ELECTRIC MOTOR SYSTEM MARKET TRANSFORMATION

N. Richard Friedman[1]
R. Neal Elliott[2]
Bruce Meberg[3]
Jeffery Dowd[4]
Carl A. Burrell[1]
John F. DeKorte[3]

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American Council for an Energy-Efficient Economy
1001 Connecticut Avenue, NW, Suite 801, Washington, DC 20036 (202)429-8873

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1 Resource Dynamics Corporation
2 American Council for an Energy-Efficient Economy
3 Easton Consultants
4 Office of Efficiency and Alternative Fuels Planning, U.S. Department of Energy

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EXECUTIVE SUMMARY

Motor systems consume about 70 percent of all the electric energy used in the manufacturing sector of the United States (Elliott 1995). Numerous studies have shown that opportunities for efficiency improvement and performance optimization are greatest in the integration for the system. To date, however, most public and private programs to improve motor system energy efficiency have focused on the motor component. This is primarily due to the complexity of motor-driven equipment and motor systems as a whole.

To realize this potential for efficiency improvement, organizations will have to change the manner in which they design, maintain, and operate motors and motor systems. New market-based initiatives that encourage behavioral and infrastructural development will play an important role in achieving this potential. Such initiatives, known as "market transformation" initiatives, attempt to permanently change the structure of a product market in a desired way (in this case, toward greater energy efficiency). The long-term goal is to transform the markets so that efficient equipment and practices become the norm. The transformation process: (1) increases market penetration of current technologies and services; (2) encourages the development and introduction of advanced technologies; and (3) enhances current market infrastructures to facilitate the ongoing transformation process. Market transformation may seek to introduce desired products and services faster by enhancing the demand for them (market-pull) or by enhancing their supply (market-push).

To date, most market transformation efforts have focused on residential and commercial sector appliances, with notable successes including residential refrigerators and multiple glazed windows. These product areas are fairly simple in their energy performance and market dynamics. By contrast, motor systems and their markets are complex, not as well defined, and frequently have widely varying operating conditions. Therefore, market transformation strategies that were appropriate for refrigerators or multiple glazed windows may not be appropriate for industrial electric motor systems.

In this report, we discuss the development of a market transformation strategy for industrial electric motor systems. It lays out a general framework for formulating a market transformation strategy and describes how to apply this framework to the electric motor systems market. The goal of the electric motor systems market transformation process is to accelerate the movement of the market from a component focus (the existing market) to a systems-oriented focus (the transformed market).

In order to develop a targeted market transformation strategy, we have segmented the market by application. We focus on the top three motor-driven equipment segments in the manufacturing sector: industrial fan and blower systems, compressed air systems, and process pump systems. These three manufacturing applications comprise an estimated 25-30 percent of the total motor-related electricity consumption by the manufacturing sector, but represent more than 70 percent of the motor-driven electrical energy savings potential (Easton 1995).

Deficiencies exist in electric motor systems markets that will result in slow implementation of efficiency measures. Some deficiencies apply to individual markets while others are common to all markets. Deficiencies that are common to the various electric motor system market segments include:

- A lack of end-user knowledge of the motor system energy savings potential;
- A lack of incentive or motivation for certain market stakeholders to promote efficient system design or equipment purchases;
- A lack of technical expertise and tools to quantify and verify savings;
- Current efficiency efforts focus on the energy-efficient components, not system-level savings opportunities; and
- End-users may not perform life-cycle cost analysis.

A market transformation strategy is built from a mix of different actions that address different market deficiencies. The strategy is composed of two different types of actions: those that build and strengthen the market infrastructure to enable follow-on actions with direct results (infrastructure or enabling actions) and those that lead directly to enhanced system performance and reduction in energy consumption (direct market actions). In general, infrastructure/enabling actions address knowledge, information, or awareness deficiencies. Direct market actions include financial incentives such as rebates for energy-efficient motors and audit services to identify and quantify savings resulting from performance optimization. Without the infrastructure/enabling actions, direct market progress would be limited. Enabling actions may also address a deficiency within the marketplace, which allows the market to naturally evolve to a higher level of efficiency without any direct market actions.

Table 1 lists broad categories of actions that may be included as elements of a market transformation strategy. Different actions may be appropriately targeted at a specific, industrial-sector application segment within each market. In practice, to successfully implement market transformation, a number of these actions may need to be implemented in parallel, with market-pull (supply-side) and market-push (demand-side) actions coordinated in some way.

Table 1
Elements of a Motor System Market Transformation Framework

Infrastructure/Enabling	*Direct Market*
Test protocols	Recognition activities
Training and education	Opportunity identification
Development of information systems and databases	Encouragement of purchasing collaboratives
Development/distribution of decision support tools	Promotion of facilities management businesses
Development of best practices guidelines	Financial incentives (e.g., rebates, grants, financing, tax incentives)
Voluntary rating and labeling guidelines	Promotion of voluntary certification
Development of common user specifications (e.g., performance or purchasing)	Encouragement of early equipment retirement
Technical Assistance	Minimum efficiency regulations
Demonstrations	
Research and development	

Different organizations can play roles in implementing market transformation activities including:

- end-users,
- industry and professional trade associations,
- motor and original equipment manufacturers,
- utilities,
- equipment distributors,
- government agencies,
- engineering consultants and contractors,
- educational institutions,
- public interest groups, and
- research organizations.

Certain parties may engage in direct market participation, while other parties, such as government and trade associations, are expected to play a facilitation and support role. Partnerships and alliances between market players can enhance strategic business opportunities and foster development of cost-effective market transformation programs, particularly where commonalities exist to leverage resources and combine strengths. Partnerships, alliances, and collaboratives can also greatly influence purchasing power. They can create large market demand, influence product mix and pricing, and encourage the introduction of higher-efficiency products and services. Strategic partnerships can be formed at the regional, national, and international level. Initiatives at each level have different and often complementary characteristics.

Chapter 1

INTRODUCTION

1.1 Introduction

Motor systems consume about 70 percent of all the electric energy used in the manufacturing sector of the United States. To date, most public and private programs to improve motor system energy efficiency have focused on the motor component. This is primarily due to the complexity of motor-driven equipment and motor systems as a whole. The electric motor itself, however, is only the core component of a much broader system of electrical and mechanical equipment that provides a service, e.g., refrigeration, compression, or fluid movement. Numerous studies have shown that opportunities for efficiency improvement and performance optimization are actually much greater in the other components of the system — the controller, the mechanical system coupling, the driven equipment, and the interaction with the process operation (see Figure 1.1) (DOE 1993; Elliott 1994; Howe et al. 1993; Nadel et al. 1992). Despite these significant system-level opportunities, most efficiency improvement activities or programs have focused on the motor component or other individual components.

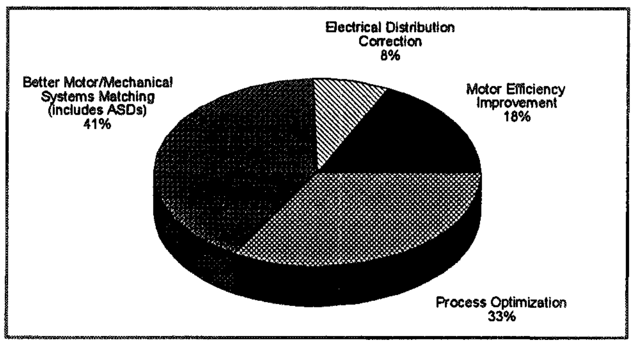

Figure 1.1 Energy Savings Potential in Electric Motor Systems (Source: DOE 1995b).

Taking a "systems approach" can increase the efficiency of electric motor systems by shifting the focus from individual components and functions to the total system performance. The total system efficiency of an electric motor system is determined by the weighted component efficiency and the interaction between the components. It is not enough to specify high-efficiency components to increase the efficiency of a motor system. In fact, emphasis on components alone may obscure the more important fact that greater cost savings are possible by optimizing the performance of the entire system. Careful consideration must be given to the selection of each of the components in the system to ensure that they will operate at their peak performance once they are integrated.

To realize this potential for efficiency improvement, organizations will have to change the manner in which they design, maintain and operate motors and motor systems. New market-based initiatives that encourage behavioral and infrastructural development will play an important role in achieving this potential. Such initiatives, known as "market transformation" initiatives, attempt to permanently change the structure of a product market in a desired way (in this case, toward greater energy efficiency). The long-term goal is to transform the markets so that efficient equipment and practices become the norm. The transformation process: (1) increases market penetration of current technologies and services; (2) encourages the development and introduction of advanced technologies; and (3) enhances current market infrastructures to facilitate the ongoing transformation process.

To date, most market transformation efforts have focused on residential and commercial sector appliances. Successes in these areas have included refrigerators (efficiency was increased by 175 percent from 1972 to 1993) and multiple glazed windows (sales were increased from 37 percent of the market in 1974 to 87 percent in 1991) (Geller and Nadel 1994). These product areas are fairly simple in their energy performance and market dynamics. For example, how refrigerators are used and how far technology can evolve with respect to energy efficiency is well understood.

By contrast, motor systems and their markets are complex, not as well defined, and frequently have widely varying operating conditions. It is difficult to determine how efficient products currently are or how much efficiency can be increased. For example, the efficiency of an adjustable speed drive (ASD) is defined more by the process application than the inherent efficiency of the component. Correctly applied, the ASD can greatly enhance process control and energy efficiency. If misapplied, ASDs may have adverse effects on the process without yielding any significant savings (Elliott 1994). Therefore, market transformation strategies that were appropriate for refrigerators or multiple glazed windows may not be appropriate for industrial electric motor systems.

1.2 Purpose and Organization of Report

This report discusses the development of a market transformation strategy for industrial electric motor systems. It lays out a general framework for formulating a market transformation strategy and describes how to apply this framework to the electric motor systems market. The report is intended to provide a foundation for actions of various market players — industrial end-users, trade associations, equipment suppliers, utilities, government, and other organizations — who wish to take advantage of the business opportunities that arise from participation in the market transformation process. In addition, the report provides the DOE's Motor Challenge program with direction for future market transformation efforts.

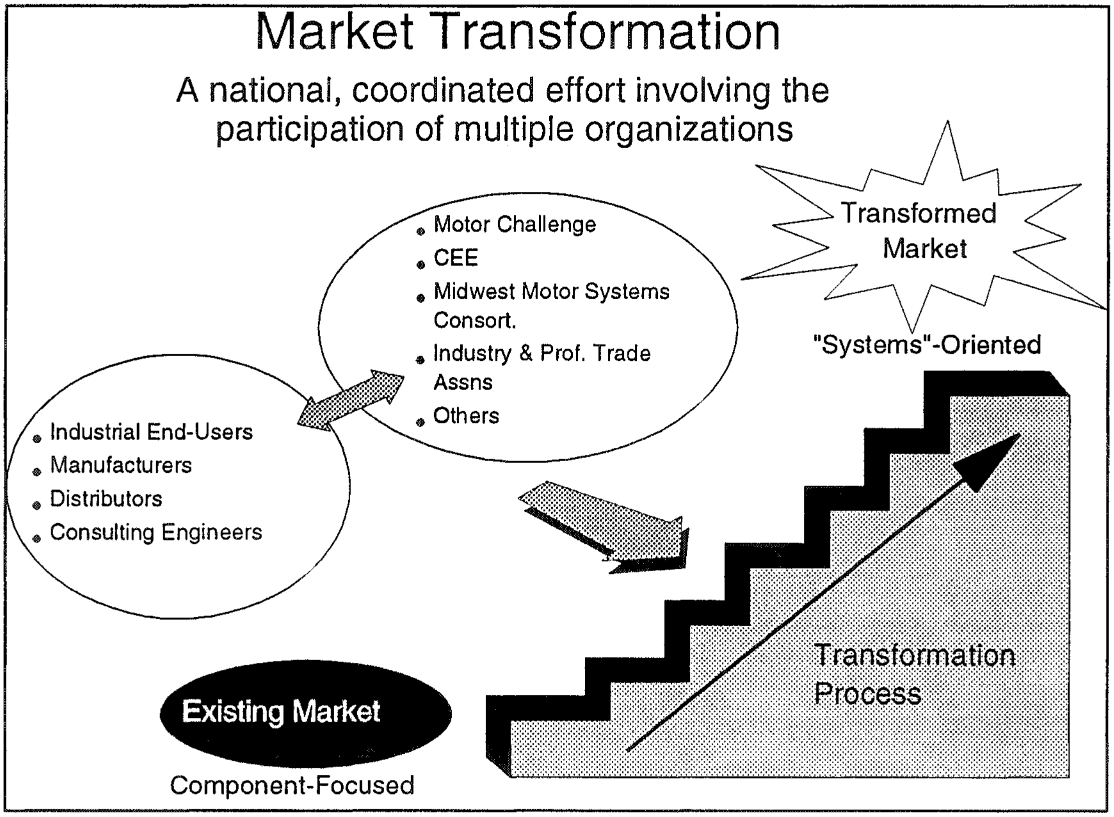

Figure 1.2 The Market Transformation Process

The report is organized into six chapters and an appendix. Chapter 1 introduces the concept of market transformation and summarizes the development of a market transformation strategy for electric motor systems. Chapter 2 provides background information on what constitutes an electric motor system and the basic concepts associated with market transformation, and discusses several characteristics of a transformed marketplace. An overview of motor and motor-driven equipment markets (industrial fan/blower, compressed air, and pump systems) is provided in Chapter 3. Chapter 4 presents a framework for formulating market transformation strategies and presents a range of possible market transformation actions. In Chapter 5, this framework is applied to the four specific market segments (motor, fan/blower, air compressor, and pump systems) profiled in Chapter 3. Chapter 6 examines the potential roles of private and public stakeholders — including end-users, government, utilities, engineering consultants, manufacturers and distributors — and provides examples of possible strategic partnerships. The Appendix provides a more detailed description of the list of the possible enabling and direct market actions that were identified by this research into transforming the motor systems market.

1.3 Goals of Motor Market Transformation

The goal of the market transformation process, illustrated in Figure 1.2, as applied to the electric motor systems market, is to accelerate the movement of the market from a component focus (the existing market) to a systems-oriented focus (the transformed market). Transformation of the marketplace to greater efficiency is a complex process, involving linked actions and a diverse group of stakeholders. The strategic actions presented in this report arise from a market-oriented, collaborative process over the past two years involving a number of diverse groups. The report represents the culmination of extensive market research, focusing on both the generic market transformation process and the electric motor system market.

DOE's market research in this area began in 1992, highlighted by the February 1993 *Round Table on Efficient Electric Motor Systems for Industry*. Subsequently, DOE participated with a number of electric utilities and other organizations in an original equipment manufacturer (OEM) market assessment organized and conducted by Easton Consultants. The Motor Challenge Program has held various meetings and focus groups with key market stakeholders to gain their perspective and learn from their experience in the marketplace. Most notable was DOE's *Round Table on Market Transformation Strategies for Industrial Electric Motor Systems* (DOE 1995b).

In parallel with this electric motor system research, DOE and other industry stakeholder investigators pursued the emerging field of market transformation from a generic perspective, seeking to define an overall approach to strategy development. Early contributors to the market transformation literature participated in this study, including key groups such as ACEEE and the Consortium for Energy Efficiency's (CEE) Motor System Committee.

1.4 Elements of a Market Transformation Strategy

Market transformation can be defined as a process to achieve accelerated, sustainable market penetration of "desired" products and services. Products are desired for the things they make possible, for example: increased productivity; efficiency; and competitiveness. Market transformation may seek to introduce desired products and services faster by enhancing the demand for them (market-pull) or by enhancing their supply (market-push).

A market transformation strategy is composed of two different types of actions: those that build and strengthen the market infrastructure to enable follow-on actions with direct results (infrastructure or enabling actions); and those that lead directly to enhanced system performance and reduction in energy consumption (direct market actions). In general, infrastructure/enabling actions address knowledge, information, or awareness deficiencies.

Direct market actions include financial incentives such as rebates for energy-efficient motors and audit services to identify and quantify savings resulting from performance optimization. Without the infrastructure/enabling actions, direct market progress would be limited.

In order to be successful, this process requires a national, coordinated effort, with the full participation of all relevant stakeholders. The range of stakeholders includes both the direct market players (e.g., end-users, manufacturers, distributors) as well as key organizations that can facilitate and support (e.g., utilities, government, engineering consultants, public interest groups, trade associations, etc.). Strategic partnerships and alliances among stakeholders – such as the Motor Challenge Program, Midwest Motor Systems Consortium, and CEE in the case of electric motor systems – can enhance individual stakeholder's business opportunities as well as foster development of cost-effective market transformation strategies, particularly where commonalities exist to leverage knowledge, resources, and purchasing power. They can also provide a forum to encourage discussion and a platform from which to influence market behavior (initiate market change).

1.5 Segmentation of the Electric Motor System Market

In order to develop a targeted market transformation strategy, in this report we segment the market by application based on information gathered through market research. In addition to motors, we focus on the top three motor-driven equipment segments in the manufacturing sector: industrial fan and blower systems; compressed air systems; and process pump systems. This decision is based on energy consumption and savings potential. These three manufacturing applications comprise an estimated 25-30 percent of the total motor-related electricity consumption by the manufacturing sector, but represent more than 70 percent of the motor-driven electrical energy savings potential (Easton 1994). From a market transformation perspective, market movement can be facilitated by focusing on these three broad driven equipment markets.

Once the market was segmented, the market deficiencies — practices and behaviors that do not lead to minimum motor-driven electricity consumption — that apply to each of these four markets were identified with the help of industry stakeholders. The existence of numerous market deficiencies makes it clear that the market for electric motor systems will likely not quickly implement efficiency measures. Some deficiencies apply to individual markets while others are common to all four markets. Deficiencies that are common to the various electric motor system market segments provide a blueprint of the most pressing needs of market stakeholders. These deficiencies include:

- A lack of knowledge at the end-user level regarding the energy savings potential available through optimizing motor-driven system design and equipment purchases.

- A lack of incentive or motivation for certain market stakeholders to promote efficient system design or equipment purchases.

- A lack of technical expertise and tools required to accurately quantify savings potentials and verify actual performance and savings.

- The current efficiency facilitation efforts (primarily utility programs) that typically focus on the energy-efficient components, not system-level savings opportunities.

- End-users may not perform life-cycle cost analysis when considering equipment or system investments.

1.6 Development of a Market Transformation Strategy for Electric Motor Systems

Drawing on all of its market research over the past two years, this effort identified a menu of strategic actions to potentially transform the market (Appendix A). This compilation of potential electric motor system market actions provided the starting point for identification of a final electric motor system action set (Table 1.1) as described in detail in Chapter 5.

1.7 Conclusions

We expect that businesses and organizations who participate in the market transformation process will find clear business opportunities and mutual interest in working cooperatively with other participants, and this will put them at a market advantage over those who do not participate in the process. We hope that efforts such as DOE's Motor Challenge Program and CEE will use the results of these efforts as a dynamic starting point for an aggressive market transformation initiative. Key trade allies in this effort have guided it from the beginning, and will continue to be an integral element in the expanding industry-government partnership being formed to pursue electric motor system market transformation.

