Transforming Energy Efficiency Markets: Lessons Learned and Next Steps

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Executive Summary

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 be best achieved in some cases by fundamental changes in selected markets for energy-efficient technologies and related practices. Transforming markets is ambitious. It is a large, complex undertaking whose goal is 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.

Market transformation is about strategic interventions to overcome market barriers that exist for products, technologies, and practices that yield higher energy efficiency. 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. We can draw on more than 25 years of experience with such programs to characterize the markets best suited to this model as well as identify the steps and interventions typically taken in market transformation programs.

Our research shows clear examples of successful transformations of markets for energy efficiency products, technologies, services, and behaviors. Diverse markets have been targeted for transformation. These include:

- Mass markets for inexpensive, common household goods (e.g., light bulbs)
- Mass markets for major appliances (e.g., clothes washers)
- Markets for major residential mechanical equipment (e.g., quality HVAC installation, ductless heat pumps, and heat pump water heaters)
- Markets for major residential building components (e.g., ENERGY STAR® windows)
- Commercial building markets (e.g., new construction and leasing)
- Building design and construction practices (e.g., high-performance schools)
- Commercial building operations (e.g., Building Operator Certification training)
- Industrial equipment (e.g., premium efficiency motors)

Such diversity demonstrates the flexibility of market transformation as a strategic program model. This list indicates that market transformation is not just about targeting mass consumer markets, but also about targeting professional practices, industrial products, building components, human behavior, and commercial building markets.

The experience gained from a variety of market transformation programs reveals many lessons that are important in looking ahead to new potential programs and target markets. The keys to successful market transformation include the following.

National/regional scope and coordination. Regional and/or national organizations have been vital in leading and coordinating market transformation. These include regional energy efficiency organizations such as the Northwest Energy Efficiency Alliance (NEEA), Northeast Energy Efficiency Partnerships (NEEP), and Midwest Energy Efficiency Alliance

(MEEA), as well as national organizations such as the Consortium for Energy Efficiency (CEE), the US Department of Energy (DOE), and the Environmental Protection Agency (EPA). Target markets for transformation are regional and national; programs need to be at this scale to be effective.

Collaborative effort with common vision. Collaboration among key stakeholders and key market actors—manufacturers, suppliers, retailers, tradespeople, design professionals, and utilities—is fundamental to addressing the many barriers faced in transforming markets.

Market understanding. To transform a market requires in-depth understanding of how that market functions: who is involved, what their motivations are, what the key relationships are, what creates customer demand, and what the baseline is. 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 them from the baseline.

Long-term commitment. The many changes required to facilitate and coordinate market transformation occur over a relatively long period, typically 5–10 years.

A structured process and multipronged effort. The complexity of transforming markets demands a well-structured process and multiple, coordinated program initiatives that may include performance specifications, marketing campaigns, midstream or upstream incentives, labeling, and training.

Effective marketing strategies that address the multiple benefits of a measure. Ultimately the success or failure of market transformation depends on customers responding positively to a targeted product or service. To be attractive to customers requires that the product or service offer clear benefits and value. Energy savings alone generally do not provide sufficient motivation to transform markets.

Flexibility and adaptability. Markets are dynamic. Changes may be unpredictable. Market transformation programs need to be responsive to such changes, and this requires flexibility and adaptability of program approaches and delivery.

Exit and transition strategies. Market transformation programs are fundamentally limited-term efforts. They reach a point at which program efforts are substantially reduced or possibly eliminated. In some cases, the end state may be the establishment of codes and standards that lock in performance and efficiency gains. In others, it may be more limited program support to sustain the gains made by the larger market transformation initiative.

We have identified several markets that are promising or may already be in the early stages of market transformation. These include:

- Strategic energy management
- Smart thermostats
- Advanced variable-speed commercial and residential air conditioners
- Zero net energy buildings
- Amorphous core distribution transformers
- Electric vehicles

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 markets where transformations have occurred due to strategic interventions by numerous stakeholders over long periods. In the United States, such products faced numerous barriers that eventually were overcome through a variety of interventions. Absent such interventions, it is doubtful that these markets would be where they are today, with energy-efficient products enjoying dominant market shares.

As we look to future applications of market transformation, two broad categories hold the greatest potential. First, there are markets undergoing transformations that are not yet to large scale. Promising market transformation is occurring in quality installation of HVAC, high-performance schools, and ductless heat pumps, among others. Program administrators should continue to be engaged in these markets and support market transformation initiatives to build on initial successes and grow to large scale.

Second, market transformation approaches are promising for reaching underserved populations. Emerging research on participant demographics is demonstrating low participation rates among certain groups of eligible consumers. Innovative approaches to market transformation are needed to reach and serve customer segments that traditional approaches have not served because of the larger barriers they face for implementing energy efficiency measures. If markets can be transformed, even hard-to-reach customers will find mainly efficient products and services when they shop.

We see several top priorities for policies and actions to support existing and future market transformation initiatives. Facilitating regulatory reforms is especially important. Some of the biggest barriers to more widespread market transformation stem from utility regulation, such as restrictive cost-effectiveness screening focused on single-year results and short funding periods (three years or less). Part of addressing regulatory barriers is the need to increase education and outreach to key stakeholders and decision makers, such as regulators, on the benefits and results possible from market transformation.

There also is a growing opportunity to establish linkages between market transformation and transformation of the electricity industry through such advances as smart technologies and distributed energy resources, as well as the development of new utility business models that may be more supportive of customer energy efficiency than traditional models are.

Further efforts are needed to support existing programs and create new ones as well. Such supportive efforts include research on new opportunities for market transformation—promising new energy efficiency products, technologies, and services. Part of such research may include demonstration projects and pilot programs. Programs also

need to continue to lock in efficiency gains by supporting enactment or upgrading of building codes and appliance/equipment standards.

Changes in markets have required new ways of thinking about energy efficiency. Market transformation is a bold approach to energy efficiency programs. Market transformation experience demonstrates that strategic market interventions targeting improvements in energy efficiency can successfully change some markets to meet ambitious energy savings goals. We are reaping the benefits of such efforts and can point to many energy-efficient products and technologies readily available today that have resulted from past market transformation programs. The potential and need for continued transformation of markets for energy efficiency products and services remain high.

Introduction

Efforts to reduce energy waste by improving energy efficiency have their roots in the energy crises of the 1970s—a time of growing public concern about energy supplies, rising energy prices, and the environmental impacts associated with energy use. In response, some electric and natural gas utilities began offering programs to their customers to improve energy efficiency in their homes, businesses, institutions, and industries (Nadel, Elliott, and Langer 2015).

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 be best achieved in some cases by making fundamental changes in selected markets for energy-efficient technologies and related practices. It was evident in many markets that barriers prevented more efficient products and related services from gaining a significant or even dominant market share.

Since market transformation's emergence nearly 30 years ago, it has been applied successfully in several markets. As discussed later in this report, leading examples of market transformation's success include front-loading (horizontal-axis) clothes washers, high-efficiency (condensing) natural gas furnaces, compact fluorescent light bulbs, and high-efficiency windows (specifically those with ENERGY STAR® ratings).

The American Council for an Energy Efficient Economy (ACEEE) has played a central role in the development and application of market transformation since its inception. For example, ACEEE partnered with the Consortium for Energy Efficiency (CEE) to organize and host the annual National Symposium on Market Transformation, which began in 1996. Given this long, active engagement, ACEEE determined that it would be valuable to examine experience with market transformation and assess how the lessons learned thus far could be applied to existing and new programs seeking to transform markets for energy-efficient products and energy efficiency services.

Improving the energy efficiency of our economy offers multiple benefits. Market transformation has proved itself to be an effective approach toward this end, but it is not suited to all markets. As utilities, states, and regions seek to achieve high energy savings through energy efficiency, it is important to critically examine the opportunities and limitations of market transformation as a program model to reach such goals.

Study Objectives and Methodology

The objectives of the study are to

- Examine the theory and practice of market transformation
- Document selected market impacts of market transformation programs
- Develop recommendations for future program designs and change models

This report updates earlier reviews of market transformation by ACEEE (Nadel et al. 2003; Nadel and Latham 1998) and other key literature (Prahl and Schlegel 1994; Eto, Prahl, and Schlgel 1996; York and Paulos 1999; EPRI 2001; Prahl and Keating 2011; Nevius et al. 2013; Keating 2014; Prahl and Keating 2014). Our intent is to provide an up-to-date look at market

transformation in the context of profound changes underway in energy utilities, especially electric utility systems. A secondary intent is to introduce market transformation to program professionals and stakeholders who are new to, or unfamiliar with, this approach to programs.

Our research employed three methods: literature review, interviews, and case studies. The literature on market transformation is well developed, beginning with seminal pieces written in the 1990s as market transformation was being defined and developed as a program model (e.g., Eckman, Benner, and Gordon 1992; Geller and Nadel 1994; Eto, Prahl, and Schlegel 1996). As energy savings targets have increased in many states and regions, program administrators are seeking the most effective program designs and approaches to reach these savings. There are a few more-recent publications that provide comprehensive reviews of market transformation and best practices for program design, implementation, and evaluation (Keating 2014; Nevius et al. 2013; Prahl and Keating 2011).

We interviewed a selected set of experts on market transformation programs, both those involved with program administration and those who performed program evaluation. Our interviews focused on experience with existing and past programs. We especially were interested in lessons learned that can be applied to existing and future market transformation programs.

Our third research method was examination and analysis of selected case studies of market transformation. Our set of case studies includes these programs:

- Residential CFL and LED lamps
- Clothes washers
- Quality installation of residential HVAC units
- High-performance schools
- ENERGY STAR windows in the northwestern United States
- Heat pump water heaters
- Building operator certification
- Leadership in Energy and Environmental Design (LEED) buildings
- NEEA ductless heat pumps
- Premium efficiency motors
- LED traffic signals

We present the first four of these examples in depth within the body of the report; we present the others as brief case studies in Appendix C. We selected these examples to illustrate the broad range of markets that have been addressed by market transformation programs. These include mass-market consumer products, professional practices, residential mechanical equipment (HVAC and water heating), and commercial building markets.

History and Development 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 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, which means examining and analyzing both supply and demand options for best meeting customer energy needs (Nadel 2013). Customer energy efficiency programs typically are a least-cost option when compared with supply options, such as building additional generation capacity.[1]

As utilities and key stakeholders gained experience with DSM and associated energy efficiency programs, a number of industry experts posited that programs could achieve much higher impacts if they could facilitate fundamental transformations that resulted in significant or even 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 that sought similar impacts.

Some early energy efficiency programs transformed markets even before the concepts and terminology of market transformation were created. Examples include high-efficiency natural gas furnaces in Wisconsin and new homes in the Pacific Northwest (Geller and Nadel 1994). Appendix A provides commonly accepted definitions of market transformation and offers more background on key concepts.

Market transformation resonated with upheavals occurring in the 1990s as the electric and natural gas utility industries were restructured and deregulated. Many states and regions enacted policies to introduce or support greater competition within a traditionally heavily regulated industry. In these areas, the concept of facilitating and even transforming markets for energy efficiency was attractive as an alternative to utility DSM programs that focused on individual customer changes, not entire markets. Traditional, short-term utility DSM programs became characterized as *resource acquisition*. In contrast, market transformation programs apply strategic interventions in targeted markets, often over long periods, to accelerate or expand the uptake of energy efficiency products or services. These two approaches, market transformation and resource acquisition, are complementary and mutually reinforcing. Some programs have elements of both strategies. Appendix B discusses market transformation and resource acquisition as energy efficiency program models.

While there was some debate early in the development of market transformation as to whether it was a policy goal or a strategic approach to intervening in markets, our review of the literature showed that the latter outlook prevailed. This report 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. We recognize that the

[1] Another term commonly used for integrated resource planning is *least-cost utility planning*.

term *market transformation* is used outside of this context to refer to other policies and desired changes in markets.

Transforming markets is ambitious. It is a large, complex undertaking whose goal is to effect fundamental changes in targeted markets. Typically, market transformation programs require substantial initial costs, 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.

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. We can draw on more than 25 years of experience with such programs to characterize the markets best suited to this model as well as identify the steps and interventions typically taken in market transformation programs. In this section, we present an overview of market transformation in practice.

BEST-SUITED PRODUCTS, TECHNOLOGIES, AND SERVICES

Market transformation is not suited to all types of products, technologies, and services. Characteristics of products and technologies that are most amenable to market transformation are those that fit these guidelines, as outlined by Keating (2011), offering:

- A clearly defined and manageable market
- A large enough opportunity for savings to justify the resources and time commitment to achieve the desired change
- A story that logically and defensibly links the present state of the market to the desired future state of the market
- Strong nonenergy benefits to help its acceptance and sustainability in the market
- Cost-effective energy savings over a long-term program horizon
- An efficient version of a product that is likely to be sold with or without efficiency consideration (e.g., new home, replacement heating system), or a service or relatively low-cost add-on device. High-capital-cost additions to buildings, such as insulation, are not good candidates.

A prior ACEEE review (Nadel et al. 2003) reached complementary conclusions about common attributes of measures showing significant progress in reaching market transformation goals. These attributes are:

- 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 is about strategic interventions to overcome market barriers that exist for products, technologies, and practices yielding higher energy efficiency. Eto, Prahl, and Schlegel (1996) identified 14 such market barriers. EPRI (2001) collapsed these into eight categories of overarching barriers according to Keating (2014):

- Limited access to information (customer unaware of savings opportunities)
- Performance uncertainties and risks
- Limited access to financing
- Split incentives (i.e., who pays is not who gains)
- Decision making issues—rules of thumb, habits, organizational decisions
- Problems with product or service features—cannot 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

PROGRAM STEPS AND PROCESSES

Market transformation can be a complex program model. Several reports describe the process and key steps typically followed in market transformation programs (Nevius et al. 2013; Keating 2014; Prahl and Keating 2011). One way to view these steps is to group them into an analytical process and an implementation process, as summarized in figure 1. The processes themselves are interwoven in the development, design, implementation, and evaluation of market transformation programs. The figure is simplified; in reality there are a number of feedback loops and other connections between steps. There also are some steps not readily shown by such a simplified figure, such as midstream evaluation to assess impact and adjust design early in a program launch.

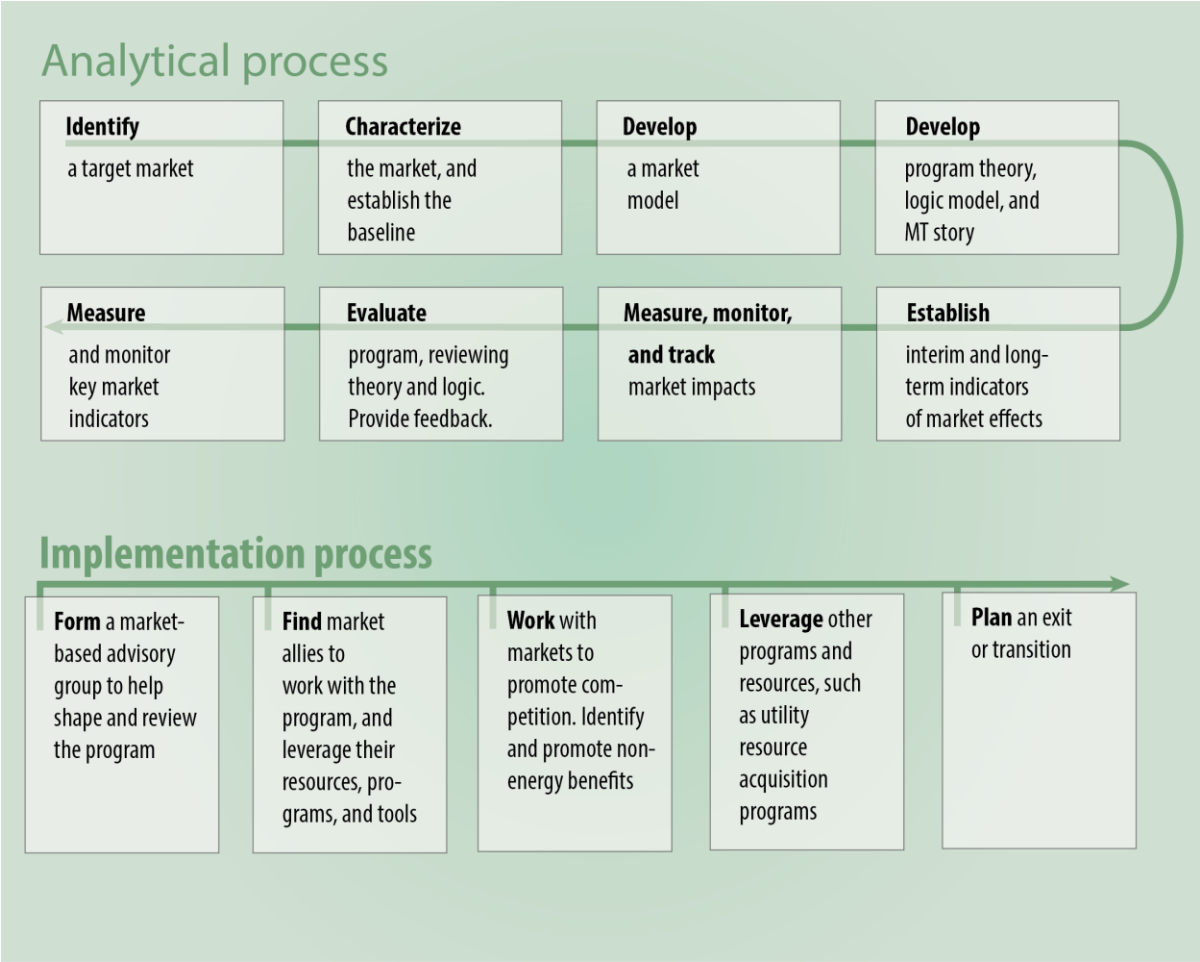

Figure 1. Market transformation processes

INTERVENTIONS

The types of interventions taken for market transformation programs vary widely. They address different market actors—members of any kind of group actively engaged in a targeted market and having some type of stake in the market. Table 1 shows examples of common interventions taken in market transformation programs grouped 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 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 performance of products
	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 differentiator for potential customers
	Best-practice guides	Improve professional practices

Market actors	Intervention or action	Goal
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

This table shows that market transformation program developers have a wide set of interventions and actions from which to choose. To be successful, programs must identify, select, and implement sets of interventions that effectively address key market barriers. Below we present selected case studies that illustrate how market transformation has been applied in different markets.

