CHAPTER 9. SHIPMENTS ANALYSIS

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CHAPTER 9. SHIPMENTS ANALYSIS

9.1 INTRODUCTION

Future product shipments estimates are a necessary input to the national energy savings (NES) and net present value (NPV) calculations. Shipments, combined with the characteristics of the applications in which the motors are used and the motor lifetime, allow the Department to estimate the total energy used by the installed stock of small motors each year. Shipments are also a necessary input to the manufacturer impact analysis. The core of the shipments analysis is an accounting model that the U.S. Department of Energy (DOE) developed to simulate how future purchases are incorporated into an in-service stock of aging motors that are gradually replaced. DOE's small motors shipments forecasts are based on forecasts of economic growth, and do not incorporate a distinction within shipments between replacements and purchases for new applications.

DOE developed a shipments forecast for each of the three covered small motor equipment categories (polyphase, capacitor-start induction-run, and capacitor-start capacitor-run motors). Within each category, small motor shipments are comprised of products in a number of horsepower ratings and three rotation speeds (corresponding to 2-pole, 4-pole, and 6-pole motors). DOE conducted its life-cycle cost analysis (see chapter 8) using representative 4-pole motors in each equipment category.

To formulate its shipment estimates, DOE began with shipments data provided by National Electrical Manufacturers Association (NEMA) for the determination analysis,[1] along with a comprehensive survey of the number of covered models listed in manufacturer catalogs available on the internet[2] and a review of U.S. Census data regarding production and imports of motors and equipment containing motors. Based on these data, DOE estimates that polyphase motors account for an estimated 19 percent of current total unit shipments while capacitor-start induction-run (CSIR) motors are 77 percent and capacitor-start capacitor-run (CSCR) motors are 4 percent.

Section 9.2 provides a summary of the data DOE used to develop estimates of the shipments of covered small electric motors in several applications, and the resulting estimates of total covered motor shipments. Section 9.3 addresses the distribution of these motors into product classes (horsepower and number of poles) within each category, based in part on the number of models currently available for sale in each product class. Section 9.4 presents DOE's forecasts of covered motor shipments throughout the analysis period.

9.2 TOTAL SHIPMENTS AND MOTOR APPLICATIONS

Based on comments from NEMA manufacturers in combination with DOE's previous estimates and an application analysis conducted for this stage of the rulemaking, total annual shipments of polyphase covered motors were modeled to total 750,000 per year. DOE's preliminary analysis suggested total covered polyphase shipments as 557,000, and a motor manufacturer representative at the preliminary public meeting suggested that the total was closer to 1 million. Upon analyzing the various applications for these motors, DOE determined that the total number of shipments lay between these two estimates, at roughly 750,000. This total is also consistent with U.S. Census-reported small polyphase motor shipments, adjusted for the breakdown of 2/3 enclosed, 1/3 open polyphase motors determined from a NEMA survey in the Determination phase. CSIR motor shipments total 3.1 million units per year, according to the written comment from NEMA, and CSCR motor shipments total roughly 163,000 (based on DOE's assumption, in turn based on a joint NEMA/SMMA survey in 2000,[1] that 5% of capacitor-start shipments are capacitor-run motors). CSIR and CSCR motors are used for the same range of applications, although CSCR motors are generally more widely available in higher horsepower ratings.

DOE drew upon several data sources to develop a model of the applications for which motors covered in this analysis are used: data collected by Easton Consultants in the preparation of the Small Motors Determination Analysis,[3] DOE's own analysis in the Determination and Framework stages,[4,5] U.S. Census reports, comments from interested parties, both written and at the preliminary public meeting[6], and interviews with experts in motor OEM industries.[7] The report by Easton Consultants developed for the Small Motors Determination Analysis provided the foundation for initial shipment estimates. However, the motor applications summarized in that report did not reflect DOE's current definition of general purpose small electric motors.

9.2.1 Compressors

Most small air compressors (under 11 CFM) use small electric motors. Based on studies of compressor manufacturer and retailer catalogs, DOE concluded that these motors are commonly open-enclosure, general purpose electric motors of the sort covered in this rulemaking. Very small (hand-carry-sized) compressors often use universal or permanent-magnet-DC motors, and some smaller compressors use special-purpose assemblies in which the compressor and motor are intimately linked. Some larger compressors use motors (referred to as "compressor-duty" motors) which do not meet the service factor requirements for a NEMA general purpose small electric motor. However, a significant fraction of portable and small stationary air compressors do use general purpose small electric motors which would be covered by this rulemaking.

The U.S. Census reports that total U.S. shipments of portable air compressors totaled roughly 2.7 million units in 2007[8]. Shipments of stationary air compressors with motors smaller than or equal to 1.5 hp are not reported by the Census due to the small number of manufacturers. However, the Census does report that the value of these shipments totaled $101 million. DOE

assumed that these small compressors are less valuable, per unit, than compressors with larger motors, and estimated that stationary compressor shipments with motors less than 1.5 hp exceed 250,000 per year, indicating total "small air compressor" shipments of roughly 3 million units. DOE assumed that about 20% of these compressors use motors covered by this analysis, with 80% of those being capacitor-start motors and 20% polyphase. DOE therefore estimated motor shipments for compressors to be 500,000 capacitor-start motors and 130,000 polyphase motors.

9.2.2 Conveyors

The U.S. Census reports that conveyors and material handling shipments totaled roughly $5.9 billion in 2002[9]. This total includes parts (roughly $400 million), as well as bulk handling and unit handling conveyors. DOE assumed that roughly $2 billion of conveyor and material handling system shipment value in 2008 is accounted for by electrically driven conveyors and material handling systems. Conveyor sales catalogs indicate a typical system cost (per single-motor driven conveyor) of between $1500 and $5000[10], which implies unit shipments between 400,000 and 1.3 million. The Determination Analysis assumed small motor shipments for conveyors of roughly 700,000, which is consistent with these estimates. DOE recognizes that conveyors are driven by a range of motors, including enclosed motors and variable-speed DC motors. Therefore, DOE estimated covered motor shipments for conveyor applications to total 500,000, of which 80% (400,000) are assumed to be capacitor-start motors, and 20% (100,000) to be polyphase motors. This represents a reduction in polyphase shipments of a factor of two relative to the Determination Analysis. DOE assumed that polyphase motors are more likely to be used in industrial settings, where enclosed motors play larger role.

