MARKET TRANSFORMATION PROGRAMS: PAST RESULTS AND NEW INITIATIVES

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ABSTRACT

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. In the past few years, utilities, government agencies, and public interest organizations have taken an interest in encouraging market transformation through activities such as research and demonstration (R&D); demonstration projects; manufacturer incentives; education and training; consumer incentives; building codes; and equipment efficiency standards. In this paper we review a number of market transformation efforts that have occurred in recent years and also discuss several new market transformation initiatives. Based on these case studies, we conclude that: (a) market transformation is feasible; (b) the preferred market transformation strategy varies from product to product, depending on characteristics of the technology and the market being served; and (c) minimum efficiency standards and building codes often play a critical role in achieving market transformation. In order to increase the success of market transformation efforts, it would be helpful to plan and implement more comprehensive, long-term transformation strategies, develop evaluation procedures for market transformation, and design rewards for utilities that participate in successful market transformation efforts.

INTRODUCTION

Market transformation can be visualized in terms of the classic S-shaped logistic diffusion curve. Once a new product or other type of innovation is introduced, its penetration (in terms of the eligible sales in any particular year) begins to rise through early adopters. Penetration then "takes off" as awareness of the technology and its advantages grows. The adoption process continues until market penetration levels off at "full market potential." Market transformation also implies lasting change such that the market does not regress to lower levels of efficiency at some later time.

In the past few years, some utilities and government agencies have begun to encourage and accelerate market transformation for certain energy efficiency measures. Instead of saving energy building-by-building or product-by-product, a market transformation approach seeks to change the entire market so that efficient products or services are the norm and do not need to be promoted with incentives. Relative to conventional program approaches, market transformation programs can potentially increase the amount of energy that is saved (because participation rates approach 100 percent) while lowering long-term program costs per unit of energy saved.

EXAMPLES OF MARKET TRANSFORMATION

We recently reviewed eight end-uses where substantial energy efficiency improvements occurred during the past 15 years and market transformation took place to a moderate or high degree (Geller & Nadel 1994). These case studies illustrate that certain products and markets are relatively easy to transform to high efficiency, while other products and markets present a greater challenge.

In this paper we summarize three examples of highly successful market transformation — refrigerators, fluorescent lighting ballasts, and new residential construction in the Pacific Northwest. We also briefly discuss four cases of partial market transformation. Other examples of market transformation, such as the shift to high-efficiency motors in British Columbia and high-efficiency furnaces in Wisconsin, are discussed elsewhere (Flanigan & Fleming 1993; Schlegel & Prahl 1994).

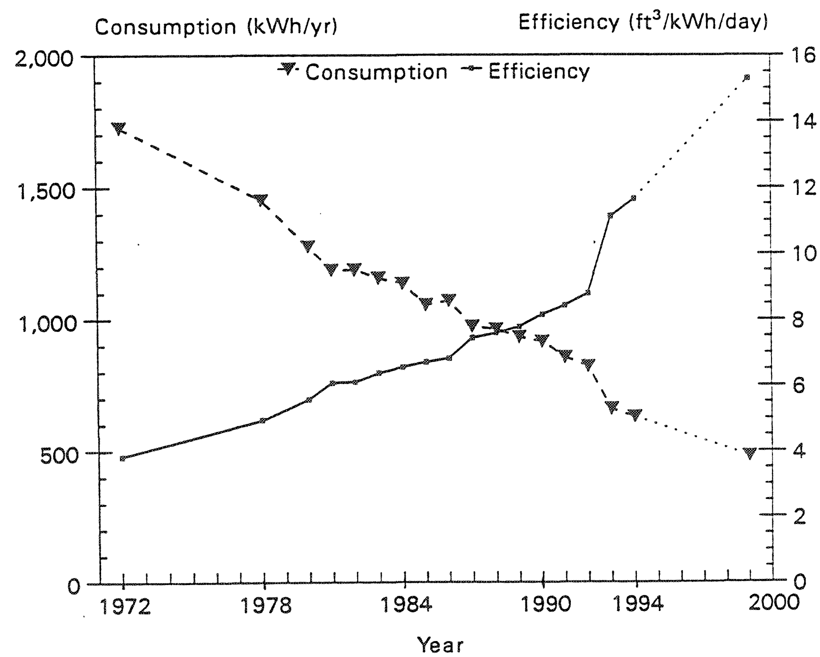
Refrigerators

The average electricity use of new refrigerators declined about 60 percent during the past 20 years (see Figure 1). The efficiency gains occurred without dramatic technological or product innovation. The steady improvement in the energy efficiency of new refrigerators has been very cost-effective. For example, it is estimated that recent energy efficiency gains cost consumers about $0.02 per kWh saved (Geller & Nadel 1994). The simplicity and low cost of the efficiency improvements no doubt contributed to their widespread acceptance by manufacturers and consumers.

