

INDUSTRIAL MOTORS MARKET RESEARCH

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INDUSTRIAL MOTORS MARKET RESEARCH

1.	Research Objectives and Methodology	Page 3
2.	Literature Review Summary	Page 4
3.	Market Actor Interview Results	Page 16
4.	Conclusion – Key Findings and Additional Research Opportunities	Page 25

Navigant conducted a market research study to better understand savings opportunities for industrial motors. The project included a literature review and in-depth interviews to identify program opportunities for DTE.

RESEARCH OBJECTIVES

Research opportunities for energy efficiency savings in industrial motors, focusing on key sectors and a range of motor sizes.

Benchmark current practices and identify market barriers and drivers for efficient motor replacement and rewind.

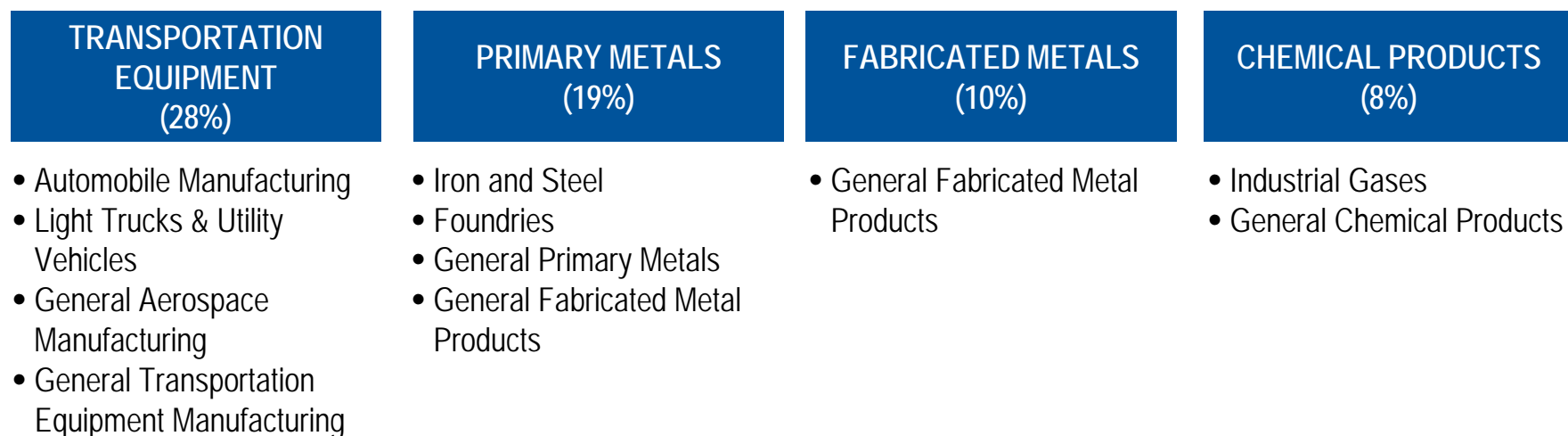
Investigate energy efficiency savings potential for industrial sector motor replacement versus rewind.

Research potential solutions to the market barriers for efficient motor replacement.

TASK	TASK DESCRIPTION
1	Conduct a literature review and secondary data analysis.
2	Finalize a research and data collection plan.
3	Conduct in-depth interviews with primary market actors.
4	Provide findings to DTE.

In a 2013 study for DTE, Navigant identified the top consumers of energy by standard industrial classification (SIC) category. The top four industrial categories (by percent annual GWh sales) are transportation equipment, primary metals, fabricated metals, and chemical products.¹

These four industries account for 65 percent of total annual industrial GWh sales.



¹ DTE Energy Industrial Sector Energy Consumption Baseline. Navigant Consulting, August 12, 2013.

Through the literature review, Navigant identified four opportunities for increasing industrial motor efficiency. These opportunities are discussed in greater detail on the following slides.

