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A Framework to Survey the Energy Efficiency of Installed Motor Systems

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Abstract

While motors are ubiquitous throughout the globe, there is insufficient data to properly assess their level of energy efficiency across regional boundaries. Furthermore, many of the existing data sets focus on motor efficiency and neglect the connected drive and system. Without a comprehensive survey of the installed motor system base, a baseline energy efficiency of a country or region's motor systems cannot be developed. The lack of data impedes government agencies, utilities, manufacturers, distributers, and energy managers when identifying where to invest resources to capture potential energy savings, creating programs aimed at reducing electrical energy consumption, or quantifying the impacts of such programs.

This paper will outline a data collection framework for use when conducting a survey under a variety of execution models to characterize motor system energy efficiency within a country or region. The framework is intended to standardize the data collected ensuring consistency across independently conducted surveys. Consistency allows for the surveys to be leveraged against each other enabling comparisons to motor system energy efficiencies from other regions. In creating the framework, an analysis of various motor driven systems, including compressed air, pumping, and fan systems, was conducted and relevant parameters characterizing the efficiency of these systems were identified.

A database using the framework will enable policymakers and industry to better assess the improvement potential of their installed motor system base particularly with respect to other regions, assisting in efforts to promote improvements to the energy efficiency of motor driven systems.

Introduction

Motor systems account for approximately 64% of manufacturing electricity use and are ubiquitous in industrial facilities worldwide [9]. Motor systems, such as compressed air, pumping, and fan systems, represent a largely untapped, cost-effective source for industrial energy efficiency savings that could be realized with existing technologies and best practices [2, 3, 5, 7, 9]. Although motor systems have the potential to contribute substantial energy savings, on the order of 2.58 EJ in final energy use, this potential is largely unrealized [3].

A major barrier to effective decision making to capture the energy savings potential, and to more global acceptance of the energy efficiency potential of motor systems, is the lack of sufficient data to assess the energy efficiency of motor systems across regional boundaries and to document the magnitude and cost-effectiveness of energy savings by country and by region [6].

This paper outlines a data collection framework for use when conducting a survey to determine the energy efficiency of the installed motor system base of a given country or region. Particular focus is paid to pumping, compressed air, and fan systems as these represent a large portion of the energy consumption attributable to motor systems.

The framework is created in the form of a series of tables that identify the information needed to better understand the design, operations, use, and maintenance of the installed motor system base in a given country or region. With this information, the energy efficiency of a particular installed motor system base can be assessed. This framework is intended to standardize the data collected ensuring consistency across various surveys, thus allowing for broader applicability of the survey results. The data collected can serve many purposes. One such purpose may be to develop regional indicators for the energy efficiency of a country or region's motor systems against which to measure energy efficiency improvement.

The framework was informed by several previous studies. Using a combination of experts' opinion and available data, McKane and Hasanbeigi developed an innovative approach to characterize the energy efficiency of motor systems in the United States, Canada, the European Union, Thailand, Vietnam, and Brazil. This approach used bottom-up energy efficiency supply curve models to estimate the cost-effective electricity efficiency potentials and CO_2 emission reduction for three types of industrial motor systems (compressed air, pumping, and fan) for the selected countries/region. The motor system data collection framework proposed in this paper has extensively benefited from the approach developed by McKane and Hasanbeigi [4]. Additional work used to inform the development of the framework includes a comprehensive assessment of U.S. industrial motor systems conducted by the U.S. Department of Energy (US DOE) and an extensive assessment of industrial motor systems and their energy efficiency potential in the EU conducted be de Almeida [8, 1].

The framework described in this paper is meant to be a beginning. The authors seek to initiate an international dialogue with other interested researchers to further refine the proposed framework and to develop ideas on how to get it utilized by government as well as non-government programs addressing motor system energy efficiency.

