Measure, Application, Segment, Industry (MASI):

Motors Baseline and Opportunities in the Industrial, Food Processing, and Agricultural Sectors, and Early Motor Retirement in Refineries

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Introduction

For the motors baseline and opportunities study, Navigant Consulting, Inc. (Navigant) assesses the current state of electric motors installed and operating in California's industrial, food processing, and agricultural sectors, in addition to early motor retirement opportunities in refineries. Navigant also explores market trends such as codes and standards and key market drivers and barriers, as well as customer decision-making processes in each sector. The market insights lead to sector-specific findings and utility program recommendations aimed at providing information to program planners to develop strategies to effectively address targeted opportunities in future program design efforts.

While each sector has distinct market and motors operating characteristics, cross-cutting insights are applicable across the industrial, food processing, and agricultural sectors. The first section of the report will compare and contrast the industrial, food processing, and agricultural motors markets; the second section of the report will explore early motors retirement opportunities in refineries.

Depending on the industry, machine drive contributes from 29 to 88 percent of facility electricity consumption, thus, an important end use to understand for energy efficiency opportunities. Within the industrial subsector, Navigant focused on the chemicals, cement and building materials, and wastewater industries, based on their overall electricity use, reliance on motors, and the recommendations of subject matter experts.

Market Trends

Due to the increased federal efficiency standards put in place by the Energy Security and Independence Act of 2007 (EISA), there are few utility motor efficiency programs remaining in California. . This reflects the national market trend , as utilities move away from motor replacement programs to other motor-related programs. According to CEE's member program tracking database[1], there are 22 prescriptive motors programs within their member utilities compared to 50 VFD programs. With these standards, motor efficiency gains are reaching diminishing returns, as the efficiency standard is approaching the maximal efficiency the current technology is capable of achieving. Even so, there are still areas where utility programs can provide efficiency gains in industrial motors.

[1] CEE member programs tracking database:http://library.cee1.org/content/cee-2013-summary-member-programs-motors-motor-systems/ Access on Feburary 27th, 2015

Navigant interviewed facility managers and subject matter experts by subsector, the interview sample size are summarized in the following table, details of the SME and FM can be found in Section 2:

Table 1: Navigant Interviews by Subsector

Interview Type	Chemicals	Cement/ Building Materials	Wastewater	Food Processing	Agriculture	Refineries
FM	2	1	2	2	2	2
SME				1	3	4

By subsector, the high-level secondary literature and interview results are as follows:

- **Cement/Building Materials**: From an electric motor systems market opportunities study done by the DOE[2], Navigant expected most motors in this subsector to be in the 10-200 hp range. The cement/building materials subsector facility interviewed reported 85% of its motors in this range. Most motors are reported as premium efficiency, and when rewound the facility uses green rewind certified shops.[3]
- **Wastewater**: Based on the two wastewater facility manager interviews, the two facilities rely on 10-200-hp motors. Since individual plants do not compete with each other, they exchange efficiency strategies and report high efficiency in their motors.
- **Chemicals**: The chemicals subsector predominately installs small (<10-hp motors) in their operations based on the three facility manager interviews. Many of these motors are highly specialized, which do not always fall under EISA regulations. The knowledge gap of motor efficiency suggests that energy efficiency is not a priority in these operations.
- **Food Processing**: Food processing, similar to chemicals, uses mostly small, often specialized motors. Similar to the chemical industry, the two small food processors interviewed in this industry exhibited a lack of knowledge about efficiency, and stated that production, and minimization of downtime, takes precedence over efficiency in the subsector.

[2]Xenergy, Inc. 1998. United States Industrial Electric Motor Systems Market Opportunities Assessment. Prepared for the US Department of Energy's Office of Industrial Technologies and Oak Ridge National Laboratory

[3] Green Rewind Certified shops are certified by the Green Motors Practices Group (GMPG) as returning their rewound motors to factory-level nominal efficiency. More at http://www.greenmotors.org/

- **Agriculture**: According to the two facility manager interviews and the three motors manufacturer interviews. Outdoor agriculture relies on large pumps for irrigation purposes, driven by mostly 10-200-hp motors, with larger motors not uncommon (~10-15% of motors). Motors are not replaced often, and especially well pumps are often rewound rather than replaced, leading to lower efficiency motors being more common. Indoor agriculture uses smaller (<10-hp) motors almost exclusively. This subsector indicated a higher efficiency standard.
- **Refineries**: The refineries sector prioritizes maximizing production over energy efficiency. According to a utility program manager a payback requirement of less than two years is a major barrier preventing refineries from implementing motor efficiency upgrades. Although refinery facility managers did not affirm the two year payback, they agreed that measure payback and reliability is of utmost importance and early motor retirement measures must rank above other efficiency measures in terms of payback.

Findings and Recommendations

Industry Findings

Motor drives are key contributors to electricity consumption in the industrial sector. Depending on the industry, the machine drive end-use consumption ranges from 21 percent to 88 percent of the whole facility usage. The following table summarizes our interview findings. Having a small sample size is a limitation to this study. Navigant recommend conducting further research to validate industry characteristics.

Table 2. Summary of Sector-Specific Motor Traits for Targeted Programs

Sector	Motor Size (hp)	Repair/ Replace Practice	Industry Awareness of EE	Industry Interest in EE	Standard/ Specialized Motors	Seasonal/ Continuous
Chemicals	<10	Replace (<50 hp) Rewind (>50 hp)	Medium	Medium	Specialized	Varies
Cement/ Building Materials	10-200	Replace (<100 hp) or Green Rewind	High	High	Standard	Continuous
Wastewater	10-200	Replace (<20 hp) or Green Rewind	High	High	Standard	Continuous/ Rotating
Food Processing	<10	Rewind Specialized. Replace others	Mixed	Low	Specialized	Continuous and Seasonal
Agriculture (outdoor)	10-200	Repair/ Rewind Extensively	High	Medium	Specialized	Seasonal
Agriculture (greenhouse)	<10	Replace	High	High	Standard	Intermittent

Source: Navigant Analysis

- **Cement/Building Materials**: With the focus on energy efficiency, Navigant recommends targeting this subsector for a more traditional motor replacement program. With plants that are running high-efficiency motors, Navigant recommends focusing on the motor-driven equipment to increase system efficiency.
- **Wastewater**: With the extensive use of pumps, and the stock of already efficient motors, Navigant recommends focusing on the motor-driven equipment in the wastewater subsector.
- **Chemicals**: Based on the two facility manager interviews, specialized motors are common in chemical facilities. Further research on the shelved motors efficiency and the timing of replacement in the chemical industry could help determine if a on the shelf custom motors replacement program is feasible to target the chemical industry..
- **Food Processing**: As with the chemicals subsector, the food processing subsector is a good candidate for specialized motor efficiency programs and a spare motor efficiency program.

- **Agriculture**: A standard motor incentive program is applicable to indoor agriculture. Outdoor agriculture is likely a good target for the traditional motor incentive, and possibly a frame adaptor incentive.
- **Refineries**: Customers in refineries indicated lack of interest in utility motor programs, making it difficult for utility programs to succeed. Due to the limited number of refineries in California, a custom approach with account executives working directly with each of the refineries for motors upgrade might be deemed appropriate.

Program Recommendations:

- **Traditional Motor Replacement Program:** In subsectors in California that frequently replace motors, there is evidence that the traditional rebate for replacement program type may be well received. Xcel Energy New Mexico is one of the remaining utilities that administers a rebate program for replacing existing motors with NEMA Premium efficient or better motors.[4] There are two specific cases involved in this rebate program. The first requires an existing motor that may or may not still be functioning, with a motor that is at least one efficiency band above NEMA Premium efficient (the EISA standard efficiency). This would benefit subsectors that already emphasize efficiency in their operations. The second requires a currently functioning motor be replaced by a NEMA Premium efficient motor. This would be better targeted at subsectors that lag in their efficiency practices.
- **Explore Feasibility of Green Rewind Incentives**: Most subsectors in California have established protocols for rewinding certain motors rather than replacing them. Instead of attempting to change these customer protocols, there is a way to get savings out of quality rewinds. Dubbed "green rewinds," a quality rewind can achieve a higher motor efficiency. Rebates for green motor rewinds will encourage facilities to use a certified green-rewind shop to repair and rewind their motors. Such a program is already in place at Pacific Power, whose motors rebate program is shown in Figure 7.[5] This program provides a $2/hp incentive to the green rewind shop, which in turn subtracts $1/hp from the customer's invoice.
- **Investigate System-Level Approaches to Energy Efficiency:** If the utilities want to continue to support energy efficiency activities at refineries, two facility managers and a third-party energy efficiency implementer alike advised against addressing the efficiency of motors individually, as refineries have already been looking at motor efficiencies for years and remaining potential does not exist currently for motors. Federal regulations already mandate that any motors (1–500 hp) that are replaced must be replaced with NEMA Premium efficient motors. This finding was supported by secondary literature from LBNL and the DOE. The 2005 LBNL study also identified the importance of focusing on the "system approach", which looks at pump, compressor, motor, and fan efficiency in order to capture the most savings.[6] The US DOE Motor

[4] http://www.xcelenergy.com/staticfiles/xe/Marketing/Files/NM-Bus-Motors-Rebate-Application.pdf.

[5] https://www.pacificpower.net/content/dam/pacific_power/doc/Business/Save_Energy_Money/CA_FinAnswer_Express_Motors_Incentives.pdf.

Challenge Program study agreed that the greatest savings potential lies with the system savings measures, indicating that compressed air and pump systems have the most potential. System improvements overall account for 71 percent of total potential motor system energy savings.[7] A third-party energy efficiency implementer indicated that he believes that "you will find larger opportunities at the process level." This finding warrants further investigation to determine the potential savings through the focus on a system approach.

» **Custom Approach for Motor Improvements in Refineries:** The most favorable selection of energy efficiency opportunities should be made on a plant- specific basis.[8] With 20 refineries operating in California, program managers seem to already be working closely with facility managers. Navigant recommends that utilities work with refineries on an individual basis to target custom motors that could be replaced. The success of taking the custom approach is supported by the fact that a California utility program manager is currently working with a refinery client to replace what is considered an inefficient 9,000-hp motor when compared to existing motors on the market. Navigant recommends that utilities particularly focus on working with smaller refineries on a case-by-case basis, as they seem to repair or rewind a much higher percentage of their motors than larger refineries, resulting in additional existing savings potential.

[6] Ernest Orlando Lawrence Berkeley National Laboratory. February 2005. *Energy Efficiency Improvement and Cost Saving Opportunities for Petroleum Refineries: An EnergyStar Guide for Energy and Plant Managers*. http://www.energystar.gov/ia/business/industry/ES_Petroleum_Energy_Guide.pdf.

[7] Office of Energy Efficiency and Renewable Energy, US Department of Energy, Motor Challenge, United States Industrial Electric Motor Systems Market Opportunities Assessment, December 1998, http://www1.eere.energy.gov/manufacturing/tech_assistance/pdfs/mtrmkt.pdf

[8] Ernest Orlando Lawrence Berkeley National Laboratory. February 2005. *Energy Efficiency Improvement and Cost Saving Opportunities for Petroleum Refineries: An EnergyStar Guide for Energy and Plant Managers*. http://www.energystar.gov/ia/business/industry/ES_Petroleum_Energy_Guide.pdf.

Motors Baseline and Opportunities in the Industrial, Food Processing, and Agricultural Sectors

1 Introduction

1.1 Overview of this Study

In the motors baseline and opportunities study, Navigant Consulting, Inc. (Navigant) assesses the current state of electric motors installed and operating within California's industrial, food processing, and agricultural sectors. The study objective is to provide current motors market data and insights that are immediately useful by program planners to develop strategies to effectively address targeted opportunities in future program design efforts. Areas of focus include recognizing sector-specific motor measures and identifying market barriers and potential solutions to those barriers. In addition, Navigant identifies research program opportunities to implement energy efficiency measures related to motor applications in these California sectors.

In this report, we present the refineries sector in its own section because 1) refineries have different business practices and a different structure than the other sectors Navigant investigated, and 2) the scope of the refineries study is geared towards early retirement, a different objective from the other motors studies.

This study covers motors in the industrial, agricultural, and food processing segments, focusing on 10- to 200-horsepower (hp) motors, including process motors, motors driving pumps, and heating, ventilating, and air-conditioning (HVAC) equipment.

1.2 Approach

Navigant started the motors baseline project by reviewing literature of existing programs and codes and standards relevant to industrial motors in California. Simultaneously, Navigant interviewed program managers at utilities to inform the rest of the study. After these were complete, Navigant proceeded to interview subject matter experts (SMEs) and facilities managers (FMs).

- ***Secondary Research and Literature Review:*** Navigant reviewed literature on both codes and standards relevant to industrial motors and existing motors programs in California and elsewhere. Additionally, Navigant reviewed relevant published literature through a web search and reaching out to internal and external resources.
- ***Program Manager Interviews***: Navigant interviewed program managers of former motors programs from two California utilities (Pacific Gas and Electric Company [PG&E] and Southern California Edison Company [SCE]) and procured written feedback from a third (San Diego Gas & Electric Company [SDG&E]). For the detailed interview guide, please see Appendix B.

- *SME Interviews*: Navigant interviewed SMEs, including 2 repair shop managers, 2 pump testers, 1 distributor, 1 academic institution motors expert, and 2 experts from energy efficiency associations . For the detailed interview guide, please see Appendix C. To dissect the refineries sector, Navigant used the guide in 6.2.2Appendix G to interview four subject matter experts:
    - An electrical engineer with motor utility program experience
    - A third-party implementer of energy efficiency measures for refineries
    - An oil and gas consultant with prior experience working as a facility manager at three major refineries

A utility consultant focusing on early motor retirement

- *FM Interviews*: The Navigant team conducted interviews of facilities managers from the industry subsectors identified in both the Statement of Work and by the SMEs interviewed earlier in the study. For a broader scope, Navigant interviewed at least one facility manager in each of the four industry subsectors. For the full interview guide, please see Appendix D.

Table 3: Navigant Interviews by Subsector

Interview Type	Chemicals	Cement/ Building Materials	Wastewater	Food Processing	Agriculture	Refineries
FM	2	1	2	2	2	2
SME				1	3	4

- ***Limitation:*** The primary limitation of this report is the limited number of interviews included in the study. Navigant was aware of this from the outset, and so sought to supplement the interviews with secondary research.

1.3 *Sectors*

For the motor baseline study, Navigant focused on motors in the industrial, food processing, and agricultural sectors. Within the industrial sector, Navigant contacted facilities in the electronics (semiconductor), chemicals, building materials, and wastewater subsectors based on their relative electricity usage and reliance on motors.[9] After contacting representatives in the semiconductor industry, who indicated that semiconductor manufacturers were leaving California, Navigant chose not to pursue further interviews in this subsector.

[9] Based on Navigant's 2013 Potential Goals Study Analysis that draws from Quarterly Fuel and Energy Reports (QFERs), http://energyalmanac.ca.gov/electricity/web_qfer/.

1.3.1 Industrial

Navigant stated in the Scope of Work (SOW) that these studies would focus on the semiconductor and chemical subsectors, since these account for 25 percent of California's industrial energy usage.[10] When Navigant first contacted them, representatives of these industries indicated that they were moving out of California due in part to high utility costs. The semiconductor subsector in particular has shrunk in California during recent years, with most moving out of state or out of the country.[11] The one electronics manufacturer Navigant could contact in California indicated that they were the last remaining semiconductor manufacturer in the state. Navigant was able to interview two facilities managers in the chemicals subsector, with one representing pharmaceuticals. In addition, Navigant relied on SME interviews to direct the interviews to cement and building materials facilities managers (one interview) and the wastewater industry (two interviews). The cement and building materials subsector has a particularly heavy reliance on motors, with approximately 61 percent of its electricity consumption due to motors (see Table 4).[12]

1.3.2 Food Processing

The food processing sector accounts for 18 percent of industrial electricity use in California, in which machine drives account for 42 percent of overall electricity use.[13] Navigant interviewed one SME specializing in this area, and three facility managers, in addition to doing a background literature review.

1.3.3 Agriculture

Across the agriculture sector, pumps and their associated motors are an important consumer of electricity. A prior Navigant study of energy use in California agriculture found that pumping accounts for 73 percent of electricity use in fruit, tree, nut, and vine agriculture, 46 percent of electricity use in vineyards, 51 percent of electricity use in dairies, and 72 percent of electricity use in field crop agriculture.[14] The same study found that refrigeration is the second-greatest electricity usage group in California agriculture.

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[10] ibid.

