EFFICIENT ELECTRIC MOTOR SYSTEMS FOR INDUSTRY

Report on Roundtable Discussions of Market Problems and Ways To Overcome Them

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MASTER

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Preface

This report synthesizes the results of the expert roundtable on Efficient Electric Motor Systems for Industry that was held in Baltimore, Maryland, on February 11, 1993. The Office of Energy Demand Policy and the Office of Industrial Technologies, both of the U.S. Department of Energy, jointly organized the roundtable.

The roundtable comprised 45 experts assembled from across the country, including electric motor system market participants (for example, motor manufacturers, designers-specifiers, original equipment manufacturers, and industrial end-users) and incentive strategists and technical specialists (for example, demand-side management experts, regulators, and State energy officials). Discussions focused on alternating current (ac) motors of 20 horsepower or greater for applications in pumps, fans, blowers, compressors, and materials processing and handling equipment.

The roundtable's main purpose was to address two questions:

- What is keeping more efficient electric motor systems from penetrating the marketplace?
- What might help relieve these market problems?

Group consensus on these two questions was not the roundtable's goal. Rather, participants brought differing perspectives on the issues addressed based on their particular experiences and expertise. The roundtable was organized to record and analyze these individual perspectives and then synthesize them in a coherent document.

The lists of perceived market issues and problems in this report result from gathering together the input of industry experts. The problems reported are representative of the views expressed by individual participants. The Department of Energy has not ranked the problems in terms of market impact.

The findings from this study have already played a major role in providing evidence for the Department of Energy to use in advancing program support for accelerated commercialization of efficient electric motor systems. The findings also should offer insights to nongovernmental entities, such as utilities, industry associations, research institutions, and energy-efficiency institutions, all of which play an active role in providing incentives to industry.

Contents

Executive Summary	ix
List of Roundtable Participants and Observers	xii
I. Introduction	1
II. Opportunities To Improve Electric Motor System Efficiency	3
Efficient Electric Motor System Technology	3
Opportunities for Increased Electric Motor System Efficiency	4
III. The Structure of the Electric Motor System Market	7
IV. End-User Decisionmaking Practices	9
V. Market Problems for Efficient Electric Motor Systems	11
Inadequate Coordination and Leadership	12
Lack of Focus in End-User Decisionmaking	13
Weaknesses in the Functioning of the Electric Motor System Market	14
Deficiencies in Information	15
Lack of Broad-Based Technical Expertise	16
VI. Suggestions for Overcoming Market Problems	19
Exercising National Leadership	19
Providing Focus to End-User Decisionmaking	21
Improving the Functioning of the Electric Motor System Market	22
Information Collection and Dissemination	23
Building Technical Expertise	24
VII. Conclusions	25
Appendix A: Organization of the Roundtable on Efficient Electric Motor Systems for Industry	A-1
Background	A-1
Accomplishments	A-2
Agenda	A-2
Discussion Questions	A-3
Discussion Groups	A-4

Contents (continued)

Appendix B: Background Papers	B-1
Electric Motor Systems Technology Characterization, by Ben McConnell, Oak Ridge National Laboratory	B-2
The U.S. Electric Motor System Market Delivery System, by N. Richard Friedman, Resource Dynamics Corporation	B-6
Decision-Making Processes for Industrial Energy-Efficient Electric Motor Systems, by Jean-Louis Poirer, RCG/Hagler, Bailly, Inc., and Joseph Roop, Battelle Pacific Northwest Laboratory	B-13
Utility and State Industrial Electric Motor System Incentive Programs, by Joseph Roop and D. J. Stucky, Batelle Pacific Northwest Laboratory	B-21
Appendix C: Reprint of Summary of Conference Highlights: Efficient Electric Motor Systems Conference, February 9-10, 1993, Baltimore, Maryland	C-1

Executive Summary

The U.S. Department of Energy (DOE), in collaboration with the Electric Power Research Institute, conducted preliminary market research and sponsored the expert roundtable on Efficient Electric Motor Systems for Industry, held in Baltimore, Maryland, on February 11, 1993. This report synthesizes the roundtable findings.

Electric motor systems—consisting of motors, drives and control systems, and mechanical loads and processes—account for more than two-thirds of the electricity used by U.S. industry. Efficient electric motor systems are one of the best energy-saving opportunities for the United States, representing the largest potential source of energy savings among industrial end-uses. Opportunities include energy savings from the use of energy-efficient motors, electronic adjustable speed drives, improved motor-driven equipment, and advanced motor-driven processes or systems.

The potential energy savings from efficient electric motor systems are substantial. DOE estimates that improving the energy efficiency of industrial electric motor systems could save roughly 240 billion kilowatthours of electrical energy annually and could reduce electrical demand by 50,000 megawatts in 2010. The saved electricity would reduce greenhouse gas emissions annually by 44 million metric tons (or about 3 percent of total U.S. emissions). U.S. industry's electricity bill would be reduced by \$13 billion per year—a significant contribution to competitiveness and job preservation.

The primary problem faced by market participants is the absence of a coordinated effort to encourage increased market penetration for more efficient electric motor systems. The market participants need leadership to help establish a shared vision, a national strategy, and better coordinated programs to achieve that market penetration.

As of the date of this publication, the DOE Office of Industrial Technologies has taken steps to follow up on the roundtable discussions and, especially, is working to increase collaboration among important stakeholder groups in the Federal Government, in State governments, and in the private sector. For example, the market problems and opportunities identified in the roundtable have led to the development of DOE's MOTOR CHALLENGE Program, which was launched in October 1993.

The following market issues and problems pertaining to the adoption of efficient electric motor systems were identified at the roundtable discussions:

Inadequate Coordination and Leadership

- There is no coherent national leadership for coordinated efforts to introduce more efficient electric motor systems into U.S. markets. This leadership void is in three areas: strategic vision, incentive coordination, and standards development.
- Utility-sponsored programs for electric motor systems lack consistency, stability, a "system" focus, and a perspective that encourages long-term economics.

Lack of Focus in End-User Decisionmaking

- End-users' major criterion is low first cost, rather than life-cycle cost.
- The immediacy with which replacement motors are needed (sometimes because of crisis management decisionmaking) leads to lost opportunities for energy-efficiency improvement.
- When an engineering contractor (non-owner) determines motor system characteristics, the

end-user can become decoupled from the motor system purchase decision.

- End-users are not always aware of the costs and benefits of efficient electric motor systems.

Weaknesses in the Functioning of the Electric Motor System Market

- Market fragmentation limits industry's responsiveness to new electric motor system technologies and applications.
- End-users and suppliers of electric motor systems lack system responsibility.
- Competitive markets coupled with a reluctance of end-users to pay higher first cost for efficient electric motor systems result in low-cost bidding practices.

Deficiencies in Information

- Lack of information on electric motor systems and tools to evaluate those systems hampers end-users' ability to make informed economic decisions and suppliers' ability to segment and target their markets effectively.
- Misinformation about efficient electric motor systems hinders market acceptance.
- The sporadic and inconsistent nature of most programs informing participants about efficient electric motor systems limits their effectiveness.

Lack of Broad-Based Technical Expertise

- Many end-users do not have sufficient experience with motor "systems" and thus do not always make the best technology choices. Many manufacturers, dealers, and distributors, some specifiers or agents to end-users, and most utility representatives have limited familiarity with applications of adjustable speed drives (ASDs) and do not always provide

detailed ASD application information to their customers.

The roundtable participants suggested actions to alleviate these market problems, primarily in the following three areas:

1. **Stakeholders should apply the systems approach to electric motor systems.** Stakeholders should be encouraged to look not only at efficient motors to improve efficiency, but at the overall electric motor system, comprised of motors, motor controlling devices (such as electronic ASDs), and motor-driven equipment (such as pumps and compressors).
2. **DOE should fill the national leadership void in the electric motor system area by helping to guide stakeholders toward a systems approach.** DOE should unite Federal sector activities in the electric motor system area and develop an electric motor system program approach that involves active participation of end-users of electric motor systems, original equipment manufacturers, motor and drive manufacturers, architect-engineering firms, and other key market participants.
3. **DOE could play an important role in collecting and disseminating information on efficient electric motor systems.** DOE could function as a national clearinghouse for electric motor system activities, collect better information on electric motor system applications and the electric motor system market, and perform selected case studies. This suggestion emerged from the observation that many of the problems related to market acceptance for efficient electric motor systems could be alleviated through more complete and consistent data, case studies and market studies, and more effective dissemination of information to market participants.

The roundtable participants suggested the following specific activities to achieve greater market penetration for efficient electric motor systems:

- Establishing better communication networks, including uniting Federal motor system activities and exploring collaborative efforts with industry (individual companies, utilities, and associations).
- Supporting education and training activities and intensifying outreach efforts.
- Expanding information and data sources, including establishing a comprehensive, reliable, and accessible information system.
- Expanding and enhancing national data collection efforts, particularly for end-user and applications-oriented information.
- Conducting market studies to develop a better understanding of the electric motor system market.
- Targeting a broad base of stakeholders that may include end-users, motor and drive manufacturers, original equipment manufacturers, distributors, consulting firms and architect-engineering firms, utilities, industry associations, financial institutions, State and local energy offices, and research institutions.
- Applying and promoting the systems approach to electric motor system technology, including supporting case studies and demonstrations of efficient electric motor system applications.
- Establishing regional collaboratives to promote increased coordination and communication by regional electric motor system stakeholders and organizations.
- Supporting development of national voluntary efficiency standards for efficient electric motor systems.
- Encouraging harmonization of utility incentive structures for industrial demand-side management programs.

This study's findings are expected to provide important market insights to aid DOE in advancing national efforts to support industry in achieving the common objective of improved market penetration for efficient electric motor systems where it is economically beneficial.

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I. Introduction

Improving the efficiency of electric motor systems is one of the best energy-saving opportunities for the United States. The Department of Energy (DOE) Office of Industrial Technologies estimates that by the year 2010 in the industrial sector, the opportunities for savings from improved efficiency in electric motor systems could be roughly as follows:

- 240 billion kilowatthours per year.
- \$13 billion per year from U.S. industry's energy bill.
- Up to 50,000 megawatts in new powerplant capacity avoided.
- Up to 44 million metric tons of carbon-equivalent emissions mitigated per year, corresponding to 3 percent of present U.S. emissions.

Recognizing the benefits of this significant opportunity for energy savings, DOE has targeted improvements in the efficiency of electric motor systems as a key initiative in the effort to promote flexibility and efficiency in the way electricity is produced and used. Efficient electric motor systems will help the United States reach its national goals for energy savings and greenhouse gas emission reductions.

To this end, DOE's Office of Industrial Technologies established the Electric Motor Systems Program, which emphasizes both long-term research and development and shorter-term market acceleration activities to promote greater market penetration for efficient electric motor systems. DOE's Office of Energy Demand Policy has joined with the Office of Industrial Technologies to obtain industry inputs, develop insights on market problems, and compile options for overcoming identified problems.

To provide important input for these studies, DOE hosted the expert roundtable on Efficient Electric Motor Systems for Industry on February 11, 1993, in

Baltimore, Maryland.¹ The roundtable had the following three objectives:

- Gain a more complete understanding of the complex nature of the U.S. market delivery system for electric motor systems for industry, how key players are doing business, and the forces that are driving decisions to adopt efficient motors and electric motor systems.
- Determine if key market problems are preventing accelerated and expanded adoption of efficient electric motor systems in the industrial sector.
- Define and suggest programs and promotional options that could be most helpful for DOE and other Federal agencies in efforts to encourage industry to further improve motor system efficiency.

Details on the organization of the roundtable can be found in Appendix A.

The roundtable was preceded by a literature review of the operation and functioning of the electric motor system market, including a review of decisionmaking processes for industrial end-users and an overview of utility and State incentive programs for promoting

¹The primary focus of the roundtable discussions was on three-phased alternating current motors of 20 horsepower or greater for applications in pumps, fans, blowers, compressors, and materials processing and handling equipment. Designer-built (custom) motors were excluded from the roundtable discussions. The roundtable focused mainly on discussions of efficient electric motor systems for large and medium-sized industries (for example, industries with annual energy expenditures greater than \$500,000). Electric motor system use in small industries, the commercial sector, and the agriculture sector were outside the scope of this study. Both the "new motor/new construction" market and the "replacement/rewind" market were addressed at the roundtable. The roundtable did not include any discussion of the effect that the Energy Policy Act of 1992 might have on national or local deployment of electric motor systems.

efficient electric motor systems in industry.² Four background papers completed as part of the review are found in Appendix B.

The remainder of this report is organized in six sections. Section 2 focuses on the questions, "What is an efficient electric motor system?" and "What are the opportunities for increased electric motor system efficiency?" In discussing opportunities for efficiency improvement, a clear distinction is made between

improving the energy efficiency of individual electric motors and improving the overall efficiency of the electric motor system, of which the motor is merely one component. Section 3 is an overview of the structure of the electric motor system market. Section 4 is a brief overview of end-user decisionmaking processes. Section 5 reports on the efficient electric motor system market problems identified during the roundtable discussions. Section 6 is a summary of suggested actions for overcoming these market problems. The report's conclusions are in Section 7.

²The Electric Power Research Institute provided funding for the background paper on decision-making processes for industrial end-users.

II. Opportunities To Improve Electric Motor System Efficiency

Efficient Electric Motor System Technology

An efficient electric motor system is the integration of energy-efficient electric motors, electronic adjustable-speed drives (ASDs), and driven mechanical systems (for example, pumps, fans, or compressors within a process).³ Efficiency in the system derives from both efficient components, such as an energy-efficient electric motor, and optimal integration of those components into a working system. Although efficiency improvement opportunities for individual motor components alone are significant, the greater energy efficiency opportunities lie in the system integration.

³The discussion in this section is adapted from Ben McConnell, "Electric Motor Systems Technology Characterization," (see Appendix B, section 1). Material on electric motor system efficiency improvement opportunities is provided by Paul Scheihing.

The distinction between an electric motor system and its components is made clear in Figure 1. The system consists of (a) a power distribution system; (b) a starting, speed control, and electric drive system; (c) an electric motor; (d) a mechanical system coupling; and (e) a mechanical load and process. In the energy flow sequence, an electronic adjustable speed drive control precedes the motor, and a mechanical speed control follows the motor.

In this electric motor system, the energy efficiency of the motor itself (typically 3 to 10 percent greater than that of standard efficiency motors) is only part of the energy efficiency of the total system.

Historically, various types of mechanical and hydraulic speed controls have been used to control motor speed for loads requiring varying speed or torque. Most of these speed controls have low efficiency and problems with reliability. Recently, alternating current drive and adjustable speed drive technology has advanced to the point where it can

Figure 1: Electric Motor System

provide precise speed control under varying torque and power requirements.

Opportunities for Increased Electric Motor System Efficiency

Although the electric motor and drive can be a source of energy-efficiency improvement, the overall system must be considered to achieve maximum efficiency.⁴ The emphasis on motors *per se* generally obscures the more important fact that much greater energy savings are possible by optimizing the process or systems

⁴This discussion of efficiency improvement opportunities for electric motor systems is adapted from an Electric Motor System Program Plan prepared by the Department of Energy's Office of Industrial Technologies.

external to the motor. That is, beyond the motors themselves, energy efficiency improvements can be found in ASDs, improved motor-driven equipment, and advanced motor-driven processes or systems. This is especially true in energy-intensive industries (such as the process industries—chemicals, pulp and paper, food, and petroleum).

The potential for energy-efficiency improvement in an electric motor system is application- and plant-specific, depending on the mechanical load serviced by the motor, the type of motor, and so forth. However, opportunities for increased efficiency in electric motor systems generally fall into four categories. These opportunities are illustrated in Figure 2, and the energy savings potential of each is shown in Figure 3.

Figure 2: Efficiency Improvement Opportunities

Figure 3: Potential U.S. Energy Savings by Opportunity Area

Opportunity #1: Motor Efficiency Improvement

An obvious opportunity for industry is to replace standard electric motors with more efficient models. Motors generally convert electricity to mechanical energy with relatively high efficiencies, with typical “off the shelf” motors providing efficiencies of 80 to 90 percent.⁵ With energy-efficient motors that routinely provide 90 to 95 percent efficiency now available, replacing older, less efficient motors can provide meaningful savings. Such motor “change out” activities represent 18 percent of the total national energy savings potential for electric motor systems.

Opportunity #2: Electrical Distribution Correction

Significant efficiency losses can be attributed to a plant’s power distribution system, which supplies electricity to the electric motor system. Imbalanced three-phase voltage supplies and worn or inadequate

distribution equipment can waste significant amounts of energy. To reduce these losses, several actions are possible. For example, the electric motor system’s three-phase voltage supply can be balanced, in-plant distribution lines and equipment can be upgraded, and the motor’s power factor can be improved. These efficiency opportunities represent 8 percent of the total national energy savings potential for electric motor systems.

Opportunity #3: Better Motor-Mechanical Subsystem Matching

The most significant efficiency opportunities arise from an improved ability to match motor-drive subsystems to the mechanical subsystems. To ensure adequate power for peak system requirements, oversized motors are often selected for applications. With limited ability to control the motors themselves, the mechanical subsystems are often operated in ways that reduce overall efficiency. Electronic ASDs—either alternating current (ac) or direct current (dc)—are now available to control motor speed, allowing a better match of motor-drive

⁵Older motors may have somewhat lower average efficiencies, but even these motors might be operating at 75 percent efficiency.

and mechanical subsystem operations to process requirements. This results in motor-drive and mechanical systems that do the job more efficiently together. In addition to ASDs, proper sizing of motors to the driven load (that is, avoiding extreme motor oversizing) will save additional energy. These efficiency opportunities represent 41 percent of the total national energy savings potential for electric motor systems.

Opportunity #4: Process Optimization

Another significant opportunity to capture energy savings involves using equipment or processes that require less motor shaft power. Options include downsizing oversized pumps, fans, and compressors; installing more efficient mechanical systems; and designing a new unit operation or process that requires less shaft power to make a product or drive a process. Such process optimization improvements represent 33 percent of the overall energy savings potential for electric motor systems.

III. The Structure of the Electric Motor System Market

Figure 4 is a characterization of the market delivery system for electric motor systems that was developed from the background research conducted for the roundtable.⁶ The diagram provides a good representa-

⁶The discussion in this section is adapted from a background paper by N. Richard Friedman, "The U.S. EMS Market Delivery System" (see Appendix B, section 2).

tion of the complex national market for electric motor systems, describing the paths from manufacturer to end-user. Although representative of the national system, regional market variations are reflected by regional variations in end-use processes.

Beginning with the assembly of components—including electrical steels, magnet wire, carbon-based brushes, terminal blocks, and steel housings—motor

Figure 4: Market Delivery Channels for Electric Motor Systems

manufacturers construct a diverse line of products capable of converting electrical power into mechanical work. Once an electric motor leaves the manufacturer's production plant, it is taken by a distributor and sold to end-users; sold to an original equipment manufacturer (OEM) who incorporates the motor into a compressor, pump, or other equipment product line; sold to architect-engineers (A&Es), engineering contractors, or other agents of end-users; or sold directly to large industrial end-users.