Table 1.1
Leading Motor System Market Transformation Actions

Action Category	*Leading Action*
Training and Education of Market Players	■ training in strategic marketing ■ performance optimization training ■ customer motor system awareness
Information System and Database/Common User Specification	■ equipment performance and cost database ■ estimation of non-energy benefits ■ performance and cost savings case studies ■ common equipment and service purchase specifications
Decision Support	■ life-cycle costing tools ■ equipment selection software
Voluntary Rating and Labeling	■ guidelines for package-system performance ■ standardized energy user report for equipment ■ consistent information on equipment test procedures

Chapter 2

BACKGROUND

This chapter provides an overview of an electric motor system, describes the "systems approach" to improving energy efficiency, introduces the basic concept associated with market transformation, and discusses several characteristics of a transformed marketplace.

2.1 Elements of an Electric Motor System

Electric motor systems are a combination of electric motor-driven equipment and associated hardware that, when coupled together, converts electrical energy to mechanical or fluid power. The mechanical or fluid power is used to do work in a manufacturing process, production line, or building operation.

There can be many elements to a motor system. Although motor systems vary widely in configuration, characteristics, and their number of integrated parts, there are certain elements that are common to all types of systems (see Figure 2.1). A typical motor system will include the following components:

- Facility Power Distribution System
- Starting, Control and Feedback Mechanism
- Motor
- Coupling or Transmission
- Mechanical Load
- Accessory Equipment
- Distribution System
- Process

The analogy "wire to water" is often used to describe the boundaries of the energy transfer process in a typical motor system. The "wire" refers to where electrical power enters the system and "water" refers to the point at which mechanical power or fluid flow is transferred to the process. This concept holds true for all types of motor systems. For example, electrical energy is converted to fluid power by a motor that moves a pump, which moves water through a network of pipes, valves, connectors, and strainers in cooling processes. For a truly systems approach, though, it would be ideal if we could go further to determine if the process is optimal or even necessary. That, however, is beyond the scope of this report.

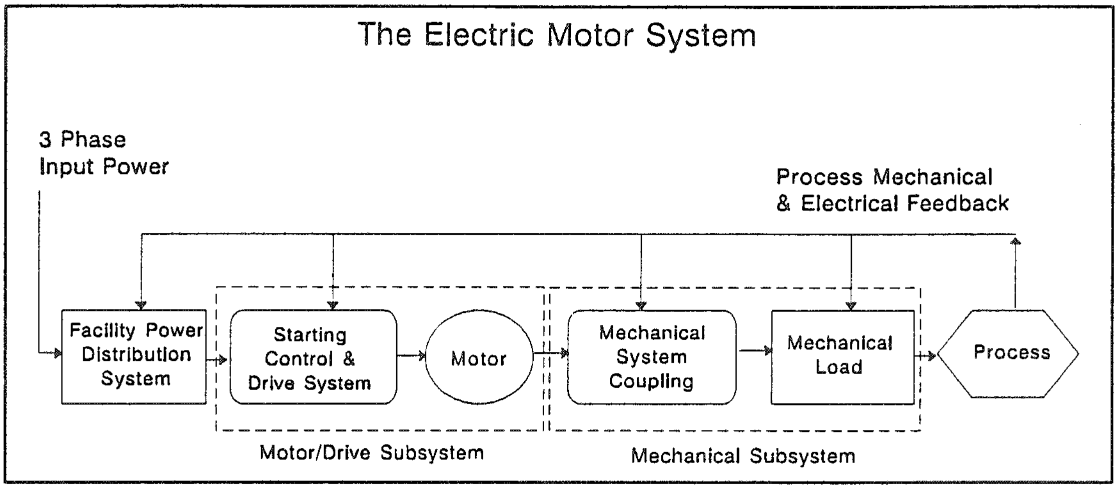

Figure 2.1 Electric Motor System (Source: Blazewicz et al. 1995).

Each of these subsystems serves a distinct purpose. For example, the facility power distribution system supplies electricity of the appropriate voltage and frequency to the motor and controls. The motor system controls serve four basic functions: (1) starting, directing, and protecting the operation of the motor and driven equipment; (2) varying the process output; (3) providing feedback from measured parameters to the control circuit; and (4) ensuring personnel safety. The motor is the part of the system that converts electrical energy to mechanical power. The motor transfers mechanical power to the load directly through a coupling or transmission system such as gears or belts. The driven equipment or mechanical load performs work. Driven equipment includes turbomachinery, such as fans/blowers, compressed air, and pumps, as well as conveyors and materials processing equipment such as cutters and grinders. Many fluid systems also include accessory equipment such as driers and screens to condition the fluid stream. A fluid system also includes a network of distribution systems (e.g., piping or ducting) to transport the working fluid to the process. Finally, we reach the process where the work is accomplished. Ultimately, the process and its requirements dictate the other components of the system.

2.2 Packaged Systems vs. Integrated Systems

Motor systems may be defined at two levels — "packaged systems" or "integrated systems." The term packaged system refers to a fan/blower, air compressor, or process pump system that is packaged and sold as a unit containing a motor, drive train, mechanical controls, outlet devices, and ancillary components. Packages are designed and assembled by original equipment manufacturers (OEMs) and sometimes may include electronic controls such as adjustable speed drives (ASDs). Figures 2.2, 2.3 and 2.4 depict what is typically included in a fan/blower, air compressor, and process pump packaged system, respectively. The fan housing package consists of an electric motor and a bladed impeller within a structural housing. Inlet and outlet devices are often sold with the fan. A standard air compressor package consists of an electric motor, a compressor, an air-end, filters, and water separators. A belt drive is offered on some models. Optional package components include dryers and after coolers. The pump "package" is not as clearly defined as other industrial equipment packages. Manufacturers and distributors sell process pumps with or without a motor and/or drive. Motors are either close-coupled, long-coupled or impart power through a belt drive.

The term "integrated systems" refers to the entire system boundary, from the energy input to the outlet of the process itself, including the piping/ducting distribution system, controls, motors, driven-equipment, and downstream process equipment. The distinction between components (component refers to a single element such as the motor, fan, or ASD), packaged systems, and integrated systems are necessary because different market transformation strategies can be targeted at different system levels.

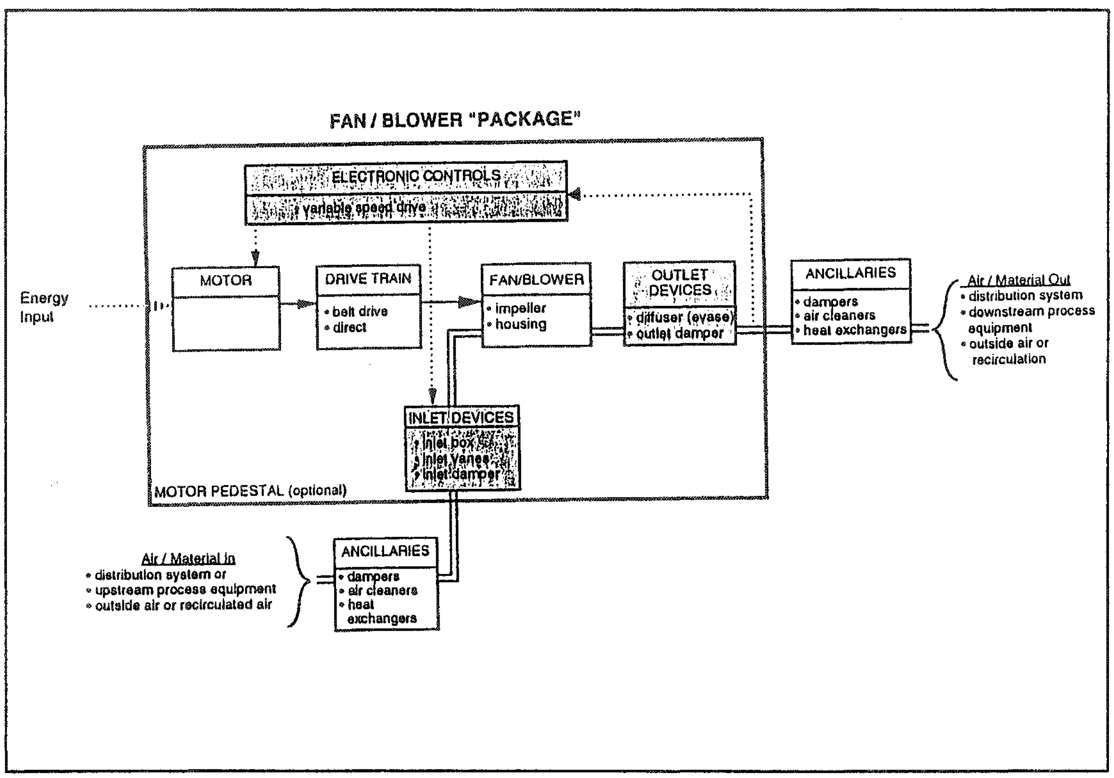

Figure 2.2 Fan Package (Source: Easton 1994)

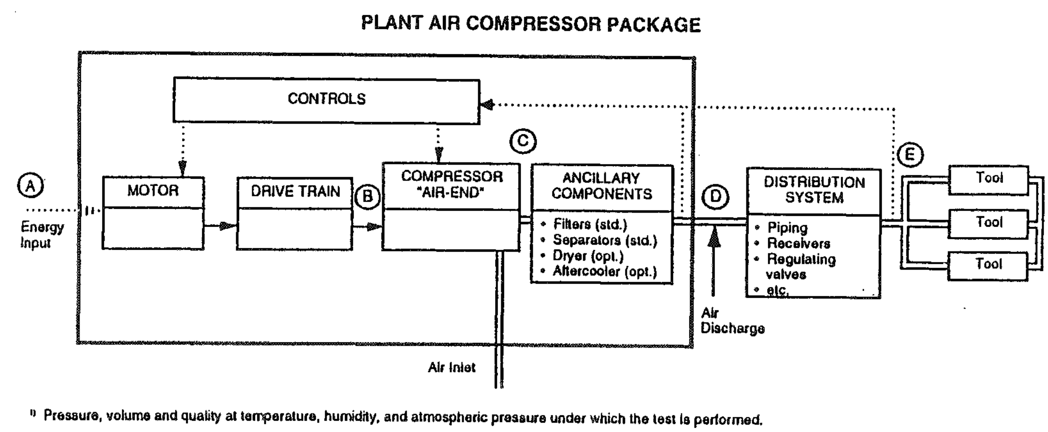

Figure 2.3 Air Compressor Package (Source: Easton 1994)

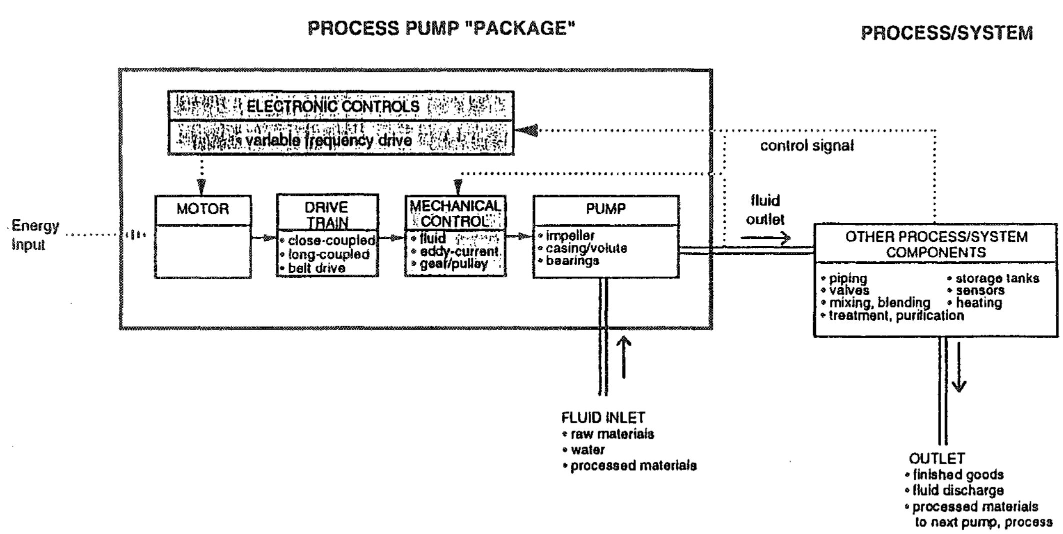

Figure 2.4 Process Pump Package (Source: Easton 1994).

2.3 The System Approach

For the electric motor system shown in Figure 2.1, total system efficiency is determined by the weighted component efficiency and the interaction between components. It is not enough to specify high-efficiency components to increase the performance of motor systems. Emphasis on components (e.g., motor, ASD, etc.) alone may obscure the more important fact that much greater energy and cost savings are possible by optimizing the performance of the complete system. In an electric motor system, the energy efficiency of the motor itself (typically 3 to 10 percent greater for energy-efficient motors) is only part of the energy efficiency of the total system. Installing an energy-efficient motor without understanding the system can reduce the benefits that otherwise would be attained.[1]

The "systems approach" is a way to increase the efficiency of electric motor systems by shifting the focus from individual elements and functions to the total system performance and effect. The components are considered as a team in which they all work continuously to maximize performance and mitigate disturbances. Careful consideration must be given to the selection of the components in the system to ensure that they will collectively operate at their peak performance once they are integrated.

The system approach process involves several interrelated actions, including, for example:

- Establishing current conditions and operating parameters (for the retrofit of existing systems)
- Determining current and future process or production needs
- Gathering and analyzing operating data, and developing load-duty cycles;
- Assessing alternative system designs
- Determining technically and economically sound options
- Refining system design
- Assessing energy and analyzing economics (energy and non-energy benefits)
- Presenting findings
- Installing and commissioning
- Guaranteeing the system will perform adequately
- Upgrading the system as needed

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1 For example, different motors have different load-speed curves. Since the load of a turbo machine (e.g., a fan) varies approximately as the cube of the speed, if an efficient, faster motor replaces an inefficient, slower motor, the total energy consumption of the system can increase. More air will be moved, but unless the process requires more air, no benefit will be achieved.

Central to applying the systems approach concept is the need for cooperation among key market players. This requires the collective efforts of all the players involved: equipment vendors, consulting engineers, contractors, and end-users, for example. Greater consideration must go to the design, specification, and application of the components that make up the motor system. For the players involved, this means considering the optimum performance of the overall motor system, and working collectively to ensure the products and services the players provide will attain this end. When retrofitting or supplying new equipment, the aim is to come up with a total system solution, not just equipment fixes.

The systems approach to optimizing motor systems is not a new concept. It has long been a foundation of value engineering and is now beginning to be used throughout industry, particularly in promoting the use of more efficient motor systems in Canada and Wisconsin (Carroll et al. 1994). The systems approach is being used as the platform for developing various marketing, training, and trade ally programs to promote efficient compressor, pump, and fan and blower systems. These programs have proven to be effective in helping utility customers increase process and operating efficiency, and addressing environmental issues. For the market players who have adopted the system approach, it has meant tremendous opportunities in new business partnerships and growing demand for premium energy-efficient products and services.

2.4 Market Transformation

"Market transformation" is a term for initiatives that attempt to permanently influence the structure of a product market in a desired way (in this case, toward greater energy efficiency). The long-term goal of market transformation is to make efficient equipment and practices the norm so that continuing market intervention is not required. This process involves: 1) increasing market penetration of current technologies and services; 2) encouraging the development and introduction of advanced technologies; and 3) enhancing current market infrastructures to facilitate and support the ongoing transformation process.

Market transformation efforts achieve these goals by addressing deficiencies that exist in a marketplace. Specific policies and programs attempt to remove market barriers to wider adoption of energy-efficient products and services. Market barriers may include: a lack of awareness regarding energy-related issues; a lack of knowledge of energy-efficient alternatives; limited access to more efficient technologies; high first cost for efficient alternatives; technology misconceptions; and high costs and risks for the development and marketing of new products.

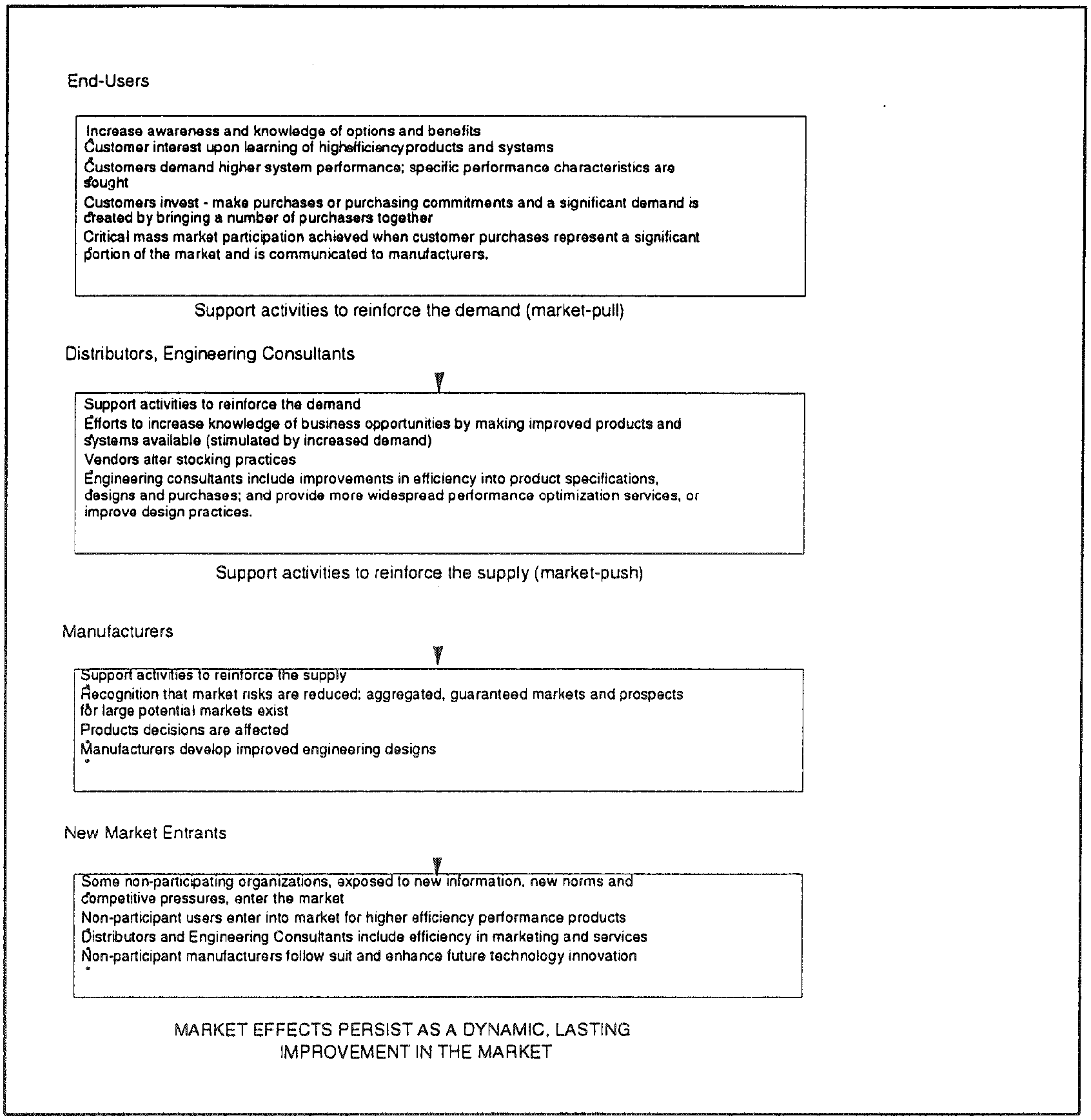

Figure 2.5 Dynamics of Market Transformation

In the context of this report, market transformation is defined as a process to achieve faster and sustainable market penetration of "desired" products and services. Products are "desired" for the things they make possible, for example, higher productivity, efficiency, or reduced environmental effects. Market transformation may seek to introduce desired products and services into the market faster by enhancing the demand for them (market-pull), and/or may seek to make desired products and services available to the market faster by enhancing the supply of them (market-push). This process is illustrated in Figure 2.5. The goal of market transformation strategies for electric motor systems that are presented in this report is to shift the market focus from individual components and functions to a total system performance perspective.

