ACEEE

The **American Council for an Energy-Efficient Economy** (ACEEE), a nonprofit research organization, develops policies to reduce energy waste and combat climate change. Its independent analysis advances investments, programs, and behaviors that use energy more effectively and help build an equitable clean energy future.

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Introduction and Background

Market transformation emerged as a program concept for energy efficiency in the early 1990s as utilities, regulators, and stakeholders began to recognize that significant gains in energy efficiency could—in some cases—be best achieved by fundamentally changing certain markets for energy-efficient technologies. It was evident in many markets that barriers prevented more-energy-efficient products and related services from gaining a large or possibly even a dominant market share. Market transformation uses strategic interventions to overcome market barriers that exist for products, technologies, and practices that yield higher energy efficiency than their business-as-usual counterparts.

Market transformation can be effective for a wide range of products, services, and professional practices. Clothes washers and residential lighting—first CFLs and now LEDs—are good examples of U.S. markets in which transformations have occurred due to strategic interventions by numerous stakeholders over long periods. Such products faced many barriers that were eventually overcome through various interventions. Absent such interventions, it is doubtful that these U.S. markets would be where they are today, with energy-efficient products enjoying dominant market shares.

Transforming markets is ambitious. It is a large, complex undertaking that seeks to effect fundamental changes in targeted markets. Typically, market transformation programs require substantial initial funding, and the resulting impacts may not be realized for a long time—generally 5–10 years. Consequently, market transformation is not universally embraced as a program model.

OBJECTIVES AND RESEARCH QUESTIONS

Markets vary widely from country to country—and even within individual countries. What may have worked to transform a market in one country may not work in another. In this paper, we update and expand prior ACEEE research on market transformation and add selected international experiences. The paper's overall objective is to identify and discuss crucial lessons for successful market transformation. Key questions we address include the following:

- What types of products, technologies, and services are best suited for market transformation?
- What organizations, institutions, and businesses need to be involved in market transformation?
- What types of initiatives, interventions, and incentives can be used to transform markets?
- What results have been achieved for selected market transformation programs?
- How are market transformation programs structured?
- What metrics and methods are used to track results?

- What are effective exit or transition strategies for market transformation?

This paper establishes the foundations for applying market transformation to a targeted product, technology, or service.

DEVELOPMENT AND DEFINITION OF MARKET TRANSFORMATION

The term *market transformation* was coined in a paper presented at the 1992 ACEEE Summer Study on Energy Efficiency in Buildings (Eckman, Benner, and Gordon 1992). The concept thereafter emerged rapidly as a program model for energy efficiency (Eto, Prahl, and Schlegel 1996; Nadel and Latham 1998; Peloza, York, and Paulos 1999; York and Paulos 1999). At that time, utility demand-side management (DSM) had become well established in many states and regions. While DSM encompasses a broad range of policies and programs, a core component of utility DSM is customer energy efficiency programs. The practice of DSM had grown rapidly in the 1980s as an increasing number of states enacted policies and regulations that required utilities to perform *integrated resource planning*—that is, examining and analyzing both the supply and demand options that best meet customer energy needs (Nadel 2013).

As utilities and key stakeholders gained experience with DSM and associated energy efficiency programs, industry experts posited that programs could achieve much higher impacts if they could facilitate fundamental transformations that resulted in a large or possibly even a dominant market share of energy-efficient products and services. In this way, such products and services would become the norm, greatly reducing or even eliminating the need for utility energy efficiency programs with similar goals.

Definitions of market transformation vary among program administrators and experts, but a few definitions are generally well accepted. Among them is this widely used definition:

> Market transformation means a reduction in market barriers due to a market intervention, as evidenced by a set of market effects, that lasts after the intervention has been withdrawn, reduced, or changed (Eto, Prahl, and Schlegel 1996).

ACEEE provided another early definition:

> Market transformation is a process whereby energy efficiency innovations are introduced into the marketplace and over time penetrate a large portion of the eligible market. Market transformation involves ongoing and lasting change, such that the market does not regress to lower levels of efficiency at some later time (Geller and Nadel 1994).

There was early debate about whether market transformation was a policy goal or a strategic approach to intervening in markets, but our review of the literature shows that the latter outlook prevailed. This paper follows this convention, viewing market transformation as a strategic intervention and program model rather than a policy goal. We focus on programs

and related initiatives led and administered by utilities or related organizations and funded primarily by utility customers.

Market Transformation in Practice

Market transformation has proved to be an effective program model for selected technologies, products, and services that improve energy efficiency in a wide variety of end uses. Drawing on more than 25 years of experience with such programs, we can characterize the markets best suited to this model, as well as identify the steps and interventions of typical market transformation programs. In this section, we present an overview of market transformation in practice.

PRODUCTS, TECHNOLOGIES, AND SERVICES BEST SUITED FOR MARKET TRANSFORMATION

Market transformation is not suited to all types of products, technologies, and services. As Prahl and Keating (2014) outlined, the products and technologies that are most amenable to market transformation are those that offer the following:

- A clearly defined and manageable market
- An opportunity for energy savings that are large enough to justify the resources and time commitment required to achieve the desired change
- A story that logically and defensibly links the market's present state to its desired future state
- Strong nonenergy benefits to help targeted technologies and products gain market acceptance and sustainability
- Cost-effective energy savings over a long-term program horizon

A prior ACEEE review (Nadel et al. 2003) reached complementary conclusions, finding that products or technologies that show significant progress in reaching market transformation goals have five common attributes:

- Low incremental cost
- Rapid payback (return on investment)
- Substantial nonenergy benefits (those beyond energy savings)
- Improvements to existing technologies or practices
- Ability to be incorporated into new or updated codes and standards

OVERCOMING MARKET BARRIERS

Market transformation involves strategic interventions to overcome market barriers that exist for products, technologies, and practices that yield higher energy efficiency. Eto, Prahl, and Schlegel (1996) identified 14 such market barriers. The Electric Power Research Institute (EPRI) (2001) later collapsed these 14 barriers into eight overarching ones (Keating 2014):

- Limited access to information (customers are unaware of savings opportunities)
- Performance uncertainties and risks
- Limited access to financing
- Split incentives (i.e., the one who pays is not the one who gains)
- Decision-making issues (rules of thumb, habits, organizational decisions)
- Problems with product or service features (inability to separate efficiency features; not easily reversed)
- Transaction costs
- Mispricing of energy or other products in the market due to regulation and/or failure to include externalities

STRUCTURE AND ADMINISTRATION OF MARKET TRANSFORMATION

Because the markets for most products and services are regional or national, market transformation operates at that scale. The complexity of markets also necessitates collaboration among a wide set of market actors, which may include manufacturers, trade associations, suppliers, retailers, utilities, contractors, government agencies, regulatory authorities, other stakeholders, and customers. Market transformation requires leadership and coordination among these many actors to work toward and achieve desired outcomes. Utilities and related organizations typically administer market transformation initiatives at the customer level. National organizations, government agencies, or collaborations can also play prominent roles, such as establishing product specifications, design competitions, labeling, and marketing campaigns. In the United States, regional and state energy efficiency organizations are also commonly involved with market transformation initiatives; such organizations include the Northwest Energy Efficiency Alliance (NEEA), the Midwest Energy Efficiency Alliance (MEEA), and the Northeast Energy Efficiency Partnerships (NEEP). These regional nonprofits are typically well positioned to facilitate and coordinate market transformation efforts across several states. They also play key roles in achieving the scale needed for effective market transformation by bringing together various market actors to work toward common goals. Although each organization's role varies, they coordinate their efforts as needed to achieve their common market transformation goals.

PROGRAM STEPS AND PROCESS

Market transformation can be a complex program model. Several reports describe the process and key steps that such transformation programs typically follow (Nevius et al. 2013; Keating 2014; Prahl and Keating 2011). One way to view these steps is to group them

according to two processes: analytical and implementation (see figure 1). The processes themselves are interwoven in the development, design, implementation, and evaluation of market transformation programs. Figure 1 is simplified; in reality, various feedback loops and other connections occur between the steps. There also are additional steps not readily shown by such a simplified figure; these steps include midstream evaluation to assess impact and design adjustment early in a program launch.

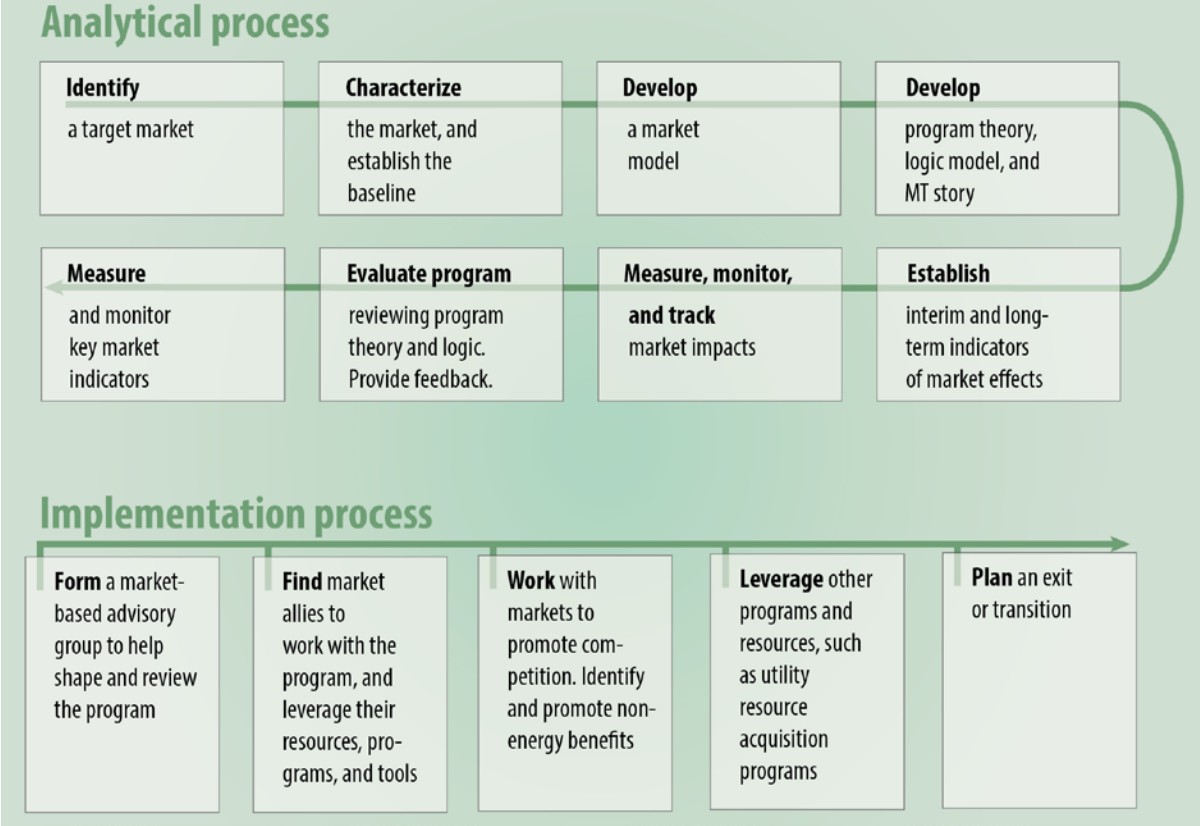


Figure 1. Market transformation processes

TYPES OF INTERVENTIONS, INITIATIVES, AND INCENTIVES FOR MARKET TRANSFORMATION

Market transformation programs engage in various types of interventions. These interventions address different market actors—that is, different members of any group actively engaged in a targeted market and having some type of stake in that market. Table 1 shows examples of common interventions that market transformation programs take, grouping them according to the targeted market actor.