Case Studies

Market transformation approaches have been used in numerous markets. We selected a set of four case studies that illustrates the range of markets targeted and the types of interventions used to achieve desired market impacts. Additional case studies are examined more briefly in Appendix C.

RESIDENTIAL CFL AND LED LAMPS

Lighting accounts for 10% of total electricity consumption in the residential sector (EIA 2017b). Incandescent bulbs first appeared in US homes in the early 1900s. Incandescent bulbs are historically inefficient—only about 10% of the electric power supplied is converted to visible light (DOE 2013b). It was not until the 1973 energy crisis that research and development began on more efficient compact fluorescent light bulbs (CFLs) and light-emitting diodes (LEDs).

Over the course of the next 30 years, CFL and LED technologies became more efficient than conventional incandescent and halogen bulbs (halogens are a more efficient type of incandescent lamp). Table 2 outlines the energy savings from replacing traditional and halogen incandescent bulbs with CFLs or LEDs that produce similar light (DOE 2017d).

Table 2. Incandescent lamps versus CFLs and LEDs

	60W traditional incandescent	43W halogen	15W CFL		12W LED	
			60W traditional	43W halogen	60W traditional	43W halogen
Energy saved		~25%	~75%	~65%	~75–80%	~72%
Annual energy cost	$4.80	$3.50	$1.20		$1.00	
Bulb life	1,000 hours	1,000 to 3,000 hours	10,000 hours		25,000 hours	

CFL and LED potential has yet to be fully realized. While there are thousands of efficient lighting products on the market, CFLs and LEDs together account for less than 50% of the light bulb market in 2017 (NEMA 2017).

There have been significant efforts to transform the lighting market by increasing the market share of LEDs and CFLs. CFLs became economically viable for mass consumption before LEDs (Sandahl et al. 2006). Several misguided transformation efforts hindered the wide-scale adoption of CFLs. Fortunately, LEDs have become cost competitive and offer a second chance at transforming the market. This case study explores the lessons learned from CFLs and how these have guided current LED transformation efforts.

CFL Market Transformation: Lessons for LEDs

CFLs entered the residential lighting market in the early 1980s (DOE 2013b). Like any new product entering an existing market, early CFLs had many barriers to overcome in order to compete with traditional incandescent. These barriers included the following:

- CFLs were significantly more expensive than traditional incandescent bulbs.
- They were bulky in size and did not fit in most lamps or sockets.
- Their light was cold and unlike the steady, warm cast of incandescent bulbs.
- Many had long start-up times, averaging around 3 seconds.
- Public awareness was limited.

Unfortunately, these barriers were not adequately addressed before CFLs were introduced to the market. Various utility program evaluations in the early 1990s revealed that early adopters of CFLs were largely unsatisfied with the products.[2] This dissatisfaction was reflected in low sales rates. Various organizations conducted market research to diagnose why CFLs were not selling well and suggest potential solutions (Sandahl et al. 2006).[3] The findings of these evaluations and research reports are summarized in Table 3.

[2] Pacific Gas and Electric (PG&E) found that 50% of its CFL program participants felt that the 27-watt CFLs they purchased did not live up to the program's claim that they were equivalent to a 100-watt bulb.

[3] These organizations included the Natural Resources Defense Council (NRDC), Lighting Research Center (LRC), Pacific Northwest National Laboratory (PNNL), and CEE.

Table 3. Causes and consequences of early CFL underperformance

Issue/barrier	Causes and consequences
Early failure	Many of the early CFLs burned out sooner than advertised. This ultimately made consumers skeptical of CFL advertising claims and less likely to buy CFLs in the future.
Sizing	One study from 1993 revealed that CFLs would not fit in more than 60% of the fixtures in an average home.
Retail price variability due to varying utility programs	Utilities did not coordinate promotions, causing the prices of CFLs to vary greatly, even in the same service area. A Southern California Edison study looked at the same CFL model in six stores within its service area and found that the price ranged from $6.97 to $19.99.
Lack of availability	Despite utility promotions, well into the 1990s many retailers did not carry CFLs. Most of those that did were home improvement stores. However most consumers bought light bulbs at the grocery store, making the purchase of CFLs less convenient than buying incandescent bulbs.
Little manufacturer marketing	While utilities rolled out educational and promotional programs, manufacturers did not market residential CFLs. This put CFLs at a great disadvantage.

Source: Sandahl et al. 2006

On the basis of these findings, market actors changed some of their approaches to better address the market barriers and issues surrounding early CFL uptake.[4]

SHIFTING INCENTIVES FROM CONSUMERS TO MANUFACTURERS

Many utility programs in the 1980s and early 1990s were giveaway, direct install, or discount mail-order programs. However in the early 1990s some utilities began offering rebates to manufacturers instead of directly to their customers, an approach known as an upstream rebate. Providing rebates to light bulb wholesalers ultimately reduced the cost of bulbs further. And consumers proved to be more likely to buy CFL bulbs when they saw an already rebated price in the store (Sandahl et al. 2006). These upstream programs would later be used in LED market transformation efforts and are still in effect today.

COORDINATING REGIONAL EFFORTS

Utilities, local governments, and regional efficiency organizations (REOs) began to coordinate efforts beginning in 1989. Regional groups worked with manufacturers to develop and disseminate promotional campaigns, and field service teams implemented these campaigns at retail stores by fashioning product displays, verifying product pricing, and ensuring product availability (Sandahl et al. 2006). They also worked to train retail employees. This ultimately sent consistent messaging to consumers and increased the visibility of CFLs. These partnerships would later lend themselves to LED market transformation efforts.

[4] Market actors included utilities, local governments, regional efficiency organizations, nonprofits, manufacturers, and the federal government.

ENERGY STAR AND FEDERAL STANDARDS

The US Department of Energy (DOE) launched an ENERGY STAR program for residential lighting in 1997. The standards it created set specific parameters and a direction for manufacturers, particularly with respect to quality and efficiency. They also aided marketing efforts by attaching a consumer-trusted brand to a relatively unknown product (Sandahl et al. 2006). ENERGY STAR requirements would be made mandatory under efficiency standards established by Congress in the Energy Policy Act of 2005 (ASAP 2017a).

LED Market Transformation: Market Barriers and Program Design

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 CFLs (DOE 2017a). To ensure the widespread market adoption of LEDs and help the technology realize its full potential, DOE addressed the following barriers:

- Inadequate quality control
- High cost
- Consumer confusion
- Consumers' negative perception of efficient lighting

DOE developed the Commercially Available LED Product Evaluation and Reporting program (CALiPER) to provide unbiased, trusted product performance information to the market and ensure that LEDs would meet consumers' 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 2017e). Under the voluntary program, manufacturers test and report their LED performance according to CALiPER test procedures. Each listed product receives a Lighting Facts label (see right) that allows consumers, retailers, and distributors to compare products easily. The program also engages retailers, distributors, and efficiency program sponsors to promote the listed products. The program currently has 1,606 manufacturer partners, 462 retail and distributing partners, and 111 efficiency program partners.

Beyond CALiPER testing, Congress, in the 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 (EISA 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 winning entries. These promotions 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 (CPUC) tasked the California Lighting Technology Center (CLTC) and the Collaborative Labeling and Appliance Standards Program (CLASP) 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 represents one of many research and development projects conducted to ensure that LEDs develop in a consumer-friendly fashion.

Education and Rebate Programs

CFLs demonstrated that education and marketing are essential for efficient lighting adoption. DOE and ENERGY STAR have both provided LED marketing materials for retailers.[5] Marketing messages 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 2016b). 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. LED Lighting Facts has an interactive map detailing the efficiency programs in each state, so consumers can easily find which rebates are available in their area.[6]

Program Impacts and the Market Today

Both LEDs and CFLs have made progress in commanding market share since they were introduced in the 1980s and 1990s. Since 2000, DOE has funded more than 250 R&D projects, which has rapidly reduced the cost of CFLs and LEDs (DOE 2016a). Since 2009, the number of LED lights installed in the United States grew from 400,000 to almost 20 million (DOE 2016a). One expert characterized this market transformation effort as follows:

> In residential lighting the transformation has been huge, and started with what we can agree is not the coolest product: CFLs. They were clunky, they didn't fit well, and it wasn't easy to put them in a range of places. It changed how people think about lighting and led the way for LEDs. People are now talking/thinking about lighting differently.

[5] ENERGY STAR material can be found at www.energystar.gov/products/marketing_materials.

[6] The map can be found at www.lightingfacts.com/UtilityPrograms.

Figure 2 depicts the market penetration of various light bulbs and demonstrates the growth in LED adoption (NEMA 2017).

Figure 2. Market penetration of various bulbs

Table 4 outlines the LED market actors and the roles they have played.

Table 4. LED market actors

Market actor	Role played
DOE	Led market transformation efforts. Developed CALiPER and LED Lighting Facts, and funds R&D projects across the United States. Sets minimum efficiencies for general service lights, as outlined in EISA 2007. Helps coordinate efforts of all market actors.
ENERGY STAR	Runs voluntary programs for efficient lighting. These programs motivate manufacturers to develop efficient technology that can capitalize on price premiums and receive marketing from ENERGY STAR programs.
Manufacturers	Develop efficient lighting that satisfies consumers' needs.
Retailers	Support quality-focused specifications, such as ENERGY STAR, through in-store promotions for qualified LEDs.
Research organizations	Provide information for all actors about LED technology and designs that best serve consumers. R&D also helps diminish the costs of LEDs.
Utilities and regional energy efficiency organizations	Provide essential educational and rebate programs for LED lights.

Looking Forward

While there have been great strides in development and growing acceptance from the market, much of the potential remains untapped (DOE 2016a). Two further actions can help close this gap.

CONTINUING UPSTREAM INCENTIVE PROGRAMS

Many utilities and local efficiency organizations have LED incentive programs that educate and provide rebates to their customers. Continued use of incentive programs is essential for not only promoting market transformation, but also preventing the market from backsliding to less efficient technologies. In 2013, New York discontinued its upstream incentives, while Massachusetts did not discontinue them. In 2016, researchers compared LED and CFL saturation rates in New York and Massachusetts to determine whether reducing incentives affects saturation rates (Barclay et al. 2016). From 2013 to 2015 in New York, CFL adoption decreased in favor of halogen light bulbs. Conversely, in Massachusetts, CFL and LED adoption increased dramatically, while halogen saturation grew slightly. This divergence demonstrates that while the market is nearly self-sustaining, reducing incentives may lead the market to backslide and slow the transformation (Barclay et al. 2016).

PROMOTING FEDERAL STANDARDS

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). Under the law, DOE was to set the new standard by January 1, 2017, a deadline that the agency missed. The law requires any new standard to average at least 45 lumens per watt for affected products. If DOE does not set a standard, the law defaults in 2020 to 45 lumens per watt, an efficiency level that LED and CFL bulbs can meet but standard incandescent and halogen bulbs cannot. If this standard goes into effect, most incandescent and halogen bulbs will be phased out, dramatically aiding the transformation of the residential lighting market.[7]

CLOTHES WASHERS

In today's market, consumers can find two types of clothes washers—top loading and front loading. Twenty years ago, however, virtually all washers sold in the United States were top loading; 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). Researchers estimated that the United States could save 9 million MWh annually if it replaced 25% of its in-use residential top-loading washers with front-loading models (deLaski and Pope 1996). This huge savings potential motivated utilities and policymakers to transform the washer market in the early 1990s.

[7] Follow the status of this rule at www.regulations.gov/docket?D=EERE-2013-BT-STD-0051

Market Barriers and Program Design

In 1994, DOE implemented a modest new minimum efficiency standard for clothes washers but also began a new rulemaking to consider much higher standards based on 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 US market.

Around the same time, many utilities were expressing interest in promoting efficient washers to reach their efficiency program requirements. In 1993, the Western Utility Consortium (WUC) and the Consortium for Energy Efficiency (CEE) collaborated on energy efficiency specifications for utility programs (deLaski and Pope 1996). Before program managers could implement these standards nationwide, utilities needed further performance and market data (deLaski and Pope 1996). A group of western utilities, DOE, the city of Seattle, and the Electrical Power Research Institute (EPRI) worked together to create The High Efficiency Laundry Metering & Marketing Analysis (THELMA). Through its research, THELMA found that the market had potential for transformation, but the following barriers had to be overcome:

- High initial cost
- Lack of consumer familiarity
- Few horizontal washers available on the market
- Lack of horizontal washers that met consumer design preferences

Availability and Consumer Preferences

Multiple manufacturers introduced European front-loading machines to the US market with little success. In 1992, Maytag collaborated with EPRI to develop a front-loading washer specifically designed for the US market: the Neptune (Peloza, York, and Paulos 1999). Beyond energy savings, the front-loading mechanics were gentler on clothing (Peloza, York, and Paulos 1999). These qualities allowed Maytag to market the Neptune as a premium product and sell it for twice the cost of conventional washers (Paton 2004). It was widely popular among consumers and surpassed sales expectations. Seeing this success, other manufacturers followed suit and developed their own front-loading washers.

The Neptune was also instrumental in developing ENERGY STAR specifications. Maytag and ENERGY STAR ran a pilot to test the performance and consumer acceptability of front-loading washers (Tomlinson and Rizy 1998). They chose the city of Bern, Kansas, to participate in the pilot because of its small population (210 residents) and occasional water supply issues (Tomlinson and Rizy 1998). Each participant was given a free Neptune washer. For five months, the researchers closely tracked water and energy use before and after installing the efficient washers; 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).

Cost and Familiarity

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 the Northwest Energy Efficiency Alliance (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. It began offering sales personnel $20, and later $10, for each efficient machine sold. Both efforts were successful and resulted in 56,000 efficient washer sales (Peloza, York, and Paulos 1999). 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). Marketing campaigns aimed to help consumers understand these lifetime savings, translating energy and water savings into more understandable terms. In a brochure, ENERGY STAR pointed out that over the 11-year average life of a qualified washer, a household could save enough water to provide a lifetime of drinking water to six people, fill three backyard swimming pools, run an ENERGY STAR dishwasher more than 15,000 times (or every day for 42 years), or take 3,000 showers. Provided with information about the potential energy, water, and cost savings over the lifetime of a single machine, consumers more readily adopted the technology.

The superior performance of horizontal-axis machines also helped its 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 efficient washers, which were noticeably gentler on clothes and cleaned better than vertical-axis 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.

Program Impacts and the Market Today

ENERGY STAR, manufacturers, and efficiency partners collaborated to effectively transform the clothes washer market. By 2006, ENERGY STAR washers had reached a 38% market share (DOE, 2008). Due to this high market acceptance, in 2007 the US 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). The Obama administration raised these standards in 2012, on the basis of another consensus agreement between appliance manufacturers and energy efficiency advocates (DOE 2012c).

Table 5 outlines the role that each market actor had in transforming the market.

Table 5. Clothes washer market actors

Market actor	Role played
Researchers	Researchers from EPRI and THELMA were instrumental in determining the barriers to market transformation; aiding manufacturers in designing washers for the US market; and helping utilities, state energy offices, and regional energy efficiency organizations design outreach, rebate, and financial incentive programs.
Manufacturers	The top three manufacturers account for 89% of the US market share. Manufacturers developed efficient products that US consumers would accept.
Utilities, state energy offices, regional energy efficiency organizations	Educated households in their area about the benefits of ENERGY STAR-qualified products. Most provided rebates and financial incentives as well.
DOE	Has the authority to set federal standards. Managed the ENERGY STAR clothes washer program.