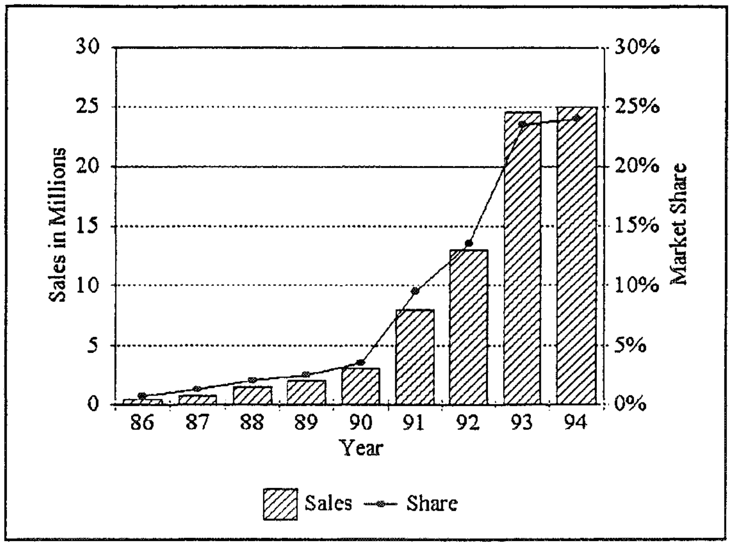

Figure 2.6 Sales and Market Share of U.S. Electronic Fluorescent Lamp Ballast (Source: Nadel and Geller 1995).

Most past efforts at market transformation, with the notable exception of energy-efficient motors, have focused on residential and commercial appliances. Successes in these areas have included: increased efficiency of refrigerators (by 175 percent from 1972 to 1993); and increased market share of multiple-glazed windows (from 37 percent of the market in 1974 to 87 percent in 1991). Another example of successful market transformation is high-efficiency, electronic, fluorescent ballasts, which reduced electricity use for lighting by 20-30 percent. R&D from 1976 to 1980, largely sponsored by DOE, led to the introduction of these ballasts in 1980. Beginning in the 1980s, utilities started offering rebates for these products and large users such as school systems began making bulk purchases. These actions provided the sales volume necessary to allow manufacturers to address reliability problems and reduce prices by two-thirds. The EPA Green Lights program, begun in 1991, further increased market interest in electronic ballasts. As a result, sales increased almost 25 fold in the period 1986-1993 (see Figure 2.6). In 1994, DOE proposed minimum efficiency standards that would essentially require electronic ballasts (see text box for a definition of standards). If these proposed standards are issued in final form, the market transformation could be completed by around 1999 (Geller and Nadel 1994).

These product areas are fairly simple in their energy performance and market dynamics. In the case of refrigerators, for example, we have a good understanding of how the products are used and how far technology can evolve with respect to energy efficiency. We plug them in and continue to use them as we have previous models with no change in their utility.

By contrast, motor systems and their markets are complex. As we move from residential and commercial to industrial equipment and systems, the relationships are more complex and not as well defined. Systems frequently have widely varying operating conditions. Often we don't know how efficient current products are or how much efficiency could be improved. For example, the efficiency of an ASD is defined by the process application rather than by the inherent efficiency of the components. Correctly applied, process

Standards

The term "standards" refers to four different concepts. These types of standards can be voluntary or mandatory. Rather than use the term standards interchangeably, this report will use the following set of terms:

- Test Procedures. Test procedures are systematic and repeatable methodologies that are used to measure the relative efficiency and performance of a product. An example of a standard test procedure is the Institute of Electrical and Electronic Engineers (IEEE) 112b test procedure that is commonly used to measure the relative performance of polyphase induction motors.

- Minimum Performance Levels. These are minimum performance indices (e.g., percentage efficiency, COP, kWh, etc.) that are used to define energy-efficient equipment or promote production or sale of energy-efficient equipment. Examples include NEMA MG-1 Table 12-10 and EPAct minimum efficiency requirements for energy-efficient motors.

- Efficiency Ratings and Labeling. Rating and labeling attempts to group products into categories that reflect similar performance and characteristics; for example, "Energy Guide" labels on household appliances.

- Good or Best Practice Guides. Good or best practice guides are recommended procedures and practices that apply to the manner in which equipment is specified, operated and serviced. For example, the Association of Heating Refrigerating and Air Conditioning Engineers (ASHRAE) 90.1 standard for commercial buildings serves as a model for state and local buildings codes.

control and energy efficiency can be greatly enhanced. If misapplied, the ASD may have adverse effects on the process without yielding significant savings. It therefore is important to note that a market transformation strategy appropriate for refrigerators, may be inappropriate for an industrial system.

2.5 Sustainable Market Development

Perhaps the most challenging aspect of market transformation is the ability to promote and sustain ongoing development. A sustainable energy-efficient motor systems marketplace would be characterized by an automatic and permanent adoption of energy-efficient products and services. This will require organizational structures and systems that are built around these products, technologies, and services. In this environment, it is envisioned that the marketplace will be more responsive to customer requirements for premium products and services that not only meet product features and functions, but are also competitively priced. The success or failure of motor systems market transformation will depend largely on the level of effort by market suppliers and to what extent the system approach is adopted.

If market transformation efforts are successful, the benefits will be maintained after the discontinuation of efforts. For example, the Canadian utilities implemented a mix of strategies to develop the energy-efficient motor market (see Figure 2.7). Initial informational and educational programs were offered to increase awareness of the benefits of energy-efficient motors. The impact was limited, prompting the utilities to implement aggressive marketing plans to support trade ally development and their direct marketing and sales efforts. This was complimented by cash rebates to the customer to offset the higher incremental cost and to distributors to promote and stock the energy-efficient alternative. The utilities collectively orchestrated biyearly increases in minimum efficiency levels, and reduced rebate levels as penetration of energy-efficient motors increased (Geller and Nadel 1994).

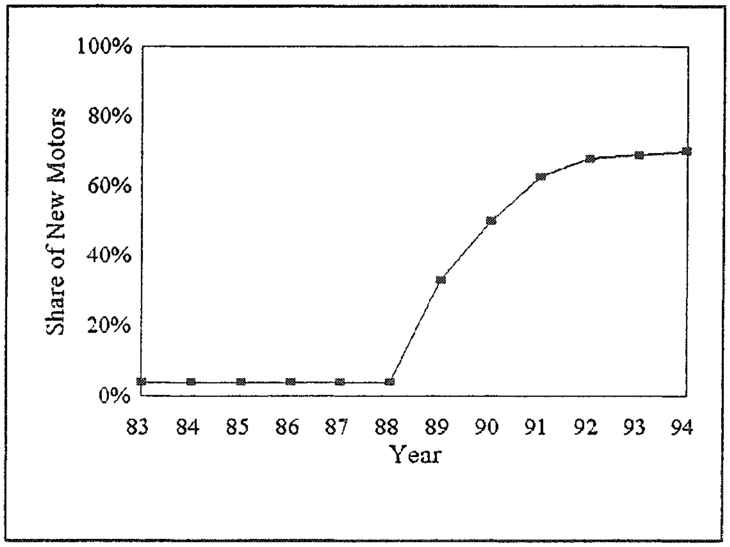

Figure 2.7 Share of High-Efficiency New Motor Purchases in BC Hydro Service Territory (Source: McMenamin et al. 1994).

Except for a few smaller markets (i.e., Manitoba), rebates were completely phased-out in 1995. National efficiency standards will ensure that the market changes will persist, at least with respect to adoption of high-efficiency motors. The utilities will shift toward quality assurance rewind services to ensure that efficiency gains are sustained through proper rewind practices and quality workmanship (McMenamin, et al., 1994).

The following are key factors for developing and sustaining transformation in motor systems markets:

- <u>Product and Service Marketability</u>. The level of demand may be the most important indicator of the marketability of energy-efficient motor systems and support services. The demand for efficient motor systems does not exist in and of itself, but rather because of the things they make possible: increased productivity, reliability, environmental performance, and competitiveness, for example. The greatest value will be placed on those systems that allow the user to conduct business in the most efficient and cost-effective manner possible. In addition, end-users may show a preference for integrated packages of products and services supplied by a single source or team. In marketing motor systems, suppliers will not only have to sell a system of interrelated products, but also a system of operating practices, inventory control, and other services to meet specific user needs.

- Product and Service Availability. In a transformed marketplace, energy-efficient products and services can be sourced cost-effectively and with relative ease. The availability of essential technologies, products, and services can hinder or accelerate the market transformation process. It can often be a "Catch-22" situation. As recently as a few years ago, lead time for a typical energy-efficient motor was six to fourteen weeks. Manufacturers were reluctant to build energy-efficient motors because their higher incremental cost made them difficult to sell. But with better economies of scale the incremental cost could have been reduced. However, low user demand limited marketing and production runs. This created a vicious circle. Today, however, energy-efficient motors are readily available, in part because of utility rebate programs. Greater availability of the product has helped to increase demand, increase marketability, and lower incremental costs.

- Information and Technology Availability. The availability of good information and access to technology is important to developing and sustaining market transformation. Market transformation strategies must include options to establish information systems that are integrated across all levels to foster effective day-to-day information and technology transfer. Going beyond this, the management of information and technology itself is crucial functions in the transformation process and requires considerable attention. This will involve supplementing energy efficiency information with economic, financial, and policy-related information and presenting it in formats that are useful to the recipients.

- Availability of Expertise. Another factor important to the transformation process is the availability of a wide network of expert groups and recognized expert centers. Strategies must be designed to promote and encourage the development of these important resources within the motor systems market transformation framework. Motor system expertise that will be essential to the market transformation process include: field performance and engineering analysis, value engineering, systems marketing, policy analysis and other interrelated services. The availability of and accessibility to knowledge will strengthen the market transformation support framework. Equally important are provisions to encourage networking among expert groups to enhance their knowledge-base, share information, and encourage strategic alliances within and across markets (DOE 1993).

- Stakeholder Equity. Stakeholder equity or "what's in it for me" is another factor in a successful market transformation. For market transformation strategies to receive a high degree of acceptance and support among the stakeholders, the perceived benefits and expected outcomes must be clearly defined. The ultimate business environment would be one in which all market players win. The development of market transformation strategies must take the stakeholder's view as the starting point. Strategies should be designed to maximize the benefits to all stakeholders.

- Behavioral and Attitudinal Change. Creating "sophisticated buyers" who are armed with timely, valuable information that will allow them to make more informed and effective decisions is important to the success of any market transformation effort. This will call for a new way of thinking. Types of behavioral and attitudinal changes include: shifts in conventional thinking, heightened awareness, and increased knowledge level.

- Tracking and Evaluation. The assessment of market trends and performance is a basic function of the transformation process. These activities are required to track progress toward specific program objectives and overall market transformation goals. Checks and balances are also needed to help identify and respond to early signs of potential market deficiencies. These mechanisms must be an integral component in program design. They should be designed to provide automatic and real-time feedback into the market transformation process. Testing and verification programs, for example, can provide a wealth of market intelligence on how well the market is performing relative to a base period.

Chapter 3

MOTOR SYSTEMS MARKET ANALYSIS

This chapter provides an overview of the motor and motor-driven equipment markets. It introduces the players, the component equipment, and the systems in which the equipment operates. For each of the four markets (motors, fans/blowers, air compressors, and pumps), this chapter describes the way these markets operate, estimate electricity use and savings potentials, and examine deficiencies that exist in the marketplace.

3.1 Market Segmentation Methodology

There are several dimensions along which to segment the "market" for motor-driven equipment: by application segment (e.g., fans, pumps and air compressors), by system level (e.g., motor-drive-fan versus total air distribution system) within which the motor-driven equipment operates, by stakeholder level in the market (e.g., manufacturer, specifier and end-user), and by new equipment versus installed base. Another way of segmenting the market is by the level of the system at which facilitation efforts are aimed – component (e.g., motor or fan), the packaged system, or the integrated system (including system layout and control).[1] The primary basis chosen for segmentation within this study is by application.

The electric motor systems market is often oversimplified by examination of only the motor itself. From a market transformation perspective, market movement can be facilitated by focusing on the broad driven equipment market. The top three application segments within the manufacturing sector — process industry pumps, industrial fans and blowers, and plant air compressor systems — are the driven equipment market segments targeted by this study.

Key factors in deciding which segments to pursue were energy consumption and savings potential. About two-thirds of the manufacturing sector electricity consumption involves motors. This motor-related consumption can be divided into five application categories. Relative energy consumption by application is illustrated in Figure 3.1. Despite having

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1 Examples of market transformation actions that may be targeted at component, packaged-system, and integrated-system levels are as follows: component — promote increased intrinsic efficiency of components (e.g., energy-efficient motors, efficient impeller types, more efficient belts); packaged-system — improve equipment designs, develop efficiency ratings and performance guidelines; and integrated-system — promote performance optimization services, component selection, and improve operation and maintenance practices.

smaller electricity consumption than material handling and material processing, fans/blowers, compressors, and pumps represent a larger potential for savings. This larger potential results from 1) the ubiquitousness of these equipment types, 2) the fact that energy use varies as the cube of rotating speed (i.e., the affinity law) so that correct sizing of the system to an actual load is critical, and 3) that design and maintenance practices have resulted in many system inefficiencies. A recent ACEEE study estimated that more than 80 percent of the efficiency improvement opportunity in manufacturing electricity use was in motor systems (Elliott 1994).

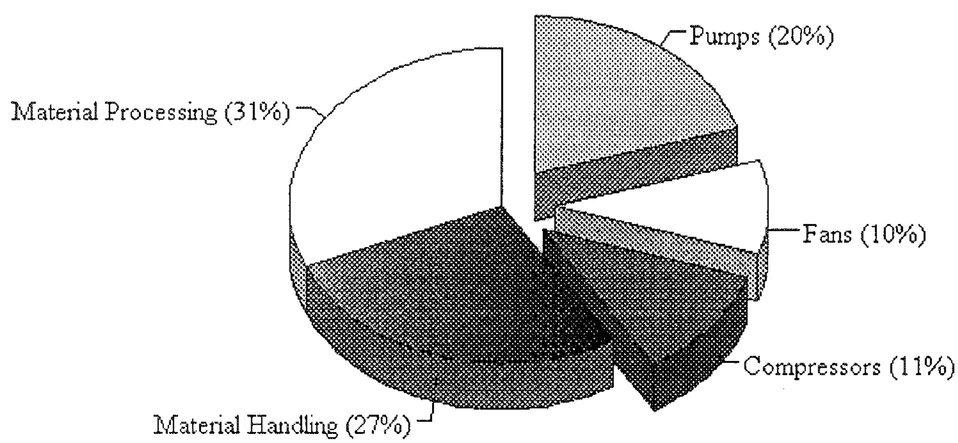
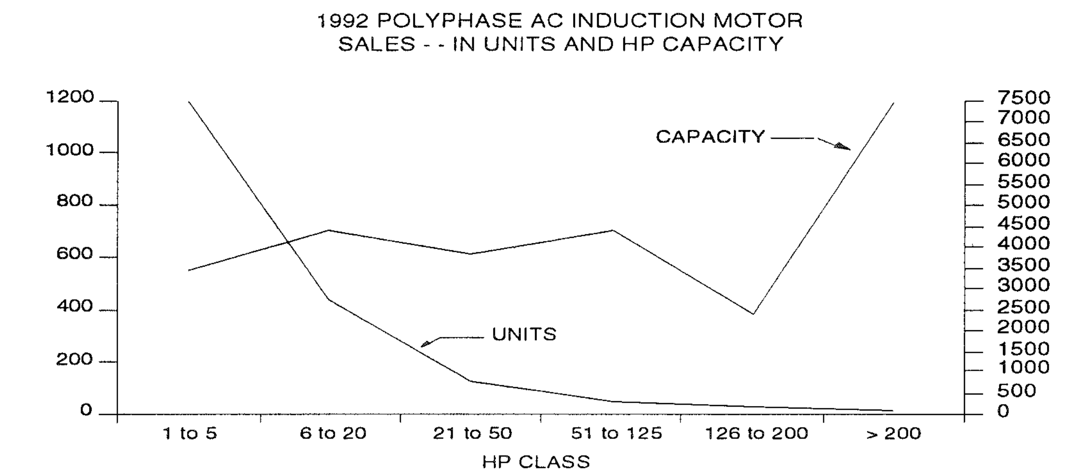


Figure 3.1 Electricity Consumption by Motor Driven Loads in the Manufacturing Sector (Source: Elliott 1994)

The focus of early industrial energy savings potential research has been on air compressor, fan/blower, and pump systems. Combined, these application segments probably represent most of the motor-driven energy savings potential. The characteristics of each of these application segments are discussed below.



Units (000)	1200	438	127	51	17	20	1853
Avg HP:	3	10	30	85	~ 140	375	
Capacity (000 HP):	3600	4380	3810	4335	2380	7500	

Figure 3.2 Motor Market Sales (Source: Easton 1995).

3.2. Motors and Drives Market

The most commonly used industrial motor is the integral horsepower AC polyphase induction motor. Nearly two million of these motors are sold in the U.S. each year, representing about 5-7 percent of the more than 25 million motors of this type in the installed base in the U.S. Motors at or below five horsepower represent more than 60 percent of unit sales, however these motors account for less than 15 percent of annual capacity sold into the market. AC induction motors over 20 horsepower, on the other hand, represent just 15 percent of unit sales but nearly 70 percent of capacity sales (Easton 1995).

OEMs purchase more than half of all integral horsepower, polyphase AC induction motors. The remaining motors are sold either through motor distributors or directly to end-users. The share of energy-efficient motors (as defined by NEMA MG-1, Table 12-10) has increased to approximately 25 percent of total sales. Penetration is highest in the distributor sales market, where it may be as high as 40-45 percent, in part due to utility rebate and incentive programs. However, sales of premium efficiency motors to the OEM market remains low. The premium-motor share in this channel is estimated at 5-10 percent (see Figure 3.2) (Easton 1995). Figure 3.3 illustrates the market delivery system for motors.