The electric motor system market characterization in Figure 4 depicts the various market players and their interactions. In practice, however, the motor, ASD, and other equipment market structures are even more complex. Market complexity is driven by the presence of distributors from OEMs to end-users, the involvement of "middlemen" (for example, engineering contractors such as A&Es), and the presence of feedback loops.

For delivery channels that involve an agent for the end-user, evaluations of electric motor system options, recommendations for purchases, and the procurement itself are typically handled by A&E firms and contractors. The role of these engineering contractors depends on the type of industry for which motors are being procured. With heavy industry, engineering contractors design the equipment for the end-user. With smaller industries, engineering contractors tend to play an even greater role in equipment evaluation and procurement. Currently, an increasing number of companies are working through A&Es, a trend that is expected to continue. Large end-users with multiple plants often have their own in-house A&E capability.

Feedback loops exist in certain market segments. For example, one important feedback loop is between the end-user and the A&E or contractor. Some end-users specify energy-efficient motors as a requirement in their contracts with the A&E or contractor.

Although Figure 4 is accurate in depicting the market delivery system, it could be broken into separate

diagrams for controllers (for example, ASDs), motors, and mechanical equipment, because electric motor system equipment typically is not manufactured and sold as an integrated system. Rather, the equipment is usually sold as controls, motors, or other components of a system. For example, although ASDs reach the end-user through all of the channels indicated in Figure 4, a diagram representing ASDs alone would be somewhat different. Resellers are a prominent part of the ASD market, while motor manufacturer representatives are not as much a part of the process. Motors are usually supplied by distributors who hold inventories, while drives are custom systems. Many of the large distributors behave like A&Es in providing services, including system integration, to the users of the ASDs.

As indicated in Figure 4, the electric motor system market comprises a complex, interconnected web of supply and distribution channels linking motor, ASD, and mechanical equipment manufacturers with electric motor system end-users. Other parties (including electric utilities; energy service companies; State regulators; Federal, State, and local government agencies; research organizations; and trade and professional organizations) influence the market. Sales of 20-horsepower or larger motors through each of these delivery channels can be broken down as follows: OEMs—49 percent; distributors—28 percent; and end-users (or agents for end-users)—22 percent.⁷ Nearly half of all electric motor systems are purchased by OEMs and contractors rather than directly by industrial end-users.

Although all market participants play a role in expanding the market for efficient motors and electric motor systems, the primary stakeholders in the market—from the most influential to the least—are large end-users, utilities, OEMs, and distributors and manufacturers.

⁷Source: *Electric Motors: Market, Trends, and Applications*, Resource Dynamics Corporation, EPRI TR-100423, June 1992.

IV. End-User Decisionmaking Practices

This section provides an overview of the factors end-users consider when purchasing electric motors.⁸ In general, electric motors are purchased for one of two fundamentally different reasons:

- To replace an existing motor because the old one is fully depreciated.
- To purchase an additional motor because a new process is introduced or an old process is expanded.

Deciding to replace an individual motor is different from deciding to purchase an additional motor. Purchases of replacement motors, generally considered maintenance expenses, are made by maintenance staff and represent a decision to restore the operation to a critical level of production. By contrast, purchases of additional motors are generally treated as capital expenditures and are made by planners as part of a more sophisticated decisionmaking process. Therefore, the end-user's decisionmaking is not as rigorous when buying a replacement motor as it is when buying an additional motor.

Decisions to purchase ASDs are more complex than those to purchase motors. The complexities include (a) the need for a basic understanding of how to apply an ASD and its effects on the process and (b) higher-level decisions involving multiple departments within an organization (research and development, maintenance, process engineering, and so forth).

Purchase decisions for electric motor systems are subject to standard financial analyses, such as return on investment or payback period, energy savings over the life of the asset, present life-cycle worth, and discounted cash flow and internal rate of return. The extent to which these criteria are used to evaluate

efficient motors and electric motor systems depends on characteristics of the end-user. For example, because of concerns related to their long-term viability, smaller end-users tend to avoid life-cycle costing. They are more interested in payback periods, often requiring paybacks of up to 18 months or less to justify an investment in efficiency. Larger, well-established end-users, on the other hand, are more inclined to look at life-cycle costs.

Opportunities to invest in more efficient motors or motor systems depend on whether the decision is a maintenance decision or a capital decision. When making maintenance decisions, not all end-users look at the alternatives ahead of time or have policies for spare parts. Because the end-user's main concern is minimizing the length of costly downtime and selecting the most reliable motor, the tendency is for the decisionmaker to take what a local distributor has in stock. If maintenance personnel have had good experience with the type of motor being replaced, they generally will request the same type of motor.⁹ This practice is in line with crisis management rather than strategic planning. The result is lost opportunities for efficiency improvement. By contrast, purchases of additional motors or motor systems are typically a result of a more sophisticated decisionmaking process.

End-users who are not looking at the long term when deciding on motors need to better understand the long-term economics of energy efficiency. When deciding to procure an efficient electric motor system, long-term ownership issues—such as insurance, depreciation, taxes, interest, and maintenance—need to be factored in.

⁸The discussion in this section is adapted from a background paper by Jean-Louis Poirer, "Decision-Making Processes for Industrial Energy-Efficient Electric Motor Systems" (see Appendix B, section 3).

⁹Industry studies show that 52 percent of survey respondents seek the exact same nameplate for the exact same brand as the motor to be replaced. Another one-third of the respondents indicated that they sought the same brand they currently use. (Source: RCG/Hagler, Bailly, Inc., estimate based on analysis and judgement factors derived from industry studies.)

V. Market Problems for Efficient Electric Motor Systems

Five apparently market-related obstacles to rapid and more widespread adoption of energy-efficient electric motor systems were identified in the roundtable discussions.¹⁰ These market problems are summarized below. A detailed discussion follows.

Inadequate Coordination and Leadership

- There is no coherent national leadership for coordinated efforts to introduce more efficient electric motor systems into U.S. markets. This leadership void is in three areas: strategic vision, incentive coordination, and standards development.
- Utility-sponsored programs for electric motor systems lack consistency, stability, a "system" focus, and a perspective that encourages long-term economics.

Lack of Focus in End-User Decisionmaking

- End-users' major criterion is low first cost rather than life-cycle cost.
- The immediacy with which replacement motors are needed (sometimes because of crisis management decisionmaking) leads to lost opportunities for efficiency improvements.
- When an engineering contractor (non-owner) determines motor system characteristics, the end-user can become decoupled from the motor system purchase decision.
- End-users are not always aware of the costs and benefits of efficient electric motor systems.

¹⁰This section summarizes findings from the first and second discussion topics of the roundtable: "Electric Motor System Marketing and User Decisions" and "Experiences with Electric Motor System Incentives and Promotional Options."

Weaknesses in the Functioning of the Electric Motor System Market

- Market fragmentation limits industry's responsiveness to new electric motor system technologies and applications.
- End-users and suppliers of electric motor systems lack system responsibility.
- Competitive markets coupled with a reluctance of end-users to pay higher first cost for efficient electric motor systems result in low-cost bidding practices.

Deficiencies in Information

- Lack of information on electric motor systems and tools to evaluate those systems hampers end-users' ability to make informed economic decisions and suppliers' ability to segment and target their markets effectively.
- Misinformation about efficient electric motor systems hinders market acceptance.
- The sporadic and inconsistent nature of most programs informing participants about efficient electric motor systems limits their effectiveness.

Lack of Broad-Based Technical Expertise

- Many end-users do not have sufficient experience with electric motor systems and thus do not always make the best technology choices. Many manufacturers, dealers, and distributors, some specifiers or agents to end-users, and most utility representatives have limited familiarity with applications of ASDs and do not always provide detailed ASD application information to their customers.

When following the discussion below, note that the impact of market problems on companies may differ

by company size. For example, emphasis on first cost, the prevalence of crisis management decisionmaking, and lack of awareness can be more prevalent among small companies than among larger companies. Also note that the roundtable did not include any discussions of the relative importance of the various market problems.

Inadequate Coordination and Leadership

Problem: *There is no coherent national leadership for coordinated efforts to introduce more efficient electric motor systems into U.S. markets. This leadership void is in three areas: strategic vision, incentive coordination, and standards development.*

This appears to be the overarching problem hindering wider market penetration for efficient electric motor systems. There is little or no coordination of Government, industry, and utility electric motor system programs. The absence of a shared strategic vision that would encourage market penetration for more efficient electric motor systems has contributed to the absence of nationally accepted standards for electric motor systems, for ASDs, and particularly for motor-driven equipment (for example, pumps and compressors). This absence has also contributed to the lack of an effective, efficient, and broadly understood system for collecting, analyzing, and disseminating relevant information on efficient electric motor systems to industrial end-users when they need it and can act upon it.

Electric motor system stakeholders are not effectively coordinated, either regionally or nationally. For example, utility demand-side management (DSM) programs typically are not coordinated with one another. State programs targeted at various aspects of electric motor systems are not coordinated with utility programs serving a similar function. The activities of the Federal Government and State governments are poorly coordinated. The result is that these programs are not directed toward satisfying common and

consistent goals. Lack of leadership on the part of the Federal Government also contributes to these apparent weaknesses in incentive coordination.

No nationally accepted standard for ASDs or motor-driven equipment exists. For example, there is no agreed-upon test procedure for compressed air components. While the Institute of Electrical and Electronic Engineers (in IEEE 112 and other standards) addresses motor efficiency testing, few national or international standards activities address other electric motor system components, such as ASDs. Some roundtable participants felt that standardized ASDs would not benefit drive manufacturers, because the market for ASDs is determined by differentiating each drive from all the others, making ASD standardization a disincentive. The same may be true for standardization of other electric motor system components.

Motors have energy efficiency standards, electric motor systems don't.

—Participant Comment

Problem: *Utility-sponsored electric motor system programs lack consistency, stability, a "system" focus, and a perspective that considers long-term economics.*

Many utilities throughout the country are running DSM programs related to various parts of the market delivery system for electric motor systems. One concern some end-users and OEMs have about utility-run DSM programs is the inconsistency and instability of these programs.

Utilities have different eligibility criteria and rules, rebate approaches (for example, fixed versus sliding scale), rebate levels, efficiency thresholds, and marketing methods. For many utilities, DSM programs are in transition as they adjust to lessons learned from past experience. The issue of utility program instability is a concern for some end-users. When utilities

change user programs or half-heartedly pursue those programs, users become confused. End-users wishing to incorporate utility rebates and incentives into their business planning cycles need to know that they can count on such incentives over time when they are needed, especially during replacements and retrofits. The absence of common DSM approaches and the ever-changing nature of DSM programs contribute to confusion among users. This is especially true for those who cross the boundaries of utility territories, such as OEMs, for whom program inconsistency contributes to very low participation in DSM programs.

Some participants at the roundtable felt that utilities also tend to lack a system focus, emphasizing instead efficient electric motors in isolation from other system components. Most utility programs tend to be prescriptive rather than customized. For many utilities, prescriptive approaches have provided a useful starting point, and they are easier to administer. Starting with electric motor programs enables utilities to "get a foot in the door" of industrial customers. Ultimately, though, to more substantially improve market penetration for electric motor systems, utilities may need to shift the focus of customer incentives from components to system-based programs.

Several roundtable participants said that many utilities do not focus enough on promoting longer term capitalization investment because their incentives are not always tied into the long-term planning cycles of industrial plants. Plants are required to undergo capitalization and multiyear planning cycles. However, several roundtable participants felt that utilities tend to go after the immediate, short-term promotion. Too much emphasis on short-term buydown approaches will not have much influence on the long-term energy management and capitalization planning strategies of end-users. This issue is especially relevant for investments in ASDs, which may need to be rationalized in the context of an end-user's longer term capitalization plans.

Lack of Focus in End-User Decisionmaking

Problem: *End-users' major criterion is low first cost, rather than life-cycle cost.*

Many end-users do not ensure that long-term economics are in place when evaluating electric motor system options. End-users typically select the electric motor system option having the lowest purchase cost.

The cost issue varies somewhat by industry size. End-users are a heterogeneous group. Besides producing different types of products, they differ in size even when they produce the same product. Decisionmakers in small establishments frequently use different decisionmaking criteria than those in large establishments. Even with perfect information, first-cost bias is more prevalent among small end-users and many medium-sized end-users. Their criterion for purchasing energy efficiency is typically the payback period, which is often 12 to 18 months.

Very large industrial end-users, on the other hand, use different criteria that emphasize longer time periods and life-cycle cost rather than the narrower payback period. Very large end-users often can tell their contractors what to buy. They might even say exactly what to buy, down to the model number of an energy-efficient motor. At higher management levels of larger end-users, there is often more awareness and knowledge of the long-term benefits of energy-efficiency possibilities.

Problem: *The immediacy with which replacement motors are needed (sometimes because of crisis management decisionmaking) leads to lost opportunities for efficiency improvement.*

Many end-users do not think about replacing a motor until that motor fails. Then they become concerned about "downtime" and thus do not have time to

investigate the most efficient option, determine an appropriate efficient motor replacement, and go through the procurement process. In such instances, for the end-user it may seem easier to replace the failed motor with the same standard efficiency motor, or to rewind the failed motor. This decisionmaking problem is compounded if the motor vendor does not have an appropriate efficient motor in stock.

Decisions to replace motors often are made under crisis conditions that include the risk of shutdown for extended periods and the consequent loss of a significant amount of output. If a plant does not have an inventory of energy-efficient motors, the maintenance supervisor responsible for getting the system operational will select a motor on pragmatic rather than energy-efficiency grounds. A pragmatic response to crisis is to replace the deficient motor or component with a familiar or proven one.

If end-users can be presented with options and encouraged to make decisions before the crisis stage is reached, there is a better chance of ensuring that an energy-efficient electric motor or motor system will be selected. If any time constraint is involved, the battle for efficiency will most likely be lost.

Problem: *When an engineering contractor (non-owner) determines motor system characteristics, the end-user can become decoupled from the motor system purchase decision.*

Motor system evaluation and purchase decisions are not always made by the end-user. In some cases, a non-owner such as an engineering contractor (for example, an A&E), influences these decisions. When an end-user allows an engineering contractor to determine the characteristics of a system, the non-owner has control of the motor purchasing and configuration decisions. An example of what could happen in this instance is when A&Es bid for a job at a low price. Once they get the job, the A&Es may have little incentive to take into consideration anything but the motor's first cost. As a result, the electric motor system is not as efficient as it could have been if the end-user had specified that an efficient motor be used as

part of the system configuration. Large end-users using engineering contractors typically have the knowledge and leverage to dictate what type of motor should be included in an electric motor system. By contrast, most small and many medium-sized end-users generally do not have this knowledge or leverage.

Problem: *End-users are not always aware of the benefits of efficient electric motor systems.*

Most small and medium-sized end-users are not always aware of the benefits of efficient electric motor systems. Even larger end-users experience some confusion about the costs and benefits of using efficient electric motor systems.

In the last 6 to 10 years, the variety of electric motor system configurations has grown rapidly, and countless electric motor system options are now competing head on. With increased development of ASDs, the traditional distinctions between ac induction, ac synchronous, dc brush type, and ac/dc brushless permanent magnet motors have blurred. In addition, drive standards vary significantly. This variety of electric motor system options creates confusion among purchasers and inhibits easy application, understanding, and purchase. Differences in definitions of efficiency and in eligibility standards for rebates under utilities' motor system programs add to the difficulty in decisionmaking. These market and incentive variants inhibit greater awareness or create confusion regarding the potential benefits of efficient electric motor systems, thus holding down the demand for premium equipment.

Weaknesses in the Functioning of the Electric Motor System Market

Problem: *Market fragmentation limits industry's responsiveness to new electric motor system technologies and applications.*

Market fragmentation arises because of the wide variety of electric motor system applications and the het-

erogeneity of users (both end-users and OEMs); and because system components—such as motors, ASDs, and pumps and compressors—come from different manufacturers. For example, end-users are heterogeneous in their decisionmaking criteria and processes; factors include the varying conditions under which decisions are made, the size of the firm making the decisions, and resultant variations in the implied discount rates used to make purchase decisions.

From the incentive perspective, there is very little communication between OEMs and utilities, largely because OEMs operate over wide sales areas—including international—and cross boundaries of utility territories. Because of this market situation, many OEMs are not eager to participate in utility-sponsored DSM programs, and utilities have not been successful in marketing their DSM program incentives to OEMs. This may be because efficiency standards are not available for pumps, compressors, and other motor-driven equipment, and because utilities are not fully coordinated to adequately create large DSM markets.

Problem: *End-users and suppliers of electric motor systems lack system responsibility.*

This problem arises because many parties are involved in the evaluation and procurement process for each application. Within a company, several groups, such as production engineers, maintenance and purchase personnel, and electrical and mechanical contractors, have varying responsibilities for electric motor system procurement and thus varying perspectives on that procurement. However, it is often the case that no one party assumes overall responsibility for making electric motor system recommendations or decisions.

For example, a typical project will have both mechanical and electrical contractors, and neither takes overall responsibility for matching the motor, drive, and mechanical equipment to the load. The mechanical contractor is responsible for the driven equipment. ASDs, on the other hand, generally come under the domain of electrical contractors. A mechanical contractor not intimately familiar with ASDs making a decision on the speed or torque of

motors in a system may opt for two motors or a two-speed motor rather than a more energy-efficient motor-ASD system. On the other hand, an electrical contractor who has no communication with the mechanical contractor may install motors with ASDs that may not be compatible with the driven equipment.

Problem: *Competitive markets coupled with a reluctance of end-users to pay higher first cost for efficient motor systems result in low-cost bidding practices.*

End-user concerns about higher first cost discourages OEMs and contractors from offering or recommending the more efficient options to customers who do not specifically request them. As a result, energy efficiency suffers. End-users who want efficient motors as components in their motor systems must specify the purchase of efficient motors to the contractor.

Deficiencies in Information

Problem: *Lack of information on electric motor systems and tools to evaluate those systems hampers end-users' ability to make informed economic decisions and suppliers' ability to segment and target their markets effectively.*

There is so much going on in [information gathering and dissemination] that we can barely keep up with the developments.

Conflicting and ambiguous information of vendors and utilities leaves customers uncertain of real benefits.

—Participant Comments

This problem is characterized by information deficiencies related to (a) end-use applications and market information and (b) technical and educational information.