From 1997 to 2009, introducing efficient clothes washers to the market has saved 30 billion kWh and 110 trillion British thermal units (EPA 2012). The success of this program can be attributed to the following:

- Strong support from manufacturers
- Nonenergy benefits (e.g., water savings, quality of washing)
- Regional awareness and rebate programs
- Federal standard

Looking Forward

The washer market continues to pursue further savings. The fifth federal standard for clothes washers will go into effect in 2018 (ASAP 2017b). This standard will be updated again in 2020, effective in 2024, and could potentially lead to additional energy savings. ENERGY STAR and associated utility programs continue to promote savings beyond the federal standard. Washers qualifying for an ENERGY STAR Most Efficient designation save 33% more energy and 34% more water than a washer meeting just the federal standard (EPA 2015). As of 2015, ENERGY STAR washers held a 56% market share, proving that these voluntary programs have been successful in furthering this market transformation effort (ENERGY STAR 2017a).

QUALITY INSTALLATION OF RESIDENTIAL HEATING, VENTILATION, AND AIR-CONDITIONING (HVAC) UNITS

Heating, ventilation, and air-conditioning (HVAC) systems are large energy users in residential homes, and they also greatly affect the indoor environment. In 2016, the US Energy Information Administration (EIA) found that space cooling and heating together account for 25% of electricity consumption in residential homes (EIA 2017a). HVAC systems affect humidity and moisture levels, indoor air quality and mold, noise in the home, temperature, and utility bills. These systems are critical to home comfort, health, and to reducing energy bills.

The quality and efficiency of the HVAC equipment itself, as well as how the system is installed, are critical to creating a comfortable and safe indoor environment. Poor installation or incorrect sizing of HVAC systems can lead to leaky ducts, increased energy use, and poor indoor environmental quality. In the United States, almost half of all HVAC systems are installed incorrectly (ENERGY STAR 2017b). Common issues associated with improper installation can increase HVAC energy usage by up to 30% (Domanski, Henderson, and Payne 2014).

In order to combat these problems, many utilities, trade associations, and stakeholders concerned with building energy use are encouraging quality installation (QI) practices for residential HVAC systems. A few industry associations have taken market transformation approaches to solving this issue. Programs utilize national standards to enable QI practices and aim to increase education for contractors and homeowners. This improves the efficiency of residential HVAC systems and reduces overall energy consumption.

Quality installation focuses on a few major aspects of the design and installation process. Systems must be properly sized, ventilated, and designed for the intended space. Systems that are too large can cycle more frequently than necessary, causing increased energy use, increased wear on the equipment, and uncomfortable indoor environments. Ducts must be properly sealed to reduce energy waste while ensuring proper airflow to maintain proper humidity, temperature, and air quality. Additionally, the amount of refrigerant should be optimized and checked for proper system function. All of these steps make the system run more efficiently to reduce energy usage (ENERGY STAR 2017c).

Various research efforts (for example, Taylor, Hourahan, and Parlapiano 2004) identified initial market barriers to large-scale penetration of QI practices:

- Lack of customer awareness regarding HVAC systems and the benefits of quality installation
- Lack of contractor education
- Diversity of contractor companies and difficulty of reaching them
- Lack of standard QI practice specifications
- Higher up-front costs to customers

In general, consumers lack an understanding of the HVAC industry and its importance for creating efficient and healthy homes. This can lead to undervaluation of the industry as a whole, as well as undervaluation of potential energy savings relative to the higher up-front costs of quality installation. This problem can also lead contractors to expect that consumers will desire quick and inexpensive installation rather than QI practices, when this is not always the case (Taylor, Hourahan, and Parlapiano 2004; Taylor and Hourahan 2006; Atwater 2016).

Other challenges can impede adoption. Since HVAC equipment replacements are often unplanned, customers have less time for research and financial preparation for their purchases. With such a diverse group of individual contractors, it is also difficult to build consistent brand recognition surrounding QI practices and to consistently verify that systems have been installed properly. Additionally, QI practices provide varying levels of

value for different types of HVAC systems (e.g., gas versus electric) and in different climate regions. Savings are well established for electric equipment where HVAC systems are used intensively but can be less reliable in other contexts (F. Gordon, director of planning and evaluation, Energy Trust of Oregon, pers. comm., October 30, 2017).

In order to overcome the market barrier of not having a standard definition or set of practices for QI HVAC, the Air Conditioning Contractors of America (ACCA) created a set of standards for residential QI HVAC that was released in 2007. The standard is recognized by the American National Standards Institute and has continued to evolve over the years. Most recently, Version 5 was released in 2015. In conjunction with this standard, the ACCA runs accreditation and education programs for contractors and has created a standard for verification of QI practices. These efforts aim to overcome the market barrier of inconsistent licensing and educational practices across the country.

The ACCA standard informs the following elements of residential QI HVAC: design (including ventilation and sizing), installation (including airflow, refrigerant charge, and electrical requirements), distribution (including duct leakage and airflow balance), proper system documentation, and owner education. The standard is meant to be applicable to any residential HVAC system, whether the system just meets the minimum efficiency requirements or has the highest possible efficiency (ACCA 2015).

ENERGY STAR implemented a program called ENERGY STAR Verified HVAC Installation (ESVI) based on the ACCA standard. The program ensures QI of residential HVAC systems through third-party verification and certification. Similar to the ACCA standard, the ESVI program specifies measures related to installation, sizing, and other technical elements. It also requires that the installation be verified by a third party in order to overcome challenges associated with consistent verification of QI practices (ENERGY STAR 2017c).

Both the ACCA and ENERGY STAR programs work in conjunction with state, utility, and third-party QI market transformation programs. These programs often offer incentives such as rebates for residents who hire verified contractors to install their HVAC systems. Utilities also maintain websites that are a good source of information for consumers who want to educate themselves on HVAC systems and energy savings. These programs help to overcome the market barriers of low consumer demand and high up-front costs.

Iowa HVAC SAVE, a program run by the Midwestern Energy Efficiency Alliance (MEEA), focuses on training contractors and working with utilities to get qualified contractors into homes. This program also ensures proper installation through verification of each project (Edwards, Baker, and Graham 2015). California's Energy Efficiency Strategic Plan, implemented in 2008, states a goal of having 100% of HVAC systems installed to quality standards by the year 2020 (Engage360 2011). This program focuses on streamlining contractor permitting for HVAC installations, updating building codes to include ACCA standards, verifying installations, and enforcing penalties imposed on contractors who do not have required licenses or permits. A review of Pacific Gas & Electric, Southern California Edison, and San Diego Gas & Electric found that all three had QI programs in place in 2015 to meet these goals (Relf, Baatz, and Nowak 2017).

Table 6 summarizes the role of each market actor involved with QI HVAC market transformation processes.

Table 6. Residential HVAC quality installation market actors

Market actor	Role played
Air Conditioning Contractors of America (ACCA)	HVAC contractor trade association convened stakeholders to develop a standard QI specification and accreditation/education program.
ENERGY STAR	Developer of ENERGY STAR Verified HVAC Installation standard, based on the ACCA standard. Provides brand recognition and standard specifications for QI HVAC.
Contractors, installers, and technicians	Implement QI HVAC practices.
Utilities	Run QI HVAC programs for customers, including rebates, contractor training, customer education, and help finding certified contractors.
Consumers/homeowners	Decision makers who drive demand for QI HVAC.
Midwestern Energy Efficiency Alliance (MEEA)	Runs the Iowa HVAC SAVE program to train contractors in QI practices and verification.
California Public Utilities Commission	Outlined a vision for transforming the residential HVAC installation market in California. Convened utilities, contractors, and government agencies to create and implement the plan.

Program Impacts and the Market Today

Indicators such as contractor qualification numbers, customer awareness, program participation, and contractors adhering to QI practices are used to set baselines and measure progress for QI programs. MEEA's HVAC SAVE program trained 185 contractors in 2010; this number grew to a total of 2,235 trained contractors in 2015. The program has processed more than 31,000 jobs since it began (Edwards, Baker, and Graham 2015). The percentage of total contractors reached by the program is difficult to determine, as new contracting companies frequently enter the market and others close. These data are key to gauging the success of the market transformation initiative without continued market intervention.

HVAC SAVE has adapted to challenges it faced during implementation. Initially, MEEA found that contractors were concerned about meeting specifications required for their customers to receive rebates; they were also worried about high costs for software used in verification of savings. Through frequent meetings, the various parties (stakeholders, MEEA, the utilities, and contractors) were able to adjust their business and training models to overcome these challenges. The utilities began offering free access to software, and MEEA adjusted its training programs to adjust to the needs of the contractors.

The program also credits its successes to its data-driven approach and strong marketing through the single HVAC SAVE program branding. With strong data to verify savings, contractors are able to demonstrate benefits to their customers. However this information is not published in program reports by MEEA, making overall program impacts and market penetration difficult to estimate. The program created strong buy-in from all levels of the

value chain, which amplified branding and marketing. Perhaps most important were the constant communication and adaptation to challenges that arose, such as unreasonable deadlines and new training needs. Frequent stakeholder meetings promoted knowledge spillover, recognition of benefits, and the ability to adapt to portions of the program that were not seeing success (Edwards, Baker, and Graham 2015).

In California, market penetration remains low but is growing. A 2015 baseline study of QI programs run by the investor-owned utilities (IOUs) found that 42% of residential contractors were aware of the ACCA standards but only 14% of them claimed to adhere to all of the specifications. Additionally, the IOUs had trained only 1–3% of contractors. Southern California Edison had more than 40 trained contractors active between 2010 and 2015. This translated to more than 10,000 units successfully installed in its territory, with energy savings of about 3,300 MWh (Atwater 2016). This is likely less than 1% of air conditioner sales in the territory over the 2010–2015 period. Across the state, reluctance to pay for QI practices is still the largest barrier to implementation. In a survey, 63% of residential respondents cited this as their number one barrier, and only 10–21% of survey respondents had heard of their utility's rebate programs (NMR Group 2015).

The program in California, as well as others in the future, can likely learn from the MEEA experience. Given the low contractor participation in California, it is important to use data to prove the value of QI practices to installers and their customers in order to justify the higher up-front costs and training time. Additionally, simplified branding and increased marketing could help raise customer awareness for these programs and ultimately drive additional energy savings (Messenger 2008).

With such high potential for energy savings, utilities and regulators may consider implementing QI market transformation programs more widely across the country. The MEEA and California examples provide models and lessons for future programs. A recent ACEEE review of 51 large electric utilities found that only 16 ran a QI program for residential HVAC in 2015, indicating a large potential for growth in utility participation (Relf, Baatz, and Nowak 2017). This may be especially enticing to utilities that are aiming to go beyond the low-hanging fruit within their energy efficiency portfolios to achieve deeper savings. In addition, these programs highlight the importance of strong data collection, transparency, and communication among market participants. These are lessons applicable to all market transformation efforts.

HIGH-PERFORMANCE SCHOOLS

Safe and comfortable buildings are critical to teacher performance and student achievement. Buildings must have good air quality and lighting, provide a comfortable temperature, and be easy to maintain and operate. In addition, school buildings that are well designed and energy-efficient save money for school districts (CHPS 2017b). Energy efficiency in schools is also particularly important, as these buildings use a lot of energy. When the EIA last conducted its Commercial Buildings Energy Consumption Survey, more than 389,000 schools, representing 7% of all commercial buildings, used 11% of the electricity consumed by this sector (EIA 2016a). Both new and existing school buildings have high potential for energy savings, and students can particularly profit from the nonenergy benefits of energy efficiency.

In California, the school system faces a diverse set of challenges related to rapid growth in student populations (Mills et al. 2002). To address this growth, the government implemented mandatory classroom size reductions, which gave rise to the construction of many new schools in a short period of time. Additionally, a 2002 study found that 30% of the existing stock of schools needed significant facility upgrades (Mills et al. 2002). Given all the building activity, the Collaborative for High Performance Schools (CHPS) was created in 1999 and incorporated as a nonprofit in 2002. The organization originally brought together utilities in California to address energy efficiency in schools; it has since expanded to include a wider range of stakeholders and to address additional aspects of school design. Other energy-efficient schools programs exist on the national level, including DOE's ENERGY STAR Certified K-12 Schools program, the Northeast Energy Efficiency Partnerships' (NEEP) development of regional CHPS criteria, and the Alliance to Save Energy's PowerSave Schools program.

The CHPS defines high-performance schools as "facilities that improve the learning environment while saving energy, resources, and money" (CHPS 2017b). Documented benefits of such schools are numerous, including higher test scores for students, better student attendance, higher teacher satisfaction and retention, reduced operating costs, reduced liability exposure, and reduced environmental impacts (Bucaneg 2008). In addition, attractive building design is often a point of pride for students and staff. To realize these benefits, however, a diverse group of stakeholders must be willing to advocate for high-performance building design principles and the funding necessary to put them into practice.

Programs promoting high-performance schools are a good example of a segmented market transformation approach used within the public sector. They focus on a strategy of bringing together market actors and providing education and training resources to those with decision-making power. The effort for high-performance schools began in California and has since expanded to many other areas across the country. While there is not yet widespread market penetration for high-performance schools nationwide, the number of such schools is growing steadily. The effort has also made gains in other areas, such as increasing awareness of the benefits of high-performance schools. The CHPS example provides good lessons for future efforts and for the expansion of high-performance schools into new regions.

Market Barriers and Program Design

Working in the public sector presents unique challenges for market transformation. High-performance schools cannot be built without explicit support and direction from the school district and from state funding agencies. Major barriers to widespread implementation of high-performance schools include:

- Tight state funding and construction time lines
- High up-front costs
- Limited school district budgets
- Lack of awareness of benefits
- Lack of information regarding high-performance building design (Mills et al. 2002)

Considering construction time lines as a market barrier for high-performance schools is especially important. School districts must commit to implementing high-performance building principles early in the planning and design process. This allows them to appropriately plan and request funding and to better manage project time lines when there are strict government agency deadlines to meet and a school calendar to accommodate. Prioritizing energy-efficient building principles early in the process also allows the district more time to communicate the important benefits of high-performance schools to state funding agencies.

The CHPS aims to address these challenges to widespread market adoption by building a strong stakeholder group and creating buy-in. The organization began working in California but has expanded to be a nationwide effort. The program pulls together utilities, design professionals, companies (landscape design firms, construction companies, and many others), nonprofits, government officials, and school district professionals. With such broad participation and expertise, the group is able to recognize and address issues that arise throughout the high-performance schools implementation process. Engaging these various stakeholders allows the organization to focus its messaging on the benefits that are most important to them (e.g., greater student achievement) (Mills et al. 2002). Additionally, having active members across market segments allows the organization to build expertise in a variety of subject areas and to better engage with the many government agencies that are involved in schools, building codes, energy usage, and state funding. For example, the CHPS worked with two government agencies in California to streamline the funding process for high-performance schools and to offer additional funding options for schools that meet CHPS criteria (Mills et al. 2002).

Collecting dues from all members (except school district representatives) allows the organization to provide free trainings and resources to schools and to a variety of other stakeholders. This helps to overcome the market barrier of lack of information regarding the benefits of high-performance schools and the more technical aspects of high-performance school design and operations. This is especially important for school districts with small budgets. An additional step that the collaborative has taken to improve awareness is to set up demonstration schools. This has allowed the organization to assess and market the benefits of CHPS schools (Bucaneg 2008).

CHPS developed a set of best-practice manuals for high-performance schools in 2002 and updated them in 2006. The manuals cover the full time line of implementing a high-performance school, from planning and design to operations and maintenance of the facilities. They provide step-by-step guidance for policy and technical aspects of high-performance schools across school districts, and they also outline criteria for becoming a verified CHPS school. These criteria are flexible, in order to work for schools in different climates and regulatory environments (CHPS 2017b).

CHPS provides recognition for schools at two levels. Schools that self-certify as CHPS-designed receive a certificate and may use the program logo. Schools that are verified by independent reviewers receive a plaque. These recognition programs can create competition among school districts, driving increased adoption of CHPS standards across districts (CHPS 2017c).

Other programs, such as NEEP's energy-efficient schools efforts, take a similar approach. The ENERGY STAR program, however, focuses on creating clear requirements for achieving the ENERGY STAR label, which is highly regarded.

Table 7 summarizes the role of each market actor involved with the high-performance schools market transformation process.

Table 7. High-performance schools market actors

Market actor	Role played
Collaborative for High Performance Schools (CHPS)	Brings together stakeholders for development of high-performance schools criteria. Holds trainings for participants and manages branding and marketing for the program.
School districts	Direct and organize funding for school construction and upgrades. Drive demand for high-performance schools.
School occupants (teachers, students, other staff)	Experience improved working and learning environments from high-performance equipment and school buildings.
California Division of the State Architect	Develops and enforces building codes for schools. Leads an incentive program that provides funding for schools with high-performance design elements (CalRecycle 2014).
State departments of education	Manage educational policies that influence construction and modernization of schools.
California State Allocation Board (and equivalents in other states)	Must approve state funding requests for modernization and new school construction.
Building designers	Facilitate the high-performance building design process.
Utilities	Collaborators in the CHPS. Aid in developing best practices and in implementing energy efficiency designs and projects for high-performance schools. Some may offer financial incentives for efficient school programs.