9.2.3 Pumps

Pumps represent the largest application of general-purpose small electric motors. U.S. pump manufacturers ship roughly 20 million pumps each year, of which roughly 15 million are industrial pumps (or labeled "other" by the U.S. Census)[8]. Of the 15 million industrial pumps produced by U.S. companies, between 1 and 2 million are close coupled to their driver (motor), and therefore are not driven by general purpose motors. Roughly 1 million industrial pumps shipped each year are submersible, and therefore cannot be open, general purpose motors. The possible universe of industrial pumps which might use small general purpose motors is therefore between 12 and 13 million. Residential applications total about 5 million pump shipments per year and include pool pumps, hot water circulators, irrigation pumps, sump pumps, and well pumps. U.S. Census totals include 1.3 million non-submersible water pumps, which could be driven by general purpose motors. The total shipments of pumps that might use a covered general purpose small motor are therefore roughly 13 million. DOE assumed that 15% of these pumps use motors which would be covered under this proposed rule. DOE estimated a total of 2.18 million shipments in 2008 of covered small electric motors in pump applications, of which 1.8 million are capacitor-start and 380,000 are polyphase.

9.2.4 Fans and Blowers

The 2002 U.S. Economic Census[11] reported that industrial and commercial fan and blower manufacturers spent $103.8 million on drivers (motors) for their products. Fans and blowers use a wide range of motor sizes (although small motors are highly represented due to the relatively low power necessary to move large volumes of air), as well as a mixture of open and enclosed motors. DOE estimated that the average cost of a fan or blower motor to a manufacturer in 2002 was $150, which resulted in an estimate of 650,000 motors shipped to drive fans and blowers. Many of these motors are permanent-split capacitor (PSC) motors or other motors with low starting torque, suitable for driving fans. DOE estimated that 230,000 capacitor-start motors and 55,000 polyphase motors covered by this proposed rule are used in fan and blower applications.

9.2.5 General Industry and Miscellaneous

DOE calculated the total motors in "general industrial" applications by subtracting the four specific applications from the estimated shipments. This application category includes the small number of covered motors used in application categories which DOE has not analyzed separately, such as medical applications, commercial clothes dryers, machine tools, food processing equipment, packaging machinery, and HVAC/R. DOE estimated that the total shipments into this broad range of applications are 450,000 capacitor-start motors and 85,000 polyphase motors.

9.2.6 Covered Motor Applications Summary

Table 9.2.1 shows the percentage of shipments in each motor category that are used in the five applications DOE examined.

Table 9.2.1 Application Shares by Equipment Type

		Equipment Category		
No.	**Application**	**Polyphase**	**CSIR**	**CSCR**
1	Air and gas compressors	17.3%	14.9%	14.9%
2	Conveyors	13.3%	11.9%	11.9%
3	General industrial machinery	11.3%	12.5%	12.5%
4	Industrial and commercial fans and blowers	7.3%	6.9%	6.9%
5	Pumps and pumping equipment	50.7%	53.7%	53.7%
	TOTAL	100%	100%	100%

For each equipment category, DOE calculated an average annual shipments growth rate by weighting the growth rates in the application sectors by the ownership shares of each sector in that class. In order to develop these forecasts, DOE estimated the percentage of motors within

each application which are used in industrial, agricultural, commercial, or residential sectors. The estimated sector ownership shares are shown in Table 9.2.2 for each application.

Table 9.2.2 Shares of Motor Owner Type by Application

		Motor Owner Type			
No.	**Application**	**Industrial**	**Commercial**	**Agricultural**	**Residential**
1	Air and gas compressors	40%	40%	10%	10%
2	Conveyors	40%	50%	10%	0%
3	General industrial machinery	50%	40%	10%	0%
4	Industrial and commercial fans and blowers	50%	50%	0%	0%
5	Pumps and pumping equipment	40%	35%	20%	5%

9.2.7 Application Data Submitted by NEMA

In comments submitted following the NOPR stage of this rulemaking, the National Electrical Manufacturers Association (NEMA) submitted alternate versions of the data shown in Tables 9.2.1 and 9.2.2, based on a survey of Original Equipment Manufacturers (OEMs). These alternate tables are reproduced below, as Tables 9.2.3 and 9.2.4. This data submittal added a sixth motor application, Service Industry. DOE used these data to develop alternate scenarios for the life-cycle cost and national impact analyses, and the results of these sensitivity scenarios are presented in chapters 8 and 10 of this TSD.

Table 9.2.3 Application Shares by Equipment Type (NEMA)

		Equipment Category		
No.	**Application**	**Polyphase**	**CSIR**	**CSCR**
1	Air and gas compressors	45%	22%	45%
2	Conveyors	5%	2%	2%
3	General industrial machinery	7%	1%	1%
4	Industrial and commercial fans and blowers	23%	51%	29%
5	Pumps and pumping equipment	15%	13%	12%
6	Service Industry	5%	11%	11%
	TOTAL	100%	100%	100%

Table 9.2.4 Shares of Motor Owner Type by Application (NEMA)

		Motor Owner Type			
No.	**Application**	**Industrial**	**Commercial**	**Agricultural**	**Residential**
1	Air and gas compressors	0%	15%	15%	70%
2	Conveyors	65%	35%	0%	0%
3	General industrial machinery	80%	20%	0%	0%
4	Industrial and commercial fans and blowers	20%	80%	0%	0%
5	Pumps and pumping equipment	10%	40%	20%	30%
6	Service Industry	10%	80%	0%	10%

9.3 SHIPMENTS BY PRODUCT CLASS

DOE developed an estimated distribution of shipments for 2008 among the various product classes. (Average motors within each product class use different amounts of energy; see chapter 6). DOE used two data sources to develop these estimates: a distribution for many product classes for the year 2000, provided by NEMA as part of the Determination Analysis, and a survey of internet catalogs of 9 small electric motor manufacturers, undertaken between April 1 and May 1, 2009.[2]

For the Determination Analysis, NEMA provided shipment data on small electric motors to DOE. Tables 9.3.1 and 9.3.2 show this data, which provided the basis for the Department's estimated distributions of shipments for polyphase and CSIR motors. NEMA was unable to provide shipments for some product classes, as well as virtually the entire CSCR equipment category, due to anti-trust restrictions. The product classes for which NEMA provided no data are shown as asterisks in Tables 9.3.1 and 9.3.2.

