THE U.S. MOTOR SYSTEMS MARKET ASSESSMENT OVERVIEW AND PRELIMINARY FINDINGS

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Abstract

This paper summarizes the current status of the US Motor Systems Market Assessment. This component of the U.S. Department of Energy's Motor Challenge program will provide a detailed portrait of the inventory of motor systems currently in use in US industrial facilities and a baseline characterization current practice in regard to motor system component selection, system design, maintenance, and management. This equipment and behavioral baseline will be used to target Motor Challenge program activities and to evaluate the program's impact on the motor systems markets. This paper presents an overview and selected findings from the project's principal research activities: a review of secondary sources on motor systems markets and inventory; compilation and reanalysis of existing primary information on the motor systems inventory; and an on-site survey of 300 industrial facilities.

Introduction

The Motor Challenge Program

In 1993, the US Department of Energy initiated Motor Challenge, a voluntary collaborative effort among government agencies, motor systems suppliers, and industrial end-users designed to demonstrate, evaluate, and accelerate the adoption of efficient motor systems. The Motor Challenge program seeks to transform the markets for industrial motor systems through multiple approaches. Program activities fall into three major categories.

*Programs Targeted to End Users***.** The principal programs targeted to industrial end-users are designed to provide facility managers with information and decision tools to support the adoption of efficient equipment, design practices, and maintenance routines. Information resources include a clearinghouse of motor systems technical information and training programs in various aspects of motor system selection, design and maintenance. Decision tools include computer programs that provide catalog information and support economic analysis of the selection and application of efficient motors and adjustable speed drives.

The *Motor Challenge Partnership* provides industrial facilities managers with access to the information clearinghouse, the decision tools, and some training opportunities free of charge. Motor Challenge Partners are under no obligation to implement specific practices, designs, or equipment purchases. Rather, access to information through the various Motor Challenge channels is designed to reduce the information costs and perceptions of risk associated with adoption of efficient technologies and practices.

Other end-user oriented program components include the following.

- *Showcase Demonstrations* are designed to develop information on the field performance of efficient motor system technologies and design practices.
- *The Excellence Partnerships* targets large, multi-facility companies. The program provides intensive technical and monitoring support for the development and documentation of comprehensive strategies to improve motor system purchase, management, design, and, ultimately, efficiency.

*Manufacturer Initiatives***.** *Industry Partnerships* focus on working with trade associations that represent the major motor and OEM equipment makers (pumps, fans, and compressors) to facilitate the flow of information about efficient equipment and practices from manufacturers to end-users. Most of these initiatives involve the development and operation of joint training programs oriented to designers and end-users. As part of this effort, the Compressed Air and Gas Institute is developing equipment test certification procedures, produce efficiency labels, and efficiency specification sheets.

Channel Development Motor Challenge has recruited a number of organizations to help disseminate its materials and services to end-users through the *Allied Partnership.* Allied partners include primarily utilities, designers, and contractors who perceive a value in providing their own customers with information on how to increase the energy efficiency of their facilities.

The Motor System Concept

The term "motor system" refers to a set of motor-driven equipment which are connected together and operated to achieve a single, identifiable result. Motor systems can be as simple as a drill press in a machine shop or as complex as a rolling stand in a steel mill. Motor systems are generally made up of the following three groups of equipment.

- *The Motor-Driven Package.* The package consists of *components* including the motors themselves, pumps, fans, air compressors, and blowers (and associated drive trains and controls) which are often assembled by original equipment manufacturers (OEMs) for delivery to end-users.

- *The Process System.* The process system consists of the equipment "downstream" from the motor-driven package which actually applies energy to the materials to be processed or moved. Examples of process systems would include grinding machines, printing presses, process refrigeration equipment, and machine tools of all kinds. The process system also consists of the piping, ducts, and mechanical transmissions used to connect the motor-driven package to the equipment that operates directly on the materials in question.
- *The Power Supply.* The power supply consists of the switches, transformers, cables, and, in some cases, the power quality mitigation equipment that links the motor to the plant's external power supply.