Replacement with a premium efficiency model

Downsizing a motor during replacement

Efficient (green) rewinds

Variable frequency drives (VFDs)

Motor Efficiency Opportunity 1: Replacement with a premium efficiency model. Roughly 55 percent of the 51-100 HP U.S. motor stock and 69 percent of the 101-200 HP stock were efficient models in 2006. Motors in this size range have an average operating life of 28 years. Figure 2-3 suggests a significant fraction of low-efficiency motors are still in use.

Estimated 2006 Energy Use And Peak Demand Of Electric Motors

Size Range (HP)	2003 Shipments U.S.	Average Life (Yrs)	Efficiency %			Avg. Op. Hrs.	Annual kWh/Motor
			Base	Efficient	Efficient		
51-100	40,669	28	0.941	0.95	55.07%	4663	154,452
101-200	22,177	28	0.95	0.958	69.18%	4735	310,526

Source: Impact of Proposed Increases to Motor Efficiency Performance Standards. ACEEE, October 2007.
 Note: Estimates are for 2006 but shipment data is from 2003.

Annual energy and dollar savings from replacing a standard efficiency motor with a premium efficiency motor are significant, as shown in the table below.

New Motor Purchase: Annual Energy Savings Vs. Motor Rating

Motor Rating, hp	75% Load Motor Eff (%)		Annual Savings from Use of a Premium Efficiency Motor	
	Standard Eff. Motor	Premium Eff. Motor	Annual Energy Savings, kWh/year	Annual Dollar Savings, \$/yr
50	91.6%	95.0%	4,917	\$ 393
100	92.2%	95.3%	8,879	\$ 710
200	93.3%	96.2%	16,263	\$ 1,301

Note: Estimates based on \$0.08/kWh electric rates, 4,500 hours/year operation.
 Source: Navigant calculations.

Motor Efficiency Opportunity 2: Downsizing a motor during replacement. If a motor typically operates at low loads (below 40 percent of full load), it is running less efficiently than its optimal performance and is likely oversized for that application.

A significant portion of motors operate for extended periods below the efficient range. In 2002, the U.S. Department of Energy (DOE) measured a selection of 1,991 motors, of which 44 percent were at less than 40 percent of their full load.

The following table shows that running a motor at 75 percent load is at least two percent more efficient than running at 25 percent load.

MOTOR SIZE CATEGORY	AVERAGE EFFICIENCY AT 25% LOAD	AVERAGE EFFICIENCY AT 75% LOAD	SAVINGS FRACTION
51-100 HP	87.9%	89.9%	2.2%
101-200 HP	89.1%	91.6%	2.7%

Source: Industrial Electric Motor System Market Opportunities Assessment. DOE EERE, December 2002.

Most importantly, running a motor at low loads means that it can be replaced with a smaller, less expensive motor. The smaller motor will have a lower upfront cost in addition to running more efficiently.

Motor Efficiency Opportunity 3: Efficient (green) rewinds. Motor rewind savings come from improving rewind practices at service centers to follow Electrical Apparatus Service Association (EASA) rules or other rigorous protocol that maintain or even improve motor efficiency.

GUIDELINES FOR A GOOD MOTOR REPAIR

Conduct a stator core test before and after winding removal.

Repair or replace defective stator core laminations.

Calibrate all test equipment and measuring devices at least annually.

Measure and record winding resistance and room temperature.

Have the appropriate power supply for running the motor at rated voltage.

Have a quality assurance program.

Have and use, at a minimum, the following test equipment: ammeter, voltmeter, wattmeter, ohmmeter, megohmmeter, and high potential tester.

When good motor repair practices are followed, efficiency losses should be minimal or nonexistent. Example: EASA's study on the effect of motor rewinding, involving 22 motors from 50 to 300 HP.