Purpose and implementation of motor system evaluation

The series of tables developed for this paper are intended to serve as a framework for designing surveys to assess motor system energy efficiency. Before designing the framework, its eventual use, including its purpose and implementation, needs to be understood. By considering aspects of the survey implementation such as the intended user, the larger process for assessing motor system energy efficiency potential into which the survey fits, and the execution model for collecting data, a framework can be devised that best meets the needs of future motor system surveys.

Intended User

A survey of the installed motor system base in a region can be useful to many entities. Government agencies at all levels may be interested in a survey of the installed motor system base to help guide policy towards reducing electric energy consumption within their purview. Utilities may be interested in a motor system survey to better estimate the savings associated with rebate and incentive programs directed towards improving motor system energy efficiency and reducing electricity consumption. Providers of motor system equipment and services may use the information gained from a motor system survey to develop and market products that address energy saving opportunities within the installed motor system base. Energy managers may use the results of the surveys to compare the performance of their motor systems to their peers and identify potential energy saving opportunities. By focusing on the data requirements for characterizing motor system energy efficiency, the framework can be adapted for a range of applications by those seeking to better understand the energy efficiency of an installed motor system base.

The use of data collection framework in energy efficiency policies and programs:

Ultimately, the framework developed here can fit into a larger goal of developing policies that encourage the adoption of technologies, processes, and best practices for improving installed motor system energy efficiency. One example of the steps to achieve this larger goal is provided in the textbox. These steps fall into two phases: baseline current energy efficiency (Steps 1 – 3) and assess energy efficiency potential (Steps 4 – 6). The framework presented here develops Step 2.

Step 1: Collect identifying information on installed motor system(s) base
Step 2: Collect data on the energy efficiency of installed motor system(s) base
Step 3: Using the data collected in Step 2, develop indicators to profile motor system(s) energy efficiency and allow for comparison to similar systems across regional boundaries
Step 4: Enumerate technologies, processes, and best practices for improving motor system(s) efficiency
Step 5: Assess technical potential and economic feasibility of energy efficiency improvement from implementation of identified technologies, processes, and best practices
Step 6: Identify potential policies and programs to assist industry in achieving those energy efficiency improvements that are technically and economically feasible

The framework presented assumes Step 1 has been completed. Step 1 provides basic information regarding the installed motor system equipment and estimated total energy consumption. Sample information for Step 1 can be found in **Figure 1**. Step 2 uses data collection samples to gather further information on system design, operating characteristics, use, maintenance, and other indicators for assessing energy efficiency.

Sample Information to determine for Step 1		
Electricity Consumption	Motor system type	Motor type
Motor count	Pumping	AC
Motor size	Compressed Air	DC
Operating hours	Fan	Electricity Costs
Power factor	Materials handling	Usage cost
Nameplate efficiency	Materials processing	Demand charge

Figure 1: Sample information of installed motor system base to collect for Step 1

Survey Execution Method

There are many considerations for the execution of a survey of the energy efficiency of an installed motor system base. In addition to determining the data to be collected, some of the considerations that the designers of the survey need to take into account include identifying the sources for the data and establishing the method for implementing the data collection instrument. For example, the data can be collected at the end-user facility or indirectly through surveying providers of motor system equipment and services, experts in the field, and many other channels. The data collection instrument can be implemented through analysis of existing data sources, remotely through questionnaires, on-site surveys at a facility, or through some combination of all three. The selection of the survey execution method will be based on factors included but not limited to current data availability, desired level of detail and comprehensiveness of the survey, and the availability of time, human, and financial resources for survey implementation. It is anticipated that a field sampling model would need to be developed to obtain credible results with a limited amount of resources

In all likelihood, it would not be feasible to survey all motor systems of interest in a given country or region. A more likely execution model would leverage existing data sources for the installed motor system of interest combined with site surveys and remote data gathering (questionnaires). A representative sample of the facilities in the study region would need to be surveyed based on motor system and facility characteristics within the region of study. Further, decisions will need to be made concerning the relative importance of systems to be surveyed. For example, smaller motor systems (i.e., < 15 kW) or motors that operate very infrequently (i.e. < 2000 hours) can likely be excluded from the survey with minimal loss of accuracy in the analysis for Step 3.