In a given motor system, the three equipment groups listed above are closely integrated. Changes in any one of them will likely affect the operation of the others, and thus the efficiency of the system in terms of kWh used per unit of output.

Requirements of the Motor Challenge Baseline

To be useful for evaluation, the Motor Challenge baseline needs to estimate current efficient equipment saturation and market penetration and to identify market barriers. However, the size and complexity of the motor system markets, the nature of motor system energy efficiency measures, and the range of Motor Challenge program activities requires that the baseline incorporate additional kinds of information. The following paragraphs provide examples of these requirements.

- *Scale and diversity of the targeted markets.* There are roughly 350,000 manufacturing establishments in the US; over 125,000 with 20 or more employees. Among industry groups defined at the broadest level (2-digit Standard Industrial Classification (SIC) codes), motor drive consumption varies from as low as 26 percent of all net electrical use (Instruments and Related Products) to over 80 percent (Pulp and Paper Products, Petroleum and Coal Products
- *Program objective of changing on-going practices.* In most industrial facilities, motors and motor-driven equipment are replaced or reconfigured on a fairly continuous basis as machinery wears out and production requirements vary. Thus, Motor Challenge targets change in an interrelated set of design, purchasing, maintenance, and operating practices which can involve a number of different individuals and divisions within a facility. These include, for example: decision rules applied to deciding whether to replace or rewind a motor and the application of certain kinds of "best practices" to maintaining air compressors or pumps. The baseline therefore needs to contain information on who makes decisions on these matters in various kinds of facilities, as well as on the prevalence of a broad range of practices.
- *Nature of energy efficiency opportunities in motor systems.* In most industrial motor systems, the greatest portion of potential energy savings derive from proper configuration (or reconfiguration) of the Process System to minimize load on the Motor-driven Package. Additional savings are then available through proper sizing package components, selecting control strategies that most efficiently meet the reduced load, and implementing appropriate maintenance procedures. The substitution of efficient components into otherwise unchanged systems yields low savings when compared to the strategies involving system design and maintenance. Thus, useful estimates of efficient equipment saturations requires some characterization of the configuration and principal process applications of motor systems in various industries.

Market Assessment Research Activities and Products

The Baseline Survey

The principal research effort of this project is a national survey of a representative sample of 300 industrial facilities.[i] The survey consists of two parts:

- *Motor Systems Inventory:* The inventory contains the results of on-site surveys of the sample facilities carried out by trained field engineers. The survey for each facility contains records of all motor-driven packages (one horsepower and above) at the site, including identification of the motor systems and processes in which they are used, characterization of load, and nameplate data such as motor type, horsepower, and nominal efficiency. In larger sites, motor systems are sampled rather than inventoried as a census. The results of the Motor Systems Inventory will be used to estimate the magnitude of motor energy usage by industry group and type of industrial process and the extent of potential energy savings available through various efficiency measures.

[i] For a detailed description of sampling and data collection procedures for the baseline survey, see XENERGY Inc. (1997) *Interim Report: United States Industrial Electric Motor System Market Assessment*, Appendix B.

- *Motor System Purchase and Maintenance Practices Survey (Practice Survey).* The Practice Survey gathers information on the prevalence of various motor system design, purchase, maintenance, and management practices in the sample facilities. It also collects information needed to model the change in the motor systems inventory over time, for example: the percentage of motors rewound versus replaced upon failure in various horsepower ranges; the number of times motors are rewound; the percentage of motors in service that fail each year.

The survey is currently in the field and is scheduled to be completed in September 1997. Results will be available in the form of a report and public access data base by the end of 1997.

Review of Secondary Literature. Prior to designing and deploying the Baseline Survey, we undertook extensive research on the existing motor systems inventory, purchase and maintenance practices, energy efficiency measures and their application, and motor systems markets.

