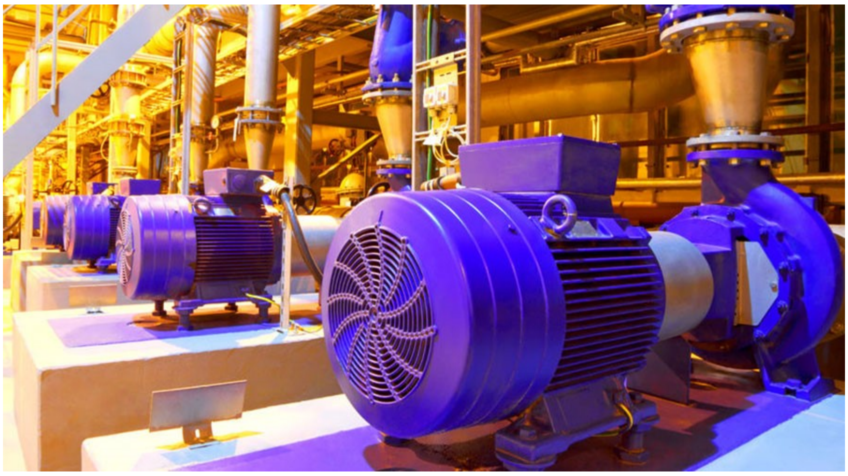
Induction Motor Energy Efficiency Assessment and MEPS Proposition for Ethiopian Market



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EXECUTIVE SUMMARY

Electric motor systems consume about 75% of electricity demand in industry, the largest proportion of motor electricity consumption being by the mid-size induction motors with output power of 0.75 kW to 375 kW.

Electric motors in Ethiopian industries have long years of service, more than 50 years in some factories, most of them are refurbished, have been repaired and rewound many times. Hence, the motors are energy-intensive and contribute to the bulk of the electrical energy consumption and power demand in the country. The energy efficiency of electric motors in Ethiopian factories and commercial businesses is low. The low efficiency of electric motors affected the electric power supply infrastructure by demanding high power, overloading and effecting frequent power interruptions, outages and voltage drops.

The purpose of the energy efficiency assessment study and Minimum Energy Performance Standard (MEPS) proposition was to estimate the number of induction electric motors, and efficiency level of imported and existing motors in the country; assess the magnitude of the losses imposed and the impact on power distribution, propose the MEPS for Ethiopian Market and develop a business model for the implementation of energy efficiency improvement program. The study was conducted through collecting data at sample industrial sector factories and commercial businesses (Milling houses), electric motor importers, maintenance service providers and government institutions. Data analysis and Impact assessment has been conducted to determine the impact of setting the MEPS to higher values on industries, commercial businesses and at national level.

The number of Induction electric motors ranging from 0.75kW to 375kW in existing factories and milling houses in the country is determined to be 126,912. The quantity and IEC efficiency classes of the installed motors in the country is assessed to be IE0 (below standard efficiency) - 82.16%, IE1 - 3.56%, IE2-10.82%, IE3 - 3.39% and IE4 - 0.06%. The energy consumption and peak power demand share of electric motors in Ethiopia is estimated to be 4,044.36 GWh/yr and 919 MW respectively in the year 2018. There are estimated average import of 21,000 motors per year in the years 2016 to 2020. Imported motors constitute 86.6% - IE0 and 13.4% - IE1 in efficiency. There is a one and half to twofold price difference between same power and country of origin of IE0 and IE1 motors indicating the existence of significant quality differences in the market.

Based on the impact assessment made, IE2 MEPS is proposed as it is the modest MEPS having better simple payback period and medium upfront cost. The Life Cycle Cost analysis indicated that it will cost the end-users an annualized additional cost of Birr 2,254, and energy saving revenue of Birr 8,607 to transition to IE2 motor, which results in Birr 6,353 net revenue per IE2 motor. There will be energy saving of 1,568 kWh/yr (for 3KW motor) to 6,272kWh/yr (for 18.5 kW Motor) per motor, and 415.57 GWh/yr of energy consumption, and peak power demand saving of 98.3 MW at national level, if MEPS is set to IE2. The monetized benefits of IE2 MEPS for energy consumption and power demand charge saving are estimated to be Birr 662.5 Mill/yr and Birr 19.67 Mill/month respectively.

The Revolving fund along with Partial credit Guarantee business model and financing mechanism has been proposed for the implementation of the program which is proposed to take effect, for IE2 MEPS, by mid-2023 on imported motors and beginning of 2022 on new factory installations.