End-Use Application and Market Information. The average industrial end-user does not have information on possibilities for system-level energy-

efficiency savings for specific end-user applications. Distributors, specifiers, and representatives of utilities running energy-efficiency programs often do not have information to discuss system-level energy savings for specific industrial processes. There are market information gaps on basic aspects of the delivery system for electric motor systems, such as the stock of motors and end-use breakdowns by motor application. There are also gaps in cost and benefit information on efficient motors and electric motor systems. Accurate performance and reliability data on efficient electric motor system components such as ASDs do not exist. Information on how to properly interface ASDs with motors and the costs and downtime involved is limited. There is a lack of current ASD sales data to better establish the current level of market penetration for ASDs and where future ASD opportunities lie. Data on the loads and duty cycles for various motor system applications are also needed to help Federal and State agencies, utilities, and other incentive providers as well as market entities better segment and target the market for efficient electric motor systems.

Technical and Educational Information. In many cases, end-users and their contractors lack information and tools to allow them to properly evaluate system issues. There are no evaluation tools to facilitate cost justification or determine energy savings and performance risk at the system level. Information on performance risk could help alleviate common misconceptions about efficient electric motor system technology. Little information on verification and motor testing protocols is available.

Problem: *Misinformation about efficient electric motor systems hinders market acceptance.*

Misinformation on ASD performance and reliability has led to some end-user skepticism about the economic and energy savings potential of ASDs. End-users may perceive ASDs as being less reliable than standard drives and thus may be unwilling to sacrifice reliability for energy efficiency, even if efficiency is one of their purchase criteria. They will choose

energy efficiency only if they also can be assured of quality and reliability. Some end-users believe that energy-efficient motors use less steel and run hotter, have a reduced service life, and will revert to standard efficiency when rewound. Such misinformation has contributed to the reluctance of potential end-users to purchase efficient electric motor system equipment.

Problem: *The sporadic and inconsistent nature of most programs informing participants about efficient electric motor systems limits their effectiveness.*

Information programs about electric motor systems are not always timely. Disorganized methods of dissemination also are a problem. For example, duplicate data yield an overabundance of information, which is counterproductive. Also, the available data are sometimes inconsistent; readers do not know what information is most accurate and under what circumstances. There is no national or regional information system that extends to all participants in the market. In many cases, a decisionmaker's only source of information is through mailings, industry journals, trade associations, or conferences. Such information is often generic and unsuited to the needs of a specific plant or industry.

Lack of Broad-Based Technical Expertise

Problem: *Many end-users do not have sufficient experience with electric motor systems and thus do not always make the best technology choices. Many manufacturers, dealers, and distributors, some specifiers or agents to end-users, and most utility representatives have limited familiarity with applications of ASDs and do not always provide detailed ASD application information to their customers.*

Limited "system" experience impedes market penetration for energy-efficient electric motors and electric motor systems. Each plant and each process is different. If engineers are not experienced in dealing with plants on a systemwide basis, they will understand only individual components of the overall electric

motor system, such as the motor, and not how those components work together.

The shortage of system-wide technical expertise is not limited to end-users. It pervades the entire market delivery system. Many dealers and distributors, for example, do not have the expertise needed to provide detailed ASD information to customers. They cannot demonstrate the applicability or energy savings inherent in an optimally structured ASD-motor system. Many designers and specifiers for end-users have limited familiarity with applications of ASDs. ASDs are not commodity products and require engineering, economic, and reliability considerations.

Finally, systems engineering expertise is hard to find. It no longer exists in traditional places and must be sought in different ways. There is a general lack of information on who offers specialty services on

energy-efficient motors and electric motor systems and what form these services take. Even when they are available, experts trained in one discipline can create problems by working independently as opposed to working as part of multidisciplinary team composed of, for example, mechanical and electrical engineers and economists.

Preserving and expanding the system focus requires talented system engineers among motor manufacturers and distributors, OEMs, designers and specifiers, end-users, and motor rewinders. It also requires utilities interested in carrying out more customized energy audits and acquiring the systems engineering resources to do so. Optimization of an end-user's entire system requires customized (system level) audits, but the talents required to perform those audits are scarce.

 

VI. Suggestions for Overcoming Market Problems

This section summarizes the many suggestions made by the roundtable participants for overcoming identified market problems.¹¹ Suggested actions are grouped by categories that reflect the general nature of the required market solution. The results presented are drawn from the participants' suggestions and the separate analyses of those suggestions by DOE.

Exercising National Leadership

Issues

There is no coherent national leadership for coordinated efforts to introduce more efficient electric motor systems into U.S. markets.

Utility-sponsored programs for electric motor systems lack consistency, stability, a "system" focus, and a perspective that encourages long-term economics.

A message to DOE: Let's look at the whole system, rather than just carving out a piece.

[Efficient] motors are out there, people just have to ask for them.

Broader based utility DSM incentives need to be offered, primarily focusing on system components other than the motor, or on overall system efficiency.

We need case studies of more comprehensive approaches to motor systems, potentially demonstrating the much larger savings available.

—Participant Comments

¹¹This section summarizes discussions on the third topic of the roundtable, focused on suggestions for overcoming market problems.

Suggested Solutions

As indicated in the previous section, the lack of effective coordination and leadership is the overarching problem that needs to be addressed if substantial improvements in market penetration for efficient electric motor systems are to be achieved. DOE needs to coordinate with other Federal agencies; with States, utilities, and trade associations; and with market stakeholders to set a strategic direction for motor system programs and to avoid duplicate efforts. In this spirit, it is particularly important that the private sector be involved if programs are to succeed in the long term.

Several solutions to the systemic national leadership gap related to efficient electric motor systems were suggested at the roundtable. First, DOE needs to develop a national strategic plan for promoting efficient electric motor systems that provides vision and links organizations interested in similar goals. The strategy should look at the future, capitalize on what has already been achieved so far (especially in terms of data gathering), and promote more effective coordination between all relevant Federal and State agencies. DOE should work with industry to develop a strategic plan that provides focused vision, missions, and objectives and measurable deliverables to which all participants, in and out of government, can subscribe. DOE, in conjunction with other organizations, needs to address the larger issues, such as ensuring that legislation, tax incentives, and other national activities push forward in the right strategic direction.

A second way DOE could help fill the national leadership gap is by increasing its coordination with other institutions associated with electric motor systems to ensure consistent efforts related to market penetration for efficient electric motor systems and to avoid duplication of those efforts. DOE should coordinate its activities with other Government agencies and bodies such as the Environmental Protection

Agency, the Federal Energy Regulatory Commission, the National Association of Regulatory Utility Commissioners, and national organizations such as the Electric Power Research Institute, the National Association of Manufacturers, the National Electric Manufacturers Association, Edison Electric Institute, and so forth. In turn, of course, these better coordinated promotional activities need to be coordinated with the efforts of motor and drive manufacturers, distributors, designers-specifiers, OEMs, utilities, and end-users.

Another area for potential coordination is with Canadian authorities. Canadian institutions have been involved with testing, developing standards for, and developing mechanisms for increasing market penetration for energy-efficient electric motor systems for the past several years. Lessons learned from these experiences could be useful in guiding continuing U.S. efforts in this area. However, a number of roundtable participants felt that much of what has been done in Canada cannot be directly applied in the United States because of fundamental differences between the U.S. and Canadian situations.

The third way DOE could exert national leadership is to develop a national clearinghouse for activities and data related to efficient motor systems, including (a) reliable and consistent data that would be made accessible in a manner as convenient as the Bonneville Power Administration and DOE-sponsored Motor Master program in the Northwest, (b) case studies describing real implementation experiences, and (c) relevant market and technology studies and analyses. An effective clearinghouse would disseminate information only after the release has been coordinated with other national institutions.

A fourth action by DOE might be to use Federal facilities as showcases to demonstrate the savings available from efficient electric motor systems.

Fifth, DOE should help industry, including OEMs, develop voluntary efficiency standards and guidelines for electric motor system components. These standards and guidelines should not be limited to motors alone, but should also include ASDs, air compressors, pumps, and so forth. DOE should work with standards-developing institutions on a voluntary basis

to develop standards for ASDs and drives. Standards should be developed in close cooperation with such institutions as the Institute of Electrical and Electronic Engineers, the Hydraulic Institute, the Compressed Air and Gas Institute, the American National Standards Institute, and the American Society of Mechanical Engineers. One of the technical issues that must be resolved is how to establish standard performance testing procedures for motor-driven systems. Such protocols should address how this equipment will really perform; measurements acquired on test stands do not always provide reliable indices on how actual motors and associated equipment will work out in real operating circumstances. DOE should support associations such as the National Electric Manufacturers Association in efforts to coordinate testing programs (for example, for heat, noise, and waveform) for motor and ASD manufacturers. The Canadian electric motor system experience should be carefully reviewed to determine how it relates to the U.S. experience.¹² There may be a need for research and development to support development of technically sound testing protocols.

A final area for further action suggested at the roundtable involves improving the effectiveness and widening the sphere of influence of utility-sponsored DSM programs targeted at efficient motors and electric motor systems. Utility-sponsored prescriptive programs that focus only on efficient motors become an entrée for subsequent system-level custom rebate programs. To make this mechanism effective, however, it is necessary to get information about available rebates out to end-users, to supplement it with sufficient technical guidance that enables end-users to capitalize upon it, and to make the rebate programs more uniform across different utilities to conform more closely with electric motor system markets such as OEM sales regions.

Utilities need to move from prescriptive programs to customized audits of entire systems. These tailored

¹²Canada has been involved with testing, developing standards for, and trying different delivery mechanisms to increase market penetration for energy-efficient electric motor systems over the past several years. These experiences should be evaluated from the perspective of their applicability to the United States.

approaches would enable utilities to better respond to real needs of customers. Tailored approaches might also include utilities working cooperatively with vendors upstream to ensure that energy-efficient motors are in stock. Utilities might wish to explore positioning their incentives further upstream (for example, to motor vendors) so that customers can be served with electric motor systems at the moment when existing motors fail.¹³

Utility-to-utility and geographic consistency among rebate programs would help utilities further develop vendor and trade ally relationships to promote incentives. If DSM programs are too varied, users will view them as too difficult. The key is for utilities to do a better job in establishing regional consistency in criteria and rules. Consistent incentives and rebates will help increase the sphere of influence of utilities and thus may provide end-users and OEMs with the security they need to incorporate utility rebates and incentives into their long-term business planning activities. In addition, DSM program longevity that smooths out the temporal differences in user business cycles is needed to maximize the effectiveness of utility-based incentives. Motor system users need to know that they can count on the incentives over time when they are needed.

Finally, all of the suggested solutions described in the preceding paragraphs indicate that if DOE is to exercise a leadership role, it needs to strike a balance between long-term research and development activities and short-term commercialization activities.

¹³Vendors often have little incentive to sell energy-efficient equipment; profit margins and available manufacturer discount rates may be more attractive in standard product lines. Utilities can play an important role in encouraging vendors and distributors to stock and sell energy-efficient equipment. Puget Power has such a program. Bonneville Power Administration has a two-part rebate program that targets the end-user and the dealer; dealers are encouraged to buy motors for inventory, which allows the end-user to buy a replacement motor out of a secured inventory of energy-efficient motors.

Providing Focus to End-User Decisionmaking

Issues

End-users need to ensure that long-term economics are in place when evaluating electric motor system options.

Lost efficiency improvement opportunities can be minimized by motor system planning on the part of end-users.

End-users need to be better informed of the costs and benefits of applying energy-efficient electric motor systems.

Suggested Solutions

Because end-users are the most important decision-makers in the adoption of efficient motors and electric motor systems, information, educational programs, tools, and training programs aimed at end-users should be a high priority. Motor system end-uses with the highest potential payoff should be targeted. For example, because 60 percent of the motor load is on pumps, fans, and compressors, end-users employing these types of end-uses might be targeted first.

The first-cost problem is a market issue that could be solved by the Government and utilities providing educational material and case studies aimed at specific stakeholder groups and end-user segments. Life-cycle analysis needs to be made available to *all* end-users, not just the larger ones. End-users need to specifically request or perform life-cycle analysis when evaluating available electric motor system options. DOE can play a role in impressing upon end-users the difference between "inexpensive" and "cost-effective over the long-term."

To avoid the low-bid syndrome, the end-user has to specify that an energy-efficient motor be used. Education to raise awareness of efficiency benefits and recognition for companies that are setting leadership examples could encourage users to develop a reflex to demand energy-efficient electric motor systems.

Energy efficiency for electric motor systems would be better served if more end-users were encouraged to make decisions ahead of time, rather than at crisis time. DOE and utilities should encourage end-users to develop a companywide electric motor system planning¹⁴ that incorporates the following principles:

- End-users should inventory energy-efficient motors for future replacement opportunities.
- End-users and distributors should have better, sustained communication so that energy-efficient motors are in stock when the replacement crisis happens.
- Replacement decisions by end-users should be made ahead of time.
- Opportunities for motor system efficiency improvement should be continually evaluated within the context of the total productivity of the facility.

As part of the motor system plan, end-users could develop a relationship with a supplier who can meet their needs. They may even establish partnerships with manufacturers and choose vendors who will have efficient motors and other components in stock. For critical processes, however, end-users are likely to maintain onsite stock.

End-users need information on available options before crisis time. To further support efforts by industry to establish motor system plans, DOE could provide end-users with information about various options available to them *before* they face a crisis decision. Quantifying the advantages of using efficient electric motor systems is an important first step. Demonstrating the effectiveness and usefulness of system evaluation, especially to smaller end-users, would increase end-user confidence.

Finally, as an incentive for improving efficiency, DOE should identify and target industries as models for electric motor system efficiency improvement and develop a process to recognize excellence (similar to

¹⁴Some companies already have a policy to replace their motors with energy-efficient motors or motor systems. Dow Chemical and 3M Company are examples of companies that have motor system programs.

the Malcolm Baldrige award¹⁵) in improving the energy efficiency of electric motor systems while achieving profitability and environmental objectives.

Improving the Functioning of the Electric Motor System Market

Issues

Market fragmentation limits industry's responsiveness to new electric motor system technologies and applications.

End-users and suppliers of electric motor systems lack system responsibility.

The reluctance of end-users to pay higher first cost creates a low-cost bidding syndrome that discourages suppliers and contractors from offering efficient motor systems in the marketplace.

Better identification of the full decisionmaking group beyond the end-user [is needed]. Most purchases are influenced by consultants in new construction and maintenance companies in retrofits. How do we encourage their participation?

—Participant Comment

Suggested Solutions

DOE could undertake market analyses and share information to help the private sector better segment and target markets for efficient electric motor systems. To achieve better coordination all along the market delivery chain, DOE could play a more active role in encouraging end-users, manufacturers, and distributors to coordinate activities more effectively, perhaps through new market alliance programs. For example, more effective partnerships between utilities and

¹⁵The Malcolm Baldrige Award recognizes industry excellence in overall quality management. The award is administered by the U.S. Department of Commerce.

OEMs could help utilities to better understand the subtle dynamics of the OEM market. If utilities join forces to establish more consistency in motor system incentive programs, they could have a greater impact on the OEM market. A regional utility alliance may be the answer. On the other hand, efficiency standards for electric motor systems could help open channels of communication between OEMs and utilities, because utility DSM programs benefit from unified efficiency standards for the DSM technologies they promote. Perhaps an important first step should be for DOE to bring OEMs to the table to discuss opportunities and strategies for improving the efficiency of electric motor systems.

Information Collection and Dissemination

Issues

End-users need consistent information on electric motor systems and better evaluation tools to make informed economic decisions.

Misinformation about efficient electric motor systems that has hurt market acceptance needs to be dispelled.

The effectiveness of most efficient electric motor system information programs needs to be improved.

We need a Pump Master, a Compressor Master, and a System Master.

—Participant Comment

Suggested Solutions

The most pervasive suggestion of the participants was that DOE should address information weaknesses in the electric motor system market. DOE has an opportunity to play an important role in collecting and targeting information for specific stakeholders. The trick is to find ways to make information transfer

work better, and the key to this is to rethink the way that it is being done. Three categories of information, discussed below, should be collected.

End-Use Applications. User groups should be encouraged to exchange success stories; basic educational materials should be developed and targeted at specific end-user segments; and a national marketing campaign to disseminate the information should be established. As part of such marketing, DOE should track and distribute information about activities and events related to electric motor systems.

Technical and Educational Needs. DOE should develop better evaluation tools to use in comparing the life-cycle costs of standard-efficiency and energy-efficient motor systems, DOE should also work with industry to develop testing and verification procedures for electric motor system equipment.

Market Information Needs. Rather than limiting data collection exclusively to electric motors, DOE should collect different types of data related to electric motor systems. For example, as part of its routine data collection activities, DOE should analyze market structures on the supply side and the demand side and include more information about systems in which motors are but one component. DOE could expand the kinds of information in its data base beyond technical data to include information on applications. This data collection, analysis, and dissemination should be carried out in collaboration with industry and other national institutions.

The end-user has the most influence on energy-efficiency investment decisions. Education of the end-user to appreciate the importance of life-cycle analysis—accounting for all of the costs and benefits of energy-efficient electric motor systems over the useful life of the process—will play an important role in driving the market for energy-efficient electric motor systems in the future. Education is especially important to the small- and medium-sized end-user, who may need to receive training in addition to information. DOE needs to work with other organizations collaboratively to expand the development and dissemination of educational materials promoting

electric motor system efficiency. Materials should be focused on specific stakeholders and end-user segments.

To address end-user awareness, DOE could work with industry to develop a marketing campaign. Such a campaign must be national, because corporations extend beyond state lines. Suggested educational products could include a toll-free number for information on any existing motor and a set of basic educational tools and documents.

DOE could also conduct or sponsor case studies on applications of electric motor systems and disseminate the results. Because electric motor systems vary radically from facility to facility, the case studies should be very specific and chosen carefully to make meaningful inferences for a broad portion of the industry. This activity could be a collaborative effort with industry. The case studies, or success stories, could then be disseminated, possibly through user group meetings, to help dispel myths about reliability and availability. In addition, DOE should distribute information to help users understand the influence that financial and nonfinancial factors, such as capitalized interest, insurance, taxes, reliability, and requirements for specialized maintenance skills, have on the ASD investment decision and on users' evaluation of the long-term cost of ownership of electric motor system equipment.

DOE could conduct a national scoping study to assess the markets for ASDs and other electric motor

system equipment. For example, this study would require collecting data on ASD sales to establish the present market penetration of ASDs; the future market and efficiency potential for ASDs; and data on what loads are out there, how drives are sold, and so forth.

Building Technical Expertise

Issue

Many manufacturers, dealers, and distributors, some specifiers or agents to end-users, and most utility representatives need to increase their familiarity with applications of ASDs to be better able to provide detailed ASD application information to customers. Many end-users need to have a broader base of knowledge on electric motor systems to make informed technology choices.

Suggested Solutions

Training and experience are the keys to long-term market acceptance and adoption of energy-efficient motor systems. If more engineers acquire training and experience that enables them to deal with plants on a system-wide basis, efficient electric motor system applications will be better understood and communicated to users, and utilities will find it easier to promote custom incentives. DOE should work with associations and other organizations to establish or strengthen process expertise in specific electric motor system application areas.