[11] The share of energy attributed to the electronics industry in Figure 1 for 2011 is likely no longer representative of the current situation.

[12] From Navigant's 2013 Potential Study Analysis that references the Manufacturing Energy Consumption Survey (MECS), http://www.eia.gov/consumption/manufacturing/.

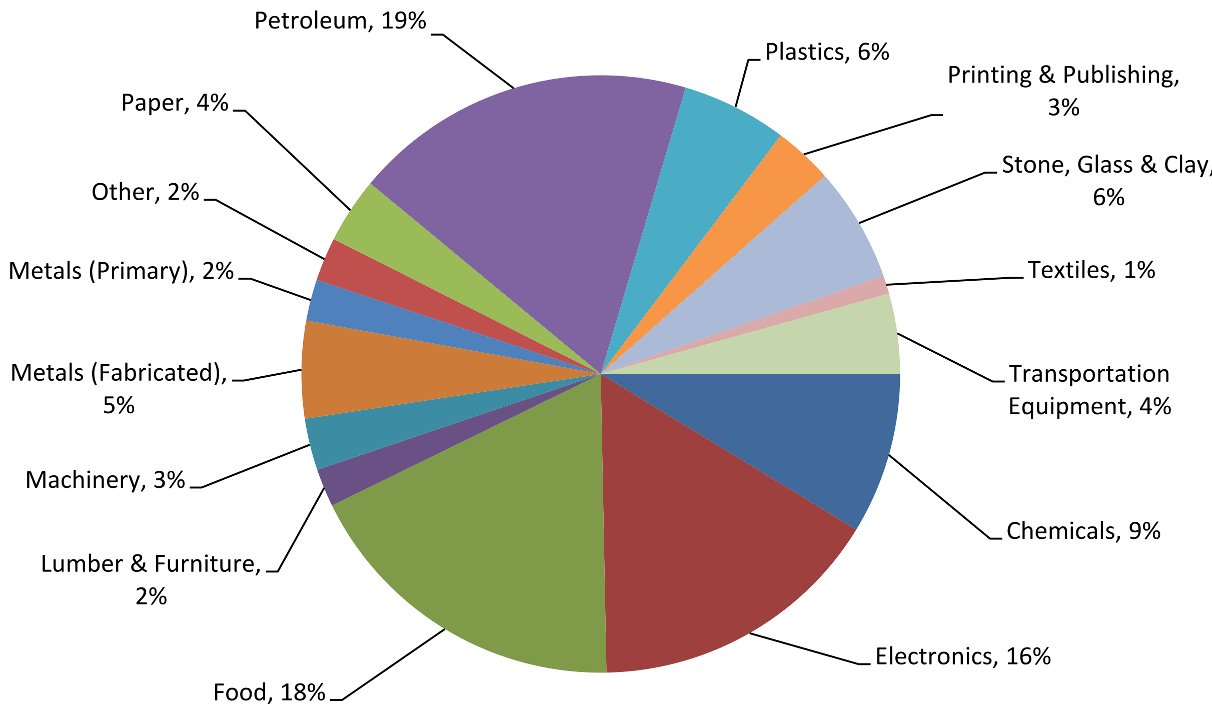
[13] Ibid.

[14] Navigant. 2013. *Market Characterization Report for 2010-2012 Statewide Agricultural Energy Efficiency Potential and Market Characterization Study*.

1.3.4 Refineries

As shown in Figure 1, the petroleum industry accounts for 19 percent of California's industrial electricity usage, in which machine drives account for 88 percent of electricity usage. That means motors in the petroleum subsector alone account for approximately 17 percent of California industrial electricity consumption. Navigant was unable to find many studies done on motors in oil refineries, indicating that this is an important area to research.

Figure 1. Distribution of Industrial Sector Electric Consumption in California, 2011[15]



[15] From Navigant's 2013 Potential Study Analysis that draws from Quarterly Fuel and Energy Reports (QFERs).

Table 4. Electric End-Use Distributions in the Industrial Sector in the United States[16]

Industrial Segment	Segment North American Industry Classification System (NAICS) Code(s)	Lighting	HVAC	Machine Drives	Process Heat	Process Refrigeration	Other	Total
Petroleum	324	2%	4%	88%	0%	6%	1%	100%
Food	311x, 312	7%	8%	42%	7%	29%	8%	100%
Electronics (Semiconductors)	334x, 335	10%	26%	21%	12%	12%	19%	100%
Stone-Glass-Clay	327x	6%	6%	61%	24%	1%	3%	100%
Chemicals	325	4%	7%	61%	5%	9%	15%	100%
Plastics	326	9%	11%	51%	15%	9%	5%	100%
Fabricated Metals	332	9%	10%	49%	20%	3%	9%	100%
Primary Metals	331	3%	3%	29%	29%	1%	34%	100%
Industrial Machinery	333	18%	24%	33%	9%	6%	9%	100%
Transportation Equipment	336	14%	19%	37%	13%	6%	10%	100%
Paper	322x	4%	5%	77%	4%	2%	9%	100%
Printing & Publishing	323, 511, 516	11%	18%	52%	2%	7%	9%	100%
Textiles	313, 314, 315, 316	16%	26%	31%	5%	3%	19%	100%
Lumber & Furniture	337, 321, 1133	16%	21%	36%	8%	4%	15%	100%
All Other Industrial	339	18%	24%	33%	9%	6%	9%	100%

[16] From Navigant's 2013 Potential Study Analysis that references the Manufacturing Energy Consumption Survey (MECS). The MECS is a nationwide sample survey collecting information on, among other data, energy consumption of US Manufacturers.

2 Market and Industry Analysis

2.1 *Motor Characteristics in California Industries*

T Table 5 below summarizes the results of a study done for the DOE in 1998 on the distribution of motors in US manufacturing. Table 6 gives the percentage of total motors in each size category by industry. Table 7 gives the percentage of overall motor energy use by size category. Since this study focuses on manufacturing, it does not include the wastewater or agriculture subsectors, but it gives a good picture of the other three subsectors.

Table 5: Percentage of Total Surveyed Motors by Size Category

	Chemicals	Cement/Building Materials	Wastewater	Food Processing	Agriculture
Motor Size	% of Motors	% of Motors	% of Motors	% of Motors	% of Motors
<6 hp	42%	58%	*	66%	*
6-200 hp	54%	42%	*	33%	*
>200 hp	3%	0%	*	1%	*
Total Motors	1,048,745	205,482	*	992,230	*

Source: DOE Motor Study [17]

Table 6: Percentage of Total Surveyed Motor Energy Use by Size Category

	Chemicals	Cement/Building Materials	Wastewater	Food Processing	Agriculture
SIC					
Motor Size	% Energy	% Energy	% Energy	% Energy	% Energy
<6 hp	2%	17%	*	10%	*
6-200 hp	39%	83%	*	61%	*
>200 hp	59%	0%	*	29%	*
Total Energy	144361	2231		36796	

Source: DOE Motor Study[18]

In 2005, Kaufman et al., from North Carolina, performed a "100-Motor Study" that proposed to study 100 motors, 50 of them in California, from 1971 or earlier.[19] The study discovered that it was difficult to

[17] Xenergy, Inc. 1998. United States Industrial Electric Motor Systems Market Opportunities Assessment. Prepared for the US Department of Energy's Office of Industrial Technologies and Oak Ridge National Laboratory
[18] Ibid.

find 50 motors from 1971 or earlier, and the date range was relaxed to 1981. Results found that motor efficiencies are difficult to predict, and the efficiency ranges can range from 85-95% on older motors, which in some cases match National Electrical Manufacturers Association (NEMA) Premium standards. The older the plant, the older the motors tend to be, with some plants running motors as old as 50 years that have usually been rewound several times rather than replaced.

According to SME interviews, very few industrial motors run more than 4,000 full load hours[20] per year. Even in facilities that run 24/7, 2,000-4,000 full load hours is much more common. This agrees with the 2002 DOE motors survey, which reports average hours of use (but not full load hours) ranging from 2700 to 7,500, with larger motors (>200 hp) running the longest hours.[21] The interviews also indicated that around 95 percent of motors are alternate current (AC) motors, though direct current (DC) motors are commonly used in high-torque applications and may make up 10-15 percent of the overall plant load.[22] This SME's expertise is in food processing and cement plants, so this may not apply to the other sectors.

Advanced control systems, particularly variable frequency drives (VFDs), are increasingly prevalent across industries. This is due to several factors, including the increased reliability of VFD systems themselves, as well as the success of utility-driven rebate programs. One of the SMEs Navigant interviewed suggested that the most cost-effective applications of VFDs have already been installed, particularly in the food processing and cement/building materials subsectors.

2.1.1 Subsector-Specific Motor Characteristics in California Industries Based on Facilities Managers Interviews

For each subsector identified above, Navigant interviewed one or more facility managers. In each industry, the Navigant team asked the managers about the characteristics of their motors, including: sizes, efficiencies, and vintages of the facility's motors; motor runtime characteristics; prevalence and application of VFDs; and repair/rewind versus replacement methodology. For more details of the interview, please see Appendix D.

Table 7 and Table 8 present the overall findings from the FM interviews conducted by the Navigant team. Table 7 shows the reported distribution of sizes by facility based on these interviews. . Percentages in the table represent the percent of the total count of motors in the facility.

The results reported in Table 7 indicate that, outside of the chemicals, food processing and indoor agriculture industries, the predominant size for motors in California industry falls in the 10-200-hp range

[19] Kaufman, Nicole M. and Daniel Welch, Advanced Energy, and Richard R. Johnson. 2005. "A 100 Motor Study: Investigating Pre-EPAct Motors as a Subset of the Industrial Motor Population for its Effects on the Economics of Motor Replacement, Preliminary Results." ACEEE Summer Study on Energy Efficiency in Industry.
[20] A full load hour is the equivalent of the motor running at full capacity for an hour. For an example, a motor running at 85 percent capacity for 100 hours would run 85 full load hours.
[21] Xenergy, Inc. 1998. United States Industrial Electric Motor Systems Market Opportunities Assessment

that this study focused on. These are the range of motors covered by the Energy Independence and Security Act of 2007 (EISA) ruling, mandating NEMA Premium motors.

Table 7. Reported Distribution of Motor Size by Industry

Motor Size	Chemicals	Cement/Building Materials	Wastewater	Food Processing	Agriculture
<10 hp	85-100%	0-15%	0%	60-85%	0% (100% for greenhouses)
10-200 hp	0-15%	85%	90-100%	15-40%[23]	80-85%
200+ hp	0%	0-15%	0-10%[24]	0%	15-20%
Interviews	3	1	2	2*	2*

*Source: facility manager interviews *Navigant also interviewed one or more SMEs in this subsector.*

Table 8 presents a short summary of the other motor characteristics Navigant asked about in the FM interviews. The results indicate that whereas the cement/building materials and wastewater subsectors have newer, more efficient motors, the food processing and agriculture subsectors lag behind in this regard. Agriculture has an extremely large range of motor ages compared to the other industries covered in this report. This is consistent with prior research, and likely reflects the at times haphazard way that the agriculture industry approaches their motor management.

Table 8. Reported Additional Motor Characteristics by Industry

	Chemicals	Cement/Building Materials	Wastewater	Food Processing	Agriculture
Reported Age	10-15 years	10 years	10-15 years	20 years	1-60 years
Reported Efficiency	Lower than NEMA Premium*	NEMA Premium	NEMA Premium	Lower than NEMA Premium*	Varies
Runtime Characteristics	Varies Widely	Varies Widely	Most Continuous, Some Rotating	Continuous	Off-Peak Seasonally

**These industries reported a large number of specialized motors, many of which are not subject to the same standards as NEMA Design B motors.*

Source: facility manager interviews

2.1.1.1 *Cement/Building Materials Subsector*

The cement/building materials industry uses motors intensively; some facilities run 24/7 with energy-intensive processes. Roughly 85 percent of the motors in the plant where the Navigant team interviewed for this study are 7.5 to 200 hp. This is consistent with the 2002 DOE report finding that motors in the 6-200 hp range use 82% of the total energy used by motors in the Stone, Clay, glass, and Cement products

[23] These motors are generally on HVAC equipment on air compressors, not on process equipment.

[24] Larger motors are for aeration pumps.

SIC. The FM reported that motors are used in most aspects of plant operation, including the quarry, the raw mill, the finish mill, the blending system, kiln system, cooler system, clinker transport, grinding, and shipping. He also indicated that the raw mill and the finish mill are down once a week for preventative maintenance. VFDs are in use at the facility, but primarily are used on fans.

Ten years ago, an SCE motors program was instituted that was designed to replace older motors with more efficient options. This increased the efficiency of the motors at the plant from the 80 to the 90 percent efficiency range. More recently, according to the facilities manager, the entire subsector has mostly switched to Premium Efficiency motors. The FM reported this based on a network of contacts through repair shops and the Portland Cement Association, which hosts an annual and bi-annual conference dealing with energy efficiency and working group papers.

More generally, the plant looks to replace motors prior to failure and perform regular service on their fail. Otherwise, they repair or replace motors on failure, always with Premium efficient motors. The decision to perform a green rewind in this industry rather than replace depends greatly on the availability of a motor. For example, the FM reported that there is currently a 6-12 month lead time for custom motors, where a rewind is typically finished in 7-8 weeks. However, he reported that the size cutoff for motor repair versus replacement is 100 hp.

The key point Navigant took from the interview in this sector is that the cement/building materials subsector is already quite energy efficient. The facilities exchange information about energy efficiency, and take the opportunity to utilize utility incentives when they're available. The facility manager indicated that they will "absolutely" use energy efficiency incentives where they are available, suggesting that a motor efficiency program incentivizing motors above NEMA premium would be successful if targeted at this subsector.

2.1.1.2 Wastewater Subsector

The wastewater industry is similar to the cement/building materials industry in that most wastewater treatment plants must run 24/7 with energy-intensive processes. The primary application for motors in the wastewater treatment industry is in pumping. The two plants interviewed ran motors of very different sizes. One had motors generally ranging from 50 to 200 hp, while the other reported that their motors were in the 10-15 hp range. The motors at the first facility interviewed average about 15 years. The second FM was unsure of the typical age of the facility's motors, but other answers throughout the interview suggested they were replaced frequently with the help of their utility. This FM also understood that though first cost was a barrier, operational cost savings could be shown to warrant that upfront investment.

The two facilities managers Navigant interviewed for this study said that VFDs are used extensively in the wastewater treatment industry for process control purposes. In general, the plants do not want simple on-off operation of their motors, but require more control. VFDs help provide that control to critical processes, such as aeration, which is the largest energy-consuming process on-site.

Similar to the cement/building materials interview, the FMs interviewed in the wastewater industry indicated that they try to predict when their pumps will fail by performing testing on them. Both indicated that their utilities play a big role in this process, performing testing and providing incentives for motor replacement. Rewinding was common in one facility utilizing larger motors, but not the facility that reported smaller motor sizes. When making the decision to rewind or replace a motor, motor size was a primary consideration, as was lead time for replacing versus rewinding a motor. Both indicated that motors less than 20 hp are always replaced rather than rewound.

As with the cement/building materials subsector, both FMs in the wastewater subsector reported a high emphasis on efficiency, though the suggestion from both FMs is that other facilities are not as efficient. The one statement that stands out is that, while operational cost savings can justify a more efficient motor purchase, first-cost is a significant barrier. This again suggests that a motor efficiency program incentivizing motors above NEMA premium would be successful if targeted at this subsector.

2.1.1.3 Chemicals

The Navigant team was able to procure two FM interviews in the chemicals subsector – one in the targeted pharmaceuticals industry and the other in agricultural and commercial products, including insecticides. While the operations and motor inventory of the two facilities vary, the inability to answer questions about the efficiency of existing motors suggests that this is not a high priority. Nevertheless, they may consider more efficient replacement options if they were presented to them as cost effective at the time of replacement.

Based on our interviews, operations among chemicals facilities vary greatly, but there are some similarities in their motor populations. While the pharmaceutical FM related runtimes of only a few hours each day, five days a week, the agricultural chemical manufacturer ran operations 24/7, except in situations when product inventory had built up and put production on standby. Still, both use relatively small motors, similar to food processing operations. The pharmaceuticals facility's two largest operations are grinding and blending at 7-10 hp each, but the other motors are mostly only 0.25 or 1 hp. The agricultural chemicals operations primarily use 0.5 hp and 1 hp motors, with motors up to 125 hp at the largest. Also similar to food processing, and perhaps due to the similar size of motors, motors at the chemicals facilities were largely unregulated with regards to efficiency. Nevertheless, the agricultural chemicals FM noted that some motors were required to be explosion-proof. It is possible that the precision required in pharmaceuticals results in the heavy use of three-phase motors and VFDs, while the other manufacturer expressed that 80-90 percent of motors ran at constant speed, so only some motors had VFDs.