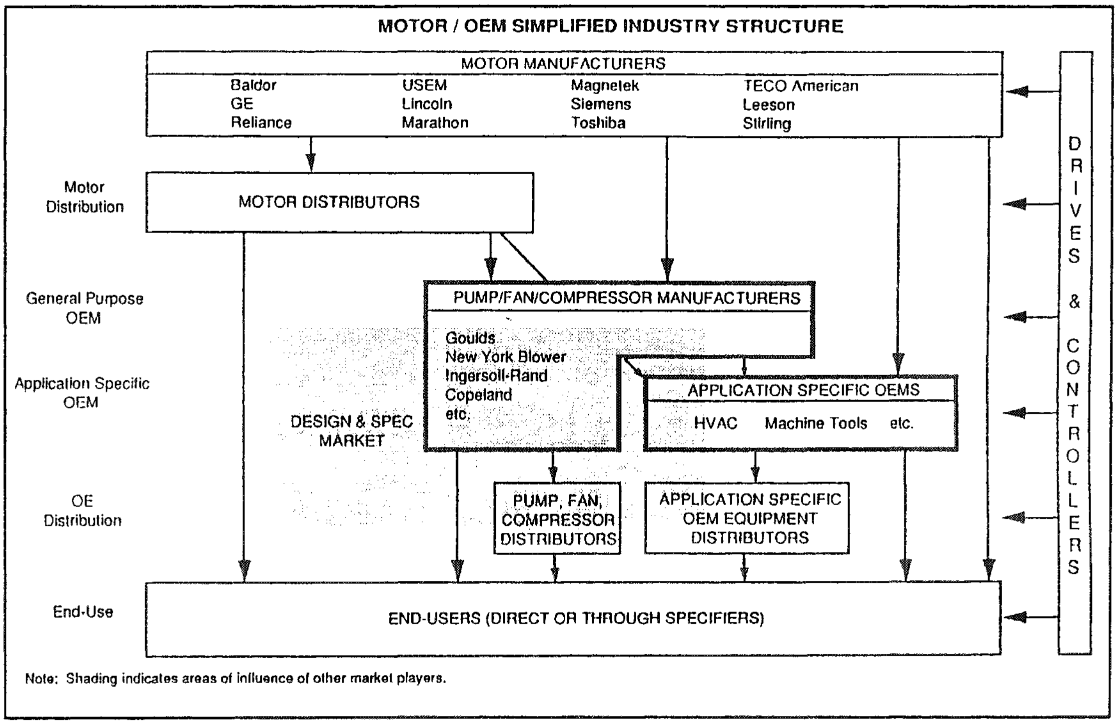


Figure 3.3 Market Delivery System for Motors (Source: Easton 1995).

Relative to the sales of AC polyphase induction motors, U.S. purchases of adjustable speed drives are small. Drives are being installed at a rate of approximately 100,000 units per year, less than 5 percent of the rate of AC induction motors. However, sales have been growing at an average annual rate of 35 percent based on dollar volume since 1988 (Easton 1995). The market for adjustable speed drives (ASDs) has been growing for several reasons. Improved technology allows ASDs to replace DC drives in applications requiring precise speed control. Unit costs have been declining, and utility rebate programs promoting ASDs are becoming more common. Finally, motors and ASDs sold as a packaged unit, an important recent trend, are becoming less expensive and more attractive to less sophisticated end-users.

Because of their higher rate of consumption and typically higher hours of use, large motors consume more electricity than small motors despite their relatively lower unit sales. However, the savings potential from increasing efficient motor penetration is greater with smaller motors because the relative potential to improve the energy efficiency of smaller motors is greater and the penetration of efficient motors in smaller motor classes is lower. Several market deficiencies impede penetration of energy-efficient motor and drive equipment and practices. For the purpose of this report, market deficiencies are defined from the point of view of practices and behaviors that do not lead to minimum motor-driven electricity consumption and are not intended to suggest market failure. Table 3.1 lists some of these market deficiencies (Easton 1995).

Table 3.1
Deficiencies Associated With the Motor and Drive System Market

Market Deficiency	*Description*
Insufficient information dissemination and knowledge regarding: - True savings potential of energy-efficient motors - Applicability of ASDs - Actual performance characteristics of premium efficiency motors and ASDs	- Many users do not know how or do not have the tools to easily and quickly calculate the life-cycle cost savings that energy-efficient motors can provide. - Many users remain skeptical about using ASDs in their applications. Making changes in a process entail risk on the part of the initiator, a risk that may not seem to be worth the reward, especially if lack of application knowledge increases the perceived risk. - Until recently motor/drive packages, which were tested as a unit, were not available. There are still conflicting accounts of torque, temperature and other characteristics of energy-efficient motors, and of the impacts of ASDs on new or existing motor performance.
Uncertain and changing definitions of "high" and "premium" efficiency motors are confusing and potentially misleading to stakeholders.	NEMA's suggested definition of "energy-efficient" motor per MG-1 Table 12-10 provides a benchmark for nominal full load efficiency levels, but manufacturers and specifiers often use different terminology and definitions. "High" and "premium" efficiency levels may be set relative to NEMA tables, competitors' products, or a manufacturer's own standard line. In October 1997 NEMA's definition becomes obsolete when EPAct levels (the same as Table 12-10) become the <u>minimum</u>, not the definition of "energy-efficient."
Sub-optimal failed motor situation practices including poor motor rewind practices and "like-for-like" and low first-cost purchase behavior.	Most end-users do not have pro-active plans for what to do when motors fail. In the rush to obtain a replacement motor as soon as possible, they do not always use repair shops that have been evaluated in terms of rewind and repair practices and their effect on motor efficiency. They typically do not perform a life-cycle cost study to determine whether an energy-efficient motor would provide a rational return on investment.

3.3 Industrial Fan and Blower System Market

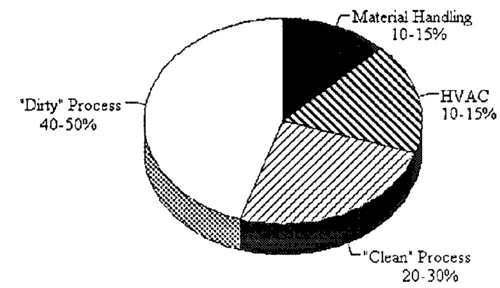


Figure 3.4 Industrial Fan Sales by Application (Source: Easton 1995).

Fan and blower systems are used in a variety of applications in the industrial market. The applications can be roughly categorized as "clean" process, "dirty" process, material handling, and HVAC (Figure 3.4). These categories tend to blend together and it is often difficult to differentiate and segment fans and blowers by application category. Electricity consumption by the installed base of industrial fans and blowers is estimated at 45-55 terawatt-hours (TWh) per year, roughly 8-10 percent of total motor-driven manufacturing sector electricity consumption (Easton 1995). Centrifugal fans dominate the fan and blower market in the manufacturing sector, accounting for more than 90 percent of fan and blower energy consumption. An estimated 45,000 to 50,000 centrifugal fans are sold to the manufacturing sector each year. Axial fans, which are used primarily in commercial HVAC applications or for large flow, clean air applications in the mining, utility, and transportation sectors, make up the remainder of the market.

The industrial fan and blower market is fragmented and competitive, with no manufacturer accounting for more than a 12 percent market share (Easton 1995). Manufacturers sell fans and blowers through manufacturer representatives or to other OEMs, including dust collection, HVAC, oven, boiler, and pollution control equipment manufacturers, among others (Figure 3.5).

Contractors install most fan and blower systems. Specifiers work with the contractor, end-user, and manufacturer representatives to design the system and select equipment. Finally, independent air balancing firms may be called upon to test the system after installation and certify that it meets design criteria.

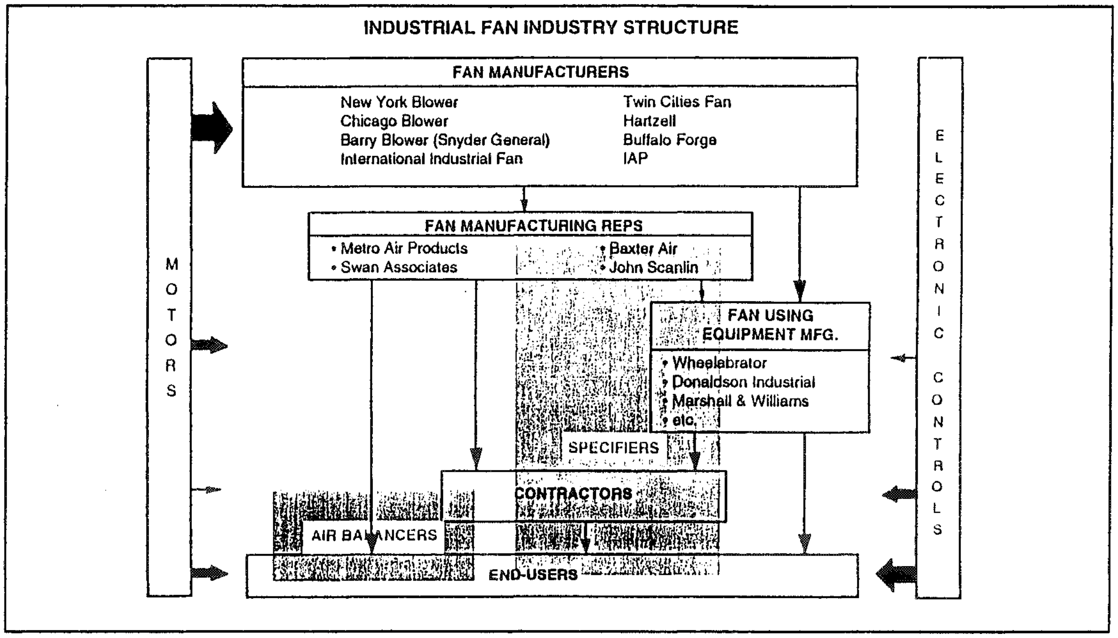


Figure 3.5 Fan/Blower Market Structure (Source: Easton 1995).

Initial field research suggests that substantial further reductions in industrial fan and blower electricity consumption are possible (see Table 3.2).[1] Moderate equipment-level savings potential exists, but these savings opportunities may be applicable to a large share of the market. Although intrinsic efficiency gains are not likely, improving motor, drive train and impeller selection practices offers modest savings potential. Improving system design to reduce the "system effect" in poorly designed systems can reduce consumption at selected sites. The large number of different industrial fan and blower applications, and site-specific operating conditions limit the potential for broad-based prescriptive equipment and system solutions.

1 Identifying savings opportunities requires detailed analysis of specific sites and system operation. Because fan and blower systems vary widely from site to site, predicting the total available savings potential will require a thorough understanding of current design, selection, and operations and maintenance practices by industry and application.

Table 3.2
Energy Savings Potential for Specific Fan and Blower Systems

Equipment	5 - 15%
Speed Control	20 - 50%*
System Design	5 - 25%

* Applies to variable flow systems.
Source: Easton 1995.

Initial field research also suggests seven main obstacles to encouraging greater industrial fan and blower system efficiency. These deficiencies are summarized in Table 3.3.

3.4 Air Compressor System Market

General plant compressed air systems are pervasive throughout the manufacturing sector. Analogous to a utility, compressed air lines run throughout factories and other facilities and support air-driven hand tools, clamps, and motors, among other uses. The systems vary widely in configurations, but have several similar characteristics. They typically range from 90 to 125 pounds per square inch (psi) and 100 to 1,500 cubic feet per minute (cfm). All systems consist of one or more electric motors, compressor air-ends/packages, filters and/or dryers, pressurized air reservoirs, distribution piping and valves, and point-of use tools.

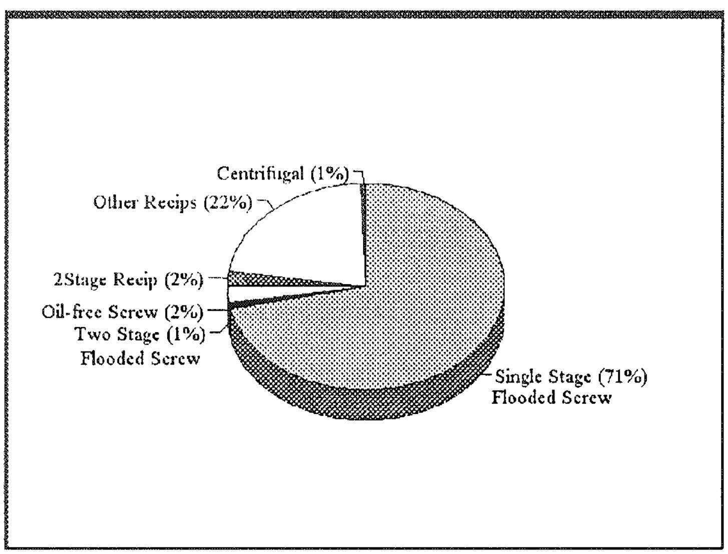


Figure 3.6 Distribution of Estimated Annual Plant Air Compressor Unit Sales (Source: Easton 1995).

Slightly more than one million air compressors are sold to the U.S. market each year, of which 98 percent are five horsepower or smaller (Easton 1995). These small compressors are sold largely to the commercial and residential markets. Due to the very low hours of use, however, they account for only 12 percent of annual electricity consumption by the new units. Air compressors at or above twenty-five horse-power, while accounting for

Table 3.3
Deficiencies Associated With the Fan and Blower Systems Market

Market Deficiency	*Description*
ASDs are not used in many applications for which they are suit-able due to: ■ lack of knowledge of applicability and ■ the high first-cost of ASDs.	Many users remain skeptical about using ASDs in their applications. Making changes in a process entail risk on the part of the initiator, a risk that may not seem to be worth the reward, especially if lack of application knowledge increases the perceived risk.
Lack of system design expertise creates (from an efficiency standpoint) a sub-optimal system design, specification development, and equipment selection.	System designs can be improved in terms of: designing ductwork layouts that minimize the "system" effect (where bends are too close to an outlet causing increased pressure and energy consumption), minimizing pressure drops, etc. Because fans from different manufacturers have their Best Efficiency Points at different conditions, selecting the most efficient fan for the required head and flow from a wider set of choices could save energy. Minimum equipment efficiency levels are often not included in specifications or are easily met by many models. Even when minimum fan or motor efficiency levels or specific models are written into specs, lax bidding procedures may allow lower efficiency models to be purchased.
The most efficient fan type for the specific operating conditions is often not used due to lack of information about alternative equipment designs and performance capabilities.	Airfoil blades (either metal or fiberglass) could be used in place of less efficient backward inclined blades in some applications. Likewise, backward inclined blades could replace some less-efficient radial tip impellers if users were provided with appropriate application information. Variations in practices across industries and geographies indicate the potential for improvement. Energy-efficient backward inclined fans (larger diameter, narrower and lower speed) could substitute for standard, backward inclined fans in many applications.

Table 3.3 (continued)
Deficiencies Associated With the Fan and Blower Systems Market

Market Deficiency	*Description*
Equipment/system end-users and purchasers do not always specify minimum efficiency levels or energy consumption requirements	Minimum equipment efficiency levels often are not included in specifications or are too low. Ambiguous phrases such as "or equivalent model" provide loopholes for lower efficiency fans to be selected. Requiring bids to include energy consumption data (for the given operating conditions) rather than efficiency, may be more accurate, allow easier comparison among bids, and simplify life-cycle cost calculations.
End-users may base purchase decisions on first cost and do not consider the life-cycle energy cost savings associated with higher efficiency fans	By providing the operating conditions and asking the bidder to calculate (and, perhaps, guarantee, with penalties for noncompliance) energy consumption, it would be easier to select the model that provides the lowest life-cycle cost for the given conditions. Efficiency is often treated as a yes-no hurdle — any fan that passes the screen potentially could be selected. This approach does not guarantee the most rational choice. Another approach would be to select the fan that minimizes the total lifetime energy costs associated with each model by adding operating costs to the initial price (discounted for the cost of money).
It is difficult to make comparisons between different manufacturers' products because the existence of energy efficiency performance data is not widely known or easily analyzed.	Manufacturers provide detailed data on fan efficiency (fan curves) but it is not easy to calculate energy consumption for the given conditions. Some manufacturers provide software that automates these calculations for their own models, but comparing models from several manufacturers requires learning and running several software applications. No third party software directory such as Pump-Flo or MotorMaster exists for fans and blowers.
The equipment seldom operates under design conditions.	Actual conditions may vary from projected design conditions. Proper air balancing after installation or use of controls to align operating conditions and fan peak performance range could reduce energy consumption.

less than 1 percent of annual unit sales, comprise an estimated 80 percent of annual electricity consumption by the new units. It is estimated that 72 percent of the approximately 17,000 annual unit sales are single-stage, flooded rotary screw type (Figure 3.6) (Easton 1995).

Field research and secondary sources suggest that general industrial plant air compressor consumption, estimated at 27-32 TWh per year, could be reduced by 50 percent or more (see Table 3.4). Opportunities exist to improve equipment efficiency by as much as 25 percent. Efficient plant air system design could reduce electricity consumption by as much as 20 percent. Finally, proper system operation and maintenance could contribute as much as 30 percent savings. Together, a combination of these measures could result in total system savings on the order of 50 percent or higher (Easton 1995).

Table 3.4
Energy Savings Potential in Compressed Air Systems

Equipment	15 - 25%
System Design	15 - 20%
Operations and Maintenance	20 - 30%

Source: Easton 1995.

Compressor "air-end" manufacturers/packagers are key players in the air compressor industry (see Figure 3.7). These OEMs are involved in component design and manufacturing, package design and assembly, and in some cases, distribution. As a result, they determine the level of compressor engineering and design and the overall efficiency of the compressor packages. Some manufacturers also rebuild compressors. Motor and other ancillary compressed air system component manufacturers, as well as foreign air-end manufacturers, also supply components to the compressor OEMs. Distributors have little stake in equipment energy efficiency. Because most of their revenue is derived from parts and service, they typically offer lowcost, low efficiency compressor models in their bids in an attempt to win the business in order to establish the more lucrative service relationship.

Consulting engineers design and plan compressed air systems for ease of maintenance, low noise, and reliability. Efficiency is rarely a primary concern for either the designer or the customer because the focus is on providing sufficient compressed air to meet a need. Few engineering firms have a compressor system specialist on staff, and expertise is rare. Engineers focus primarily on ensuring the system can deliver sufficient air flow at the required pressure to all point-of-use locations.

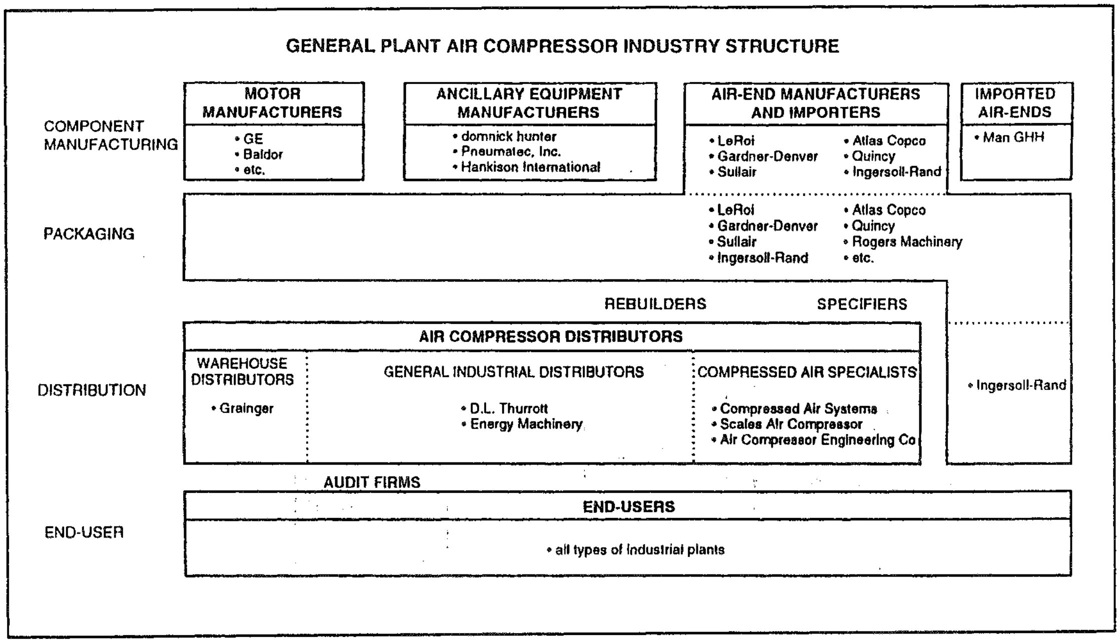


Figure 3.7 Market Structure for Industrial Compressed Air Packaged-Systems (Source: Easton 1995).