Table 1. Market transformation interventions

Market actors	Intervention or action	Goal
Manufacturers	Promotions and incentives	Increase demand
	Design prizes	Develop high-efficiency products
	Research funding	Develop high-efficiency products
	Development of standard performance specifications	Ensure performance and quality of high-efficiency products
Dealers, wholesalers, retailers	Promotions and incentives	Increase product sales and product availability
	Training of sales staff	Increase knowledge of energy efficiency products to increase sales
Trades, technical professionals, industry allies	Training	Increase awareness of and expertise in working with energy-efficient products, technologies, and services
	Certification and professional recognition	Provide professional credentials that have value in the job market; create market differentiator for potential customers
	Best-practice guides	Improve professional practices
Customers	Mass advertising	Increase awareness of products
	Demonstration products and customer testimonials	Increase confidence in product performance
	Bulk procurement and purchases	Increase demand quickly and seek lower prices due to economies of scale
Trades, technical professionals, industry allies	Training	Increase awareness of and expertise in working with energy-efficient products, technologies, and services
	Certification and professional recognition	Provide professional credentials that have value in job market; create market

Market actors	Intervention or action	Goal
		differentiator for potential customers
	Best-practice guides	Improve professional practices
Regulators	Codes and standards	Increase minimum performance of products and buildings—lock in improved efficiency
	Support of pilot programs and projects	Demonstrate feasibility and performance of innovative programs, products, and services
	Funding of market transformation programs	Enable market transformation
National governments and national organizations	Labeling	Create customer awareness of differences in energy efficiency among targeted products

Source: Keating 2014

As table 1 shows, market transformation program developers can choose from a wide set of interventions and actions. To be successful, programs must identify, select, and implement sets of interventions that effectively address key market barriers. Later, we present selected case studies that illustrate how market transformation has been applied in different markets. First, however, we discuss various measures for tracking and assessing intervention results.

METRICS AND METHODS TO TRACK AND ASSESS RESULTS

Programs use market data as the metrics to track and measure market transformation. Establishing a market baseline is a key first step in any market transformation initiative. Such a baseline will be the foundation for determining changes that result from interventions in a targeted market. Specific metrics and market data will vary depending on the type of market, but common metrics and data include the following:

- Market share/penetration
- Sales data
- Product/service availability (stocking)
- Customer survey data

Periodic data collection is a key activity for market transformation initiatives. Collecting data allows administrators and actors to measure progress toward their market transformation goals and to make adjustments if their progress is insufficient.

ADJUSTING INTERVENTIONS

As figure 1 shows, market transformation is an iterative process. It begins with initial interventions based on identified market barriers and expected outcomes. Monitoring and tracking the outcomes provides feedback on how well the interventions are working. If they are not achieving desired results, changes to the interventions are likely necessary. Based on its experiences with market transformation initiatives, NEEA calls this process "adaptive management"—that is, continually using feedback on transformation efforts to assess progress, identify problems, and adjust interventions as needed.

TRANSITION AND EXIT STRATEGIES

Market transformation initiatives go through various stages. At some point, they reach an end stage; this typically occurs either when the initiative has reached its goals or the actors involved in and supporting the initiative decide to end it. Thus, the people leading a market transformation initiative need to plan for an eventual transition or create an exit strategy. Such strategies include the following:

- Locking in a targeted product or service's efficiency by establishing appliance/equipment standards or building codes
- Reducing and changing interventions, such as ending customer incentives for purchasing energy-efficient products, but continuing to support marketing and labeling of the products or services to avoid slipping back from market progress
- Ending all interventions if no support is needed to sustain market progress

In the worst cases, the interventions and intended market progress may not be sufficient to warrant continued involvement. Given the dynamic and often unpredictable nature of markets, not all market transformation initiatives will succeed.

U.S. Experience

Here, we discuss eight representative U.S. market transformation initiatives: four that are largely completed, and four that are underway. Our first two descriptions offer additional detail to help illustrate market transformation strategies, drawing on prior work by York et al. (2017). The descriptions that follow the first two are shorter and were developed specifically for this paper.

HISTORIC EXAMPLES OF MARKET TRANSFORMATION INITIATIVES

Clothes Washers

In today's market, U.S. consumers can find two types of clothes washers—top loading and front loading. Thirty years ago, however, virtually all washers sold in the United States were top loading, and front-loading models commanded only a 2% market share (EPA 2012). Meanwhile, front-loading washers were already very popular in European countries. These countries saw significant energy savings because front-loading washers used approximately 40% less water and 60% less electricity than top-loading machines (EPA 2012). This huge savings potential motivated utilities and policymakers to transform the washer market in the early 1990s.

In 1994, the U.S. Department of Energy (DOE) implemented a modest new minimum efficiency standard for clothes washers, but it also began a new rulemaking to consider much higher standards based on the front-loading machine's horizontal-axis technology (Paton 2004). This spurred market transformation efforts because none of the major manufacturers had a qualifying machine, and it was evident that they would need to develop horizontal-axis washers for the U.S. market. Around the same time, many utilities were expressing interest in promoting efficient washers to reach their energy efficiency program requirements. In 1993, the Consortium for Energy Efficiency (CEE) collaborated with a group of utilities in the western United States to develop energy efficiency specifications for utility programs (deLaski and Pope 1996).[1] Before program managers could implement these standards nationwide, however, utilities needed further performance and market data (deLaski and Pope 1996). The DOE, the city of Seattle, several western utilities, and EPRI worked together to create The High Efficiency Laundry Metering & Marketing Analysis (THELMA). The THELMA research found that the market had potential for transformation, but that four barriers had to be overcome: (1) high initial cost, (2) lack of consumer familiarity, (3) limited availability of front-loading products, and (4) a lack of front-loading washers that met consumer design preferences.

In 1992, Maytag collaborated with EPRI to develop the Neptune, a front-loading washer specifically designed for the U.S. market. In addition to energy and water savings, Neptune's front-loading mechanics were gentler on clothing (Peloza, York, and Paulos 1999) than top-loading machines. These qualities allowed Maytag to market the Neptune as a premium product and sell it for twice the cost of conventional washers (Paton 2004). The Neptune was

[1] The Consortium for Energy Efficiency is a nonprofit organization whose members—efficiency program administrators across the United States and Canada—work together to accelerate energy efficiency products and services in targeted markets (CEE 2021).

so popular among consumers that there was a waiting list to buy one. Seeing this success, other manufacturers followed suit and developed their own front-loading washers.

The Neptune was also instrumental in developing ENERGY STAR specifications.[2] Maytag and ENERGY STAR ran a pilot program in the small city of Bern, Kansas, to test the performance and consumer acceptability of front-loading washers (Tomlinson and Rizy 1998). Each participant was given a free Neptune washer, and researchers closely tracked energy and water use by each participant for five months. They found that the Neptune used 38% less water and 58% less energy than conventional machines (EPA 2012). Using these data, ENERGY STAR developed its clothes washer specification, and in 1997 the Neptune became the first ENERGY STAR–certified clothes washer (Paton 2004).

Utilities, state energy offices, and regional energy efficiency associations led education and rebate programs across the United States. Among these was WashWise, a successful program run by NEEA. WashWise offered cash rebates to households that purchased qualifying washers (Kunkle and Lutzenhiser 1998). After two years, the program switched to upstream rebates, delivering incentives to retailers instead of directly to customers. These Other programs across the country took similar forms. As a result of these efforts, the incremental cost of an ENERGY STAR washer declined from more than $500 to around $200 (EPA 2008a).

Initially, the typical $200 price premium for ENERGY STAR machines deterred many consumers. To address this, many of the programs highlighted the financial benefits of purchasing an ENERGY STAR–qualified washer, which could save an owner $340 in energy costs over its lifetime (EPA 2008a). The Environmental Protection Agency developed marketing campaigns that aimed to help consumers understand these lifetime savings, translating energy and water savings into more understandable terms.

The superior performance of front-loading machines also helped their rapid acceptance in the American market. In 2000, Consumer Reports gave the Neptune its highest rating and called it an "overall excellent" washer (Koncius 2001). A year later, it reviewed the Kenmore Elite Calypso and called it "one of the best washers we've ever put through the wringer." These reviews emphasized the nonenergy benefits of the efficient washers, which were noticeably gentler on clothes and cleaned better than top-loading machines with agitators (Paton 2004). These nonenergy benefits made consumers view efficient washers as premium-quality machines, and they became more willing to pay a higher price for them.

[2] ENERGY STAR is a labeling program created and administered by the U.S. Environmental Protection Agency. Products receiving an ENERGY STAR rating and label are those that meet energy efficiency criteria and rank among the most energy-efficient products of a given product type (e.g., refrigerator, air conditioner, or television).

As this case shows, ENERGY STAR, manufacturers, and efficiency partners collaborated to effectively transform the clothes washer market. By 2005, ENERGY STAR washers had reached a 38% market share (Karney 2006). Given this high market acceptance, in 2007 the U.S. government raised federally required standards, implementing a consensus agreement negotiated between appliance manufacturers and energy efficiency advocates. These standards were set at the 2001 ENERGY STAR efficiency level, making every washer more efficient than 99% of the models sold in 1997 (EPA 2008b).

Introducing efficient clothes washers to the market saved 30 billion kWh and 110 trillion British thermal units from 1997 to 2009 (EPA 2012). The success of this program can be attributed to four factors:

- Strong support from manufacturers
- Nonenergy benefits (e.g., water savings, quality of washer performance)
- Regional awareness and rebate programs
- Enactment of a federal standard

Screw-In LED Lightbulbs

In the early 2000s, LED technology showed potential for residential lighting. DOE created the Solid-State Lighting Program to guide LED development and avoid the pitfalls experienced during the development of compact florescent lights (CFLs) (DOE 2017a). [3] To ensure the widespread market adoption of LEDs and help the technology realize its full potential, DOE addressed four key barriers: (1) inadequate quality control, (2) high cost, (3) consumer confusion, and (4) consumers' negative perception of efficient lighting.

DOE developed the Commercially Available LED Product Evaluation and Reporting (CALiPER) program to provide unbiased, trusted product performance information to the market and ensure that LEDs would meet consumer expectations for quality (DOE 2017b). Having a single evaluation standard allows market participants to compare the performance and quality of LED products and acts as a guide for manufacturers. DOE also launched the LED Lighting Facts® program to promote the accurate and consistent reporting of LED product performance (DOE 2017c). Under this voluntary program, manufacturers test and report their LED performance according to CALiPER test procedures. Each listed product receives a Lighting Facts label that allows consumers, retailers, and distributors to compare products

[3] Many early CFLs suffered a range of problems, including delays in reaching full intensity, poor color rendition, flickering, and premature burn-out/failure. Many also failed to fit existing lamps and fixtures, and CFL costs were much higher than standard incandescent lightbulbs.

easily. To promote the listed products, the program engages with retailers, distributors, and efficiency program sponsors.

Beyond CALiPER testing, the U.S. Congress, in its Energy Independence and Security Act of 2007 (EISA), directed DOE to design the L Prize competition to challenge companies to develop products that push the boundaries of performance benchmarks (110th Congress 2007). Beyond efficiency, the competition required that the products could be mass-produced in the United States, ensuring American job creation. Utilities and efficiency program managers promoted the winning entries, which allowed manufacturers to capitalize on rapid development of efficient technology.