But policy initiatives, particularly minimum efficiency standards, played a critical role in the market transformation that occurred during 1972-94. Major improvements in refrigerator efficiency primarily took place in the periods leading up to and following the effective dates of new refrigerator efficiency standards in 1977 and 1979 (California), as well as 1990 and 1993 (national).

Efficiency improvements are expected to continue in the near future as a result of two main efforts. First, the Super Efficient Refrigerator Program (SERP), a utility-funded contest among refrigerator manufacturers, is providing $30 million to the winning manufacturer for the development, commercialization, and sale of refrigerators using 30-40 percent less energy than current standards. The SERP program primarily affects large, full-feature models. The New York Power Authority and the Consortium for Energy Efficiency recently extended the concept to a program for smaller, apartment-size refrigerators (CEE 1995a). As a result, Maytag has committed to begin offering an apartment-size refrigerator in 1997 that reduces energy use by more than 30 percent relative to U.S. refrigerator efficiency requirements (Brown 1995). Second, refrigerator manufacturers and energy efficiency advocates reached agreement in September, 1994, to jointly support new federal efficiency standards nearly 30 percent lower than the 1993 standards (Association of Home Appliance Manufacturers 1994). These new standards are expected to take effect in approximately 1999, three years after final standards are issued by the U.S. Department of Energy (DOE).

Figure 1. Trends in the Average Electricity Consumption and Efficiency of New Refrigerators.



Source: Association of Home Appliance Manufacturers 1995.

Ballasts

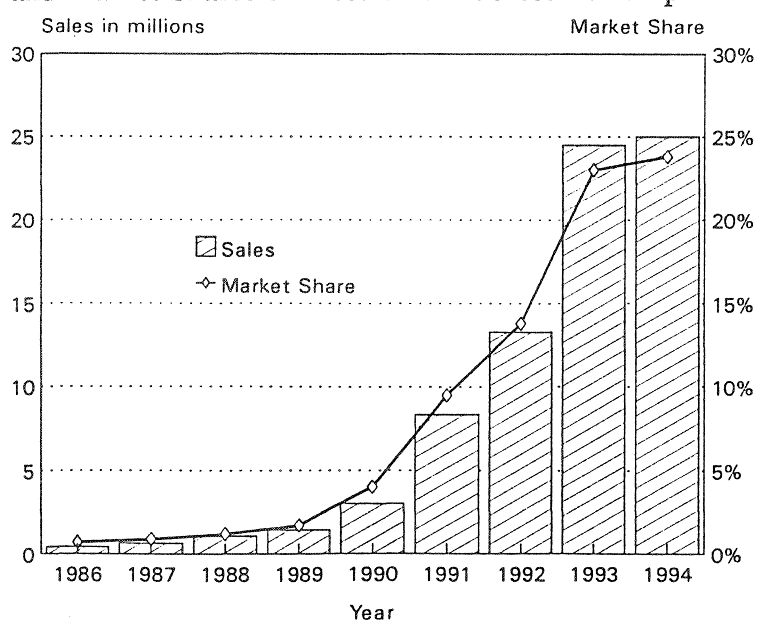
The transformation of fluorescent lighting ballasts occurred in two phases. The first involved shifting to energy-efficient magnetic ballasts and the second to electronic ballasts.

Ordinary magnetic ballasts dissipate as heat about 20 percent of the total power entering a fixture. Efficient magnetic ballasts, which reduce ballast losses by 50-60 percent, were developed and introduced by major ballast manufacturers during the 1970s in response to rising energy prices and heightened consumer interest in energy use. By 1987, about one-third of ballast sales were energy-efficient magnetic ballasts due to the impact of utility incentive programs and minimum ballast efficiency standards in several large states (Geller & Miller 1988). In 1988, federal ballast efficiency standards were adopted that mandated use of efficient magnetic ballasts (or electronic ballasts) effective in 1990, thereby completing the initial transformation of the fluorescent ballast market.

R&D on electronic ballasts, including research funded by DOE, took place during 1976-1980, leading to the introduction of electronic ballasts in 1980. First-generation electronic ballasts were expensive and subject to reliability problems, resulting in limited sales. As the 1980s progressed, sales gradually increased, aided by product quality improvements, cost-cutting, utility incentives, and large bulk purchases. In the 1990s, the U.S. Environmental Protection Agency's (EPA) "Green Lights" program strongly promoted electronic ballasts. Utility incentives have played an especially important role. One study estimated that utilities spent $35 million on incentives for high-efficiency ballasts as of 1990 and would spend $140 million on incentives as of 1994 (Gough & Blevins 1992). Assuming an average incentive of $11 per ballast, this implies that utility incentives were included in the majority of electronic ballast sales in recent years.