There is also the issue of specialized motors in this subsector. These motors are embedded in equipment in such a way that the motor cannot be replaced alone; the whole machine would need to be replaced. This inhibits early retirement of these motors and may keep them in place for extended periods of time; the pharmaceutical FM admitted to having a 64-year-old motor still in operation. (This does not necessarily mean it is inefficient compared to a newer model, as some specialized motors have not increased in efficiency for quite some time.) Nevertheless, the majority of motors are 10-15 years old with the agricultural chemicals producer citing a mixed practice of replacing and rewinding motors.

The key finding that was corroborated by both interviews in this subsector was the lack of enthusiasm for energy efficiency. This means that incentives will need to be both timely and cost-effective. Specialized motor replacements incentivizing more efficient models as well as green rewind incentives may each be applicable depending on individual facility protocol for repairing and replacing motors.

2.1.1.4 Agriculture Subsector

In agriculture, the primary application of motors, as reported in the interviews, is pumping for irrigation. This agrees with what Navigant found in a previous study of energy use in California agriculture.

The exception is greenhouses, which are unique within agriculture in that they use primarily 1-hp motors, with some up to 10 hp, for exhaust fans, water pumping, refrigeration, conveyors, and other uses. They consider 10-15-year-old motors to be fairly old because they typically don't rewind anymore. These facilities are drawn to the cost savings associated with efficiency, and one FM had realized that pumps lasted longer with VFDs due to reduced wear on the system from starts and stops.

Otherwise, agricultural pumps vary in size: well pumps may exceed the 200-hp focus of this study, while booster pumps are generally between 50 and 150 hp. The age of motors reported is highly varied, from 1970s vintage up to new, Premium efficient, motors. This response is supported by the 2013 Navigant study on California agriculture. One FM added that the big well pump motors were only 5-6 years old while the smaller booster pump motors were 15-20 years old. Many agricultural motors operate seasonally, with one FM Navigant interviewed reporting that his pumps run seven months a year, from 6 p.m. to 12 p.m. (off-peak times). While an interviewee from a pump test group mentioned that irrigation pumps are almost all constant speed, other interviews indicate that VFDs are often used on deep pumps, either because the motors on those pumps must be run very slowly or to prevent power surges. One FM stated that if a better utility program was available for putting VFDs on smaller (booster) pumps, he would participate; without the rebate, they are still not perceived to be cost effective. VFDs are also highly beneficial when implementing drip irrigation because these more efficient systems require less pressure. System automation is also emerging with the rise of drip irrigation.

Pump efficiency tests are conducted every six months to every two years, but some facilities don't test all pumps every time. Nevertheless, without the utility providing the tests, one FM said he wouldn't test all of his pumps every time, and the pump test groups say that there is a strong culture of "if it's not broken, don't fix it."

Most motors at the facility are repaired rather than replaced, matching Navigant's findings in a study of California agriculture. One FM reported most motors at his facility had been rewound at least once over the prior 40 years, and has only replaced two motors in the past 15 years. As an example of why motors may be repaired rather than replaced, well pump motors are matched to a specific set of bowls, which encase the pump's impellers, and well depth. Often times, new motors will not match with the old-style bowls, requiring the purchase of new bowls and additional equipment to make the new motor fit. The result is a more costly alternative as compared to rebuilding/rewinding the motor.

When driven to replace a motor, which was reported as happening when the prior motor was "blown to smithereens," the most important consideration for buying a more efficient motor is return on investment (ROI). The FM indicated that if the ROI is more than five to seven years, they do not consider the Premium efficient (higher efficiency than mandated by standards) motor. Since the motors operate seasonally, it is more difficult for them to see a five-to-seven-year ROI than it would be in a year-round operation.

Consistent with prior Navigant research, agriculture cited upfront costs as a primary barrier to installing energy efficient equipment. Both the current research and prior research indicate drip irrigation is becoming more prevalent as water conservation becomes a higher priority for the agriculture sector. Conversion to drip agriculture and emphasis on water efficiency presents an opportunity to target this sector for energy efficiency upgrades when they are already purchasing equipment.

2.1.1.5 Food Processing Subsector

In the food processing interview, one facilities manager indicated that approximately 15-40 percent of motors at facilities are in the 10-200-hp range. The majority of these are on chillers, air compressors, cooling towers, and boilers. The remaining population of motors falls below 10 hp. The primary applications of these motors are driving conveyors, packaging equipment, compressors, and pumps within the facility, often for refrigeration. Motors for refrigeration may be serviced by a specific refrigeration service contractor. Facilities run 24/7, and one manager reported that, as a general rule in the food processing industry, "production is king." The facility manager is therefore willing to sacrifice efficiency for reliability and motors are not replaced before they burn out.

Another FM interviewed reported that VFDs are used in their facility primarily for process control. VFDs in that facility were not used for energy-saving purposes. FMs responded that VFDs were on 50-90 percent of motors.

In the food processing industry, the SME and FMs both reported that motors are often rewound, even below the generally accepted 50-hp threshold. This is primarily because motors are specialized and must be ordered directly from the OEM. These motors carry a cost premium that makes facilities more likely to rewind and repair them rather than replace and update the motors. With specialized motors, there can be a significant lag time for ordering a new motor (one SME reported a 52-week or more lag time for custom motors), making rewinding a more attractive option in the food processing industry. Despite the propensity for rewinding motors, the FM exhibited a lack of knowledge regarding green rewinding processes, which represents the lack of energy efficiency awareness of small food processors.

Our interviews revealed that facility managers in small food processors are concentrated on production. Energy efficiency falls outside their scope of focus simply because they do not have the bandwidth to investigate potential opportunities. Routine servicing of equipment may even be contracted out for standard systems like refrigeration. These facility managers need to be presented with a case for energy efficiency projects to move forward. Energy audits that can summarize the opportunities and provide cost-effectiveness metrics would be a valuable and welcome tool in this subsector.

2.2 *Initiatives to Date*

Motor efficiency standards have been steadily increasing for the last three decades. Motor efficiency programs have generally followed suit, offering incentives for the replacement of older, less efficient motors with high-efficiency motors.

2.2.1 Federal Initiatives

Prior to the implementation of EISA,[25] many utilities offered a prescriptive motor program for replacing an existing or failed motor with a NEMA Premium motor. Since EISA made NEMA Premium the standard efficiency for most motors in the United States, most utilities have halted their motors programs. Those that remain (see section **Error! Reference source not found.**) offer incentives for motors over the NEMA standard, or for early retirement of older, less efficient motors.

2.2.2 California Programs

The majority of California utilities have dropped their efficient motors rebate programs with the implementation of EISA. This federal standard mandated that the majority of new motors within the target range for this study, 10 to 200 hp, be NEMA Premium Efficiency.

Since efficiency gains beyond NEMA Premium are minimal (see section 2.3 for details), there is less reason to implement motors programs. Many utilities, however, still have programs for the installation of VFDs and other motor controls on existing motors, particularly in HVAC applications. At least one utility with service territory in California, Pacific Power, has a Green Motor Rewind program, providing an incentive to both the motor repair shop and the customer. This program is presented in Section 3.2.2.

California Title 24[26] implemented additional motor requirements for the state of California. These efficiency guidelines, for certain motors, reach above and beyond the NEMA Premium Efficiency levels. These standards went into effect on July 1, 2014.[27]Nevertheless, federal regulations supersede California Title 20 and Title 24 standards, even in cases where the federal regulation stipulates lower efficiency.

2.2.3 Other State Initiatives

The Green Motor Practices Group (GMPG) initiated a program with Bonneville Power Administration several years ago that incentivizes green motor rewinds. This pilot program provides an incentive of

[25] Available here: http://www.gpo.gov/fdsys/pkg/BILLS-110hr6enr/pdf/BILLS-110hr6enr.pdf.
[26] Available here: http://www.energy.ca.gov/title24/2013standards/index.html.
[27] Title 24 standards are available here:
http://www.energy.ca.gov/title24/2013standards/implementation/documents/2013_nonres_ACM_reference/2012-10-26_2013_Nonres_ACM_Refernce_manual.pdf.

$2/hp to shops that carry the GMPG's certification, and the shop then applies a $1/hp rebate to their customer. This program has since been replicated across the northwest.[28]

2.3 Codes and Standards

The U.S. Department of Energy (DOE) established the most recent final rule for motors in May 2014. Compliance with new motor standards among manufacturers will be required starting June 1, 2016.[29] Motor standards for the most common motors (1 to 200 hp NEMA Design B) remain the same as EISA 2007 (NEMA Premium standard) that went into effect in 2010, but DOE has expanded the scope of their coverage to include motors not previously covered. This includes 201- to 500-hp NEMA Design B motors, as well as other motor types such as NEMA Design C and fire pump motors.[30]

The recent rulemaking/standard developments reflect an agreement among stakeholders involved in the process. Specifically, manufacturers pushed back on proposals to increase motor standards by another efficiency band. (A band reflects a motor's range of efficiencies on a motor curve.) For example, manufacturers indicated that differences between NEMA efficiency bands are becoming increasingly small as standards approach the top end of electric losses. Achieving these higher efficiencies is possible, but can be cost-prohibitive. The rulemaking analysis identified maximum technology designs as having all-copper rotors.

Figure 2, Figure 3, and Figure 4 present the historical efficiencies for example motors specifically analyzed for the DOE analysis. As size (hp) increases, the gap between the baseline standard and the efficiency options narrows. The maximum technology efficiency level may increase over time, but that is not certain. Either way, this indicates that, over the past 20 years, efficiency standards have almost caught up with the maximum technology available, and consequently efficiency gains over the standards are smaller and more difficult to achieve and promote.

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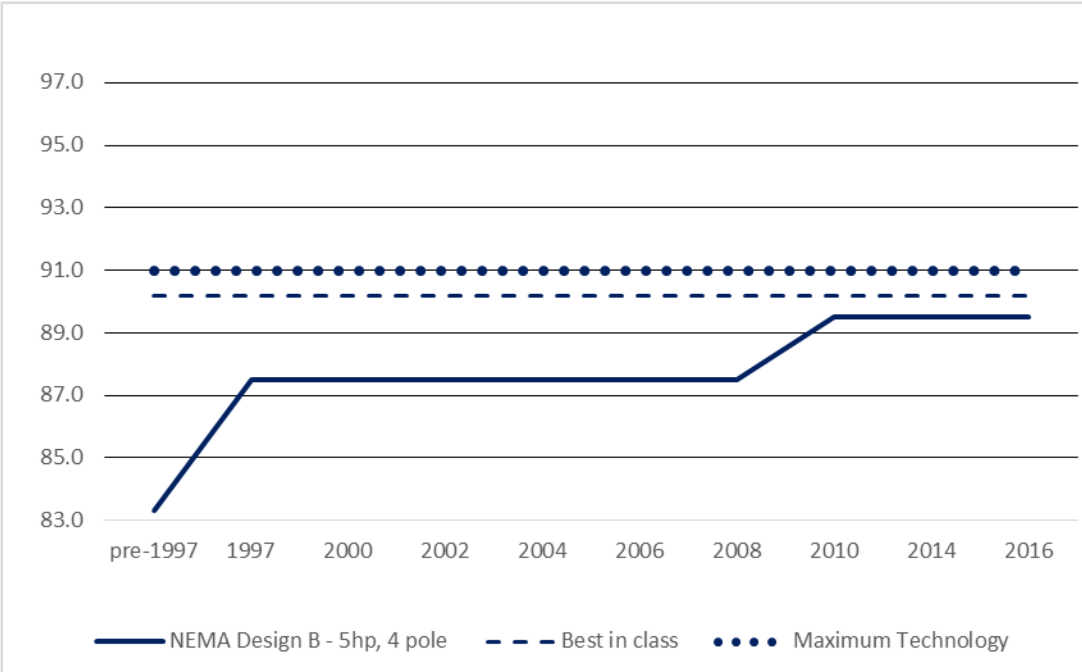
[28] For a full list of participating utilities, please see http://www.greenmotors.org/utilities.htm.

[29] For more information, see http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/50.

[30] U.S. Department of Energy. *Electric Motors Rulemaking Page*. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/50.

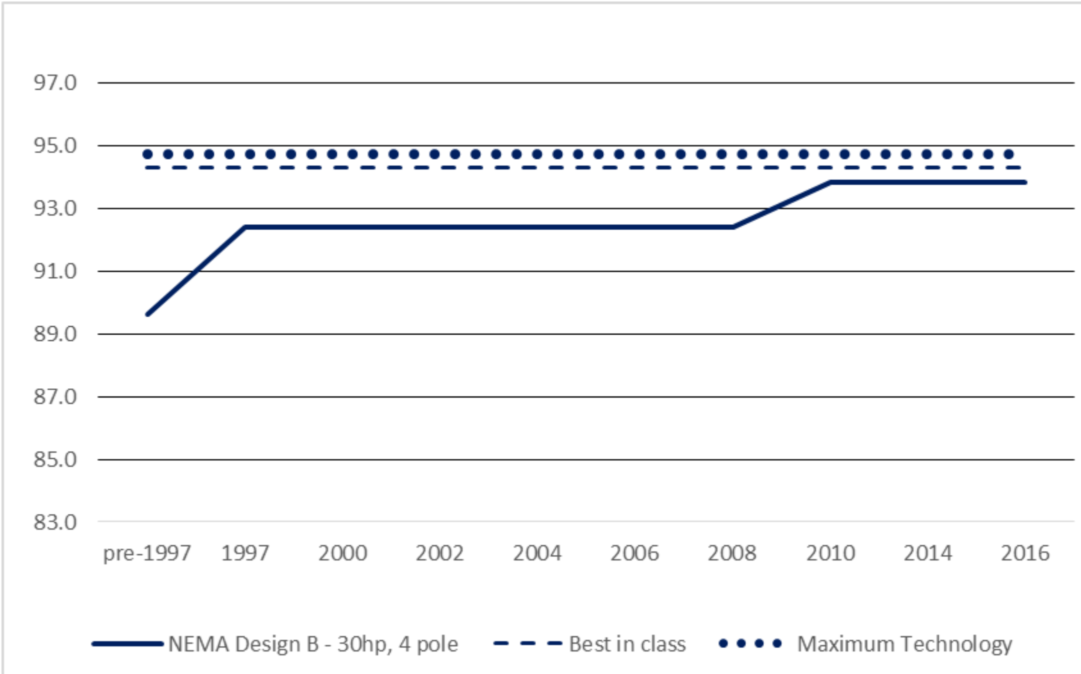
Figure 2. Efficiency Standards for 5-hp Motors by Year



Source: Navigant spreadsheet drawing from DOE rulemaking page[31]

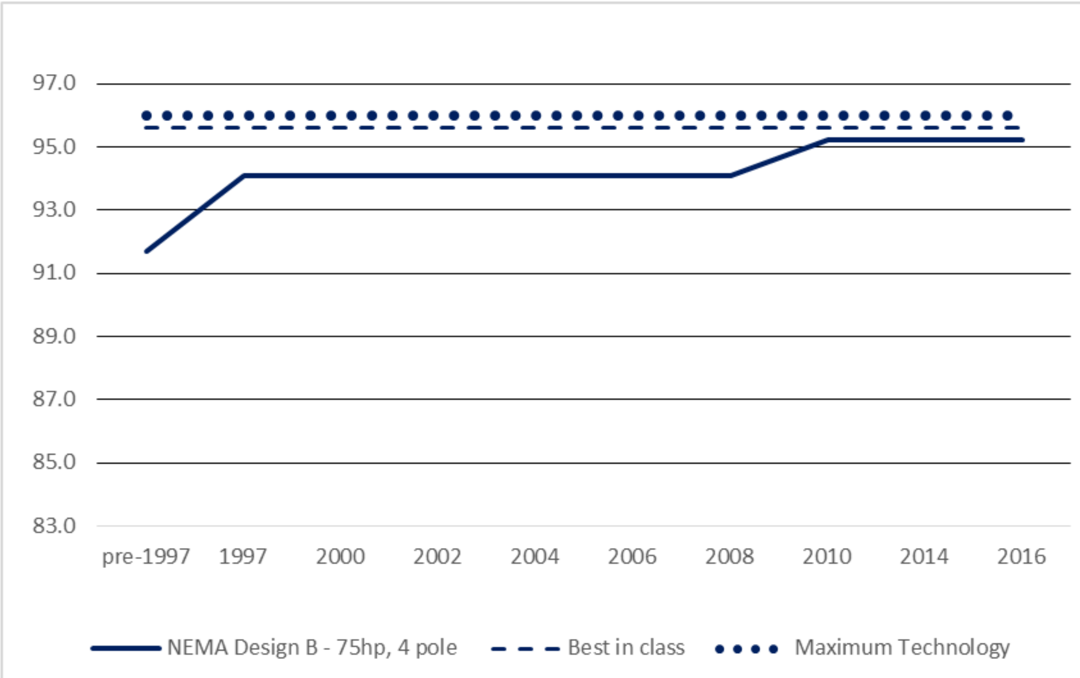
[31] http://www1.eere.energy.gov/buildings/appliance_standards/rulemaking.aspx/ruleid/42

Figure 3. Efficiency Standards for 30-hp Motors by Year



Source: Navigant spreadsheet drawing from DOE rulemaking page

Figure 4. Efficiency Standards for 75 hp Motors by Year



Source: Navigant spreadsheet drawing from DOE rulemaking page

Similar to NEMA's classifications, the International Electrotechnical Commission (IEC) has developed efficiency rankings, as shown in Table 9. NEMA does not have a name for motors more efficient than Premium because this level of efficiency requires special motor technology that may not be applicable across motor types or applications. As seen above, NEMA Premium is very close to the theoretical maximum motor efficiency, limiting improvements.