VII. Conclusions

Opportunities for substantial cost-effective energy savings exist for the range of technologies comprising an electric motor system, particularly for fully integrated systems. A coordinated effort among market stakeholders and Government and private-sector institutions with complementary skills is key to capturing these opportunities.

DOE recognizes the importance of establishing an active dialog with industry to address market issues and improve the efficiency of electric motor systems. In executing the roundtable, DOE worked to encourage the active participation of a wide range of stakeholder groups to ensure a balanced discussion and exchange of perspectives on the issues and options facing the electric motor systems market.

The roundtable laid the groundwork for a focused discussion of market problems and suggestions for overcoming those problems. Key suggestions made by roundtable participants are listed below.

1. **Stakeholders should apply the systems approach to electric motor systems.** Stakeholders should be encouraged to look not only at efficient motors to improve efficiency, but at the overall electric motor system, comprised of motors, motor controlling devices (such as electronic ASDs), and motor-driven equipment (such as pumps and compressors).
2. **DOE should fill the national leadership void in the electric motor system area by helping to guide stakeholders toward a systems approach.** DOE should unite Federal sector activities in the electric motor system area and develop an electric motor

system program approach that involves active participation of end-users of electric motor systems, original equipment manufacturers, motor and drive manufacturers, architect and engineering firms, and other key market participants.

3. **DOE could play an important role in collecting and disseminating information on efficient electric motor systems.** DOE could function as a national clearinghouse for electric motor system activities, collect better information on electric motor system applications and the electric motor system market, and perform selected case studies.

DOE's Office of Industrial Technologies is taking steps to follow up on the roundtable discussions and is working to increase collaboration among the important stakeholder groups in the Federal Government, in State governments, and in the private sector.

In October 1993, DOE launched the MOTOR CHALLENGE Program, which addresses critical market problems and opportunities identified by roundtable participants. MOTOR CHALLENGE is a voluntary collaborative effort of the public and private sectors. Its goal is to demonstrate, evaluate, and accelerate the use of efficient industrial electric motor systems. As part of MOTOR CHALLENGE, DOE is taking steps to accomplish the following:

- Foster broad-based industrial participation in information exchange and technology deployment activities
- Provide technical assistance to industry for establishing showcase demonstrations of efficient

electric motor systems aimed at highlighting how industries can apply internal resources to improve the energy efficiency, productivity, and environmental performance of their facilities.

- Develop a national electric motor system database to provide consistent information to aid industrial decisionmakers in identifying efficient electric

motor system opportunities and in evaluating options.

MOTOR CHALLENGE is also identifying industry leaders in efficient electric motor system use. DOE will recognize those companies that demonstrate excellence in implementing efficient electric motor system strategies.

Appendix A: Organization of the Roundtable on Efficient Electric Motor Systems for Industry

Background

The roundtable on Efficient Electric Motor Systems for Industry, sponsored by the U.S. Department of Energy (DOE),¹ was held in Baltimore, Maryland, on February 11, 1993. The roundtable's 45 participants represented a broad cross-section of institutions concerned in one way or another with electric motor systems, including motor manufacturers, motor distributors and rewinders, original equipment manufacturers, industrial customers, electric utility experts, regulators, state energy officials, and market researchers and strategists. The roundtable concentrated on efficient electric motor systems for large and medium-sized industries.² Electric motor systems used in small industries and in the commercial and agricultural sectors fell outside the scope of the study.

An energy-efficient motor is defined as a motor that has a nominal full-load efficiency exceeding the National Electrical Manufacturers Association's minimum efficiency standard. For the purposes of the roundtable, this definition includes "high" and "premium" efficiency motors. The particular focus of the roundtable was on electric motor systems employing alternating current (ac) motors, 20 horsepower or greater, for applications in pumps, fans, blowers, compressors, and materials processing and handling equipment. Designer-built (that is, custom) motors were excluded. Both the "new motor/new construction" market and the "replacement/rewind" market were addressed.

¹The roundtable was cosponsored by the DOE Office of Energy Demand Policy and the DOE Office of Industrial Technologies. The Customer Systems Division of the Electric Power Research Institute provided funding for one of the four background review papers produced in preparation for the roundtable.

²Roughly defined as industries with annual energy expenditures greater than \$500,000.

The roundtable considered how the U.S. electric motor system market functions, market and institutional problems that are preventing electric motor systems from penetrating the marketplace, options for overcoming those market problems, and the most useful role for DOE and other Federal agencies in promoting efficient electric motor systems. The specific objectives of the roundtable were as follows:

- Gain a more complete understanding of the complex nature of the U.S. market delivery system for electric motor systems for industry, how key players are doing business, and the forces that are driving decisions to adopt efficient motors and electric motor systems.
- Determine if key market problems are preventing accelerated and expanded adoption of efficient electric motor systems in the industrial sector.
- Define and suggest programs and promotional options that could be most helpful for DOE and other Federal agencies in efforts to encourage industry to further improve motor system efficiency.

The roundtable was attended by two groups of electric motor system experts. The first group included *market participants*, such as major motor manufacturers, distributors, industrial end-users, original equipment manufacturers, rewinders, and designers and specifiers. The second group included *incentive strategists and technical specialists* who influence the market environment, such as market research and demand-side-management experts, State energy officials, regulators, and technical specialists. The names and affiliations of the roundtable participants are listed later in this appendix.

The roundtable was organized around three sessions. A moderator and group leader guided the deliberations in each session.

The first session included background presentations by DOE contractors on the following subjects (the background papers are found in their entirety in Appendix B):

- Technology characterization for electric motor systems.
- The U.S. market delivery system for electric motor systems.
- Decisionmaking processes used by purchasers of industrial electric motor systems.
- Utility and State incentive programs promoting the use of efficient electric motor systems.

The second session was devoted to participant discussions aimed at characterizing the U.S. electric motor market system and its subsystems, exploring issues in decisionmaking by original equipment manufacturers and industrial users of electric motor systems, determining key market problems, and discussing utility and state government experiences with incentives for promoting efficient electric motor systems.

In the final session, suggestions were solicited from the roundtable experts on actions DOE and other Federal agencies should consider to overcome market problems. Plenary group reporting followed the second and third sessions.

Accomplishments

The aim of the roundtable was not to obtain a group consensus on problems faced in increasing market penetration for efficient electric motor systems and their corresponding solutions. Participants brought a unique perspective, highlighting their experiences with and relationships to the motor system market. The roundtable was organized to hear and analyze these perspectives and then synthesize them in a coherent document. These objectives were accom-

plished. Specifically, the discussions at the roundtable led to:

- A better understanding of the operation of the market.
- Determination of key problems in the market.
- Identification of key decisionmakers.
- Determination of actions DOE could take to help improve market penetration of energy-efficient electric motor systems.

These accomplishments are documented in the main report.

Agenda

The agenda for the roundtable is presented below.

- 7:30 a.m. Continental Breakfast
- 8:30 a.m. Welcome by the Department of Energy
Introduction, Roundtable Objectives and Organization
- 9:10 a.m. EMS Definition and Technology Characterization
- 9:20 a.m. Orientation I:
The U.S. Electric Motor Delivery System
- 9:35 a.m. Orientation II:
EMS User Decisionmaking
- 9:50 a.m. Questions & Discussion:
The Electric Motor Market and User Decisionmaking
- 10:20 a.m. Orientation III:
Electric Motor System Incentive Experiences
- 10:35 a.m. Questions & Discussion:
Incentive Experiences
- 10:50 a.m. Working Groups:
Discussion of Ground Rules

11:00 a.m. Concurrent Working Group Sessions:

Groups 1 & 2

Topic 1: Electric Motor System Marketing and User Decisions

Groups 3 & 4

Topic 2: Electric Motor System Incentive Experiences and User Decisionmaking

12:00 p.m. Working Lunch/Continuation of Working Group Deliberations

12:50 p.m. 10-Minute Break

1:00 p.m. Plenary Group Reporting

2:00 p.m. Concurrent Working Group Sessions

Groups A, B, C, & D

Topic 3: Suggestions for Overcoming Market Barriers

3:30 p.m. Plenary Group Reporting

4:20 p.m. Synthesis and Closing Remarks

4:30 p.m. Adjourn

Discussion Questions

This section presents the questions used to guide the roundtable discussions of topics 1 and 2. Discussions of topic 3 of the roundtable were left open to the participants.

Topic 1: Electric Motor System Marketing and User Decisions

1. *Please Examine the U.S. Electric Motor Market System Diagram in Figure 1—The Department of Energy recognizes the very complex nature of the U.S. market delivery system for electric motors, with respect to its structure, segmentation, and forward and feedback linkages. We suspect that the market system for electric motor systems, viewed from an overall "whole system" efficiency perspective, is characterized as shown in Figure 1.*

Does your experience confirm this market characterization for the supply and demand of 20-horsepower or greater electric motor systems by large and medium-sized industry? How does the market delivery system differ when the motor is viewed on the basis of individual component efficiency as opposed to whole system efficiency, where motor control and mechanical equipment markets are involved?

2. What purchase decision processes and evaluation criteria are typically applied to electric motor systems in different market segments? Who are the key industrial decisionmakers and at what organizational level are decisions undertaken? Distinguish between the "new motor" market and the "replacement/rewind" market.
3. What procurement decision processes and evaluation criteria are typically applied by original equipment manufacturers of electric motor systems? Who are the key decisionmakers for original equipment manufacturers and at what organizational level are decisions undertaken?
4. Do industrial end-users and original equipment manufacturers generally feel confident they are making the correct investment decisions with respect to electric motor and electric motor system purchases or replacements?
5. Market research studies report a number of barriers to greater market penetration for energy-efficient electric motors and electric motor systems. Some examples of reported barriers are first cost; return on investment; market availability; lack of interest or awareness; mismatch between timing of incentive delivery and equipment need that leads to lost opportunities; lack of internal incentives for cost-effective decisionmaking; and lack of data about production, sales, stocks, and purchase behavior. Does your experience suggest that these studies are identifying the major market problems? Do participants in the electric motor system market experience other key barriers?

Figure 1: Market Delivery Channels for Electric Motor Systems

Topic 2: Electric Motor System Incentive Experiences and User Decisionmaking

1. Are some incentives for energy-efficient motors offered for whole systems as opposed to individual components?
2. Of the various participants in the electric motor system market, in general, which have the most influence in encouraging expansion of the market for efficient motors and motor systems?
3. Do utility demand-side management programs offer an effective means for promoting efficient motors and efficient electric motor systems in the industrial sector? What types of programs appear most attractive to the industrial customer? What are examples of improvements that have been made? What are examples of program elements that should not be changed?
4. Eighteen states provide some form of financial assistance for installation of energy-efficient motors and drives independent of utility programs, such as low-interest financing, loans, and tax credits. Does your experience suggest that such programs provided by states are effective in improving market acceptance of efficient electric motor systems?

5. Are market participants sufficiently aware of the economic and energy-saving benefits of efficient motors and motor systems? Who offers educational services, what form do those services take, and to whom are they offered?
6. What are examples of productive partnership relationships between motor manufacturers, distributors, original equipment manufacturers, end-users, and utility and energy service companies that have helped improve market penetration for efficient electric motor systems? Which market participants are typically involved? What have been the benefits of such partnerships?
7. The Energy Policy Act of 1992 mandates that manufacturers of motors (up to 200 horsepower) upgrade efficiencies within 5 years. To date, what has been the experience with state motor standards programs? What have been the observable market responses to motor standards? What have been the impacts on utility industrial DSM programs?

Discussion Groups

Topic 1: Electric Motor System Marketing and User Decisions

Group 1

Leader

N. Richard Friedman,
Resource Dynamics Corporation

Reporter

Peter Tsivitse, Reliance Electric

Participants

Larry Ambs, University of Massachusetts
Harry Baker, Marathon Electric Manufacturing
Tom Bishop, Longo Industries, Inc.
Steve Darby, Darby Electric
Robert Groendyke, Sullair Corp.
Thomas M. Jahns, General Electric Company
Jack Johnson, Dow U.S.A.
Tom Lowenberg, 3M Company

Jim Poole, CRS Serrine Engineers, Inc.
Ken Reituran, Lukens Steel Co.
Byron D. Speice, Baltimore Aircoil Co.
James Brodrick, DOE (observer)
Paul Scheihing, DOE (observer)

Group 2

Leader

Jean-Louis Poirier, RCG/Hagler, Bailly, Inc.

Participants

Robert B. Boteler, Emerson Electric Company
James C. Hirzel, General Electric Company
Tom Ryan, Motor Tech Inc.
Jeffrey Gamble, PACO Pumps
Roy Summers, Gardner-Denver
Carl Castellow, North Carolina State College of Textiles
Richard L. Doughty, E.I. Dupont
Robert Matthews, 3M Company
Michael Muller, Rutgers University

Topic 2: Electric Motor System Incentive Experiences and User Decisionmaking

Group 3

Leader

Joseph M. Roop,
Battelle Pacific Northwest Laboratories

Reporter

Steve Sheek, Duke Power Company

Participants

Stephen Umans, Massachusetts Institute of Technology
Barry Hedden, Baltimore Gas and Electric
Mark Kendall, Oregon Department of Energy
Alex Flemming, Demand-Side Energy Consulting Services
Joe Klenotich, McKay and Company
Paul Meagher, Electric Power Research Institute

Theo McGregor, Massachusetts Department of Public Utilities

Oskars Peterson, National Institute of Standards and Technology

Group 4

Group Leader

Robert F. Robinson, The Center for Applied Research

Reporter

Craig Wohlgemuth, Bonneville Power Administration

Participants

Robert Banister, Puget Power

Sharon Costello, New York State Energy Office

Neil Elliott, American Council for an Energy-Efficient Economy

Dale Friesen, Manitoba Hydro

Nikhil Gandhi, Xenergy, Inc.

Richard Hackner, Wisconsin Center for Demand-Side Research

Wade Malcolm, Electric Power Research Institute

Phil Muhlmeister, Aspen Systems Corporation

Dick Nailen, Wisconsin Electric Power Company

Mary Beth Tighe, Maryland Public Service Commission

Craig Wohlgemuth, Bonneville Power Administration

Mike Wommack, Pacific Gas and Electric

Ian L. Harry, Electric Power Research Institute

Topic 3: Suggestions for Overcoming Market Barriers

Group A

Leader

Richard Friedman, Resource Dynamics Corporation

Reporter

Richard Hackner, Wisconsin Center for Demand-Side Research

Participants

Roy Summers, Gardner-Denver

Richard Doughty, E.I. DuPont

Theo McGregor, Massachusetts Department of Public Utilities

Harry Baker, Marathon Electric Manufacturing

Pete Tsvitse, Reliance Electric

Craig Wohlgemuth, Bonneville Power Administration

Steve Darby, Darby Electric

Barry Hedden, Baltimore Gas and Electric

Mike Mueller, Rutgers University

Paul Scheihing, DOE (observer)

Group B

Leader

Jean-Louis Poirier, RCG/Hagler, Bailly, Inc.

Reporter

Ian L. Harry, Electric Power Research Institute

Participants

Robert Boteler, Emerson Electric Company

Bob Groendyke, Sullair Corporation

Les Harry, Electric Power Research Institute

Mark Kendall, Oregon Department of Energy

Tom Lowenberg, 3M Company

Dick Nailen, Wisconsin Electric Power Company

Oskars Peterson, National Institute of Standards and Technology

Jim Poole, CRS Sirrine Engineers, Inc.

Ken Reituran, Lukens Steel Company

Group C

Leader

Joseph M. Roop, Battelle Pacific Northwest Laboratories

Reporter

Nikhil Gandhi, Xenergy, Inc.

Participants

Tom Bishop, Longo Industries, Inc.

Carl Castellow, North Carolina State College of Textiles

Neal Elliot, American Council for an Energy-Efficient Economy

Dale Friesen, Manitoba Hydro

James C. Hirzel, General Electric Company

Thomas M. Jahns, General Electric Company

Robert Matthews, 3M Company

Byron D. Speice, Baltimore Aircoil Co.

Dr. Stephen D. Umans, Massachusetts Institute of Technology

Michael Wommack, Pacific Gas and Electric

Group D

Leader

Robert F. Robinson, The Center for Applied Research

Participants

Tom Ryan, Motor Tech, Inc.

Jeffrey Gamble, PACO Pumps

Lawrence Ambs, University of Massachusetts

Jack Johnson, Dow U.S.A.

Roger Bannister, Puget Power

Paul Meagher, Electric Power Research Institute

H. Alex Fleming, Demand-Side Energy Consulting Experts

Steve Sheek, Duke Power Company

Sharon Costello, New York State Energy Office

Mary Elizabeth Tighe, Maryland Public Service Commission

Joseph M. Klenotich, MacKay and Company

Philip E. Muhlmeister, Aspen Systems Corporation

Appendix B: Background Papers

Electric Motor Systems Technology Characterization

Prepared by Ben McConnell, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Processes involving electric motors for converting electrical energy into mechanical energy in industrial applications consume some 65 percent of the electric energy in the industrial sector of the United States economy. While there are energy losses in electric motors and increasing the use of energy efficient motors is important, the emphasis on motor losses generally obscures the more important fact that much larger savings are possible through optimization of the process or systems external to the motor.

Electric Motor Systems

Figure 1 graphically depicts the concept of an electric motor system (EMS) which consists of the following¹: (1) facility power distribution subsystem, (2) starting, control and electric drive subsystem, (3) electric motor, (4) starting, speed control and drive system, (5) mechanical system coupling and load, and (6) driven end process. The system efficiency is the product of the load weighted efficiencies of the

individual components and each component efficiency may depend upon the operating characteristics of other systems components.

Power Distribution

The function of the facility power distribution system is to deliver electric power from the host utility. Ideally, the energy supplied to an EMS would be a pure sinusoid with perfectly balanced voltage of appropriate magnitude. In reality, significant deviations occur in harmonic content, voltage and current conditions. These deviations are called power quality (PQ) problems and can influence total EMS efficiency and reliability. Correction is generally cost effective and provides increased efficiency, enhanced reliability and longer lifetime. EMS efficiency improvements of about 0.5 percent for PQ corrections are possible for the entire facility but non-efficiency savings, such as increased productivity and improved equipment reliability, generally dominate.

Increasing the distribution wire size is a very effective method of reducing energy losses in the distribution system, since electric losses in distribution wiring vary with wire sizing which is based on thermal

¹Note: Electronic speed control precedes the motor, and mechanical speed control follows the motor in the energy flow sequence.

Figure 1: The Electric Motor System

loading. EMS efficiency improvements of about 1.0 percent are possible through reduced distribution wiring losses.

Starting, Speed Control, and Electric Drive Sub-System

The starting, speed control and electric drive sub-system in the EMS may range from as simple as a fixed pulley system which supplies only a step change in speed to as elaborate as electronic adjustable speed drive (ASD) systems which provide precise speed control under varying torque and power requirements. No speed control system is 100 percent efficient; for example, the simple pulley system results in 4–10 percent energy loss but can be reduced to 1–2 percent by the use of a cogged and synchronous belt drive. Careful selection and sizing of other mechanical speed control systems can provide similar improvements.