By 1993, the market share for electronic ballasts reached 23 percent, although this figure appears to have risen only slightly in 1994 (see Figure 2). In early 1994, DOE proposed new efficiency standards for fluorescent ballasts, which would essentially require use of electronic ballasts. The standards could be finalized in 1997, in which case they would take effect in 2000. If the final standards resemble the proposed standards, they will complete the second phase of the ballast market transformation.

Figure 2. Sales and Market Shares of Electronic Fluorescent Lamp Ballasts.

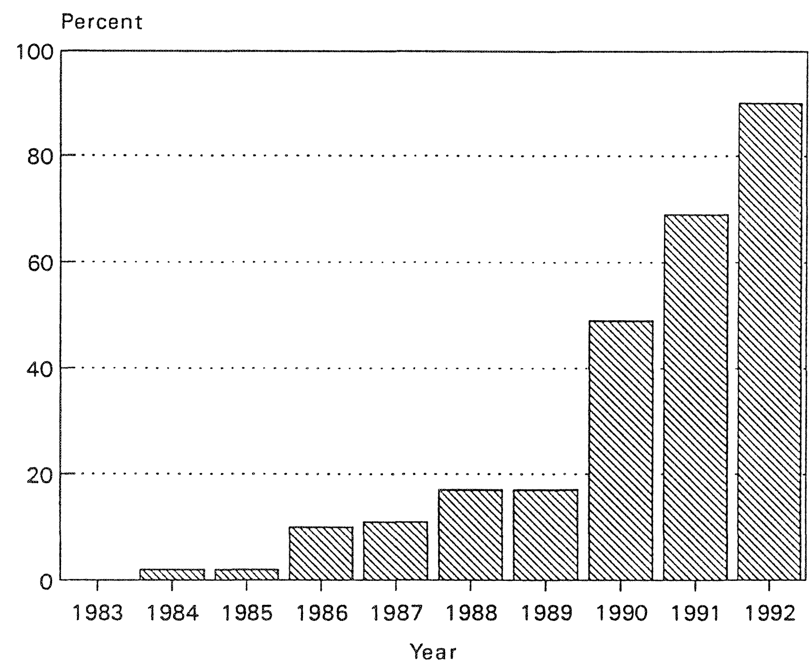


Source: Bureau of Census 1995.

New Housing in the Pacific Northwest

The Northwest Power Planning Council (NPPC) and the region's major electric utilities led a successful drive to transform residential construction practices in the Northwest. This effort involved development of Model Conservation Standards (MCS), demonstration projects to validate the standards, training and incentives for builders, technical assistance and financial incentives to encourage early adopters, and finally statewide adoption of MCS-based building codes. This entire effort took eight years. Most electrically heated homes in the region now meet the MCS (see Figure 3), with typical energy savings of 40 percent or more compared to previous construction practices (Geller & Nadel 1994).

Figure 3. Market Shares of New Homes Meeting the Model Conservation Standards in the Pacific Northwest.



Source: Geller & Nadel 1994.

An economic analysis of this entire process projects that utilities in the region will pay about $112 million during 1983-2003 to support this transformation, with projected electricity savings of approximately 1350 GWh per year by 2003 (Schwartz, Byers & Mountjoy-Venning 1993). The overall utility cost is estimated to be just $0.005 per kWh saved. This example illustrates the value to utilities from leading or participating in market transformation efforts, although it can take many years before large-scale benefits are obtained.

Other Case Studies

Not all energy end uses have experienced efficiency improvements to the degree observed in the previous examples. For example, efforts to transform the market for windows, personal computers, compact fluorescent lamps, and adjustable speed drives have only been moderately successful. Regarding windows, energy-efficient products with low-emissivity (low-E) coatings, argon gas fill, and improved frames have made significant strides in the market, facilitated by government-funded R&D, building codes, and development of test procedures and performance ratings. Low-E coatings were used in 32 percent and argon gas fill in 45 percent of residential windows sold in 1993 (American Architectural Manufacturers Association 1994).

The energy performance of personal computers is being transformed through the adoption of power management capabilities, which can reduce total PC electricity use by 60-70 percent. The introduction of this feature was stimulated by the EPA Energy Star program. It is estimated that 45 percent of PCS sold in the first 12 months after the launch of this program in mid-1993 included power management capability. However, in the initial years of the program most of these computers were sold without the feature enabled, a problem that EPA has addressed through 1995 modifications to the program (Latham 1995).