The findings of the assessment showed that there is an urgent need to implement MEPS on electric motors in the county as the efficiency of 82.16% of installed electric motors are below standard efficiency and the current electric motor market is not in a good shape.

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ABBREVIATION AND ACRONYMS

AC	Alternative Current
CIF	Cost, Insurance, and Freight
CoO	Country of Origin
DC	Direct Current
EC	European Commission
E.C	Ethiopian Calendar
ECAE	Ethiopian Conformity Assessment Enterprise
ECC	Ethiopian Customs Commission
EE	Energy Efficiency
EEA	Ethiopian Energy Authority
EEM	Energy Efficient Motor
EEU	Ethiopian Electric Utility
EEP	Ethiopian Electric Power
EISA	Energy Independence and Security Act
EMDs	Electric motor drive systems
EPC	Energy Performance Contract
ES	Ethiopian Standard
ESCO	Energy Service Company
EU	European Union
G.C	Gregorian Calendar
IEA	International Energy Agency
IEC	International Electrotechnical Commission
kW	Kilowatts
LC	Letter of Credit
MEPS	Minimum Efficiency Performance Standard
NEMA	National Electrical Manufacturers' Association
OEM	Original Equipment Manufacturer
PCG	Partial Credit Guarantees
PVoC	Pre-Export Verification of Conformity
UNIDO	United Nations Industrial Development Organization
US	United States
VSD	Variable speed drive

1. INTRODUCTION

1.1. Background

Electric motor systems in industry, buildings, agriculture and transport use estimated more than half of electricity consumed globally. Electric motors are used extensively in various subsectors of industry including chemicals, paper, food, metal and textile, and they account for just over 70% of industrial electricity consumption (IEA, 2016). The consumption of electric motor systems has further increased to account for 75% of electricity demand in industry (IEA, 2019).

The largest proportion of motor electricity consumption is attributable to mid-size motors with output power of 0.75 kW to 375 kW, the alternating current (AC) induction motors being the most frequently used and consuming the most energy. These motors are either sold to original equipment manufacturers (OEMs) and integrated into pre-packaged electromechanical products (such as pumps, fans, compressors, etc.) or sold as stand-alone motors that final customers then integrate into a specific application on site. Such stand-alone motors are produced in large volumes, according to standardized input power and size specifications, with varying channels to market and integration into electromechanical systems. This has a significant impact on the type of barriers to adoption of energy-efficient solutions for Electric motor drive systems (EMDS) and, hence, on the most appropriate policy packages to overcome such barriers.

Motors in the mid-size range are most commonly found in industrial applications, but they are also widely used in commercial applications, infrastructure systems and, less often, in the residential sector. In general, their main applications are mechanical movement, compressors, pumps and fans, which in turn have many types of sub-applications. In electric motor-driven systems, some energy losses occur in the motor itself, but energy losses are greater in the rest of the mechanical system to which the motor is coupled. A typical electromechanical system involves a motor, an electrical control system, a variable-speed drive (VSD) and a mechanical load. The magnitude of energy losses depends on the application and the degree to which an advanced technical solution is used.

The potential exists to cost-effectively improve energy efficiency of motor systems by roughly 20% to 30%, which would reduce total global electricity demand by about 10%. Without policy intervention, many barriers make it difficult or impossible to realize these savings in the current market environment. In unregulated markets, purchasers tend to underinvest in higher-efficiency options and choose electric motor systems with a low first cost. To overcome these barriers, many countries have adopted MEPS for the main class of industrial electric motors. More countries are in the process of developing such requirements (Waide and Brunner, 2011).

To this effect, the Ethiopian Energy Authority had prepared a Project document on Energy efficiency standards and labelling of Electric motors in Ethiopia in 2015 which showed there could be huge power demand reduction and energy savings obtained as a result of the implementation of Energy Efficiency (EE) standard and labeling program. It has been recommended that Ethiopia like other countries shall consider adopting IEC EE and labeling standards as mandatory MEPS and implementation of regulatory and non-regulatory measures (Danas Electrical Engineering, 2015).

In this study an assessment on energy efficiency of induction motors installed, imported to the country and general recommendations drawn from countries that have already implemented the related policy will be employed to set the MEPS based on updated data.