- Six low voltage motors (100-150 HP) rewound once had a final average efficiency change of -0.4 percent
- Ten low voltage motors (60-200 HP) rewound once had a final average efficiency change of -0.03 percent
- Five low voltage motors (100-200 HP) rewound two or three times had an average efficiency change of -0.1 percent

¹ Guidelines to a Good Motor Repair. Advanced Energy.

Replacement with a premium efficiency model is the largest savings opportunity of the three opportunities so far, as outlined in the table below.

Energy Savings Opportunities for Various Efficiency Measures and Motor Upgrades

Size Category (HP)	System Efficiency Measure Savings (GWh/Year)				Motor Eff. Upgrades		
	Fan Systems	Pump Systems	Compressed Air Systems	Other Process Sys.	Downsize Motors	Efficient Replacement	Rewinds Improved
51-100	470	5,268	1,090	636	753	2,213	656
101-200	776	4,204	1,599	774	559	2,105	756

Source: Industrial Electric Motor System Market Opportunities Assessment. DOE EERE, December 2002.

A systems approach takes into account the big picture for efficiency opportunities, analyzing how different components interact for efficiency opportunities.

1. Assess motor and drive system operating conditions – large motors that operate for long periods of time are the best candidates for improvements.¹
2. Establish a motor management program, including a formal repair/replace policy. For example, a motor purchase policy may specify premium efficiency motors for all new 1-500 HP motors.

Source: Improving Motor and Drive System Performance. DOE Advanced Manufacturing Office, February 2014.
¹Average annual motor system operating hours for 51-100 HP motors in manufacturing: 5,329 hours/year. 101-200 HP: 5,200 hours/year (Industrial Electric Motor Systems Market Opportunities Assessment. DOE EERE, December 2002)

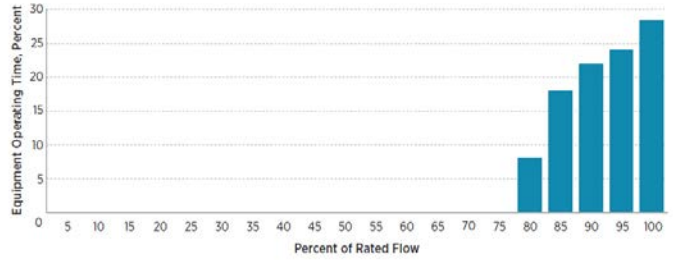
Motor Efficiency Opportunity 4: Variable Frequency Drives (VFDs). A VFD is a device that controls the frequency and voltage of the electrical power supplied to a motor to match the speed of the motor to the requirements of a fluctuating load.

Matching motor speed to application requirements through the use of VFDs can achieve significant electricity savings when connected to motors in appropriate applications.¹ The Advanced Manufacturing Office estimates a \$42,000 installed cost for this 200 HP rated VFD, resulting in a simple payback of approximately 1.1 years.

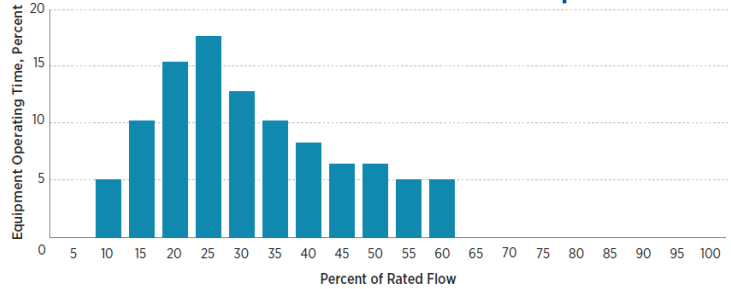
The DOE estimates that motors representing 18 to 25 percent of total manufacturing energy could be cost-effectively equipped with VFDs. The cost-effective VFD applications are:²

- Generally, the higher the horsepower, the more likely to be cost-effective (30 HP+ can be excellent candidates).
- 2,000+ operating hours per year or more.
- Centrifugal loads, such as pumps and fans.
- Loads that vary over time by 30 percent or more of full load.
- Circulating pumps, rather than systems with static head.