Compressors used in general plant air applications are attractive targets for market transformation programs. Hours of use are high, and consumption is significant. Efficiency variation across compressor types, and between different manufacturers' products within types, means there is potential to improve equipment selection practices. Manufacturers have significant influence on equipment and package and controls design, a potentially valuable leverage point. Finally, research suggests that there is significant savings potential in system design and operations and maintenance improvements. Deficiencies in the industrial compressed air packaged-system market are listed in Table 3.5.

3.5 Industrial Process Pump System Market

In general, pumps perform two basic functions in the manufacturing sector: pumps are either a part of the production process (process pumps) or they support ancillary systems such as cooling water loops or boiler feed systems. Process pumps are integral in the production process. These pumps supply raw materials and circulate, mix, and move materials throughout the process. They move liquors, stocks, and water in the pulp and paper production process, circulate and mix chemical products and slurries in chemical production, and move petroleum products throughout the refining process.

Table 3.5
Deficiencies Associated With the Compressed Air System Market

Market Deficiency	*Description*
Loose test standards and voluntary participation make it difficult to compare compressor performance across compressor types and between manufacturers; selecting the most efficient compressor is difficult	Existing test standards do not define a standard air compressor package and test conditions sufficiently to allow reliable comparison of units across manufacturers and models. Measurement of part load performance is not required. Not all manufacturers use the latest standards.
There is no "watchdog" organization to certify test results and encourage greater adherence to test standards	Unlike other industries in which the trade association performs tests or collects test data (e.g., AMCA for fans, NEMA for motors), this "watchdog" function is not performed for air compressor packages. Standards such as ISO 1217 do exist but have not been universally adopted.
Lack of design expertise resulting in sub-optimal system design, specification development, and equipment selection	Many design firms or end users design compressor systems infrequently and so have no opportunity to build up their skills in this area. Demand control is a potentially fruitful area that has been neglected by most designers. Specifications rarely request data on part-load energy consumption. Estimating the required capacity is often oversimplified leading to oversized systems.
Lack of knowledge of high-efficiency options including higher efficiency compressors, ASDs, control systems, part-load mechanisms, etc. at the end-user and specifier levels	Due to poor availability of accurate data on energy consumption of compressor models, it is very difficult to evaluate competing efficiency options such as part-load controls. Competing manufacturer claims confuse the issue further.

Table 3.5 (continued)
Deficiencies Associated With the Compressed Air System Market

Market Deficiency	*Description*
Poor operation and maintenance	Compressed air systems are subject to leaks and other maintenance problems that can lead to excess use of air and electricity. These systems are typically given low priority within manufacturing plants. As a result, energy is wasted.
Lack of end-user awareness of energy consumption; end-users do not demand high-efficiency compressor system designs.	Using compressed air to power end-use tools is a very expensive approach (air is used because its tools are light, safe and versatile). Because it is not a prominent production system it is often overlooked and air is treated like a "free" utility. As a result, users are not as careful as they might otherwise be to operate and maintain systems well, and to select the most efficient systems and equipment packages for their applications.

Pumps in the manufacturing sector consume an estimated 120-125 TWh per year, approximately 15 percent of total manufacturing sector electricity consumption and more than one-fifth of the sector's motor-driven electricity consumption. Pumps in the chemical, pulp and paper, and petroleum processing industries consume approximately 90-95 TWh, more than three-fourths of all manufacturing sector pumping electricity consumption. Within these three segments, process pumps account for about two-thirds of the total pump consumption, or roughly 60-70 TWh.

Several types of pumps are used in manufacturing processes for pumping different fluids at different pressures. For example, rotary pumps often handle higher pressure fluid applications, and reciprocating diaphragm pumps are used where contamination prevention is critical. However, centrifugal pumps dominate the process pump market in terms of annual unit and capacity sales, installed units and capacity, and total electricity consumption. A typical industrial process uses many size and types of pumps performing different functions.

The pump "package" is not as clearly defined as other industrial equipment packages. Manufacturers and distributors sell process pumps with or without a motor or drive. Motors are close-coupled, long-coupled or impart power through a belt drive.

Initial field research indicates that industrial process pumping electricity consumption, estimated at 60-70 TWh per year, could be reduced by as much as 30-40 percent (see Table 3.6). However, the savings potential may be difficult to capture. Realizing the energy savings potential will require a coordinated effort by all industry stakeholders. Opportunities exist to improve pump package efficiency by approximately 5-10 percent. More efficient system design could reduce process pump system consumption by an estimated 10-20 percent. Finally, increased use of speed control could reduce pump system consumption by anywhere from 10-40 percent, depending on the individual system and the applicability of speed control devices such as ASDs.

Table 3.6
Energy Savings Potential for Process Pump Systems

Equipment	5 - 10%
System Design	10 - 20%
Speed Control	10 - 40%

Source: Easton 1995.

The process pump market is extremely competitive and not every manufacturer serves each process market. Manufacturers sell pumps through manufacturers' representatives and distributors, or, in some cases, directly to very large end-users (see Figure 3.8). Many process pumps are engineered specifically for a particular end-use application and thus are sold directly to the end-user through the manufacturer. Manufacturers and their agents (internal sales staff, distributors, and manufacturers' representatives) exert strong influences on this market, as together they play a strong role in determining pump efficiency and selection.

Pump distributors vary widely in sophistication. Some provide design, repair, and maintenance services while others simply order and obtain pumps for the end-user or contractor. Distributors use manufacturer-provided manuals, pump curves, and software to help select pumps. The information provided by the manufacturers is adequate for proper pump selection. Pump distributors play an important role in determining which pump is chosen for a job; however, they have little stake in pump system efficiency.

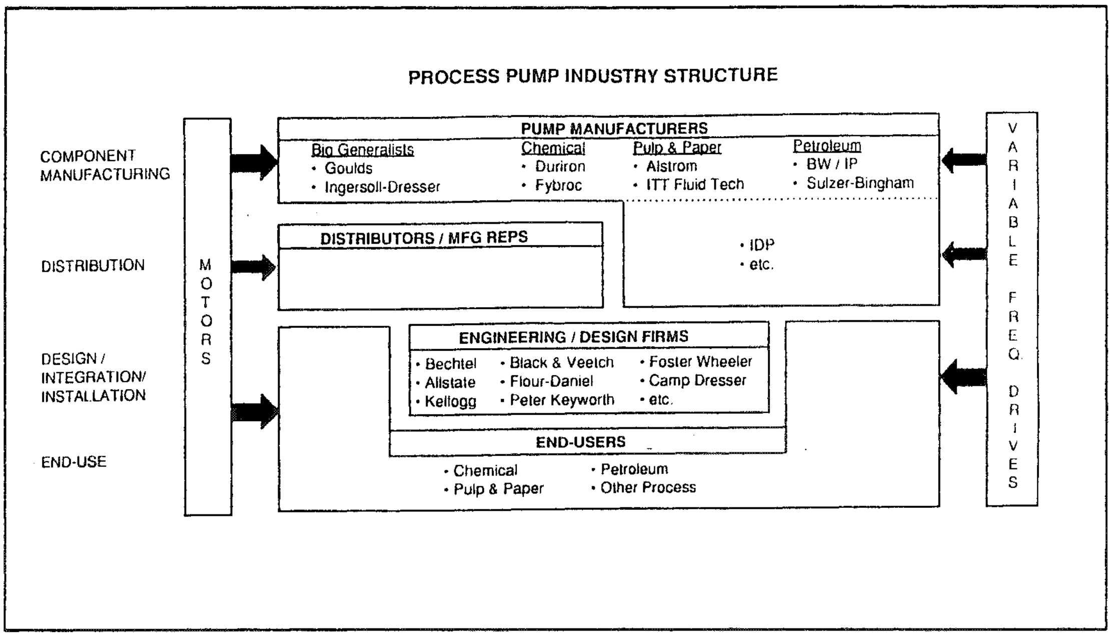


Figure 3.8 Process Pump System Market (Source: Easton 1995).

Mechanical contractors install most process pumps. Consulting engineers design nearly all new greenfield sites (i.e., new manufacturing facilities being constructed from the ground up) and may also get involved with system renovation or major retrofit situations. End-users often design smaller system renovations themselves. Larger end-users, particularly in the chemical and petroleum industries, often have internal process engineers who perform system design work.

A number of current market deficiencies prevent process pump systems from being more efficient. These deficiencies are presented in Table 3.7.

3.6 Deficiencies Common to All Motor and Motor-Driven Equipment Markets

Each industrial motor-driven equipment market, as well as the motors and drives market, has a number of deficiencies that prevent motor systems from being more efficient. While some of these deficiencies, identified in the previous sections of this chapter, are particular to individual markets, a number of them (Table 3.8) are found in each market and could thus be considered general deficiencies to more efficient motor systems. Market transformation efforts that target these deficiencies would have broad impacts. These efforts can also be viewed as preparing the market to accept more targeted strategies.

Table 3.7
Deficiencies Associated With the Process Pump System Market

Market Deficiency	*Description*
A lack of knowledge at the end-user, distributor, and specifier levels regarding which pump (impeller) types are applicable for particular applications (which may prevent the most efficient type for an application from being selected)	Pump efficiency is limited by the size and shape of the impeller relative to the volute or casing. With a larger impeller, relative to the size of the volute, the clearance between the impeller and the volute will be smaller and the pump will be more efficient. When specifying or purchasing a pump to move viscous fluids or those containing suspended particles or solids, the engineer or end-user often overestimates the amount of clearance required and selects a less efficient pump.
A lack of knowledge of the applicability of ASDs and the associated energy savings potential	Poor availability of application- and system-specific information regarding the applicability of ASDs prevents them from being considered in many process pumping applications. End-users and specifiers are often not well-informed regarding the energy savings potential associated with ASDs and remain somewhat skeptical regarding their performance.
End-users weight reliability and performance considerations more heavily than efficiency concerns	In many process applications, the value of production lost due to potential equipment failure or system downtime outweighs the energy savings available from selecting more efficient equipment. For this reason, specifiers and end-users select pumps with reliability in mind, rather than efficiency. This often leads to the selection of a pump (or an impeller) that is not the most efficient model available for the operating conditions.

Table 3.7 (continued)
Deficiencies Associated With the Process Pump System Market

Market Deficiency	*Description*
Over sizing due to engineering design — engineers add large margins to head and flow requirements when specifying pumps to allow for pump degradation and system friction increases over time	In process pumping applications, friction buildups, particularly in piping, are often inevitable. In addition, in caustic fluid pumping applications the impeller may erode over time, decreasing pump performance. Pumps are oversized to compensate for these changes in pump and system performance. As a result, the most efficient pump for the system or applications not always chosen.
Process systems are often designed to run at a number of flow rates; pumps cannot be at or very close to their best efficiency points at each flow rate.	Manufacturers often want the ability to run a system at less than full-load capacity in response to changing demand. Unless systems are designed with full redundancy and can operate in "stages" to regulate capacity, a more costly approach than simply regulating production with value or by changing motor (therefore pump) speed, pumps will not always operate near their best efficiency point.
The equipment seldom operates under design conditions.	A pump is selected with one or more specific operating conditions in mind. Because of errors in calculating the system curve and changes in pump and system performance over time, systems often actually operate at a point far from the original calculated operating condition. Under actual operating conditions, the pump selected may not be the most efficient model available.

Table 3.7 (continued)
Deficiencies Associated With the Process Pump System Market

Market Deficiency	*Description*
The equipment seldom operates under design conditions.	A pump is selected with one or more specific operating conditions in mind. Because of errors in calculating the system curve and changes in pump and system performance over time, systems often actually operate at a point far from the original calculated operating condition. Under actual operating conditions, the pump selected may not be the most efficient model available.
Difficult to compare different manufacturers' pumps because common rating and labeling guidelines are not used.	Pump performance is application-specific, depending on the system and the fluid being pumped. Manufacturers do not provide performance data at "common" operating conditions. Pump performance must be calculated for the given conditions. Some manufacturers provide software that automates these calculations for their own models, but comparing models from several different manufacturers to compare efficiency and operating cost is time consuming. Third-party software such as Pump-Flo would require the end-user to reload pump databases and recalculate for each manufacturer's models.

Table 3.8
Deficiencies Common to All Motor & Motor-Driven Equipment Markets

Market Deficiency	*Description*
Lack of knowledge at the end-user level regarding the energy savings potential available through optimizing motor-driven system design and equipment purchases.	While end-users may think they understand the benefits of an energy-efficient component (e.g., an efficient pump), they may not understand the effect the interaction of all the components will have on overall system efficiency. In the end, the addition of the more efficient component could actually increase the energy use of the system as a whole.
Lack of incentive or motivation for certain stakeholders to promote efficient system design or equipment purchases.	Stakeholders such as engineering consultants and distributors have no incentive to specify those components that would improve the overall efficiency of the end-users system. For example, an ASD distributor has an incentive to sell an ASD to any end-user who wants to buy one, whether or not their system efficiency would benefit from the addition of an ASD.
A lack of technical expertise and tools required to accurately quantify savings potentials and verify actual performance and savings.	In general, end-users lack the technical information and expertise to determine where their systems are currently operating, and how to improve or optimize systems' performance. This deficiency also leads to sub-optimal specification or selection of equipment.
Current efficiency facilitation efforts (utility programs) typically focus on the equipment, not system-level savings opportunities. In particular the focus has been on motors and drives almost exclusively.	It is easier and customary for a utility program to focus on one component of the motor systems (e.g., many offer rebates on the purchase of energy-efficient motors). This discourages end-users from taking a systems approach to efficiency improvement.
End-users may not perform life-cycle cost analysis when considering equipment/ system investment.	Often, end-users base their purchase decision on first cost and use energy efficiency as a yes-no hurdle. Instead they should be encouraged to calculate the total lifetime energy costs of each of the equipment options.

Chapter 4

FORMULATING MARKET TRANSFORMATION STRATEGIES

A market transformation strategy is built from a mix of different actions. A portfolio of possible actions exists that can be grouped into two broad categories: infrastructural/enabling and direct market actions. This chapter will present the range of possible actions from voluntary to mandated. Chapter 5 focuses on those actions that are appropriate to the four motor system market segments and how they can be integrated into a comprehensive market transformation strategy.

4.1 Elements of a Market Transformation Strategy

The framework for formulating market transformation strategies distinguishes between: 1) actions leading directly to enhanced system performance and reduction in energy consumption, and 2) those that lay the foundation for follow-on actions with direct results. We call the latter "infrastructure/enabling actions" because they build and strengthen market infrastructures to enable future market actions to take place. Without these enabling actions, direct market progress would be limited. Infrastructure/enabling actions, in general, address knowledge, information, or awareness deficiencies that exist in a marketplace. For example, motor rebate programs that have led to direct benefits and results are only possible today because standards for testing and labeling motors were already in place. Enabling actions may also address a deficiency within the marketplace that allows the market to naturally evolve to a higher level of efficiency without any direct market actions.

"Direct market actions" attempt to influence market behavior directly. Actions may include recognition promoting purchase collaboration and financial incentives such as motor rebates. Direct market actions are intended to directly influence the behavior of those in the marketplace. There are forward and backward linkage between the enabling actions (e.g., demonstrations showcase the resulting improved performance from adoption of the systems approach) and direct market actions (e.g., audit services to identify and quantify savings resulting from performance optimization). While in many cases, the enabling action is a prerequisite for conditioning the market such that it is ready to accept the direct market action, there are always instances where the enabling action will not be followed by a direct market action. Similarly, there are other instances where direct market actions may proceed independently and without need for an enabling action.

Table 4.1 lists broad categories of actions that may be included as elements of a market transformation strategy. Different actions may be appropriately targeted at a specific, industrial-sector application segment within each market. In practice, to successfully implement market transformation, a number of these actions may need to be implemented in parallel, with market-pull (supply-side) and market-push (demand-side) actions coordinated in some way. Each of these actions is discussed in more detail below.

Table 4.1
Elements of a Market Transformation Framework

Network Organization Development	
Infrastructure/Enabling	*Direct Market*
Test protocols	Recognition activities
Training and education	Opportunity identification
Develop information systems and databases	Encourage purchasing collaboratives
Develop/distribute decision support tools	Promote facilities management businesses
Develop best practices guidelines	Financial incentives (e.g., rebates, grants, financing, tax incentives)
Voluntary rating and labeling guidelines	Promote voluntary certification
Develop common user specifications (e.g., performance or purchasing)	Encourage early equipment retirement
Technical Assistance	Minimum efficiency regulations
Demonstrations	
Research and development	

Infrastructure/Enabling Actions

Infrastructure/enabling actions, in general, address knowledge, information or awareness deficiencies that exist in a market. The following are descriptions of some actions that may be included as elements of a market transformation strategy.

- Test Protocols. If efficiency choices are to be made in the marketplace, it is necessary to have a consistent indicator of relative product performance. Test procedures provide that common basis upon which to compare performance. The criteria for developing these procedures are that they can be performed at a reasonable cost, be readily reproducible, and provide an indication of the relative performance of the product in service. Because the performance of a product in an actual application is often influenced by many variables, the test procedures are frequently not designed to accurately measure actual performance.

- Training, Education, and Technical Assistance. With many motor system applications requiring site-specific design, it is necessary to make specialized technical resources available to end-users to optimize the design and equipment selection. Many programs have been limited by a lack of available expertise. A DOE Roundtable held in 1993 identified the lack of motor system expertise as a significant barrier to improving the efficiency of electric motor systems. Innovative programs such as the Performance Optimization Service (POS) program (Carroll et al. 1994) not only have provided technical assistance, but also are providing training to designers and users about the design process required to optimize the design of electric-motor systems.

- Information Systems and Databases. Knowing how to measure a product's performance is only the first step in selecting the most efficient product. Its performance must be compared with that of other available products. Therefore, it is critical that product performance data be collected and presented in a form that is accessible to end-users as has been done for electric motors with the MotorMaster Data Base (WSEO 1994) and the Canadian Utilities' Motor Catalog (Hydro Quebec 1994). Many decisions are involved in the design of these databases, such as whether to accept manufacturers' reported data or to require independent testing verification. These decisions represent quality evaluations. With many motor-system products, little or no data are available, so it is impossible to make any informed selection decision.

- Decision Support Tools. The application of motor drive equipment determines the system efficiency in many cases, as was discussed earlier. Knowing the efficiency of products is a major step in the design process, but tools that can aid in system design and selection of motor-driven equipment can assist designers and end-users in optimizing system efficiency. Such software is commercially available for designing and selecting pumps and fans, though in some cases it is manufacturer-specific, not allowing for comparison across all available equipment. Many of these tools also include financial analysis components that aid in the decision making process and help to justify the investment in energy efficiency.