Program Impacts and the Market Today

The Collaborative for High Performance Schools has trained thousands of professionals and has more than 225 members. More than 300 schools in the United States currently meet CHPS criteria, with 300 more underway. In addition, 41 school districts across the country have committed to using CHPS criteria for new school construction or school modernization (CHPS 2017a). In 2008, 27 out of approximately 1,000 school districts in California had adopted similar resolutions (Ed-Data 2013). Given that only 41 districts throughout the US are currently committed to the criteria, adoption of the standards may have stagnated or shifted toward other programs such as ENERGY STAR schools.

CHPS standards are being adapted to fit the needs of school districts across many states other than California. Currently, 11 states and the District of Columbia have CHPS

standards in place that are specific to their climate and region.[8] This is up from seven states in 2008 (Bucaneg 2008). For example, NEEP led the development of CHPS criteria for the northeastern United States with collaboration from local stakeholders across a diverse range of market participants (NEEP 2014). In conjunction with this effort, the Rhode Island Department of Education requires that new school construction and renovation costing more than $500,000 meet the Northeast CHPS (NE-CHPS) criteria. The New Hampshire Department of Education will verify any schools built to CHPS criteria. NEEP currently lists 63 schools that are NE-CHPS verified (NEEP 2017b).

In 2017, 34.4% of all the buildings to become ENERGY STAR certified were schools—a total of more than 1,300 (NASEO 2017). This program is achieving greater reach than CHPS, likely due to strong brand recognition. Twenty-four states certified at least 10 K-12 ENERGY STAR schools in 2017 (NASEO 2017).

The CHPS market transformation effort is largely regarded as successful in delivering energy savings. A study of CHPS schools in California found that on average, the schools were 27% more energy efficient than those meeting only the minimum code compliance standards (Bucaneg 2008). CHPS design practices have reached many states and have been adopted or encouraged by state government agencies and school districts. A key aspect of the initiative is the engagement of key stakeholders across sectors in the market. The collaborative engages with private companies, technical designers, and utilities, as well school system and government agency officials. This unified approach addresses the needs of each player and increases buy-in across the board. The collaborative was able to identify market barriers like the need to streamline financing opportunities and to address them quickly. Additionally, CHPS demonstration projects allowed the organization to showcase the benefits of high-performance schools in a real-world setting. This encouraged the further adoption of resolutions by school districts to require CHPS verification in school construction and modernization. Finally, although the CHPS focused largely on California, its criteria were flexible enough to apply to a variety of climates and regulatory environments.

OTHER NOTEWORTHY MARKET TRANSFORMATION PROGRAMS

Market transformation has been applied successfully in a number of markets other than the set we selected for our case studies. Other successful examples of market transformation are discussed in Appendix C and include:

8 The 11 states are Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, and Vermont (NEEP 2017b).

- ENERGY STAR windows in the northwestern United States
- Heat pump water heaters
- Building Operator Certification (BOC)
- Leadership in Energy and Environmental Design (LEED) buildings
- NEEA ductless heat pumps
- Premium efficiency motors
- LED traffic signals and street lighting

Other notable examples, discussed by Nadel et al. (2003), include residential refrigerators and dishwashers, room air conditioners, residential central and commercial air conditioners, LED exit signs, and dry-type distribution transformers.

A few additional initiatives are also worth a brief mention.

80 PLUS COMPUTERS

In 2004 Ecos Consulting led an industry initiative to launch a voluntary certification program to promote energy-efficient computer supply units (PSUs). This initiative, called 80 PLUS™, certifies products that are more than 80% efficient at 20%, 50%, and 100% of rated load, and that have a power factor of 0.9 or greater at 100% of load. PSUs achieving this performance waste 20% less electric energy than typical units. EPRI developed applicable test procedures for rating PSUs as needed to achieve the 80 PLUS™ rating. Other key partners and supporters of the initiative include ENERGY STAR, CEE, NEEA, California's electric utilities, ConEd, Snohomish County PUD, and the New York State Energy Research and Development Authority (NYSERDA). The market transformation approach included manufacturer partnerships, targeted demonstrations, and midstream incentives.[9] The objective was for PSUs rated 80 PLUS to be the default product in desktop units. ENERGY STAR specifications for desktop computers have incorporated this rating (and subsequent versions of it) since 2007.

HIGH-EFFICIENCY TELEVISIONS

The Northwest Energy Efficiency Alliance (NEEA) launched its Consumer Electronics Television Initiative in 2009. While it was a regional effort, it also had national impacts. It was a multipronged approach that included retailer incentives, manufacturer engagement, development of ENERGY STAR specifications, and in-store marketing. In 2013 NEEA determined that the television market had been sufficiently transformed for it to transition its involvement to long-term monitoring and tracking (NEEA 2015b).

COMMERCIAL LIGHTING

Lighting retrofits have long been a staple of commercial energy efficiency program efforts. Throughout the 1990s, programs offered incentives for the replacement of T12 fluorescent

[9] Midstream incentives are payments made to distributors or retailers of products rather than to customers. The objective is to increase the supply, stocking, and sales of targeted energy-efficient products by incentivizing businesses to sell more of them.

lamps and magnetic ballasts with more efficient T8 lamps and electronic ballasts. Adoption of these improved fluorescent lighting technologies led to a 37% increase in system efficiency between 2001 and 2010 (DOE 2012a). New standards adopted in 2009 (effective in 2012) locked in significant efficiency gains in linear fluorescent lamps. With advances in technology and widespread adoption of these technologies, program efforts shifted to focus on retrofits driven by more sophisticated lighting design strategies using high-performance T8 and T5 lamps, advanced ballasts, and controls to reduce the overall lighting load and better match light levels to occupant needs.

HIGH-EFFICIENCY COMMERCIAL AIR CONDITIONERS (HECAC)

Various initiatives to improve the efficiency of commercial rooftop air conditioners date back to the early 1990s. In those years PG&E, several other utilities, and ACEEE worked on an initiative to develop efficiency tiers for manufacturers to aim for in their product development efforts. With the formation of the Consortium for Energy Efficiency, the initiative was moved under CEE's auspices. The original HECAC initiative had two efficiency tiers, one slightly above then-current federal minimum efficiency standards and a higher, "reach" tier to inspire more ambitious efforts. The lower tier called for an energy efficiency ratio, or EER—a measure of efficiency on a hot day—of 10.[10] The higher tier was EER 12, with slightly higher values for part-load efficiency. Since then, the average efficiency of commercial air conditioners has steadily increased, driven by progressively higher incentive tiers and progressively higher building code and federal minimum efficiency standards. The next federal minimum standard was finalized recently and will average about 14 IEER (Integrated EER, a part-load value, but somewhat different from the one used in the 1990s).[11] Thus, by 2023, the market will have largely transformed to exceed what in the early 1990s was a "reach" target. Efforts to promote even higher efficiency levels continue, as discussed further in the new initiative section of this paper.

Not all market transformation initiatives are successful. For example, while quality installation and high-performance schools have had some successes, for the most part neither market has been especially transformed. The same applies to heat pump water heaters (discussed in Appendix C), duct sealing, ground-source heat pumps, and motor management (all discussed by Nadel et al. 2003). In the next section, we elaborate further on why some initiatives have been successful and others have not.

Analysis and Discussion

Our research shows clear examples of successful transformations of markets for energy efficiency products, technologies, services, and behaviors. The experience gained from a variety of market transformation programs reveals many key lessons that are important in looking ahead to potential new programs and target markets. In this section, we identify

[10] We use the value for equipment with a cooling load of 65,000–135,000 Btus per hour. We believe, but were not able to confirm, that the same values applied to equipment with a capacity of 135,000–240,000 Btus per hour.

[11] This is the value for equipment with a non-electric heating section and a cooling capacity of 125,000–240,000 Btus per hour. The distinction about type of heating system was added in the early 1990s.

and discuss these lessons. We also draw on comments and observations made by the experts we interviewed as part of our research.

IMPACTS ON DIVERSE REGIONAL AND NATIONAL MARKETS

Markets for most products and services are regional and national. Manufacturers and suppliers work at this scale, and so should market transformation programs. It takes coordination among multiple states and regions for key elements of market transformation, such as branding and marketing campaigns, to be successful. On the other hand, there have been a few cases where market transformation has occurred at the state level, such as with high-efficiency natural gas furnaces in Wisconsin.

Diverse markets have been targeted for transformation. These include:

- Mass markets for inexpensive, common household goods (e.g., light bulbs)
- Mass markets for major appliances (e.g., clothes washers)
- Markets for major residential mechanical equipment (e.g., quality HVAC installation, ductless heat pumps, gas furnaces, and heat pump water heaters)
- Markets for major residential building supplies (e.g., ENERGY STAR windows)
- Commercial building markets (e.g., new construction and leasing)
- Building design and construction practices (e.g., high-performance schools)
- Commercial building operations (e.g., BOC training)
- Industrial equipment (e.g., premium efficiency motors)

Such diversity demonstrates the flexibility of market transformation as a strategic program model. Market transformation is not just about targeting mass consumer markets; it has been applied to professional practices, industrial products, building supplies, human behavior, and commercial building markets. Illustrations include the quality installation of HVAC, Building Operator Certification, and LEED buildings.

Some of the examples of market transformation we selected and examined in this research have been largely successful, as evidenced by key market data. A couple of programs are still relatively new; early signs in these cases are positive, but ultimate success cannot yet be determined. Here are selected data for each example that summarize market impacts:

- *Residential CFL and LED lamps*. Since 2009 the number of LED lamps installed has grown from 400,000 to almost 20 million.
- *Clothes washers*. By 2006 ENERGY STAR clothes washers had reached 38% market share; in 2015 penetration was 50%.
- *Quality installation of HVAC*. In the Midwest a total of 2,235 contractors had been trained and more than 31,000 installations had been processed through 2015 in MEEA's QI program. In 2006 the industry's trade association, ACCA, created industry standards that have been the basis for QI programs in several states and regions.
- *High-performance schools*. More than 300 high-performance schools across the United States have been built, and 300 more are underway. Standards based on the CHPS are in place in 12 states.

- *ENERGY STAR windows*. The market share of ENERGY STAR windows in the Northwest grew from about 15% to 66% in three years and has become the baseline for efficiency programs.
- *Heat pump water heaters.* A program led by NEEA is still relatively new; the alliance has worked with 93 distributor companies and provided training to 443 installation firms. This is an example of successful development of a resource acquisition program that over time may become a market transformation program.
- *Building Operator Certification*. More than 12,000 building operators have been certified through the BOC program.
- *LEED buildings*. Currently 2.5 million people in the United States work in LEED-certified spaces, which represents 2.8% of all workers in commercial buildings in 2012. In 2014 the US Green Building Council (USGBC) reported that LEED had certified three billion square feet of construction space, about 3.4% of the total commercial building space in the country.
- *Ductless heat pumps*. While this is still a relatively new technology, the market share for this equipment has increased from zero to about 13% in the Northwest over five years. A significant market is developing beyond that, subsidized by utility programs.
- *Premium efficiency motors*. Federal standards now require most motors on the market to be premium efficiency units.

KEYS TO SUCCESS

National/Regional Scope and Coordination

The successful market transformations we profile in this report and review in the literature all have had involvement and leadership provided by regional and/or national organizations. Regional energy efficiency organizations, notably NEEA and NEEP, have been market transformation pioneers. 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 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 some degree to support market transformation.

While California is not part of any of these regional groups, the size of the state and its markets makes it virtually its own region, as evidenced by its ability to influence national markets. California utilities, their regulators, and key stakeholders have worked as a strong statewide market transformation organization in many respects. In 2015 California Senate Bill 350 was passed. This law requires the California Energy Commission (CEC) to establish annual targets that will achieve, by 2030, a cumulative doubling of statewide energy efficiency savings and demand reductions in electricity and natural gas end uses. To achieve this, an analysis prepared for the CEC specifically notes that market transformation must be part of the portfolio of programs and related initiatives (Jones et al. 2017).

The state of New York has been similar to California in functioning like a regional organization to advance market transformation. In each of these cases, there are regional-scale markets within state boundaries.

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

One national program merits special mention for its role in market transformation. The ENERGY STAR program run by the US EPA and DOE has led efforts for a wide array of products to be labeled as energy efficient. ENERGY STAR has become widely recognized by consumers as the label for energy efficiency, distinguishing products in given markets as the most efficient. One expert interviewed commented:

> 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, which typically include manufacturers, distributors, retailers, trade groups, professional organizations, utilities, environmental advocates, and consumer groups. As discussed above, typically there is a single regional or national organization that leads and coordinates market transformation among such groups. A regional or national scope also is important to attract the interest of key market actors, stakeholders, and program administrators. The target for any initiative needs to be realistic, but it also must be aggressive and large enough to achieve a significant market impact.

Effective collaboration for market transformation also requires a common vision for successful outcomes. Each stakeholder group needs to see clear benefits to its own objectives from collaboration on a given market transformation initiative. Effective collaboration also requires gaining the input, active participation, and support of all major actors. Some experts 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, typically big-box retailers have one or two people responsible for making product decisions. Reaching them and persuading them to change products will have a large impact on the market because manufacturers will build what the big retailers request. An 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 emphasized in key literature and by the experts we interviewed, 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 such identified problems—not just one or some of them.

Quantification of the market is a key part of market understanding. To measure 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 the baseline.

Success in the market often happens when efficient products and services can be successfully differentiated in the eyes of purchasers 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 take time, including market research, establishing a baseline, developing a logic model, creating a key stakeholder collaborative, working with market actors, intervening in the market, and evaluating 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 likely will lead to failure of an initiative. In some cases (e.g., lighting, furnaces, televisions), measures provide cost-effective annual savings within a couple of years to help sustain the initiative. But often it takes longer to get to the point where there are significant annual savings.

Gaining a long-term commitment is a major challenge for market transformation. As we found in our current and past research (Nadel et al. 2003), such a commitment is key to successful outcomes. There is a clear correlation between the level of effort and progress toward market transformation. In some cases, the key groups leading and coordinating a

market transformation effort have been able to make such long-term commitments. This has been 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 NYSERDA's market transformation efforts with long-term funding commitments. In cases where regulators are the key decision makers affecting utility program spending, budgets and performance criteria may have to be established specifically for market transformation programs. California has used this approach.

A Structured Process and Multipronged Effort

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

The complexity of market transformation also generally demands a multipronged effort. Most of the 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 from the perspective of program participants. The benefits to them should be clear and participation simple; the complexities of the program should be invisible to participants.

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 promote and increase 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, 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 energy-efficient products and services targeted for transformation initiatives also 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. These 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. This can expand the reach of a market transformation initiative 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 tied to more local conditions and markets. For example, ductless heat pumps are better suited to certain climates. National and regional platforms can also provide turnkey marketing elements for more localized programs to incorporate into their program designs. For example, many utilities participating in regional market transformation initiatives have relied on such regional marketing platforms to promote products and services to their customers.

Professional certifications may not be seen as marketing, but they have been key elements of market transformation programs targeting professional practices, such as quality installation of residential HVAC and BOC. Such certification gives individuals a professional credential to distinguish themselves and becomes a market differentiator for 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 credibility and recognition of the benefits of a selected product or service. 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 American market was surprising (Paton 2004; Peloza, York, and Paulos 1999). The Neptune was a premium product with a corresponding price premium over most conventional, vertical-axis clothes washers. Despite this, there was high demand for the product—even waiting lists for customers. Manufacturers and organizations involved in market transformation had to adapt plans accordingly—changing marketing, product development, and incentives.

Programs also have had to respond to weak consumer responses to product introductions, such as heat pump water heaters. In this 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 performance and quality problems early in their introduction. 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:

- Developing codes and standards; examples include standards for clothes washers, motors, and windows
- Increasing the qualification levels for a product, 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 seek to reach a point where interventions can be substantially reduced or withdrawn. However there may be some need for continued engagement. More limited market support may be required as well as periodic monitoring of market developments to track progress and watch for any backsliding of desired market impacts. It now is more common to talk about transition strategies than about exit strategies.

Codes and Standards

Codes and standards often are important components of market transformation and may also be viewed as the endpoint or exit strategy for many market transformation 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 endpoint for all market transformation initiatives, however. Some technologies and practices do not lend themselves to code or standard requirements. Furthermore, as discussed above, market transformation in some cases can be more of a continuum or a series of efficiency stair steps than a process with a clear ending point. In some markets, there may be technological progress or other developments that create room for advancements after adoption of initial program targets in codes and standards. In these cases, requirements established by codes or standards may need to be adjusted periodically to reflect higher performance levels or other significant advances in the market. This is, in fact, the process for most building codes and equipment standards.

One expert invoked a colloquial expression often heard within 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 performance of a product or technology. Market transformation is not just about raising the

floor, but also about moving markets forward more quickly to the next generation of efficient technologies.

CHALLENGES

Role of Regulators and Policymakers

Regulators and other policymakers may strongly influence market transformation. This influence is positive when they back market transformation and provide support and flexibility for utilities and related organizations either engaged in or administering programs. It is negative when they do not provide such support or possibly impede market transformation initiatives through various decisions and requirements placed on programs.