Table 9. IEC Equivalents to NEMA Efficiency Classifications

NEMA	IEC	Efficiency Level
None	IE4	HIGHEST | LOWEST
Premium Efficiency	IE3	
Energy Efficient	IE2	
Standard Efficiency	IE1	

Source: International Electrotechnical Commission

2.3.1 Cost of Efficiency

The DOE rulemaking analysis also examined cost differences between the efficiency levels. Table 10 presents the results of this examination. "Motor Relative Cost" indicates the price of an average motor of that efficiency level relative to the standard efficiency noted in the comment column. As indicated by the table, once the efficiency moves beyond NEMA Premium, the prices rapidly increase.

Table 10. Cost Premiums for Efficiency Beyond NEMA Premium

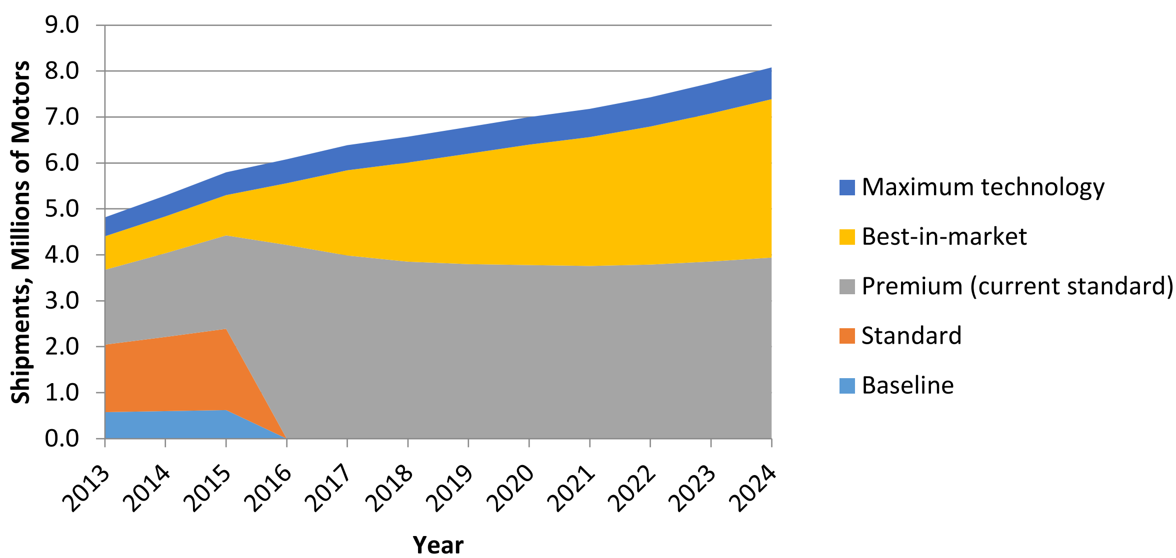
Motor Relative Cost	Efficiency Level	Comment
Basis	Standard	EISA 2007 for 1- to 200-hp motors, and standard going into effect in 2016 for 201- to 500-hp motors (NEMA Design B and other types). NEMA Premium.
14%	Best-in-Market	One NEMA band (nominal efficiency level) above the standard (above NEMA Premium).
72%	Maximum Technology	One NEMA band (nominal efficiency level) above the best-in-market efficiency.

Source: Navigant Analysis

2.3.2 Shipments Forecast

The DOE rulemaking also projects shipment forecasts to reflect the impacts of the new 2016 standard. The following represents roughly 80 percent+ of the motors market, and this figure relates to NEMA Design B motors and motors ranging from 1 to 500 hp. The standard and baseline motors showing shipments activity in 2013 to 2015 represent previously unregulated motors ranging from 201 to 500 hp. In 2016 the new standard goes into effect that prohibits the manufacture of 1- to 500-hp motors below NEMA Premium levels. As see in Figure 5, DOE forecast models estimate that a portion of shipments (in the absence of future standards) will include efficient motors above the standard. According to DOE, best-in-market motors will represent roughly 30 percent of market share, and maximum technology will represent roughly 10 percent.

Figure 5. Shipment Forecast Reflecting the Impact of the 2016 Standard



Source: Navigant research for DOE motors rulemaking[32]

2.3.3 Navigant's Estimation of Standards and the Motor Market Looking Forward

Per EISA 2007 requirements, DOE will revisit the motor standards again in six years (2020). This will likely result in another standards update occurring in 2023 following the multiyear rulemaking process. Therefore, these standards, and standards for these NEMA Design B motors, will be in place for roughly the next seven years. Although uncertainty is currently high, Navigant estimates that standards in 2023 will likely increase motor efficiencies again by one NEMA band for Design B motors. DOE's scope of authority may also increase if they choose to adopt regulations for a wider range of motor types. Navigant also anticipates the maximum technology available to the market will remain constant for the next year. However, this may change and increase in following years. Navigant notes that the maximum

[32] Shipment data sourced from the Government Regulator Impact Model, available at http://www1.eere.energy.gov/buildings/appliance_standards/rulemaking.aspx/ruleid/42.

technology identified relies on significant amounts of copper and is, therefore, sensitive to fluctuating copper prices.

2.4 Industry Standard Practice (ISP)

Across subsectors, the primary finding regarding ISP was the size threshold at which motors become large enough to rewind rather than replace. This threshold ranged between 50 and 100 hp, with 100 hp being the most commonly quoted cutoff point. It is standard practice to replace any motors below this threshold because below about 100 hp, purchasing cost approximately equals rewinding cost, and manufacturers also warranty new motors, providing additional benefit to this option. This is consistent with prior Navigant research, including interviews with EASA, the Green Motors Practices Group, and CEE.

VFDs are also often a debated topic of ISP. In general, our interviews found that VFDs were often in place for process control on those motors that did not run constantly at full power. FMs appeared not to view VFDs as efficiency measures, but to value the operational control that they afford. This attitude does not necessarily mean that VFDs are ubiquitous in appropriate circumstances, as the Measure, Application, Segment, Industry (MASI) study on efficiency in wastewater treatment plants found that there is still potential remaining even though a recent study found VFDs to be ISP for new construction in certain applications in small facilities (those processing 10 MGD or less). [33]

2.5 Decision Making

2.5.1 Customer Awareness and Experience

The wastewater and cement/building materials industries reported greater awareness of efficiency and more interest in energy matters than the agricultural, food processing, and chemicals industries. Facility managers from the wastewater and cement/building materials subsectors reported previously participating in energy efficiency programs on a large scale. They also reported a relatively new (approximately ten years old) population of motors as well as a high-efficiency level for their motors, despite most motors being manufactured before the EISA standards came into effect.

Agricultural and food processing FMs reported a tendency to rewind motors rather than replace them. This is due to a number of factors.In food processing a primary reason is that the motors these industries use are often specialized, matching the specific application. The agricultural FMs reported rewinding pump motors because they were matched to a specific pump setup. The FMs that the Navigant team interviewed also show a lack of knowledge about green rewinding processes that suggest a possible education program or incentive may be of use there. Both these subsectors reported older motors as well as varied efficiency levels in their motors.

Across all subsectors, facility managers reported that the most important relationship in regards to energy efficiency programs and their participation is their account representative at the utility. This

[33] Industry Standard Practice Study, New Load VFD Additions to Wastewater Treatment Pumps, ASWB (2014).

personal interaction allows them to stay informed of the rebates and incentives available in their area, and all FMs reported that the utility account representative is their primary source of information in regards to energy efficiency.

2.6 *Key Drivers and Market Trends*

Across industries, overall motor cost, and particularly ROI and payback periods, are critical drivers. This is particularly the case in the agricultural subsector and seasonal food processors, where seasonal operation means that energy savings do not add up as quickly, and the resulting cost savings do not repay the initial investment as quickly. One FM in the agricultural sector indicated that a payback period of five to seven years is critical and an SME said this was more like a two- to three-year payback; otherwise, the facility is likely to rewind the motor rather than replace it. Another FM specified that in building a new facility, he wanted to look at incorporating savings over time into cost calculations.

The primary driver for motor decisions in the food processing industry is production, with one facility manager stating that "production is king." This drives the industry to rewind rather than replace motors unless the motor is below the 100-hp threshold. Spare motors may also be stored on-site for critical processes. When looking to replace a motor, efficiency does not take a high priority. The reason given is that many motors in this industry are highly specialized to a specific application, and replacements are generally limited to what the original equipment manufacturer has in stock. This is consistent across SME and FM interviews.

The small, specialized motor population also puts efficiency behind production in the chemicals industry. This inattention to motors results in a general lack of knowledge on motor efficiency and little movement toward more efficient motors.

Energy is the primary expense in the wastewater and cement/building materials industries, and the FMs the Navigant team interviewed work closely with the utility to take advantage of incentive and rebate programs and to keep the facility running as efficiently as possible.

2.7 *Key Barriers*

The interviews with SMEs and FMs revealed a number of barriers that prevent companies from upgrading their motors to higher efficiency bands.

2.7.1 Technical Barriers

As suggested in section 0, the gains to be made in motor efficiency are shrinking as the motor efficiencies approach the theoretical maximum efficiencies for each motor size. This represents the key significant technical barrier for increasing motor efficiency, particularly as SMEs report that approximately 90 percent of motors they encounter are NEMA Design B.

2.7.2 Market Barriers

As mentioned in section **Error! Reference source not found.**, the food processing and agricultural sectors are more often seasonal operations than other subsectors are. Because of the downtime inherent in seasonal operations, these subsectors are less likely to consider a premium efficient motor unless the payback period is shorter than required for most industries, because they will not get the same energy savings as 24/7 operations.

In both the agricultural and food processing subsectors, the facilities managers interviewed by the Navigant team exhibited little knowledge of green rewinding opportunities. Navigant had anticipated this in the agricultural subsector, but had not foreseen this knowledge gap in the food processing subsector.

One theme that emerged across the SME and FM interviews was the importance of minimizing downtime. Facilities, particularly in food processing, try to maximize production and minimize downtime. One way they do so is to rewind motors, as this can take only two weeks compared to four weeks to replace a motor, particularly for custom orders. The FM in the cement/building materials subsector reported even longer wait times (7-8 weeks for a rewind and 6-12 months for custom motor orders). A second method is to use a spare motor from their existing stock of spare parts. Often the existing inventory is not Premium efficient, but the cost of energy is seen as secondary to the cost of having equipment offline.

The food processing subsector in particular uses a significant number of specialized motors, which for the most part do not fall under the EISA standards. These motors carry a price premium, and are usually repaired rather than replaced. Two examples of motors that may be candidates for energy improvements are wash-down motors, which are expensive to replace, and right-angled gear drive motors, used on conveyors, which facilities will repair even when they are low-horsepower motors.

2.8 Energy Savings Opportunities

Agriculture and food processing tend to rewind motors rather than replace them. They show a lack of knowledge about green rewinding processes that suggests a possible education program or incentive may be useful. According to the green rewind-certified shop the Navigant team interviewed, a poorly rewound motor can lead to a drop in efficiency of 1.5 percent. Since both these industries are often seasonal operations, one opportunity would be to target their downtimes for possible energy efficiency upgrades. By working within existing schedules, the facility managers can avoid the commonly cited issue of minimizing downtime. Both DOE and Motor Decisions Matter have information regarding motor management that could be used for educational purposes.[34]

Facilities quote a cutoff of 50 to 100 hp, rewinding motors larger than the cutoff horsepower at certified green rewinding motor shops, and replacing those smaller than the cutoff with Premium efficient motors.

Additional energy savings may be found in improving the efficiency of motors that are not currently in use. Facilities will often keep a store of motors as spares for those that may break down. These motors

[34] Available at http://www.motorsmatter.org/ and http://www.energy.gov/eere/amo/articles/motormaster

may be a worthwhile target for efficiency upgrades, as replacing them does not require the plant to shut down production. As indicated in at least one interview, these are often spare motors for specialized applications. Many of these are not subject to the EISA efficiency standards and may be good candidates for efficiency upgrades.

A common theme across SME interviews is a suggestion to focus not on the motors themselves but on the equipment driven by those motors. As one SME said, attaching a 1 percent more efficient motor to a 60 percent efficient pump does not give you as much energy savings as increasing the efficiency of the pump itself. Since pumps in particular degrade at around 2 percent efficiency a year,[35] this may be one area to explore for future program opportunities.

[35] SME interview.

NAVIGANT

3 Findings and Recommendation

3.1 *Findings*

The targeted sectors in this study have reported a variety of traits and attitudes towards motor efficiency in California industries, as shown in Table 11. Based on the interviews and secondary research, Navigant has developed a variety of findings and recommendations for motors programs moving forwards that leverage these traits to provide a more targeted approach towards motor efficiency.

Sample size is one of the limitations of this study, while the SME are knowledgeable of the industry trends and FMs we interviewed are familiar with their facility energy use, additional research to confirm industry characteristics are recommended prior to program design.

Table 11. Summary of Sector-Specific Motor Traits for Targeted Programs

Sector	Motor Size (hp)	Repair/ Replace Practice	Industry Awareness of EE	Industry Interest in EE	Standard/ Specialized Motors	Seasonal/ Continuous
Chemicals	<10	Replace (<50 hp) Rewind (>50 hp)	Medium	Medium	Specialized	Varies
Cement/ Building Materials	10-200	Replace (<100 hp) or Green Rewind	High	High	Standard	Continuous
Wastewater	10-200	Replace (<20 hp) or Green Rewind	High	High	Standard	Continuous/ Rotating
Food Processing	<10	Rewind Specialized. Replace others	Mixed	Low	Specialized	Continuous and Seasonal
Agriculture (outdoor)	10-200	Repair/ Rewind Extensively	High	Medium	Specialized	Seasonal
Agriculture (greenhouse)	<10	Replace	High	High	Standard	Intermittent

Source: Navigant Analysis

3.1.1 Specialized Motors Programs

Specialty motors, particularly in the food processing subsector, are often rewound rather than replaced. Navigant suggests the utilities perform an analysis on the opportunity in California's relevant subsectors to replace specialized motors with higher-efficiency models. Using utility account representatives to inform FMs about these upgrades may be an immediate way to improve energy efficiency.

Based on Table 11, Navigant suggests utilities to explore targeting the subsectors in the following manner. All subsectors would likely benefit from a green rewind incentive and energy audits.

3.1.2 Cement/Building Materials Subsector

The cement and building materials subsector reports high efficiency in its motors, and a high emphasis on efficiency in their business practices. Since they are already running NEMA Premium motors, the traditional motor incentive program will likely be well received. Additionally, while the facility interviewed for this study performs green rewinds, this is likely not the case at all facilities in the cement and building materials industry, and Navigant recommends targeting a green rewind incentive at this subsector. If facilities are already running high-efficiency motors, a focus on driven equipment is recommended.

3.1.3 Wastewater Subsector

Wastewater is unique among the subsectors interviewed in this study because the individual facilities are not in competition with each other and are therefore more likely to share information with each other. Perhaps because of this, the wastewater sector already reports a high level of efficiency operation in its motors. This sector is a prime candidate for driven equipment incentives. Since they are running high-efficiency motors and utilizing green rewind shops, driven equipment is likely the prime inefficiency in the system.