Table 9.3.1 Polyphase Small Electric Motors, NEMA Shipment Data, 2000

Motor Horsepower	Six Poles	Four Poles	Two Poles	Total
1/4 hp	*	*	*	9,163
1/3 hp	3,788	12,899	2,585	19,272
1/2hp	6,478	39,501	2,856	48,835
3/4 hp	9.729	47,084	65,405	122,218
1 hp	*	56,783	*	84,670
1 1/2 hp	*	115,638	*	124,959
2-3 hp	-	22,384	10,149	32,533
TOTAL				441,650

** Data withheld by NEMA due to insufficient number of manufacturers reporting for those ratings / poles*

Table 9.3.2 CSIR Small Electric Motors, NEMA Shipment Data, 2000

Motor Horsepower	Six Poles	Four Poles	Two Poles	Total
1/4 hp	*	342,064	*	882,878
1/3 hp	551,566	609,264	354,258	1,515,088
1/2hp	301,198	493,151	465,799	1,260,148
3/4 hp	*	385,013	*	1,121,644
1 hp	-	53,042	143,571	196,613
>1 hp	-	23,638	24,892	48,530
TOTAL				5,024,901

** Data withheld by NEMA due to insufficient number of manufacturers reporting for those ratings / poles.*

The Department used the number of models currently sold by NEMA-member motor manufacturers as an estimated measure of relative shipments for product classes where NEMA provided no collective data. Tables 9.3.3 through 9.3.5 show the number of models in each class as determined from the Department's survey of internet motor catalogs.

Table 9.3.3 Polyphase Small Electric Motor Models in Manufacturer Catalogs, 2009

Motor Horsepower	Six Poles	Four Poles	Two Poles	Total
1/4 hp	7	13	2	22
1/3 hp	8	30	21	59
1/2hp	15	45	29	89
3/4 hp	16	42	26	84
1 hp	7	48	24	79
1 1/2 hp	2	39	28	69
2 hp	0	32	29	61
3 hp	0	12	14	26
TOTAL				489

Table 9.3.4 CSIR Small Electric Motor Models in Manufacturer Catalogs, 2009

Motor Horsepower	Six Poles	Four Poles	Two Poles	Total
1/4 hp	7	57	4	68
1/3 hp	11	91	35	137
1/2hp	15	88	52	155
3/4 hp	6	60	40	106
1 hp	0	59	37	96
1 1/2 hp	0	27	24	51
2 hp	0	6	25	31
3 hp	0	0	4	4
TOTAL				648

Table 9.3.5 CSCR Small Electric Motor Models in Manufacturer Catalogs, 2009

Motor Horsepower	Six Poles	Four Poles	Two Poles	Total
1/4 hp	0	2	0	2
1/3 hp	0	7	0	7
1/2hp	0	7	0	7
3/4 hp	9	22	0	31
1 hp	2	8	4	16
1 1/2 hp	0	18	9	27
2 hp	0	12	9	21
3 hp	0	0	5	5
TOTAL				114

DOE developed shipment distributions among product classes for the year 2008 by first scaling the polyphase and CSIR distributions in Tables 9.3.1 and 9.3.2 so that their totals were equal to the total estimated shipments determined in the application analysis in Section 9.2 (3.1 million CSIR and 750,000 polyphase small electric motors). DOE developed estimates for the product classes not provided by NEMA by using the number of models currently sold as a measure of relative shipments. For ¼ horsepower polyphase motors, for example, DOE used the scaled total shipments, 15,560, and divided them among the three product classes in the ratio 7:13:2 because it found 7 six-pole models sold, 13 four-pole models sold, and 2 two-pole models sold in its catalog survey. For 1 and 1½ horsepower polyphase motors and ¼ and ¾ horsepower CSIR motors, DOE first calculated the difference between the total shipments with each power and the four-pole shipments, and then divided this value between the two unknown product classes in proportion to the number of models sold in each class. The resulting estimates for shipments in each product class of polyphase and CSIR motors are shown in Tables 9.3.6 and 9.3.7, respectively.

Table 9.3.6 Estimated Polyphase Small Electric Motor Shipments by Product Class, 2008

Motor Horsepower/Standard Kilowatt Equivalent	Six Poles	Four Poles	Two Poles	Total
1/4 hp/0.18 kW	4,951	9,195	1,415	15,560
1/3 hp/0.25 kW	6,433	21,905	4,390	32,727
1/2 hp/0.37 kW	11,001	67,080	4,850	82,930
3/4 hp/0.55 kW	16,522	79,957	111,069	207,548
1 hp/0.75 kW	10,694	96,428	36,664	143,785
1½ hp/1.1 kW	1,055	196,374	14,773	212,203
2-3 hp/1.5-2.2 kW	-	38,012	17,235	55,247
Total	50,655	508,950	190,395	750,000

Table 9.3.7 Estimated Capacitor-Start Induction-Run Small Electric Motor Shipments by Product Class, 2008

Motor Horsepower/Standard Kilowatt Equivalent	Six Poles	Four Poles	Two Poles	Total
1/4 hp/0.18 kW	212,318	211,029	121,325	554,672
1/3 hp/0.25 kW	340,276	375,872	218,552	934,700
1/2 hp/0.37 kW	185,817	304,238	287,364	777,420
3/4 hp/0.55 kW	59,276	237,525	395,172	691,973
1 hp/0.75 kW	-	32,723	88,573	121,296
1.5 hp/1.1 kW	-	11,931	6,954	18,885
2-3 hp/1.5-2.2 kW	-	2,651	8,403	11,054
Total	797,688	1,175,970	1,126,342	3,100,000

DOE's 2006 Determination Analysis concluded that CSCR motors make up roughly 5% of all capacitor-start shipments. DOE assumed the same ratio for this analysis (for total shipments of 163,158), and divided the shipments among product classes in proportion to the number of models sold in each class. For example, of the 114 models of CSCR motor sold, 22 are four-pole, ¾ horsepower, so DOE estimated the shipments to that class as 22/111 = 19.8% of the total, or 31,487 in 2008. Table 9.3.8 shows DOE's shipment estimates for each CSCR product class.