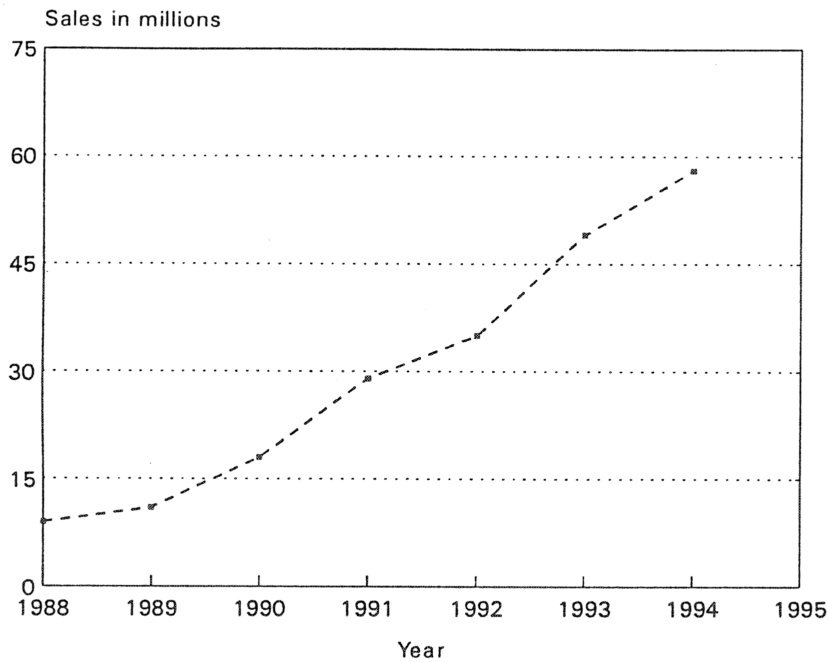
The market for compact fluorescent lamps (CFLs) is rapidly growing due to technical improvements and utility incentives. Sales of CFLs in North America were approximately 58 million units in 1994, approximately 7 percent of the general purpose lamp market, and over three times the level of sales in 1990 (see Figure 4). Initiatives to continue the transformation of the lamp market are discussed below.

Adjustable speed drives (ASDs) can reduce the electricity consumption of motors by 15-50 percent in applications where there is a great deal of part-load operation. It is estimated that ASDs were installed in 10-30 percent of appropriate applications as of 1993 (Geller & Nadel 1994). Policy initiatives to promote ASDs have been limited, although demonstration and education projects as well as utility rebate programs have increased awareness and adoption.

NEW MARKET TRANSFORMATION INITIATIVES

Given the potential benefits of market transformation, many utilities and government agencies are interested in developing market transformation strategies for new products as well as for existing but underutilized products. For example, the Consortium for Energy Efficiency (CEE) is helping to establish initial markets for a variety of highly efficient technologies (Tatsutami 1995). In the paragraphs below, we discuss several market transformation efforts, focusing on technologies where there is large potential for cost-effective energy savings. Most of these technologies emerged as high priorities for market transformation based on a systematic analysis of the electricity savings potential, cost-effectiveness, and likelihood that intervention could make a difference (Nadel & Geller 1994).

Figure 4. Trends in the Sales of Compact Fluorescent Lamps in North America.



Source: Borg 1994; Mills 1995

Clothes Washers

Two clothes washer efficiency improvements — horizontal-axis design (which reduces hot water use) and high spin speed (which extracts more water from clothes, reducing dryer energy use) — can reduce energy use for home laundering by nearly 50 percent, as well as substantially cut water use by the clothes washer. High-efficiency washers are widely sold in Europe, but so far have made only limited inroads into the U.S. market. However, three efforts are beginning to change this picture.

First, major U.S. manufacturers are developing new high-efficiency horizontal-axis washers that are expected to be marketed in 1996 or 1997 (CEE 1995b). One of these development projects is partly supported by the Electric Power Research Institute.

Second, CEE has developed an utility incentive program to stimulate commercialization and sales of high-efficiency washers. Utilities that participate in this program will use identical rebate eligibility levels (CEE 1993). CEE intensified its promotion of the program in early 1995, and both electric and water utilities have begun to respond. For example, PG&E is teaming up with three California water utilities to offer rebates of over $200 to purchasers of qualifying washers.