Collaboration among government, industry, and research organizations has also guided LED development. For example, the California Public Utility Commission tasked the California Lighting Technology Center and the Collaborative Labeling and Appliance Standards Program to research consumer preferences to incorporate into standards (Siminovitch and Papamichael 2012). Their research suggested that consumers cared about color brilliance, light color appearance, light color uniformity, dimmability, longevity, and circadian rhythm effects. Ultimately, ENERGY STAR incorporated these characteristics into its LED lighting specifications. This effort was one of many research and development projects aimed at ensuring that LEDs were developed in a consumer-friendly fashion.

Earlier experience with CFLs demonstrated that education and marketing are essential for efficient lighting adoption. DOE and ENERGY STAR have both provided LED marketing materials for retailers, with marketing messages that help consumers understand the financial benefits of purchasing LEDs. For example, DOE offers this effective messaging: "A mother who installs a LED light when her child is born won't need to change the bulb until after her kid graduates from college. For every LED light she might use, she'd have to buy 25 incandescents" (DOE 2016). Communicating the savings and longevity of LEDs to consumers is essential for shifting the market away from incandescents.

Utilities, state energy offices, and regional energy efficiency associations have also developed educational and marketing campaigns, typically for their incentive and rebate programs. Many utilities and local efficiency organizations have LED incentive programs that educate and provide rebates to their customers. EISA 2007 set minimum efficiency requirements for general-service lamps, effectively removing the least-efficient bulbs from the market. Phase 2 of EISA, effective in 2020, sets higher efficiency levels (Miziolek, Wallace, and Lis 2015). As prices decrease, the need for such programs is diminishing.

Figure 2 depicts the market penetration of various light bulbs and the growth in LED adoption from 2012 to 2017 (NEMA 2017). Figure 3 shows the continued growth from 2017 to 2019. Because figure 2 includes incandescent A-line lamps, while figure 3 does not, the LED share in the latter figure is somewhat larger.

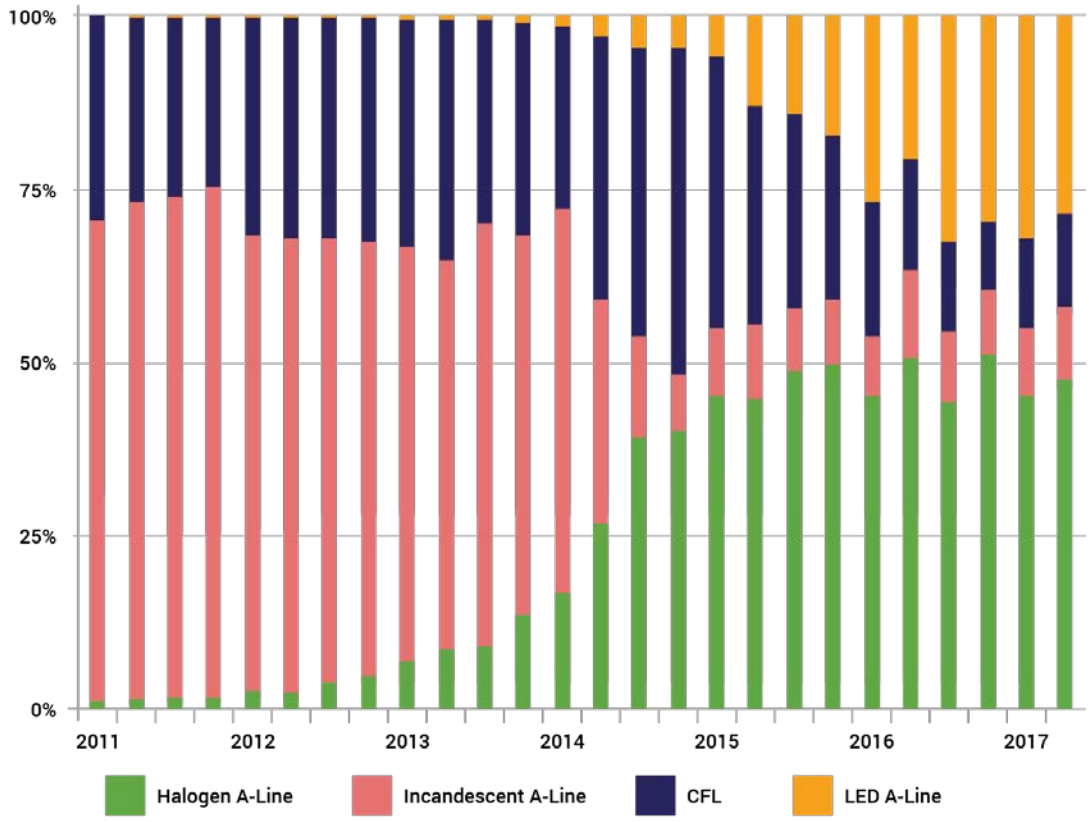
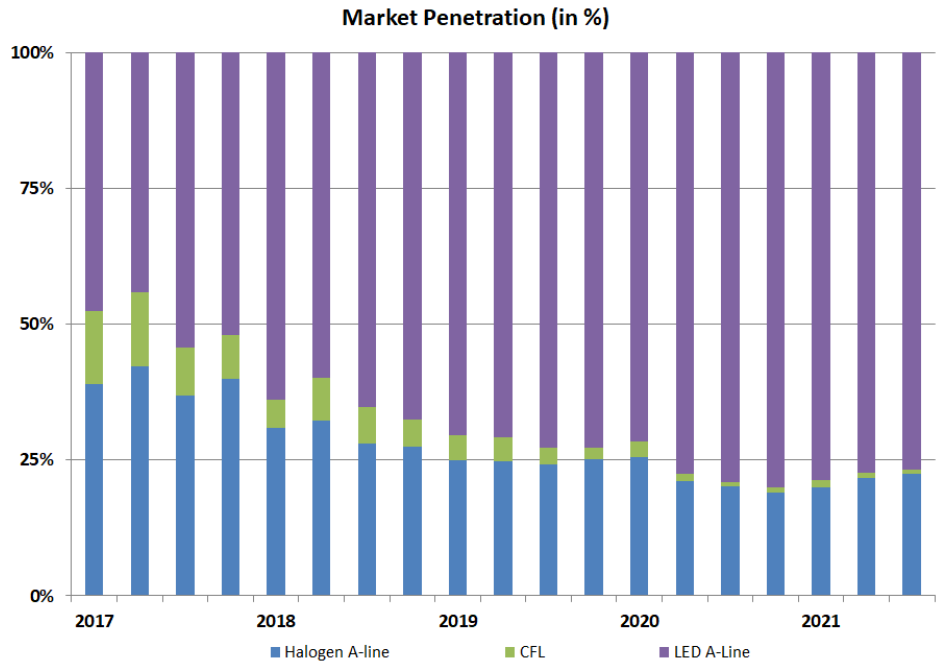


Figure 2. Market share of various screw-in bulb types, 2011–2017. Source: NEMA as published in ACEEE, ASE, and BCSE 2019.



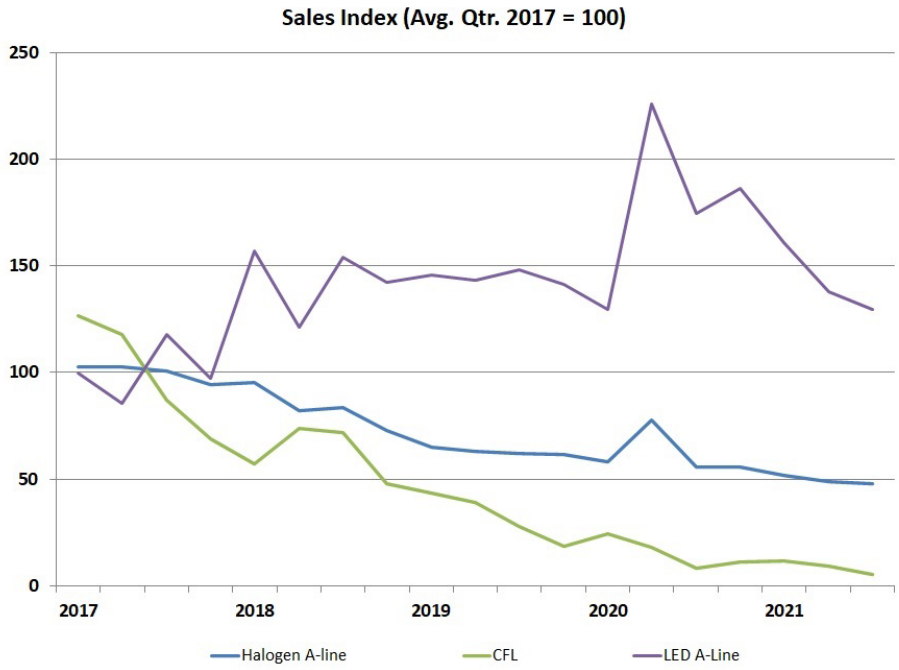


Figure 3. Market share of various screw-in bulb types, 2017–2021. Source: NEMA 2021.

LEED Building Ratings

In the late 1990s, the U.S. Green Building Council (USGBC) developed Leadership in Energy and Environmental Design (LEED) to advance green construction practices in the United States and throughout the world. Originally developed for new commercial buildings—and since expanded to include residential and renovations of existing buildings—LEED provides a framework for healthy, efficient, and cost-saving green buildings.

LEED includes two major pillars: certification of building professionals, and certification of green building projects. For building professionals, LEED now offers five certifications: Building Design + Construction; Operations + Maintenance; Interior Design + Construction; Neighborhood Development; and Homes (USGBC 2021a). LEED provides educational materials and administers certification exams. For buildings, certification is based on a point system, with specific points for energy efficiency, renewable energy, and other green building attributes. LEED has four building certifications: Basic, Silver, Gold, and Platinum, with higher levels requiring more points. The organization periodically revises its certification levels and is currently on version 4 of its core specification (USGBC 2021b). USGBC also hosts LEED training sessions and conferences and is involved in policy development and implementation.

LEED certification began in 2000 and while participation in both programs was initially slow, it has dramatically ramped up since 2008 (see figure 4). In recent years, certification of new building professionals has dropped off, as the market was somewhat saturated in the early years. Also, building certification declined in 2020 due to the COVID-19 pandemic. In 2019, approximately 0.35 billion square feet of floor area was LEED certified; this amounts to about

17.5% of annual commercial floor space additions, which the U.S. Energy Information Administration (EIA 2022) estimates to be about 2.0 billion square feet per year. Total U.S. LEED certifications through 2020 amount to approximately 5 billion square feet of floor area and 200,000 building professionals.

LEED building ratings is an example of a market transformation initiative targeting professional practices that affect energy efficiency. In this case, the target includes architects, engineers, building owners, investors, contractors, and suppliers. LEED is largely market driven, and functions with little to no involvement of government agencies and utilities. LEED has grown due to customer demand for certification, which provides a visible and readily understandable means to identify a given building as a green, sustainable building.