For the ASD, the system efficiency is a function of motor speed and torque, and while the motor must be derated in performance and efficiency because of the drive's non-sinusoidal waveform, the ASD can correct other PQ problems and optimize the power input to the driven load. Thus, the objective of ASD applications is to improve the efficiency and productivity of the driven process enough to offset the added ASD and motor losses. As Table 1 indicates, the use of a throttle valve to control flow to a fixed process, results in a system efficiency of 48 percent. In contrast,

the energy flow using an ASD to achieve the same results yields a system efficiency of 71 percent and a 32 percent net reduction in energy consumption.

Besides motor and ASD improvements, the mechanical system and the driven process present opportunities for enhanced efficiency. A pump impeller may be adjusted in size to nearly match flow requirements and the impeller polished or coated to reduce friction losses, for example. With ASD, the process may be adjusted or modified to take advantage of the speed, torque, and power control not available using conventional control techniques.

The use of ASD to increase motor speed can also be economically justified. Consider the case of a specific high speed axial flow compressor (HSC) which requires 20 hp at 15,000 rpm using step-up gearing and a standard 40 hp induction motor for a net system efficiency of 50 percent. By using an advanced high speed, axial gap, permanent magnet, brushless DC motor and ASD (net efficiency of 85 percent), a motor output of 25 hp is sufficient to drive the HSC, a net reduction of 35 percent in energy for the same HSC performance. In this case, the potential of advanced and alternative motor designs is also illustrated.

Motor Component

The focus on increasing the efficiency of the motor component in EMS can *under certain conditions* result

Table 1: Per Unit Energy Flow in Throttle Valve and ASD Pumping Application

Power (In/Out)	Facility Power Distribution System	Starting Control and Drive System	Motor	Mechanical System Coupling	Mechanical Load	Process
Throttle Valve (TV) (48 percent)	100/98	98/98	98/87	87/82	82/48	48/0
Adjustable Speed Drive (ASD) (71 percent)	68/67	67/63	63/55	55/48	48/48	48/0
TV Net Losses	2	2	13	18	52	
ASD Net Losses	1	5	13	20	20	

in increased energy consumption. In general, energy efficient AC induction motors operate at higher speeds (less slip) than do standard AC induction motors. With certain types of continuously operating affinity loads, such as pumps, fans and blowers, higher energy consumption can result when using energy efficient motors. This can be corrected in some cases by altering the pulley or gear ratios to more carefully match the driven load speed requirement to that of the motor. While this effect has been known for years, it is often overlooked by field technicians.

Mechanical System Coupling

It is also possible to control the speed of the driven load through a fluid coupling, an eddy current brake, or a manual transmission. However, such systems are expensive, have limited speed control range, and are generally very inefficient. These drawbacks were the initial reason for the increased emphasis on electronic ASD. The above example of the high speed compressor is an excellent case in point.

Mechanical Load and the Driven Process

In many EMS optimization studies, a mismatch between electric motor operating characteristics and those of the driven load is readily apparent. For example, all equipment driven by AC motors without ASD

is limited to a discrete number of speeds which is dependent upon the number of pole pairs in the machine. If higher, lower or variable speeds are required a highly inefficient mechanical speed control is required. Full use of ASD in EMS means that the driven load can be designed to function at its optimal speed and not be limited by the limited speed range offered by conventional electric motors. As a result, *the most important need for improving EMS efficiency is not increased motor efficiency but increased ASD efficiency and lowered ASD costs.*

Payback Analysis

Table 2 provides a simple payback economic analysis of such a system application. However, note the need for additional data on the load-duration, the pump, and the motor load characteristics. The savings indicated are typical of proper ASD applications.

Advanced Motors and Drive Systems

Several types of advanced motors and drives are presently under development and some older designs are currently enjoying revised interest primarily because of modern ASD technology. The ASD and induction motor are not the perfect technical marriage but one major obstacle to the use of advanced motors with ASD is the strong position of the induction motor in

Table 2. Throttle Valve—Adjustable Speed Drive Simple Payback Analysis*

Flow Rate (percent)	Pump BHP	TV System Input (kW)	ASD System Input (kW)	Savings kW	Hour/Year @ Flow	\$/Year Savings @ 0.07\$/kWh
100	100	80.32	83.00	(2.68)	3000	(\$562.26)
75	48	68.95	41.21	27.74	2800	\$5,437.05
50	22	63.21	19.33	43.87	1500	\$4,606.73
Cost of Motor/ASD: \$25,000.00; Simple Payback: 2.64 years; Savings (\$/Yr): \$9,481.52						

*This illustrative analysis does not reflect a full account of all relevant evaluation factors. In addition to energy savings and initial cost, other factors make up part of the evaluation process for EMS, such as capitalized interest, insurance, taxes, reliability, maintenance requirements, and requirements for spare parts.

industry. This entrenched position may be difficult to overcome but careful application of advanced motor and drive designs to niche markets can establish their viability and reliability. Efficiency gains of 2–5 percent appear possible in most advanced designs.

Summary and Conclusions

The overall system must be considered to achieve maximum utilization of energy in electric motor systems. In the systems context, the interaction of EMS components plays a crucial role and relatively simple changes can provide significant benefits. The largest gains in EMS efficiency improvements are often made in the use of ASD systems; therefore major goals in improving EMS efficiency should be to reduce ASD cost, increase ASD operating efficiency, reduce ASD PQ problems, and develop synergistic motor and ASD designs.

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The U.S. Electric Motor System Market Delivery System

Prepared by N. Richard Friedman, Chairman, Resource Dynamics Corporation, Vienna, Virginia.

The electric motor system (EMS) market is comprised of a complex and interconnected web of supply and distribution channels linking equipment manufacturers to the motor end users. Beginning with the assembly of components including electrical steels, magnet wire, carbon-based brushes, terminal blocks, and steel housings, motor manufacturers construct a diverse line of products capable of converting electrical power into mechanical work. This paper focuses on the various channels for getting the motor to the end user, and describes the EMS market delivery system at work.¹

Over half of the electricity consumed in the United States is converted to mechanical energy by motors. Industrial motor end users obtain motors from manufacturers, original equipment manufacturers (OEMs), distributors/resellers, and agents of end-users, such as architect and engineering (A&E) firms and contractors. Within industry, motor drive applications represent the largest use of electricity, with motors primarily used for the movement of materials and compounds through a vast range of processes. Motor drives in the sector account for nearly 70 percent of all electricity usage, and in some motor-intensive industries, over 90 percent. In the manufacturing sector, the most motor-energy-intensive industries are the process industries, especially chemicals, pulp and paper, food, and petroleum.

In the commercial and industrial sectors, the use of electric motors on **pumps, fans, and compressors** is predominant, including HVAC applications, fluid processing, convection drying, and refrigeration and air compression. In the area of **materials processing**,

motors furnish the power for cutting, mixing, grinding, and crushing. Finally, raw materials and manufactured products are moved around the factory floor by **materials handling** motors driving conveyors, cranes, elevators, and robots.

Market Focus

This paper characterizes the market for large industrial motors—polyphase AC motors, 20 horsepower and larger. While smaller motors down to integral horsepower size do offer efficiency improvement opportunities, this segment is important because these motors account for half of all the electricity used by industrial sector equipment, and the segment offers major opportunities for energy efficiency improvement. Moreover, in addition to significant energy use, three factors make this market somewhat unique.

- The flexibility of the larger equipment in the industrial sector makes it easier to change out the motor. The larger sized motors are typically stand-alone applications, with the motor almost always an easily replaceable "bolt-in" item. In contrast, the smaller motors are often part of an OEM product such as an air compressor or a component of a custom-designed system, much less easily replaced.
- The more direct contact the manufacturer has with the user, the more likely that solutions can be found to motor or EMS problems that will involve component replacement. This is especially true for the larger motors that are often purchased directly from the manufacturer.

¹This overview of the magnitude and dynamics of the U.S. electric motor systems market requires an examination of supply (production) and demand (sales). The primary data available, however, is published by the U.S. Commerce Department and only presents motor sales by horsepower by year. Moreover, only limited information is available on manufacturer production, types

of applications, and motor retirements. Yet these data are essential for developing a comprehensive understanding of the EMS market. As a result, much of the market analysis presented here is drawn from expert estimates of industry motor sales and applications activity.

- The larger motors have a much higher than average load and duty cycle and need to be reworked or replaced more often.

Electric motor applications in industry are ubiquitous, representing a large market for the sale of industrial equipment. U.S. sales of polyphase AC motors 20–200 hp were \$327 million in 1991, representing total unit sales of nearly 202,000 motors. These motors accounted for 10 percent by quantity and 35 percent by value of the polyphase integral horsepower motors sold in 1991.²

Energy efficient AC polyphase motors accounted for 27.3 percent of motor sales in 1990 and 30.2 percent of sales by quantity in 1991 in the 20+ hp range. By contrast, in the 1–5 hp range, high efficiency motors sales were 7.5 percent in 1990, actually falling to 6.9 percent of sales in 1991.

The Market Delivery System

Once the electric motor leaves the manufacturer's production plant, it is either (1) taken by large and small distributors and sold to end users, (2) sold to OEMs who incorporate the motor into their compressor, pump or other equipment product line, (3) sold to

²Current Industrial Reports, *Motors and Generators*, U.S. Department of Commerce, Bureau of the Census, MA36H(91)-1, November 1992. Average runtime of 20+ hp motors assumed at 4 times that of motors less than 20 hp.

Figure 1. Efficient Motor Market Penetration

the agents of end users, or (4) sold directly to large industrial end users. The manufacturer will sometimes use factory-affiliated manufacturers' representatives as intermediaries in these transactions. As an example, Baldor Electric sells all motors through representatives.

The interaction of these market participants results in a complex and dynamic EMS delivery system (See Figure 2). Unit sales of motors of 20 hp or greater through each of these delivery channels are broken down as follows: OEMs—49 percent, distributors—28 percent, and end users (or to agents for end users)—22 percent.

The larger the motor size, the more likely the manufacturer will be dealing with the end user directly. Over one-half of all motors over 200 hp and 25 percent of motors from 125 to 200 hp are purchased this way. Beyond very large motors, the motor manufacturer has very little contact with end users. The major exception occurs with new, large plant construction, with manufacturers dealing with architect-engineers or engineering and construction firms who act as agents for their clients. Distributors represent the major supply channel for most motors below 200 hp bought directly by end users, with large distributors handling large customers through national account relationships and blanket orders.

The Market Participants

Each of the market participants and their role are discussed below.

Major Motor Manufacturers

The U.S. motor market for 20 hp and over polyphase induction motors is dominated by a few major manufacturers, most of whom offer a full range of motors, including both standard and energy efficient. There are other manufacturers that produce specialty motors in small quantities, but the bulk of manufacturing industry motors are produced and marketed by approximately sixteen companies.

Major U.S. producers of electric motors include large diversified corporations such as the General Electric Company, as well as smaller companies that focus more narrowly on production of motors

Figure 2. The Market Delivery System

(Leeson, Marathon). Some U.S. producers of electric motors manufacture a relatively complete line of motors while others concentrate on specific segments of the industry. Still others are small to medium sized businesses for whom motors are just a small part of their product line.

The North American market (United States, Canada and Mexico) accounts for a substantial portion of total exports of many foreign competitor firms, such as Toshiba (Japan); ABB (Sweden); Siemens (Germany); Leroy Somer (France); and GEC and Hawker Siddeley (UK). As a result, the economics have strongly supported the development of separate pro-

duction lines to manufacture motors to U.S. standards.

Manufacturers' Representatives

Factory-affiliated manufacturers' representatives are intermediaries that act as the marketing arm for large EMS equipment producers. They are typically organized on a regional basis, providing motors to large independent distributors and large OEMs. As noted earlier, some companies, such as Baldor Electric, sell all motors through representatives. Others may sell both through the representative and through other

OEM Motor Selection Examples

A Cincinnati Fan distributor indicates that their fans can be furnished with any motor the customer requests, and that around 15 percent of the requests are for high-efficiency motors. If the customer does not request a motor type, the fan is supplied with a "high-quality" motor (not a "no-name" import).

Gelber Industries is a distributor of OEM pumps. Its pump catalog presents a generic description of motors used to replace failed pump motors, or for pumps that do not come pre-packaged with motors. In the catalog, motors are treated completely as a commodity item, with the note that "the motors may be from one of several manufacturers." Efficiency is not mentioned at all.

Major Motor Manufacturers

A.O. Smith	Magnetek
Baldor	Marathon
Brook Crompton	Reliance
Dayton	Siemens
Emerson Electric	Sterling
General Electric	Teco
Leeson	Toshiba
Lincoln	Westinghouse

Distributors

Large distributors are independent motor sellers whose volume is such that they can obtain motors directly from the factory, or through manufacturers' representatives. These distributors will often handle multiple motor lines, and usually sell other types of equipment. Stocking and broker distributors approach the market from a different perspective, reflecting their financial strength, sales volume, and customer profiles. Stocking distributors generally purchase motors in quantity and stock a range of motors to timely fill customer orders. Broker distributors order motors as needed from manufacturers. Most distributors will act both as stocker and broker for different equipment lines.

channels. A number of companies do not use manufacturers' representatives.

Most manufacturers' representatives respond to sales leads developed on their own, by the distributors they service, or from the manufacturer. They do not usually stock any equipment, acting primarily as a technical resource and broker, with all equipment shipped directly from the manufacturer to the equipment purchaser. Although not specifically shown on Figure 2, in some cases involving "lot purchases" and larger sized motors, the manufacturer's representative will sell directly to the larger end user.

Table 1. EMS Equipment Distributor Sales

Distributor Marketing Option	Description	Delivery
Stocked	Purchased on account and placed into distributor warehouse stock	By Distributor
Brokered	Sold from product specification sheets or catalogue cuts with order placed for manufacturer shipment	By Distributor, or Drop Shipment ^a

^aOrdered and billed by distributor, but shipped directly from manufacturer to end using customer. Manufacturer shipping invoice shows sale to distributor and shipment to customer.

These large distributors sell motors to resellers (in effect, smaller distributors), small OEMs, agents for end users, and directly to end users. A distributor stocks and orders motors based on (1) what is profitable, (2) the wants and needs of their customers, and (3) what the manufacturers have to offer.

Resellers

Resellers are small industrial supply firms that supply motors directly to end-users and small OEMs. Resellers obtain their motors from large distributors, and many resellers will also repair and rewind motors. Resellers often respond to requests for price quotes over the phone. Unless a specific brand or energy efficient motor is requested, the reseller will typically quote the price of the least expensive brand of motor in stock that matches the customer's specifications. Resellers typically stock a limited number of smaller motors and rely on distributors to ship large and special service equipment when ordered by a customer.

Within this category, a special class of *value-added resellers* (VARs) offer extra service to their customer by providing the motor in a custom (or semi-custom) designed package suited to a specific application, such as a compressor package, complete with process controls and sensors.

Original Equipment Manufacturers (OEMs)

Many electric motor purchasers are also manufacturers—of equipment such as compressors, pumps, fans, machine tools, appliances, and other devices that convert electricity into the motion of a drill or cutting tool, compressed air or gas, or refrigerated air or fluid. OEMs are purchasers of electric motors who then combine the motor with a controller, driven equipment such as a compressor or pump, and an overall housing or mounting package to provide an EMS to end users.

Large OEMs obtain motors directly from manufacturers (or through manufacturers' representatives). Small OEMs get motors from distributors or resellers. Specialized or large orders of OEM equipment are usually ordered directly from the manufacturer. Most OEMs typically deal with two to three manufacturers for each type of motor used in their product. A recent

trend noted in this market is the emergence of the single-source motor supplier, allowing the OEMs to control costs more effectively and establish a "vested" working relationship with their suppliers.

Motors typically account for 5 percent or less of total OEM product cost. In the case of compressors, however, this amount can reach as high as 15–20 percent; in some cases, the compressor and motor package is purchased by the OEM for installation in its product.

In effect, the OEMs act as the decision maker on motor efficiency for the end user, although in some cases the user has the option to select (and pay extra for) a premium efficiency motor either separately or as part of a "premium efficiency option" offered by the OEM. Typically, a distributor of OEM equipment will not stock a unit with a high efficiency motor, reflecting limited demand to date for higher efficiency equipment. The presence of a utility rebate program may encourage the OEM distributor to stock at least a limited number of high efficiency units.³ For "commodity" OEM machinery such as pumps and fans, this limited stock availability may present a barrier to customers that have an immediate equipment need, but most other equipment is custom made, and could be ordered with a high efficiency motor at the request of the customer.

Agents for End Users

Agents for end users are typically architectural and engineering firms and contractors. These consulting engineers can design projects, set specifications, supervise project bidding, and in some cases, execute the project construction. Agents involved in *turnkey* design and construction (the "design-build" approach) of a new, large plant project will typically purchase the EMS equipment as part of their contract, dealing with the manufacturers on behalf of their clients, the ultimate EMS end user.

Engineering firms will typically obtain motors from large distributors, although (as shown on Figure 2) for some very large jobs they may obtain motors directly

³Conversations with personnel at Carey Machinery, an industrial air compressor distributor.

from the manufacturer. All motors from agents go directly to the end user. Generally, agents are under pressure to keep first cost at a minimum, so energy efficient equipment is often not specified. This is especially true if the agent is also the builder and is competitively bidding on the project.

End Users

Industry motor users cut across all lines and products. End users obtain motors from manufacturers, OEMs, distributors/resellers, and agents as shown below.

In the smaller sizes, end users get most of their motors as part of OEM equipment; while in the largest sizes, most of the motors are obtained directly from the manufacturer. Users also have motors repaired and rewound.

Rewinders

Because they often both sell new motors and rewind failed motors, motor repair and rewind shops are often indistinguishable from small distributors. Rewind shops usually sell at least one line of new motors. The smaller shops tend to focus primarily on their repair business. Some larger distributors offer rewinding as part of a full range of services available to customers, but may contract out rewinding jobs to smaller specialty shops.

Table 2. Sales Distribution of Motors to End Users (Percent of Total)

	21-50 hp	51-125 hp	126-200 hp	200 + hp
Manufacturers	3.0	15.0	30.0	51.4
OEMS	60.0	40.0	14.9	5.3
Distributors/ Resellers	35.0	40.0	44.8	20.0
Agents	2.0	5.0	10.3	23.3

Other Parties

Outside parties that can influence the motor market include electric utilities, energy service companies, state regulators, Federal/state/local governments, research organizations, and trade and professional organizations. The impact of these parties on market dynamics and user decision making are discussed in the other orientation papers.