The traditional role of utility regulators is to control costs and ensure system reliability, not to transform markets for energy-efficient products and services. A commission that strictly focuses on its traditional role may not support utility expenditures and engagement for market transformation. Such a commission may not want to finance an initiative whose benefits are multiple years in the future or may not believe that these benefits extend beyond reliability. As a result, utilities and regulating bodies lag behind market transformation efforts in many states. Such lack of regulatory support can inhibit progress in transforming markets. Regulators tend to take a traditional view of what energy efficiency programs look like—generally resource acquisition. The challenge noted by experts we interviewed is to get regulators to see the value of the broader efficiency gains possible through market transformation, gains that result in lower customer utility bills along with other benefits.

Although resource acquisition is a closer fit than market transformation to the traditional role of regulators and the objectives of utility regulation, the ability of resource acquisition to meet the challenges posed in today's markets is uncertain. The resource acquisition program model was built during a period when the large energy efficiency gains possible justified high program costs, including those for comprehensive program evaluation and technical measurements of savings. The savings gains that have been achieved in many markets generally mean that the remaining savings opportunities are much smaller than before. Resource acquisition alone may be insufficient to capture these savings. Market transformation can complement resource acquisition approaches or provide a complete alternative for selected markets. Market transformation approaches may become more vital to achieving and sustaining high energy savings through energy efficiency programs.

Cost-Effectiveness Testing

A specific regulatory challenge for market transformation is requiring such programs to pass the same cost-effectiveness screening designed for resource acquisition programs. The longer duration and lagging impacts that typify market transformation make it more difficult to assess cost effectiveness if the commission creates an accountability framework based on year-by-year savings. Market transformation benefits may be diffuse and not realized for several years, while the up-front program costs can be substantial. Consequently, market transformation programs may have difficulty passing the commonly used cost-effectiveness tests.

Past success with market transformation also can create a challenge for the cost effectiveness of new initiatives. The ramping up of codes and standards over the past decade or more raises baseline performance of the product or technology. This clearly is a positive outcome for advancing energy efficiency. However it also means that the efficiency gains that remain to be captured generally are smaller than what was possible earlier from less efficient baselines. This can make it difficult for new market transformation initiatives to be cost effective. Some might see this situation as a sign that no more intervention is necessary or desirable. However there typically remain further advancements in efficiency that may yield significant long-term benefits relative to costs if an initiative is carefully structured to work cost effectively.

Markets Resistant to Transformation

Markets that are difficult or resistant to transformation toward energy efficiency may be that way due to inherent characteristics of the products or technologies. They may be expensive (as has been the case thus far for heat pump water heaters), or there may be split incentives for purchasing them (as in multifamily buildings). In other cases, the market may be too small or composed of too narrow a group of players.

The retrofit market for both residential and commercial buildings has been particularly challenging. Whole-home and whole-building retrofit programs (especially residential) have struggled to find scalable designs and approaches. Progress has been made in the design and performance of these programs, but overall their results have fallen far short of the potential and the need. The primary barrier is that few home and building owners are willing to make major investments solely for the sake of energy efficiency. Most owners have higher priorities, especially since the cost effectiveness of whole-building retrofits is generally low due to high up-front costs and a correspondingly long payback period. Other barriers include:

- The low-tech nature of the market (roof insulation is not as appealing to consumers as rooftop solar panels)
- The industry and customers are very diverse
- The product (a weatherized and well-insulated home) is expensive and slow to install
- Many of the benefits of a weatherized home, such as improved comfort and health, are not known to potential purchasers

Commercial Property Assessed Clean Energy (PACE) is another market transformation effort that has made only modest progress .[12] An expert familiar with this market observed that there have been few deals relative to the investment of time and money that has gone into it. PACE has had mixed results. Success appears to depend on its structure and administration. Part of the challenge is that PACE can be very complicated, which requires a

[12] PACE is a financing instrument for implementing energy efficiency and renewable energy projects. In its most basic form, PACE enables property owners to finance up to 100% of the up-front cost of clean energy projects through a voluntary assessment on their property tax bill. The funds for financing PACE can come from the local government that enables the program, or, more commonly, they can be provided by a third-party financier.

great deal of coordination and work with the many parties involved. Also, PACE offers a type of financing that only some property owners are interested in; for the remainder, other approaches are needed.

Although relatively uncommon, efforts to transform residential real estate markets via home energy ratings have also not been very successful. Home buyers base their purchasing decisions on a large set of 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. Home energy ratings themselves have sometimes been barriers due to implementation problems and generally are not supported by realtors.

One expert interviewed who was familiar with quality HVAC installation programs (included earlier as a case study) raised some questions about these programs' success. This person commented that quality installation is proving to be a challenging market to change because it is not a product but behavior. It requires thousands of contractors to change the way they size and install equipment. The industry has a high turnover, and customers face time constraints for purchases. Other contractors can undercut those doing quality installation, and customers would not know the difference.

Air and duct sealing, too, has been resistant to market transformation. About 15 years ago various parties tried to create a market based on trade allies for duct and air sealing of homes. There does not seem to have been a compelling enough business proposition for the market to grow. The difficult required contractor practices made it hard to be cost effective.

OPPORTUNITIES

Promising Markets for Transformation

Earlier we identified the characteristics of markets best suited for transformation. As products and technologies change, new opportunities may arise. There also are existing markets that may be promising candidates but have not yet been targeted for transformation. While we did not conduct an exhaustive search to identify a large set of promising markets for transformation, we did identify several that hold potential or may already be in the early stages of market transformation. These include:

- Strategic energy management
- Smart thermostats
- Advanced variable-speed commercial and residential air conditioners
- Zero net energy buildings
- Amorphous core distribution transformers
- Electric vehicles

STRATEGIC ENERGY MANAGEMENT

Strategic energy management (SEM) is a workforce education, training, and organizational change program. SEM creates structure that facilitates discovery and ensures a systematic and continual effort to improve energy use in large commercial and industrial facilities. The majority of SEM programs are implemented by utilities in the northeastern and northwestern parts of the country. In the Pacific Northwest, a collaborative of practitioners

formed to share best practices and resources. Key members of the Northwest Industrial Strategic Energy Management Collaborative are NEEA, Bonneville Power Administration, Energy Trust of Oregon, CEE, and several utilities and service providers. The group meets regularly to discuss strategies for implementing SEM programs and how to perform measurement and verification. Programs in the Northwest, like others around the country, have historically focused on medium-size industrial facilities, although more recently they have been expanding into commercial and institutional facilities. Programs are also including implementation and training on energy management information systems (EMIS), which enable the automated recording, analyzing, and tracking of energy savings. Utilities up and down the West Coast and in the Midwest are also rolling out SEM programs, and there are promising developments for SEM programs in the mid-Atlantic.

CEE has published a couple of reports that qualify and quantify the details of SEM programs. It also is facilitating development of SEM through communications and meetings among its member organizations. An outcome of the SEM Summit at the 2017 ACEEE Summer Study on Energy Efficiency in Industry was an action item to determine if there is a need and support for a national collaborative effort among SEM program implementers and stakeholders. For SEM to succeed, industries will need to see it as a profit center, enmesh it within their overall management approach, and remain committed to its implementation.

SMART THERMOSTATS

Smart thermostats---also called learning thermostats—are the next generation of controls for residential HVAC systems. They differ from traditional programmable thermostats in their ability to record people's temperature preferences, identify living patterns, and use that information to predict future behavior and optimize performance. They also can provide alerts to extreme weather, HVAC problems, or required maintenance. With two-way connectivity, smart thermostats also can communicate with electric utilities and respond to requests to decrease energy use during times of peak grid load. Such connectivity also can be used to control household systems to take advantage of time-of-use pricing.

The number of smart thermostats has grown rapidly since the technology first entered the market. In 2015 the market share of smart thermostats was 40%, and it was expected to reach 50% in 2017. This market is well poised for market transformation, gaining much of this momentum on its own—although many utility programs promote and offer incentives for smart thermostats and may accelerate the change. The product is attractive to customers for its ease of use and for improving home comfort. At the same time, utilities can benefit from its capabilities for demand response and increased energy efficiency. It is a relatively low-cost product with high-tech appeal.

ADVANCED VARIABLE-SPEED COMMERCIAL AND RESIDENTIAL AIR CONDITIONERS

As discussed previously, efforts to promote high-efficiency commercial air conditioners contributed to a new federal minimum efficiency standard taking effect in 2023 that will result in an average efficiency for commercial packaged equipment of about 14 IEER. However even higher efficiencies are possible and available. In 2011 DOE began the Rooftop Challenge, a program that encouraged manufacturers to develop new models reaching at least 18 IEER and also meeting several other criteria (DOE 2012b). To achieve these higher efficiency levels required optimization of compression staging and use of modulation on the

indoor fans (R. Lord, fellow, Carrier Corp., pers. comm., September 19, 2017). To date, two major manufacturers, Daikin and Carrier, have developed a product line of complying rooftop units (RTUs), and three other manufacturers are working to follow suit (Advanced RTU Campaign 2017a). These efficiency levels are contained in the Advanced efficiency tier published by CEE (CEE 2016a). However sales of these models have been slow due to their higher prices and to the fact that these units often require roof modifications to fit where existing less-efficient air conditioners were located (Wang and Katipamula 2013). Likewise, variable-speed residential air conditioners are also on the market, typically with seasonal energy efficiency ratios (SEERs) of 18 and above, but these also have limited sales due to higher costs.

Strategies are needed to build the market for both commercial and residential variable-speed systems, helping to generate economies of scale and lower costs. Such strategies also need to find ways to address the roof modification issue for existing commercial buildings and to promote the increased comfort and other benefits of variable-speed systems. DOE has begun such an effort for the commercial sector, the Advanced RTU Campaign (DOE 2017c). Still, much more is needed.

ZERO NET ENERGY BUILDINGS

With advances in energy-efficient technologies and construction practices, zero net energy buildings and homes (ZEBs) and near-zero net energy buildings are becoming a realistic and affordable option for new construction. To date, more than 6,000 new homes and 200 new commercial buildings have been constructed and are operating as ZEBs, and many more have the potential for zero net energy with the addition of renewable energy systems (NBI 2016; Net-Zero Energy Coalition 2015).

A number of programs are now promoting ZEB construction with technical guidelines; outreach and training for builders, developers, and the construction trades; incentives; and other activities. DOE's Zero Energy Ready Home (ZERH) program provides specifications and guidance to residential builders to ensure construction of safe, healthy, and durable solar-ready homes that can achieve zero net energy performance with the addition of a photovoltaic system. The ZERH program works directly with the building industry and is also being promoted through utility and other customer-funded programs in conjunction with incentives, promotions (including competitions), and other activities. In the commercial sector, programs are supporting the integrated design process that is key to achieving ZEB goals. Training and educational opportunities for local design firms, builders, and other trades are offered to accelerate the shift to ZEB. These initial program initiatives are increasing the number of ZEBs in a handful of states, particularly in the Northeast, on the West Coast, and in Colorado. Broader market transformation efforts could move ZEBs into the mainstream in these states and expand their reach across the country. ZEBs may transform markets incrementally by influencing building codes over multiple cycles as various technologies become economical and accepted practice.

AMORPHOUS CORE DISTRIBUTION TRANSFORMERS

Distribution transformers are used by utilities and medium to large commercial and industrial customers to reduce distribution voltage to the voltage used in homes, buildings, and factories. Transformers consist of a steel core with many wraps of copper wire around

it. More efficient transformers use low-loss metals in the core and more copper wire. The most common types of distribution transformers are subject to minimum efficiency standards established by the DOE, which have eliminated low-efficiency designs from the new equipment market. However higher-efficiency transformers are available, particularly units using amorphous metal cores, which typically reduce core losses by 50–70% compared with the much more common steel cores (DOE 2011, see Engineering Analysis).

Some utilities and large customers in the United States have purchased amorphous core transformers, but these probably represent only a few percentage points of total US transformer sales due to a variety of market barriers. These include higher costs, resistance from steel manufacturers, the fact that the costs of transformer losses are generally passed on to all utility ratepayers and not absorbed by the utility, and lack of attention to transformer losses by most state regulators. Amorphous core sales appear to be higher in countries like China and India than in this country, although sales are higher in a few jurisdictions (e.g., the District of Columbia and Maryland) where lawmakers and regulators have paid attention to transformer efficiency (D. Millure, senior vice president of sales and marketing, Metglas, pers. comm., September 27, 2016). A market transformation initiative could help spread these practices to other states. In addition, EPA is working on an ENERGY STAR specification for distribution transformers; if this effort is completed, it could be another element in a market transformation initiative (ENERGY STAR 2016). Finally, test procedure changes are needed; the current test procedure for most utility transformers assumes that transformers on average are operated at 50% of full load when the actual average is likely closer to 35% (DOE 2013a). At high assumed loads, core losses become less important.

ELECTRIC VEHICLES

Electric vehicles (EVs) are an entirely new type of product for consideration in a market transformation context. No market transformation programs to date have targeted any transportation technologies or markets. Electric vehicles also represent a fundamental fuel switch that will increase electricity use while reducing gasoline or diesel fuel consumption. This market is growing quickly on its own. Most analysts project even faster growth as momentum builds in the market and the technology becomes well accepted by consumers. According to one analyst, the US electric vehicle market experienced an annual growth rate of 32% between 2012 and 2016 and was reaching 40% midway through 2017 (Lambert 2017). As utilities and stakeholders examine such efforts as beneficial electrification and expansion of distributed energy resources, EV growth may accelerate. For this to happen, there needs to be infrastructure in place to support this market, primarily a convenient network of charging stations. Programs could also support EV growth through rate structures to optimize charging times relative to daily power demand cycles. Customer and midstream or upstream incentives also could be used to promote EV sales.

Conclusions and Recommendations

Market transformation has established a strong legacy and continues to offer an effective program model to achieve further advances in markets for energy-efficient products, services, and behaviors. Our review of 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 these markets due to strategic interventions by numerous stakeholders over long periods. Such products faced numerous barriers in US markets and eventually overcame them through a variety of interventions. Absent such interventions, it is doubtful that these markets would be where there are today, with dominant shares of these energy-efficient products.

As we look to new opportunities for market transformation, there are two broad categories that hold the greatest potential. First, there are markets undergoing transformation that are not yet to large scale. As shown in our case studies, promising market transformation is occurring in quality installation of HVAC, high-performance schools, and ductless heat pumps, among other markets. Program administrators should continue to be engaged in these markets and support transformation initiatives to build on initial successes and grow to large scale. While promising, the untapped potential in these markets remains large due to their sheer size.

Second, market transformation approaches also are promising for reaching underserved markets. New and emerging research on participant demographics is demonstrating low participation rates among certain groups of eligible consumers. If markets can be transformed, even hard-to-reach customers will find mainly efficient products and services when they shop. Market segmentation can be helpful to target and engage specific customer groups that have been difficult to reach. It also will take innovative approaches to market transformation in order to reach and serve these customer segments because of the larger barriers they face for implementing energy efficiency measures. While market transformation has achieved significant success as a program model, it is not appropriate in all situations and therefore will need to be complemented with other approaches.

We see several top priorities for policies and actions to support existing and future market transformation initiatives. Facilitating regulatory reforms that would increase support for market transformation is especially important. Some of the biggest barriers to more widespread market transformation have been issues stemming from utility regulation, such as restrictive cost-effectiveness screening and short funding periods (three years or less). Part of addressing regulatory barriers is the need to increase education and outreach to key stakeholders and decision makers, such as regulators, on the benefits and results possible from market transformation. In conjunction with effective education and outreach, it is important to continue to measure, evaluate, and document results from market transformation programs. It is vital to be able to tell the stories of successful market transformation to policymakers and decision makers in ways that are convincing. There also is a growing opportunity to establish linkages between market transformation and transformation of the electricity industry through such advances as smart technologies and distributed energy resources, as well as the development of new utility business models that may be more supportive of customer energy efficiency than traditional models.

In looking to the future of market transformation, there are a number of efforts needed to support existing programs and create new ones. Such supportive efforts include research on new opportunities for market transformation—promising new energy efficiency products,

technologies, and services. Such research may include demonstration projects and pilot programs. Programs also need to continue to lock in efficiency gains by supporting enactment or upgrading of building codes and appliance/equipment standards.

Changes in markets have required new ways of thinking about energy efficiency. Market transformation is 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 meet this latter set of challenges for products, as well as to change professional practices and human behavior.

To fulfill the potential for a more energy-efficient economy will take daring initiatives. Market transformation experience demonstrates that strategic market interventions targeting improvements in energy efficiency can successfully change some markets to meet ambitious energy savings goals. We are reaping the benefits of such efforts and can point to many energy-efficient products and technologies whose ready availability today has resulted from past market transformation programs. The potential and need for continued transformation of markets for energy efficiency products and services remains high. Market transformation is a proven program model for reaping this potential and responding to the continued need for improving energy efficiency wherever energy is used.

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Appendix A. Definitions of Market Transformation

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

> 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).