3.1.4 Chemicals Subsector

The chemicals subsector uses a large number of small, specialized motors and has an emphasis on production. With this in mind, this subsector is probably a good target for specialized motor efficiency programs, and a spare motor efficiency program.

3.1.1 Food Processing Subsector

The food processing subsector also runs a large number of smaller, specialized motors and has an emphasis on production. As with the chemicals subsector, the food processing subsector is a good candidate for specialized motor efficiency programs and a spare motor efficiency program. They may also be a good target for the frame adapter program.

3.1.2 Agriculture Subsector

The agriculture subsector is split into indoor and outdoor agriculture. Indoor agriculture uses a large number of small motors, and already is highly efficient. These motors are reportedly replaced often, and this subsector is therefore a good target for the standard motor incentive program.

Outdoor agriculture lags behind a bit in motor efficiency. They are a good target for the traditional motor incentive for this reason. In addition, outdoor agriculture tends to rewind motors extensively, and so is a good target for green rewind incentives. The frame adapter incentive may also be useful here.

3.1.3 Spare Motors Incentives

A theme that emerged across several subsectors in our California interviews was the notion of downtime. In industries where continual production and minimization of downtime are valued highly, facilities will often keep spare motors in storage. One program option for these industries is to incentivize purchasing more efficient spare motors so that when a motor does go down, they have a readily available, efficient spare already on hand with which to replace it. Further research is needed to assess the time that these spare motors spend on the shelf and how to most effectively time their replacement.

3.1.4 Frame Adapter Rebates

One SME suggested that companies tend to rewind older, T-Frame motors rather than replacing them with the newer, U-Frame motors because they are unaware there are frame adapters available. These new frames arise out of advances in insulation and winding materials that enable the motor industry to fit more horsepower into a smaller frame. Thus, U-Frame motors are designed to have the same power as their T-Frame predecessors, but now fit on smaller mounts. Adapters reposition the mounting holes and shaft height so that the shaft extension ends and motor axial centerline of the new motor is interchangeable with the old motor being replaced. Generally costing less than $200, and available even in adjustable or custom solutions, mounting adapters are also available as kits with instructions for ease of use. Putting frame adapters in the toolkit that account executives could offer to FMs educationally may promote purchases of newer, more efficient motor models. The utilities cannot incentivize frame adapters themselves as energy efficiency measures because they are not the energy-consuming piece, but investigation into whether this is a suitable solution to help motor upgrade is warranted. Navigant has been warned that frame adapters have caused unacceptable vibrations in some cases, and thereby suggests further research into how this can be prevented.

3.2 Program Suggestions

Based on the results of SME, FM, and program manager interviews, Navigant recommends two different possibilities for programs in industrial motor efficiency.

3.2.1 Traditional Motor Replacement Program

In subsectors in California that frequently replace motors, there is evidence that the traditional rebate for replacement program type may be well received. Xcel Energy New Mexico is one of the remaining utilities that administers a rebate program for replacing existing motors with NEMA Premium efficient or better motors.[36] Figure 6 shows the available rebates through this program. There are two specific cases involved in this rebate program. The first requires an existing motor that may or may not still be functioning, with a motor that is at least one efficiency band above NEMA Premium efficient (the EISA standard efficiency). This would benefit subsectors that already emphasize efficiency in their operations. The second requires a currently functioning motor be replaced by a NEMA Premium efficient motor. This would be better targeted at subsectors that lag in their efficiency practices.

Figure 6. Xcel Energy New Mexico's Rebate Program for Efficient Motors

NEMA Premium Efficiency Criteria						
	Open Drip Proof (ODP)			Totally Enclosed Fan Cooled (TEFC)		
Motor HP	1200 rpm	1800 rpm	3600 rpm	1200 rpm	1800 rpm	3600 rpm
1	82.5	85.5	77.0	82.5	85.5	77.0
1.5	86.5	86.5	84.0	87.5	86.5	84.0
2	87.5	86.5	85.5	88.5	86.5	85.5
3	88.5	89.5	85.5	89.5	89.5	86.5
5	89.5	89.5	86.5	89.5	89.5	88.5
7.5	90.2	91.0	88.5	91.0	91.7	89.5
10	91.7	91.7	89.5	91.0	91.7	90.2
15	91.7	93.0	90.2	91.7	92.4	91.0
20	92.4	93.0	91.0	91.7	93.0	91.0
25	93.0	93.6	91.7	93.0	93.6	91.7
30	93.6	94.1	91.7	93.0	93.6	91.7
40	94.1	94.1	92.4	94.1	94.1	92.4
50	94.1	94.5	93.0	94.1	94.5	93.0
60	94.5	95.0	93.6	94.5	95.0	93.6
75	94.5	95.0	93.6	94.5	95.4	93.6
100	95.0	95.4	93.6	95.0	95.4	94.1
125	95.0	95.4	94.1	95.0	95.4	95.0
150	95.4	95.8	94.1	95.8	95.8	95.0
200	95.4	95.8	95.0	95.8	96.2	95.4
250*	95.5	95.8	95.0	95.8	96.2	95.8
300*	95.5	95.8	95.4	95.8	96.2	95.8
350*	95.5	95.8	95.4	95.8	96.2	95.8
400*	95.9	95.8	95.8	95.8	96.2	95.8
450*	96.3	96.2	95.9	95.8	96.2	95.8
500*	96.3	96.2	95.9	95.8	96.2	95.8

REBATES			
Premium efficiency (as shown at left)		Enhanced Efficiency (must be at least 1-point greater than shown at left)	
Plan B - must replace working motor	Motor HP	Plan A - New or Restored Capacity	Plan B - must replace working motor
$220	1	$60	$420
$220	1.5	$60	$420
$220	2	$60	$420
$250	3	$80	$480
$330	5	$80	$650
$500	7.5	$120	$930
$550	10	$140	$1,040
$830	15	$180	$1,560
$940	20	$240	$1,780
$1,100	25	$300	$2,100
$1,100	30	$360	$2,120
$1,320	40	$440	$2,560
$1,650	50	$550	$3,200
$1,980	60	$640	$3,840
$2,480	75	$750	$4,800
$3,300	100	$1,000	$6,400
$4,130	125	$1,250	$8,000
$4,950	150	$1,500	$9,600
$5,500	200	$1,800	$10,800
$6,880	250	$2,250	$13,500
$6,880	300	$2,700	$16,000
$6,880	350	$3,150	$17,000
$6,880	400	$3,600	$19,000
$6,880	450	$4,050	$21,000
$6,880	500	$4,500	$24,000

[36] http://www.xcelenergy.com/staticfiles/xe/Marketing/Files/NM-Bus-Motors-Rebate-Application.pdf.

Source: Xcel Energy New Mexico rebate application

3.2.2 Incentives for Green Rewinds

Most subsectors in California have established protocols for rewinding certain motors rather than replacing them. Instead of attempting to change these customer protocols, there is a way to get savings out of quality rewinds. Dubbed "green rewinds," a quality rewind can achieve a higher motor efficiency. Rebates for green motor rewinds will encourage facilities to use a certified green-rewind shop to repair and rewind their motors. Such a program is already in place at Pacific Power, whose motors rebate program is shown in Figure 7.[37] This program provides a $2/hp incentive to the green rewind shop, which in turn subtracts $1/hp from the customer's invoice.

According to a 2000 report on motors by the Department of Energy[38] "You should generally subtract two points from motor efficiency on smaller motors (<40 HP) and one point for larger motors" due to rewinding. The same report later indicates "Shops with the best quality-control practices can often rewind with no significant efficiency degradation." This is supported SME interviews of rewind shops and industry experts. Ensuring that motor rewind shops follow best practices then has the potential to save 1-2% efficiency on rewound motors.

To guarantee that shops follow best practices, there are currently two options for certification The first is the Green Motors Practices Group (GMPG) and their Green Motors Initiative. [39] This certification covers energy efficiency only, and requires yearly oversight. Pacific Power has partnered with the GMPG for their Green Rewind program. As a second option, the Electrical Apparatus Service Association, Inc. (EASA) has recently launched their own accreditation program. There is debate in the motors industry whether the EASA accreditation is on par with the GMPG certification. It covers both repair and rewinding, but relies on audits every three years, and self-auditing the two off years. As GMPG is already established, and at least one of the motor shops Navigant interviewed is GMPG certified, there is an advantage to using the GMPG certification for this incentive program.

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[37] https://www.pacificpower.net/content/dam/pacific_power/doc/Business/Save_Energy_Money/CA_FinAnswer_Express_Motors_Incentives.pdf.

[38] Department of Energy. 2000. Energy Management for Motor Driven Systems. http://www1.eere.energy.gov/industry/bestpractices/pdfs/NN0116.pdf. Washington D.C.: U.S. Department of Energy, Energy Efficiency and Renewable Energy's Office of Industrial Technologies.

[39] A list of Green Motors Practices Group certified shops can be seen here: http://www.greenmotors.org/service_centers.htm.

Figure 7. Green Motor Rewind Incentives for Pacific Power

Incentives for motors

Equipment Type	Size Category	Sub-Category	Minimum Efficiency Requirement	Customer Incentive
Electronically Commutated Motor (Retrofit only)	≤ 1 horsepower	Refrigeration application	--	$0.50/watt
		HVAC application	--	$50/horsepower
Variable Frequency Drives (HVAC fans and pumps) (Retrofit only)	≤ 100 horsepower	HVAC fans and pumps	See note 2	$65/horsepower
Green Motor Rewinds	≥ 15 and ≤ 5,000 hp	--	Must meet GMPG standards	$1/horsepower (See note 3)

Notes for motor incentives:

1. Equipment that meets or exceeds the efficiency requirements listed for the equipment category in the above table may qualify for the listed incentive.
2. Throttling or bypass devices, such as inlet vanes, bypass dampers, three-way valves or throttling valves must be removed or permanently disabled to qualify for HVAC fan or pump VFD incentives. VFDs required by or used to comply with energy code are not eligible for incentives. Savings will only be realized for installations where a variable load is present.
3. For green motor rewinds, the participating electric motor service center is paid $2/horsepower for eligible green motor rewinds. A minimum of $1/horsepower is paid by the service center to the customer as a credit on the motor rewind invoice. The balance is retained by the service center. Green motor rewind motors that are installed or placed in inventory may qualify for an incentive.

ECM = Electronically Commutated Motor
GMPG = Green Motors Practices Group
HVAC = Heating, Ventilation and Air Conditioning
NEMA = National Electrical Manufacturer's Association
VFD = Variable Frequency Drive

Source: Pacific Power rebate application for motors and drives

3.2.3 System Efficiency Education

Several SMEs mentioned system efficiency as an often overlooked section in motor efficiency programs. When an existing motor might be 94 percent efficient, upgrading that motor one efficiency band will not gain you much if the pump attached to that motor is running at 60 percent efficiency. Even in the best situations, one SME suggested that pumps lose up to 2 percent efficiency per year. Incentivizing driven equipment—pumps are a prime example of this, rather than the motors themselves—presents an opportunity for further efficiency gains, especially for facilities that already have highly efficient motors. Navigant understands that there are pump efficiency programs and others incentivizing more efficient driven systems, but suggests these be linked to create a comprehensive suite of options for driven systems. The suite could have rebates for high efficiency components that are most popular – fans, compressors, and pumps – and include more customized options for other technologies. Such a program would likely have traction across California's subsectors.

3.2.4 Energy Audits

Several California FMs mentioned in their interviews that energy audits are very useful tools for them when they provide realistic savings opportunities in working towards increased energy efficiency. In the food processing subsector, one FM reported that he "considers it very beneficial when [utility name redacted] conducts audits in [their] facilities because it helps [them] identify potential areas for improvements." Across all subsectors, FMs often do not have the bandwidth to investigate efficiency opportunities on their own, so they are unaware of the opportunities that exist. Nevertheless, they are willing to implement efficiency measures when shown they are cost effective, presenting an opportunity for savings. This is corroborated by an agricultural FM who added that "it would be helpful if the utility could offer assistance by conducting studies at [their] facilities which would inform [them] over what period of time a new, more efficient motor would pay for itself by the energy savings it provides."

Early Motor Retirement in Refineries

4 Early Motors Retirement in Refineries MASI Description

4.1 Study Overview

This Early Motors Retirement for Refineries study explores program opportunities specifically for early motor replacement in the petroleum refinery sector. In alignment with the Project Coordination Group's indicated interests, the study's objective was to verify if an early replacement program can be designed [for refineries] to replace a batch of motors on the customer's schedule. This study evaluates refinery motors of all sizes but focuses on the 50- to 200-hp motors, including process motors and motors driving pumps, cooling fans, compressors, and mixers. The study focused on motors of this size because larger motors above 200 hp are more often custom and according to one subject matter expert typically have higher efficiencies from original designs.

The CPUC's 2013 California Statewide Potential Study (2013 Potential Study) estimated that machine drive end-use economic potential exists for the petroleum subsector. The study included a range of energy efficiency interventions, accounting for ISP estimates. In addition to motor retrofits, these interventions include controls upgrades, compressor, pump, and motor size optimization, VFD installations, and other equipment upgrades related to machine drives. Navigant's economic analysis estimated equipment-related savings (i.e., not operational or operations and maintenance [O&M] related savings) of roughly 4 percent of the energy consumed by machine drive end uses within the petroleum sector. However, only a portion of that relates to efficient motor retrofits and the remainder reflects measures that are not related to motor replacements.

The motor replacement measures associated with the 2013 Potential Study indicated to have payback periods range from 0.06 to 11.1 years, with an average payback period of 2.6 years. However, Navigant notes that a utility program manager indicated that refineries would only accept a motor replacement program with a payback period of two years or less, indicating that the market potential, which includes market acceptance, is actually much lower than the economic potential. Refinery facility managers spoken to for this study affirmed measure payback and reliability is of utmost importance and early motor retirement measures must rank above other efficiency measures in terms of payback. In the absence of California-specific data on refinery installation and other facility maintenance practices, the Navigant MASI team sought to understand current customer motor replacement practices and their acceptance of certain energy efficiency interventions as a means to verify if an early replacement motors program remains a viable option for California investor-owned utilities (IOUs).

EISA generally set motor efficiency levels equivalent to NEMA Premium.[40] The EISA standard captures a significant portion of the remaining motors' efficiency potential; therefore, the IOUs placed less emphasis on motors measures.

[40] One Hundred Tenth Congress of the United States of America. *Energy Independence and Security Act, 2007*. http://www.gpo.gov/fdsys/pkg/BILLS-110hr6enr/pdf/BILLS-110hr6enr.pdf.

However, this research effort was still deemed useful as the IOUs have experienced success with motor programs in the past, motor technologies and measures are proven and carry low risk and low uncertainty, and measure acceptance is generally high and supported by an established industry of contractors and suppliers.

4.2 Methodology

Our study relied on secondary literature, program tracking data from the utilities, and program manager, facility manager, and subject matter expert interviews, to address the research items outlined in our scope of work. Navigant worked with ASWB Engineering [41] to collect information for this study as well as incorporating findings from the 2013 Potential Study dataset..

4.2.1 Literature Review

Navigant and ASWB reviewed literature on refinery motors and the potential for early motor retirement. Due to the specific scope of this study and confidential nature of the refinery industry, Navigant concluded after an exhaustive search that publicly available literature was very limited.

4.2.2 In-Depth Interviews

Because of the limited secondary research, the majority of our findings and recommendations come from in-depth interviews with facility personnel and subject matter experts. Navigant's extensive research experience finds that interviews, more so than literature sources, offer deeper insights and findings to support strategic decisions even if anecdotal information is provided.

Navigant and ASWB interviewed the following:

- Three program managers: one from PG&E and two from SCE
- Two refinery facility personnel: facility operator from a minor refinery; plant maintenance manager from a major refinery
- Four subject matter experts: Electrical engineer with motor utility program experience; third-party implementer of energy efficiency measures for refineries; oil and gas consultant with prior experience working as a facility manager at three major refineries; and a utility consultant focusing on early motor retirement

[41] Navigant's subcontractor on the MASI project, for more information, see http://www.aswengineering.com/html/index.htm.

4.2.3 Evaluation Challenges

Although our findings were fairly consistent across conversations with refinery personnel and subject matter experts, our study faced a number of barriers that impacted the results of our study.

- » Publicly available secondary literature specific to refinery motors is very limited.
- » Only 13 companies across 20 locations refine oil in California, limiting the number of facility managers that could be contacted across this sector.
- » Refineries could not share specific motor inventory data (e.g., number, vintage, and efficiency), as it was considered confidential business information.