Market Barriers

There are a number of apparent barriers to the rapid and widespread adoption of energy efficient electric motor systems. These barriers are summarized below and include:

- Lack of Data:
 - Data on the motor market and motor end-uses on national or state-wide basis.
 - Current data on stock of motors in the United States and end-use breakdowns by motor application.
- Competitive markets and higher first cost considerations prevent OEMs from offering the more efficient option to their customers. Customer's major criteria is first cost.
- End user confusion on cost and benefits from application of high efficiency EMS tends to hold down demand for the premium equipment.
- Manufacturers, distributors and dealers think they are responding to user preference for low cost, lower efficiency EMS equipment. In practice, many suppliers are not encouraged or educated on the associated benefits. Competitive markets coupled with a reluctance of customers to pay high first cost results in "low cost bidding" practices; efficient motors are not offered to customers, unless specifically requested.
- Many dealers/distributors have limited expertise to provide detailed ASD application information to customers.

- Accounting for as little as 5 percent of total product cost, the motor is often overlooked (or ignored) as an efficiency improvement opportunity.
- In some selected cases, the energy efficient motor may reduce the operating flexibility of the OEM equipment by limiting overspeed capability. Overall efficiency can be reduced in some cases.
- ASDs are not commodity products and require engineering, economic, and reliability considerations. In this context, some specifiers/agents to end-users have limited familiarity with applications of ASDs, and insufficient technical expertise.
- Misinformation on the performance and reliability of energy efficient EMS equipment has contributed to a reluctance of some potential end users to purchase this equipment. Concerns include a belief that (1) the motors use less steel and run hotter, (2) service life may be reduced, and (3) when rewound, they will revert to standard efficiency anyway. These perceptions have hurt market acceptance.

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Decision-Making Processes for Industrial Energy-Efficient Electric Motor Systems

Prepared by Jean-Louis Poirier, RCG/Hagler, Bailly Inc., Arlington, Virginia, and Dr. Joseph Roop, Battelle Pacific Northwest Laboratories, Richland, Washington.

This paper reviews the internal decision-making processes of purchasers of industrial electric motor systems (EMS) over 20 hp. The paper focuses on how EMS units are purchased, not how they are operated and maintained thereafter.¹

In focusing on the purchase of EMS units for industry, we recognize four important factors:

- In the last 6 years, the number of EMS models and configurations have roughly tripled. Now, with the increased development of adjustable speed drives (ASDs)², the traditional distinctions between AC induction, AC synchronous, DC brush type, and AC/DC brushless permanent magnet motors have blurred. A myriad of EMS options are now competing head on, often creating confusion among purchasers.
- Nearly half of EMS systems are purchased by original equipment manufacturers (OEMs) and contractors, not by end-users.
- Many purchase decisions call for not only selecting an individual motor but also the "whole" EMS configuration, including a drive system to match process characteristics.
- EMS purchasers can be influenced by other players besides motor manufacturers and their distributors, including electric contractors, architects and engineers (A&Es), engineer/constructors (E/Cs), energy-service companies (ESCOs), state and Federal governments, and utilities offering demand-side management (DSM) programs.

¹Industrial O&M practices are, however, also very important because they are recurrent and can significantly influence how much electricity is being used in EMS applications. In maybe as many as 20 to 25 percent of the cases, the EMS units not being used the way that they were intended.

²Using either pulse-amplitude modulation or pulse-width modulation.

In this context, we first describe the types of EMS purchases. Second, we review how EMS purchase criteria vary by size of EMS purchaser, and size and type of end-use application. Third, we discuss how EMS purchasers evaluate their choices. Finally, we conclude on the barriers limiting the purchase of energy-efficient EMS applications in U.S. industry.

Type of EMS Purchase

There are five types of EMS purchases, each of which can involve end-users or OEMs to different degrees, often with a varying propensity for considering the whole EMS system at the time of purchase. Ranked from least to most discretionary, they are:

- *Replacement purchases* which are usually made by end-users' maintenance or repair departments who often opt for same (or "as-close-to") motor specs with a premium on the motor only and on lowest cost, availability and consistency of motor parts.

End-users have different policies on rewinding versus replacing motors. More often than not, they will not rewind if it costs more than 50–60 percent of the replacement cost and many companies do not rewind motors in sizes below 30–50 hp.³

Delivery speed is often a critical concern, especially when no spare motor is stocked (usually the case for units above 50 hp) or when rewinding may take too much time.

- *Bundled new purchases* which occur when EMS end-users buy in large quantities as part of a plant expansion or modernization program which is being procured by a turnkey E/C contractor who is self-engineering or working with an A&E firm. Such EMS purchase decisions are then often delegated to the A&E or E/C firms; a frequent complaint in these cases is EMS oversizing.

³In addition, very few will rewind more than 2 to 3 times.

OEMs also make bundled new purchases to fit their standard product lines. Once the OEM's engineering department has issued the EMS specs for each product line, its procurement shop often takes over. Bundled new purchases are divided between individual motors and whole EMS systems, although contractors will very much look at the whole EMS system for overall performance.

- *Unbundled new purchases* which are made by EMS end-users that can self-engineer their own plant projects. OEMs also make unbundled new purchases for customized sales. Often, the purchase will be for the entire EMS system.
- *Specific retrofit purchases* which are early replacement applications which can be made by end-users pre-evaluating their most critical motors. Such purchases are divided between individual motors and whole EMS systems.
- *Program-retrofit purchases* which combine several specific retrofit purchases as part of a planned (often multi-year) EMS plantwide upgrade program. In most cases, these purchases take into account the entire EMS system.

Overall, almost one purchase out of four is a replacement, with new purchases accounting for 60 percent of sales and retrofit purchases for 20 percent.⁴ In addition, we estimate that purchases with consideration for the whole system (at least for its drive) occur only 40 percent of the time. Finally, we estimate that 44 percent of EMS systems over 20 hp are procured through OEMs.

EMS Purchase Criteria Segmentation

In this context, we find that EMS purchase criteria vary according to three major factors, which are discussed later in detail and include:

- Size of EMS purchaser (small versus large)
- Size of EMS application, and
- Type of EMS end-use application.

⁴Only rough estimates as the result of the lack of comprehensive marketing data; in addition, sales patterns have noticeably changed in the last 2-3 years of economic weakness.

Type of EMS Purchaser

Purchasing approaches not only differ between end-users and OEMs but they also vary by purchaser size (that is, small or large).

The size of an EMS end-user is not always a direct function of plant size or energy budget because both factors are not always correlated with the number of electric motors over 20 hp. Large EMS end-users have large EMS populations—say, over 30–40 units over 20 hp—with a well established buying approach, previous buying experience, frequent consultations with other company plants, with possibly a designated “resident” motor expert, and with access to a corporate engineering office or outside engineering consulting services.

Large end-users tend to be technically and economically more sophisticated, and can devote more time to conduct engineering and financial analyses. Reliability is often a primary concern. In the process industries, the higher annual use of the motors allows more rapid payback for energy and reliability improvements. In addition, larger end-users have more general knowledge about the ASDs and there will be some initial reluctance on the part of purchasers to commit to relatively new technology for very large and critical needs.

In contrast, small end-users—with less than 30 units—tend to focus more on EMS reliability, availability and one-to-one replacement; they rely, most of the time, on maintenance contractor input or distributor advice. Yet, we estimate that small end-users buy about 40 percent of the motors over 20 hp, although that proportion varies by industry and region.

Large OEMs also tend to have sufficient capabilities to analyze EMS motors but their focus is on reliability to avoid failure under warranty. In most cases, savings in EMS purchase prices allow OEMs to be more cost competitive on their own products, although more OEMs are offering customized product lines with energy-saving features. Still, OEMs may use energy-efficient motors only one-fifth as often as end-users do for similar applications. Furthermore, end-users buying from OEMs tend to be less aware of motor performance than the typical end-user buyer

who buys a large motor, since motor efficiency may represent only a portion of the efficiency of the equipment. OEMs sometimes allow end-users to specify a desired motor, but usually only as the size increases (for example, over 75–100 hp).

Differences also exist between large and small OEMs. Larger OEMs have more technical capability and will be more sensitive to sales of whole EMS systems as opposed to individual motor sales. Larger OEMs will also tend to offer more diverse product lines as they use more flexible manufacturing processes. Smaller OEMs will be less concerned with product customization except for niche market applications.

Exhibit 1 shows the relative mix of purchasers by type of purchase. Large end-users account for nearly 60 percent of all end-user purchases and for a third of all EMS purchases. Three observations need to be made at this point:

- Small end-users often delegate their replacement purchases to outside maintenance contractors while few OEMs will replace systems unless they are under maintenance contracts. Most end-user

engineering departments do not get involved unless the unit to replace is over 100–125 hp.

- Program-retrofit purchases are generally overseen by the engineering departments of larger end-users or by special contractors of smaller end-users.
- Larger OEMs may offer retrofit programs if they want to “reach out” and offer improved after-sale service to end-users.

EMS Size

The larger the EMS size, the more likely the end-user will be a direct buyer, no OEM being involved. This is important because OEMs and end-users are likely to have different purchase criteria. For more detailed information, see the table on Sales Distribution in the orientation paper on the EMS Market Delivery System.

The size of an EMS application will also often dictate the level of technical analysis conducted. For larger applications, there is a greater incentive to assess options, except if it involves the urgent replacement of a crucial motor. However, the larger the motor, the more likely the end-user may have

Exhibit 1. Preliminary EMS Market Segmentation Percent Sales of Motor Units >20 HP

Type of Purchase	Other Players Involved	Fraction of Whole EMS Decisions	Percent Total Sales by Purchaser Type			
			OEM	End-User		Overall
				Small	Large	
Replacement	MC	L	4% (b)	8% (b)	10% (b)	21–26%
New/Bundled	E/C	L/M	22% (c)	5% (b)	8% (b)	30–37%
New/Unbundled	E/C; D	L/M	15% (c)	4% (b)	5% (b)	23–25%
Retrofit/Specific	D	M	2% (b)	4% (a)	5% (b)	10–13%
Retrofit/Program	E/C	H	1% (b)	2% (a)	5% (b)	7–9%
Total			44%	23%	33%	100%

E/C = Engineer/Constructor; D = Distributor; MC = Maintenance Contractor; L = Low; M = Medium; H = High.

(a) = +/- 1 percent; (b) = +/- 2 percent; (c) = +/- 3 percent.

Source: RCG/Hagler, Bailly Inc; January 1993.

conducted some early prefeasibility assessment to be able to quickly decide in case of crisis replacement.

EMS End-Use Application

Finally, the type of EMS application will dictate the kind of criteria considered to evaluate the fit of an EMS in terms of:

- *Technical fit* to gauge how the EMS can perform the same or better job with equal or higher quality and yield—while fitting a plant layout or process configuration that may change in the future. The key to this fit is the quality of the match between the motor, its ASD, the process and the plant power distribution system.
- *Energy fit* to measure the potential for energy savings, lower demand peaks and cheaper electric bills.
- *Operating Environment*—including EMS reliability and longevity, especially in harsh process intensive environments.

Depending on the complexity of the application, up to twelve criteria can be considered:

- Precision/speed control requirements (for example, closed or open-loop speed control)
- High torque/low speed profile
- Electric motor size and weight constraints
- ASD interface (for example, number of motors/ASD)
- ASD requirements (for example, speed ramps, breaking, switching, speed adjustment range)
- Radio-frequency-interference (RFI) and harmonic limitations
- Environmental stability/longevity
- EMS reliability
- EMS availability
- EMS overall energy efficiency (both motor and whole EMS)
- Ease and cost of design, installation, and operation (both motor and whole EMS)

- Impact on process productivity and plant yield.

Not all criteria will be assessed every time. How many criteria are considered will depend on the specificity and size of the application, the type of purchase, and the type of user involved. For example, precision and speed control will be very important for fiber drawing, steel roll out, and molding/shaping applications; while energy efficiency will be most important for cooling tower pumps and refrigeration compression. We show in Exhibit 2 how industrial EMS end-users are likely to rank their various criteria for applications such as plastic extrusion, materials handling, wire drawing, molding/shaping, pumping, gear drives, pulp refiners and refrigeration compressors.

Overall Customer Preference Segmentation

Overall, technical fit criteria carry the most weight, especially in retrofit programs for complex material-flow industries (for example, in the chemical or pulp and paper industries). Unfortunately in mid-size plants, there is often a lack of information on the actual (flow and usage) characteristics of the process.

We have summarized in Exhibit 3 how the relative importance of seven fit criteria may vary by type of EMS purchase situation—across various types of EMS end-users, types of EMS purchases, and the size and type of EMS applications.

Overall, technical fit criteria account for probably 60–70 percent of the end-users' decision. In contrast, energy efficiency plays a pivotal role (with a weight in the purchase decision over 40 percent) in only 30–35 percent of potential EMS applications (that is, larger sizes, high load applications in plants with high electricity prices or where there are concerns for future rate increases).

EMS Evaluation Approaches

Different end-users usually apply different approaches to evaluate the *price-for-performance* trade off of a new EMS based on its projected costs under expected operating conditions.

We estimate that in about 30–35 percent of the cases over 20 hp, EMS purchase decisions follow cor-

Exhibit 2. Applicability Criteria for Sample Industrial EMS Applications

Type of Application	Size Range (hp) (Over 20 hp)	Application Characteristics					
		Precision/Speed Control	High Torque/Low Speed	ASD Interface/Requirements	Environmental Stability Longevity	Energy Efficiency	Ease of Installation/O&M
Materials Handling	20-50	+++	++	++	+++	+	++
Materials Handling	>50	++	++	++	++	+	+++
Packaging Equipment	20-50	+++	++	++	++	+	++
Fiber Drawing	20-50	+++	+++	+++	+++	+	+
Steel Roll Out	20-50	+++	+++	+++	+++	+	++
Servos	20-50	+++	+++	+++	++	+	++
Plastic Extrusion	20-50	+++	++	++	+++	+	+
Wire Drawing	20-125	+++	+++	+++	++	+ / ++	+
Molding/Shaping	20-200	+++	+++	+++	+++	+ / ++	+
Wire Winders	20-300	++	+++	+	+	+ / ++	+
Pumps (Explosion-proof)	20-500	+	+	++	+++	++	+
Gear Drives	20-500	++	++	++	++	+++	+
Refrigeration Compressor	20-750	+	+	++	++	+++	+
Pulp Refiner	1000-1750	+	++	++	++	++	++
Cooling Tower Pump	1000-2250	+	+	++	++	+++	+
Pumps	20-20000	+	+	++	+	+++	+

Source: RCG/Hagler, Bailly, Inc; January 1993. Key: +++ = very important; ++ = moderately important; + = not as important.

porate guidelines while in another 35-40 percent of the cases, decisions are very much influenced by previous purchases. In both cases, there may be a resident expert in the company if that company has several plants nationwide. In the balance (25-35 percent) of the cases, the purchase will be made based on a customized study.

We also estimate that most end-users—over 55 percent—will analyze the life-cycle costs of the unit. However, they will use different analytical techniques, including payback, internal rate-of-return (IRR) and net present value (NPV), depending on the situation (See Exhibit 4).

Exhibit 3. Variations in EMS Purchase Criteria Importance

Type of Market Application	Relative Purchasing Criteria Criticality*						
	Precision /Control	ASD Interface	Reliability	Deliverability	Environmental Performance	Energy Efficiency	Improving Impact on Operations
Replacement			++	+++		+/++	
New/Bundled	+/++	+	+/++	++		+/++	+/++
New/Unbundled	++	+/++	++	+++		++	
Retrofit/Specific	++	++	+++	++	+	++	
Retrofit/Program	+/++	++	++	+	+/++	+++	++
Size: <50 hp		++					
Size: 50–200 hp		+++				++	
Size: >200 hp		+++	+++	+++		+++	
Complex EMS use	+++	+++					++
Simple EMS use							
Harsh Environment					+++		
High Energy Prices	+/++	+++			+	+++	+/++
Overall Criticality	High	High	Medium	Medium	Low–Med	Low–Med	Low–Med

* Key: +++ = Highly Critical; ++ = Quite Critical; + = Somewhat Critical.

Blank indicates no special mention by purchaser.

Source: RCG/Hagler, Bailly Inc., based on interviews with EMS purchasers; January 1993.

We further estimate that in about 40 percent of the cases, end-users and OEMs will apply evaluation tools (for example, computer diskette spreadsheets) developed by equipment vendors and used during direct-buy discussions or used by distributors. Most of these tools use life-cycle costs and internal rate of return. Any purchaser using these tools will generally make a more-educated decision, *assuming that all the parameters of the application do make technical sense and process characteristics are well known.*

In our opinion, in over 60–65 percent of the cases, the implicit IRR has to be 25 percent to 40 percent or

the equivalent of a 1.2–2.5 year payback. However, different end-users will apply different payback, IRR or NPV hurdles to account for various financing costs and access to capital. These two factors together can help justify adjustments of 1–2 years in estimated payback.

Furthermore, end-user location can have a big influence on EMS economics since electric rates continue to vary significantly—by a factor of 1 to 4—across regions and utility service areas. End-users' prospects for electricity price increases can also vary a lot depending on the financial and capacity situations

Exhibit 4. Variations in EMS Purchase Evaluation Approaches

Evaluation Method	When it tends to be applied	Comments
First Cost	Small customers Replacement Guidelines in place/proven precedents	
Payback	Small/large customers Small motor sizes (for example, below 50 hp) Simple applications/precedents exist	
Rate of Return	Large customers Larger/complex applications New/unbundled or retrofit/specific	Will depend on third-party involvement (for example, distributor, E&C, vendor) Requires corporate hurdle IRR
NPV	Small/large customers Larger size motors Complex applications New/unbundled or retrofit/specific High electricity price areas	Will depend on third-party involvement (for example, distributor, E&C, vendor) End-user needs to be able to relate to NPV results
Life-Cycle Costs	Small/large customers Larger size motors/critical ASD interface Complex applications Program retrofits High electricity prices	Will depend on third-party involvement (for example, distributor, E&C, vendor) Requires the end-user to do more projections

Source: RCG/Hagler, Bailly Inc.; January 1993.

of the utility involved. Still, more often than not, there is not enough attention paid to possible changes in demand rates or good analysis of the impact of alternate rate structures, with or without plantwide demand-side management.

Finally, EMS end-users apply different discount rates to reflect different risk perceptions. This may work both ways, however. For example, large end-users engaged in program retrofits may select a whole slate of retrofit opportunities with paybacks that may range between 1 and 6 years but they will then sequence these motor investments over a 2–3 year program to accommodate capital constraints and hedge in case of potential process changes.

Barriers to Energy-Efficient EMS Purchases

There appear to be four major barriers to the increased penetration of energy-efficient EMS applications over 20 hp:

- The wide variety of applications and types of end-users—both end-users and OEMs—implies that industry's responsiveness to new EMS technologies and applications will be limited by this market fragmentation. As a result, manufacturers, distributors and utilities must be able to segment and target their markets effectively.

- The difficulty of reaching end-users at the right time in replacement applications (over 30 percent of what is at stake). There is a need to achieve a better coordination all along the delivery chain to ensure the "pre-selling" of potential end-users and create a "built-in" reflex to think energy-efficient EMS.
- End-users do not always have access to the right information needed to diffuse their confusion about what is the best EMS option (from a technical or energy-related standpoint) for their application.
- Turnkey contractors do not coordinate enough their EMS purchases with OEMs when they purchase new equipment on behalf of end-users.