  In addition, tools can aid in the management of motor systems. Significant energy savings opportunities have been identified from establishing a motor repair and replacement policy. Integral to management is establishing a motor inventory. Software tools can aid in this process, and may be integrated into preventive maintenance programs (IEL 1993).

- Best Practices Guidelines. The proper application of motors and motor-driven equipment has been identified as the most important aspect of the energy efficiency of a motor system (Elliott 1994). In the industrial sector, it is often infeasible to make general recommendations for the application of equipment because many of the applications are process-specific. There are, however, cases where general application recommendations would be beneficial to the design and specification community, and to the end-user. In some cases these may be guidelines for those issues to be considered, rather than explicit specifications. These suggestions can reflect the best practices implemented by those with a proven record of good motor system management.

- Voluntary Rating and Labeling Guidelines. In order to easily compare a product's efficiency with that of other similar products, a common rating or labeling system that allows consumers to select products by efficiency class is valuable. In order to make such determinations, both an accepted test procedure and information about the performance of available products is required.

- Common User Specifications. While much about industrial motor systems is application specific, there remains an important role for guideline specification for the purchase of efficient products and services. These specifications can range from a simple definition of what is efficient, to a more complex guideline on how to prepare a purchase specification for a product or service. These guidelines may also provide a user with information on how a product should be applied and a reasonable expectation of how it should perform.

- Research and Development. A significant part of energy efficiency improvements has been due to technology evolution and innovations. There have been improvements in the efficiency of induction motors (Van Son 1994), the efficiency, affordability and reliability of ASDs (EPRI 1992), and new motor designs (E-Source 1994) in the past decade. Non-manufacturer groups such as EPRI have helped with the research that has supported this product development.

- Demonstration. Once new products are developed, it is necessary to test and demonstrate their performance in actual applications. Demonstrations also allow potential users to see how these products may be of benefit to them.

Once the informational and infrastructural deficiencies are addressed by enabling activities, sometimes no further action is required for the market to move to greater energy efficiency. In other cases, additional activities are required to overcome the inertia or other barriers of the marketplace.

Direct Market Actions

Direct market actions are intended to directly influence the behavior of those in the marketplace. As discussed previously, the infrastructural/enabling actions discussed above are frequently required first to establish the information and awareness foundation upon which these direct market actions can be built. Some examples of direct market actions appear below:

- Voluntary Commitment and Recognition Activities. Recognition of leadership among peers has long been a staple in the promotion of energy efficiency with programs such as EPA's Green Lights and Energy Star equipment programs. Voluntary commitment and recognition are also an important part of DOE's Motor Challenge. These programs elevate the importance of energy in the eyes of corporate management by providing a public forum for pledges and accomplishments in energy efficiency.

- Opportunity Identification. Many manufacturing companies, particularly small- and medium-sized, do not have the time or expertise to identify energy efficiency improvement opportunities (Elliott 1995). A successful approach has been to provide "audit" services to end-users to assist them in identification and prioritization of these opportunities. These audits can take the form of the "walk-through" type audits performed by DOE's Energy Analysis and Diagnostic Centers, state energy offices and many electric utilities. Audits identify "generic" efficiency opportunities, many of which involve general maintenance, operation or incremental equipment upgrade actions.

  A number of utilities and other entities also offer more in-depth "process" audits conducted by experts in particular industries. These efforts focus on "systems integration" and "performance optimization," and normally involve site-specific evaluation of production processes, recommendations for elimination of waste and changes to the production process (Smith 1995).

- Purchasing Collaboratives. A single entity has limited purchasing clout and presents a small sales opportunity in the marketplace. If several entities coordinate their purchasing of energy-efficient products, they can exert greater influence on the marketplace and attract the interest of manufacturers and suppliers. Market aggregation through purchasing collaboratives can be facilitated by numerous groups such as governments, utilities, trade associations, or regional collaboratives.

- Facilities Management Businesses. One new approach to managing motor systems is to look to an outside group to own and operate the system delivering the service (e.g., compressed air, chilled water). The facilities management company is motivated to implement cost-effective, efficiency measures since energy will be a major portion of their variable cost. The Easton Study (1994) identified this concept as a promising new business venture opportunity. Some electric utilities are already beginning to look at these service agreements as a means of offering greater value to their customers (Elliott 1995).

- Financial Incentives. Financial incentives offered by electric utilities in the United States and Canada have played a major role in encouraging increased efficiency of electric motors (Van Son 1994). Incentives have targeted end-users, suppliers, manufacturers and specifiers. Incentives can address many market barriers, among them the higher price of alternative products, limited stocking of alternative products by distributors, limited production and distribution of alternative products by manufacturers, and hesitance to specify alternative products by designers. It is important to set the efficiency levels for which financial incentives are provided at appropriate levels if correct market signals are to be sent (McKane 1994).

  In spite of these proven benefits and cost effectiveness, incentives can be expensive. Changes in the structure of the electric utility industry and demand-side management programs, as well as national minimum standards taking effect, will likely limit the future use of conventional utility rebates (Elliott 1995), though some new programs are being introduced such as CINergy's ASD rebate program (Bolubasz 1995). Also, utilities may shift the emphasis away from end-users, toward dealers or manufacturers in order to reduce costs while still influencing the marketplace.

- Voluntary Certification. When a buyer looks for technical assistance, he seeks some indication of the proficiency of the provider. The end-user frequently cannot assess the technical competence of the service provider because he doesn't have the expertise internally (which is why they are seeking the assistance). Certification provides a means of identification of proficiency (as we see with medical and engineering professionals).

The certification can be provided by many different groups including professional trade associations, electric utilities or governmental entities.

- Encourage Early Equipment Retirement. While effecting new equipment selection and equipment replacement decisions are the least difficult portions of the motor system population to target, they do not address much of the installed base of motor systems that can operate for many years. If the efficiency of the overall population is to affected, actions will be required that encourage change-out of operating equipment. Since it is often not-cost effective to replace operating equipment, specially targeted incentives — perhaps financing, rebates or tax credits — will be required to affect the installed population.

- Minimum Efficiency Regulations. Regulations set minimum levels thus eliminating some energy-inefficient new products and practices from the marketplace. Regulations can take many of the forms discussed in the introduction including minimum efficiency requirements, standard practices, and required use of certified professionals (e.g., engineers, technicians or installers). Minimum efficiency requirements on integral horsepower induction motors should take effect in Canada in early 1996, and are scheduled to take effect in the U.S. in October 1997.

  Analyses of efficiency trends in the new motor marketplace indicate that regulations have had a profound effect. In anticipation of the minimum-efficiency regulations, efficiencies of both standard and high-efficiency motors have been rising (Van Son 1994). While some controversy has surrounded the appropriateness and implementation of the regulation (in part resulting from the complexities associated with application of motors), no one questions that the law has increased awareness of motor efficiency issues and the efficiency of new motor populations.

  Regulations are not the ultimate solution for all products, however. Minimum efficiency levels can be difficult to set (McKane 1994), especially if complete information is not available about a product. Some products such as ASDs are not amenable to minimum efficiency levels, since the application, not the inherent efficiency of the product, determines the energy consumption. In addition, minimum energy efficiency requirements may not take into account the relationship of energy efficiency to other operating parameters. An example is V-belts in which belt slip, an inefficiency, often provides the overload protection for the system. Changing to cogged belts improves efficiency but reduces the overload safety protection.

Network Organization Development

Fundamental to all these actions is the development of networks of stakeholders, including end-users, manufacturers, distributors, designers, researchers and other market influencers. As was seen at the recent DOE *Round Table on Market Transformation Strategies for Industrial Electric Motor Systems* (DOE 1995), limited interaction exists between various stakeholder groups. Improved communication is required to undertake many of the actions discussed above. In some cases, one group many have valuable information available that others are unaware exists, as is the case with fan manufacturers and industrial end-users. It is essential to involve manufacturers when developing a test procedure or performance database since not only do they have a real, vested interest, but they possess significant knowledge about the products they manufacture. However, in the industrial arena the end-user is likely to possess essential information about the application of the equipment. Thus, end-user involvement may be necessary to achieve an optimal system design. The network brings key parties together in an attempt to create benefits to all involved.

4.2 Formulating Strategies

Market transformation activities should always keep sight of their targets to achieve maximum impact. The elements selected, and the forms that they take are determined by the product, market characteristics, and the market deficiencies to be addressed. Different actions may be appropriately targeted at specific industrial sector application segments within each market. For example, regarding industrial fans and blowers, there are several application subsegments, such as mechanical draft, exhaust, drying, and air cleaning. The fan/blower segment also involves several types of equipment, including, for example, boilers, ovens, ventilation, automobile painting, dust collection and air pollution control equipment.

Another aspect of targeting actions is the point in time that the actions affect the market players. For example, some actions affect market players prior to the sale to capitalize on potential lost opportunities (e.g., availability of efficient models from OEMs, equipment selection or system design), others at the time of sale (e.g., end-user repair and replacement policies), and some long after the sale (e.g., maintenance, repair, component replacement, and operations practices). The first two time-categories relate to transactions involving new or replacement equipment, the latter to the installed base. While total potential savings are greater for end-users who are involved in transactions that take place long after the sale, transactions prior to or at the time of equipment sales are more attractive from a program point of view because of the high potential for leveraging program efforts. It may also be necessary to undertake actions in parallel. For example, creating demand for motor system expertise without addressing the lack of available experts will cause the first action to fail.

Market transformation strategies target specific market players (e.g., OEMs, distributors, specifiers, installers, and users) and actions for different "levels of the system" that will best enable market transformation goals to be achieved. The "level of the system" refers to whether the program is aimed at the component (e.g., motor or fan), the packaged system, or the integrated system (including system layout and control). Examples of strategies that may be targeted at component, packaged-system, and integrated-system levels are as follows:

component	– promote increased high-efficiency components (e.g., energy-efficient motors, efficient impeller types, more efficient belts)
packaged-system	– improve equipment designs, – develop efficiency ratings – develop performance guidelines
integrated-system	– promote performance optimization services – improve operation and maintenance practices

CHAPTER 5

ELECTRIC MOTOR SYSTEM MARKET TRANSFORMATION STRATEGY

5.1 Introduction

Transformation of the electric-motor system marketplace to greater efficiency is a complex process, involving linked actions and a diverse group of stakeholders. The strategy discussed in this chapter represents the culmination of extensive market research by a number of groups (including DOE, ACEEE, CEE, New York State Energy Office and Easton Consultants) that focused both on the generic market transformation process and the electric motor system (EMS) market. Various investigators have pursued market research in the emerging field of market transformation from a generic perspective, seeking to define an overall approach to strategy development. ACEEE and CEE were two early contributors to the market transformation literature who participated in this study. A number of key papers on the topic were presented at the *1994 ACEEE Summer Study on Energy Efficiency in Buildings* (Feldman 1994, McKane 1994, McMenamin et al. 1994, Oswald et al. 1994, Wirtshafter and Sorrentino 1994).

The EMS market research helped describe the market structure and identify the market deficiencies presented in Chapter 3. The generic research yielded the strategic framework presented in Chapter 4. This chapter applies the Chapter 4 framework to the four specific EMS segments profiled in Chapter 3, resulting in development of a comprehensive action set that also reflects the input received from participants at the April 1995 Market Transformation Round Table meeting.

5.2 Market Assessment Approach

The overall approach to motor system market transformation development is presented in Figure 5.1. Two parallel paths of market research were conducted. The EMS research profiled the structure of the EMS market segments (Chapter 3), identified the market deficiencies (discussed in Chapter 3 and summarized in Table 5.1), and compiled a comprehensive menu of potential market actions (Appendix A). The generic market transformation research helped lay the foundation for a more complete understanding of the market transformation process, and identified the type of enabling and direct market actions generally applicable to market transformation initiatives. Most of the prior experience on which this study is based took place in areas such as lighting, building energy systems, and residential appliances. The challenge inherent in developing the EMS

Table 5.1
Electric Motor System Market Deficiencies

Motors and Drives
- Insufficient knowledge on true savings potential of energy-efficient motors and of ASD applicability
- Uncertain and changing definitions of "high" and "premium" efficiency motors are confusing and potentially misleading to stakeholders
- Sub-optimal failed motor situation practices including poor motor rewind practices and "like-for-like" and low first-cost purchase behavior.

Fan and Blower Systems
- ASDs under used due to lack of knowledge of applicability and high first-cost of ASDs
- Lack of system design expertise creates from an efficiency standpoint sub-optimal system design, specification development, and equipment selection
- The most efficient fan type for the specific operating conditions is often not used due to lack of information about alternative equipment designs and performance capabilities
- Equipment/system end-users and purchasers do not always specify minimum efficiency levels or energy consumption requirements
- End-users may base purchase decisions on first cost and do not consider the life-cycle energy cost savings associated with higher-efficiency fans
- It is difficult to make comparisons between different manufacturers' products because the existence of energy efficiency performance data is not widely known or easily analyzed
- The equipment seldom operates under design conditions

Compressed Air Systems
- Loose test standards and voluntary participation make it difficult to compare compressor performance across compressor types and between manufacturers; selecting the most efficient compressor is difficult
- There is no "watchdog" organization to certify test results and encourage greater adherence to test standards
- Poor operation and maintenance practices
- Lack of design expertise resulting in sub-optimal system design, specification development, and equipment selection
- Lack of knowledge of high-efficiency options including higher-efficiency compressors, ASDs, control systems, part-load mechanisms, etc. at the end-user and specifier levels
- Lack of cooperation among industry stakeholders to promote efficiency
- Lack of end-user awareness of energy consumption; end-users do not demand high- efficiency compressor system designs

Processed Pump Systems
- A lack of knowledge at the end-user, distributor, and specifier levels regarding which pump (impeller) types are applicable for particular applications
- A lack of knowledge of the applicability of ASDs and the associated energy savings potential
- End-users weight reliability and performance considerations more heavily than efficiency concerns
- Over sizing due to engineering design — allowance for pump degradation and system friction losses
- Process systems designed to run at varying flow rates; therefore, pumps frequently operate far from their best efficiency point
- Difficulty comparing different manufacturers' pumps — common rating and labeling guidelines not used
- Equipment seldom operates at design conditions

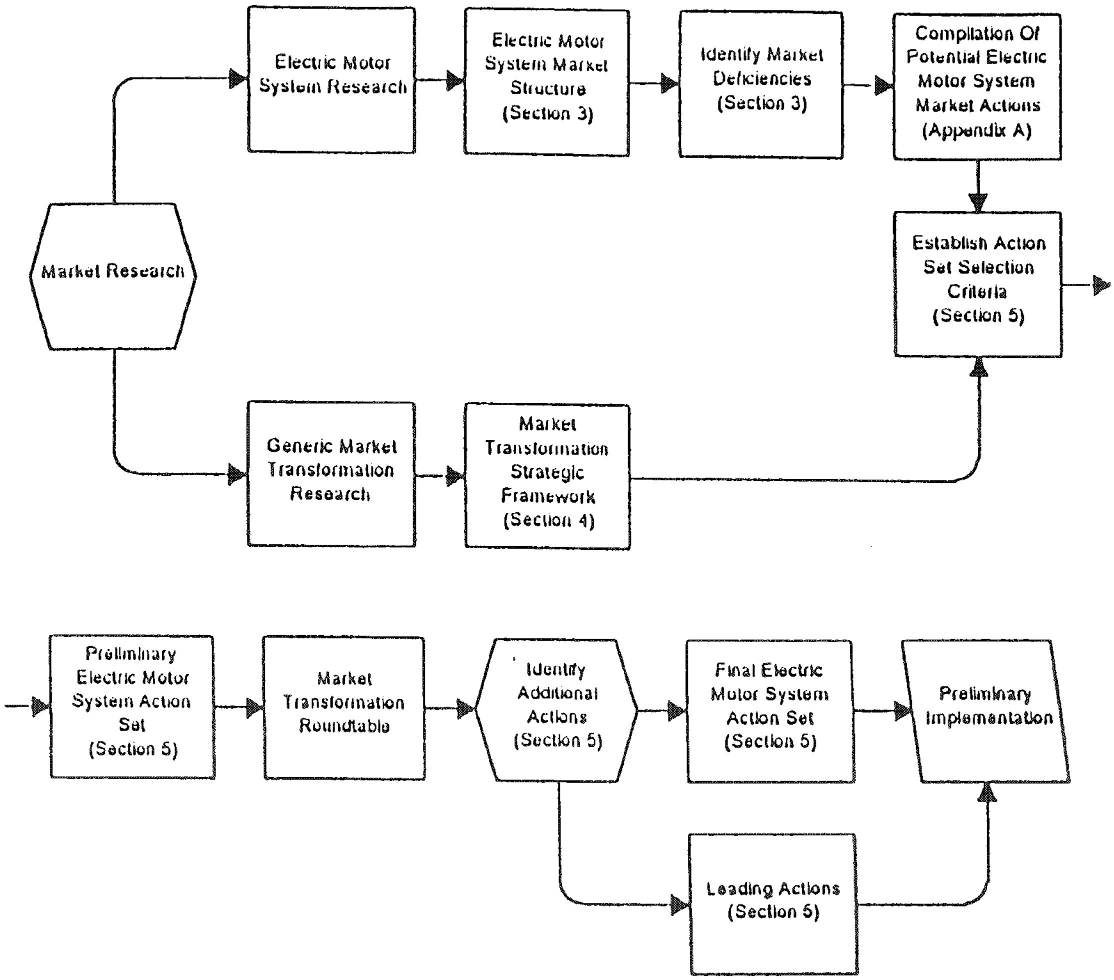


Figure 5.1 Electric Motor System Market Transformation Development

market assessment approach was drawing on this prior experience to address much more complex and interactive electric motor-driven industrial processes.

5.3 Action Set Selection Criteria

The EMS market research yielded an extensive listing of potentially applicable market actions (as included in Appendix A). The extent of this listing reflects the complexity of the EMS market. While this listing was helpful in documenting the full range of possible actions, its length suggests that a realistic examination of options must focus on a subset of leading actions. Project investigators quickly recognized that identification of preliminary market actions was needed to create a workable base for ongoing market participation. To screen the wide range of market actions in Appendix A and arrive at the preliminary action set for detailed discussion and analysis, actions were selected that:

1. Offer the greatest leverage potential. The selected actions should target: (1) market deficiencies with the greatest likelihood of being overcome, least resistance to change, and offering the greatest opportunity to leverage the impact of other relevant actions; and (2) market actors most ready to change established patterns of behavior and decision-making processes.

2. Remove common barriers. Selected actions should target the removal of common barriers supporting multiple market deficiencies, and address themes that are common to individual market segments and that cut across the entire electric motor system.

3. Yield the greatest technical opportunities. The implementation of market transformation actions that result in the greatest efficiency gains will prove out the effectiveness of the approach, catalyze expanded industry and other stakeholder support of the program, and help build a foundation for initiation of longer-term actions with less quantifiable results.

4. Represent a balanced portfolio mix. The preliminary action set should include a mix of actions that: (1) target different system levels (component, package-system or integrated-system, (2) represent key enabling and direct market actions, and (3) target specific influential market players (e.g., end-users, distributors, specifiers, etc.).