Table 9.3.8 Estimated Capacitor-Start Capacitor-Run Small Electric Motor Shipments by Product Class, 2008

Motor Horsepower/Standard Kilowatt Equivalent	Six Poles	Four Poles	Two Poles	Total
1/4 hp/0.18 kW	-	2,862	-	2,862
1/3 hp/0.25 kW	-	10,018	-	10,018
1/2 hp/0.37 kW	-	10,018	-	10,018
3/4 hp/0.55 kW	12,881	31,487	-	44,367
1 hp/0.75 kW	2,862	11,450	5,725	20,037
1.5 hp/1.1 kW	-	25,762	12,881	38,643
2-3 hp/1.5-2.2 kW	-	17,175	20,037	37,211
Total	15,743	108,772	38,643	163,158

9.4 SHIPMENTS FORECAST

DOE forecasted shipments of covered motors throughout the 30-year analysis period, which stretches from 2015 (the assumed effective date of the standard) to 2045. DOE forecast the total shipments in two categories of motors, polyphase and capacitor-start, using a model driven by forecasted economic growth. DOE's forecast assumed that motors sales are driven by macroeconomic activity of the sectors in which they are used. DOE used the estimated shares of motor owner type shown in Table 9.2.2 to develop a weighted-average market growth driven by the Nation's economic growth.

Annual shipments growth rates for each sector are set as equal to annual growth rates in the following drivers, which are provided by the 2009 Annual Energy Outlook (*AEO 2009)*[12] through 2030:

- Industrial and Agricultural: Manufacturing activity (total shipments—manufacturing only, in dollars);
- Commercial: Commercial floor space;
- Residential: Number of households.

DOE continued the growth trend in AEO forecasts through 2045 by, first, determining the growth rate for these drivers between 2020 and 2030, and then continuing this rate from 2030 to 2045.

DOE modeled four scenarios, which the user may select in the National Impact Analysis spreadsheets available on the internet at <http://www1.eere.energy.gov/buildings/appliance_standards/commercial/small_electric_motors.html>. The Department's reference scenario, for which NES and NPV results are reported in chapter 10, is the American Recovery and Reinvestment Act reference scenario, released by the EIA in April, 2009. The High Growth and Low Growth scenarios are from the *AEO 2009* release, March 2009. The fourth scenario reflects comments from interested parties who forecast a falling market share for motors covered by this rulemaking. In this scenario, DOE forecast that total shipments would remain equal to the 2008 shipments throughout the forecast period, regardless of economic growth between 2008 and 2045.

9.4.1 Sensitivity of Shipments to Installed Cost

Sales of small electric motors may be sensitive to increases in the installed cost that may result from efficiency standards. Totally enclosed motors are potential substitutes for the open-construction motors covered in this rulemaking. These types of motors come in the same frame sizes, horsepower ratings and have similar performance characteristics (although they commonly have lower service factors). Today, the incremental purchase cost of a totally enclosed motor instead of an open-construction motor is approximately 18 percent. If the installed cost of open-construction motors were to increase much beyond 18 percent due to energy efficiency standards, there might be some migration to (non-covered) totally enclosed motors.

DOE believes that increases in the installed cost of small electric motors could reduce their purchase due to migration to totally enclosed motors or other factors. However, DOE has not found any data that would allow it to estimate the elasticity of small electric motor shipments to change in their purchase price. Interested parties at the preliminary public meeting indicated that they believe this elasticity to be negligible. DOE included an elasticity variable in the publicly-available National Impact Analysis spreadsheet models (with user-selectable choices of elasticity equal to 0, -0.25, and -0.5), but all results presented in this chapter and in chapter 10 assume that overall small electric motor sales are price-inelastic.

9.4.2 Polyphase Motor Shipment Forecast

DOE's forecast of annual polyphase small electric motor shipments is shown in Figure 9.4.1 and summarized in Table 9.4.1. The figure shows the four different growth rates modeled by the Department. The average annual shipments growth rate in the reference case is 1.33%. In the price-inelastic case (the Department's reference case), polyphase shipments are unaffected by the standard level.