References

Discussions with motor manufacturers, distributors, OEMs and utilities.

Electric Motors: Markets, Trends, and Applications, EPRI report TR-100423, 1992.

Energy-Efficient Motor Systems, American Council for an Energy Efficient Economy, 1991.

Utility and State Industrial Electric Motor System Incentive Programs

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Over the last several years, much has been done to improve the efficiency of electric motor systems (EMS). Public utility commissions, by encouraging utilities to undertake integrated resource planning, have spawned more efficient motor systems through demand-side management programs. Some states have also encouraged efficient motor systems through building code standards. Some states have also been active in promoting efficient motor systems without formal programs, such as the information provided by the Washington State Energy Office's MotorMaster database. Most recently, the Energy Policy Act of 1992 has called for motor efficiency standards that will increase the efficiency of industrial motors systems in industry.

This paper summarizes the results of a survey of utilities with industrial demand side management (DSM) programs that address efficient motors and/or motor controllers. In addition, state energy offices were contacted to determine whether they sponsored efficient motor programs independent of utility programs.¹ In all, information was collected on 25 programs within 21 utilities and various programs within the 50 states.

Description of Utility Industrial DSM Programs

Most utility DSM programs do not specifically target industrial customers. Instead, industrial customers are combined with commercial, and in two programs surveyed, agricultural customers. Fifteen programs provide incentives for both motors and motor controllers, usually referred to as adjustable speed drives (ASDs); seven programs target only motors; and three

programs are aimed at ASDs. Most programs provide an incentive for both new and replacement motor installations. However, three programs limit the incentives to replacement installations.

Motor and motor drive DSM programs are structured to provide incentives, financial assistance, or information to customers. The various types of programs are identified in Table 1. The type of program, how it works, and how it affects the motor market are shown in separate columns.

Marketing methods vary by utility, with most utilities relying on more than one method. Eighteen programs utilize personal contacts, primarily in the form of customer or field representatives. Sixteen programs include marketing through vendors, ten programs use letters or other forms of mailing, seven programs advertise in trade journals or through other media, and ten programs incorporate other marketing methods such as seminars.

Only seven programs include a vendor incentive, although four others are considering this option. The most popular customer incentive is a direct rebate, usually based on a per hp basis, although some rebates are per motor or drive. Other customer incentives include low-interest loans and payments for demand reduction.

All but two utilities provide educational materials to their customers regarding efficient motor systems; and all but one provide technical information to the customer in some form. Only about half of the utilities surveyed provide educational materials to the motor vendors.

Utility Experience

There are many factors which contribute to the success of a DSM program. The common focus between these factors is that they address one or more barriers that the customer has raised toward the installation of EMS. All utilities surveyed rely on some form of

¹Additional information about state programs was provided by the reports, "Electrical Motor and Drive National Inventory," by the U.S. Department of Energy and "Incentives for Demand-Side Management," by Reid and Brown. An EPRI study, to be available in Spring, 1993, is not included in this study.

Table 1. Industrial DSM Program Elements for EMS

Program Element	Description	How It Affects the Motor Market
Prescriptive Rebates	Rebates (according to schedules) are given to customers that purchase energy efficient motors or equipment such as ASDs.	Shortens the payback period for energy efficient equipment and motors, increasing sales.
Customized Rebates	Rebates (customized for each customer) are given to customers that purchase energy efficient equipment and motors.	Shortens the payback period for energy efficient equipment and motors, increasing sales.
Payments	Payments are made to the customer to cover a percentage of the installed cost; or for estimated kW or kWh savings.	Shortens the payback period for energy efficient equipment and motors, increasing sales.
Loans	Low interest loans are provided to customers purchasing energy efficient equipment.	Allows customers with limited capital access to purchase energy efficient equipment.
Audits	Efficiency audits of customers' facilities are sponsored by the utility.	Identifies opportunities customers may not be aware of otherwise.
Technical Assistance	Technical Assistance is given to customers in selecting a motor, or before facilities are built or expanded.	Helps customers select the appropriate motor, makes customers aware of opportunities before decision to purchase.
Educational Assistance	The benefits of energy efficient equipment are publicized by the utility.	Customers obtain information on the benefits of energy efficient products that they might not be aware of.
Case Studies	Successful energy efficiency projects are publicized by the utility.	Customers become more confident in proceeding with similar projects.

Source: *EMS Sourcebook*, Table 3-1—*Motor-Related DSM Program Elements*, revised to reflect PNL Survey responses.

customer incentive to encourage the purchase of efficient motors and drives, and some also employ vendor incentives as well. The various utility incentive programs are discussed more thoroughly in this section.

Customer Incentives

All utility DSM programs identified provide some type of incentive to the customer to encourage the selection of efficient motors and/or the installation of motor controllers. As with the financial incentives offered by some states, the utility customer incentive helps to reduce the difference in price between stan-

dard efficiency motors and higher efficiency motors. This section discusses the types of incentives offered and presents examples of programs which have changed or plan to change the incentive portion of their program.

Structure of Programs

Customer incentives offered by the utilities are as varied as the programs themselves. In all, 22 programs offer rebates for motors and ASDs. Two programs offer payments based on energy reduction or as a percentage of the cost of the efficiency measure, and one

program offers grants for efficiency projects. Of the programs that use rebates, five also have other incentives available. Two programs offer low-interest loans, three programs offer payments, and one program offers a cash incentive for customers who identify motors that they will replace in the future with energy efficient motors.

Rebates for motors range from \$3 per HP to \$20 per HP in programs which base their rebates on horsepower, and from \$30 to \$3,200 per motor depending on motor size. In all, fifteen out of 22 programs offering motor rebates have a fixed, easy to calculate, rebate level. The other seven programs either base incentives on project payback, usually calculated for one or two years, make payments based on project cost, or customize the rebate. Customized rebates are also offered in conjunction with some of the fixed rebate programs for the larger sized motors, usually greater than 200 horsepower.

Rebates for ASDs are just as varied. Most are offered on a per horsepower basis, ranging from \$20 to \$140 per horsepower. Others are customized, depend on purchase cost, or depend on expected energy savings.

Out of the 25 programs, four have increased their incentive level, or plan to increase it; four have reduced or plan to reduce their incentive level; two programs have made modifications involving increases and reductions for individual sizes; and one program is considering a change in their incentive level. Reasons for the changes include the results of cost-effectiveness studies, feedback from vendors and customers, and program success. For example, B.C. Hydro is planning to reduce customer incentives for its motors program due to surveys which indicate that efficient motors compose 80 percent of motor sales, while another utility is considering an incentive increase because information from vendors and potential customers has indicated that the current level does not stimulate enough interest in the program.

Verification of Savings

Less than half of the programs surveyed have completed an evaluation, and of those that have, most

relied on customer surveys and engineering estimates in order to perform process and impact evaluations. Some programs do use monitoring or end-use metering, while others may rely on metering by the customer or billing analysis.

Five evaluation reports were obtained to provide more detailed information about the evaluation processes. Four of the five studies estimated the free-rider participation, and then adjusted the savings levels to determine the amount of savings attributable to the program. The level of savings, in most cases, is determined by engineering estimates and calculations. One study used actual customer load and equipment data, determined from a survey, while the others tended to rely more on assumptions about the average load.

While it may be more expensive or time-consuming to perform metering or re-audits, it can be much more informative. For example, when B.C. Hydro re-audited customers who had installed ASDs under their Power Smart Efficient Fans program, they found that 20 percent of the firms had failed to use the ASDs as intended, primarily due to changed schedules or new operators. The program is now working on better educating those firms so that their equipment is more fully utilized.

Other Factors that Affect Choice

One problem with performing extensive audits both before and after an installation is that it can delay the installation of a measure. Large expenditures may need to be approved by the plant, making replacement of failed equipment more difficult since most plants can't afford to wait. Concerns such as these can raise barriers to implementation of EMS as many firms may operate under time constraints. Utilities which encourage planning ahead and that attempt to work their program time line coincide with their customers can help to alleviate part of the time constraint barrier.

One of the changes Minnesota Power made was to increase the application and installation period to 24 months because customers were having difficulties in making the project time frame coincide with their capital expenditure planning process. The program is geared toward large industrial customers who are

planning major efficiency improvements, so two years is most likely not a problem. For customers who are looking for immediate replacement or who have not considered efficient motors, a lengthy processing period can be detrimental.

Successfully marketing the DSM program can also help in reducing the time constraint barriers, as knowledge of a program may encourage advanced planning on the part of the customer. One would expect that as barriers are addressed, participation rates would rise. While no programs suggested changes in their marketing techniques, the way in which a program is marketed can have direct effects on the successfulness of that program. For example, due to budget cutbacks, one utility currently must rely on word of mouth advertising by vendors. Because this limits the awareness of the program, the participation rate is affected. Bonneville Power Administration (BPA) has found that face-to-face contacts are the most effective, and 18 out of 25 programs utilize some form of personal contact, usually through the use of company representatives.

BPA also believes that it is very important to get to know the customer and the customer's facility. This knowledge can be applied toward program changes, as Minnesota Power has discovered. The main focus of Minnesota Power's customers is not on energy conservation, so the utility has added provisions for productivity and efficiency projects to their program. Targeting the program toward the customer's concerns can increase participation.

Marketing the program from different angles may also increase participation. Commonwealth Edison in Illinois distributes brochures which approach the benefits of program participation in a variety of ways. Approaches include environmental benefits and the potential savings involved.

Three programs raised concerns about efficiency level requirements during the survey. Most programs rely on efficiency guidelines set by the National Electrical Manufacturers Association (NEMA), although some use other efficiency levels, such as those developed by the Washington State Energy Office (WSEO) and BPA. Two programs are considering raising their current efficiency requirements to make

qualification for the program more difficult, while one is considering a decrease because so many applicants are turned down. In the case where efficiency requirement levels are viewed as being too high, barriers to installation of EMS may be introduced. If customers attempt to participate but find that their selected motors don't qualify, they may opt to purchase standard efficiency motors due to the cost associated with higher efficiency motors.

Vendor Incentives

Vendor incentives are provided for a variety of reasons. Incentives can be considered a payment for services rendered, as the vendor can help the customer select the proper motor and take care of the paper work associated with the rebate application; or to encourage the vendor to stock the more efficient equipment that he/she might not otherwise carry. Other programs consider the incentive as a means to increase participation rates, assuming that incentives will encourage vendors to be more thorough or aggressive in marketing the motors that qualify for rebates.

Vendor incentives may also address some of the barriers to customers. If a customer needs a motor immediately and the vendor has been encouraged to stock efficient motors in that size, then the customer may be more likely to buy the efficient motor, assuming he/she knows about the customer incentive, since it is immediately available. Vendors can also eliminate some of the hassle of paperwork and processing for rebates so that the customer is not discouraged by the amount of paperwork needed to receive the incentive.

Currently, there are seven programs that offer vendor incentives, however, one is being phased out at the end of 1992, and another will be reducing the incentive amount. Incentive levels usually are based on horsepower, although one program pays on a per motor basis while another is based on kW saved. The incentive amount ranges from \$1 to \$3 per horsepower for motors and from \$1 to \$5 per HP for ASDs. Programs offering incentives greater than \$1 per HP place limits on the total rebate amount.

New York State Electric and Gas (NYSEG) does not have a specific motors program, but does provide

motor rebates as a part of each of three programs that they run. NYSEG has been offering a vendor incentive equivalent to approximately 10 percent of the customer incentive, which equates to \$2 per HP for motors and from \$14 per HP for smaller ASDs to \$7 per HP for the larger ASDs. Originally, the incentive was designed as an award to vendors for stocking energy efficient motors. Vendors have seen the merits of this practice, and have changed their stocking habits. Both the utility and their trade allies, which include vendors and distributors, believe that the incentive is no longer necessary. NYSEG also participates in cooperative advertising with vendors, and provides up to half of the advertising costs, up to a set limit. This aspect of the utility-vendor relationship is expected to continue.

B.C. Hydro offers many efficiency programs as a part of their Power Smart program. Suggested changes for their High-Efficiency Motors program include reduction of rebate amounts for both customers and vendors, as vendors receive a percentage of the customer rebate level. Currently vendors receive 20 percent, usually \$75 per kW saved, so the more efficient the motor, the higher the rebate. If the customer is trading in a motor, both the customer and the vendor are eligible to receive an extra 50 percent of the rebate level. The utility has determined that the market has reached a stage where a reduction in incentive level would not be detrimental. Efficient motors are a four-to-one seller over standard motors, and the utility has determined that efficient motors have an 80 percent market share.

There are also four programs which are looking into the addition of vendor incentives. For example, when New England Electric System's Design 2000 program was originally designed, it did not include a vendor incentive because vendors claimed that they did not need one; however the program is now considering the addition of an incentive to try to increase market penetration.

Trade Allies

One of the points made in B.C. Hydro's evaluation of their motors program was the recognition of the

importance of trade allies. Trade allies include vendors, distributors, and manufacturers, and almost all of the programs involve trade allies to some extent. The degree of involvement varies from informing vendors about the program and providing them with rebate forms, to sharing advertising costs and involving vendors in seminars and workshops. Some programs also work with the manufacturers, holding annual meetings, coordinating program expectations with available motors, or tracking industry developments.

Education and Technical Assistance Programs

While the financial incentive attempts to interest a customer in the program, it may not be enough if the customer is unfamiliar, and therefore apprehensive, about the installation of new technologies. To address this concern, educational materials are often presented explaining the benefits of efficient motor systems. Only two of the utility programs surveyed do not offer any educational materials.

Once a customer is interested in the program, all but one program surveyed will offer the customer technical assistance in some form. Technical assistance can range from the provision of software and worksheets to help calculate potential energy savings to extensive energy audits and recommendations for efficient measures. By providing educational and technical assistance, the utility reduces barriers associated with the cost of information to the customer.

Customers

While almost all utility programs offer educational and technical assistance to the customer, the degree of the assistance varies. Educational assistance is provided through brochures and pamphlets, seminars and workshops, and software packages. Technical assistance ranges from the assistance in the calculation of savings estimates to retaining consultants to full scale energy audits, provided free of charge.

Northern States Power Company—Wisconsin sponsors sessions with motor and ASD manufacturers who present seminars to interested customers. The utility, in conjunction with other Wisconsin utilities, also holds an energy conference every other year

which provides information from vendor booths and includes technical sessions about the latest technologies and how they are applicable to the commercial and industrial sectors.

Vendors

Almost half of the programs provide educational materials to vendors, either to help them in marketing the program to smaller customers or to try to convince them to stock efficient motors. Eleven programs offer marketing assistance to vendors, ranging from brochures and display materials to cooperative advertising and cost-sharing for mailings.

Trade Allies

Assistance to trade allies, other than vendors or distributors, is primarily limited to an exchange of information.

Public

While some utilities use mass media approaches to advertise their motors programs, most do not extend their educational or technical assistance programs to the general public.

Characterization of State Programs

States were contacted to determine what state-sponsored programs were in effect to encourage the use of efficient motors and adjustable speed drives. An overview of programs offered by states and utilities appears in Table 2.

While most states contacted do have some conservation programs in effect, no state sponsored a program specifically aimed at efficient motors. With funding from DOE and the Bonneville Power Administration, personnel at the Washington State Energy Office developed the MotorMaster program which is currently used by several states to identify high efficiency motors for particular applications. Individuals in five state energy offices indicated their states were either considering programs specifically stressing efficient motors or including motors with other conservation options such as efficient lighting.

Financial Incentive Programs

Eighteen states do provide some financial incentive for the installing efficiency measures. Depending on the type, financial assistance can help to reduce or eliminate the difference in cost between standard and efficient technologies. Financial assistance can occur as a tax credit, a low-interest loan, a general loan program, rebates, or grants.

Tax Credit Programs

Only two states currently offer a tax credit for investment in energy efficient measures. **Idaho** provides a three percent investment tax credit for businesses, and efficient motors and drives installations may be eligible. **Oregon** makes a tax credit of 35 percent of energy efficient project costs available through the Oregon Department of Energy.

Low-Interest Loan Programs

Six states offer low-interest loans for efficient motors and drives. **Idaho** provides low-interest loans through the Idaho Department of Water Resources for efficient motors and drives systems. The **New York State** Energy Office provides interest subsidies for the installation of efficient motors and drives through the Energy Investment Loan Program. The **North Carolina** Department of Economic and Community Development, Energy Division, provides low-interest loans to commercial and industrial firms for projects to improve energy efficiency. **Oregon** makes low-interest loans available for energy efficient motors and drives. **Rhode Island** offers low-interest loans for installation of efficient motors and drives systems through the Rhode Island Governor's Office of Housing Energy and Intergovernmental Relations. The **Tennessee** Department of Economic and Community Development Energy Division offers 5 percent interest loans for energy efficient projects under the Tennessee Small Business Energy Loan program.

Other Financial Incentive Programs

Twelve states offer other forms of financial incentives, including regular loans, grants, and rebates.

Table 2. State-by-State Overview of Motor and Drive Incentives

State	Utility C&I DSM Programs	State-Supported Financial Incentives	Motor Standards	State Laws and Regulations*	PUC Regulatory Incentives
AL, AK, DE, KY, MS, SC, WV, WY					
AR, LA	Yes	Funding available			
Arizona		Loans			Yes
CA, CO, IN, MD, MI, MT, NJ	Yes				Yes
Connecticut	Yes	Grants	Yes		Yes
DC, MA	Yes		Yes		Yes
Florida	Yes		Have not yet gone into effect		In Progress
Georgia	Proposing		Yes; upgrading		In Progress
Hawaii		Yes: Counties		In Progress	
Idaho, Oregon	Yes	Tax credits, Low-interest loans		Yes	
Illinois	Yes				No formal action
Iowa	Yes			Yes	Yes
KS, NH, OH					Yes
Maine	Yes	Grants			Yes
Minnesota	Yes		Proposed		Yes
Missouri		Loans under dev.			
Nebraska, Utah		Loans			
Nevada	Yes				In Progress
NM, VA					In Progress
New York	Yes	Interest subsidies	Yes		Yes
North Carolina	Yes	Low-interest loans			In Progress
North Dakota	Yes	Grants, Rebates			
Oklahoma	Yes	Funding available			No formal action
Pennsylvania	Proposing				In Progress
Rhode Island	Yes	Low-interest loans			Yes
South Dakota	Yes	Loans			
Tennessee	Yes	5 percent interest loans			
Texas	Yes	Funding available			Yes
Vermont	Yes		Yes	Yes	Yes
Washington	Yes		Some cities		Yes
Wisconsin	Yes				No formal action

*Requiring the purchase or use of efficient motors.

Source: Battelle, Pacific Northwest Laboratories; January 1993.