Nevius et al. (2013) offer this definition of strategic market transformation, a subset of market transformation, based on the work of Prahl and Keating (2011):

> Strategic market transformation is a program approach that uses "the tools of market transformation to make a deliberate and rigorous effort to intervene in [a targeted], clearly defined market. " Strategic MT programs are *expected* to have market-transforming effects. Strategic MT acknowledges that not all markets are transformable and allows for the tactical incorporation of other programs in the effort to change the target market.

As a final definition to illustrate the fundamental tenets of market transformation, the State of California defines it as:

> long-lasting, sustainable changes in the structure or functioning of a market achieved by reducing barriers to the adoption of energy efficiency measures to the point where continuation of the same publicly funded intervention is no longer appropriate in that specific market. Market transformation includes promoting one set of efficient technologies, processes, or building design approaches until they are adopted into codes and standards (or otherwise substantially adopted by the market), while also moving forward to bring the next generation of even more efficient technologies, processes, or design solutions to the market. (CPUC 2009)

The definition of market transformation has remained fairly stable since it was first coined in the early 1990s. A couple of experts did note, however, that some stakeholders and decision makers hold somewhat different perspectives on market transformation. One expert commented that to many, "market transformation still suggests utility programs," while another expert noted that the standard definition does not really address "organic technological advances," those that arise apart from any interventions and do not necessarily involve products and services other than those addressing energy efficiency.

One expert commented, "The components of market transformation as first defined are just as relevant today as when we first formalized them." Another echoed this observation, saying, "The definition has changed very little, although it changed for a period, then came back." This expert added, "The biggest change is that market transformation is not a one-time intervention but a continuous involvement."

One expert simply noted, "Market transformation is a tool in a toolkit." Another commented on the importance of including building codes and building transparency laws as elements of market transformation.

While definitions of market transformation among industry insiders have not changed, there remain misperceptions and lack of understanding among broader stakeholders and newer entrants into the field. As one expert commented, "If you asked 99% of state regulators, they wouldn't have a clue what market transformation and energy efficiency means. There is a need to inform and educate."

Appendix B. Market Transformation and Resource Acquisition

The market transformation program model is viewed as the principal alternative to resource acquisition, which is a program model grounded in utility demand-side management. The term itself arose in conjunction with the development of market transformation as a way to distinguish these two primary program models for energy efficiency. The main objective in resource acquisition is to achieve energy savings from improved energy efficiency; no explicit effort is directed toward causing fundamental changes in markets. The focus for resource acquisition is individual customer savings on a relatively short time horizon—often year by year within a 1- to 3-year program cycle.

Table B1 presents a framework from Keating (2014) for the distinctions between resource acquisition and market transformation; our additional comments are in parentheses.

Table B1. Distinctions between resource acquisition and market transformation

	Resource acquisition	Market transformation
Scale	Program (typically a utility service territory within a single state)	Entire defined market (typically statewide, regional, or national)
Target	Participants (utility customers)	All consumers (within the defined market)
Goal	Near-term savings	Structural changes in the market leading to long-term savings
Approach	Save energy through customer participation	Save energy through mobilizing the market
Scope of effort	Usually from a single program	Results from effects of multiple programs or interventions
Amount of program administrator's control	Program administrators (PAs) control the pace, scale, geographic location, and can identify participants in general	Markets are very dynamic, and the PAs are only one set of actors. If, how, where, and when the impacts occur are usually beyond the control of the program administrators
What is tracked, measured, and evaluated	Energy use and savings, participants, and free-ridership	Interim and long-term indicators of market penetration and structural changes, attribution to the program, and cumulative energy impacts
Time frame for cost effectiveness	Usually based on first year or cycle (program period) savings	Usually planned over a 5- to 10-year time frame

Source: Keating (2014)

While resource acquisition and market transformation are formulated as distinct approaches to advancing energy efficiency, in practice there is often crossover. Resource acquisition

programs may support broader market transformation objectives. For example, incentives paid to customers can increase demand for energy-efficient products as part of wider, integrated market transformation initiatives. The transformation of markets for high-efficiency residential lighting products (first CFLs and now LEDs) and horizontal-axis clothes washers can be partially attributed to utility resource acquisition programs that promoted and paid incentives for these products.

The same can be seen for commercial lighting. Most of the programs in this market have been utility resource acquisition and have delivered high energy savings. They also have played a leading role in transforming these markets.

Tension and misunderstanding still exist between market transformation and resource acquisition. One expert commented:

> Market transformation often is shoehorned into resource acquisition, which is an uneasy fit due to the resource acquisition frameworks. Many programs are forced to share two objectives; in some cases there are market transformation efforts that are then held to resource acquisition standards, such as evaluation.

Another distinction is that market transformation is more flexible and adaptable. Such programs read and respond to market changes. Resource acquisition, on the other hand, tends to be much less flexible. Once such programs are initiated, they focus on the near-term savings from participating customers, not broader market effects. Market transformation at its core requires "adaptive management," as one regional organization terms its approach. And this requires real-time evaluation, not the more typical ex-post evaluations performed for resource acquisition programs to determine program savings. As one expert said,

> Markets can shift in short amounts of time, so we need to pivot and adapt with them as soon as possible. . . . Resource acquisition is not as adaptable; market transformation is better suited to today's rapidly changing regulatory environment and transformation of the grid.

One expert posed a challenge for the future of resource acquisition and market transformation:

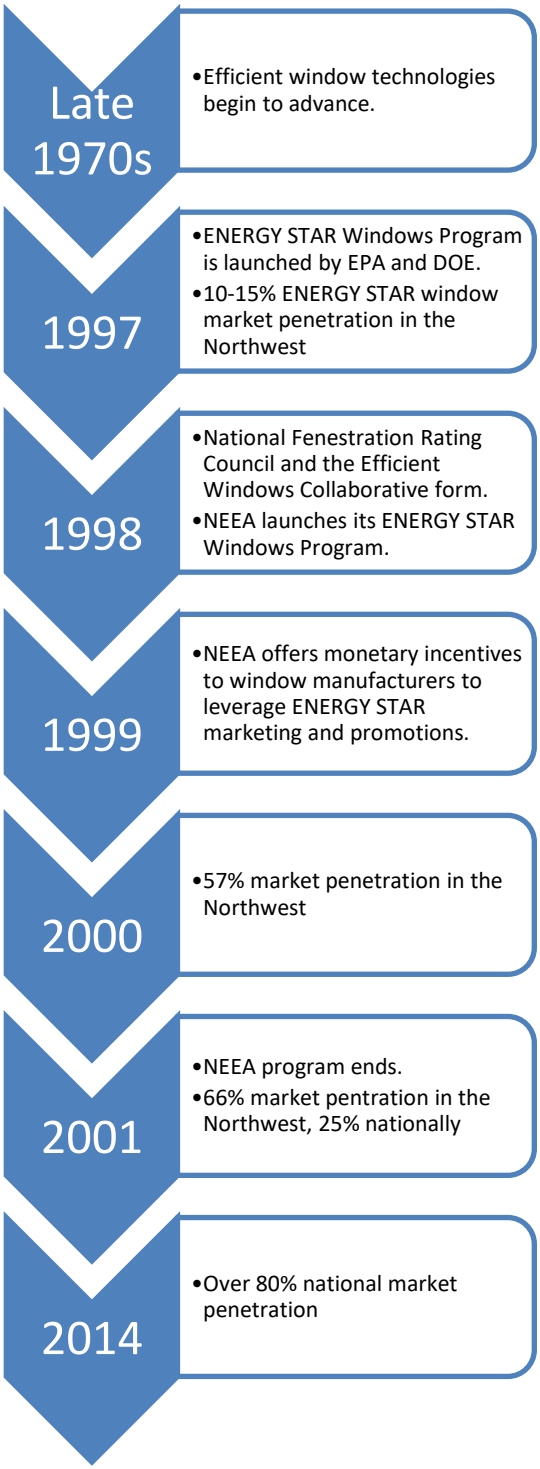
> The RA program delivery model that we have today was built around a time when we had big changes in efficiency that could justify the cost, which includes big overhead for program evaluation and technical measurements of savings. . . . The savings opportunities that are left are a lot smaller than before—the question is, can resource acquisition serve this new frontier?

From this perspective, market transformation approaches may become more vital to achieve and sustain high energy savings through energy efficiency programs.

Appendix C. Additional Market Transformation Case Studies

ENERGY STAR WINDOWS IN THE NORTHWESTERN UNITED STATES

In 1994, heating and cooling losses through windows were estimated to be responsible for 25% of heating and cooling costs in typical homes and 2% of total US energy consumption. At the time, researchers showed that with accelerated adoption of available technologies, this energy use could be reduced by a third (NEEA 2002). As new window technologies began to develop and mature, EPA and DOE launched the ENERGY STAR Windows Program to provide marketing opportunities for standardized efficient windows. The Northwest Energy Efficiency Alliance (NEEA) followed suit and launched its own market transformation program targeting the residential window sector. The alliance worked in Idaho, Montana, Oregon, and Washington between 1998 and 2001, with a goal to achieve 54% market share for ENERGY STAR windows in the residential new construction and remodel markets (NEEA 2002).



Market Barriers and Program Design

In 1998, NEEA launched its ENERGY STAR Windows Program to decrease initial cost premiums and increase brand and value awareness of efficient windows. In order to realize the large potential energy savings through efficient window adoption, the program needed to overcome these market barriers:

- High production costs and high retail prices
- Lack of educational and marketing materials
- Lack of awareness of benefits and availability of products
- Split incentives for stakeholders

NEEA carefully chose program implementers skilled in bringing together many market actors with these barriers in mind. In the first year of the program, the implementers began by working with manufacturers to develop new technologies for efficient windows, resulting in shorter production times, lower production costs, and thus, lower retail prices. The program focused on each piece of the supply chain. Implementers demonstrated to manufacturers how they could achieve greater market share and worked closely with window retailers to provide marketing trainings, kits, and financial aid to help them achieve higher sales margins and increase

orders to manufacturers. The marketing strategy was designed around simple and clear messages to communicate to consumers the energy and nonenergy benefits of ENERGY STAR windows.

Throughout the program, implementers engaged with stakeholders. This continuous feedback allowed the program to adapt to the changing needs of participants and to create value for each member of the supply chain. Table C1 provides further detail on the role of each market actor (Prahl and Keating 2014).

Table C1. NEEA ENERGY STAR Windows Program market actors

Market actor	Role played
Northwest Energy Efficiency Alliance (NEEA)	Leader of the ENERGY STAR Windows Program market transformation effort. Convened market actors and developed various aspects of the effort, including technical manufacturing assistance, training, and marketing aid.
National Fenestration Rating Council (NFRC)	Provided technical ratings for window efficiency on characteristics such as U-factor and solar heat gain coefficient. Brought uniformity to window ratings.
US DOE and EPA	Organized ENERGY STAR branding. Used NFRC ratings to educate consumers and provide recognizable efficient products to them.
Efficient Windows Consortium (EWC)	Group of manufacturers, researchers, labs, governments, utilities, and others. Filled an education and marketing gap and supported ENERGY STAR, NFRC, trade allies, and others.
Window manufacturers and retailers	Performed key implementation of program strategies, including production of windows, marketing, and signing industry partners to promote the products.
Utilities, building industry, media, and other partners	Coordinated on marketing activities and support for ENERGY STAR window use and promotion. Partnered with retailers to sign on to the project.

Program Impacts and the Market Today

The NEEA ENERGY STAR Windows Program is largely regarded as a great success, with an increase in market share in the Northwest from 10–15% to 66% in three years. In comparison, market share nationally grew from 17% to 25% (NEEA 2002). The program increased awareness of the ENERGY STAR brand to 100% of manufacturers and doubled awareness among builders. However there was not much growth in awareness among retailers. Additionally, the program reduced window production costs, and the percentage of builders who cited high costs as a reason for not installing ENERGY STAR windows fell from 84% to 41% (NEEA 2002).

The success of this program has been attributed to many factors, including the flexibility of implementation staff to adapt and create tailored marketing strategies for individual actors, and an approach designed to create competition among manufacturers. These strategies created clear value for each player, as evidenced by manufacturers investing more than $1 million of their own money on marketing for the program. The program also centered on small technological change that did not require manufacturing plant redesign. It focused on a small number of large players, including one very larger retailer and only six

manufacturers who held about 80% of market share. This later expanded to 12 manufacturers, covering 100% of market share. The program was also especially strong in evaluation, starting with a clear baseline and measuring progress throughout (Anderson 2012).

By 2011, market share had reached 95% in the Northwest and more than 80% nationally in 2014 (ACEEE and Alliance to Save Energy 2011; NEEA 2017). As of 2008, building codes in Idaho, Montana, Oregon, and Washington met the window specifications included in the market transformation effort. ENERGY STAR–qualifying criteria continue to become more stringent over time, such as with updates implemented in 2015 and 2016. Tax incentives for ENERGY STAR windows implemented in 2005 continued through 2016 to encourage the market to keep up with the increasing standards (ENERGY STAR 2017d). These factors indicate successful market transformation, and this case study presents many lessons for future efforts.

Looking Forward

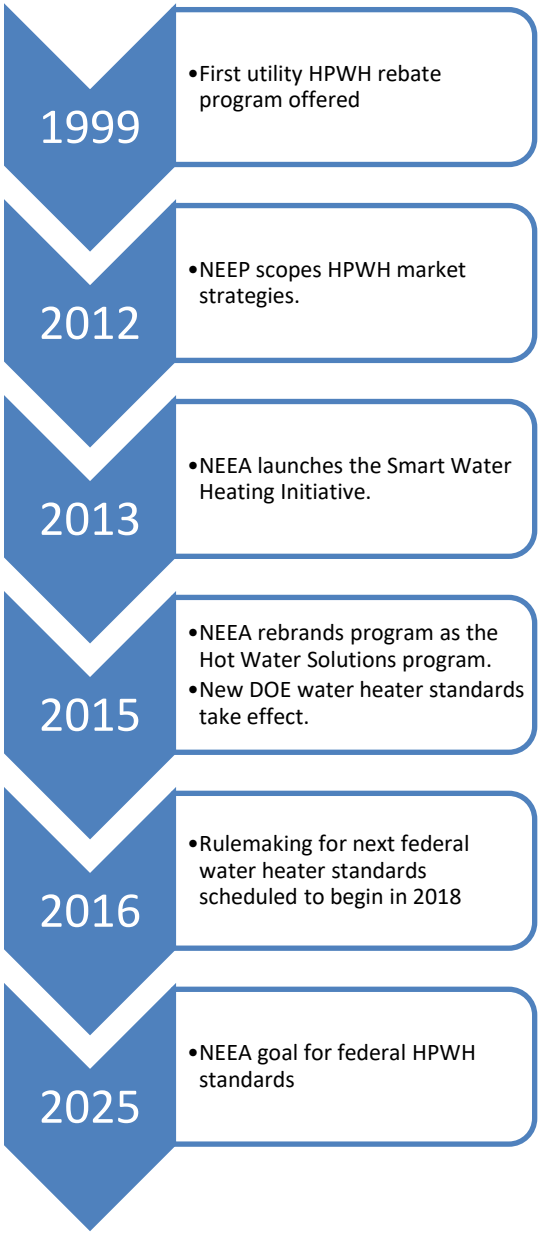
Given the high market share of ENERGY STAR windows—more than 80% in 2014 (NEEA 2017)—ENERGY STAR increased the stringency of the specification in 2015 for much of the country, and in 2016 in the north (ENERGY STAR 2014). The new specification continues to be promoted by DOE, EPA, and many other players. Market penetration data are not yet available for the new specification. Federal tax incentives for efficient windows (and many other products) expired at the end of 2016 (ENERGY STAR 2017f). These incentives were small, and it is unclear how much they influenced the market in recent years.

HEAT PUMP WATER HEATERS

Water heating systems are large energy users in residential homes. In 2016, water heating represented 9% of typical home energy use and was the second-largest energy user in the home (EIA 2017a). Homes with electric water heaters typically have electric resistance water heaters (ERWHs), which are only half as efficient as heat pump water heaters (HPWHs) (NEEP 2012). For a household of four people, HPWHs can save $330 and more than 2,600 kWh of electricity per year (ENERGY STAR 2017e). Heat pump water heaters 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. In other climates, such as the northern United States, these characteristics present technical challenges to increased market adoption. Efforts to transform the residential heat pump water heater market have had varying degrees of success across the country, providing good lessons for future efforts.

Market Barriers and Program Design

Utility programs to encourage the adoption of HPWHs 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 2016b). In addition to limited product availability, there were performance issues associated with what early product was available. DOE and EPA developed ENERGY STAR requirements for HPWHs, but most programs use a rating system called the Energy Factor to determine the level of incentive offered. Early HPWH programs were based on these first, unreliable products and were not successful (F. Gordon, director of planning and evaluation, Energy Trust of Oregon, pers. comm., October 30, 2017).