Third, DOE has begun a formal rulemaking to set more stringent clothes washer efficiency standards. Horizontal-axis and high spin speeds will be important issues addressed in this proceeding. In early 1995, three major manufacturers (representing over 75 percent of the residential clothes washer market) and several energy efficiency groups announced support for a DOE standard that would require efficiencies achieved with horizontal-axis, high spin speed designs (ACEEE et al. 1995; Maytag 1995). Preliminary analysis by DOE has found that horizontal-axis, high spin-speed washers have the lowest lifecycle costs of all options examined (U.S. Department of Energy 1995). This rulemaking is highly contentious; a final decision on new clothes washer standards could be made in 1998, with the new standards taking effect in 2001 or possibly later. The success of the first two efforts mentioned above could influence DOE's decision on new standards.

Central Air Conditioners

Residential central air conditioners presently on the market range in efficiency from SEER 10 to more than 16. In areas with utility rebates, units with SEERs of 11 and 12 are widely sold. However, less than one percent of central air conditioners sold nationwide in 1994 had SEERs of 14 or more, due to high unit costs, limited product availability, and modest utility incentives for these very efficient units (Martz 1995).

To address these barriers, CEE has developed the High-Efficiency Residential Air-Conditioning Initiative under which participating utilities would use similar rebate eligibility levels, just like in the CEE clothes washer program. Eligibility is determined on the basis of both SEER (a measure of average seasonal performance) and EER (a measure of peak load performance). By focusing on EER as well as SEER, significant peak savings should result with very high-efficiency units, allowing utilities to afford higher rebates for units of SEER 14 or more (CEE 1994a). As of late 1995, eight utilities collectively serving 14 percent of U.S. residential customers were using the CEE specifications in promoting high-efficiency central air conditioners (CEE 1995c).

In addition, DOE has begun a rulemaking to determine new efficiency standards for central air conditioners and heat pumps (U.S. Department of Energy 1993). The new standards will probably take effect in the first few years of the next century, with the exact date depending on when DOE completes this rulemaking. Electricity and peak demand savings of 20 percent or more are likely as a result of these new standards.

Packaged Commercial Air Conditioners

Approximately two-thirds of commercial cooling loads are served by packaged systems (assembled in a factory and shipped to the construction site ready to install). These systems tend to be the least costly commercial cooling system, and there is intense price competition between manufacturers. As a result, efforts to improve unit efficiency have been limited. This situation has begun to change. In 1992, the U.S. Congress established minimum efficiency standards for packaged commercial air conditioners and heat pumps up to 240,000 Btu/hour cooling capacity.

In 1994, CEE developed a program to promote commercial packaged cooling systems at least 10 percent more efficient than the Federal standard. The centerpiece of this program is a two-tier rebate eligibility scheme. In part due to this program, several major manufacturers introduced new units that met CEE's first threshold. Research and demonstration projects are underway to develop and test units meeting CEE's second threshold (CEE 1994b; Kopko & Hibberd 1994). As of late 1995, 14 utilities, which collectively provide 19 percent of U.S. electricity, were using the CEE specifications (CEE 1995c).

In addition, ASHRAE has begun to develop new efficiency standards for packaged commercial air conditioners as part of its model building code. The initial ASHRAE draft proposes a standard approximately 6-12 percent more efficient than the current Federal standard (varying by unit type and size) (American Society of Heating, Refrigerating and Air-Conditioning Engineers 1996). Once ASHRAE's work is completed, DOE will establish revised national efficiency standards for these products.

Compact Fluorescent Lamps

Significant progress has been made in increasing sales of CFLs in the residential and commercial lighting markets (see Figure 4). A number of initiatives are now taking shape that will further boost the CFL market. First, manufacturers continue to improve the product. For example, CFLs of equal size and light output of a 60 Watt incandescent lamp were commercialized in 1993 (Atkinson 1994). Manufacturers are now trying to develop products that are truly equivalent in size and light output to a 100 Watt incandescent lamp.

Second, under a provision of the Energy Policy Act of 1992, the Federal Trade Commission developed a labeling program for general service incandescent and compact fluorescent lamps. These labels, which began appearing on all product packages in mid-1995, will facilitate consumer comparisons between incandescent lamps and CFLs (Federal Trade Commission 1994).

Third, CEE has developed a program in which utilities will pay incentives to manufacturers in order to reduce the cost of CFLs sold in local retail stores. Manufacturers will compete for the utility subsidies based on technical specifications such as product efficiency and size, and marketing factors such as cost reductions pledged by manufacturers and size of the local distribution network. Initially this program will be offered by the Sacramento Municipal Utility District and a consortium of utilities in the Pacific Northwest (CEE 1994c; CEE 1995d).

Fourth, efforts are underway by EPA and by a consortium of New England utilities to develop market transformation programs to promote residential CFL fixtures. Both of these efforts are still in the initial planning stages (Cokely 1995; Latham 1995).