Acquisition and Analysis of Existing Primary Data Sources. Through work in this field, we became aware of a number of databases of facility audits that contained motor inventories or detailed descriptions of selected motor systems. We acquired, compiled, and reanalyzed most of the primary sources we could identify to both supplement and guide our work on the baseline survey. These sources included:

- *The Midwest Utility Database.* Between 1987 and 1992, several Midwest utilities commissioned XENERGY to undertake energy audits of representative samples of commercial and industrial facilities. These audits included motor system inventories which captured information on motor size, efficiency, application, and hours of operation. The samples were statistically selected to represent the composition of commercial and industrial customers within the client utilities' service territories.
- *The Industrial Assessment Centers Database.* This is a database of 4,852 industrial facilities audits conducted by a Federally-supported, university-based engineering program provides a "bottom up" view of available motor energy savings. These energy audits were conducted by engineering students and faculty throughout the United States over the past 12 years under the auspices of the Industrial Assessment Center (IAC) program. In addition to general facility and consumption information, the database contains on the number and type of energy efficiency measures identified and estimated savings associated with those measures. The engineers identified the most apparent energy savings opportunities on the basis of quick tours of the facilities. The results therefore reflect a practical lower bound for energy savings.
- *System-level Motor Energy Consumption and Savings.* We obtained engineering studies of process system improvements from the Performance Optimization program offered by a consortium of Wisconsin utilities. These studies ranged in depth from preliminary inspections to detailed estimates of system energy usage and savings using end-use metering data. Generally, these studies contained sufficient data to estimate motor system energy usage prior to optimization retrofits and projected energy savings. Altogether, we received usable reports covering 53 facilities, 64 different motor systems and 78 energy efficiency measures. These data were useful in corroborating estimates of potential system-level energy savings based on engineering judgment and individual case studies.

Selected Findings

The remainder of this paper presents selected findings from the research described above. We focus on three aspects of the end-user side of the market: descriptions of the motor systems inventory in place; estimates of energy savings potential; and motor system purchase and maintenance practices. [ii] This presentation is not intended to be comprehensive. Rather, we provide examples that could have implications for program and policy design or which illustrate the value and limitations of information derived from various data sources.

Aspects of the Motor System Inventory

A Note on Data Sources. A number of recent publications offer fairly comprehensive portraits of the population of industrial motor systems. (E-Source 1993; EPRI 1992; Nadel et al. 1992) These publications take as their principal point of departure the 1980 study *Classification and Evaluation of Electric Motors and Pumps* sponsored by the Department of Energy and carried out by the firm of Arthur D. Little (ADL). The ADL study synthesized a portrait of the motor population in 1977. This consisted of tables showing the number of motors in use and motor energy by horsepower category and industry (SIC). These tables were developed using a variety of sources, with heavy reliance on Census statistics on installed horsepower

[ii] For an excellent overview of the structure of motor system markets, behavior of supply side actors, and barriers to adoption of efficient measures, see Easton Consultants, 1995, also published as **xxx**. Another good source on this topic includes Elliott, 1996.

in manufacturing facilities which were discontinued in 1963.

While the methods used for combining these various sources are not documented, the basic approach appears to have been that of a standard stock adjustment model. That is, some initial population distribution (perhaps provided by the 1963 Census statistics) is "aged" using annual Census data on equipment shipments, exports and imports, and selected materials consumed by establishments in various SICs, less comprehensive information from individual industry studies, control totals provided by national energy consumption statistics on energy consumption by industry, and a long list of assumptions needed to weave these data together. The Electric Power Research Institute study *Electric Motors: Markets, Trends, and Applications* updates this "top down" approach, and provides breakdowns of energy use by broad industry category, motor size, and application.