Very few motor repair shops actually work with refineries. The two that do the majority of the work with refineries in California did not want to participate in this study, eliminating that perspective from our findings. The motor repair shops did not give a reason for why they did not want to participate, other than time constraints. The IOUs would also likely face similar barriers if they tried to launch a motors early retirement program. Despite these limitations, the six interviews conducted with industry experts indicated that industry interest and existing potential for early motor replacement in refineries does not warrant the development of a utility-focused early motor replacement program.

4.2.4 Report Format

This report begins by characterizing the refinery industry and the importance of electric motors and providing insight on motor inventory and operational practices. Through interviews with facility managers and subject matter experts, Navigant identifies decision- making behaviors, key drivers and barriers to early motor retirement, and energy-saving opportunities. Complementing the interviews is the simple payback analysis for early retirement of 5–200-hp motors. The report concludes with strategic recommendations based on secondary research and in-depth interviews.

5 Market and Industry Analysis

5.1 Industry Characterization

With refineries located in the San Francisco Bay area, Los Angeles area, and the Central Valley, California's 20 refineries process approximately two million barrels of petroleum into a variety of products each day. A refinery produces many different products; however, the four basic groups include motor gasoline, aviation fuel, distillate fuel, and residual fuel.[42] Interviews indicated that refineries operate 24 hours a day and 365 days a year, with minimal scheduled and unscheduled maintenance time as "production is king." Due to California's large demand for gasoline, utilization rate, which is the ratio of barrels of input to the refinery operating capacity, is very important and some refineries have utilization rates as high as 95 percent.

It is unlikely that new refineries will be built in California and further refinery closures are only expected for small refineries with capacities less than 50,000 barrels per day. The cost of complying with environmental regulations and low product prices make it difficult to operate older and less efficient refineries, so continuing to upgrade refinery equipment remains an important component of everyday operation.[43] According to a subject matter expert, energy costs account for about 40 percent of the facility's operational costs and "refineries are in the business of energy, so they understand energy efficiency very well."

Navigant's 2013 Potential Study Analysis indicated that the petroleum industry accounts for 19 percent of California's industrial electricity usage, in which machine drives account for 88 percent of electricity usage. That means motors in the petroleum subsector alone account for approximately 17 percent of California industrial energy consumption.[44]

Electric motors are used throughout the refinery and according to a 2005 study done by Lawrence Berkeley National Laboratory (LBNL), represent over 80 percent of all electricity used in refineries. Major applications include: pumps (60% of motor use), air compressors (15%), fans (9%), and other applications (16%).[45] Refinery facility personnel and subject matter experts agreed that pumps and air compressors are the main applications of motors, with other applications including fans and mixers. When the LBNL paper was written in 2005, data indicated that most petroleum refineries can economically improve energy efficiency by 10-20 percent, with 10 percent of those savings coming from

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[42] California Energy Commission. *Energy Almanac, California's Oil Refineries*. http://energyalmanac.ca.gov/petroleum/refineries.html.
[43] Ibid.
[44] From Navigant's 2013 Potential Study Analysis, which draws from Quarterly Fuel and Energy Reports (QFERs).
[45] Ernest Orlando Lawrence Berkeley National Laboratory. February 2005. *Energy Efficiency Improvement and Cost Saving Opportunities for Petroleum Refineries: An EnergyStar Guide for Energy and Plant Managers*. http://www.energystar.gov/ia/business/industry/ES_Petroleum_Energy_Guide.pdf.

motor and motor applications, indicating that even a decade ago the maximum economic potential from motors and motor applications was only 1-2 percent.[46]

5.1.1 Motor Inventory

This study aims to characterize the current inventory of motors in operation in refineries in California; however, both the refineries we spoke with were not able to share specific motor inventory data as it was considered "confidential business information."

Table 12 summarizes the general information received from two California refineries. The general take-away is that motor vintage and efficiency vary depending on facility and motor size. Motors typically operate close to 8,760 hours/year and the majority of motors are small and not specialized.

Table 12. Refinery Facility Motor Inventory

	Interview 1: Small Refinery	Interview 2: Large Refinery
Motor Vintage	1920—present	15 years–present
Motor Efficiency	Rewound several times to NEMA Premium Efficiency	78%—96%
Number of Motors	"Too many to list"	"Too many to list"
Typical Annual Runtime	8,760 hrs./year; no longer run motors lead/lag	7,500—8,000 hrs./year; No longer run motors lead/lag
Motors w/ VFDs	Several	Some VFDs installed which received utility incentives
Type of Specialized Motors	Cooling Tower Motors	Most are "Off-the-Shelf" to provide rapid replacement.
Energy Consumed: Small vs. Large Motors (%)	80% energy consumed by motors under 100 hp	Not Answered

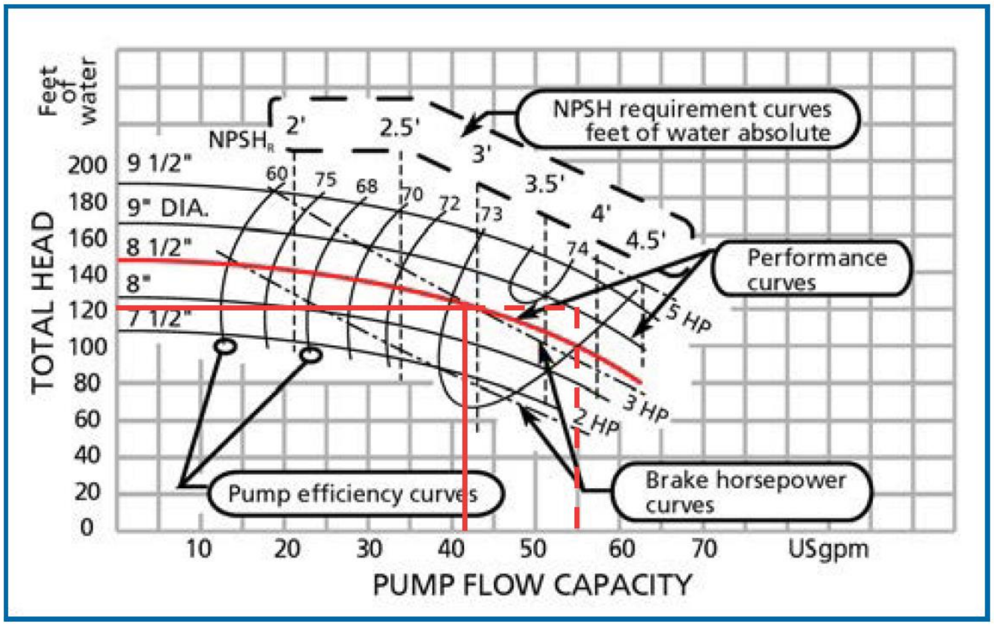
Source: Navigant Analysis

[46] Ibid.

5.1.2 Operational Practices

In an industry where "production is king," keeping the refinery operational is the most important consideration in meeting business objectives. One of our four subject matter experts discussed that motors in the refinery industry range from ½ hp to 4,000 hp and that most refineries pay particular attention to big motors, 1,000 hp and above. Each motor comes with a Best Efficiency Point (BEP) Curve and plants try and operate their motors along those curves to maximize efficiency and minimize equipment failure. An example BEP Curve is shown in Figure 8.

Figure 8. Best Efficiency Point Curve[47]



When it comes to energy efficiency upgrades, one of the two facility managers explained that all projects are ranked based on payback, with utility incentives included in this calculation. The projects with the shortest payback are ranked the highest, but always after the projects required to maintain plant operation. Utility costs are considered important but secondary to operations.

Both facility managers interviewed indicated that their operations follow a controlled process from start to finish, and inspections of all motors and other pieces of equipment are conducted regularly. The facility manager that works at the large refinery indicated that they implement energy efficiency projects all the time and regularly receive utility incentives, while the small refinery reported that they did not typically utilize utility incentives.

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[47] Satterfield, Zane. *Tech Brief Reading Centrifugal Pump Curves*. National Environmental Services Center. http://www.nesc.wvu.edu/pdf/dw/publications/ontap/tech_brief/tb55_pumpcurves.pdf.

An industry expert explained that facility equipment is assessed to determine whether it is considered critical. Criticality is a function of importance of the motor to maintain the safe and reliable operation of the plant. That means that critical and noncritical equipment both run 24 hours a day. According to one of the four subject matter experts, today 50 to 60 percent of motors are now considered critical compared to 30 to 40 percent in the past, due to the fact that refineries now run their spare motors as a plant strategy to increase production. This SME explained that for equipment deemed critical, a strategy is usually developed based on one of the following three approaches:

1. Spare Motor – Identical spare motor is kept at the facility, available to replace the motor if it fails. A spare is only kept on the shelf if it is required by the equipment strategy.
2. Preventative Maintenance Plan– Includes motor lubrication, winding cleaning and/or recoating and bearing, rotor/stator, belt, brush/commutator, and mount inspection.
3. Predictive Maintenance Plan– Motor testing to identify early signs of potential failure, which include vibration-analysis tests, field vibration, and motor temperature control testing. Requires ordering a new motor or scheduling a repair/rewind prior to failure to minimize plant downtime. This type of program is developed for highly critical motors (~5% of facility motor population).

Motors driving "critical" process equipment can only be overhauled or replaced during a turnaround, which is a scheduled event wherein an entire process unit is taken off stream. Typically, turnarounds take place every 2.5 to 5 years and facility managers need to time equipment replacements appropriately to fit within this schedule. Often large critical motors also have periodical vibration analysis to test for bearing conditions that may indicate failure. On the other hand, low criticality motors may not have a specified program and simply run to failure. All these strategies are developed into an overall facility O&M program.

5.1.2.1 Motor Replace vs. Rewind

An O&M strategy is an important aspect of operating a refinery, where production remains of upmost importance; however, sometimes motors fail and the facility manager needs to determine whether to replace or rewind the motor. It is important to point out that many of repairs are bearing replacements or simple electrical fixes, not rewinds. As required by EISA, both refineries indicated that NEMA Premium efficient motors are used when replacing motors between 1 and 500 hp. Companies rules of thumb for whether the motor should be repaired/rewound or replaced vary across the industry. This decision is usually based on cost and the length of time required to get the motor or a replacement back in operation. For example, the two refineries interviewed had different equipment replacement approaches, with the small refinery rewinding the majority of their motors (despite motor size) and the large refinery mainly rewinding motors over 1,000 hp. The maintenance team at the large refinery would rather replace even the large motors; however, replacement takes more time than rewinding these motors and is often unrealistic as the goal is to get the plant back in operation as soon as possible.

An SME interviewed who has over 20 years of experience working for three major players in the refinery industry, indicated that smaller and non-critical motors are usually replaced on burnout and that refineries use a basic cost and reliability decision matrix to determine whether the motor should be replaced on burnout or rewound. When asked about the concept of green rewind, in which motors retain the original nominal efficiency values, the SME was not familiar with that term but indicated that refineries assume motors that are rewound maintain original efficiency values. Table 13 highlights motor replacement practices from the small refinery, large refinery, and a subject matter experts perspective.

Table 13. Summary of Motor Practices

	Small Refinery	Large Refinery	SME
Replace vs. Rewind	We repair most motors and seldom replace motors. **Below 15 hp - repair in house **Above 15 hp - send out for repair	Replace all motors up to 200 hp and rewind motors above 1,000 hp	Replace < 50 hp (~60% of motors) Rewind > 50 hp (~40% of motors) Early Replacement – Capital justification required, which is very difficult for large, expensive motors
Lead-Lag Motor Program	All of our major/critical motors have a backup/redundant motor in place. Primary motor runs 8,760 hrs./year, if no issues are encountered.	No Lead-Lag Motor Program	Lead-Lag Motor programs are not common in the industry anymore. Refiners in great majority are running spares to increase overall output.
EE Upgrade Payback Requirement	No defined metric	No defined metric, but must rank higher in the matrix than other measures	No defined metric, but must comply with equipment strategy and have capital justification
Payback Requirements Vary by Motor Size	No	No	Not discussed
Replace vs. Rewind Drivers	Replace – Often 2x repair cost Rewind – Typically least- cost option and fastest turnaround time Early replacement – Not cost justified	Replace – When required, rebates pay differential cost for efficient motors Rewind – Custom motors >1,000 hp Early replacement – Not cost justified	Cost and reliability; Often costs more to rewind a small motor than to replace one
In-house Capability to Replace Large Motors	No	No, we replace small and mid-sized motors in-house but the larger motor replacements are contracted out.	Not discussed
Available Spare Motors	Standby motors are placed into operation immediately when motors fail, which provides time to repair the failed motor.	No, unless it is a special, mission-critical motor	Typical refinery may have 3,000-4,000 motors; 5-7% of these motors would have a spare.

Source: Navigant Analysis

5.2 Initiatives to Date

Please reference the *Motors Baseline and Opportunities in the Industrial, Food Processing, and Agricultural Sectors* section of this report for a discussion about the evolution of federal initiatives, California programs, and codes and standards, as these regulations apply to the refinery industry.

According to one refinery industry expert, attempts have been made to develop refinery-specific motor programs in California, yet these efforts did not pan out due to insufficient motor annual run hours to make the financial case. Others in the industry were not aware of any general refinery motor programs, but had worked with their utility program manager on plant-specific motor projects. This aligned with LBNL's report that indicated, "The most favorable selection of energy efficiency opportunities should be made on a plant specific basis." [48] Many of the smaller motors are very generic; however, these are regulated by NEMA Premium standards. The larger motors are often site-by-site specific, indicating the custom nature of early motor retirement in refineries.

5.3 Codes and Standards

Please reference the *Motors Baseline and Opportunities in the Industrial, Food Processing, and Agricultural Sectors* section of this report for a discussion about motor codes and standards.

5.4 Application Requirements

Regarding the refinery industry, two of two facility managers and four of four subject matter experts indicated that production standards and product controls are the most important factors governing the industry. Specifically pertaining to motors, additional important requirements for refinery motors depend on their operational application but could include a combination of the following requirements:

- Explosion proof
- Totally Enclosed, Fan-Cooled – Motor enclosure does not permit outside air to freely circulate through the interior of the motor, offering increased protection against weather, dirt, and moisture.
- Open, Drip Proof – Motor enclosure does not permit water dripping on the motor to normally flow into the motor.
- High torque rating
- Vibration monitoring

Based on our conversations, motor suppliers do not have difficulty meeting these specifications. Most motors are simply transporting fluids that are not highly volatile and do not require special characteristics or encasement beyond weather proofing.

[48] Ernest Orlando Lawrence Berkeley National Laboratory. February 2005. *Energy Efficiency Improvement and Cost Saving Opportunities for Petroleum Refineries: An EnergyStar Guide for Energy and Plant Managers*. http://www.energystar.gov/ia/business/industry/ES_Petroleum_Energy_Guide.pdf.

5.5 Industry Practices

The ability to categorize industry practices was limited due to the smaller refinery "doing things their own way," and the larger refinery unable to share due to the topic being considered "confidential business information." No ISP study on early motor retirement had been conducted as the majority of utility motor programs have ended. Additionally, the DOE EISA codes and standards have pushed motor replacement standards fairly close to premium efficiency.

Of the six industry experts we spoke with, no one had any ISP concerns or believed there were variations of ISP perceptions among refineries in California as codes and standards heavily regulate motor replacement options. One standard practice that did come up in discussion was the importance of replacing or conditioning "Critical Equipment" motors during a turnaround cycle. Otherwise, operations do not often get interrupted outside of the five-year cycle.

5.6 Decision Making

As one industry expert puts it, "decision making in refineries all boils down to money;" keeping the plant operational and increasing production while minimizing costs. When it comes to repairing/rewinding or replacing motors, industry consensus indicates that motors are repaired/rewound or replaced when they display signs of failure or burnout. Motor replacement selection is based on financial metrics and payback. A utility program manager indicated that refineries require a payback of less than two years, although neither refinery facility manager verified a two-year strict requirement (even though payback is the main factor in the decision between rewind versus replacement). The facility operations manager or person who manages rebates and cost evaluations makes the decision of rewinding versus replacing motors. When asked, both facilities interviewed indicated they were not interested in early motor retirement and that they would not find value in case studies evaluating the return on investment for replacing motors in their facility. Refineries consider energy to be their business and indicated that they have conducted their own analysis and seemed confident this type of analysis on motor stocks would not help them.