Energy-Efficient Windows

As mentioned above, low-E and other improved windows have gained market share as a result of technological improvements, cost reductions, performance testing and information programs, and building code requirements. The National Fenestration Rating Council (NFRC) began a rating and labeling program that allows builders and consumers to compare the energy performance of windows (National Fenestration Rating Council 1993). Some utilities provide incentives for use of low-E windows in new construction. In addition, recently commercialized "southern low-E" film reduces the amount of solar heat gain through windows, providing substantial cooling energy savings in hotter climates (*Energy Design Update* 1994).

Due to the success of these efforts, low-E windows are cost-effective in most climates and should be incorporated into local and state building codes, as well as national voluntary codes upon which many state and local codes are based. For example, Oregon has adopted performance-based requirements for window U-value that effectively requires low-E windows in new homes (Rivera 1994). In some states, utility incentives may be needed to lay the groundwork for building code requirements as well as to stimulate adoption of energy-efficient windows in the replacement market. DOE is considering a major market pull collaborative involving builders, retailers, utilities and procurement officials to greatly expand the market for very high-efficiency "superwindows" (Geller & Nadel 1994).

Gas-Fired Heat Pumps

Gas-fired heat pumps are considerably more efficient than gas furnaces now on the market. A typical condensing gas furnace has a coefficient of performance (COP) of approximately 0.9; first-generation gas heat pumps have COPs of 1.3-1.7. Gas heat pumps also provide cooling in the summer although cooling efficiencies are lower on a systems basis than electric heat pumps or air conditioners. In order to promote high-efficiency residential gas heat pumps, a strategy is being implemented covering the R&D, commercialization, and initial sales stages.

R&D has focused on two different gas heat pump technologies. In one project, the Gas Research Institute worked with a large air conditioner manufacturer to develop an engine-driven gas heat pump with a seasonal heating COP of approximately 1.3. In the other project, DOE is supporting the development of an advanced absorption heat pump. The engine-driven heat pump was commercialized in 1994; the absorption heat pump is scheduled to be introduced in the late 1990s (Hughes 1994).

In order to support the commercialization of these new products, a consortium of gas utilities, under the auspices of the American Gas Cooling Center, has developed programs to provide customer incentives towards the purchase of a limited number of heat pumps, with the incentives gradually decreasing as sales increase. When sales of the engine-driven system exceed 50,000 units, the manufacturer will begin to reimburse consortium members for their initial investments (Stoddard 1994). A similar effort is being planned for the advanced absorption gas heat pump.

Ground-Source Heat Pumps

In the area of electric-powered space conditioning equipment, ground-source heat pumps are the most efficient option available. Several manufacturers presently sell products with cooling energy efficiency ratings greater than 16 and heating COPs greater than 3.4. Ground-source heat pumps have been on the market for many years but, due to high initial costs for the in-ground loop system, sales have been limited. In recent years, a lower cost ground-loop system called the "slinky coil" has been developed along with higher efficiency heat pump designs (L'Ecuyer, Zoi & Hoffman 1993).

In order to increase use of ground-source heat pumps, two major promotion efforts are underway. First, the Geothermal Heat Pump Consortium (GHPC), a collaborative effort of the electric utility industry, DOE, EPA, and other public/private sector organizations, has developed the National Earth Comfort Program. The program aims to increase annual ground-source heat pump installations to 400,000 units (equivalent to about 10 percent of annual sales of residential central air conditioners and air-source heat pumps) by 2000. To build up the market for this technology and reduce equipment costs, the consortium will conduct R&D, sponsor demonstration projects, establish regional training centers, assist utilities with the design of geothermal heat pump promotion and financing programs, develop standards, and provide visibility (Geothermal Heat Pump Consortium 1994).

Second, CEE has developed a model program design that individual utilities can adapt to promote ground-source heat pumps. This program is very similar to the CEE High-Efficiency

Residential Air-Conditioning Initiative discussed above in that the program includes multiple efficiency tiers and a set of recommended installation specifications (CEE 1994d). The GHPC and CEE programs differ in that the GHPC program promotes all ground-source heat pumps, while the CEE program concentrates on promoting the more efficient ground-source heat pumps available.

Heat Pump Water Heaters

Heat pump water heaters have been on the market for more than a decade but have not garnered significant market share due to high costs, reliability problems with early models, and lack of an installation and maintenance infrastructure. In the 1990s, new heat pump water heaters were introduced to the market with installed costs significantly less than earlier models, and/or with improved designs to address reliability problems. Several electric utilities are conducting extensive field tests on these new units. In addition, several groups including DOE, CEE, and a consortium of New England utilities are considering a coordinated utility program to promote heat pump water heaters. In its initial phase, it is expected that this program will concentrate on large bulk purchases by utilities, government agencies, and others in order to promote development of improved technologies and achieve lower prices through economies of scale (Hewitt & Pratt 1996).