These criteria recognize that each market segment has unique characteristics, displays varying deficiencies, is at a different point in its development, and requires more or less movement toward greater energy efficiency. As a result, the preliminary actions selected for each segment may be different.

5.4 Preliminary EMS Action Set

The selection criteria discussed above were applied to the compilation of potential EMS market actions (Appendix A) to develop the preliminary EMS action set (see Table 5.2). This action set played a key role at the Market Transformation Round Table, a meeting organized to bring together a broad cross-section of institutions concerned in one way or another with electric motor systems. Round Table participants included industrial customers, motor manufacturers, motor distributors and manufacturing representatives, original equipment manufacturers for three motor-driven application segments (i.e., fan/blower systems, air compressor systems, and process pump systems), electric utility experts, government officials, and market researchers and strategists.

Table 5.2
Preliminary EMS Action Set

Common Across Markets

- Rating and labeling guidelines for fan and blower, air compressor and pump packages
- Access to quality technical, marketing and financial information on the Internet
- Establish purchasing collaboratives
- Life-cycle costing tools and methodologies
- Electric motor-driven systems certification program
- Education and training of strategic marketing for motor systems products and services
- Demonstration projects
- Early equipment retirement
- Market transformation partnerships

Motors and Drives

- Rating and labeling guidelines for motors
- Quality assurance rewind guidelines and practices
- Best practices for efficient motor rewind

Fan/Blower Systems

- Develop common purchase specifications for fan/blower packages
- Fan/blower selection software

Air Compressor Systems

- Develop common purchase specifications for air compressor packages
- Plant air compressor package testing procedures
- Compressed air facilities outsourcing

Process Pump Systems

- Training program for existing and new pump systems

One of the specific objectives of the Round Table was to design a portfolio of specific actions to achieve market transformation. This resulting action set was to help in the formulation of a blueprint for a coordinated, national effort involving business, government, utilities and other interested parties for achieving sustainable improvements in industrial performance and energy efficiency. The preliminary action set (Table 5.2) was presented to Round Table participants at the April 1995 meeting, and comments and suggestions for additional actions were solicited.

Table 5.4
Final EMS Action Set

Action Categories	Motors and Drives	Pump Systems	Fan/Blower Systems	Air Compressor Systems
Network Organization Development		• market transformation partnerships • *encourage better internal & trade ally communication*	• market transformation partnerships	• market transformation partnerships
Voluntary test protocols	• quality assurance rewind guidelines and practices			• plant air compressor package testing procedures
Training and Education		• training in strategic marketing for motor systems product/services • training program for performance optimization • *develop models of optimized systems* • *develop case studies for benchmarking* • *conduct pump seminars*	• training in strategic marketing for motor systems product/services • training program for performance optimization • *promotion of energy-efficient fans and blowers through education and awareness*	• training in strategic marketing for motor system products and services • training program for performance optimization • *customer awareness programs*

Table 5.4 (continued)
Final EMS Action Set

Action Categories	Motors and Drives	Pump Systems	Fan/Blower Systems	Air Compressor Systems
Information Systems and Databases		• *develop catalogues of equipment cost and performance information* • *quantify life-cycle costs of pumping* • *quantify non-energy benefits* • Internet access to technical, marketing, and financial data	• *focus on non-energy benefits* • Internet access to technical, marketing and financial data	• *a directory of shareholders* • *directories of services and information* • *case studies of cost savings & performance improvement benefits* • Internet access to technical, marketing and financial data
Decision-Support		• life-cycle costing tools and methodologies • *develop Pump Selection Software*	• *life-cycle costing tools and methodologies* • develop fan/blower selection software	• life-cycle costing tools and methodologies
Guidelines and Best Practices	• best practices for efficient motor rewind			• *in-plant air distribution guidelines*

Table 5.4 (continued)
Final EMS Action Set

Action Categories	Motors and Drives	Pump Systems	Fan/Blower Systems	Air Compressor Systems
Voluntary Rating/Labeling		• *develop guidelines for package efficiency labeling*	• develop guidelines for package efficiency labeling • *standardize performance reporting practices for the fan industry*	• *CAGI test procedure fact sheet* • develop guidelines for package efficiency labeling
Common User Specifications		• *Develop Specification Guidelines*	• Develop common purchase specifications for packages	• *Develop common purchase specifications for packages*
Demonstrations		•	•	• projects
Purchasing Collaboratives		• establish collaboratives	• establish collaboratives	• *collaboratives*

Table 5.4 (continued)
Final EMS Action Set

Action Categories	Motors and Drives	Pump Systems	Fan/Blower Systems	Air Compressor Systems
Facilities Management				• compressed air facilities outsourcing • *improve the consistency and availability of plant energy audits*
Financial Incentives		• *identify and provide financial (and non-financial) incentives*	• *identify and provide financial (and non-financial) incentives*	
Voluntary Certification		• *develop certification process for pump packages*	• program certifying the performance of systems	• program certifying the performance of systems
Early Equipment Retirement	• early retirement program	• early retirement program	• early retirement program	• programs

5.5 Final EMS Action Set

The DOE *Market Transformation Round Table* provided valuable insights into the EMS market transformation process, and allowed an expansion of the preliminary action set based on meeting input and the expert judgement of participants. The resulting final action set combined the market research and Round Table input (see Appendix A).

The Final EMS Action Set reorganizes the preliminary actions and Round Table conclusions into the generic actions categories presented in the Chapter 4 strategic framework. In addition, the actions that are common across markets are repeated under the market segments to which they apply. The actions shown in italics are those additions made at the Round Table meeting. The combined total of 61 actions in the Final Action Set provides a foundation for subsequent implementation by stakeholders. Details on each action within the Final Action Set are presented below. Following these discussions, the highest priority actions are discussed in detail.

5.6 Illustrative Program Example

Market transformation activities should always keep sight of their targets to achieve the greatest energy efficiency improvement that is technically and economically achievable. Different actions may be appropriately targeted at specific industrial sector application segments within each market. While, in many cases, the enabling action is a prerequisite for conditioning the market such that it is ready to accept the direct market action, there are always instances where the enabling action will not be followed by a direct market action; similarly, there are other instances where direct market actions may proceed independently and without need for an enabling action. To facilitate a complete understanding of the interaction between enabling and direct market actions, the following example of a market transformation activity is presented for the compressed air system market segment.

Packaged compressed air systems have been singled out by market participants as the one area most in need of standard, voluntary test procedures and performance certification guidelines. Current conditions in this market segment make it difficult to compare performance across compressor types and among manufacturers, making it a difficult task at best to select the most efficient air compressor package-system.

The promulgation of widely-accepted, voluntary test procedures for air compressors would provide a foundation for easy comparison of compressor performance. As compressed air system end-users become more sophisticated and demanding in their purchasing practices, OEMs would be encouraged to adhere to energy efficiency rating and labeling guidelines to maintain market shares and satisfy customer requirements. Broadly-endorsed certification programs for validation of test results would increase the comfort level of system so purchasers that their decision process was conducted on a "level playing field."

Successful transformation of this market segment requires a combination of both an enabling or infrastructural change, coupled with selected direct-market actions. The enabling action is development of a voluntary test protocol for air compressor package efficiency testing. However, existence of the protocol alone will do little to move the market toward greater efficiency. A number of direct market actions, including voluntary certification, establishing purchasing collaboratives, and development of common purchase specifications for packages, are needed to initiate the market transformation process (see Figure 5.2).

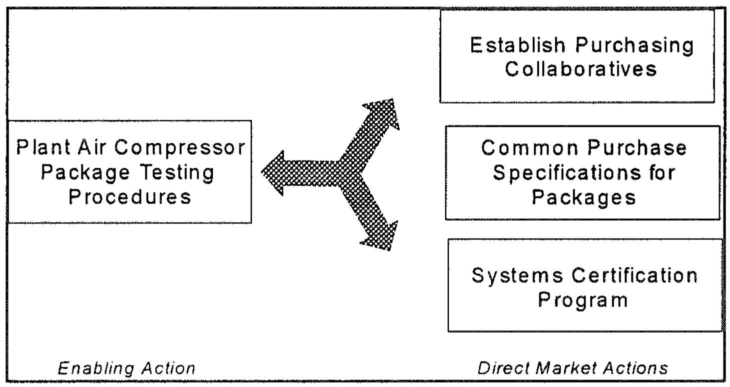


Figure 5.2 Example of Compressed Air System Market Action Integration

In this example, the enabling action of establishing the air compressor package testing procedures prepares the market for the direct actions to follow. Similarly, existence of the testing procedures would have little market impact without a means of certifying the accuracy and application of the procedure, encouraging end-users to specify the testing and certification of purchased compressor systems, and focusing the combined market power of groups of customers in a collaborative venture to demand equipment meeting the testing requirement. These forward and backward linkages are quite typical of the relationship between the enabling and direct market actions. However, as noted earlier, a given enabling action is not always a precursor for one or more direct market actions – in a given situation each type of action may proceed independently of the other.

5.7 Leading Near-Term Actions

From the Final EMS Action Set presented above, the Round Table participants and other EMS market stakeholders identified a set of leading actions that either meet pressing market needs today, or have the greatest near-term potential to initiate the market transformation process on a fast-track (Table 5.4). As is seen from the previous discussion, there are many potential actions and it is difficult to choose which to pursue. These leading actions appeared to resonate with Round Table participants in that they addressed a good mix of short-term concerns, and pave the way for eventually institutionalizing energy efficiency as part of the corporate culture. While some areas of concern were equally or more important, they were not selected because no clear path to implement an action was seen. It was felt that there were so many opportunities that it was better to work on those for which a clear path was seen and to defer others until a later time. Each leading action is discussed below, presented within the generic action category identified in the final action Set.

Table 5.4
Leading Motor System Market Transformation Actions

Action Category	*Leading Actions*
Training and Education	• training in strategic marketing • performance optimization training • customer motor awareness
Information System and Databases/Common User Specification	• equipment performance and cost database • estimation of non-energy benefits • performance and costing-saving case studies • common equipment and service purchase specifications
Decision Support	• life-cycle costing tools • equipment selection software
Voluntary Rating and Labeling	• guidelines for package-system performance • standardized energy use reporting for fans • information on air compressor test procedures

Training and Education

There is a fundamental lack of knowledge of energy efficiency issues among end-users, specifiers, and distributors. Therefore, education is a key component in the effort to creating more sophisticated, demanding buyers. Training programs should be targeted at both end-users and design professionals. Training should provide technical and performance information, including system design expertise and techniques for identifying efficiency improvement opportunities. The training and education programs should rely heavily on items such as directories of stakeholders, services, and information, as well as case studies on real-world efficiency improvements.

Information Systems and Databases/Common User Specifications

These actions include the development of purchasing specifications for individual system components (e.g., pumps, fans/blowers, air compressors). These specifications would ensure that the end-user is specifying energy efficiency when procuring a motor-driven system or component. Development of a comprehensive Specifier's Guidebook would incorporate case studies highlighting cost and performance characteristics of EMS equipment.

Development of databases of equipment cost and performance specifications, similar to the successful *Motor Master* database should be developed for other motor-driven equipment such as fans and blowers, pumps and air compressors. While some vendors provide this data on their own products, it would be desirable for these databases to list similar equipment available from most, if not all, manufacturers.

In most cases, electricity accounts for only 5 percent of total manufacturing costs. As a result, non-energy benefits such as productivity, reliability, quality and cost can provide a way to interest the end-user in energy-efficient motor systems. Quantifying these costs will help to focus more attention on the efficiency of the system, rather than on the efficiency of an individual component.

Decision Support

End-users need decision-making software tools to help them identify opportunities for energy savings. Motor system component selection software can provide decision-makers with accurate, standardized information on the availability of energy-efficient components. These tools should include life-cycle cost analysis tools, as well as application guidelines, and O&M recommendations.

Voluntary Rating and Labeling

Rating and labeling practices need to be standardized for individual motor-driven system components. This will improve the end-user's or specifier's ability to compare different manufactured components. Rating and labeling will also protect the end-user, ensuring that the manufacturer is held responsible for any energy efficiency claims. The development of a common definition for what is high efficiency would go a long way toward addressing the confusion that currently exists in the marketplace. Fact sheets could be developed that educate end-users about packaged system efficiency testing procedures and the importance of efficiency.

5.8 Implementing the Actions

It is anticipated that the Final EMS Action Set, and especially the leading actions identified above, will form the basis for subsequent early implementation consideration by the Motor Challenge Program. This report will be used as a dynamic starting point by DOE's Motor Challenge Program for an aggressive market transformation initiative, with the participation of Motor Challenge partners and allies. The roles of market players and strategic partnerships are discussed in detail in Chapter 6.

CHAPTER 6

POTENTIAL ROLES OF MARKET PLAYERS AND STRATEGIC PARTNERSHIPS

6.1 Potential Roles of Market Players

The types of organizations that may play roles in implementing market transformation activities include: end-users; industry and professional trade associations; motor, ASD, and original equipment manufacturers (OEMs); utilities; distributors; government agencies; engineering consultants and contractors; educational institutions; public interest groups; and research organizations.

Many of these parties have already played an active role in helping to design the strategic actions listed in this paper. Certain parties may engage in direct market participation, while other parties, such as government and trade associations, are expected to play a facilitation and support role. Some organizations may have a broad range of interest and be involved in activities that cross several markets, while others may want to be vertically focused on a particular equipment segment or specific end-use or market segment.

6.2 Strategic Partnerships

Partnerships and alliances between market players can enhance strategic business opportunities and foster development of cost-effective market transformation programs, particularly where commonalities exist to leverage resources and combine strengths. Partnerships, alliances, and collaboratives can also greatly influence purchasing power. They can create large market demand, influence product mix and pricing, and encourage the introduction of higher-efficiency products and services. By pooling knowledge, working cooperatively and sharing cost, partnerships enable market players to undertake ambitious efforts (e.g., development of test procedures and energy-efficient product databases) that might otherwise be prohibitive for a single organization to undertake. These partnerships are characterized by such efforts as the Motor Challenge Program, the Midwest Motor Systems Consortium, the CEE Motor Systems Committee, and the Canadian Coordinated Utilities.

Strategic partnerships can be formed at the regional, national, and international level. Initiatives at each level have different and often complementary characteristics. For example, regional efforts can provide support and address issues that are unique to regional and local markets. Nationally, organizations such as CEE can work to develop consistent national programs and develop essential links with manufacturers to market efficient products and services. Equipment manufacturers are growing more global. For example, the North American Free Trade Agreement (NAFTA) includes language encouraging the harmonization of standards among the United States, Canada and Mexico. These types of partnerships are described in more detail below.

- Regional Partnerships. A regional partnership offers frequent interaction between the members and supports individuals involved in the decision process at the regional and local level. These partnerships can also address unique local issues. These can include such situations as regional concentrations of a specific type of motor system application for which there are opportunities for significant replication. It also offer opportunities to harmonize local utility program designs. These regional partnerships can be focused around specific professions, markets or segments (e.g., building managers, textile plant engineers, distributors, motor repair shops, etc.) or bridge across different categories such as the Midwest Motor Systems Consortium. They are well suited to deliver initiatives that are aimed at developing and supporting local constituents such as end-users, vendors and local trade skills development.

- National Partnerships. National partnerships can help to address markets that are loosely connected and regionally skewed. These efforts may involve activities that would be difficult to implement with a high degree of success at the regional or local level, such as testing and verification, energy efficiency ratings and labeling, and research and development programs. Incentive programs for manufacturers may be most effective at the national level because of the size of the market effected.

- International Partnerships. At the international level, the potential for partnerships exists to address technical and informational issues. For example, Canada and the U.S. have been successful in harmonizing motor test procedures and minimum performance levels. These efforts benefit organizations in both countries by making consistent information available in an increasingly global equipment market, as well as streamlining and promoting trade activities.

6.3 Opportunities for Participating in the Market Transformation Process

Numerous opportunities exist for involvement in market transformation partnerships. The extent of the partnership will be driven by opportunities to capitalize on the benefits of shared resources and a common vision. This may involve participation in existing activities, creating new partnerships, and/or collaboratives or business alliances to maximize market transformation opportunities. The six examples below reflect the range of national and regional opportunities available.

DOE Motor Challenge

The Motor Challenge program was established by the U.S. Department of Energy to help stakeholders transform markets and to facilitate the development and adoption of the best equipment and practices possible in pursuit of the program mission of "creat(ing) a partnership with our allies to deliver products and services that assist our customers in gaining a competitive advantage in managing their electric motor systems, while saving energy and enhancing environmental quality." The Motor Challenge partnership draws upon the diverse perspectives and needs of stakeholders to form coordinated marketing and deployment strategies. Partner organizations include industrial end-users, OEMs and distributors, utilities, state energy offices, engineering firms, trade associations, research institutions, universities, and public interest groups. Specific activities include:

- Showcase Demonstrations,
- information exchange through a national Information Clearinghouse, publications, database tools (e.g., MotorMaster), and conferences
- joint training development and implementation,
- support of trade allies with program materials and referrals, and
- market research.

Activities such as its Showcase Demonstrations facilitates and supports market transformation initiatives by bringing together various disciplines who are involved in system design, integration, and operation to test new concepts and to develop innovative approaches to maximize energy efficiency opportunities.

Motor Systems Committee of the Consortium for Energy Efficiency (CEE)

CEE is a non-profit organization comprised of utilities, environmental and public interest groups, and government agencies. The purpose of this unique coalition is to encourage the development of markets for "super-efficient" appliances and other technologies and services in the residential, commercial, industrial, and agricultural sectors. CEE and its members seek to marshall a variety of program resources to facilitate market transformation through market-pull strategies.

CEE has formed a Motor Systems Committee, consisting of electric utilities, industrial end-users, government agencies, research organizations, and public interest groups. The committee also obtains input from trade associations and individual equipment manufacturers. The Committee's purpose is to assess and develop programs to capitalize on opportunities for accelerating transformation of the motor systems marketplace. Committee activities include:

- Identifying strategic business opportunities to encourage market change;
- Facilitating communications to build a consensus among stakeholders;

- Coordinating and combining participants' resources and strengths; and
- Developing market-based programs to increase the energy efficiency of motor systems.

The CEE Motor Systems Committee is emerging as an important player in North America's motor systems market, providing a forum to encourage discussion and a platform to influence market changes.

Regional Motor Systems Consortium

DOE and the Energy Center of Wisconsin have been instrumental in the formation of the Midwest Motor Systems Consortium. The Consortium is a voluntary organization dedicated to improving efficiency in motor systems. It is comprised of end-users, utilities, equipment manufacturers and distributors, and engineering consultants and contractors. The main focus of the group is to leverage resources through integrated business partnerships to provide an effective means of non-proprietary energy efficiency information transfer to industry. Specific activities include: cost sharing, information exchange, joint training development and implementation, and development of product profiles for energy-efficient products. By its nature, the Consortium has a regional focus, with emphasis on industries located within a ten-state area. The Consortium was established as a model that can be replicated in other regions in the country.

Purchasing Collaboratives

The consolidation of purchasing power can have a significant effect in transforming a market as demonstrated in the fluorescent ballast market. The Energy Efficient Procurement Collaborative and Purchasing Network, formed in 1994, is comprised of federal and state government agencies, utilities, and public interest groups. Collectively they aim to influence the production and supply of energy-efficient products. Their mission is to provide large purchasing agencies with accurate and easily accessible information about energy-efficient and environmentally-preferred equipment and appliances. To date, the Collaborative's activities have been limited to developing information resources. However, future activities may involve initiatives such as the development of common purchase specifications.