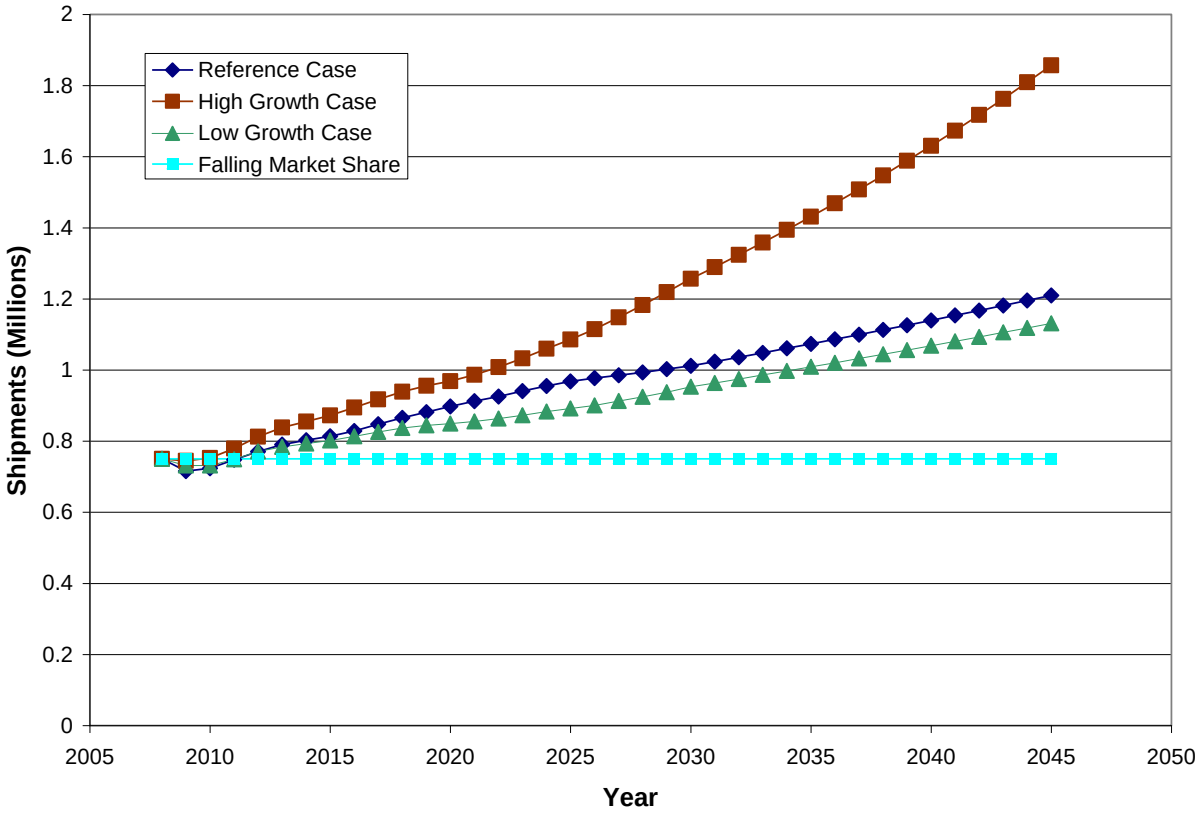

Figure 9.4.1 Shipments Forecasts for Polyphase Small Electric Motors

Table 9.4.1 Annual and Cumulative Shipments Forecast for Polyphase Small Electric Motors

Growth Scenario	Annual Shipments (millions)				
	2015	2025	2035	2045	Cumulative 2015–2045
Reference Case	0.813	0.968	1.074	1.210	31.5
High Growth	0.872	1.086	1.431	1.857	40.0
Low Growth	0.802	0.892	1.009	1.132	29.7
Falling Market Share	0.750	0.750	0.750	0.750	23.3

Figure 9.4.2 shows the affected stock forecast from the shipments model for polyphase motors, in the Department's reference case. (The Department could produce similar plots for each product class, or each shipment forecast, but shows only one here as an illustration.) The affected stock is the accumulation of motors in use that are subject to standards, and energy savings from a standard tends to increase with the accumulating affected stock of equipment. The affected stock increases rapidly initially as the older, inefficient stock of equipment is

replaced by standard-compliant equipment. The stock then experiences a relatively long period of a gradual increase as the stock of equipment increases with gradually increasing national economic activity. Then at the end of the forecast period for annual shipments at 2045, the equipment is rapidly replaced by equipment purchased after the end of the forecast period.

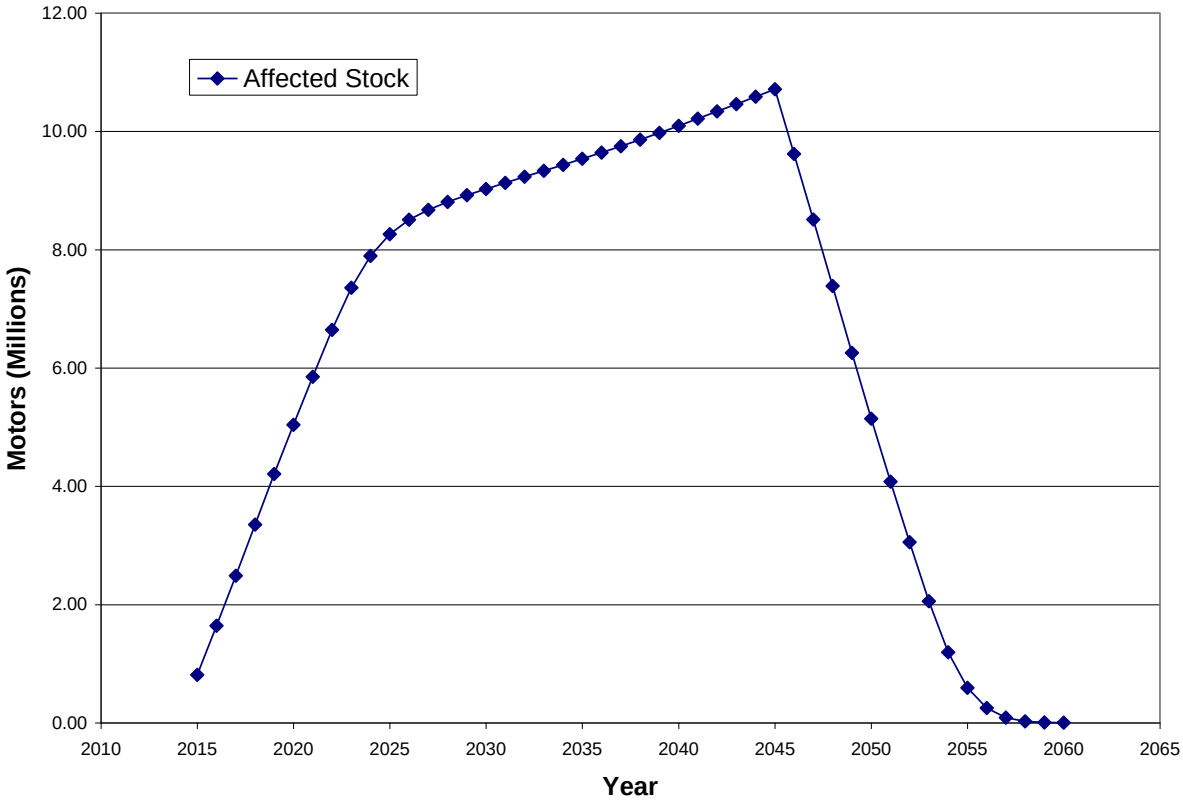

Figure 9.4.2 Affected Stock of Polyphase Small Electric Motors

9.4.3 Capacitor-Start Motor Shipment Forecast

DOE's forecasts of annual capacitor-start small electric motor shipments are shown in Figure 9.4.3. The figure shows the four different growth rates modeled by the Department. The average annual shipments growth rate in the reference case is 1.33%. Table 9.4.2 presents the annual and cumulative shipments for CSIR and CSCR motors in the base (no standards) case. Total capacitor-start shipments are unchanged by standards in the Department's price-inelastic reference scenario. However, the shares of these shipments that are CSIR or CSCR motors are affected by the standard. Section 9.4.4 explains the Department's CSIR/CSCR market share model used to forecast shipments in the standards cases.