The framework presented here seeks to inform the development of a motor system data collection survey instrument under multiple execution methods:

- Where facilities would be surveyed, either onsite or remotely, the framework will guide the development of the questions and measurements to be made at the facility. Information would be gathered with the assistance of energy managers or operators of the motor driven systems

- Where existing data is leveraged to better understand the energy efficiency of the installed motor systems, the framework is intended to guide database querying and analysis by providing the information to be determined from the data sources.

In all cases, the information identified within the framework is to be collected at the facility level for use in a bottom-up analysis of the regional level of motor system energy efficiency. To support the bottom-up analysis and enable efficient data processing, data should be gathered and/or stored electronically. When applied, the information identified within the tables will need to be tailored depending on the availability of resources to conduct the survey, the relevant existing data, and the overall purpose of the survey.

Tables for Motor System Survey Framework

The developed framework for surveying the energy efficiency of an installed motor system base is presented as a series of tables. Directions for using the series of tables are provided below.

Structure of data collection framework

The categories for the questions within the tables have been developed as part of the work undertaken by McKane and Hasanbeigi [5] to characterize the motor system energy efficiency baseline of several countries/region. For their study, the information needed to define pumping, compressed air, and fan system energy efficiency in several countries/region was developed in consultation with industry experts. The information collected took the form of energy efficiency practices that indicate the energy efficiency of each system.

The tables are organized into five columns as follows:

Characteristics: Lists general characteristics of motor systems with respect to assessing their energy efficiency. These characteristics include system sizing, operations, design, use, and maintenance.

Information Needed: Identifies information regarding energy efficient practices for each *Characteristic*

Purpose: Provides a brief explanation of how the energy efficient practice identified in the *Information Needed* column can help to assess overall system efficiency

Sample questions: Provides sample questions for identifying the pertinent information to assess the level of adoption of the energy efficient practice identified in the *Information Needed* column.

Sample Measurements: Provides sample measurements for collecting the necessary information to answer the respective *Sample Question*. “Qualitative” is used to indicate data that can be collected through interviews of facility personnel.

Use of the survey tables

The framework developed intends to be applicable to a wide variety of execution models and abilities of the survey responders. As such, it recognizes the varying degree of time and resources that can be afforded to collecting data by either the surveyor or the person responding to the survey. Multiple tables are developed each balancing the representativeness of the information collected for assessing motor system energy efficiency and the level of effort necessary to collect the data. Practically, not every question will be answered for each facility. The selection of tables for use by the survey executors will depend on the availability of resources and the goals of the ensuing analysis.

Three series of data tables are constructed:

Table 1: The first table is intended to capture the basic information necessary to assess the general motor system efficiency of a facility. The information collected using Table 1 provides a high level understanding of the motor system energy efficiency of a facility. The data identified in this table can be collected without taking measurements within the facility. Questions in Table 1 are applicable to all motor systems including pumping, compressed air, and fan systems. Table 1 should be used if the time allowed for collecting data for any one facility is less than a half-day.

Table 2 Series: Table 2 Series consists of four separate tables that are intended to be used after gathering the information from Table 1. In addition to better characterizing the general energy efficiency of the motor systems, Table 2 Series begins to assess the energy efficiency of specific motor systems, namely pumping, compressed air, and fans by collecting information on energy efficient practices specific to the system. Table 2 delves deeper into the general motor system characteristics whiles Tables 2a-c provide a framework for better characterizing pumping, compressed air, and fan systems respectively. Table 2 series should be used if the burden associated with completing the survey is less than 1 day.