The other key source of information in characterizing current industrial motor energy use is the Manufacturing Energy Consumption Survey (MECS). MECS is a survey of roughly 15,000 industrial facilities drawn from the Census of Manufactures sample frame. It is designed by the Energy Information Agency and administered by the Bureau of the Census. The survey's principal objective is to estimate consumption of various forms of energy by the population of facilities in all manufacturing industries (SICs 20 through 39). Respondents to the survey report consumption based on fuel and energy bills. MECS estimates the proportion of total electricity used by motors in industrial processes by industry for all two digit SICs, and selected three and four-digit SICs. This allocation is based on the respondents estimate of the allocation of fuels among end-uses. It is not verified through field observations.

Comparing the Results of "Top Down" and Survey Methods. Survey data of the type being collected for the baseline study supports a broad range of detailed characterization and analysis. However, these methods are expensive. Over the past several years, a variety of analysts have used the shipment-based, "top down" methods described above to estimate some basic descriptive parameters on the motor system inventory. In this section, we compare the results of the EPRI study to analyses of the Midwest Utility Database. The results are not strictly comparable in the sense that the EPRI study is national in scope and the other is regional. Moreover, they cover somewhat different time periods. However, as we will see below, the major findings are similar. These findings suggest that inventory characterizations based on aging of shipment data can be useful at least for some purposes.

Distribution of motor drive energy by application. The distribution of motor drive energy among major application groups is a key characteristic of the inventory, in terms of assessing opportunities for energy efficiency. Pump, fan, and compressor systems offer numerous opportunities for energy savings through speed control, as well as other improvements in process system design and operations. Systems-level efficiency improvements are less well understood for materials handling applications. Materials processing applications are so diverse that is difficult to make generalized statements about the nature or extent of energy savings opportunities for those applications.

Table 1 displays estimates of the distribution of motor drive energy among the three major application groups for the four manufacturing subsectors and for manufacturing facilities as a whole.[iii] The results of the two estimating procedures agree in many respects. Pumps, fans, and compressors account for a very large percentage of total motor energy, with particularly high concentrations in the process industries. The estimates differ considerably, however, in the amount of motor energy accounted for by materials handling applications. The Midwest surveys found that materials handling applications accounted for 6 percent of total motor drive energy; versus 27 percent for the EPRI study. We believe that some of this difference could be based on definitions and protocols used in the Midwest surveys. Under these protocols, only machines that were used exclusively for materials handling -- conveyors, cranes, elevators -- were characterized as such. Many kinds of machines, such as packaging lines, rolling mills, and printing presses have materials handling elements incorporated in them.

Distribution of Motor Systems by Motor Size. The distribution of motor systems by size is important for a number of reasons. First, the difference between standard and premium efficiencies are substantially larger in the smaller motor sizes than in the large sizes. Second, historical statistics are available on motor shipments by size. Comparison of this distribution to the size distribution of motors in place can support inferences about patterns of motor retirements and rewinds.

The EPRI (1992) study contains estimates of the distribution of the number of motors, motor horsepower, and motor drive energy by size for large industrial divisions -- manufacturing, mining, agriculture. The break points in the distributions from the two sources could be matched except for the highest category. The Midwest

[iii] SICs contained in each grouping are as follows: **Process Industries**: 20 - Food and Kindred Products, 21 - Tobacco Products, 22 - Textile Mill Products, 26 - Paper and Allied Products, 28 - Chemicals and Allied Products, 29 - Petroleum and Coal Products. **Metals Production:** 33 - Primary Metals Production **Metals Fabrication:** 34 - Fabricated Metals Products, 35 - Industrial Machinery and Equipment, 36 - electronic and Other Electric Equipment, 37 - Transportation Equipment, 38 - Instruments and Related Products, 39 - Miscellaneous. **Non-Metals Fabrication:** Apparel and Other Textile Products, 24 - Lumber and Wood Products, 25 - Furniture and Fixtures, 27 - Printing and Publishing, 30 - Rubber and Misc. Plastics Products, 31 - Leather and Leather Products, 32 - Stone, Clay and Glass Products

database breaks at 100 HP, the EPRI estimates at 125 HP. As discussed in the paragraphs below, the outcomes of both methods are quite similar.