Poor Candidate Example



Excellent Candidate Example



Source: Continuous Energy Improvement in Motor Drive Systems. DOE Advanced Manufacturing Office, February 2014.

¹ Energy Efficiency Policy Opportunities for Electric Motor Driven Systems. IEA, 2011.

² Industrial Electric Motor System Market Opportunities Assessment. DOE EERE, December 2002.

There are general rules of thumb to help determine when motor replacement may be more appropriate than rewind.

- **Motor purchase:** Purchasing properly sized and efficient motors is most cost-effective in industrial applications with annual operation greater than 2,000 hours, high electricity rates, significant repair costs, and available rebates and incentives.
 - Electricity typically accounts for 95 percent of the cost of electric motors over a 10-year period.²
- **Motor failure:** Replace the failed motor with a new efficient one and also do a size assessment, replacing oversized motors.
 - With adequate sizing, a replacement can lower power output by 20-50 percent; therefore, a 30 percent smaller motor can be 25 percent cheaper. This offsets the initial price premium for a premium efficiency motor.
- **Motor repair:** Custom motors above 500 HP are often already high efficiency models and more cost-effective to repair rather than replace.

STANDARD RULES OF THUMB FOR REPLACEMENT VS. REWIND

Motors less than 40 HP in size and older than 15 years should be replaced with a premium efficiency motor when a rewind is required.

If repair costs exceed 60 to 65 percent of a new premium efficiency motor price, buy a new premium efficiency motor.

For repairs, use an ISO 9000 or EASA-Q quality assurance program service center.

Market actors face a number of barriers to making the most energy efficient motor decision. These barriers exist in all levels of the market, from manufacturers to end users, and include the following:

Energy Efficient Motor Decision Barriers

Lack of awareness among motor purchasers of the potential for savings using more efficient motors.

Company organizational structures that manage equipment procurement budget separately from operations and maintenance budgets.

Short term thinking over investments and operation (not choosing the option with least life cycle cost).

Lack of performance visibility within main production performance benchmarks.

Confusion in standards and labels.

Motors are often integrated into equipment produced by original equipment manufacturers (OEM) before sale to the final end user.

Research to date indicates that the number of utility motor efficiency programs declined after the Energy Independence and Security Act of 2007 (EISA) mandated National Electrical Manufacturers Association (NEMA) premium efficiency standards for new motors in 2010.

However, some utilities have redesigned their motor rebate programs to remove old standard efficiency motors from plant floors.¹ The following table includes examples of two types of current programs: rebates for upgrading older motors and repair shop accreditation incentives.

Rebate and Incentive Programs

MOTOR UPGRADE REBATES	MOTOR REPAIR SHOP INCENTIVES
Xcel Energy Motor and Drive Efficiency Program: Offsets first costs for motor upgrades by offering rebates for installing qualified high-efficiency motors and constant speed motor controllers or drives. ²	Bonneville Power Administration pioneered an efficient (green) rewind program with the GMPG, called the Green Motor Initiative (GMI). GMI offers utility-financed incentives to verified member service centers and their customers who report rewound motors meeting the program standards. ⁴
Alliant Energy offers rebates for efficient motors and VFDs in Iowa, Minnesota, and Wisconsin. Rebates are based on horsepower, revolutions per minute (RPM), and efficiency. ³	EASA launched its EASA Accreditation Program, which evaluates service centers for evidence of compliance with their good practice standards (EASA-AR100-200). ⁵

¹ Premium Efficiency Motor Selection and Application Guide. DOE Advanced Manufacturing Office, February 2014.
² www.xcelenergy.com/Energy_Solutions/Business_Solutions/Rebates_&_Energy_Savings/Motors_&_Drives
www.xcelenergy.com/staticfiles/xcel/Marketing/Managed%20Documents/mn-bus-motor-efficiency-application.pdf
³ www.alliantenergy.com/SaveEnergyAndMoney/Rebates/BusIA/031057.
⁴ www.greenmotors.org/gmi.htm.
⁵ www.easa.com/accreditation.