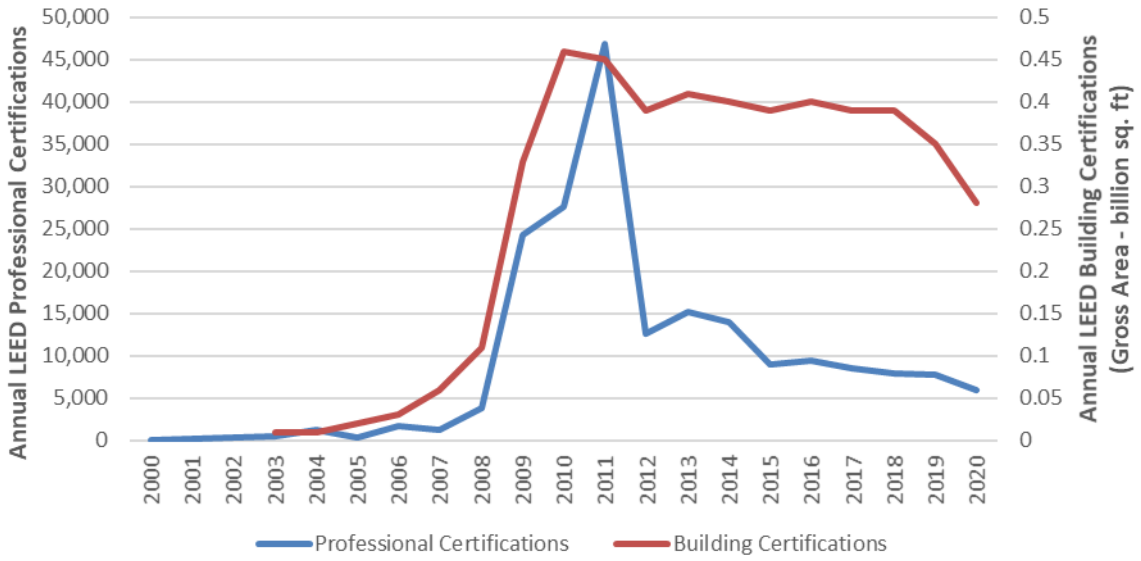


Figure 4. LEED certifications for U.S. buildings and building professionals by year. Source: Data provided by U.S. Green Building Council.

Building Operator Certification

Building operator training and certification was developed to improve building maintenance quality; to provide a building's workforce with skills to make the building more efficient, healthy, and environmentally friendly; and to provide a way to recognize skilled operators and elevate the market value of their maintenance skills. This is another example of using a market transformation model—rather than a product or technology—to change professional practices. This initiative arose from the observation that more-effective building operation can itself result in large energy savings without necessarily requiring any new investments in equipment or technologies.

The Building Operator Training and Certification Program (BOC) began in the Northwest in 1997 under contract with NEEA, building on previous work in Idaho and Washington State. BOC is administered nationally by the Northwest Energy Efficiency Council (NEEC) and Smart

Buildings Center (SBC) with a national network of licensed partners. The program includes two levels of training: Level I Building Systems Maintenance, and Level II Improving Building Operational Performance. Participants attend a series of classes spread over several months, completing tests after each class as well as projects at their facility. Successful attendance at classes, passing the tests, and completing projects results in a Training Certificate of Completion credential. Students are also eligible to sit for the BOC Certification exam to earn the additional BOC Certification credential after completing BOC Level I. The original program has since expanded; in addition to NEEC and the SBC's provision of training in Washington, California, Idaho, Montana, and several northeastern states, a network of licensed partners provides training in 37 U.S. states and Canada (M. Danuser, director of education and training, Smart Buildings Center and Northwest Energy Efficiency Council, pers. comm., May 18, 2021).

Since the program's inception, staff members from more than 20,000 facilities have earned a BOC credential. In the Northwest, where the program has been operating the longest, more than 18% of the target market had participated as of 2015. An evaluation of the Northwest program found that 74% of employers of BOC graduates reported that their credentialed staff maintained equipment more efficiently and lowered their energy bills (Research Into Action 2015). Energy savings among participants average 100,500 kWh of electricity per credentialed operator per year (BOC 2020). Employers of BOC graduates also overwhelmingly (98%) said that they will recommend BOC to their peers, and 92% said that they would look for BOC certification on resumes of job applicants. Finally, nearly 50% of BOC graduates have seen an increase in job responsibilities and compensation since earning their certification (York and Kushler 2003). Similar results were found in an evaluation of the program in the Northeast (Peters et al. 2002).

BOC training is well established in the market and well received by attendees and their employers. The program's market penetration continues throughout the regions where training is available.

The BOC concept was carefully thought out at the beginning to appeal to both students and their employers. Students receive high-quality training, credentials, and opportunities for career growth and higher compensation. Employers receive documented improvements in building operations and reductions in operating costs. The program found an important market niche and developed a successful strategy to fill it.

CURRENT MARKET TRANSFORMATION INITIATIVES

California Zero-Energy New Construction

In 2008, California state agencies adopted a Long-Term Energy Efficiency Strategic Plan that laid out four "big bold" initiatives. The first two initiatives relate to zero-energy new construction: (1) all new residential construction in California will be zero net energy (ZNE) by 2020; and (2) all new commercial construction in California will be ZNE by 2030 (CPUC 2008). Subsequent action plans were developed accordingly. For example, the new

residential action plan called for (a) creating awareness of the value and benefits of ZNE and building demand; (b) increasing participation in and improving the quality of ZNE education and training; (c) ensuring availability, effectiveness, and efficiency of technical tools; (d) quantifying ZNE's value, supporting robust financing, and ensuring affordability; (e) driving future grid infrastructure and technological improvements; and (f) aligning regulations, policies, incentives, and codes (CPUC and CEC 2015). State agencies and state utilities took various steps to pursue these actions, but with an emphasis on facilitating support for a series of improvements to the state energy efficiency building code, which is revised every three years. In 2016, energy efficiency requirements in the energy code were tightened, resulting in average energy use reductions for single-family homes of 28% (Energy Code Ace 2018). In 2019, the energy efficiency requirements in the code were further tightened to reduce energy use by approximately 7% and, for the first time, to require installation of photovoltaic systems, effectively bringing new residential construction to zero net electricity, with space heating still generally provided with natural gas furnaces (Energy Code Ace 2018).

Since then, the focus on zero-energy new construction has shifted both to commercial buildings, to help meet the 2030 target, and to electrification of space and water heating, since California is moving toward a 100% zero-emissions electric grid. Utilities are encouraging all-electric new construction with new programs, and the 2022 code includes a variety of energy efficiency improvements to the commercial code, requires many new commercial buildings to use photovoltaics, and requires mixed fuel buildings to be "electric ready"—meaning that connections for electric heating and appliances are installed during initial construction to enable future conversion to electric equipment (CEC 2021).

Overall Structure for Market Transformation in California

In late 2019, the California Public Utilities Commission (CPUC) approved a decision to support a statewide market transformation initiative that will fund emerging energy efficiency programs and technologies (CPUC 2019). The decision outlined a market transformation policy framework that establishes a phased procedure for considering new technologies and programs and is partly inspired by the Northwest Energy Efficiency Alliance (NEEA) experience with market transformation programs (Ettenson 2019). Appendix D in the decision provides a schematic describing the three phases (CPUC 2019). The first phase (concept development) involves two stages: concept scanning and identification, and concept development and assessment. Phase two (program development) includes strategy development and strategy testing, while the final phase (market deployment) has three stages: market development, long-term monitoring, and transition or sunset for the market transformation initiative. The new framework will give innovative technologies and programs a chance to flourish and increase market share due to less restrictive rules, such as those on cost effectiveness.

The decision also sets aside a budget of $250 million for market transformation initiatives over a five-year period and institutes an independent statewide administrator to be chosen through a competitive solicitation conducted by Pacific Gas and Electric (Walton 2019). In addition, an informal Market Transformation Advisory Board will be created to advise the statewide administrator on projects and activities. A market transformation administrator has been selected and, as of this writing, details are still being negotiated.

Heat Pump Water Heaters

Water heating systems are large energy users in residential homes. In 2021, water heating represented 12% of typical home electricity use and was a home's third-largest energy user (EIA 2022). While many homes with electric water heaters use electric resistance water heaters (ERWHs), heat pump water heaters (HPWHs) are generally two or three times more energy efficient than ERWHs (DOE 2021). HPWHs utilize a vapor compression refrigeration cycle to heat ambient air, which in turn heats water for in-home use. In warm climates, these systems provide added benefits of dehumidifying and cooling the space around them. For example, the dehumidification work can offset the need for a separate dehumidifier that consumes hundreds of kilowatt-hours per season. Despite these benefits, HPWHs captured only about 2% market share in 2020 (ENERGY STAR 2022).

Utility programs to encourage HPWH adoption through customer rebates have existed since 1999 but did not really take off until around 2011, after the major water heater manufacturers introduced products to the market (CEE 2016). In addition to limited product availability, there were performance issues associated with the early available products. DOE and EPA developed ENERGY STAR requirements for HPWHs, but most programs use product efficiency (based on the *modified energy factor* metric) to determine the level of incentive offered. Early equipment that did not meet customer expectations for reliability hurt the technology's reputation and hampered utility promotion and incentive efforts. The early HPWH programs were based on these initial unreliable products and were not successful (F. Gordon, director of planning and evaluation, Energy Trust of Oregon, pers. comm., October 30, 2017). Also, some states required separate plumbing and electrical installation permits, which raised costs.

NEEA is dedicated to increasing market share of HPWHs. In 2013, it launched the Smart Water Heat Initiative—now the Hot Water Solutions program—with a regional goal of increasing HPWH market share to 30% by 2030 (NEEA 2020). The group also aims to influence the 2025 federal standard to effectively require HPWHs for water heating needs above 45 gallons (NEEA 2021). NEEA identified major market barriers including high upfront cost; lack of distributor, contractor, and consumer awareness; and the absence of a product specification for manufacturers. To address these barriers, NEEA established the Advanced Water Heater Specification (AWHS) to guide manufacturers on technical and reliability measures. NEEA also collaborates with utilities and energy efficiency administrators to verify product performance and savings, offers rebates to incentivize customers and distributors, provides quality installation and installer training, and has developed promotional websites and marketing materials to support utilities. So far, more than 60,000 HPWHs have been sold in the Northwest. As table 2 shows, NEEA's latest *Market Progress Evaluation Report* shows that market share for HPWHs has slowly increased over time but is still relatively low in the Northwest (NEEA 2022). Most HPWH installations occurred in Washington and Oregon.

Table 2. Market share of northwest heat pump water heater installations by state

State	2017 (MPER 4)			2018 (MPER 5)			2019 (MPER 6)			2020 (MPER 6)		
	Electric WH Installs	HPWH Installs	HPWH Market Share	Electric WH Installs	HPWH Installs	HPWH Market Share	Electric WH Installs	HPWH Installs	HPWH Market Share	Electric WH Installs	HPWH Installs	HPWH Market Share
Total	*156,900*	*13,353*	*8.5%*	*151,600*	*11,693*	*7.7%*	*148,700*	*15,217*	*10.2%*	*150,200*	*17,442*	*11.6%*
WA	87,700	8,734	10.0%	84,100	8,117	9.7%	82,700	9,198	11.1%	83,400	10,543	12.6%
OR	40,200	4,179	10.4%	38,700	3,450	8.9%	37,500	5,831	15.5%	38,300	6,684	17.5%
MT	12,000	71	0.6%	12,000	77	0.6%	11,900	28	0.2%	11,700	32	0.3%
ID	17,000	369	0.2%	16,800	49	0.3%	16,600	160	1.0%	16,800	183	1.1%

Source: NEEA 2022

The Advanced Water Heating Initiative (AWHI), spearheaded by the New Buildings Institute, was established in 2019 to enable widescale market transformation for efficient and grid-connected HPWHs (AWHI 2021). AWHI has more than 50 partner organizations and 100 individuals to drive the initiative forward. The initiative seeks to increase the market share of efficient and grid-connected HPWHs to 45% on the West Coast by 2030. While the program was created in California and the Northwest region, AWHI is pursuing a program to increase market penetration of HPWHs nationally. In 2021, DOE provided funding to support a national AWHI program that will help the initiative achieve its regional goals as well (NBI 2021).