Value Systems, Inc.
Example of a Purchasing Collaborative as a Strategic Partnership

Value Systems, Inc. provides an excellent example of a strategic partnership in action. This existing purchasing association exemplifies the power of a purchasing collaborative and shows the valuable role such an organization can play in the electric motor system market transformation process. The company is a textile manufacturers' purchasing association with members including the American Textile Purchasing Association (120 members representing 60 textile companies), and the Textile Plant Engineers Association (42 plant engineers from 27 companies). These textile companies represent the broad range of textile manufacturers, from integrated manufacturers that make yarn and weave fabric to non-integrated yarn manufacturers and weaving companies. In total, Value Systems members represent more than 475 operating textile plants, primarily in the Southeastern U.S.

By joining Value Systems, members benefit from:

- Reduced-cost supplies;
- Networking with peers, suppliers, and experts;
  Information on ways to reduce energy costs;
- Improved supplier performance;
- State-of-the-art problem-solving information for plant engineers; and
- Benchmarking information, a bi-annual motor/energy survey, research, and quarterly meetings, including case studies.

In addition to overall purchasing and plant engineering benefits, the purchasing association has pursued a wide range of motor-related activities that help members to specify, purchase, and manage more efficient motor systems. These activities include:

- Helping members purchase motors at the best price and locating metric motors for European and Japanese textile manufacturing equipment;

- Conducting bi-annual motor/energy survey to determine, for example, whether companies are specifying premium efficient motors, have a written motor policy, and are using MotorMaster to assist in motor purchasing;

- Developing a model motor policy;

- Holding workshops, including Motor/Energy workshops, a motor system predictive maintenance workshop, and a seminar on how to evaluate motor repair shops; and

- Analyzing more than 200 motor repair invoices and making recommendations for members' next purchases.

As a result of these activities, Value Systems has increased the percentage of new motor purchased versus repaired from 16 percent in 1992 to 32 percent in 1995. The association's ultimate goal is to increase this to 80 percent.

A second example of a purchasing collaborative is Value Systems, Inc. — a textile manufacturers purchasing collaborative with members including the American Textile Purchasing Association (ATPA) and the Textile Plant Engineers Association (TPEA). This organization is profiled in more detail in the accompanying text box.

Industry Trade and Professional Associations

Like the American Textile Purchasing Association, industry and professional associations can play important roles in helping their members benefit from market transformation. Examples of such associations include:

- Air Movement and Control Association (AMCA)
- American Forest and Paper Association (AFPA)
- American Institute of Plant Engineers (AIPE)
- American Petroleum Institute (API)
- American Society of Mechanical Engineers (ASME)
- Association of Energy Engineers (AEE)
- Chemical Manufacturers Association (CMA)
- Compressed Air and Gas Institute (CAGI)
- Edison Electric Institute (EEI),
- Electric Power Research Institute (EPRI),
- Hydraulic Institute (HI),
- National Association of Manufacturers (NAM),
- National Electrical Contractors Association (NECA), and
- National Electrical Manufacturers Association (NEMA).

6.4 Benefits of Participation

The benefits of participation in the market transformation process are varied, depending on the organization (see Table 6.1). Organizations who choose to participate will do so out of a sense of opportunity and mutual interest in working cooperatively with other organizations that share a common vision.

Table 6.1
Benefits of Improved "System Efficiency" to Market Stakeholders Through Participation in the Market Transformation Process

Stakeholder	*Primary Benefits*
End-Users	Reduced energy cost, improved process/operations, productivity improvement, better environmental performance, competitive advantage
Manufacturers/OEMs/ Distributors	Increased sales, sale of higher margin equipment and services, competitive advantage
Specifiers/Designers	Increased design activity, improved skills, reduced costs, competitive advantage
Electric Utilities	Avoided cost of new plant, improved customer relations
Other Trade Allies	Increased service business activity
U.S. DOE and Nation	Reduced CO_2 emissions, improved national energy security

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Appendix

Motors Market Transformation Final Action Set

A.1 Motors and Drives

Motors and drives are perhaps the most closely-examined segments of the Electric Motor System market. The primary focus of industrial DSM programs through the early 1990s, they still offer opportunities for efficiency improvement. The Final Action Set includes the following actions for motors and drives:

Table A.1
Final EMS Action Set: Motor and Drive Actions

Action	*Description*
Quality Assurance Rewind Guidelines and Practices	A wide range of "quality" exists in rewind services There is no performance standard for rewound motors. This action focuses on enabling motor repair facilities to assure the quality of repair/rewind services and achieve a "near original" efficiency level while removing poorly rewound and inefficient motors from the market. The action is linked with *Best Practices for Efficient Motor Rewind*, with the proposed quality assurance guidelines facilitating purchases and encouraging end-users to demand quality rewind services. These linked actions are expected to improve the availability of quality rewind services.
Best Practices for Efficient Motor Rewind	Best Practices will facilitate and encourage motor repair shops to provide quality rewind services. Best practice guides for motor rewind shops will illustrate proper rewind methods and tests to achieve optimum "repaired" quality and efficiency.
Early Retirement for Motors	Older and less efficient motors and driven equipment may still be used although more efficient alternatives are currently available. The performance and efficiency of the equipment may have deteriorated considerably after many years of service. In some case, the process for which the equipment was designed has changed and the equipment or technology is now outdated. An assessment of the system may show that current process requirements can be met more efficiently and cost-effectively by replacing existing equipment. This action is designed to encourage users to assess early equipment retirement opportunities, and encourage them to replace this equipment, and to provide financial incentives and technical assistance.

A.2 Process Pump Systems

Pumps account for the greatest portion of motor-drive electricity use in the process industries and are significant energy consumers in most other segments. A typical industrial process uses many sizes and types of pumps to perform different functions.

Table A.2
Final EMS Action Set: Process Pump System Actions

Action	*Description*
Market Transformation Partnerships	Lack of awareness regarding the energy-savings potential available through optimizing motor-driven systems; market stakeholders do not collectively promote energy efficiency at the system-level; and certain stakeholders lack incentive or motivation to promote efficient system design or equipment purchases. This action encourages strategic business partnerships with an emphasis on cultivating relationships between systems-oriented end-users and trade allies who promote systems design and integration.
Encourage Better Internal & Trade Ally Communication	Better communication needed, both among employees within the end-user's company (e.g., maintenance, energy management, purchasing, finance) and with suppliers and other trade allies. Working in partnership, the end user can target opportunities for improved energy efficiency that they might otherwise not have identified.
Training in Strategic Marketing for Motor Systems Products & Services Training Program for Performance Optimization	There is a generally-acknowledged lack of availability of pump technical and performance information and system expertise in the marketplace. To provide this information, including access to system design expertise and to increase end-user awareness of pump system efficiency opportunities, this training program would be modeled after similar efforts undertaken in Ontario and Wisconsin. It would offer end-user and design professionals an opportunity to learn proven techniques for the optimization of motor systems with an emphasis on pumps.
Develop Models of Optimized Systems	Develop models of optimized systems to encourage end users to begin taking a "systems approach" when specifying new or making changes to existing pumping systems.
Develop Specification Guidelines	Develop specification guidelines to arm users with the knowledge of what to ask for in a new system.
Develop Catalogues of Equipment Cost and Performance Information	This information is not always easy for end-users to obtain on a range of competitive products. These catalogues could be in hard-copy or electronic form, modeled after the MotorMaster package.

Table A.2
Final EMS Action Set: Process Pump System Actions

Action	*Description*
Quantify Life-Cycle Costs of Pumping Quantify Non-Energy Benefits	End-users don't understand the value of an energy-efficient pump system and there is a lack of focus on the efficiency of the system as a whole. To focus more attention on the pump system rather than on individual efficiency of a pump or motor, reliable techniques for establishing the life-cycle cost of pumping must be disseminated. Both the energy and non-energy benefits of energy-efficient pumping systems should be quantified, highlighting productivity improvements.
Internet Access to Technical, Marketing and Financial Data	Currently, energy efficiency information systems are limited in their scope and availability. Even with the proliferation of commercially available information technologies and systems there are few information systems available to support decision-making processes for the design and use of efficient motor systems. The situation simply isn't a lack of energy efficiency information sources, but rather a lack of accessible information systems which complements user and trade disciplines' decision making systems and processes. This action seeks to provide greater access to quality technical, marketing and financial information; and to increase the capacity of information systems to increase storage and processing capabilities and the speed with which information is transmitted.
Life-Cycle Costing Tools & Methodologies	This action is to develop life-cycle costing tools and methodologies to estimate the cost of new and replacement electric motor systems by considering such factors as initial cost, installation, start-up, energy, maintenance and repair, and salvage value. The methodologies and tools will improve decision-making for end-users and specifiers. Examples of costs and benefits associated with the use of efficient electric motor systems could be verified through the Showcase Demonstrations.
Develop Pump Selection Software	End users need software to tell them where the energy savings are. Pump selection software can help decision-makers obtain accurate, standardized information on what is available in terms of energy-efficient pumping system components. While pump manufacturers all have their own software programs, they are different so it is impossible for end-users to make good comparisons between products.
Develop Rating and Labeling Guidelines for Packages	Extend available efficiency guidelines with development of rating and labeling guidelines by the Hydraulic Institute to improve the end-user's or specifier's ability to compare different manufacturers' pumps.

Table A.2
Final EMS Action Set: Process Pump System Actions

Action	*Description*
Demonstration Projects	Demonstration projects (such as the Motor Challenge Showcase Demonstrations) can effectively generate technical information and marketing intelligence. The technical information that is derived is invaluable in addressing broader application engineering issues and substantiating the viability and performance of the technologies in question. Demonstrations provide a forum to test new concepts, establish design principles, and develop practical application guidelines for effective operation of motor systems in the field. Demonstration projects also facilitate and encourage value engineering by bringing together the disciplines involved in design, integration and operation to the same table.
Establish Purchasing Collaboratives	Purchasing collaboratives can leverage the buying power of users (e.g., industry groups, utilities, government agencies) to create a demand-pull for high performance process pump systems. This action involves organizing industry groups, utilities, government agencies, and other motor system users to encourage the purchase of electric motor systems that meet minimum energy efficiency guidelines at desired performance levels. Purchasing collaboratives could provide the "critical mass" necessary to achieve market transformation.
Identify and Provide Financial (and Non-Financial) Incentives	Incentives are important in encouraging the adoption of energy-efficient pump systems and management practices. While many utility rebate programs are being phased out, other incentives may be worth pursuing, including tax incentives, innovative utility rate structures (e.g., reactive power charges and time-of-use rates), and utility leasing or financing arrangements. For those utilities continuing to offer incentives, rebates for efficient pumps could help establish a market demand. Other potential incentives include environmental benefits and recognition. A definition of a high-efficiency pump is needed to implement this action.
Develop Certification Process for Pump Packages	A certification program would address the lack of knowledge and technical expertise at the systems level barrier cutting across all motor market segments. A certification process will ensure that the rating and labeling guidelines are being followed. In addition, the certification programs could cover areas such as: efficient systems design, selection of equipment, performance optimization, life-cycle costing, energy and cost analyses, testing, and maintenance and repair. Certification programs could offer strategic business opportunities to the engineering consultants.
Early Retirement Program	*Common Action - see description under Motors and Drives*

A.3 Fan and Blower Systems

Fans and blowers are used in a variety of applications in the industrial market. The large number of industrial fan and blower applications and distinct operating conditions limit the potential for broad-based prescriptive equipment solutions. The final action set for this market includes the following:

Table A.3
Final EMS Action Set: Fan and Blower System Actions

Action	*Description*
Market Transformation Partnerships	*Common Action - see description under Process Pump Systems*
Encourage Better Internal & Trade Ally Communication	*Common Action - see description under Process Pump Systems*
Training in Strategic Marketing for Motor Systems Products & Services	*Common Action - see description under Process Pump Systems*
Training Program for Performance Optimization	*Common Action - see description under Process Pump Systems*
Promotion of Energy-efficient Fans and Blowers Through Education and Awareness	Industry can derive many benefits from campaigns to promote energy-efficient fan and blower systems through education and awareness. This creates opportunities for industry segments to learn from the experience of other industry segments. Information exchange also may be possible between similar industrial applications, although competition is often a major barrier.
Quantify Non-Energy Benefits	In most cases, electricity accounts for only 5 percent of total manufacturing costs. As a result, non-energy benefits can provide a way to interest the customer in energy-efficient fan and blower systems. Non-energy benefits may include: reliability, quality, cost, and reputation. Productivity at the plant may increase due to the use of energy-efficient equipment. *(Common Action - see description under Process Pump Systems)*
Internet Access to Technical, Marketing and Financial Data	*Common Action - see description under Process Pump Systems*
Life-Cycle Costing Tools and Methodologies	*Common Action - see description under Process Pump Systems*

Table A.3
Final EMS Action Set: Fan and Blower System Actions

Action	*Description*
Develop Fan/Blower Selection Software	These software-based and other tools should provide industry with a valid, third-party substantiation of manufacturers' claims and will streamline purchasing decisions for customers. Ideally, the tools should include life-cycle costing tools as well as, application guidelines and O&M recommendations. Contributors to the development of decision-making tools identified by the group include OEMs, end-users, manufacturers, engineers, distributors, trade groups, government, and consultants.
Rating and Labeling Guidelines for Packages	*Common Action - see description under Process Pump Systems*
Standardize Rating & Labeling Practices for the Fan Industry	Customers will benefit when integrated rating and labeling practices become standard for the fan industry. Standard rating and labeling will clear up the confusion that presently exists regarding factors such as minimum efficiency and nominal efficiency. Labeling and rating will protect the customer, ensuring that the manufacturer is held responsible for any energy efficiency claims.
Develop Common Purchase Specifications for Packages	OEMs lack incentives for innovative products; equipment end-users and purchasers do not always specify minimum efficiency levels. Common specifications for fan/blower packaged systems will facilitate the purchase of equipment that meets minimum efficiency requirements. This action is linked to collaborative purchases and is dependent upon the development and promotion of test procedures or protocols. *(Common Action - see description under Process Pump Systems)*
Demonstration Projects	*Common Action - see description under Process Pump Systems*
Establish Purchasing Collaboratives	*Common Action - see description under Process Pump Systems*
Incentives for Selecting Energy-efficient Fans and Blowers	Financial incentives, including rebates and alternative financing arrangements, provide strong inducements to customers to purchase energy-efficient fan and blower systems. Environmental benefits of efficient equipment are another strong incentive for companies anticipating that environmental regulations will be stricter in the future. A company on the environmental-technology cutting edge has a distinct public relations and economic competitive advantage. In order for incentive programs to be effectively offered, a definition of an energy-efficient fan needs to be developed.
Systems Certification Program	*Common Action - see description under Process Pump Systems*
Early Retirement Program	*Common Action - see description under Process Pump Systems*

A.4 Air Compressor Systems

Compressed air systems are widely used throughout the manufacturing sector to support air-driven hand tools, clamps, and motors, among other uses. The systems typically range from 90 to 125 pounds per square inch (psi) and 100 to 1500 cubic feet per minute (cfm). All systems consist of one or more electric motors, compressor air-ends/packages, filters and/or dryers, pressurized air reservoirs, distribution piping and valves, and point-of-use tools.

Final action set items include:

Table A.4
Actions Addressing the Air Compressor Market Segment

Action	*Description*
Market Transformation Partnerships	*Common Action - see description under Process Pump Systems*
Plant Air Compressor Package Testing Procedures	Voluntary adoption of testing procedures makes it difficult to compare performance across compressor types and among manufacturers; selecting the most efficient air compressor package-system is difficult. Promulgation of widely-accepted test procedures for air compressor packages to allow easy comparison of energy consumption across manufacturers and types; and encourage improved OEM adherence to energy efficiency rating and labeling guidelines.
Training in Strategic Marketing for Compressor System Products & Services	*Common Action - see description under Process Pump Systems*
Training Program for Performance Optimization	*Common Action - see description under Process Pump Systems*
Customer Awareness Program	Compilation of a series of questions and talking points for end-users to reference when purchasing equipment would allow the users to become demanding, sophisticated buyers.
Directories of Stakeholders	Information on the stakeholders involved in the industrial compressed air system market is difficult to collect. A directory of the compressed air system market players would allow end users to save time and money by providing this information in a single source.
Directories of Services and Information	Availability of a compressed air system reference guide, including an information directory and ordering information, would provide end-users with ready access to the books, training, technical literature, and databases needed to improve system performance in this market.

Table A.4
Actions Addressing the Air Compressor Market Segment

Action	*Description*
Case Studies of Cost Savings & Performance Improvement Benefits	One- or two-page summaries of real-world improvements to existing compressed air systems would ease the transition to efficient system design for many end users. These case studies would include data on independently verified savings and a kWh-cost reference matrix to show savings and paybacks as a function of electricity price.
Internet Access to Technical, Marketing and Financial Data	*Common Action - see description under Process Pump Systems*
Life-Cycle Costing Tools & Methodologies	*Common Action - see description under Process Pump Systems*
In-Plant Air Distribution Guidelines	Current industrial compressed air systems are not being designed, maintained and operated in the most efficient manner. A checklist and informal guidelines on how to achieve optimum system performance would be a simple way to make end-users aware of the available opportunities.
CAGI Test Procedures Fact Sheet	There is currently a lack of confidence in the ability to directly compare efficiency ratings from competing OEMs. A one-page fact sheet, including a description of the components that make up "the package" and description of performance testing, would be a valuable user reference. This product would educate end-users about packaged compressed air system efficiency testing and the importance of efficiency. A partnership between OEMs and the Compressed Air and Gas Institute could be the implementor.
Develop Rating & Labeling Guidelines for Packages	*Common Action - see description under Process Pump Systems*
Develop Common Purchase Specification for Packages	End-users are not always aware of what questions to ask vendors, distributors, and OEMS when procuring a compressed air system. Some end-users don't know how to specify energy efficiency in their requests for proposals. Common "boilerplate" language and specifications for end-users to use when requesting proposals, including references to CAGI/PNEUROP test codes, is needed. It would also require performance to be measured in terms of kW, not just horsepower.
Demonstration Projects	*Common Action - see description under Process Pump Systems*
Improve the Consistency & Availability of Plant Energy Audits	Development of: (1) a compressed air system plant auditor certification program, and (2) educational training sessions or seminars that explain the benefits of having an audit performed would be valued by end users. The certification program allows end-users to know if a given energy auditor has the knowledge to complete the certification process. The training sessions should target the corporate financial staff and plant managers and operators.

Table A.4
Actions Addressing the Air Compressor Market Segment

Action	*Description*
Establish Purchasing Collaboratives	*Common Action - see description under Process Pump Systems*
Compressed Air Facilities Outsourcing	End-users devote minimal resources to developing O&M expertise in this area. Produce and supply reliable compressed air services needed for customers to meet operating demand (existing and planned) in the most efficient manner. Encourage qualified firms to offer system design and O&M compressed air system services.
Systems Certification Program	*Common Action - see description under Process Pump Systems*
Early Retirement Program	*Common Action - see description under Process Pump Systems*