The CEE tracks programs for motors and motor systems offered by its members. The count of different types of programs in 2013 follows:

CEE Motor Programs Count

CEE MOTORS PROGRAMS	EFFICIENCY STANDARD	PROGRAM COUNT
Prescriptive Motors Programs	Above NEMA Premium/EISA	8
	At and Above NEMA Premium/EISA	10
	CEE Premium Efficiency Motor List	4
	Total	22
Motor Rewind Programs	Varies	10
Prescriptive Motor Upgrade Incentives	Varies	2
Prescriptive Alternating Speed Drive (ASD) Incentives	Varies	50
Programs with specific (non-custom) pump offering	Varies	14
Programs with specific (non-custom) fan offering	Varies	9
Programs with specific (non-custom) small industrial blower offering	Varies	7
Programs with specific (non-custom) compressed air offering	Varies	27

Source: CEE Summary of Member Programs for Motor and Motor Systems, 2013. www.cee1.org.

Note: There are approximately 100 Program Administrator members listed on the website at www.cee1.org/content/member-directory.

Though CEE recorded several motor programs in Michigan, they were solely for VFDs. See the table below. CEE did not find other motor efficiency programs.

CEE MI Motor Programs Count

MI MOTOR PROGRAMS	EFFICIENCY STANDARD	PROGRAM COUNT
MI Utilities with VFD Programs	HVAC Only	3
	HVAC and Other Motors	1
MI Utilities with Custom Motors Programs	Varies	0*
MI Utilities with Green Rewind Programs	Green Rewind Certified Shop performs the Rewind	0*
MI Utilities with other Motors Programs	Electronically Commutated Motor (ECM)	0*

Source: DSIRE Database of Utility Programs. www.dsireusa.org.

*Other utilities with programs may not be listed in the Database of State Incentives for Renewables & Efficiency (DSIRE database).

The research for the Industrial Motors Market Research project included in-depth interviews and surveys with the following market actor groups:

- **Utility (1):** The Navigant team spoke with the DTE representative in charge of motor programs at the beginning of the project in order to better align the effort with DTE's expectations.
- **Trade Groups (3):** The Navigant team interviewed three motor trade group representatives. Interviews with motor trade groups focused on identifying barriers and solutions for industrial motor efficiency and describing current motor efficiency programs.
- **Vendors and Repair Shops (3):** The Navigant team contacted 36 service centers and distributors in DTE territory via phone and email. The Navigant team interviewed three service centers. These centers included repair and rewind services as well as new motor sales. Interviews with motor service centers focused on repair and rewind practices and customer behavior regarding motor efficiency.
- **Major End Users (6):** Facility managers in DTE territory completed the six surveys as part of a larger Compressed Air survey effort for DTE by Navigant.

Navigant conducted in-depth interviews with representatives from the following three regulatory and trade groups:

1. **Green Motors Practices Group (GMPG):** A non-profit organization made up of member motor service centers, electric utilities, and energy efficiency organizations with the objective to promote and improve the energy efficiency and reliability of motor-driven systems while sustaining efficiency in the motor repair/rewind process. GMPG created the Green Motor Initiative (GMI), which offers utility-financed incentives for rewind motors meeting GMI process standards.¹
2. **Electrical Apparatus Service Association (EASA):** An international trade organization of more than 1,900 electromechanical sales and service firms providing engineering and educational programs. EASA publishes a wide range of reference materials, maintains a database with the largest variety of motor winding data, and provides engineering consulting services to members.²
3. **Consortium for Energy Efficiency (CEE):** A consortium of energy efficiency program administrators from the United States and Canada with the goal to achieve lasting and verifiable energy efficiency. CEE influences markets to accelerate the uptake of increasingly efficient goods and services by working with manufacturers, stakeholders, and government agencies to maximize the impact of efficiency programs.³

¹ More information on the Green Motors Practices Group at www.greenmotors.org.