In 2012 and 2013, two regional energy efficiency organizations took on the challenge of broader market transformation for water heaters. The Northeast Energy Efficiency Partnerships (NEEP) researched the HPWH market and scoped plans to work toward a goal of having a federal standard in place for HPWH units of 50+ gallons by 2021 (NEEP 2012). However this program was never implemented, for unknown reasons. NEEA also launched a Smart Water Heat Initiative, which was rebranded as the Hot Water Solutions program in 2015. NEEA set a goal to assist in making HPWHs the default electric water heater and thereby reduce energy consumption in the Northwest. Going

forward, the group also aims to influence the 2025 federal standard for HPWHs above 45 gallons (NEEA 2015a).

Through these efforts, NEEP and NEEA both identified major market barriers to HPWH adoption. These included:

- Technical challenges, such as inconsistent performance across climate zones and increased home heating costs in cold climates
- High up-front cost relative to electric resistance water heaters
- Lack of distributor and contractor awareness
- Lack of consumer awareness stemming from a lack of branding and lack of desire to replace a functioning unit; invisibility of water heat as a utility

Both organizations designed programs to address these barriers. NEEP's program recommendations included engagement with a regional stakeholder group, designing new product specifications for cold climates, midstream training targeted at distributors and contractors, and an extensive consumer marketing campaign. NEEA developed a logic model with similar activities, including aiding in product development and verification (to develop a northern climate specification and qualified products list); providing training throughout the supply chain; and making products more available through engagement of market actors, reduced costs, and increased marketing. NEEA specifically partnered with a manufacturer to refine the product manufacturing process. This led larger players, such as General Electric, to get into the space and ultimately drove widespread adoption of the technology by manufacturers. This continued even after the original player and General Electric got out of the space due to limited success (F. Gordon pers. comm.). Currently the program offers upstream incentives to manufacturers to lower costs throughout the distribution channel. This works in conjunction with utility rebates offered directly to consumers. Table C2 outlines the market actors and the roles they played in transforming the heat pump water heater market.

Table C2. Heat pump water heater program market actors

Market actor	Role played
NEEA	Leader of the Smart Water Heat Initiative/Hot Water Solutions program. Currently offers manufacturer markdown incentives for HPWHs.
US DOE and EPA	Organizer of ENERGY STAR requirements and branding for all efficient water heaters (electric and gas).
Manufacturers	Developed and refined a complex new product after decades of unreliable products.
Installers	Provide quality installation and installer training, which are critical to customer satisfaction with HPWH purchases.
Utilities	Offer rebates to customers for HPWHs ranging from $100–$800+ per unit.
Builders, distributors, contractors (plumbers), and consumers	Buyers of water heaters through planned or emergency purchases or for the new construction market.

Program Impacts and the Market Today

The NEEA HPWH program is relatively new, and market penetration remains very low. On a national scale, water heating has not decreased as a percentage of typical home energy use since 2011 (EIA 2017a). Including utility programs outside the Northwest, most program administrators reported penetration rates between 0% and 0.15%; this likely underrepresents market penetration because it measures the number of units rebated per residential electric customer, which includes those who use natural gas for water heating (CEE 2016b). In 2015, NEEA counted 4,720 manufacturer markdowns and 2,081 utility incentives (customer rebates) for HPWHs in its region. Despite these low numbers thus far, there are many indications that NEEA's program is having a positive effect. NEEA has worked with 93 distributor companies and provided training to 443 installation firms. (The percentage of total distributors and contractors reached by the program is difficult to determine, as new contracting companies are frequently entering the market and others are closing.) Additionally, in 2015 about one-third of purchasers cited greater efficiency as the primary reason for their HPWH purchase (NEEA 2016). A $300 federal tax incentive has also aided in increased adoption of the technology.

Looking Forward

The challenges associated with HPWH market transformation programs offer insight into adapting current programs for further success, as well as developing effective programs in the future. HPWH programs began when the product was not yet ready, leading to failure and uncertainty. The challenges associated with developing a new product mean that early adopters may not experience success and that large manufacturers may not be interested in change until a market disrupter has taken a portion of their market share (F. Gordon pers. comm.).

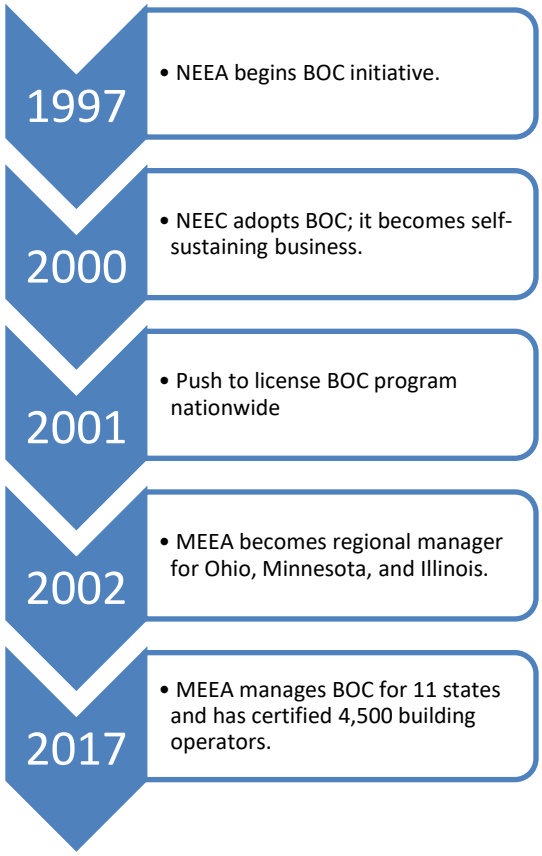
While buyers of HPWHs cite declining costs and utility rebates as very important factors leading to their HPWH purchases, the NEEA program has not overcome a few key market barriers. For instance, 83% of purchasers say the idea to buy an HPWH was their own, not something suggested by a contractor or installer (NEEA 2016). This indicates that midstream awareness is still low. Additionally, purchases of water heaters tend to be emergency decisions rather than planned purchases. This is important, as NEEA's program has faced challenges in reaching the emergency purchase market due to consumers' time and budget constraints under these circumstances. This underscores the importance of building awareness and support for HPWHs among contractors and other midstream actors. However planned purchases are on the rise, indicating that market transformation efforts may be having an impact on consumer awareness through increased marketing.

As these programs continue to grow, it is important to have a full market view before beginning. While NEEA's program has addressed one of the major market barriers to adoption (high up-front costs), the program has not yet overcome additional barriers such as lack of midstream and consumer awareness. For further success, programs should address all barriers rather than only some, include climate-specific units, and target homes where HPWHs are appropriate.

BUILDING OPERATOR CERTIFICATION

Commercial buildings require operators because their energy systems are complex and interdependent. The way an operator runs and maintains a building can significantly affect how much energy its systems use. This makes the operator's behavior important in achieving energy savings in the commercial market. NEEA established the first energy efficiency Building Operator Certification (BOC) to create a means for the market to adequately value and compensate those who learn to efficiently run and maintain a building.

NEEA launched its BOC initiative in 1997. In four years the program achieved 700 certifications and a 35% market awareness. In 2000 the Northwest Energy Efficiency Council (NEEC) adopted the program and developed it into a self-supporting business recognized throughout the United States. NEEC licenses the program to various associations to manage it at the regional level, and success is dependent on how these regional license holders run their programs. The Midwest Energy Efficiency Alliance (MEEA) is one of many regional managers transforming the market. MEEA demonstrates how dedicated regional management drives certification rates and energy savings and ultimately transforms regional markets.



Market Barriers and Program Design

MEEA is the primary license holder for 11 states. For each state, MEEA typically subcontracts the license to either state energy offices (SEOs) or investor-owned utilities (IOUs) (Pagnusat and Ehrendreich 2010). MEEA has three employees managing the BOC program, but most efforts are made at the local level in coordination with more than 50 local partners (M. Milby, program manager, and W. Baker, director of communications, MEEA, pers. comm., July 31, 2017).[13] Program implementation varies from state to state, but all are addressing the following challenges:

- Awareness
- Cost
- Developing an instructor pool
- Forming local partnership network

[13] Partners may include community colleges or IOUs, among others.

FORMING LOCAL PARTNERSHIPS

When MEEA rolls out the BOC in a new state, it first must overcome the lack of awareness for the certification. Typically, MEEA first tries to partner with the utility, which offers a direct marketing opportunity to building owners and operators (Pagnusat and Ehrendreich 2010). MEEA gains utility partners by explaining how certified building operators are more likely to suggest efficiency retrofits and participate in utility programs. MEEA also uses third-party energy savings evaluations to demonstrate that certification can help the utility meet its required energy savings from programs (Milby and Baker pers. comm.).[14]

REDUCING TRAINING COSTS

Beyond marketing, utility partnerships are key for providing incentives and lowering the cost barrier of BOC trainings (Pagnusat and Ehrendreich 2010). In MEEA's jurisdiction, the average course costs $1,695 (Milby and Baker pers. comm.). Fortunately, many states offer rebates, typically through SEOs or IOUs. A popular rebate structure is a reimbursement of 50% of the cost, contingent on the participant's graduating and completing a project that utilizes a utility incentive. This not only reduces the cost burden for operators but also ensures that the operators are applying their BOC training to implement energy efficiency projects.

QUALITY CONTENT AND INSTRUCTION

NEEC manages BOC content to ensure the quality is consistent across the United States.[15] However the quality of instruction depends on the regional operators who are responsible for recruiting instructors (Pagnusat and Ehrendreich 2010).[16] MEEA draws candidates from many fields and areas of expertise, but almost all instructors have prior teaching experience (Milby and Baker pers. comm.). MEEA sometimes forms partnerships with community colleges. These partnerships are beneficial as campuses have facilities to hold trainings and faculty to become instructors. Additionally, collaborating with community colleges helps the program gain exposure and credibility.

AWARENESS OF BOC

Local partnerships and quality instruction ultimately drive the awareness of BOC in a region (Milby and Baker pers. comm.). As programs are more established, word of mouth becomes the most commonly cited reason operators sign up for training. MEEA conducts surveys for each of its classes and asks participants how they heard about BOC. In one class, 40% of respondents said they heard about the program from a coworker and 32% from a utility representative (Milby and Baker pers. comm.). Word of mouth makes up the largest percentage because trained operators are more likely to have job satisfaction and get promotions (Friedrich et al. 2010).

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[14] These evaluations are difficult to obtain, as energy savings from behavioral programs are variable and more difficult to prove.

[15] NEEC manages a team of experts who review and update BOC curricula on a two-year cycle. NEEC also uses instructor and student feedback to inform improvements to the program.

[16] All instructors must submit applications to and be approved by NEEC.

Program Impacts and the Market Today

MEEA is one of 17 BOC program operators facilitating regional BOC programs. As of 2017, more than 12,000 building operators have become certified in 35 states (BOC 2016). NEEC reports that the average certified building operator saves 100,500 kWh annually (BOC 2017b). Over five years, this amounts to more than $10,500 in savings on energy costs.

Looking Forward

MEEA plans to continue promoting BOC in its 11 states. However in some cities it is evident that efforts have successfully saturated the market. Typically, these cities see high participation rates plateau and then decrease (Milby and Baker pers. comm.). In saturated markets, MEEA and local partners typically offer fewer training cycles a year and promote recertification.

Like MEEA, NEEA is increasing BOC rates in its region through its BOC Expansion Program. It conducts annual evaluations of the program and closely tracks market penetration rates. The latest evaluation, Report #3, estimates the current market penetration at 12%. These evaluations enable NEEA to closely follow program indicators, like market penetration and certification rates, and ultimately determine when a market becomes self-sustaining (NEEA 2015a).

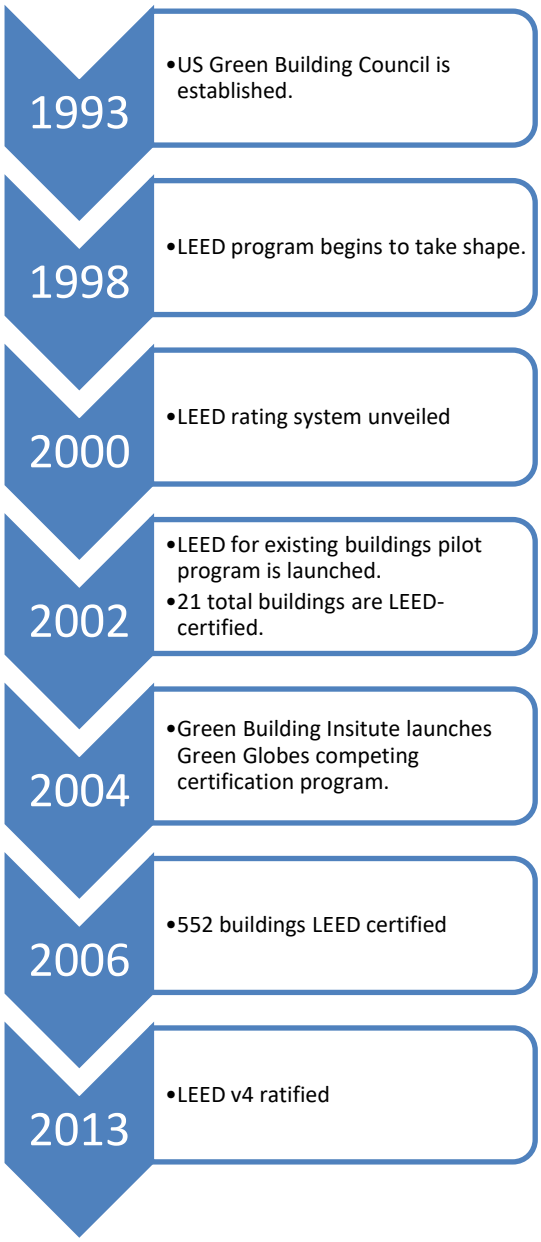
NEEC is continuing to expand the program to more states. In May 2017, NEEC announced it is partnering with the Southeast Energy Efficiency Alliance (SEEA) and Alabama Department of Economic and Community Affairs (ADECA) to expand the BOC program to Alabama (BOC 2017a).

LEADERSHIP IN ENERGY AND ENVIRONMENTAL DESIGN (LEED) BUILDINGS

Buildings account for 73% of electricity consumption in the United States (USGBC 2017). This offers high potential for increasing energy savings through efficiency measures both in the existing building stock and in the new construction market. In addition, the demand for green office space has been increasing in the United States (Ervin 2011). To meet this demand and take advantage of potential energy savings in the building sector, the US Green Building Council (USGBC) introduced the Leadership in Energy and Environmental Design (LEED) building rating system in 1993. This program aims to improve the efficiency of the building stock and transform the market for green buildings.

Market Barriers and Program Design

The LEED program aims to create more sustainable communities by encouraging thoughtful building design and construction practices from development to occupancy. In order to receive one of four levels of LEED certification, a building must meet requirements related to energy and water use, waste management, and other factors of environmental sustainability. The requirements have been revised over the years, with the most recent version (v4) released in 2013. LEED offers different options for varying project types, including building design and construction, operations and maintenance, and neighborhood development. The LEED Existing Buildings program aims to address the larger portion of the market not covered by new construction certifications (USGBC 2017).



Increasing the efficiency of the building stock presents many challenges. Market barriers to increased adoption include (Choi 2008):

- Lack of information and certainty regarding green building performance
- Lack of available expertise on green buildings
- High up-front costs for new construction and retrofits
- Difficulty of retrofitting existing buildings to specifications
- Lack of sufficient demand from tenants for green building space
- Split incentives for building owners and tenants

The LEED program design addresses many of these market barriers, largely through marketing and creation of a competitive advantage for building designers and building owners. The program aims to overcome lack of information regarding building performance, as well as lack of tenant demand by marketing the increased value of green buildings to designers, owners, and occupants. Some of the benefits of green buildings that the program markets include environmental benefits, increased comfort and productivity for tenants, and reduced energy costs.

In addition, LEED certification acts as a sort of status symbol, appealing to environmentally conscious individuals and businesses, and is a point of pride for building designers and owners. The four levels of certification create competition among building owners to be the most sustainable and act as a competitive differentiator for attracting tenants. This adds value for owners as green buildings are typically able to charge about 20% more than

average to lease the spaces (EPA 2008c). LEED certifications are often also used as community relations tools for building owners.

Table C3 summarizes the major actors in the LEED market and the roles they have played in transforming the market.

Table C3. LEED market actors

Market actor	Role played
US Green Building Council	Organization driving forward sustainable buildings policies, practices, and research. Developed and manages the LEED program.
Building owners	Make decisions regarding the design and purchase of LEED-certified buildings.
Building design and construction industries	Implement the design of LEED-rated buildings and execute the construction of green buildings through the purchase and placement of efficient products and the use of efficient construction practices.
Building tenants/occupants	Lease green space. Target audience for marketing of increased comfort and reduced costs for green office spaces.
Green Globes and ENERGY STAR	Competing green building certification programs. Green Globes are primarily for new construction, ENERGY STAR is primarily for existing buildings.