5.6.1 Motor Replacement Economics

Despite lack of interest from the refineries, Navigant did a basic payback analysis to determine whether conducting an early replacement of a 5–200-hp motor, warranted further consideration from an economic standpoint. The payback for individual motors varies based on size, load factor, and run time. The best savings are achieved on motors running for long hours at high loads.[49] A 1998 LBNL study reported that when retiring motors early, paybacks are typically less than one year from energy savings alone; however, motor efficiency has dramatically improved since EISA was implemented in 1997 so

[49] Ernest Orlando Lawrence Berkeley National Laboratory. February 2005. *Energy Efficiency Improvement and Cost Saving Opportunities for Petroleum Refineries: An EnergyStar Guide for Energy and Plant Managers*. http://www.energystar.gov/ia/business/industry/ES_Petroleum_Energy_Guide.pdf.

energy efficiency opportunities are more limited.[50] Neither of the three refineries spoken to (one refused to interview) would share any specific motor inventory data (e.g., number, vintage, and efficiency), as it was considered "confidential business information," Navigant used motor inventory data from a California refinery study from 1997. Navigant assumed that if a reasonable payback could not be achieved by upgrading the 1997 motor inventory to current NEMA Premium efficient motors, then the business case would likely not exist for the current motor inventory whose efficiencies are estimated to have improved over the last decade through standard replace-on-burnout practices. For example, Navigant notes that nonresidential Premium efficiency motor effective useful lifetimes are 15 years. [51]

Only 10 percent of the facility motors (5–200 hp) have a payback period less than two years (a requirement indicated by a utility program manager), assuming the refinery paid $0.13/kilowatt-hour (kWh) and all motors ran 8,760 hours/year, which is the best-case operation scenario. Additionally, the highest efficiency NEMA Premium motors were assumed for the replacement motor efficiency, which makes the payback analysis look more favorable (see Table 14).

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[50] Lawrence Berkeley National Laboratory (LBNL) and Resource Dynamics Corporation. 1998. *Improving Compressed Air System Performance, a Sourcebook for Industry*. Prepared for the U.S. Department of Energy, Motor Challenge Program.

[51] Database for Energy Efficient Resources, Technology and Measure Cost Data/Effective and Remaining Useful Life Values, http://www.deeresources.com/files/deer0911planning/downloads/EUL_Summary_10-1-08.xls. [2008]

Table 14. Motor Replacement Economics [52]

Motor Size (hp)	Motor population by size (%)	Base Case Motor Efficiency (%)	NEMA Premium Motor Efficiency (%)	Annual Savings/ unit (8760 hrs/yr)	New Unit Cost	Simple Payback years (8760 hrs/yr)
5	11%	85.65	89.5	$162	$1,005	6.2
10	12%	88.96	91.7	$231	$1,443	6.3
15	12%	87.38	92.4	$633	$1,855	2.9
20	21%	89.71	93	$554	$2,345	4.2
25	7%	93.30	93.6	$63	$2,527	40.0
30	5%	92.79	93.6	$205	$3,395	16.6
40	4%	92.91	94.1	$401	$4,515	11.3
50	6%	92.79	94.5	$718	$4,102	5.7
75	6%	89.52	95.4	$3,713	$5,565	1.5
100	6%	93.90	95.4	$1,262	$9,621	7.6
125	3%	93.52	95.4	$1,977	$8,225	4.2
150	4%	90.49	95.8	$6,698	$11,865	1.8
200	5%	93.87	96.2	$3,928	$18,693	4.8

5.7 *Key Drivers*

In the refinery industry, increased reliability is the main driver for upgrading equipment, as the goal of the industry is to maximize production. Both facility managers lacked interest in an early motor retirement program, as they did not believe the increased production or savings potential existed that would justify such a program. Three of the four subject matter experts interviewed had similar opinions, regarding the minimal savings value an early motor retirement program would offer.

[52] Analysis Assumptions Based on Engineering Judgment: Electric Rate = $0.12875/kWh per PG&E's guidance regarding average rates for the three classes of E-20 industrial rates; motor population by size includes the percentage of motors with the specified hp out of the total number of motors from 5–200 hp; Base New Unit Cost marked up 40% for tax, shipping, and installation; motor operates 8,760 hours per year.

5.8 *Market Trends*

In the past, refineries used to run two critical motors in parallel and share the annual 8,760 hours/year between the two motors. If one motor failed, then the other motor is already hooked up to run in its place. However, according to a SME who has worked at three refineries over the last three decades, this lead-lag approach is almost nonexistent in large refineries today, with refineries trending toward running both motors simultaneously to maximize production.

Another market trend that seems to differ between small and large refineries is the repair/rewind vs. replace decision. The decision matrix varies across refineries leading to the recommendation to continue to implement a custom approach to replace refinery motors. The small refinery interviewed repaired/rewound the majority of their motors (despite motor size) and the large refinery mainly only rewound motors over 1,000 hp. The maintenance team at the large refinery would rather replace even the large motors; however, replacement takes more time than repairing/rewinding these motors, and is often unrealistic as the goal is to get the plant back in operation as soon as possible. A utility expert indicated that their understanding was that some companies have rules of thumb for all motors sent to the shop (typically 25 Hp and larger) and that if the repair is 50% or less compared to the cost of a new motor, the refinery repairs the motor.

5.9 *Key Barriers*

Although technical barriers are not prevalent, a number of market barriers prevent the development of an early retirement motors program.

5.9.1 Technical Barriers

All four industry subject matter experts did not believe the refinery industry currently faces any technical barriers that would inhibit early motor retirement. Motor suppliers do not have any difficulty meeting the specifications required of motors, as most motors are simply transporting fluids that are not highly volatile and do not require special characteristics or encasement beyond weather proofing.

5.9.2 Market Barriers

A large market barrier is that the payback economics of early motor retirement must compete with other efficiency project economics, in order for motors to get retired early. As one IOU program manager put it, from their experience it is tough for early motor retirement to compete in an industry that requires a short payback.

Another facility manager indicated that production downtime is a market barrier to early motor retirement, which supports the reiterated comment that "production is king." Although facility maintenance periods in which motors could be replaced exist, these only occur every two and a half to five years. Facilities try and minimize these turnaround times so different retrofit projects compete for scope. Refineries tend to focus on equipment that must be overhauled, so making a case for early motor retirement is required for it to become part of the turnaround scope.

Finally, both refineries indicated they not interested in a broad, sweeping early motor retirement program, so soliciting participation would be tough. Refineries would not share their actual motor inventory due to security concerns, so it is very difficult to actually determine the savings potential that may exist.

5.10 Energy Savings Opportunities

Regarding early motor retirement in refineries, four of four industry experts and personnel indicated they did not have new ideas for programs. The two refineries spoken to indicated that they were already participating in utility energy efficiency programs throughout the state and receiving rebates for all of their energy efficiency projects. Both facility managers indicated their utilities are providing good service and that they are not interested in pursuing any motor-related programs.

Both indicated that the likelihood that other refineries would participate in early motor replacement programs were "slim to none" and did not have any suggestions for what the utility could do to increase participation in a motor program, as refineries will not stop production to replace a motor and that scheduled plant downtime is kept to a minimum. Early motor retirement must compete with other efficiency measures for priority during turnarounds. Due to the lack of data, it is inconclusive to dismiss the potential of an early motor retirement program. However, an economic analysis conducted in 1997 suggested that a general early retirement program seemed unlikely to outweigh other improvement projects.

Neither of the two facility managers or four subject matter experts spoken to indicated any new opportunities being pursued by refineries regarding motor efficiency. If energy efficiency opportunities exist in general, refineries always want to take advantage, but always make production and reliability a priority.

Regarding emerging technologies, both facility managers would not disclose this information due to its proprietary nature. A third-party industry expert indicated that refineries are looking to reuse the waste heat produced, which could have energy savings potential.

6 Findings and Recommendations

Two facility managers and four industry experts agreed that they would not recommend that utilities run a motor early retirement program. Even though some opportunities exist, the structure of an industry that maximizes production by limiting downtimes to every two to five years, does not mesh with the current design of incentive programs that could drag a project well beyond the shutdown window, causing the refinery millions of dollars in lost production. Based on conversations with the industry, Navigant would like to highlight the following findings and recommendations for targeting energy efficiency opportunities in refineries. Due to limitation in interview sample size, Navigant recommends further research on exploring opportunities with unregulated motors.

6.1 *Findings*

6.1.1 Focus on Unregulated Motors

Motors up to 500 hp are already covered by the EISA standards. However, a refinery facility manager who works at a large refinery in California suggested focusing on larger motors, such as compressor motors, in the 1,000+ hp size range, where opportunities may exist due to frequent motor overhauls.

Due to the time it takes to replace these motors, if utilities want to service these motors into an early retirement program, the utility will need to develop a program where these motors can be ordered in advance and made ready for installation on the next plant turnaround. One approach the California utilities could take would be to offer modified rebates or financing for shelved motors purchased prior to motor failure, so that these motors would be ordered early and ready to install during the next facility turnaround. However, further research is needed to determine whether a program like this would be popular across refineries and refinery motor inventory is required to calculate the potential savings.

6.2 *Recommendations*

6.2.1 Investigate System-Level Approaches to Energy Efficiency

If the utilities want to continue to support energy efficiency activities at refineries, two facility managers and a third-party energy efficiency implementer alike advised against addressing the efficiency of motors individually, as refineries have already been looking at motor efficiencies for years and remaining potential does not exist currently for motors. Federal regulations already mandate that any motors (1–500 hp) that are replaced must be replaced with NEMA Premium efficient motors. This finding was supported by secondary literature from LBNL and the DOE. The 2005 LBNL study also identified the importance of focusing on the “system approach”, which looks at pump, compressor, motor, and fan efficiency in order to capture the most savings.[53] The US DOE Motor Challenge Program study agreed that the greatest savings potential lies with the system savings measures, indicating that compressed air and pump systems have the most potential. System improvements overall account for 71 percent of total potential motor system energy savings. [54] A third-party energy efficiency implementer indicated that he believes that "you will find larger opportunities at the process level." This finding warrants further investigation to determine the potential savings through the focus on a system approach.

6.2.2 Custom Approach for Motor Improvements

The most favorable selection of energy efficiency opportunities should be made on a plant- specific basis.[55] With 20 refineries operating in California, program managers seem to already be working closely with facility managers. Navigant recommends that utilities work with refineries on an individual basis to target custom motors that could be replaced. The success of taking the custom approach is supported by the fact that a California utility program manager is currently working with a refinery client to replace what is considered an inefficient 9,000-hp motor when compared to existing motors on the market.

Navigant recommends that utilities particularly focus on working with smaller refineries on a case-by-case basis, as they seem to repair or rewind a much higher percentage of their motors than larger refineries, resulting in additional existing savings potential.

[53] Ernest Orlando Lawrence Berkeley National Laboratory. February 2005. *Energy Efficiency Improvement and Cost Saving Opportunities for Petroleum Refineries: An EnergyStar Guide for Energy and Plant Managers*. http://www.energystar.gov/ia/business/industry/ES_Petroleum_Energy_Guide.pdf.

[54] Office of Energy Efficiency and Renewable Energy, US Department of Energy, Motor Challenge, United States Industrial Electric Motor Systems Market Opportunities Assessment, December 1998, http://www1.eere.energy.gov/manufacturing/tech_assistance/pdfs/mtrmkt.pdf

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Appendices

Appendix A Motors Baseline and Opportunities in the Industrial, Food Processing, and Agricultural Sectors References

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Appendix B Motors Baseline and Opportunities in the Industrial, Food Processing, and Agricultural Sectors Program Manager Interview Guide

B.1 Program Manager Introduction Questions

1. Please take a few minutes to describe your industry, current involvement in this study's specific area of focus, related programs and knowledge of /involvement in related studies.
2. While we do have a set scope of work for these motor studies, can you tell us what you hope to gain from the baseline study? From the opportunities study?
3. What information about baseline motors and opportunities in California would be most useful to you? How would you use this information?

B.2 Technology and Process Characterization Questions

4. We want to ask you about topics, equipment, and processes that interest you particularly pertaining to motors in the Industrial, Agriculture, and Food Processing sectors.
   a. We've assumed that the Chemical and Electronics (semiconductor) manufacturing subsectors in the Industrial sector are major drivers of Industrial energy use so we are planning to focus there. Do you agree and does this match your knowledge? What other subsectors are major candidates?
   b. How do you draw the line between food processors and agricultural customers?
      i. With respect to IOU programs in general?
      ii. More specifically, with respect to motors?
      iii. We have studies occurring in both sectors, how would you like our studies to draw the line?

B.3 Market Assessment and Program Activities Questions

5. Can you describe any current or recent program activities including:
   a. Program history and targeted subsectors?
   b. Program designs and implementation approaches. (e.g.: what motors are they targeting? Early Retirement, ROB, motors that would be rewound, green rewinds?)?
   c. Baseline assumptions (existing stock for early retirements, Title 24, etc.)?
   d. What program protocols must facilities follow when faced with motor failures or replacements (audits, application process, system-wide versus single replacements, ROB versus retrofit, etc.)?

6. *Data Request: Do you have any information on these topics you can share (previously targeted opportunities or equipment, etc.)? Program tracking data?
    a. *Clarification on data requests: We understand that customer-sensitive information may be difficult or not possible to share. We are happy to remain flexible to accommodate confidentiality requirements. For example, high level program data or details stripped of sensitive customer information would still be beneficial to us.*
7. Tell us about any lessons learned or best practices developed during current and/or historical program activities.
8. What are the most important regulations governing motor efficiency? (anything beyond Title 24/Federal?)

B.4 Sector-Specific Questions

(Ask the PM whether to do this section for each sector or go through each sector as we come to each question.)

- » Industrial: Chemical
- » Industrial: Electronics
- » Food Processing
- » Agriculture

9. We are planning to focus on motors ranging from 10-200 hp that may be candidates for replacement and/or upgrades. Does focusing on motors in this size range make sense?
10. Who are the key players (customers) in this industry for California?
11. What motors do you see most often in your programs or interest area (sizes/types/applications/efficiency/vintages/running characteristics)?
12. Can you describe any current or recent program activities regarding Targeted processes? Specific subsectors? Targeted applications (fans, conveyors, other)?
13. What program marketing approaches are you using?
14. What are the most significant trends and drivers?
    a. Industrial: We anticipate the focus here to be more on minimizing cost of production than other concerns, is that consistent with what you see?
    b. Food Processing: We anticipate drivers to be costs, equipment reliability, or Federal and state regulations.
    c. Agriculture: We anticipate sustainability goals, energy usage, and energy cost to be drivers here.
15. Are there any technical or market barriers you are currently facing in motor efficiency programs?

16. Agriculture: We anticipate knowledge of the importance and cost of energy to be a major barrier, is this consistent with your experience?
17. Can you talk about any industry standard practices (ISP) that we should consider with respect to motors? How do ISPs influence motors-related programs? (i.e., are they barriers to implementation?)
18. Besides energy savings, what are the drivers you see behind efforts to pursue new opportunities for equipment or process changes for motors?
    a. General drivers we expect to see here are, maintenance (cost & time) savings, environmental concerns, meet Federal and/or state requirements (early retirement), etc.
    b. Particularly in Food Processing and Agricultural, we might expect a desire to appear "Green" and sustainable.
    c. What specifically are non-energy drivers that you see in the Chemicals and Electronics (semiconductors) industries, if any?
    d. Do you know of any new emerging technologies or processes not yet discussed that provide new opportunities for these sectors?
19. What do you see happening in the motor controls market in your area of interest? How do you think programs will respond?

B.5 Identify New Opportunities Questions

20. Do you have ideas/plans for programs in the future?
    a. Do you think this would be applicable across California? Across sectors? Across Industrial (Chemical, Electronics), Food Processing, and/or Agriculture? Alternatively, are these more focused?

B.6 Market Actors

21. *Data Request: Can you identify any subject matter experts and/or trade allies that you would recommend we interview?
    a. *Prompt as needed: Suppliers and vendors, regulators, State and Federal organizations, trade organizations etc.*
    b. Our SOW includes interviewing the Pump Test Group, but we've heard other MASI studies were instructed not to. Should we still conduct these interviews for these two studies?
22. Can you tell us about any other specific resources (market actors or other) you use to support your work in this area?

B.7 Concluding Questions

23. Were there any questions we did not ask that you think we should?
24. Do you have any additional comments or concerns? Or question for us?