1.2. Objectives and Scope of the Study

1.2.1. Objectives of the study

The objectives of the study are to:

a) Review of similar projects executed at national, regional and international levels regarding MEPS on induction motors, regulations and measures taken.
b) Assess and estimate the number of electric motors and efficiency level of imported and existing medium sized induction electric motors (0.75kW to 375kW) in the country.
c) Assess the magnitude of the losses imposed by the motors and the impact on power distribution.
d) Propose the MEPS for electric motors for Ethiopian Market and,
e) Develop a business model for the implementation of energy efficiency improvement program.

1.2.2. Scope of the study

This study covers the efficiency assessment of three phase Induction motors that have a rated power between 0.75 kW to 375 kW, have a rated voltage up to 1000 V and have either 2, 4 or 6 poles only. It covers motors that are installed and sold in Ethiopia as standalone or attached to a drive and does not cover motors that are completely integrated into a machine that cannot be tested separately from the machine.

2. AN OVERVIEW OF ELECTRIC MOTOR EFFICIENCY

2.1. Electric Motor

Electric motors are responsible for approximately half the world's electrical energy consumption. They are the core element of all motor driven systems in pumps, fans, compressors, transport and process machines, etc. (Figure 2-1). Electric motors can be found in every sector; in the residential, commercial, transport, farming and industrial sector.

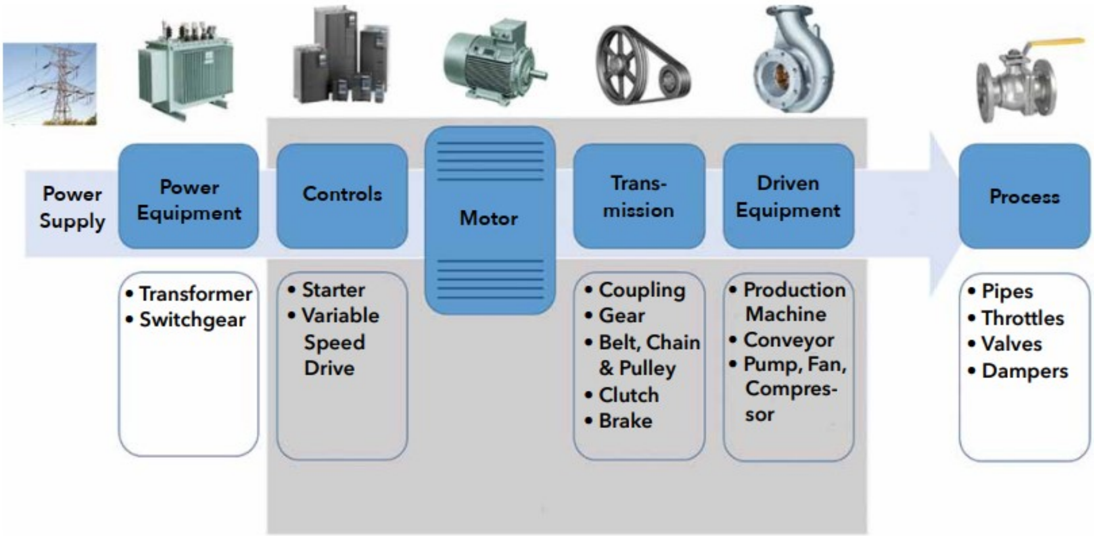


Figure 2-1: Driving unit and its components (TopMotors, 2019)

Electric Motors convert electrical energy into mechanical energy by the interaction between the magnetic fields set up in the stator and rotor windings. All motor types have the same four operating components: stator (stationary windings), rotor (rotating windings), bearings, and frame (enclosure).

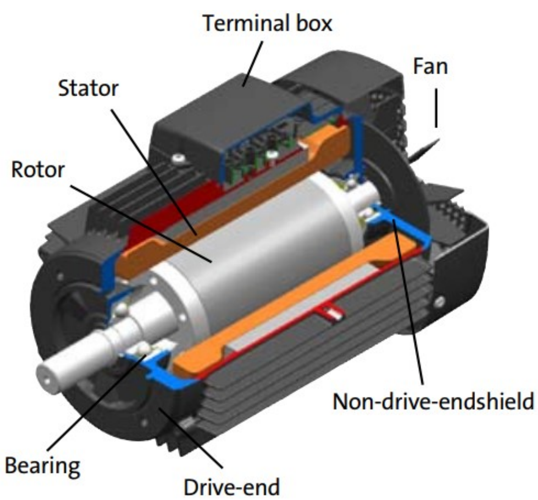


Figure 2-2: Cross section of an electric motor (Grundfos Motors, 2004)

Based on the power supply, electric motors fall into two classes: Alternating Current (AC) or Direct Current (DC). Industrial electric motors can be broadly classified as induction motors, direct current motors or synchronous motors.