As Table 2 shows, the majority of motors used in industry are fairly small, but these small motors account for relatively little motor drive energy. The EPRI study estimates that motors up to 5 HP account for about 55 percent of all units installed and 4 percent of total installed capacity (HP). Forty-three percent of the motors in the Midwest database are less than 5 HP, and they account for 8 percent of installed capacity. The average horsepower observed in these categories in the Midwest database are higher than the assumptions used in the EPRI study. This explains larger percentage of total installed capacity in the smaller categories. The only other notable difference between the two estimates is in the average HP in the ">126 horsepower" category. In the Midwest database, this is 276 HP versus 185 in the EPRI estimate.

Table 1
Distribution of Motor Drive Energy by Application, Manufacturing

	Process Industries	**Metals Production**	**Metals Fabrication**	**Nonmetals Fabrication**	**All Manufacturing**
Pumps, Fans, Compressors	57% *55%*	51% *20%*	33% *27%*	44% *41%*	49% *41%*
Materials Handling	5% *23%*	18% *30%*	6% *29%*	4% *27%*	6% *27%*
Materials Processing	38% *22%*	31% *50%*	61% *44%*	52% *31%*	45% *31%*

Note: Midwest Database estimates listed first. EPRI estimates in italics.

Table 2
Distribution of Motors and Motor Horsepower by Motor Size, Manufacturing

HP	**Count**	**Total HP**	**Average HP**
<1	19.9% *29.0%*	1.1% *0.5%*	0.9 *0.26*
1 - 5	33.1% *26.2%*	6.9% *3.5%*	3.5 *2*
6 - 20	31.6% *28.2%*	22.1% *18.9%*	11.6 *10*
21 - 50	9.6% *9.1%*	19.5% *18.2%*	33.9 *30*
51 - 100 51 125	3.9% *4.8%*	18.1% *25.5%*	76.6 *80*
>100 >126	1.9% *2.7%*	32.3% *33.3%*	276.4 *185*
TOTAL	**100.0%**	**100.0%**	**100.0%**

Note: Midwest database listed first. EPRI estimates in italics.

<u>*Distribution of Motor Drive Energy*</u>. Table 3 shows the distribution of motor drive energy by size for the four major industrial sectors, based on the Midwest database. The distribution for all manufacturing is weighted to reflect the national distribution of total motor energy provided by MECS. The EPRI results are provided for comparison. We can draw the following conclusions from Table 3.

- Motors over 125 horsepower account for an even larger share of drive energy than of installed horsepower. This is primarily because they have longer duty cycles, on average, than motors in the smaller categories.
- The share of motor drive energy among motors over 125 horsepower is particularly high in the process industries, which handle very large batches of raw materials at once.

- The EPRI estimation, which is based on a stock adjustment model and assumptions concerning load and duty cycle within the horsepower categories, yields a distribution of motor energy which is very similar to that based on observations of manufacturing sites.

Table 3
Distribution of Motor Energy, Manufacturing

HP	Process Industries	Metals Fabrication	Non-Metals Fabrication	Metals Production	All Manufacturing	EPRI
<1	0.4%	1.0%	0.4%	0.4%	0.5%	0.1%
1-5	2.9%	5.8%	3.6%	3.9%	3.7%	0.8%
6 - 20	11.2%	20.6%	14.4%	11.1%	13.3%	10.2%
21 - 50	14.7%	26.0%	27.9%	26.3%	20.6%	18.1%
51 - 100	17.6%	24.4%	17.7%	12.5%	17.8%	28.0%
>100	53.3%	22.3%	36.1%	45.8%	44.1%	42.8%
TOTAL	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**

Concentration of Motor Drive Energy by Industry. Table 4 demonstrates that motor drive energy is highly concentrated within a small number of industry groups, especially in the manufacturing sector. The ten 4-digit SIC groups listed in Table 4 account for over 50 percent of drive energy in manufacturing. Yet these groups contain fewer than 3,000 or 2.5 percent of all manufacturing establishments with 20 or more employees. The finding of high concentration of drive energy use suggests program strategies tailored to the applications and decision purchase decision making practices common in the listed industry groups.