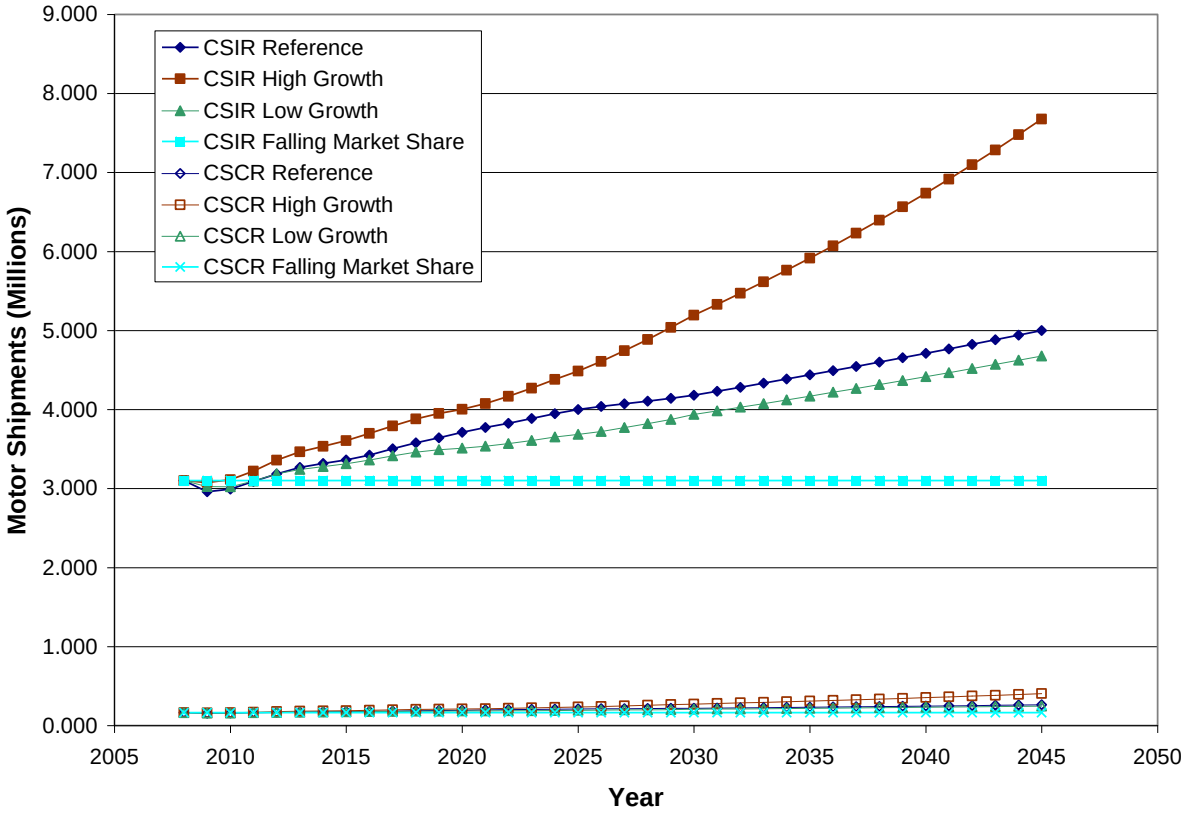

Figure 9.4.3 Shipments Forecasts for Capacitor-Start Small Electric Motors in the Base Case

Table 9.4.2 Annual and Cumulative Shipments Forecast for Capacitor-Start Small Electric Motors in the Base Case

Growth Scenario	Annual Shipments (millions)				
	2015	2025	2035	2045	Cumulative 2015–2045
CSIR					
Reference Case	3.362	4.000	4.438	5.000	130.3
High Growth	3.605	4.487	5.915	7.675	165.3
Low Growth	3.315	3.687	4.171	4.677	122.6
Falling Market Share	3.100	3.100	3.100	3.100	96.1
CSCR					
Reference Case	0.177	0.211	0.234	0.263	6.9
High Growth	0.190	0.236	0.311	0.404	8.7
Low Growth	0.174	0.194	0.220	0.246	6.5
Falling Market Share	0.163	0.163	0.163	0.163	5.1

9.4.4 CSIR/CSCR Market Share Response to the Standard Level

For most applications, small general purpose CSCR motors are potential replacements for small CSIR motors in that they meet the same NEMA criteria regarding torque, service factor, and frame size, as detailed in NEMA MG1.[13] Currently, CSCR motors are, on average, more expensive than CSIR motors for most product classes, physically larger due to the space required by a second capacitor, have lower losses, and have a relatively small overall market share. However, if a combination of standards were to be adopted which significantly changed the relative prices of CSCR and CSIR motors, DOE forecasts that this could result in significant changes in their respective market shares. DOE developed a model to analyze this potential market shift based on incremental purchase cost, incremental operating losses, and the observed market share in the current market (as derived in section 9.3). In the base case (no energy conservation standard), DOE assumed that the market shares of CSIR and CSCR motors would remain fixed at their current values for each product class.

DOE developed a three-parameter market share model to determine the market share of CSCR and CSIR motors (within each combination of horsepower and number of poles) in the case of potential standard levels. The three parameters are:

- α, the relative weight customers choose to give operating costs compared with purchase costs (the units of α are \$/kWh),
- δ, an "unfamiliarity cost" associated with CSCR motors (in dollars), and
- β, an overall elasticity or scaling factor (no units).

Customers appear to favor CSIR motors over CSCR motors, even if their initial costs and losses were almost identical. The "unfamiliarity cost" parameter δ is not a cost faced by the motor customer. Instead, DOE's model uses this dollar value to describe customer behavior favoring CSIR motors: If a CSIR and CSCR motor had identical purchase and operating costs and the

CSCR motor were δ dollars less expensive than the CSIR motor, the Department's model predicts that each motor would have 50% market share.

For each product class, DOE developed a "cost factor" based on these three parameters and the incremental purchase cost and incremental operating losses associated with a CSCR motor compared with a CSIR motor of the same power and number of poles. This cost factor *CF* is equal to:

$$CF(p, hp) = \beta \times \left(\Delta PurCost(p, hp) + \alpha \times \Delta AnnLosses(p, hp) + \delta\right)$$

Where:

α, β, and δ = fit parameters as defined above, fixed for all motor powers and speeds,[a]

$\Delta PurCost(p,hp)$ = the difference between the average purchase cost of CSCR and CSIR motors with *hp* horsepower and *p* poles (in $2008)

$\Delta AnnLosses(p,hp)$ = the difference between the average annual operating losses of CSCR and CSIR motors with *hp* horsepower and *p* poles (in kWh/year).