² More information on the Electrical Apparatus Service Association at www.easa.com.

³ More information on the Consortium for Energy Efficiency at www.cee1.org.

Dennis Bowns is the founder of the GMPG and has worked in the motor industry for 40 years. Mr. Bowns helped develop the GMPG Green Rewind certification and is in favor of repair shop accreditation programs, but also recommends that DTE look at motor-driven equipment efficiency.

- Rewind vs. replace: Suggested there may be a slight efficiency advantage in rewinding motors rather than replacing them.
 - The cost of rewinding is roughly equal to the cost of replacement at 50 HP; above this size motors are generally rewound, below this size they are generally replaced.
- There are very few new motors programs left
 - There are more rewinding options since EISA standards went into effect.
- The GMPG set up a Green Rewind program with the BPA that provides rebates of \$2/HP to certified motor repair shops, which then apply a \$1/HP credit to their customers' invoices. This program has been replicated across the Northwest.
 - EASA also recently released a similar accreditation program for motor repair shops. This program applies to repair shops overall, while the GMPG program targets individual rewound motors.



Linda Raynes is the President and CEO of EASA and has worked with the motor industry through EASA for the past 15 years. She believes motor rewinds are a minority of repairs, and a better focus may be on replacing pre-Energy Policy Act (EPAct) motors and/or motor-driven equipment.

- Rewind vs. replace: The impact of motor rewinding may be overstated. Only 10-20 percent of motors seen at the repair shop are for rewinds; the rest are mechanical failures.
 - The DOE is currently conducting a study on motor rewinding, but talking with EASA members has indicated much more work in other areas.
 - The cost of new motors has also significantly decreased.
- The main issue is not rewinding motors vs. replacing them, it is replacing the population of pre-EPAct motors.
- Most motor users do not take down a motor to save energy – they will only do so after motor failure.



Walker Larsen supports the CEE Motors and Motor Systems Committee.* CEE Member program emphasis has shifted from prescriptive incentives based on motor efficiency standards to prescriptive VFD incentives and exploration of new motor technologies, in part because the incentive program opportunity is limited by rising Federal efficiency standards for motors (EISA).

- The rewind vs. replace question is an important one because there are many old motors that are more cost-effective to rewind (when considering capital cost only, rather than lifetime energy costs).
- Unfortunately, utilities cannot offer rebates to replace these motors because they are beyond the end of their useful lives; even though there would be significant energy savings, utilities would not be able to claim them.



*The opinions expressed on this slide do not represent the views, opinions, or position of the CEE Motors Committee or the CEE Board of Directors.

¹ More information at www.motorsmatter.org.

Takeaways from the Trade Group interviews:

- **Green rewinds.** Green rewind programs can be effective, and all three interviewees discussed the opportunity for DTE to incentivize repairs at local GMPG-certified or EASA-accredited service centers.
- **Equipment focus.** Two of three interviews discussed the importance of focusing on motor-driven equipment. Motors are already quite efficient, but pumps, gearboxes, and air compression systems may be significantly less so.
- **Education.** Education is one of the most important things that DTE can do to encourage customers to increase motor efficiency.
- **Convenience.** Two of three interviews stressed convenience as key for a motor efficiency program. This means reducing paperwork and steps to encourage customers to participate.

The next page outlines Trade Group interview results.

Navigant spoke with two large repair shops and one medium repair shop, who provided feedback on the potential for motor efficiency opportunities in DTE territory.