Saturation of Energy Efficient Motors Energy efficient electric motors have been available from most major motor manufacturers since the late 1970s. However, the substantial difference in costs between efficient and standard motors and reluctance on the part of distributors to maintain extensive efficient motor inventories constrained the adoption of high efficiency models. The Midwest studies performed in 1987 - 1992 found that efficient motors represented only 5.2 percent of all motors and 6.2 percent of the horsepower-weighted capacity installed. Their saturation was somewhat higher in the process and non-metals fabrication industries. Since 1993, high efficiency motors have represented about 20 percent of all domestic integral horsepower motor shipments, with the highest penetration -- 38 percent -- in the 51 - 100 horsepower range. Based on assumptions about rates at which motors are rewound or removed from the stock upon failure, we estimate that efficient motors represent about 11 percent of the motors installed in manufacturing as of the end of 1996.

Quantification of Energy Savings Opportunities. A number of analysts have attempted to characterize potential energy savings in industrial motor systems. Most of these efforts have taken a “top down” approach, similar to that used most frequently to characterize the motor systems population. This approach involves characterizing motor loads in terms of the applicability of various kinds of energy efficiency measures such as upgrading components or installing adjustable speed drives. A “savings factor” developed from field or laboratory observations of an efficiency measure’s performance is then applied to the portion of load to which that measure is applicable. A recent paper published by the American Council for an Energy-Efficient Economy (Elliott 1994) provides an example of this approach. Table 5 summarizes the results of their estimates. The large difference between the low and high estimates highlights the level of uncertainty regarding the applicability and unit savings associated with various measures.

Table 4
Distribution of Drive Energy, Top 10 4-Digit SIC Groups

SIC Code	Industry Description	Consumption for Motors (GWh/Year)	% Consumption for Motor Drive	% Total Drive Energy	Cumulative % of Drive Energy	Establishments w/ 20+ employees
2621	Paper Mills	51,380	84%	11.83	11.83	278
2911	Petroleum Refining	34,631	82%	7.97	19.80	197
2819	Industrial Inorganic Chemicals	30,622	77%	7.05	26.85	322
2631	Paperboard Mills	22,372	83%	5.15	32.01	200
3312	Blast Furnaces and Steel Mills	21,018	47%	4.84	36.84	708
2869	Industrial Organic Chemicals nec	19,568	53%	4.51	41.35	430
2813	Industrial Gases	16,844	92%	3.88	45.23	125
2821	Plastics Materials and Resins	11,209	64%	2.58	47.81	465
3241	Cement Hydraulic	7,302	74%	1.68	49.49	137
2611	Pulp Mills	7,167	84%	1.65	51.14	43
	TOTAL	**222,113**				**2,905**

Sources: MECS 1991, Census of Manufacturers, 1992.

Table 5
"Top-Down" Estimate of Motor Energy Savings Potential
As Percent of Motor Drive Energy in Manufacturing

Measure Type	Low Estimate	High Estimate
Energy Efficient Motors	0.9%	8.3%
Improved maintenance, lubrication, electric supply	8.0%	12.0%
Correcting Motor Oversizing	2.0%	3.0%
ASDs	2.5%	19.7%
(Percentage of load to which ASDs apply)	(16.4%)	(49.2%)
High Efficiency Pumps	0.3%	1.7%
High-Efficiency Fans	0.1%	0.6%

Table 6 summarizes the results of our analysis of the IAC database discussed above. The results shown in Table 6 are consistent with estimates developed through top down methods. For example, compressors are estimated to consume roughly 10 percent of all motor drive energy. The Wisconsin performance optimization studies of savings available in compressor systems and equipment find that savings up to 20 - 50 percent are technically achievable. The 1.9% (of all motor drive energy) identified through the IAC audits, which were not comprehensive, is consistent with the findings from the engineering-based studies. Similar comments would apply to the motor measure findings, except in the case of savings asssociated with ASDs or multiple speed motors. Engineering-based studies consistently predict higher savings for these measures. However, it is difficult to identify and estimate these savings on the basis of a cursory site inspection.