Based in part on these promising developments, in 1994 DOE proposed new efficiency standards for electric water heaters that would essentially mandate heat pump water heaters (U.S. Department of Energy 1994a). Water heater manufacturers and electric utilities strongly opposed requiring such standards, while efficiency advocates supported the standards at least for larger electric water heaters. DOE is considering comments on its original proposal and is conducting further analysis. A final decision on this standard is not expected until 1998 at the earliest, with the standards taking effect three years after this date. However, given the controversy generated by this proposed standard and a more conservative U.S. Congress which is questioning whether the appliance standard program should continue, it is unlikely that a mandatory heat pump water heater standard will be issued.

Electric Motor Systems

Electric motor systems account for over half of all electricity consumption in the United States and over two-thirds of industrial electricity consumption. The Energy Policy Act of 1992 (EPAct) contains minimum efficiency standards for induction motors one horsepower and greater, and these will take effect in 1997. Nevertheless, substantial energy savings are possible through better design and selection of motor system components such as fans, pumps, and compressors, and from use of adjustable speed drives (ASDs) and other controls (Nadel et al. 1992).

Since motor system design and the feasibility of certain features such as ASDs is application specific, some elements of a market transformation strategy involve local activities. For example, a number of utilities in Wisconsin have formed a Performance Optimization Service, which trains industrial engineers, promotes motor systems assessments among industrial customers, offers financing or financial incentives for project implementation, and works with trade allies (Carroll, McKeller & Wroblewski 1994).

The CEE Motor Systems Committee is developing several market transformation activities for utilities, including: (a) minimum efficiency thresholds above the EPAct standards for very efficient motors; (b) recommended guidelines for motor repair facilities and recommended motor repair specifications; (c) development of test procedures for fans, pumps, and compressors as well as guidelines for specifying energy-efficient equipment; and (d) support for programs throughout the country modeled on the Wisconsin program (CEE 1994e). In addition, DOE has begun a Motor Challenge program, which involves demonstrations, information, and technical assistance, as well as voluntary pledges by participants to upgrade motor system efficiency where feasible (U.S. Department of Energy 1994b).

Sealing Duct Systems

Research has found that leaks in duct systems can be a significant source of energy waste, increasing energy use for residential space heating and cooling by as much as 30 percent. Present remedies include leak detection using blower doors, pressure/flow sensors, and smoke sticks, and leak sealing using mesh tape and mastic. While these methods can be effective, they are also labor intensive and expensive, and can be impossible when ducts are inaccessible. To address this problem in existing buildings, researchers at Lawrence Berkeley Laboratory have developed aerosol compounds that are sprayed inside ducts. The technique may reduce the cost of duct sealing to as little as $100 per home (Nadel et al. 1993).

Field tests of aerosol duct sealants began in 1994. Results of the initial field test found that the technique sealed approximately 60 percent of the leakage in the duct system within 15 minutes, using about $6 worth of sealing material (*Center for Building Science News* 1995). Subsequent field tests have sealed as much as 80-90 percent of duct leakage area. Funding for this work is being provided by DOE, EPA, Electrical Power Research Institute, and the California Institute for Energy Efficiency. The developers hope for commercialization of this technique in 1996 (Modera 1995). Assuming commercialization occurs, programs will be needed to train heating, ventilating, and air-conditioning (HVAC) contractors, educate consumers, evaluate performance, and assure quality when duct sealing is widely practiced.

Vending Machines and Beverage Coolers

Approximately two-thirds of the electricity used by refrigeration systems is used by packaged systems such as vending machines, beverage display cases, and small walk-in coolers, and not by large built-up refrigeration systems such as are found in supermarkets. Most of these packaged systems are very inefficient, as this equipment is often provided free of charge by beverage vendors to commercial establishments who agree to buy beverages from the vendor. Under this arrangement, since the beverage vendors buy the equipment but do not pay operating costs, they have no incentive to purchase efficient equipment. Due to the previous lack of attention to efficiency, savings of 30-50 percent are typically available at a small incremental cost (Easton Consultants, Inc. 1993; Patel, Teagan & Dieckmann 1993). To help capture these savings, EPA is now planning a national program that gives public recognition to equipment manufacturers who agree to produce, and large beverage companies who agree to purchase, efficient vending machines and beverage display cases (Latham 1995). In addition, the Canadian Electrical Association is developing efficiency rating procedures and threshold efficiency ratings that denote high-efficiency equipment so that programs can be developed to encourage purchasers to buy this high-efficiency equipment (Nadel 1994).