INTERVIEW #	MOTOR SERVICES	MOTOR EFFICENCY FEEDBACK
1 Large Repair Shop	Primarily builds custom motors (50-200 HP), about 1-2 per month.	The repair industry is unhappy with power companies because when high efficiency motors came out, many repair shops went out of business (estimates 20%-30% of shops). In Detroit, there are now only around six repair shops.
2 Medium Repair Shop	Serves food processing industry, municipal customers, and light industrial motors. Services approximately 1 motor per day.	Observes that motor users have had tighter budgets during the recession, which hurt maintenance and motor replacement programs – this is picking back up. Would like for DTE to have a rebate program and also raise customer awareness about overall system efficiency.
3 Other Large Repair Shop	Serves automotive facilities, manufacturing plants, machining plants, and engineering facilities. Rewinds 10-15 motors (50-200 HP) each month.	Customers do not consider lifetime electricity costs and choose based solely on the upfront cost. Motor decision makers are typically not in charge of the plant's overall operating budget. Customers need monetary encouragement like a rebate to consider replacing motors before failure.

Takeaways from the Repair Shop interviews:

- **Behavior varies by size.** Motors under 100 HP are typically replaced, while large motors and custom motors are typically repaired/rewound.
- **Motors are old.** Motor users tend to run motors into the ground (to failure) and there are many older motors in use.
- **Upfront costs drive decisions.** Motor users make replacement decisions based on upfront costs alone.
- **Customers lack awareness.** A small fraction of repairs are rewinds, and customers do not inquire about repair shop certifications and the motor's rewind efficiency.
- **Repair shop "green rewind" certification is not common.** While most repair shops follow professional repair protocols, the Navigant team did not interview (or locate) any repair shops that identify as "green" rewind shops in DTE territory as part of this project.

Repair shops would like to see customers better educated about motor system efficiency; however, they mostly expect motor end users to be motivated by rebates.

One section of the DTE Compressed Air Survey was dedicated to motor characteristics and repair/replace decisions at industrial plants in DTE territory. Navigant collected six survey responses related to motor decisions and characteristics.

The takeaways from the six surveys are as follows:

- Many 50+ HP motors are older than 10 years, and most are not premium efficiency models.
- Facilities are aware of and generally in favor of VFDs.
- Cost is one of the primary drivers of facility replacement policies.
- None of the facilities require repair shops to be certified for efficiency, and none have formal quality control practices for rewind motors.

These findings align with findings reported by motor repair shops.

Key findings from the literature review, interviews, and surveys are summarized below.

MOTOR CHARACTERISTICS

Motors under 100 HP are typically replaced, while large motors and custom motors are typically repaired/rewound.

Motor users tend to run motors into the ground (to failure) and there are many older motors in use. Many 50+ HP motors are older than 10 years, and many are not premium efficiency models.

New motors are already quite efficient, but pumps, gearboxes, and air compression systems may be significantly less so.

CUSTOMER AWARENESS & EDUCATION

Cost is one of the primary drivers of facility replacement policies. Most motor users make replacement decisions based on upfront costs alone, without considering lifetime operating costs.

Customers lack awareness on repair efficiency. Repair shop customers do not inquire about certifications and their motor's rewind efficiency. None of the facility managers surveyed require repair shops to be certified for efficiency, and none have formal quality control practices for rewind motors.

Facility managers are aware of and generally in favor of variable frequency drives (VFDs), but many have not implemented them.

MOTOR EFFICIENCY PROGRAMS

Motor end users would be most motivated by monetary incentives that affect their upfront costs.

Green rewind programs can be effective; all three trade group interviewees discussed the opportunity to incentivize repairs at local Green Motors Practices Group (GMPG)-certified or Electrical Apparatus Service Association (EASA)-accredited service centers.

Several interviews stressed convenience. A motor program should have minimal paperwork and steps to encourage customers to participate.

Based on interview, survey, and literature review findings, DTE may find it helpful to further investigate the following topics:

1. Number of rewind shops in DTE territory with efficient rewind certification.
2. Additional data collection on motors in DTE territory (age, operating hours, etc.).
3. Guidance on how to fit existing motors with VFDs.
4. Guidance on motor sizing.
5. Information on other motor system components for overall system efficiency.