Northeast Cold-Climate Heat Pumps

In the northeastern United States, five states (Connecticut, Maine, Massachusetts, New York, Rhode Island, and Vermont) are actively promoting the use of heat pumps for space heating to replace oil, natural gas, propane, and electric resistance heating. Across the region, NEEP is leading a Heating Electrification Market Transformation initiative to accelerate market adoption of high-performance heat pumps optimized for use in cold climates. The initiative's goal is to have 10% of homes in the region using heat pumps by 2025, increasing to 40% of homes by 2030 (NEEP 2021).

To meet these objectives, each of the five states (and/or their utilities) are offering incentives for heat pump purchases (Nadel 2020). Several states have adopted strategies to scale-up use of heat pumps by consumers and businesses (e.g., NYSERDA 2021). NEEP has developed a cold-climate heat pump specification and a list[4] of equipment that meets the specification. Many heat pump incentive programs require NEEP listing. NEEP also publishes guides on

[4] See the Northeast Energy Efficiency Partnerships' cold-climate air source heat pump product list at https://ashp.neep.org/.

heat pump sizing/selection and installation, case studies, and research reports on pressing issues such as program guidance (NEEP 2021).

As figure 5 shows, these collective efforts have resulted in a substantial increase in heat pump sales in the region.

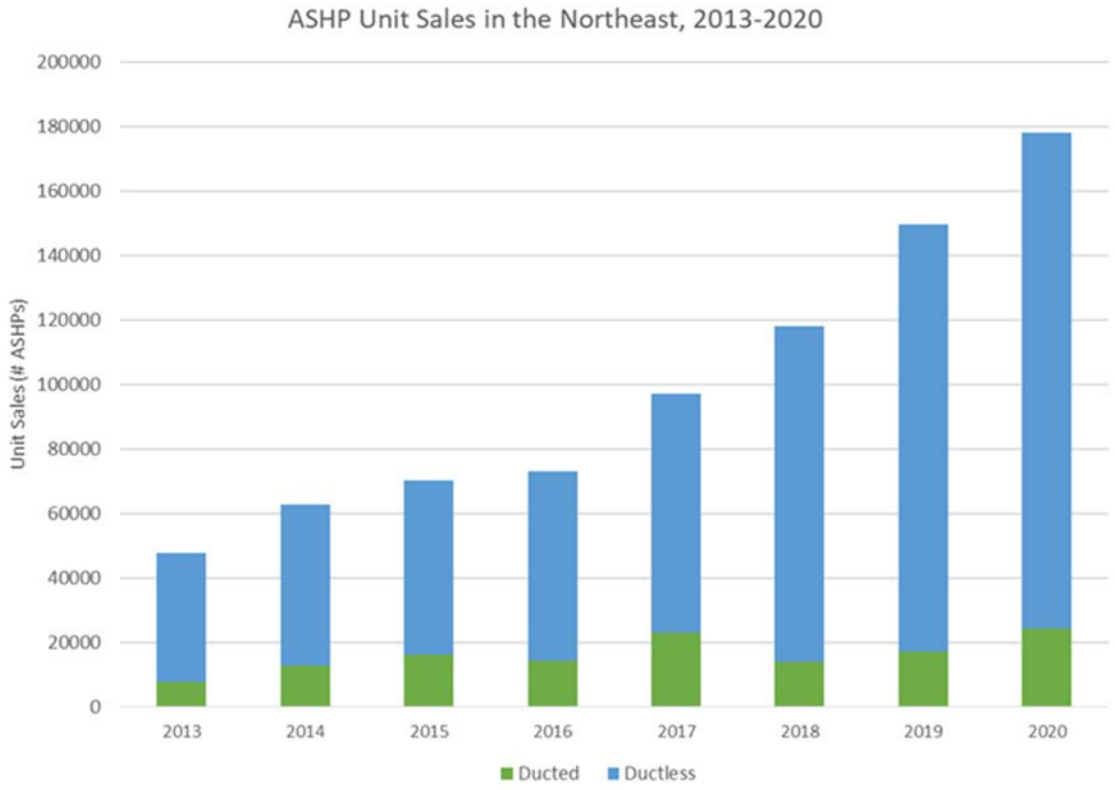


Figure 5. Air-source heat pump sales in the Northeast, 2013–2020. Source: Northeast Energy Efficiency Partnerships, using data compiled for the New York State Energy Research and Development Authority and provided by D&R International.

Strategic Energy Management

Strategic energy management (SEM) is a method of managing energy that uses continuous improvement practices and takes a systematic approach to energy performance measurement and tracking. SEM involves at least three of the following elements: commitment, energy management planning and implementation, and a system for measuring and reporting performance. The latter systems have been primarily used by large industrial and institutional energy users. Research indicates an opportunity to achieve 6–10% energy savings in the first year of program engagement. SEM initiatives can also yield many nonenergy benefits, including raw material and water savings, and waste and pollution reductions (Rogers, Whitlock, and Rohrer 2019). Furthermore, once SEM is institutionalized in a firm, the continuous improvement framework can be useful for encouraging identification and adoption of other energy- and cost-reduction measures, helping to increase savings.

Also, once firms commit to continuous improvement, the discussion becomes what to do rather than whether to do something.

A variety of SEM protocols have been developed including the ISO 50001 standard and the DOE's Superior Energy Performance and 50001 Ready programs. In the United States, many states and utilities have created programs to encourage and assist firms in adopting and implementing SEM in their facilities. Such programs often include training and technical assistance services, as well as financial incentives. SEM participants establish clear metrics to identify energy-saving opportunities and track reductions in energy use. Energy coaches help customers implement these changes. Many programs also provide incentives for operational improvements and capital investments, which are commonly based on the energy savings achieved. As of 2019, 27 SEM programs were identified in the United States and Canada, and they were typically operated by utilities and third-party program administrators (Rogers, Whitlock, and Rohrer 2019). The number of programs is slowly growing. One review found only 15 programs in 2015 (York et al. 2015). In 2021, four additional programs were identified (Whitlock 2021), for a current total of 31.

While progress is being made, only a fraction of large U.S. energy users employ SEM. And, while some data are collected, data collection and analysis can be improved (Therkelsen et al. 2021). A 2015 analysis estimated that widespread use of SEM could reach 7 terawatt-hours per year of electric savings for the commercial sector and 24 terawatt-hours for the industrial sector by 2030 (York et al. 2015). Rogers, Whitlock, and Rohrer (2019) estimate that current programs will achieve less than 10% of these savings.

Electric Vehicles in California (and Other Countries)

Electric vehicles (EVs) generally use less energy than gasoline and diesel vehicles; if they use electricity generated from zero- or low-emission power plants (e.g., natural gas), EVs also reduce emissions of pollutants such as nitrogen oxides, fine particles, and carbon dioxide (Nadel and Huether 2021). The State of California has been a U.S. leader in promoting EV adoption. In 2012, then-Governor Jerry Brown issued an executive order establishing a goal of 1 million EVs on the road by 2025. That goal was subsequently increased to 5 million—with 250,000 EV charging stations—by 2030. In 2015, the California legislature adopted SB 350, which, among other provisions, directed state agencies to take various actions to promote EVs. Subsequent state laws have added to these efforts. In 2020, Governor Gavin Newsom issued a new executive order directing that all new passenger vehicle sales be zero emission by 2035 (CPUC 2021).

As a result of these goals—and to complement federal policies such as tax incentives for charging infrastructure and electric passenger vehicles—the state has taken actions such as the following (CPUC 2021; California GO-Biz 2021):

- Incentive programs operated by the California Air Resources Board (CARB) for purchases of EVs (originally for passenger vehicles, but later expanded to many types of trucks)

- Direct state investments in charging infrastructure, along with directions to the state's electric utilities to aggressively invest in charging infrastructure
- Development of electric rates that encourage EVs
- Various efforts to educate and encourage consumers to purchase EVs and to train workers on selling and maintaining EVs
- CARB regulations to require manufacturers to sell increasing portions of zero-emission vehicles. Current regulations require 12% of passenger vehicle sales to be zero-emission vehicles in 2021, ramping up to 22% in 2025 (Transport Policy 2018). These rules are likely to be revised to the governor's goal of 100% by 2035. More recently, CARB has developed zero-emissions sales requirements for electric trucks.

As a result of these efforts, sales of EVs have climbed significantly, reaching 16% of new light vehicle sales in the first quarter of 2022 (see figure 6). California has the third highest EV market penetration in the world, behind only Norway and Sweden (JATO 2019).

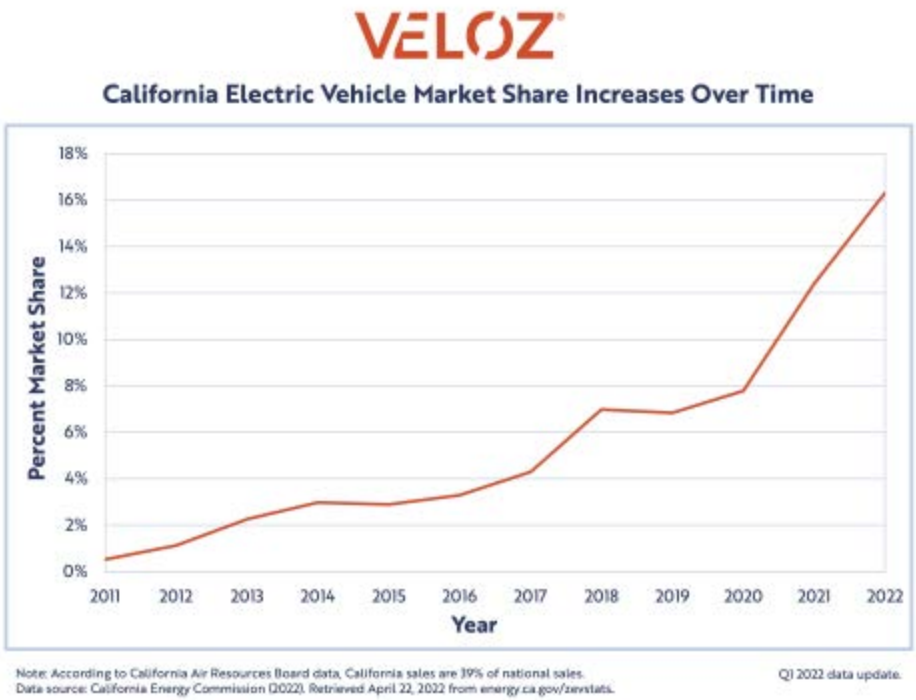


Figure 6. Electric vehicle market share in California. Source: Green Car Congress 2022.