Table 3 Series: While much of the information in the Table 3 Series can be quite indicative of a motor system's energy efficiency, the questions less critical to assessing energy efficiency as is the information collected in the other tables. In some cases, sample questions from Table 3 may be used as substitute data points for the questions developed in Tables 1 and 2 Series.

Table 1: Basic information to assess general motor system efficiencies of a facility

Characteristic	Information Needed	Purpose	Sample questions	Sample measurements
Sizing	Determine if motor system was sized with energy efficiency as a priority	Motor systems may be sized using priorities other than energy efficient operations and as a result they might be oversized resulting in low energy efficiency	• Was the energy efficiency at typical loads a consideration when sizing the motor system?	• Qualitative
Operations	Frequency of motor system energy efficiency assessments and measures taken as a result of assessment findings	Performing frequent motor system energy efficiency assessments helps to ensure that the system is continually reviewed for energy efficiency opportunities	• Has an energy efficiency assessment of the motor system been conducted?	• Qualitative
			• How frequently are energy efficiency assessments performed on the motor systems?	• Qualitative
			• Have projects identified through assessments been implemented?	• Qualitative
			• Is there a business process (including but not limited to an energy management system) for determining when to re-asses the efficiency of a motor system?	• Qualitative
	Rewind policy	An established policy dictating when to replace a motor rather than	• When motors fail, are they replaced or rewound?	• Qualitative
			• Are there qualifications	• Qualitative

		rewind it can ensure that motor systems operate efficiently in a cost effective manner	guiding the decision to replace or rewind (i.e. minimum motor size)?	
			• If replaced, are motors replaced with the most energy efficient available motor in the motor class (i.e. Premium Efficiency in the US, IE3 in the EU)?	• Qualitative
			• If replaced with a spare motor, is the spare motor capacity typically matched to the system demand needs?	• Qualitative
Design	Use of energy efficient motors in all systems	Using the most efficient motor for a purpose will help achieve maximum possible motor system efficiency	• Is energy efficiency rating a top priority when purchasing motors for the facility?	• Qualitative
			• What percentage of motors are the most energy efficient available for their class and purpose (i.e. NEMA Premium Efficiency, IEC IE3)	• Qualitative
	Determine the age of the motor driven system	Older motor systems may not take advantage of new technologies. Wear and tear on older motor systems may lower efficiency. Older systems may no longer match current process needs.	• When was the current motor system designed and installed?	• Qualitative
	Determine if the facility has designed their motor system to operate efficiently if frequently operating at low partial loads	Motor systems operate inefficiently under partial loads. For motor systems operating below a certain load factor, system efficiencies can begin to decline	• When/where applicable, are VSD technologies employed to meet partial loads?	• Qualitative
			• Are multi-sized motor systems used to meet operations with highly variable system demands?	• Qualitative
	Determine if motor shaft work is being efficiently transmitted throughout the	While the motor may operate efficiently, losses can occur during the transmission of the motor shaft work to	• What type of power transmission system is used in the motor system?	• Qualitative

	motor system	the system. These losses can be lessened through proper selection and maintenance of transmissions.		
Maintenance	Frequency and elements of maintenance program	Performing regular maintenance is essential to maintaining the energy efficiency of a motor system. A predictive maintenance program can increase system life and sustain energy efficient performance	• Is there a regular predictive maintenance program or is maintenance reactive to problems and breakdowns?	• Qualitative
			• How often are motor systems inspected?	• Qualitative
			• What aspects (e.g., belts, bearings, shaft alignment, lubrication, cleanliness, etc.) of the motor system are focused on during regular maintenance? Does the maintenance program extend beyond the motor to include the system as well?	• Qualitative
			• Are transmission systems maintained periodically (belt tightening, alignment, lubrication, etc.)?	• Qualitative

Table 2: Assessing specific motor system efficiencies in a facility – general questions