Appendix C Motors Baseline and Opportunities in the Industrial, Food Processing, and Agricultural Sectors Subject Matter Expert Interview Guide

C.1 Technology and Process Characterization Questions

1. Please take a few minutes to describe your experience in the motors industry.
2. We would like to understand the general characteristics of motors in the Industrial, Agricultural, and Food Processing Subsectors. Can you give us your view on the motors baseline over the past 5 years?
    a. What are the primary applications of motors in each of the subsectors?
    b. What is the typical size range of motors installed in facilities?
    c. What is the predominant size?
    d. What is the approximate age of the motors?
    e. What are the approximate hours of operation of the motors?
    f. How many times have these motors been repaired?
    g. What is the approximate load factor for the motors?
    h. What are the typical efficiencies of motors (NEMA Premium, Premium Efficient, Other)?
    i. What motor types are used? (i.e., DC, AC induction, AC permanent magnet motors etc)?
    j. What percent of motors are multi speed?
    k. What specific end uses are they applied to? (e.g., compressed air, blower, irrigation pump, etc.)
    l. How common are advanced motor controls on motors with variable loads?
3. What are the early retirement or replacement practices for industry equipment?
    a. Do facilities in these industries have standardized equipment specifications for motors?
    b. Do facilities in these industries have preventative maintenance plans for motors?
    c. What are the costs and drivers associated with replacing vs. repairing equipment?
    d. Where and when do you see facilities keeping and repairing/rewinding older, less efficient motors rather than replacing and upgrading the equipment?
        i. What type of motors?
        ii. What specific subsectors?

C.2 Market Assessment and Program Activities Questions

4. Tell us about any lessons learned or best practices developed during current and/or historical motors program activities.
5. Can you describe the Federal and California-specific regulations that affect purchasing decisions in the motors industry?
    a. What are the most important regulations governing motors in California?
6. What are the most significant trends and drivers in this California industry?
    a. Examples: Costs (first, lifecycle, operational), reduction in equipment downtime, State and/or Federal regulations, sustainability goals, etc.
7. Are there any technical or market barriers the industry is currently facing?
    a. We have been told that there is not much efficiency to be gained given current federal regulations. Is that consistent with your experience?
    b. Examples: technology or supplier limitations, upfront or lifecycle cost barriers, educational barriers, available data
8. Can you talk about any industry standard practices (ISP) that the motors industry is currently focusing on?

C.3 Identify New Opportunities Questions

9. What motors energy efficiency opportunities do you see in the Industrial, Food Processing, and Agricultural sectors (premium efficient motors, VFDs, other motor efficiency measures)?
    a. We have heard from Program Managers at several utilities that efficient motors programs have been phased out, and that controls are the primary area of opportunity. Is that consistent with your experience?
10. Can you tell us about any new opportunities being pursued that are related to motors in California?
11. What specific resources and services are supporting these efforts?
    a. Example: Who is at the forefront? What role do motor controls play?
12. What are the drivers behind these efforts to pursue new opportunities for equipment or process changes?
    a. Example: Energy savings vs. maintenance (cost & time) savings etc. Reliability has been a big driver so far. Is that consistent with your experience?
13. Do you know of any new emerging technologies or processes not yet discussed that provide new opportunities for the industry?

C.4 Market Actors

14. *Data Request: Can you identify any subject matter experts and/or trade allies that you would recommend we interview?

C.5 Concluding Questions

15. Do you have any additional comments or concerns?

Appendix D Motors Baseline and Opportunities in the Industrial, Food Processing, and Agricultural Sectors Facility Manager Interview Guide

D.1 Introduction

1. Please take a few minutes to describe your industry and your role as a facility manager with respect to motors.
2. Please describe the general operating hours of your facility including peak hours and seasons as well as scheduled down time.
3. What is your facility's estimated annual kW (or kWh) consumption?

D.2 Technology and Process Characterization Questions

We are focusing on motors primarily in the 10-200 hP range.

4. Can you tell us a few more details about your motors?
   a. What typical size range of motors does your facility use?
   b. What is the predominant size?
   c. What is the approximate age of your motors?
   d. What are the efficiencies of your current motors (NEMA Premium, Premium Efficient, other)?
   e. What motor types are used at your facility? (i.e. DC, AC induction, AC permanent magnet motors, enclosure type)
   f. What are the typical running characteristics of your motors? (i.e.Continuous, intermittent, occasional)
   g. Do you use any advanced motor controls on your motors with variable loads (e.g., VFDs)?
   h. What are the primary applications of your motors (pumps, drives, fans, etc)?
   i. If your facility has refrigerated space, are you aware of the energy consumption associated with motors heat gain?
      i. If so, are you aware that efficient motors produce less heat gain than standard motors?
5. What are the equipment and processes that are relevant to your industry? *[We are specifically looking at motors in the 10 to 200 hp range. Prompt interview with our assumptions and/or ask them to assess our assumptions. For Industrial, Food Processing, and Ag: Pumps and irrigation.]*

6. We would like to understand your views on a number of business and energy related topics, specifically as they relate to motors:
    a. Can you elaborate on the most important business considerations for successfully meeting your business objectives as these relate to motor operation, repair, and replacement:
    Prompt if needed: Do you look at ROI, first cost, utility bills, production rates, maintenance impacts, down times, etc.?
    b. How important are energy costs and energy savings comparing to other business objectives?
        i. Where do utility costs rank on your list of operational expenditures?
    c. What are the most important energy saving technologies in your industry relevant to motors?
    d. What do you currently do to minimize your motors' energy use, if anything?
7. What are the key barriers you when installing Premium Efficiency motors (those that exceed minimum efficiency standards)?
Prompt if needed: technology or supplier limitations, upfront or lifecycle cost barriers, educational barriers, or limited data.
    a. How are these barriers addressed?
8. What are the key drivers to above-code premium motors?
9. How do you approach equipment replacements, upgrades, and new equipment purchases?
    a. Do you have a phased schedule or bulk replacement strategy, or do you usually replace motors only when they fail?
    b. Have you used or considered Green motor rewinds?
    c. How often do you repair or rewind failed motors versus replacing the failed motor with a new motor?
    d. What are the costs associated with replacing vs. repairing motors?
        i. For example: motor application, HP, efficiency, life, operating cost, performance, reliability, availability of each option.
    e. What are the drivers associated with replacing vs. repairing motors?
        i. Again, for example: motor application, HP, efficiency, life, operating cost, performance, reliability, availability of each option.
    f. What would motivate you to replace the failed motors with premium efficient motors (rather than repairing or replacing)?
10. We would like to understand if any energy efficiency or operational practices are considered "standard" by your organization with regards to motors?

D.3 Identify New Opportunities Questions

11. Can you tell us about any energy efficient new opportunities you are pursuing that are related to motors (premium efficient motors, VFDs, other motor efficiency measures)?
12. What specific resources and services do you use to support these efforts?
    a. Example: How do you inform yourself about energy efficiency, O&M activities, new technologies and equipment, etc.
    b. Do you consider utility rebate programs? Why or why not? When would you consider rebate programs? (e.g. bulk motor purchases, new motor installation)
13. Do you know of any new emerging technologies or processes not yet discussed that provide new energy efficiency opportunities for the motors?
14. What is the likelihood that you will participate in utility efficiency programs? What can the utility do to increase participation?
15. Do you have any recommendations for the kind of assistance utilities could provide to incentivize Facility Managers to implement premium efficient motors?

D.4 Market Actors

16. *Data Request: Are there any other facility managers, suppliers, vendors, or other individuals that might be interested in sharing information with Navigant on this topic?

D.5 Concluding Questions

17. Do you have any additional comments or concerns?

Appendix E Early Motor Retirement for Refineries References

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Appendix F Early Motor Retirement for Refineries Program Manager Interview Guide

F.1 *Program Manager Introduction Questions*

1. Please take a few minutes to describe the refinery industry, current involvement in this study's specific area of focus, related programs and knowledge of /involvement in related studies.
2. While we do have a set scope of work for the Early Motor Retirement for Refineries project, can you tell us what you hope to gain from this research we are conducting?
3. What information about Early Motor Retirement for Refineries would be most useful to you? How would you use this information?

F.2 *Technology and Process Characterization Questions*

4. We want to ask you about topics, equipment, and processes that interest you particularly pertaining to motors in the refining of petroleum process.
    a. We are planning to focus on motors ranging from 50hp to 500hp for refineries that may be candidates for replacement and/or upgrades. Does focusing on motors in this size range make sense for this sector?

F.3 *Market Assessment and Program Activities Questions*

5. What are the main concerns related to motors in the petroleum refinery industry?
6. Do you currently have an incentive program that targets early retirement of motors?
    a. In the past have you had refineries utilizing this program?
    b. Do you have any data on what motors the program is targeting? (Early Retirement, ROB, motors that would be rewound, green rewinds?)
    c. Do you have any data on the types of motors that were being retired early and what kind of equipment the replacement equipment?*(e.g., sizes, types, applications, efficiency, vintages, running characteristics)*
7. What do you see happening in the motor controls market applicable to refinery motors? How do you think programs will respond? *(e.g. VFD, lead and lag program)*
8. Data Request: Do you have any information on these topics you can share (previously targeted opportunities or equipment, etc.)? Program tracking data?
    a. *Clarification on data requests: We understand that customer-sensitive information may be difficult or not possible to share. We are happy to remain flexible to accommodate confidentiality*

requirements. For example, high level program data or details stripped of sensitive customer information would still be beneficial to us.

9. What are the most significant trends and drivers in the petroleum refinery sector: We anticipate drivers to be costs, equipment reliability, or federal and state regulations (particularly environmental requirements – air quality and GHG emissions).
10. Tell us about any lessons learned or best practices developed during current and/or historical program activities.
11. What are the most important regulations governing motor efficiency? (Anything beyond Title 24/Federal?)
12. Can you talk about any industry standard practices (ISP) that we should consider with respect to motor utilized in refineries?

F.4 Identify New Opportunities Questions

13. Do you have ideas for programs or programs you are planning or envision launching in the near future?
    a. Do you know of any new emerging technologies or processes not yet discussed that provide new opportunities for these sectors?
14. Besides energy savings, what are the drivers you see behind these efforts to pursue new opportunities for equipment or process changes for motors?

F.5 Market Actors

15. *Data Request: Can you identify any subject matter experts and/or trade allies that you would recommend we interview?
    a. *Prompt as needed: Suppliers and vendors, regulators, State and Federal organizations, trade organizations etc.*

F.6 Concluding Questions

16. Do you have any additional comments or concerns?

Appendix G Early Motor Retirement for Refineries Subject Matter Expert Interview Guide

G.1 *Technology and Process Characterization Questions*

1. Please take a few minutes to discuss your background and how it pertains to energy efficiency and early motor retirement in refineries.
2. What are the most common motor applications in refineries?
3. What are specifications of the most common motors used at refineries?
    a. Would you be able to provide a list detailing the specification of these motors?
    b. Do you have data, or can you estimate the percentages by size, vintage, efficiency, application?
    c. Do you know if there are more efficient replacements for these motors?
    d. Do you have recommendations of certain motors you think should be targeted for energy efficiency?
4. What are the specialized requirements for refinery motors? (e.g., Explosion proof, high starting torque, vibration monitoring, special lubrication requirements)
5. What are the motor replacement practices at refineries?
    a. What are the costs and drivers associated with
        i. Replacing motors
        ii. Rewinding motors
        iii. Early replacement
    b. How often are motors usually rewound and how often are they replaced?
    c. Do motor type and/or size drive the Replace vs. Rewind decision?

G.2 *Market Assessment and Program Activities Questions*

6. Are you aware of any utility programs run in the past to incentivize early motor replacement with more efficient motors?
    a. If so, can you tell us about any lessons learned during these program activities?
7. What are the most significant trends and drivers in the rewinding or replacement of motors in the refinery industry?
    a. Examples: Costs (first, lifecycle, operational), reduction in equipment downtime, State and/or Federal regulations, sustainability goals, etc.

8. Are there any technical or market barriers the industry is currently facing?
    a. Examples: technology or supplier limitations, upfront or lifecycle cost barriers, educational barriers, available data
9. What are the most important regulations governing the refinery industry?
    a. Do any of these regulations affect market decisions in the industry?

G.3 Operational Practices

10. Can you talk about any industry standard practices (ISP) that the industry is currently focusing on or practices that concern you?
11. During the last five years, can you highlight important changes in the refinery industry pertaining to motor efficiency advancement?
12. We would like to understand if any energy efficiency or operational practices are considered "standard" by your organization? *(Note: this question relates to identifying current ISP practices/activities in the refinery industry)*

G.4 Identify New Opportunities Questions

13. Can you tell us about any new opportunities being pursued regarding motor efficiency in refineries?
14. What are the drivers behind these efforts to pursue new opportunities for motor efficiency?
    a. Example: Energy savings vs. maintenance (cost & time) savings etc.
15. Do you know of any new emerging technologies or processes not yet discussed that provide new opportunities for the industry?

G.5 Market Actors

16. *Data Request: Can you identify any subject matter experts and/or trade allies that you would recommend we interview?

G.6 Concluding Questions

17. Do you have any additional comments or concerns?

Appendix H Facility Manager Interview Guide

1. Please take a few minutes to describe what takes place at your facility and your role as a facility manager.

H.1 Facility Operations and Decision-Making Process

2. Please describe the general operating hours of your facility including peak hours and seasons as well as scheduled down time.
3. Please explain the decision-making process when it comes to installing and replacing motors.
    a. Would it be helpful if we did a case study evaluating the ROI for replacing motors in your facility?
4. Who typically makes the decision when it comes to motor replacement/rewinding decisions?

H.2 Technology and Process Characterization Questions

5. What equipment and processes rely most heavily on motors at your refinery?
6. Could you provide us with a list of the motors currently in use at your refinery?
    a. Motors vintage
    b. Motors efficiency
    c. Number of motors in different size classes
    d. Typical annual runtime hrs. for the different individual motors
    e. Any motors w/ VFDs? If so, what are the applications?
    f. Number of Specialized/Unique motors – not off the shelf type
    g. Percent energy consumed by the smaller vs. larger motors
7. What are the specialized requirements for refinery motors? (e.g., Explosion proof, high starting torque, vibration monitoring, special lubrication requirements)
    a. Do these requirements place any constraints on motor design? Who is responding to the market with efficient motors that meet those requirements and specialized applications?
8. Can you elaborate on the most important considerations for successfully meeting your business objectives:
    a. Do you look at ROI, first cost, utility bills, production rates, maintenance impacts, down times, etc.?

H.3 Operational Practices

9. We would like to understand your views on a number of business and energy related topics:
    a. How important are energy costs and energy savings compared to other business objectives?
    b. Where do utility costs rank on your list of operational expenditures?
    c. What are some high potential energy saving technologies in the industry?
    d. Do you use process control as an energy-saving practice?
    e. What do you currently do to reduce energy use, if anything?
    f. Does your facility have operations & maintenance strategies? If so, please describe the strategy.
    g. Are you aware of utility energy efficiency incentive programs?
        i. If so, have you leveraged utility programs?
10. How do you approach equipment replacements, upgrades, and retirement?
    a. Example: Do you have a phased schedule or bulk replacement strategy, replace-on-burnout, green motor rewind, repair versus replace views, etc.?
    b. Do you have a lead-lag motor program and if so who took initiative and set it up?
    c. What payback or ROI is required for an EE upgrade to get approved? (i.e. <2 years)
    d. Is the required payback different for the different sizes and types of motors? What is it?
    e. What is your motors repair vs. replacement practice?
        i. Is it different for different motor types /sizes/ application?
    f. What are the costs and drivers associated with
        i. Replacing motors
        ii. Rewinding motors
        iii. Early replacement
    g. Do you have in-house skill / capability to replace larger motors?
        i. If not, is not having in-house capability to replace larger motors an issue that affects motor replacement decisions?
    h. Do you have spare motors ready to install on burnout?
        i. What vintage?
        ii. For what type / size /process?
11. What are the most important regulations governing the refinery industry?

a. Do any of these regulations affect market decisions in the industry?

12. Can you talk about any industry standard practices (ISP) you are currently focusing on or ISPs that concern you?

    a. Are there variations in ISP perceptions among refineries in California?

H.4 Market Barriers

13. Related to early motor retirement, what are the key barriers you face?
    Examples: technology or supplier limitations (ex. Availability of contractors to perform work on specialized one of a kind equipment), upfront or lifecycle cost barriers, educational barriers, or limited data.

    a. Do you have suggestions on how to address these barriers?

H.5 Identify New Opportunities Questions

14. What are the drivers behind the efforts to pursue early motor retirement for refineries?
15. Do you have ideas for programs or recommendations for program designs that would be applicable across California?

    a. Example: What would you like to see from your utility?

16. What is the likelihood that you or other refineries will participate in utility early motor replacement programs? What can the utility do to increase participation?

H.6 Market Actors

17. *Data Request: Are there any other facility managers, suppliers, vendors, or other individuals that might be interested in sharing information with Navigant on this topic?

H.7 Concluding Questions

18. Do you have any additional comments or concerns?