While this example focuses on California, other excellent EV market transformation strategies exist, including Norway's strategy, which is driven by high tax incentives as well as other bonuses such as free parking (Camara, Holtsmark, and Misch 2021); and China's strategy, which is driven by a comprehensive plan involving manufacturing, consumer incentives, constraints on conventional vehicles, and a large build-out of charging infrastructure

(Wikipedia 2021). The EV market share was 75% in Norway and 6% in China in 2020. Iceland, Sweden, and the Netherlands also had a 2020 EV market share above 25% (Bhutada 2021).

International Experience

LED STREETLIGHTS IN TAIWAN

Taiwan is the second country in the world, after Singapore, to phase out mercury streetlights completely. Three driving forces contributed to this market transformation. The first is the gradual maturity of LED lighting technology and Taiwanese manufacturing capability to produce LED lighting products. The second is the Taiwanese government's promotions to develop green, low-carbon energy resources in alignment with international efforts for decarbonization. The third driving force is implementation of the Taiwanese government's plan to increase demand for LED lighting and expand industrial capacity through technology demonstrations.

In 2010, Taiwan had approximately 1.572 million streetlights; of those, about 815,000 were mercury streetlights (51.8%); 12,000 were LED street-lamps (0.8%); and 743,000 were other light sources, including high-pressure sodium lamps and fluorescent lamps (47.4%) (Republic of China MOEA 2011). By 2017, mercury streetlights were completely phased out. As of 2018, Taiwan had approximately 56.4% LED streetlights and 43.6% other light sources, primarily high-pressure sodium and fluorescent (Republic of China MOEA 2018).

In 2008, the Taiwan Inspection Centre (Metrology and Inspection, or MOEA) formulated the world's first LED streetlights standard. This laid the foundation for the domestic LED industry to flourish in outdoor lighting (Republic of China MOEA 2010).

After completing the standard formulation, the Taiwanese government strongly promoted the demonstration plan, encouraging the promotion of energy conservation while supporting the lighting industry's development of LED production technology. In April 2009, the Dawning Green Energy Industry Program was approved. Critical sectors (such as the LED and photovoltaic industries) were selected and assisted based on green technologies and energy-saving potential.

The LED lighting demonstration project—led by the Taiwanese government—can be roughly divided into three stages. In the first stage, the government initiated an LED road lighting demonstration project, which provided subsidies to several local governments to replace streetlights in 2008 and 2009. The results show that the energy savings can reach 60%; the annual electricity consumption of road lighting can save approximately 3.03 million kWh; and carbon dioxide emissions can be reduced by 1,430 metric tons (Republic of China MOEA 2016).

In the second stage, beginning in 2012, the government implemented LED streetlight demonstration projects to accelerate the replacement of low-efficiency streetlights. The total funding for this stage was NT$2.318 billion. These lamps then saved 220 million kWh of

electricity each year and reduced 110,000 metric tons of carbon dioxide emissions (Republic of China MOEA 2016).

The third stage was the Mercury-vapor Street Lamps Phase-out Project, which began in 2015. This project provided NT$5.49 billion to assist local governments in replacing NT$692,000 mercury streetlights with LED, which saved NT$988 million in electricity bills and NT$346 million in maintenance fees each year. In 2017, the government updated the road lighting regulations and banned mercury lamps for use as streetlights. Through the project's successful implementation, domestic road mercury lamps have been entirely replaced with LEDs.

Taiwan's market transformation experience with LED streetlighting provides important insights into how to structure other initiatives to transform markets for energy-efficient technologies or practices in Taiwan. Clearly, the Taiwanese government played the leading role in this initiative, with private industry and nongovernment research organizations also playing critical roles as collaborators. Research organizations, such as the Industrial Technology Research Institute (ITRI), conducted early lighting experiments that helped lead to commercialization of LED lighting. The Taiwanese government funded ITRI's research to accelerate the application of high-efficiency lighting. Taiwanese industries provided demonstrations of LED streetlighting and developed manufacturing capability to produce such technologies. The project's phased approach also provides a model for other efforts in Taiwan and is typical of market transformation initiatives in the United States and other nations.

CHINA GREEN LIGHTS

The China Green Lights Program began in 1996 with the goal of substantially increasing use of efficient lighting technologies and practices in China. As summarized by Guo and Pachauri (2017), the program has gone through four phases:

1. Raise public awareness about efficient lighting products (1996–1998)
2. Improve the quality of domestic lighting products (1999–2006)
3. Expedite the diffusion of energy-saving lamps using various diffusion schemes (2007–2010)
4. Shift program focus to emerging LED lighting technologies (after 2010)

The first phase emphasized publicity and education, promoting high-quality efficient lighting products (for more on this, see Nadel et al. 1999). The second phase involved new quality and performance standards for many types of lighting products, establishing a certification scheme for products that exceeded minimum standards, improving the ability of test centers to assess product quality and performance, and providing an annual nationwide sampling test of CFLs on the market. As figure 7 shows, through these efforts, the percentage of

products on the market that met performance standards increased from approximately 50% to 90%.

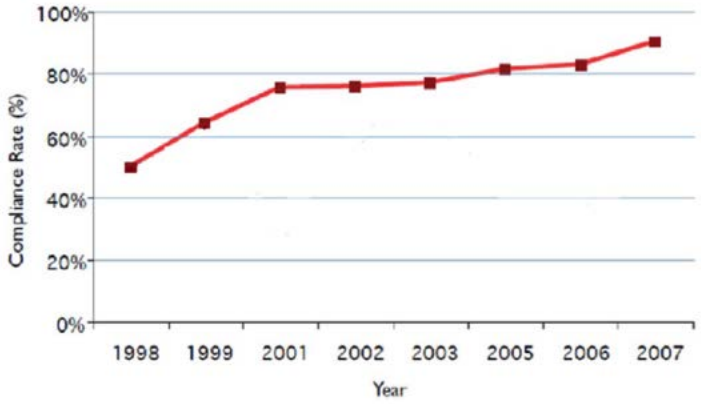


Figure 7. Compliance rate with compact fluorescent lamp (CFL) standards in China by year. Source: Guo and Pachauri 2017.

In the third phase, activities included the Ministry of Finance offering financial subsidies of 30% for bulk purchasers and 50% for consumers to reduce the price of covered efficient lighting products. Manufacturers submitted bids to participate in the program, and successful bidders were required to sell products for the bid price minus the subsidy. Many provinces and localities added their own subsidies. As a result of these efforts, the market penetration of efficient products increased from approximately 47% in 2006 to 72% in 2010. In 2011, China adopted new regulations to phase out the use of incandescent lamps over the 2012–2016 period (Guo and Pachauri 2017). Figure 8 summarizes the production of CFLs in China over time.

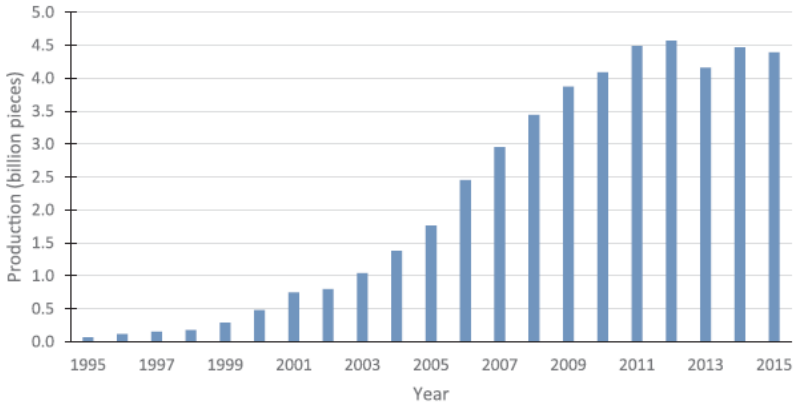


Figure 8. Production of CFLs in China by year. Source: Guo and Pachauri 2017.

In the fourth phase, subsidies and performance standards continued, but with a focus on LED lighting.

Overall, the China Green Lights program was very successful in advancing use of efficient lighting in China. Guo and Pachauri (2017) attribute this success to five factors: (1) strong and sustained government commitment; (2) prioritized focus by program stages; (3) extensive efforts aimed at product quality control; (4) a successful combination of energy efficiency policies and industrial development policies; and (5) distinct and varying incentives.

ENERGY EFFICIENCY SERVICE LIMITED (EESL) IN INDIA

Energy Efficiency Service Limited (EESL) is a government-run super energy service company (ESCO) in India that focuses on providing energy efficiency technologies and services to residential, industrial, and municipal consumers (EESL 2021a). The super ESCO was created in 2009 and implements solutions in a multitude of sectors and markets, including lighting, buildings, transportation, and agriculture. EESL's programs have resulted in overall annual energy savings of 47 billion kWh and have reduced carbon emissions by more than 36 million tons (EESL 2021a). The EESL business model relies on innovation, transformation, and transparency to incentivize market-scale adoption of energy-efficient solutions.

In 2015, the Unnat Jyoti by Affordable LED for All (UJALA) program was introduced to replace inefficient lighting by increasing the adoption of affordable LED bulbs through strategies such as bulk procurement (EESL 2019). The program requires no governmental subsidies and has been largely successful at growing the LED market in India. As of May 2021, more than 36 billion LEDs have been distributed nationwide (UJALA 2021a). EESL identified key barriers for each target group—consumers, utilities, industry, policymakers, and regulators—and designed strategies tailored to each barrier. For example, EESL engaged in bulk LED procurement, which led to a price reduction of more than 80% for consumers (EESL 2019). Energy-efficient ceiling fans are also distributed under the UJALA program, with more than 2 million fans in deployment across India so far (UJALA 2021b). However, EESL's Pavan fan program has received less praise than its LED program. When Pavan was first launched, EESL chose to procure five-star-rated 50W fans (with an AC motor) instead of a more efficient 32–35W brushless DC fans—a decision that prompted some criticism (S. Mathew, program lead, AEEE, pers. comm., May 21, 2021).

EESL's Street Lighting National Programme (SLNP), founded in 2015, is another successful program that aims to replace streetlights with efficient and Internet-connected LEDs. EESL fully invests in the streetlights, and municipalities then pay it back through the energy and operational cost savings from the replacement (EESL 2021b). Contracts between EESL and municipalities usually last seven years, with an EESL guarantee for energy savings and no-cost replacements or maintenance for cities. To date, more than 14 million LED streetlights have been installed, producing annual energy savings of more than 7 billion kWh and large utility bill savings for cities (Business Line 2021).

EESL also has a dedicated program to provide customers with efficient and affordable cooling options. The Super-Efficient AC Program (ESEAP) was launched as a pilot in 2016 with the goal of distributing 50,000 super-efficient air conditioners during the program's first

phase. Utilizing a similar bulk procurement strategy as UJALA and SLNP, EESL procured 100,000 super-efficient air conditioners that use less-harmful refrigerants at a very discounted price from Panasonic and Godrej (Singh and Gurumurthy 2019). EESL also underwent a second round of procurement, ultimately going with Indian-based air conditioner manufacturer Voltas (Madan 2019). Consumers of four major distribution utilities in India can purchase the air conditioners through EESL's online marketplace, eeslmart.in, which offers information about the product's benefits as well as customer support. EESL has sold approximately 1,300 super-efficient air conditioners, signifying that there is a long way to go to achieve widespread deployment (EESL 2021c).