Table 6
Estimated Energy Savings for Selected Recommended Measures, IAC Database

Measure	Savings as Percent of Total Motor Energy
Compressor Measures	
Reduce the pressure of compressed air	0.3%
Eliminate or reduce compressed air use	0.2%
Eliminate leaks in inert gas lines	1.1%
Install compressor air intake in coolest areas	0.4%
Total for Compressor Measures	1.9%
Motor Measures	
Utilize energy efficient belts and other drive train improvements	0.8%
Replace over-size motors and pumps	0.1%
Size electric motors for peak operating conditions	0.1%
Use multiple speed motors or ASDs to meet fluctuating load	0.8%
Use most efficient type of motors	1.1%
Total for Five Motor Measures	2.7%

Findings on Motor System Purchase, Repair, and Maintenance Practices

This section presents findings from the first 98 on-site surveys completed on motor system purchase, repair, and maintenance practices. Some caution should be exercised in using these results due to the small number of observations currently available. Moreover, the results are not weighted to reflect the probabilities of selection for the facilities involved. Given that there have been relatively few systematic studies on this topic, we felt it would be worthwhile to present selected results of the survey in progress.[iv]

Location of motor purchase decision making Fifty of the 98 facilities for which surveys were completed were branches or subsidiaries of larger corporations. Respondents in all but one of these facilities reported that all motor system design and purchase decisions were made in the local plant as opposed to corporate headquarters. This suggests that, while large, multi-plant firms may offer channels to local decision-makers, efficiency program efforts need to target those local personnel.

Rewind Practices The efficiency of motors generally decreases from 0.5 to 1.0 percent when they are rewound. Efficiency losses can be eliminated or limited to significantly lower level if certain procedures are followed. In particular, restricting oven temperatures used to burn out old windings to 650° F or less and following original winding specifications have been found to be particularly important in maintaining efficiency. However, a recent national study of 65 motor repair shops found that fewer than one-third followed these procedures. (Schueler et al. 1995) Thus, end-users' decisions regarding which motors to rewind and the specifications to use have a significant impact on the overall efficiency of their motor inventory.

The following summarize key findings regarding rewind practices.

- Eighty-eight percent of the respondents reported that they rewound at least some motors. Most of those who did not rewind motors had few if any motors above 5 HP in their facilities.
- Eighty-four percent of those who rewound at least some of their motors considered cost to be an important criterion in deciding whether to rewind or replace a given motor, versus 52 percent who considered horsepower and 44 percent who considered motor type. (Respondents could select multiple responses. Among those who indicated that cost was an important consideration in the rewind/replace decision, 93 percent said that the difference in capital cost between a rewinding and replacing was a significant consideration, versus only 3 percent who named the difference in electric costs between the two options.

[iv] See Wisconsin Demand Side Demonstrations 1995 for results of an end-user survey covering some of these topics.

- Thirty percent of respondents reported that they supplied rewind specifications to their motor repair shops. These had mostly to do with turn-around time and post-repair operations. Few had to do with factors associated with energy efficiency.
- Among motors that are rewound, roughly 20 percent are rewound once. The remaining 80 percent are rewound from two to six times, with two being the modal amount.

These findings suggest that energy efficiency plays a negligible role in end-users' rewind decisions. Table 7 shows the mean percentage of motors rewound upon failure in various horsepower ranges. This information was solicited to calibrate the stock replacement model, which is driven by shipment data provided in the horsepower ranges shown in the table.