DOE then calculated the cost factor for each product class, as a function of α, β, and δ, and developed a logistic consumer choice model. That is, DOE assumed that the product market share is a modified logistic function of the cost factor. A simple logistic model would calculate the market share as:

$$MS(p, hp) = \frac{1}{1 + e^{CF(p,hp)}}$$

Where:

$MS(p,hp)$ = market share of CSCR motors among all covered capacitor-start motors with *p* poles and *hp* horsepower.

DOE modified this model to account for the manufacturer barrier to create a new motor design in a product class in which no equipment is currently produced. DOE assumed that no manufacturer would enter a currently empty product class market until the forecast market share for that product class reached 10%. For example, DOE found no ½ horsepower, two-pole CSCR motors currently available. If the simple logistic model predicts a 3% market share for CSCR motors in this class, DOE assumed that the market share would remain zero. If the simple logistic model predicted a market share of 15% for CSCR motors in this class, DOE assumed that at least one manufacturer would enter the market in this class, and the CSCR market share would be 15%.

DOE then found the values of α, β, and δ that minimized the sum of the squares of the differences in market share (a "least squares" fit) between the current market and the model. The best-fit values of the model parameters are:

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[a] DOE fit the 6 pole, ¾ horsepower capacitor-start motor classes with their own value of δ. See the subsequent discussion.

- α = 0.537 $/kWh
- β = 0.0249
- δ = $220.43

DOE found that the relationship between the cost factor and market share for the 6 pole, ¾ horsepower motor was a significant outlier compared with all other product class pairs. DOE fit the market share and cost factor for this class with a different value of δ, $277.74. Figure 9.4.4 shows the current and modeled market shares for each CSCR product class as a function of the best-fit cost factor. Table 9.4.3 lists DOE's estimated market share and the prediction of its market share model for each combination of horsepower and number of poles, in the absence of standards.

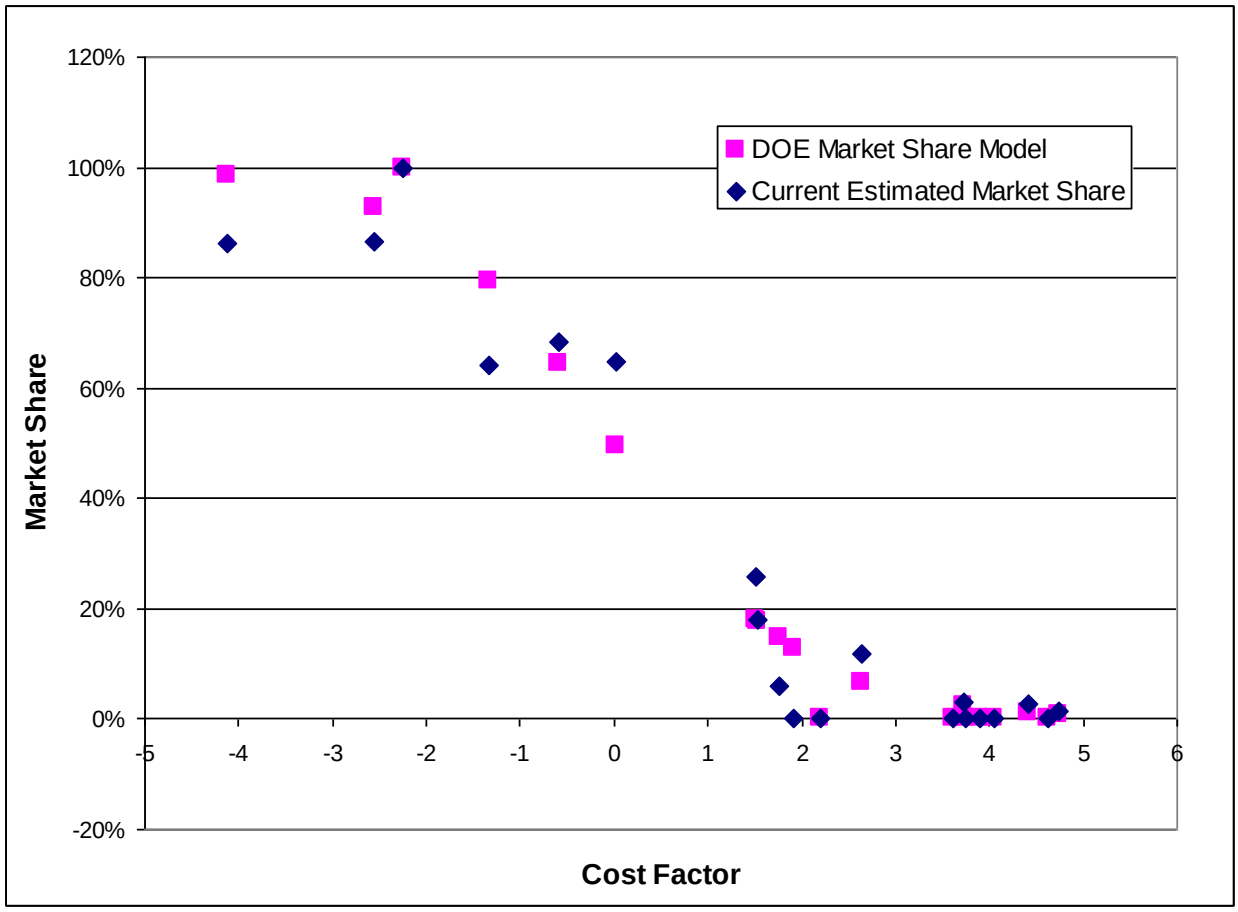

Figure 9.4.4 Comparison of CSCR Market Share Between Current Market and DOE's Logistic Model

Table 9.4.3 CSCR Current Market Share and Model Comparison for Each Combination of Horsepower and Number of Poles

Motor Horsepower	Six Poles		Four Poles		Two Poles	
	Current CSCR Mkt. Share (%)	Logistic Model Mkt. Share (%)	Current CSCR Mkt. Share (%)	Logistic Model Mkt. Share (%)	Current CSCR Mkt. Share (%)	Logistic Model Mkt. Share (%)
0.25	0.0	0.0	1.3	0.9	0.0	0.0
0.33	0.0	0.0	2.6	1.2	0.0	0.0
0.5	0.0	0.0	3.2	2.4	0.0	0.0
0.75	17.9	17.8	11.7	6.7	0.0	13.0
1	100.0	100.0	25.9	18.1	6.1	14.8
1.5	--	--	68.3	64.3	64.9	49.4
2	--	--	86.6	92.8	64.0	79.2
3	--	--	--	--	86.1	98.4