In all of the areas discussed above, considerable progress has been made toward developing market transformation strategies. However, extensive work is still needed to complete the development of these strategies and then successfully implement them.

CONCLUSIONS AND RECOMMENDATIONS

The examples of refrigerators, ballasts, and new housing in the Pacific Northwest demonstrates that transformation of energy efficiency markets is possible. But a wide range of barriers inhibit the implementation of cost-effective energy efficiency measures in many areas. Market transformation can be greatly accelerated and expanded through the adoption of a combination of policies such as R&D, demonstration projects, stimulation of market entry, financial incentives, and efficiency codes and standards.

In developing a transformation strategy, there is often an appropriate role for manufacturers, utilities, government agencies, and other organizations. Manufacturers usually lead R&D and marketing efforts. In particular, private companies usually develop without assistance the second- and third-generation products that address early problems and allow new technologies to move into the mainstream.

Government agencies can assist with R&D and demonstration of first-generation products as well as participate in bulk purchases and promotion efforts. Government agencies also adopt efficiency standards and building codes. As shown by the case studies above, efficiency standards and codes are often vital components in completing the market transformation process. Standards can also greatly shorten the diffusion cycle — the time between technology introduction and full penetration of the new sales market — and can prevent penetration from reaching a plateau well below the full market potential. However, minimum efficiency standards are not appropriate for all energy efficiency measures. Products that are application specific (e.g., ASDs or CFLs) cannot be mandated across-the-board.

Utilities can offer conventional incentives to stimulate adoption by consumers as well as less traditional incentives to stimulate product development and commercialization by manufacturers. Conventional utility incentives can increase the market share of efficient technologies, thereby paving the way for efficiency standards and contributing both directly and indirectly to market transformation. Utilities can also participate in R&D and demonstrations and can sponsor training, education, and evaluation efforts.

The preferred market transformation strategy varies from product to product, depending on the characteristics of the technology and the market being served. Some products, like refrigerators or lighting products, are made primarily by large companies that can perform R&D on their own. Other products, such as windows or buildings, are made by a large number of smaller companies that conduct little R&D and thus government- or utility-supported R&D can be critical. Manufacturer-oriented commercialization incentives can be valuable for products such as high-efficiency appliances and windows where advanced technologies are ready to be introduced. Consumer, dealer, or manufacturer incentives, on the other hand, are important for products such as CFLs, ground-source heat pumps, and heat pump water heaters where currently available efficiency measures are costly and underutilized.

A number of steps should be taken to ensure the success of ongoing market transformation efforts. First, for each technology target, it would be useful to adopt a coherent long-term market transformation strategy. The efforts discussed above generally involve coordinated efforts among multiple organizations, and a multi-year commitment, but some fall short of a truly integrated long-term strategy. In some cases, it may be possible to develop such strategies relatively quickly by bringing together interested manufacturers, utilities, government agencies, and other relevant parties.

Second, evaluation methods to assess the success of market transformation initiatives need to be refined. If utilities and government agencies are going to invest substantial resources in the transformation of end-use energy efficiency markets, they need to determine if their investments are delivering the desired results. While evaluation of conventional utility DSM programs is commonplace, evaluation of market transformation-oriented activities is more complex and less mature. Methods need to be developed to estimate what would have happened to markets if transformation strategies were not employed and to estimate the number of consumers who purchase efficient equipment but do not participate in utility or government-sponsored programs. Some progress has already been made in this area (see for example Feldman 1994; Prahl & Schlegel 1993; Wirtshafter & Sorrentino 1994), but further work is needed.

Third, while utilities can play a pivotal role in transformation initiatives, many utilities are cutting their DSM programs in order to reduce costs, fearing greater competition and "utility restructuring" (Nadel, Geller & Pye 1995). Utilities should give high priority to participating in market transformation initiatives in order to maximize the "bang per buck" of their remaining DSM efforts. At the same time, utility commissions need to support and reward utilities for participating in successful market transformation efforts. Financial rewards for market transformation should be based on evaluation results, be proportionate to the risks utilities incur and the benefits that are produced for society, and recognize that it can take many years for a market transformation effort to have a major impact.

Developing and implementing market transformation efforts will require extensive coordination and commitment on the part of many organizations. However, given the success of several past market transformation efforts, further implementation of comprehensive market transformation strategies is likely to be amply rewarded in terms of energy savings, economic gains, and environmental protection. Through effective market transformation, society can realize the large-scale and broad benefits offered by greater energy efficiency.

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