Characteristic	Information needed	Purpose	Sample questions	Sample measurements
Operations	Load profile	Motor systems operating at low part loads will operate inefficiently. Frequent operation at low part loads, as indicated by measuring the load profile, is an indicator of low system efficiency.	• What is the process and equipment load profile (i.e., profile of operating hours at various percent of full load power)?	See tables 2a - 2c *Note: Single day measurements of loads may not result in understanding typical load profiles. For a single day survey, measurements should be combined with qualitative questions to better develop an accurate load profile*
Design	Use of multiple motor systems to meet process needs	There are many advantages to using multiple motor systems to meet process needs including greater opportunity to meet process loads while running equipment at full load, but if not appropriately	• Are motor driven equipment sequenced to ensure efficient operations across all loads while also meeting process demands?	• Qualitative • Slip or kWh measurement to determine load
			• Are trim/back-up motor driven equipment fitted with VSDs if	• Qualitative

		coordinated and used multiple motor systems can operate inefficiently	applicable?	
			• How often and at what load are trim/back-up motor driven equipment used?	• On/off meters to determine operating hours of motor systems • Slip or kWh measurement to determine load

Table 2a: Assessing specific motor system efficiencies in a facility – pumping systems

Characteristic	Information needed	Purpose	Sample questions	Sample measurements
Sizing	Current pumping system size	Improperly sized pumping systems can often operate inefficiently	• Is the current pumping system sized to the current system demand?	• Qualitative • Pump curve • System curve
			• What are the load requirements for the process?	• Qualitative
			• What is the pump size?	• Qualitative • From nameplate
Operations	Load profile	Pumping systems operating at low part loads will operate inefficiently. Frequent operation at low part loads is an indicator of low system efficiency.	• What are the equipment load profiles, including those of back-up equipment?	• Continuous kWh measurement to determine pump power consumption • Qualitative
	Determine if appropriate pump type is selected for the application	Positive displacement and centrifugal pumps are better suited for certain applications than others. Improper pump selection can lead to poor system performance	• Is the appropriate pump (positive displacement or centrifugal) selected for the current application	• Qualitative

Table 2b: Assessing specific motor system efficiencies in a facility – compressed air systems

Characteristic	Information needed	Purpose	Sample questions	Sample measurements
Sizing	Current compressed air system size	Improperly sized compressed air systems can often operate inefficiently	• Do compressors frequently operate in part-load, unloaded (standby), or blow-off mode?	• Qualitative

Operations	Load profile	Several compressors operating at part loads wastes energy; Frequent operation at low part loads is an indicator of low system efficiency	• What are the equipment load profiles, including those of back-up equipment?	• Continuous kWh measurement to determine pump power consumption • System pressure • Qualitative
	Determine if air is properly filtered and dried before use	Neglected maintenance of dryers and filters, can lead to early failure of a system as well as reduced efficiency	• Are filters cleaned and replaced as recommended by the manufacturer? • Are dryers adequately maintained to ensure air is dried to required pressure dew point?	• Qualitative • Pressure dew point
Maintenance	Determine if the facility has a compressed air leak maintenance program	Compressed air leaks can represent a significant system loss	• How are leaks identified within the facility?	• Qualitative • Ultrasonic leak detection instruments • System leak test
Compressed air use	Determine if compressed air is the best choice for meeting a particular need	Often cost effective alternatives to using compressed air are available, such as blowers, fans, or mechanical devices	• Can a blower be used for any of the current compressed air applications? • Is compressed air used for personal cooling? • Is oil-free air used in applications that do not require oil-free air?	• Qualitative
	Compressed air system efficiency is optimized across all process demand loads	For processes that require variations in process demand either over time or across different applications occurring concurrently, a system should be designed to best meet all process loads as efficiently as possible	• Can the system respond efficiently to variable loads (e.g., use of VSDs, sequencing) • Are receiving tanks used? • Are compressors left on idle?	• Qualitative • On/off meters to determine operating hours of compressors • kWh to determine compressor power consumption • System pressure