Table 7
Percentage of Failed Motors Rewound by Horsepower Range

Horsepower Range	Mean Percentage of Motors Rewound Upon Failure
1 - 5 HP	27%
6 - 20 HP	56%
21 - 50 HP	74%
51 - 100 HP	77%
101 - 200 HP	82%

Motor Purchase Practices. The Practices Survey contains an extensive battery of questions on motor purchase practices. Key preliminary findings in this area include the following.

- Fifty-eight percent of respondents reported that they were aware of premium motors (the category of motors which, prior to the implementation of 1997 Federal product standards best corresponds to the Census definition of energy efficient motors). Twenty percent of respondents reported that they understood the relationship between the "premium" designation and operating efficiency. An additional 50 percent reported that they "somewhat" understood this relationship.
- Twelve percent of respondents reported that their company had adopted a corporate policy to purchase efficient motors. Twenty-two percent of respondents reported that they used written specifications in purchasing motors, although not all of these specifications contained elements covering efficiency.
- Respondents report that 29 percent of all motors purchased in the past 2 years were premium motors. The percentage of domestic motor shipments in the 1 - 200 horsepower accounted for by energy efficient models was roughly 20 percent during this period. (Department of Commerce, 1996) Given that larger companies occupied a disproportionate amount of the sample, the 29 percent finding appears to be plausible.
- Nine percent of respondents reported that they purchased only energy efficient motors. Forty-nine percent reported that none of the new motors they purchased were energy efficient.
- Nearly 40 percent of new motors enter the inventory packaged into OEM equipment. (Easton Consultants, 1995) Some market observers hypothesize that replacement motors for this equipment are, in many cases, limited to standard efficiency models. However, only 16 percent of respondents reported that they could not obtain efficient replacements for motors in their OEM equipment.

Motor Sizing Practices. Many motor market observers believe that a high proportion of motors in the inventory are oversized, that is: the load they drive is less than 40 percent of their design full load. Below this part load, the efficiency of energy conversion drops off significantly. Some studies which collected instantaneous part load information from small, unrepresentative samples have found that 25 to 30 percent of motors sampled were operating at less than 40 percent of full load. (Gordon et al., 1994)[v] Given that many industrial loads change over time, it is likely that oversizing will go undetected at the point of replacement unless load estimates are made under current conditions. The Practices Survey asked respondents to identify how frequently they used various procedures to size replacement motors. Table 8 summarizes the responses. The results indicate that customers refer to the size of the current motor most often in sizing replacements. Twenty-nine percent of the respondents reported that they measure loads all or most of the time.

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[v] The Baseline Survey is collecting measured part load data from a sample of motors in each participating facility.

Table 8
Percentage of Failed Motors Rewound by Horsepower Range

	Same as Failed Motor	Motor in Stock Closest to Existing	Based on Load Measurement	Based on OEM Specs
All of the time	69%	6%	23%	26%
Most of the time	23%	6%	6%	17%
Some of the time	6%	37%	26%	26%
Never	0%	34%	37%	17%
Don't Know	3%	17%	9%	14%

Conclusion

In addition to providing useful information to end-users, manufacturers, distributors, and policy makers, we believe this paper and the larger effort from which it is drawn illustrates a number of important points in regard to developing baselines for market transformation efforts. These are as follows:

- Although end-user surveys provide the richest data in terms of the range and detail of baseline analysis it can support, inventory characterizations based on manipulation of shipment data and information from expert market observers can be sufficiently accurate and detailed to support many policy and program design considerations. Moreover, these "top down" methods are much less expensive to implement.
- Surveys of end users and supply-side market actors can provide the detailed information on efficiency-related practices needed to create a baseline for assessing a program's market effects. For example, data from periodic surveys on the percentage of customers who are aware of efficient motors, who purchase such motors, and who have adopted corporate motor specifications for efficient motors can be used to gauge the market effects.
- Information on the structure of the markets for equipment and related services, as well as the motivations of manufacturers, designers, and distributors is an important part of the baseline for market transformation programs. In the case of motor systems, this information has been compiled, analyzed and presented elsewhere. It will be incorporated into the final report of this market assessment.

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