Bulk procurement has often been a successful model, but it has not yet worked for air-conditioning and some other markets. While the ESEAP successfully carried out procurement, there are challenges with getting air conditioners to consumers due to equipment size, high upfront costs, maintenance-related costs, and complexities with air conditioner installation (Singh and Gurumurthy 2019). Also, demand aggregation strategies are dependent on a robust stakeholder process, and ESEAP had issues with getting feedback from manufacturers, policymakers, and utilities, which contributed to a lack of demand in target markets (Singh and Gurumurthy 2019).

RESIDENTIAL RETROFITS IN FRANCE

France adopted the Energy Transition Toward Green Growth Act in 2015 (MEEM 2016). This act was essentially the means to implement the country's commitments under the Paris climate agreement signed earlier that year. The act included provisions dealing with buildings, transportation, and renewable and nuclear energy, as well as with establishing a circular economy. For buildings, the act called for annual improvements (starting in 2017) in the performance of new buildings and for renovating 500,000 homes per year—at least half of which were occupied by low-income households. The act set a goal of a 15% reduction in fuel poverty by 2020. To achieve this objective, it included a variety of programs:

- An Energy Transition Tax Credit provides a refund of 30% of the total cost of energy renovation work, up to a limit of €8,000 for a single person and €16,000 per couple.
- An interest-free Eco-Loan up to €30,000 is available to property owners carrying out energy renovation work. It can be combined with the tax credit above.
- The Habitier Mieux (Better Housing) Program, managed by France's National Housing Agency (ANAH), increased targets for renovating homes. In 2016, the target was 70,000 homes—a 40% increase relative to the prior year.
- Regional Energy Renovation Platforms provide technical and financial support to homeowners carrying out energy renovations, with a total of 450 regional "information service units" that cover the whole of France.
- An Energy Renovation Guarantee Fund provides loans to low-income households, with a government repayment guarantee.

- Digital maintenance and repair records are being established to compile and store information on individual homes so that present and future owners have ready access to information that will aid in planning home renovations (MEEM 2016).

- By 2025, all private residential buildings whose primary energy consumption exceeds 330 kWh/m^2/year must have undergone an energy renovation. In France, as in most European countries, buildings are rated and labeled on an A–G scale. The law's building performance standard means that F- and G-rated residential buildings (about 15% of the housing stock) must upgrade to at least the E level. This includes both rental and owner-occupied residences. The plan is to steadily tighten these requirements to ultimately bring the entire housing stock to low energy levels ("bâtiment basse consommation," or BBC) or equivalent by 2050; this is equivalent to 80 kWh/m^2/year in primary energy for regulated loads (heating, cooling, lighting, ventilation, and hot water). This long-term goal, which corresponds to a B rating, is also part of the 2015 law (Nadel and Hinge 2020 provide further information on this program).

In addition to these measures, France also has energy-saving requirements for energy providers (fuel, electricity, gas, heating oil, etc.) to support energy-saving initiatives. This program—the energy-saving certificate scheme (certificats d'économies d'énergie)—targets all households and businesses, with a specific minimum share for low-income households.

As a result of these steps, France is approximately meeting its goal of 500,000 renovations per year. But many of these renovations are "light" (just one or two measures) and not the more-comprehensive renovations needed to meet Paris Climate Treaty goals (Sebi et al. 2018). To help increase savings, France will be implementing its building performance standards; a 2019 law fleshes out these requirements (Nadel and Hinge 2020). France also plans to develop an Energy Efficiency Passport to help homeowners and contractors navigate the process to bring each home up to the BBC level (Fabbri, De Groote, and Rapf 2016).

GREEN STEEL IN AUSTRALIA (AND OTHER COUNTRIES)

According to the Grattan Institute (Wood, Dundas, and Ha 2020), ore-based steel production (i.e., primary steel) accounts for 7% of global carbon emissions, which is more than any other industry. Producing iron and steel from iron ore requires "reducing" the iron ore by removing oxygen from it; this produces pig iron, which in turn can be made into steel with the addition of other alloys and additional processing. Typically, this reduction process involves the use of coke, a coal derivative. High carbon emissions are produced by both the reduction process and the production of coke. An alternative here is direct reduction iron, where iron is reduced without melting by using methane and/or hydrogen as the reducing agent. The hydrogen can come from various sources, including reformed natural gas or the electrolysis of water. Direct reduction of iron from ore can reduce or largely eliminate carbon emissions from the steel-making process (assuming the electricity used in the process is zero carbon) (Hoffmann, Van Hoey, and Zeumer 2020). Another low-carbon route to producing

iron is to apply electrolysis to an aqueous iron-ore slurry (Siderwin 2021), with the same caveat on sourcing zero carbon electricity.

Australia produces about 38% of the world's iron ore. Given the tremendous amount of solar energy available to produce carbon-free hydrogen, it could produce so-called "green steel" at lower costs than many other steel-producing countries. The Australia-based Grattan Institute therefore recommends that Australia seek to become a leader in green steel. It also recommends that the Australian government contribute to such an effort, building local skills and capability, and that it support a direct-reduction flagship project and help fund studies on opportunities for low-cost hydrogen storage and workforce retraining (Wood, Dundas, and Ha 2020).

One Australian company, Fortescue, patented a new steel-making process and built a pilot green steel plant in 2021. Fortescue plans to build a commercial-scale plant within "the next few years" and to decarbonize by 2030 (Evans 2021; Cave 2021). Other countries are also working to bring green steel to market. Germany's largest steelmaker, Thyssenkrupp, plans to build a plant in Germany by 2025 (Evans 2021). In the United States, Cleveland-Cliffs recently completed a production-scale direct-reduction plant fueled with natural gas that is capable of transitioning to hydrogen once it becomes available (Cleveland-Cliffs 2021). Steelmakers in Japan, China, India, and South Korea are also developing green steel plants (Choo 2021).

Lessons from the United States and International Experience

The examples we profile above illustrate the diversity of market transformation in advancing market share for a wide variety of products, technologies, and services. Despite their diversity, successful market transformation initiatives have several common features. When considering the application of market transformation in Taiwan, it is important to identify and understand these common features to assess the likelihood of success for similar initiatives in Taiwanese markets. We now identify and discuss these features.

National/Regional Scope and Coordination

Regional and/or national organizations often lead or are involved in successful market transformations. In the United States, regional energy efficiency organizations have been pioneers in market transformation and continue to lead many of these efforts.[5]

[5] In the Pacific Northwest, NEEA continues to be a leader and innovator. In the Northeast, NEEP was founded to advance energy efficiency through regional collaboration and coordination of utilities and key stakeholders. Following on these efforts, other regional organizations have emerged, including the Midwest Energy Efficiency

Although California is not part of any regional energy efficiency organization, it has been successful in affecting both state and national markets due to its size and influence. In 2015, California legislation established high energy goals: a cumulative doubling of statewide energy efficiency savings. To achieve these goals, analysis by the California Energy Commission found that market transformation must be part of the portfolio of programs and related initiatives (Jones et al. 2017).

National organizations are also vital to market transformation. CEE plays a critical role in facilitating the development of industrywide voluntary performance standards for various technologies and products. The Institute for Market Transformation focuses much of its efforts on transforming commercial and residential real estate markets. Other examples include ACEEE, which convened an annual market transformation symposium (in partnership with CEE) from 1997 to 2017; the Appliance Standards Awareness Project, which facilitates adoption and advancement of appliance standards; the Building Codes Assistance Project, which promotes and supports the adoption and advancement of building energy efficiency codes across the United States; and the USGBC, which developed and administers the LEED building rating program.

Another national program that merits special mention for its role in market transformation is ENERGY STAR, which is run by the EPA and DOE, and has led efforts for a wide array of products to be labeled as energy efficient. Consumers widely recognize ENERGY STAR as the label for energy efficiency, distinguishing products in given markets as the most efficient. One expert interviewed commented on this as follows:

> One of the biggest examples of successful market transformation on a large scale is the ENERGY STAR Program. When it began it was not well known, but it was meant to change how people think about energy efficiency. They have really succeeded in doing that, and there are very high recognition levels, and it is providing real guidance. It has changed how people think about energy efficiency and buying products.

Collaborative Effort with Common Vision

The scope and scale of market transformation require organizational approaches that extend beyond most single-utility boundaries and engage multiple stakeholder groups. Collaboration is required among key market actors, including manufacturers, distributors, retailers, trade groups, professional organizations, utilities, environmental advocates, and consumer groups. As discussed above, a single regional or national organization typically

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Alliance, the Southwest Energy Efficiency Project, the Southeast Energy Efficiency Alliance, and the South-Central Partnership for Energy Efficiency as a Resource. While each of these regional energy efficiency organizations differs in its structure, mission, and operations, all work to support market transformation to some degree.

leads and coordinates market transformation among such groups. A regional or national scope is also important to attract the interest of key market actors, stakeholders, and program administrators. The target for any initiative must be realistic, but it also must be aggressive and large enough to achieve a significant market impact.

Effective collaboration for market transformation requires a common vision for successful outcomes. Each stakeholder group must see clear benefits regarding its own collaboration objectives for a given market transformation initiative. Effective collaboration also requires gaining the input, active participation, and support of all major actors. Some experts we interviewed suggested that some type of third-party or government-sponsored organization is best situated to drive market transformation and facilitate the collaboration required.

Early engagement with key partners—such as trade allies, manufacturers, and major retailers—is also important. For example, big-box retailers typically have one or two people responsible for making product decisions. Reaching these people and persuading them to change products will have a large impact on the market because manufacturers will build what the big retailers request. One objective for market transformation is to identify these key leverage points and engage the relevant market actors. Training service providers and equipment salespeople and installers can also be an important part of a market transformation initiative.

Market Understanding

As the key literature and the experts we interviewed emphasized, effective market transformation requires developing an accurate logic model of key relationships, decision points, value propositions, leverage points, and market actors. Program developers need to know how a targeted market works, the key barriers to higher adoption of energy-efficient options, and how such barriers can be overcome. Market transformation requires a logical plan for addressing and measuring changes in targeted markets based on a specific theory of market barriers, actions that can overcome them, and indicators to track progress from a baseline. Successful market transformation requires addressing all or most of these identified problems—not just one or some of them.

Market quantification is a key part of market understanding. Measuring changes and progress in targeted markets requires establishing a market baseline. It is critical to identify relevant metrics that can be used as market indicators to measure and track program impacts from this baseline.

Success in the market often happens when purchasers can easily differentiate efficient products and services from conventional products and services. Generally, differentiation will depend not just on efficiency, but also on related parameters. Ultimately, an initiative can succeed only if the product or service is valuable, works well, and provides clear energy and nonenergy benefits.

Long-Term Commitment

Market transformation takes a fairly long time; typically, such programs operate over a period of 5–10 years from inception to realization of significant results. The many steps required in market transformation require time for market research and to establish a baseline, develop a logic model, create a key stakeholder collaborative, work with market actors, intervene in the market, and evaluate impacts. Groups that administer and facilitate market transformation need to commit resources for a few years before expecting to see results. Prematurely withdrawing market interventions will likely lead to an initiative's failure. In some cases (e.g., lighting, furnaces, and televisions), measures provide cost-effective annual savings within a couple of years to help sustain the initiative. But often it takes longer to realize significant annual savings.

Achieving a long-term commitment is a major challenge for market transformation. As we found in our current and past research (Nadel et al. 2003), however, such a commitment is key to successful outcomes. There is a clear correlation between the level of effort and the progress toward market transformation. In some cases, the key groups leading and coordinating a market transformation effort have made these long-term commitments. This is the case in the Northwest, where NEEA and its funders have repeatedly committed the resources and time necessary to transform selected markets. The situation has been similar in New York, where policymakers have supported the New York State Energy Research and Development Authority's market transformation efforts with long-term funding commitments. When regulators are the key decision makers affecting utility program spending, they may need to establish funding mechanisms to support and sustain long-term market transformation initiatives. California has also used this approach for funding its efforts.