Table 2c: Assessing efficiency of specific motor system efficiencies in a facility – fan systems

Characteristic	Information needed	Purpose	Sample questions	Sample measurements
Sizing	Current motor	Improperly sized motor driven systems can often operate	• Is the current motor system sized to the current process?	• Qualitative • Fan curve • System

	system size	inefficiently		curve
			• What are the load requirements for the process?	• Qualitative
			• What is the fan system size?	• Qualitative
Operations	Determine if the fan systems operates in an appropriate environment	Particular fans are better suited for a particular application. Matching fan type and location can increase fan system life and efficiency	• Is the appropriate fan selected (i.e. radial for high particulate applications) for the appropriate use?	• Qualitative
	Load profile	Fan systems operating at low part loads will operate inefficiently. Frequent operation at low part loads is an indicator of low system efficiency.	• What are equipment load profiles, including those of back-up equipment?	• Continuous kWh measure-ment to determine fan power consumptio n • Qualitative
Maintenance	Determine if leaks are present in ducting	Losses in the ducting system can add avoidable loads on the fan system	• Are ducts tested for leaks? • Are leaks remedied upon discovery?	• Qualitative

Table 3: Additional assessment of specific motor system efficiencies in a facility – general questions

Characteristic	Information needed	Purpose	Sample questions	Sample measurements
Design	Use of multiple motor systems to meet process needs	There are many advantages to using multiple motor systems including greater opportunity to meet process loads while running equipment at full load, but if not appropriately coordinated and used one motor system may experience unequal wear and tear.	• Are measures taken to ensure even usage on similar size and purpose (i.e. periodic rotating of lead and lag pumps/ lag compressors)?	• Qualitative

Table 3a: Additional assessment of specific motor system efficiencies in a facility – pumping systems

Characteristic	Information needed	Purpose	Sample questions	Sample measurements
Design	Current pump system size	Operating at the Best Efficiency Point as frequently as possible optimizes pump system efficiency	• Was the pump selected to operate at the Best Efficiency Point during typical usage?	• Pump curve • System Curve • Qualitative
	Use of bypasses	Bypasses are the least efficient method of reducing flow	• How often are bypasses used to handle excess	• Qualitative

			flow?	
	Use of throttles	While more efficient than bypasses, throttling pumps does not take advantage of the natural reduction in power consumption per the affinity laws	• How often are throttles used in periods of excess flow? • Are throttles preferred over bypasses?	• Qualitative
	Use of mechanical couples	Mechanical couples can offer more energy costs savings compared to throttles, but less than achievable with VSDs.	• Are mechanical couples used for flow control?	• Qualitative
	Use of booster pumps	Booster pumps can meet high loads, allowing for main pump system size to be reduced and operated at full load more frequently	• Are booster pumps used for high demand equipment/ processes?	• Qualitative

Table 3b: Additional assessment of specific motor system efficiencies in a facility – compressed air systems

Characteristic	Information needed	Purpose	Sample questions	Sample measurements
Design	Use of dedicated compressors	Dedicated compressors for processes that require higher pressures than the balance of facility operations can lower overall energy consumption for compressed air systems	• Are dedicated compressors used for meeting isolated high pressure loads?	• Qualitative
Compressed air operating condition	Compressed air system efficiency is optimized across all process demand loads	For processes that require variations in process demand across different applications occurring concurrently, a system should be designed to best meet all process loads as efficiently as possible	• Are start/stop controls used? • Are engineered nozzles used? • Are there many pressure-reducing-valves onsite? If so, what is the pressure drop across the PRVs?	• Qualitative • On/off meters to determine operating hours of compressors • kWh to determine compressor power consumption • System pressure

Table 3c: Additional assessment of specific motor system efficiencies in a facility – fan systems