Program Impacts and the Market Today

LEED has made great strides as a brand-recognized green building certification program and is probably the leading such certifier in the United States. Currently 2.5 million employees work in LEED-certified work spaces (Blumberg 2012). This represents 2.8% of workers in commercial buildings in 2012, the most recent year for which data are available (EIA 2016b). USGBC estimates that from 2015–2018, LEED-certified buildings will have created approximately $1.2 billion in energy savings for building owners, as well as significant savings in building maintenance, water, and waste handling costs (USGBC 2015). In addition, the New Buildings Institute reported that LEED offices were an average of 33% less energy intensive than the national building stock in 2010 (Shutters and Tufts 2016). However LEED-certified buildings still make up only a small portion of the building stock. In 2014, USGBC reported that the program had certified 3 billion square feet of construction space, about 3.4% of the total commercial building space in the United States as of 2012 (USGBC 2014; EIA 2016b). Certified existing buildings represent an even smaller portion of the stock, indicating that there is quite a bit of room for growth in that market segment.

Looking Forward

The program does not address some significant market barriers, and this has likely contributed to lower market penetration. One significant market barrier not addressed by the program is the increased up-front cost of green building.[17] Financing options or additional markdowns for products involved in LEED certification could be helpful for increasing market share. In addition, the program could increase its reporting and

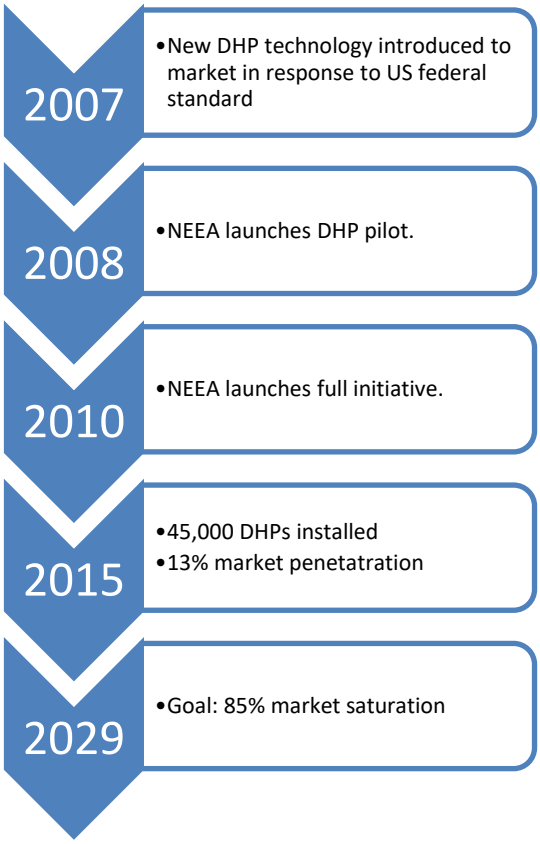
[17] Estimates of the cost differential vary widely, but one study estimates that project costs for new construction may increase by 0–8.5% to obtain LEED certification through Platinum ratings (Nicolow 2008).

transparency. Third-party and independent evaluations of the LEED program are difficult to find and do not lay out the logic model clearly or report explicitly on market share progress or other program accomplishments. However it is important to note that LEED is not intended to focus solely on energy efficiency.

NEEA DUCTLESS HEAT PUMPS

NEEA's Ductless Heat Pump (DHP) Initiative began in 2010 and is set to conclude by 2029. While its ultimate success will not be realized for at least another decade, its current progress offers lessons for creating a successful market transformation.

In 2007, the United States increased federal heat pump standards, which motivated manufacturers to develop a new generation of more efficient DHPs. NEEA recognized that this new technology could yield large savings with respect to three target markets: single-family homes with zonal electric heating, single-family homes with electric forced air furnaces, and manufactured homes with electric forced air furnaces. These target markets account for more than 500,000 eligible homes that could potentially save 200 MWh (Storm et al. 2012). In 2008 NEEA launched a pilot program to determine if these markets would accept the new technology. The pilot revealed high customer satisfaction and interest from manufacturers in developing this new market, making the DHP market ripe for transformation.



Market Barriers and Program Design

From its 2008 pilot, NEEA determined the barriers to widespread market acceptance were:

- Weak DHP marketing and training throughout the supply chain
- Supply-chain lack of acceptance of 1:1 displacement approach[18]
- Poor in-field performance from improper sizing, product choice, and design
- Low consumer awareness
- High total costs

ADDRESSING WEAK MARKETING, TRAINING, AND ACCEPTANCE IN SUPPLY CHAIN

To raise awareness among installers, NEEA started the Master Installer certification.[19] Master Installers have played a key role in improving awareness of the technology and increasing market share for DHPs. As of 2015, 90% of Master Installers promote DHPs, compared with 60% of other installers (Conzemius and Kahl 2016). Master Installers are also more likely than other installers to inform their customers of utility rebates, manufacturer discounts, and potential tax credits. As of 2016, the program had

[18] 1:1 (single-head) installation consists of one outdoor unit, or condenser, and one indoor unit. Significant barriers include climate, floor plan constraints, lack of capital, lack of awareness, mistrust of technology, and contractor inexperience. The US market is skeptical of a single DHP replacing an entire duct system.

[19] Master Installers complete an orientation and best practices training and install at least 25 DHPs. Installers must also submit installation activity, at least one homeowner testimonial, and photo-documentation of two utility incented installations.

certified 127 Master Installers and expected to train more in 2017 (Conzemius and Kahl 2016).

Beyond installers, NEEA established relationships throughout the supply chain (Conzemius and Kahl 2016). NEEA helps drive partnerships between all supply-side stakeholders to raise consumer awareness of DHPs. For example, NEEA worked with Mitsubishi and Home Depot to develop a new DHP television advertising campaign, improve in-store education, and train staff on sales closing (NEEA 2014). Table C4 outlines the role each supply-side market actor plays.

Table C4. DHP market actors

Market actor	Role played
NEEA	Works with all supply-side stakeholders to coordinate efforts to raise awareness of DHPs.
Utilities	Some provide rebate incentives to lower up-front costs. Utilities offer a platform to promote manufacturer deals and discounts.
Manufacturers	Developed new DHP technology for the US market. Provide other parts of supply chain with marketing material and sales training for their products.
Retailers	Provide in-store displays and train sales representatives to promote DHPs to their customers.
Installers	Can inform customers about DHPs and potential rebates. Additionally, quality installation, such as proper sizing, can affect consumer perception and satisfaction with DHPs.

ADDRESSING LOW CONSUMER AWARENESS

NEEA has developed marketing campaigns to raise consumer awareness. It uses surveys, focus groups, and annual program evaluations to learn about what influences consumers to purchase DHPs (Conzemius and Kahl 2016). Surveys have shown that word of mouth is the most common influence (30%), followed by utility sources (18%) and Internet research (13%) (Conzemius and Kahl 2016). NEEA plans to use this information to ensure its marketing efforts capitalize on word-of-mouth influence. Going forward, the organization intends to increase awareness through case studies, online avenues such as YouTube, testimonials, and Yelp.

Program Impacts and the Market Today

As with most market transformation efforts, the true success of the DHP Initiative will be determined over a long time frame. However it is clear the market is beginning to transform. Within five years, market penetration has increased from 0% to 13% (Conzemius and Kahl 2016).

Looking Forward

NEEA's 2016 evaluation discusses the next steps for the program going forward. These include:

- Increase online marketing to take advantage of word-of-mouth influence.
- Create marketing resources for utilities. Some program managers and installers noted that the initiative does not relate to their customers.
- Prepare to adapt market transformation efforts that to require fewer utility program resources.
- Research strategies to reduce the cost of contractor services. The furnace and heat pump industry is a low-volume and high-margin market, meaning contractors sell fewer products at higher costs. Since DHPs are a cheaper product than traditional furnaces, contractors may include large markups or multiple DHP heads. NEEA is working with contractors to actively solve this market problem and prevent high installment costs from deterring customers.

Other regions are also paying attention to this market. In 2014, NEEP launched a regional transformation to accelerate the adoption of air source heat pumps (ASHPs) (NEEP 2017a). This program promotes both ducted and ductless ASHPs. As of 2015, approximately 49% of ASHP in NEEP's region are DHPs (NEEP 2017a). NEEP provides support to local governments and efficiency organizations that are running ASHP programs. For example, Efficiency Vermont launched a cold climate heat pump program with local utilities and installed more than 1,200 ASHPs in its first year (Vermont Public Service Department 2015). Similar programs are promoted in Massachusetts, Connecticut, New Hampshire, Maine, New Jersey, Pennsylvania, and Washington, DC. If these efforts continue and expand, NEEP predicts a 40% penetration rate by 2025, as shown in figure C1.

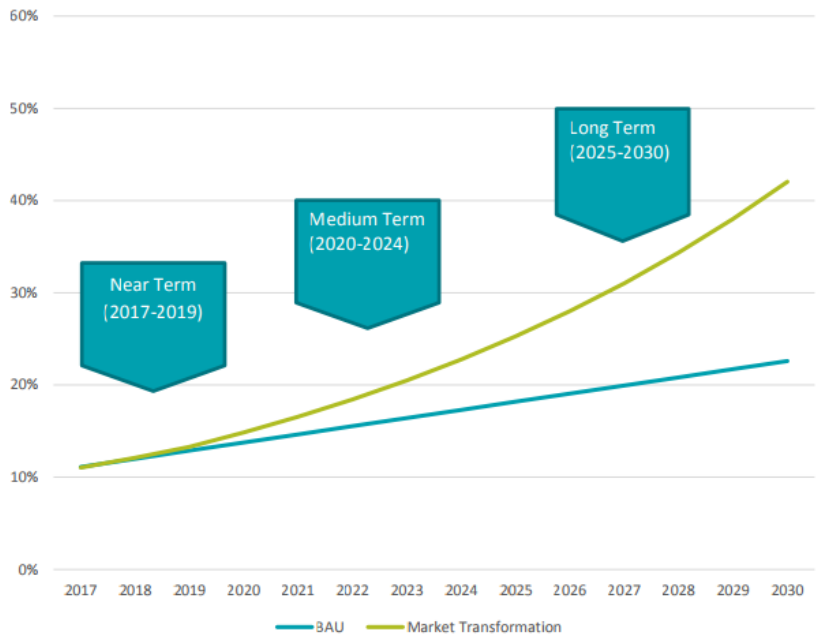


Figure C1. Penetration of ASHPs as primary heating source in the Northeast and mid-Atlantic United States. BAU means business as usual (the market without intervention).
Source: NEEP 2017a.

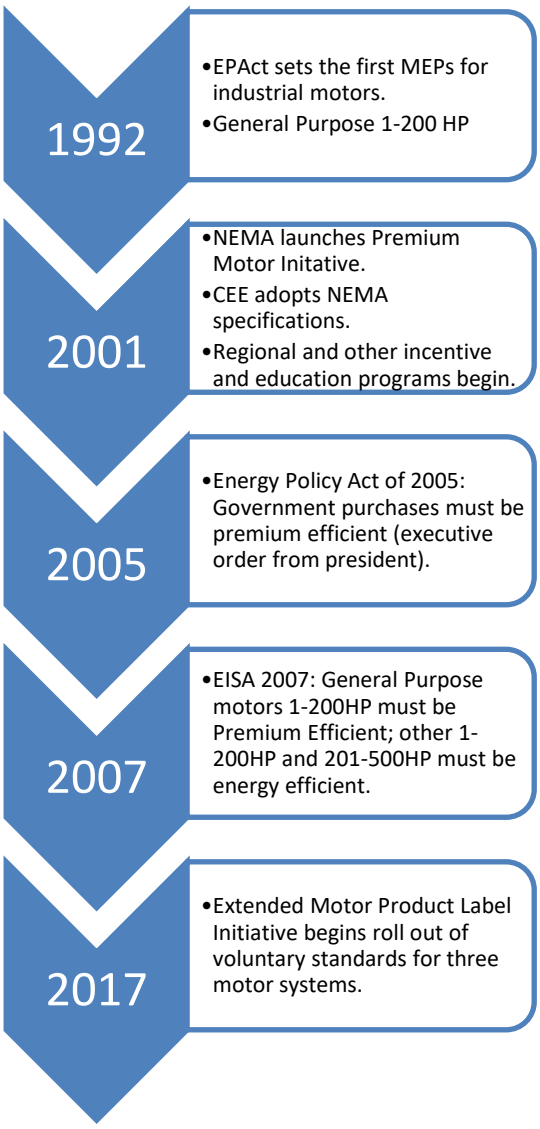
PREMIUM EFFICIENCY MOTORS

In 1992 industrial motors accounted for 23% of all energy consumed in the United States (Rosenberg, Olszewski, and Scheihing 1998). The great savings potential led to the first standards for efficient motors, enacted by Congress in the Energy Policy Act of 1992 (Elliott 2007). Congruently, the National Electrical Manufacturers Association (NEMA), the Consortium for Energy Efficiency (CEE), and several regional energy efficiency groups (e.g., the Northeast Energy Efficiency Partnership [NEEP] and the Northwest Energy Efficiency Alliance [NEEA]) began the Premium Motors Initiative, to drive the development and adoption of motors more efficient than the federal standard (Elliott 2007). The initiative began as a voluntary effort, but because of its great success, its specifications were adopted as a federal standard as part of the Energy Independence and Security Act (EISA) of 2007.

Market Barriers and Program Design

NEMA collaborated with ACEEE, CEE, and others to increase the sale and purchase of motors more efficient than those required by federal standard. By conducting a thorough market analysis, these groups were able to determine the key market barriers:

- Limited stocking of premium motors
- Payback gap
- Low priority assigned to energy matters
- Transaction cost
- Lack of internal incentives (Nadel et al. 2002)



CEE managed a public education campaign, Motor Decisions Matter (MDM), with the support of motor manufacturers and the motor repair industry (Elliott 2007). The program targeted facility managers, who often make the decision to repair or replace a motor. MDM sought to educate managers that the long-term energy savings from premium motors were greater than the up-front cost. Additionally, MDM promoted best-practice repairs and proactive motor management strategies.

Beyond the national program, several regional programs across the United States promoted "NEMA premium." NEEP, representing its regional utilities, ran the MotorUp program, which engaged five New England states, New Jersey, and Long Island. The program achieved about 20% market penetration for premium motors in the new and replacement motor market. In California, Pacific Gas and Electric (PG&E) ran a program in which upstream rebates were given to motor distributors (Elliott 2007). While premium motor sales grew,

there was not a significant impact on the number of motors sold in PG&E's region (Nadel et al. 2002).

While these regional programs began to see some market transformation success, major headway did not occur until 2005, when the federal government required all government motor purchases to be premium motors. This paved the way for the 2007 EISA, which required all general-purpose motors to be premium. The regulation also introduced minimum standards for many other 1–200HP motors and 201–500HP motors. EISA later called for a second round of efficiency standards, which required motors of 1–500HP to meet NEMA premium standards by June 2016 (Lewotsky 2015).

Table C5 summarizes the major actors and the roles they played in transforming the premium motor market.

Table C5. Premium motor market actors

Market actor	Role played
NEMA (manufacturers)	Managed Premium Motors Initiative.
NEEP, NEEA, electric utilities	Organized education and incentive programs that promoted the uptake of premium motors.
ACEEE	Worked with NEMA to develop details of specification and to negotiate federal standard.
CEE	Was involved in development of specification; ran Motor Decisions Matter education and promotion effort.
US federal government	Passed the Federal Energy Management Program (FEMP), which provides information about energy-efficient products to federal agencies. FEMP based its motor product procurement recommendations on the NEMA Premium Efficiency specifications. The government also passed federal standards that required motors to comply with premium motor efficiency levels.

Program Impacts and the Market Today

The Premium Motors Initiative was a successful market transformation effort. This was largely due to the joint activities of many players—NEMA, CEE, ACEEE, regional groups, and utilities (Elliott 2007). While there was some success from regional programs, the nationwide market transformation resulted from federal standards, which were negotiated by NEMA and ACEEE and then adopted by Congress (DOE 2014).

Currently, federal standards ensure that most motors on the market are premium efficiency. One lesson from the Premium Motors Initiative is that efficiency standards should be technology neutral, setting efficiency levels and leaving each manufacturer free to decide which combination of design options it will use to meet the specification (N. Elliott, senior director of research, ACEEE, pers. comm., August 4, 2017). As technological advancement continues, this also allows new types of products to enter the market, as long as they can meet the efficiency specifications.

Looking Forward

There are motors on the market more efficient than premium, but some of these (e.g., copper rotor motors) are very expensive; others, such as various types of advanced variable-speed motors, are not appropriate for all applications (N. Elliott, senior director of research, ACEEE, pers. comm., August 4, 2017). Due to these limitations, prescriptive programs focused just on the motor are no longer in operation. Custom programs still address opportunities for large and nonstandard motors.

However there are opportunities to improve the efficiency of common motor-driven equipment, such as fans, pumps, and air compressors. A new project, the Extended Motor Product Label Initiative (EMPLI), has been developed to identify and label more efficient fans, pumps, and compressors (Persful et al. 2016). EMPLI is mostly a voluntary program, but recently DOE adopted minimum efficiency standards for pumps. It is close to adopting very modest efficiency standards for air compressors and has begun work on fan efficiency standards. The California Energy Commission is also working on minimum efficiency standards for fans.