A Structured Process and Multipronged Effort

The complexity of market transformation demands a well-structured process, as it involves numerous steps and many market actors. Successful interventions require coordination of a market transformation program's many elements, from initial market research and identification of opportunities to eventual exiting or transitioning from an initiative. Program administration and decision making must be transparent and structured for effective collaboration. Evaluation and measurement are also integral elements of a well-structured process for market transformation, from establishing initial market baselines to conducting ex-post impact assessment.

Market transformation's complexity also generally demands a multipronged effort. Most successful market transformation initiatives have involved multiple organizations and several different market interventions (e.g., training, incentives, and promotion) that evolve over time. While programs may be multipronged and complicated from the perspective of program administrators and implementers, they should appear relatively simple to program participants. From the participants' perspective, the benefits should be clear, their participation should be simple, and the program's complexities should be invisible.

Effective Marketing Strategies

At its core, market transformation is about increasing customer demand for cost-effective, energy-efficient products and services. As with any product or service, effective marketing is vital to promoting and increasing customer demand for targeted products or services. Market transformation programs employ a full array of marketing approaches, including utility bill inserts, in-store displays, demonstrations, social media campaigns, mass marketing, customer incentives, labeling, and midstream or upstream incentives (those paid to retailers, distributors, or manufacturers). Incentives can be an important part of an initiative, particularly in the initial stages. Incentives attract attention and help address the initial costs of many efficient products and services—costs that are often high when a technology or practice is first introduced to the market.

Effective marketing for the energy-efficient products and services that transformation initiatives target typically involves touting multiple benefits, not just energy savings. For example, the rapid growth and acceptance of horizontal-axis clothes washers occurred because consumers also responded positively to the nonenergy attributes of these products. That is, the washers clean more effectively, are gentler on clothes, and use significantly less water than conventional top-loading (vertical-axis) machines.

One successful marketing strategy is product labeling. Labels can expand a market transformation initiative's reach by tying products to a recognizable symbol, such as ENERGY STAR, or an easy-to-grasp concept. Market transformation programs may leverage either national or regional program platforms that include labeling, branding and marketing materials, and usage guidelines. National platforms are effective for many nationwide mass markets. Regional platforms may be more effective for products and services that are tied to local conditions and markets. For example, ductless heat pumps are better suited to some climates than to others. National and regional platforms can also provide turnkey marketing elements that more localized programs can incorporate into their program designs. For example, many utilities participating in regional market transformation initiatives have relied on regional marketing platforms to promote products and services to their customers.

Although professional certifications may not be seen as marketing, they have been key elements of market transformation programs targeting professional practices, such as quality installation of residential HVAC[6] and BOC. Such certification gives individuals a professional credential to distinguish themselves and becomes a market differentiator for

[6] *Quality installation* is a holistic, performance-based approach to installing residential HVAC equipment and systems with the objective of ensuring optimal, high-efficiency operation. This includes proper sizing of key equipment, adding appropriate insulation and tight sealing the ductwork to avoid energy losses and air leakage, and ensuring that control systems are set and operate effectively.

excellent service. At the same time, certifications give employers information on credentials and training when hiring new employees.

Flexibility and Adaptability

Our case studies illustrate how market transformation programs change over time. Some changes are inherent in and integral to program design. For example, early strategies in market transformation may focus on limited demonstrations and pilots to build both credibility and recognition of a product or service's benefits. Such focused efforts are especially needed to prove performance and quality. Late stages of market transformation are focused on sustaining desired market impacts through transition or exit strategies, such as establishing codes or standards.

Other changes that occur in market transformation programs may be unexpected. Markets are dynamic and can take unanticipated twists and turns. Successful programs have had to respond to such developments effectively. For example, the strong, positive consumer response to Maytag's introduction of the first horizontal-axis clothes washer designed for the U.S. market was surprising. The Neptune was a premium product—with a corresponding price premium compared to most conventional, vertical-axis clothes washers. Despite this, there was high demand for the product—and even waiting lists for customers. Manufacturers and organizations involved in market transformation had to adapt their plans accordingly and change their marketing, product development, and incentives.

Programs also have had to respond to weak consumer responses to product introductions, such as the introduction of HPWHs. In that case, program administrators had to rethink education efforts for consumers, contractors, and equipment suppliers. The introduction of LED residential lamps into mass markets drew heavily from the lessons of CFLs, which suffered from early performance and quality problems. As a result, LED manufacturers, retailers, and program administrators have been very careful about focusing on performance and quality, not just price.

Exit and Transition Strategies

The concept of an exit strategy for market transformation programs has evolved over the years as organizations have gained experience. Exit and transition strategies typically used in market transformation include the following:

- Developing codes and standards, such as standards for clothes washers, motors, and windows
- Increasing the qualification levels for a product labeling, such as ENERGY STAR, once the prior target has become common practice; for instance, efficiency levels for clothes washers have increased multiple times
- Transferring project leadership from a program administrator to a trade ally or other actor
- Phasing out incentives and then other program support, such as marketing materials and education/training incentives for market actors

Some early proponents of market transformation viewed the mark of a successful program as a relatively sharp exit from interventions in the targeted market. But decades of market transformation experience have shown that most programs require a transition to a next phase or a softer ending. Generally, programs still aim to reach a point where interventions can be substantially reduced or withdrawn. However, there may be some need for continued engagement, such as more-limited market support and periodic monitoring of market developments to track progress and watch for any backsliding of desired market impacts. It is now more common to talk about transition strategies than about exit strategies.

Codes and Standards

Codes and standards often are important market transformation components and may also be viewed as the end point or exit strategy for many initiatives. Locking in the target efficiency level as the minimum requirement through codes and standards signals a full transformation of the market. The establishment of standards for LED traffic signals is a straightforward example of this.

Establishing codes and standards will not be the end point for all market transformation initiatives, however. Some technologies and practices do not lend themselves to code or standard requirements. Furthermore, as we discussed above, market transformation is sometimes more of a continuum or a series of efficiency stair-steps than a process with a clear ending point. In some markets, technological progress or other developments may create room for advancements after adoption of initial program targets in codes and standards. In such cases, requirements established by codes or standards may need to be adjusted periodically to reflect higher performance levels or other significant market advances. This is, in fact, the process for most building codes and equipment standards.

One expert we interviewed invoked a colloquial expression often heard in the industry about the use of codes and standards: "If you make the less-efficient option illegal, immoral, or unprofitable, then you know you have made structural changes." Codes and standards set the floor for product and technology performance. Market transformation is not just about raising that floor, but also about moving markets forward more quickly to the next generation of efficient technologies.

CHALLENGES AND OPPORTUNITIES

Role of Regulators and Policymakers

Regulators and other policymakers can strongly influence market transformation. This influence is positive when they back market transformation and provide support and flexibility for utilities and related organizations engaged in or administering programs. It is negative when they do not provide such support or they make decisions that may impede market transformation initiatives.

The traditional role of utility regulators is to control costs and ensure system reliability, not to transform markets for energy-efficient products and services. Commissions may not

approve utility expenditures on market transformation programs due to the long duration and associated commitment needed. As a result, utilities and regulating bodies lag behind market transformation efforts in many U.S. states. This lack of regulatory support can inhibit progress in transforming markets. The challenge, then, is to get regulators to see the value of the broader efficiency gains that market transformation can yield—gains that result in lower customer utility bills along with other benefits.

Cost-Effectiveness Testing

A specific regulatory challenge for market transformation programs is that they are generally required to pass the same cost-effectiveness screening as programs focused on low-cost energy savings by individual customers that offer results quickly and provide relatively short paybacks. The longer duration and lagging impacts that typify transformation of an entire market make it more difficult to assess cost effectiveness based on year-by-year savings. Market transformation benefits may be diffuse and unrealized for several years, while the upfront program costs can be substantial. Consequently, market transformation programs may have difficulty passing the cost-effectiveness tests commonly used for other types of utility energy efficiency programs.

Past success with market transformation can also create a challenge for the cost effectiveness of new initiatives. The ramping up of codes and standards over time raises a product or technology's baseline performance. This is clearly a positive outcome for advancing energy efficiency, but it also means that the efficiency gains that remain to be captured are generally smaller than what was possible earlier from less-efficient baselines. This can make it difficult for new market transformation initiatives to be cost effective.

Markets Resistant to Transformation

Some markets are difficult or resistant to transformation toward energy efficiency due to the product or technology's inherent characteristics. For example, the product may be expensive (as with HPWHs thus far) or purchasing them may entail split incentives (as with products for multifamily buildings). In other cases, the market may be too small or have too few players.

The retrofit market for both residential and commercial buildings has been particularly challenging. That market's basic limitation is that homeowners and commercial building owners rarely undertake a large retrofit project primarily to improve energy efficiency. Rather, most building retrofits and renovations are done for aesthetic reasons (remodeling) or to change how a building functions (e.g., converting retail space to office space). Whole home and whole building retrofit programs have struggled to find scalable designs and approaches, especially in the residential market. In both building markets, the costs are generally large relative to annual energy savings, meaning that it may take many years to realize a positive return on the investment. Although progress has occurred and much has been learned, the overall reach of these programs has fallen far short of both the potential and the need.

Efforts to transform residential real estate markets via home energy ratings have also met with little success. Home buyers base their purchasing decisions on many attributes. Their choices reflect their values and preferences in what typically is the largest investment decision they will ever make. Home buyers place much higher value on other elements of a housing purchase than its energy performance. Indeed, home energy ratings themselves have sometimes been barriers due to implementation problems, and realtors generally do not support them. However, energy ratings may be more effective with new home sales than with existing homes.

Conclusions and Recommendations

Market transformation has established a strong legacy, and it continues to offer an effective program model to achieve further advances in markets for energy-efficient products, services, and behaviors. Our review of existing experience reveals numerous examples of successful market transformations.

Market transformation can be effective for a wide range of products, services, and professional practices. Residential lighting—first CFLs, and now LEDs—and clothes washers are good examples of the transformations that have occurred in U.S. markets due to strategic interventions by numerous stakeholders over long periods. Such products initially faced many market barriers and eventually overcame them through various interventions. Absent such interventions, it is doubtful that these markets would be where there are today, with dominant shares of energy-efficient products.

Market changes require new ways of thinking about energy efficiency. Market transformation offers a bold approach to energy efficiency programs. Convincing individual customers to take advantage of a rebate for an energy-efficient product is a much smaller challenge than getting manufacturers to change product lines, distributors to change stocking patterns, and retailers to promote and increase sales of target energy-efficient products. Market transformation seeks to address these product challenges, as well as to change professional practices and human behavior.

Fulfilling the potential for a more energy-efficient economy will require daring initiatives. As market transformation experiences demonstrate, strategic market interventions targeting improvements in energy efficiency can successfully change markets to meet ambitious energy savings goals. Customers in the United States and other countries are reaping the benefits of such efforts and can point to many energy-efficient products and technologies that are readily availability today because of past market transformation programs. The potential and need for continued transformation of markets for energy efficiency products and services remains high. Market transformation offers a proven program model for reaping this potential and responding to the continued need to improve energy efficiency wherever energy is used.

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