DOE conducted an error analysis to determine the standard deviations for the values of α, β, and δ:

- $\Delta\alpha$ = 0.308 $/kWh
- $\Delta\beta$ = 0.0126
- $\Delta\delta$ = $114.95

DOE then used the standard deviation of δ to derive "high CSCR" and "low CSCR" scenarios, in addition to the best fit "reference" scenario. These scenarios model the market share in the case that the "unfamiliarity cost" is significantly lower (high CSCR model) or higher (low CSCR model) than the Department's reference case. Varying α or β does not result in a model with solely higher or lower CSCR market share (they change the relative behavior of different product classes within each motor category), and the Department feels that its "high CSCR" and "low CSCR" scenarios span the range of likely market responses.

DOE used the modified logistic model derived based on the current market shares to forecast the market shares of CSIR and CSCR motors within each product class for each combination of possible energy efficiency standards, including the 8 combinations examined as trial standard levels (TSLs). (See chapter 10 for description of the TSLs evaluated in the NOPR analysis.) For this reference market share forecast, DOE used the average price for motors in each product class, accounting for both space constrained and space-unconstrained motors with a single price. DOE estimated that the market share transition would be complete by 2015, when the standard takes effect, due to motor manufacturer anticipation of customer demand. **Error! Reference source not found.** shows the total shipments of CSIR and CSCR motors during the analysis period corresponding to Department's reference, "Low CSCR", and "High CSCR" scenarios for each trial standard level. In chapter 10, DOE presents the resulting energy savings and net present value corresponding to each scenario.

Table 9.4.4 Cumulative CSIR and CSCR Motor Shipments (Millions) Between 2015 and 2045 (Market Share Shift Complete Prior to 2015)

Trial Standard Level	Reference Scenario		Low CSCR Scenario		High CSCR Scenario	
	CSIR	CSCR	CSIR	CSCR	CSIR	CSCR
No standard*	132.9	7	132.9	7	132.9	7
1	138.3	1.7	139.8	0.1	113.8	26.1
2	137.5	2.4	139.7	0.2	108.1	31.8
3	137.2	2.8	139.7	0.3	104.9	35.0
4	131.5	5.5	136.4	0.4	94.0	43.9
5	129.7	7.3	136.2	0.7	86.1	51.9
6	122.9	0.0	122.9	0.0	122.8	0.1
7	4.4	135.0	28.3	107.7	0.3	139.6
8	9.1	126.1	41.5	90.2	0.7	135.5

* DOE did not use its market share model to predict market shares in the base case; it used its current market share estimates.

The National Impact Analysis spreadsheet tool that accompanies this TSD provides shipment estimates for each product class in each year, under each of the TSLs. The tool allows the user to select among several scenarios, including the high- and low-CSCR scenarios (with user-adjustable transition time to the new market shares), different market and economic growth rates, and different market elasticity models.

REFERENCES

[1] National Electrical Manufacturers Association, *Joint NEMA/SMMA Bulletin of US Sales of Selected Small Motors in 2000*, September 5, 2001.

[2] DOE examined online catalogs for A.O. Smith, Baldor, Emerson, Leeson, Marathon, Weg, Lincoln, McMaster Carr and Regal-Beloit motors. A spreadsheet tool showing the collected motors and their characteristics is available at <http://>.

[3] The work by Easton Consultants is summarized in Appendix B of *Determination Analysis Technical Support Document: Analysis of Energy Conservation Standards for Small Electric Motors*, June 2006 <http://www1.eere.energy.gov/buildings/appliance_standards/commercial/pdfs/small_motors_tsd.pdf>

[4] *Determination Analysis Technical Support Document: Analysis of Energy Conservation Standards for Small Electric Motors*, June 2006 <http://www1.eere.energy.gov/buildings/appliance_standards/commercial/pdfs/small_motors_tsd.pdf>

[5] Energy Conservation Standards Rulemaking Framework Document for Small Electric Motors <http://www1.eere.energy.gov/buildings/appliance_standards/commercial/pdfs/small_motors_framework_073007.pdf>

[6] Transcript of Public Meeting on Energy Conservation Standards for Small Electric Motors, January 30, 2009, <http://www1.eere.energy.gov/buildings/appliance_standards/commercial/pdfs/transcript_small_motors_standards_meeting.pdf>

[7] Joe Evans. PentAir Water Pumps, personal communication, March 5, 2009.

[8] U.S. Census Bureau. *Current Industrial Report MA333P, Pumps (except hydraulic) and Compressors – 2007.*

[9] U.S. Census Bureau. *Economic Census 2002, Industry Statistics Sampler: NAICS 333922, Industrial and Commercial Fan and Blower Manufacturing.* <http://www.census.gov/econ/census02/data/industry/E333922.HTM>

[10] See, for example, Roach Conveyors <www.roachconveyors.com>, or Material Flow and Conveyor Systems <www.materialflow.com>

[11] U.S. Census Bureau. *Economic Census 2002, Industry Statistics Sampler: NAICS 333412, Industrial and Commercial Fan and Blower Manufacturing.* <http://www.census.gov/econ/census02/data/industry/E333412.HTM>

[12] U.S. Department of Energy-Energy Information Administration. *An Updated Annual Energy Outlook 2009 Reference Case Reflecting Provisions of the American Recovery and Reinvestment Act and Recent Changes in the Economic Outlook*, April, 2009. Washington, DC. SR/OIAF/2009-03. <www.eia.doe.gov/oiaf/servicerpt/stimulus/pdf/sroiaf(2009)03.pdf> and U.S. Department of Energy-Energy Information Administration. *Annual Energy Outlook 2009 with Projections to 2030* , March 2009. Washington, DC. <www.eia.doe.gov/oiaf/aeo/pdf/0383(2009).pdf>

[13] MG1 is a standards publication for electric motors and generators (MG) issued by NEMA and updated periodically. The particular issue of MG1 explicitly cited in the legislation for the purposes of defining the scope of coverage for the small electric motors rulemaking is MG1-1987.