Characteristic	Information needed	Purpose	Sample questions	Sample measurements
Operations	Determine if fan system is operated efficiently across all loads	While fan systems are generally sized to a particular load, measures can be taken to ensure high efficiency across varying loads	• If axial fan, are controllable pitch fans used to meet variable air flow requirements?	• Qualitative
	Use of	Extensive use of dampers	• Are dampers or	• Qualitative

	dampers and bypasses	and bypasses can be indicators of poor fan system efficiency. More efficient options may exist for meeting variable loads.	bypasses used? • If so, to what extent?	
	Fan inlet	Ensuring uniformity of air flow prior to the inlet can increase fan efficiency	• Is there sufficient spacing or are airflow straighteners used to correct flow at inlet?	• Distance between fan and inlet
Design	Current fan system size	Operating at the Best Efficiency Point as frequently as possible optimizes fan system efficiency	• Was the fan selected to operate at the Best Efficiency Point during typical usage?	• Fan curve • System Curve • Qualitative
	Use of multiple fans to meet process needs	There are many advantages to using multiple fans including greater opportunity to meet process loads while running equipment at full load	• Are loads met by multiple fans? If not, can multiple smaller fans meet the loads satisfied by a large fan?	• On/off meters to determine operating hours of fans • kWh or slip to determine load

Conclusion

The common framework presented in this paper supports an assessment of the motor system efficiency in a given region. It provides a building block for developing a survey that collects the necessary data to characterize motor system efficiency, particularly for pumping, compressed air, and fan systems, under a variety of execution models. Using the data from the survey, bottom-up assessment models of the energy efficiency of a region's motor systems can be created. Such detailed assessments can inform policy makers on the energy saving potentials, the measures and technologies that can be adopted in their region, and the cost of their adoption. This will foster the design of more effective and cost-efficient programs for improving motor system efficiencies.

The framework presented can serve to initiate a dialogue regarding the appropriate data to collect when scoping the energy efficiency of an installed motor system base. By reaching a consensus among motor system experts on the framework, surveys conducted independent of each other can be analyzed together to build a more accurate profile of global motor system efficiency.

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References

[1] de Almeida, A.T.; Fonseca, P.; Bertoldi, P., 2003. Energy-efficient motor systems in the industrial and in the services sectors in the European Union: characterisation, potentials, barriers and policies. Energy 28 (2003) 673–690

[2] Fraunhofer ISI, 2009. Study on the Energy Savings Potentials in EU Member States, Candidate Countries and EEA Countries-Final Report.

[3] IEA, 2007. Tracking Industrial Energy Efficiency and CO2 Emissions. Available at: http://www.iea.org/w/bookshop/add.aspx?id=298

[4] McKane, A. and Hasanbeigi, A. 2011. Motor System Energy Efficiency Supply Curves: A Methodology for Assessing the Energy Efficiency Potential of Industrial Motor Systems. Energy Policy 39 (2011) 6595–6607

[5] McKane, A. and Hasanbeigi, A. 2010. Motor System Efficiency Supply Curves. United Nations Industrial Development Organization (UNIDO).

[6] McKane, A.; Price, L.; de la Rue du Can, S., 2008. Policies for Promoting Industrial Energy Efficiency in Developing Countries and Transition Economies, published as an e-book by the United Nations Industrial Development Organization, May 2008, Vienna, Austria http://www.unido.org/index.php?id=o71852. LBNL- 63134

[7] McKinsey & Company, (2008). Greenhouse Gas Abatement Cost Curves. Available at: http://www.mckinsey.com/clientservice/ccsi/Costcurves.asp

[8] US DOE, 2002. United States Industrial Electric Motor Systems Market Opportunities Assessment. Available at: www1.eere.energy.gov/industry/bestpractices/pdfs/mtrmkt.pdf

[9] IEA, 2011. Energy Efficiency Policy Opportunities for Electric Motor-Driven Systems. Available at: https://www.iea.org/publications/freepublications/publication/EE_for_ElectricSystems.pdf