Information about the Connecticut and Maine programs was provided by the PNL survey. **Arizona** offers an energy loan program which includes loans for efficient motors and drives. **Arkansas** Energy Office's Institutional Conservation Program Energy funds conservation measures for the installation of efficient motors and drives. **Connecticut** sponsors a grant program for water companies. The Energy Division of the **Louisiana** Department of Natural Resources has funded energy conservation measures involving the installation of efficient motors and drives through their Institutional Conservation Program. **Maine** has a grant program under which the installation of efficient motors and drives would be eligible. **Missouri** has recently authorized a new Commercial and Industrial Loan program through legislation, and it is currently under development. Motors and drives systems will be eligible for financing under the new program.

The **Nebraska** Energy Office provides loans for energy efficiency improvements in pumps, wells, and irrigation systems through their Energy and Dollar Savings Program. The **North Dakota** State Buildings Energy Program provides grants for efficient motors and drives in state institutions, and rebates are available through the SECP Buildings Program. The Division of Community Affairs and Development, **Oklahoma** Department of Commerce, funds conservation measures involving the installation of efficient motors and drives through their Institutional Conservation Program. The Governor's Office of Energy Policy, through the **South Dakota** Energy Conservation Loan Program, will provide loans for the installation of efficient motors and drives. **Texas** has provided funding for conservation measures involving the installation of efficient motors and drives through the Institutional Conservation Program of the Governor's Energy Office. The Governor's Energy Office also offers funding for retrofits through their LoanSTAR (Loan to Save Taxes And Resources) program. **Utah** makes loans available for State buildings through the Energy Office's Institutional Conservation Program.

Energy Efficient Motor Efficiency Standards

Seven states plus the District of Columbia are known to have energy codes or building standards that address efficient motors and drives systems. Two additional states have cities or counties which are addressing motor efficiencies at the local level. Through the implementation of motor standards, some of the barriers to voluntary installation of efficient motor systems are eliminated. The concerns that raised those barriers initially are still in place, however. In the absence of other programs designed to address those concerns, it is possible that building standards requiring greater efficiency will be met with more resistance than if the firms affected were informed as to the benefits of EMS. All information, except where noted, was provided by the report, "Electric Motor and Drive National Inventory."

Connecticut has recently amended its building standards by adopting ASHRAE/IES 90.1. The **District of Columbia's** minimum power factors and minimum efficiencies are specified for some motors under the Constructions Codes Supplement, DCMR Title 12: Section 430-1 of the Electrical Code Supplement. **Florida's** new commercial buildings standards based on ASHRAE 90.1-89 will go into effect in January 1994. (PNL Survey) In **Georgia**, energy codes cover residential, commercial and industrial buildings, based on the Model Energy Code (MEC) and ASHRAE-86, with specific standards for efficient motors based on federal standards. Building standards are currently being upgraded. (PNL Survey)

Counties in **Hawaii** require minimum efficiencies for air conditioning systems based on ASHRAE standards. The commercial building code in **Massachusetts** is based on ASHRAE 90.1 but allows for benefit-cost analysis to be performed to argue that conservation measures are in place. This gives builders flexibility in demonstrating that a given technology which is other than that prescribed in the code, will result in equal energy savings. (PNL Survey) The State of **Minnesota** is issuing an energy

code that will require motors to meet NEMA plan B efficiency standards. (PNL Survey) New York State Energy Code 7813.52 addresses efficient motors and drives systems. In Vermont, the 1991 Energy Conservation Standard adopted the ASHRAE 90.1 standard for motor efficiency. The standard also requires that motor replacements be judged on a life-cycle cost basis. In Washington, Seattle municipal building codes mandate energy efficient motors for HVAC systems, and other cities may have similar building code requirements.

State Laws and Regulations Pertaining to EMS

Only two states are known to have passed legislation or regulations pertaining to efficient motors and drives. Laws and regulations, like standards, mandate efficiency levels, and consequently eliminate some of the barriers associated with voluntary implementation of efficient motor technologies. The following information was taken from the report, "Electrical Motor and Drive National Inventory," (USDOE, 1993). In 1990, the State of Iowa passed legislation requiring utility DSM. Life-cycle costing for motors will be used by the State of Vermont in reviewing land-use applications for commercial and industrial development proposals in accordance with a regulatory act, Act 250.

Education and Technical Assistance Programs

Six of the states contacted by PNL mentioned that their state energy office either conducts or subsidizes technology assessments or energy audits through which customers are advised of the potential for high efficiency motors. At this point though, the customer must appeal to the utilities for programs offering incentives for efficient motors. Some states indicated they also conduct workshops on various aspects of energy consumption and, where appropriate, high efficiency motors and ASDs are discussed and encouraged.

The following states offer some form of technical assistance. With the exception of Oregon, the information was also taken from (USDOE, 1993). Energy audits are provided by the Arkansas Energy Office's State Energy Conservation Plan through the Indus-

trial Assistance Program. The Florida Energy Office is developing a Public Sector Buildings Retrofit program, under which efficient motors and drives will be eligible. The Idaho Department of Water Resources, Energy Division provides industrial facility audits and pump efficiency testing. The Building Efficiency Section of the Illinois Department of Energy and Natural Resources offers motor efficiency and load factor testing. While Massachusetts does not have a specific motors and drives program, efficient motors and drives are included as components within programs. Most programs provide energy analyses.

The State of Missouri offers engineering analyses to identify energy savings opportunities for small commercial and industrial firms. The Montana State Building Energy Program will identify energy conservation projects in state owned facilities. Technical assistance for life-cycle cost analyses and state owned and leased buildings are provided by the New Jersey Department of Environmental Protection and Energy Office of Energy SECP Life Cycle Cost Project and the New Jersey Department of Treasury, General Services Administration, Division of Facilities Management. New York provides technical assistance and energy audits through the New York State Energy Office under the Energy Advisory Service to Industry and Technical Feasibility Study Programs. North Carolina State University currently holds a contract to run the NC Energy Management Technology and Technical Assistance Project. The project includes workshops in areas including motors and drives and provides technical assistance. The Oregon Business Energy Tax Credit program does provide for technical assistance to participants. This is provided on a first-come first-served basis depending on staff availability.

Information Programs

The following states provide information to interested parties. The information was also taken from (USDOE, 1993). Seminars which include a session on efficient motors are conducted by the Arizona Energy Office. Information about motors and drives is provided on request by the Colorado Office of Energy Conservation. The Idaho Department of Water Resources, Energy Division provides information and

technology transfer by request. North Carolina State University currently holds a contract to run the North Carolina Energy Management Technology and Technical Assistance Project. The project includes workshops in areas including motors and drives and provides technical assistance. The Oregon Department of Energy provides technology transfer and information as requested. Information on energy efficient motors and drives is provided to manufacturers and industries through the Pennsylvania Energy Office regional Energy Centers. The Washington State Energy Office provides technology transfer and efficiency information. WSEO also developed and maintains the MotorMaster energy-efficient motor database, which is distributed nationally. The Wisconsin Energy Bureau will provide information about energy efficient motors when it is requested.

Other Issues

There are other issues that should be addressed although their impact on the success of a program may not be as obvious. They include motor rewinds, what to do with replaced motors, and free-riders.

Motor Rewinds

None of the programs surveyed address motor rewinds or rewind practices directly, although four are conducting research. BPA currently distributes some educational material on rewinds within their Energy-Efficient Electric Motor Selection Handbook, as part of their electric motors kit. Ontario Hydro is in the process of working with the Electric Apparatus Service Association to develop a quality assurance program for rewinds. They have conducted two studies; one examining standard motor rewinds, and the other examining multiple rewinds of a single motor. They are also examining a study conducted by B.C. Hydro regarding high efficiency motor rewinds. B.C. Hydro is also working to establish rewind quality assurance. New England Electric System is in the process of developing educational materials to improve rewind practices, and United Illuminating in Connecticut has hired a consultant to examine motor rewinds and may adjust their incentives for rewindable motors.

Replacement Motors

The issue of the replaced motor is a concern, although only five programs address it. Three require that the motor be destroyed or rendered inoperable. One allows for motors to be traded in, and the trade-ins are destroyed, and one program asks customers what they did with their old motors, but the information has not yet been analyzed. One concern raised was that of enforcement, as it is difficult for the utility to ensure that actual motor destruction takes place. For example, some programs originally required the removal of the old motor name plate, however the practice was discontinued because it did not prevent the use of the old motors.

Of the programs that do not have requirements placed on replaced motors, ten said that they did not track the information, four said that they hoped the motors were destroyed, one thought they might be recycled, and one thought that they might be rewound for emergency use, although none of the respondents knew exactly what happened. One utility knew of at least one replaced motor that had been refurbished and resold.

Free-Riders

Four programs have calculated the free-ridership associated with their programs. Central Maine Power (CMP) estimated through surveys that free riders accounted for 55 percent of the rebates. CMP questions this high rate, however, indicating that a single survey data source may not accurately reflect free-rider participation. (CMP 1990, p. 14)

New England Electric System (NEES) Design 2000 program calculated a 50 percent free-ridership for motors, based on interviews covering key areas such as whether or not the measure would have been specified without the incentive, how important the incentives were in comparison with other considerations, the stage at which the customer entered the program, changes made to original plans and specifications, if the customer specified similar measures in other service areas, and if the other service areas had any type of incentive program. The Design 2000 program

evaluation predicts that free-ridership over time will decrease since the initial participants are likely to be the most energy conscious.

For the NEES Energy Initiative program, free-ridership was calculated to be 22 percent for motors. This estimation was derived using several different methods. Participants were asked what actions they would have taken without the program, and then were asked if they would have spent the same amount of money, including the incentive amount, to install a measure within the same time frame. Estimates for both methods were similar, however, NEES considered the second method to be more accurate since it involved the willingness to commit funds.

Niagara Mohawk Power Corporation calculated an initial free-rider rate of 40 percent for their motors and drives program through a survey, and then reevaluated the respondents indicating free-ridership using payback analysis. Using the second method, the free-rider participation rate was estimated at 23 percent. The rate decline is attributed to those respondents who claimed that they would have purchased an efficient motor without the rebate, but in actuality would not have because their company had set payback policies that the efficient motor or ASD would not have met. (Bartlett et al. 1992, p. 4-16)

The CMP evaluation recommends that the utility should continue to monitor the free-rider rate. They expect the rate to increase over time as a customer is likely to apply for rebates on future purchases. The recommendation is also made, therefore, to limit the total cumulative rebate available to a given customer. (CMP 1990, p. 23) However, Northern States Power Co.—Wisconsin (NSPC) expressed a different situation. NSPC customers have been happy with the efficiency improvements and have begun to implement measures on their own, without applying for the available rebates. Part of their success may be attributable to the education of the customer in that customers can learn how to apply efficient technologies to their own processes.

Implications for Market Barriers

The most commonly mentioned reported barriers to greater market penetration of efficient motors

include: (1) their higher first cost compared to standard efficiency motors; (2) the lack of information on the part of the user about efficient motor systems; and (3) the immediacy with which a replacement motor is usually needed. Many programs offered by the states and utilities are working to address these barriers.

All utility programs surveyed contained a customer incentive to encourage the use of efficient motors over standard motors. The incentive, whether it is a rebate or a payment for demand reduction, is designed to reduce the difference in price between the efficient and the standard motor.

Another barrier is that the industry motor user may not know much about efficient motor systems, and may not have the time or money to invest in information gathering. Most utilities surveyed, and some state programs, offer educational and/or technical assistance at no charge. Educational assistance is provided through brochures and pamphlets, seminars and workshops, and software packages. Technical assistance ranges from the assistance in the calculation of savings estimates to retaining consultants to full-scale energy audits.

Services such as these take time, however, and it is often the case that the customer does not think about replacing a motor until that motor fails. Customers are then concerned about "down time" as they don't have time to spare to investigate efficient motors, determine an appropriate efficient motor replacement, and then go through a rebate process. It is also possible that the motor vendor may not have the appropriate efficient motor in stock. It therefore becomes easier to replace the failed motor with the same standard efficiency motor, or to rewind the failed motor.

Utilities are addressing this barrier by marketing their programs through personal contacts with the potential customers. These contacts can inform the customers about the program and encourage them to plan ahead. Through the additional use of vendor incentives or training, vendors may be more inclined to stock efficient motors, educate their customers about efficient motors, and may also take care of the paperwork required for the rebates. These services can reduce the down time and the inconvenience for the

customer who might otherwise have to deal with receipts and paperwork.

Utility and state programs have taken steps to encourage greater market penetration of efficient motors and EMS. There are several remaining issues that should be addressed although their impact on the success of a program may not be obvious. The most important of these are the disposition of replaced motors, motor rewinds, and free-riders.

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Appendix C: Summary of Highlights: Efficient Electric Motor Systems Conference

On February 9–10, 1993, the Department of Energy and the Electric Power Research Institute cosponsored a conference on Efficient Electric Motor Systems to draw together the many participants who affect the market distribution chain for electric motor systems (EMS) and to discuss issues and exchange information about ongoing and planned EMS activities. More than 400 participants, representing

virtually every stakeholder with an interest in EMS appeared in Baltimore for this EMS Conference. The large turnout exemplified the high interest in this undertaking. The 2-day conference preceded the February 11 expert roundtable on Efficient Electric Motor Systems for Industry.

This appendix reprints the summary of conference highlights prepared by the conference sponsors.

Energy Efficient Electric Motor Systems

EPRI
Electric Power
Research Institute

A National Conference

Coordinated by: Resource Dynamics Corporation · 8605 Westwood Center Drive · Vienna, Virginia 22182 · (703) 356-1300 · Fax: (703) 356-2230

February 9-10, 1993 -- Baltimore, Maryland

SUMMARY OF CONFERENCE HIGHLIGHTS

The first EMS Conference brought together a diverse group of stakeholders, providing the opportunity to help shape the nation's electric motor systems agenda. A structured forum of plenary, case study, and specific interest sessions laid the groundwork for an active exchange of ideas, needs and program priorities. The meeting resulted in a series of recommendations addressing key market issues and barriers impacting the widespread adoption of efficient EMS:

1. Targeted End-User Education/Identification of Decision Maker

Conference participants stressed the need for educating end-users about the benefits of efficient motors and drives, and associated procurement and maintenance programs which stress energy efficiency as an evaluation criteria. It was pointed out that while the plant engineer may be quite familiar with the advantages offered by these efficient systems, the "user" includes others from the manufacturing firm. In addition to the technical or maintenance personnel, other groups within the user organization including the purchasing department and the company senior management need to be better informed about the advantages of efficient EMS. In fact, the need for establishing a corporate commitment to efficiency improvement was underscored in a number of the conference sessions. A targeted program to make senior management more aware of and a better understanding of efficient EMS was seen as a potentially significant benefit.

Participant comments:

"Unless there is a top down directive by management to improve efficiency most plant operators will not take a chance on a new idea. Most of management are not engineers, so it is very difficult to explain basic principles such as affinity laws."

"Need better identification of the full decision making group beyond the end user. Most purchases are influenced by consultants in new construction and maintenance companies in retrofits. How do we incentivize their participation? How do we address the consultant's risk of downsizing with respect to their potential liability?"

"Conflicting and ambiguous information of vendors and utilities leaves customers uncertain of the real benefits."

2. Greater Focus on Vendor Incentives

The EMS equipment suppliers and distributors are in a unique position to influence the purchaser decision to seek (or not to seek) energy efficiency. Many vendors actually have little, if any, incentive to offer the premium efficiency product line. This occurs since they may actually obtain greater profit margins or deeper discount rates by virtue of the purchasing arrangement they have with the manufacturer. It was widely felt that the expansion or availability of utility incentives paid directly to vendors for stocking and selling efficient EMS products would be a major step in encouraging their widespread use and application.

Participant comments:

"Encourage the vendors and distributors to sell premium efficiency equipment."

3. Track and Communicate EMS Activities and Events

The first EMS conference was attended by over 400 participants. Many participants portrayed intense interest and intense confusion, primarily a result of the preponderance of technical tools, new and current products, and wide range of utility incentive programs facing the participating stakeholders. On top of this, new legislation, regulations, shifting economic policies, and research and development on new or advanced products promises to further blur the EMS marketplace.

There was a common plea for the conference sponsors to establish a tracking and communication mechanism that would keep all stakeholders informed of current and planned developments. Further, it was generally agreed that this communication mechanism should also provide a forum for exchange of ideas and information between stakeholders.

Participant comments:

"There is so much going on in this area that we can barely keep up with the developments. Put out a newsletter or phone number we can call to get the latest information."

4. More Emphasis on System Considerations and System Responsibility

The conference focus on the electric motor system, rather than only the motor itself, was a major breakthrough for many of the attendees. The EMS includes not only the motor but the electric power supply source, the controller or adjustable speed drive, the motor, the driven mechanical equipment, and the process load being served.

A number of vendors and manufacturers noted that responsibility for selection of system components is often spread across a number of suppliers or engineering groups (e.g., the adjustable speed drive specified by the electric engineer with the compressor specified by the mechanical engineer). An important step in encouraging the use of efficient systems was to

integrate system responsibility at a single decision point, with a primary criteria of achieving optimal system efficiency.

Participant comments:

"We need case studies of more comprehensive approaches to motor systems, potentially demonstrating the much larger savings available."

"Broader based utility DSM incentives need to be offered, primarily focusing on system components other than the motor, or on overall system efficiency."

5. Guidance on Implementing an Efficiency Program

Conference participants, in surprising numbers, requested assistance on evaluating EMS efficiency improvement opportunities, as well as guidelines on how to implement an efficiency program in their plant or facility. Information that might be provided should include:

- cost of individual equipment, maintenance and engineering support, and the costs associated with establishing such a program
- realistic goals for implementation and efficiency improvement
- typical timelines and schedules for establishing and implementing an efficiency program.

As part of this effort, access to specific experts in various industries and equipment applications would be quite helpful since many users lack the staff resources to evaluate their EMS applications and opportunities. Guidance on verifying program savings is also needed.

Participant comments:

"The lack of application design tools that enable quick and proper equipment selection is a barrier to user adoption of efficient EMS."

6. Standard Performance Testing Procedures

Participants expressed a need for standard performance testing procedures for motor-driven systems. One example given was the lack of such a procedure for compressed air applications. While IEEE 112 and other standards govern the efficiency testing of motors, little if any national or international standards for other component and system testing have been adopted. This is an area in which the conference sponsors may be well-positioned to foster standards development and/or associated R&D.

7. Closer Look at Motor Repair Issues

Most stakeholders were still confused regarding the role of motor repair in an EMS efficiency program. More data is needed on when to repair and when to replace. More user input into the motor repair issue was sought.

8. Suggestions for Next EMS Conference

- Hold industry trade show in conjunction with conference--similar to national ASHRAE show.
- A longer session for motor repair issues.
- More application type sessions with questions and answers focusing on user concerns.
- More detailed description of sessions up front.
- More breaks and reception time (the real value of the meeting).
- Attract more users to the conference.