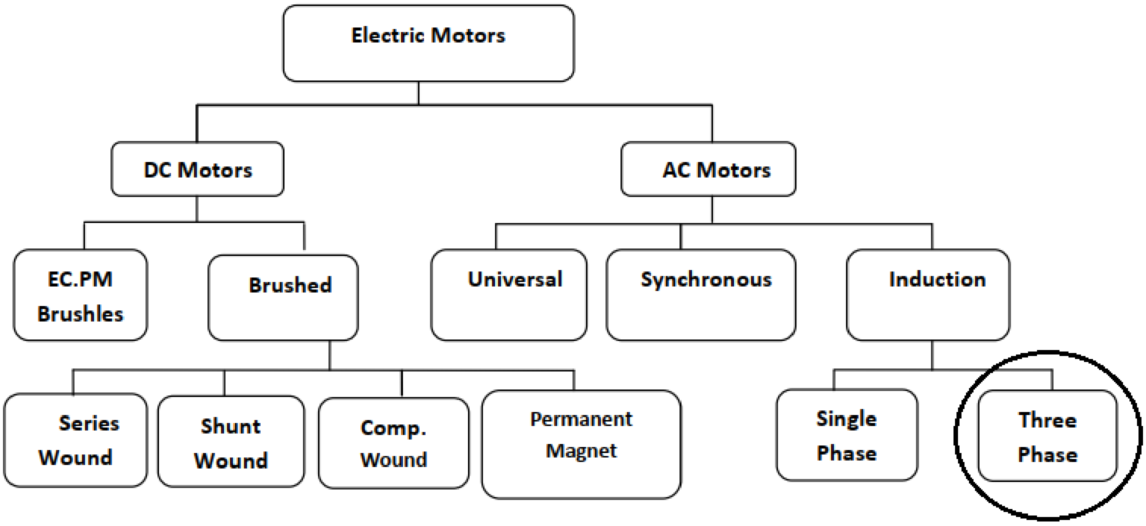


Figure 2-3: Classification of Electric Motors (Waide and Brunner, 2011)

Electric motor energy efficiency is the ratio of its useful power output to its total power input and is usually expressed in percentage, as

$$\eta = \frac{0.7457 \times \mathrm{hp} \times \mathrm{Load}}{P_{in}}$$

Where:

η	Efficiency as operated in %
hp	Nameplate rated horsepower
Load	Output power as a % of rated power
P_{in}	Three-phase power in kW

Most analyses of motor energy conservation savings assume that the existing motor is operating at its nameplate efficiency. This assumption is reasonable above the 50% load point as motor efficiencies generally peak at around 3/4 load with performance at 50% load almost identical to that at full load. Larger horsepower motors exhibit a relatively flat efficiency curve down to 25% of full load.

According to the standards, there are two major ways of efficiency determination of the induction motors: direct and indirect. The usage of the direct method means that the motor efficiency is determined from the direct measurements of the input electrical power P_{in} and output mechanical power P_{out}. The direct method is generally thought as less accurate as it applies the direct measurement of input and output values of power:

$$\eta = \frac{P_{out}}{P_{in}}$$

In the indirect method, the input power and output power may also be measured and used to determine the constituent components of the losses in the motor. This process is known as segregation or summation of the losses. The efficiency is determined from the total losses, P_{loss}, by equation:

$$\eta = \frac{P_{in} - P_{loss}}{P_{in}}$$

The efficiency determination methods that are based on loss segregation are known to be more accurate. There are five categories of losses in the motor: P_{core} is the core losses, P_{fw} is the friction and windage losses, P_{stator} is the stator copper losses, P_{rotor} is the rotor copper losses, and P_{stray} is the stray load losses, the distribution of the losses is given on Figure 2-4 (P_{ag} – air-gap power, P_m –mechanical power).

The core losses and the friction and windage losses are known as constant losses because they are considered independent of the value of the load. Core losses represent the amount of energy required to the core magnetization process. The friction and windage losses appear due to bearing friction and air resistance, which is primarily caused by the cooling fan.

The other losses are considered load dependent and therefore variable with load. The stator and the rotor copper losses occur due to current flow through the resistance of the stator and the rotor windings. The fixed losses could be determined from no-load tests at variable voltage and the conventional load losses are determined from load tests as described in various literatures.

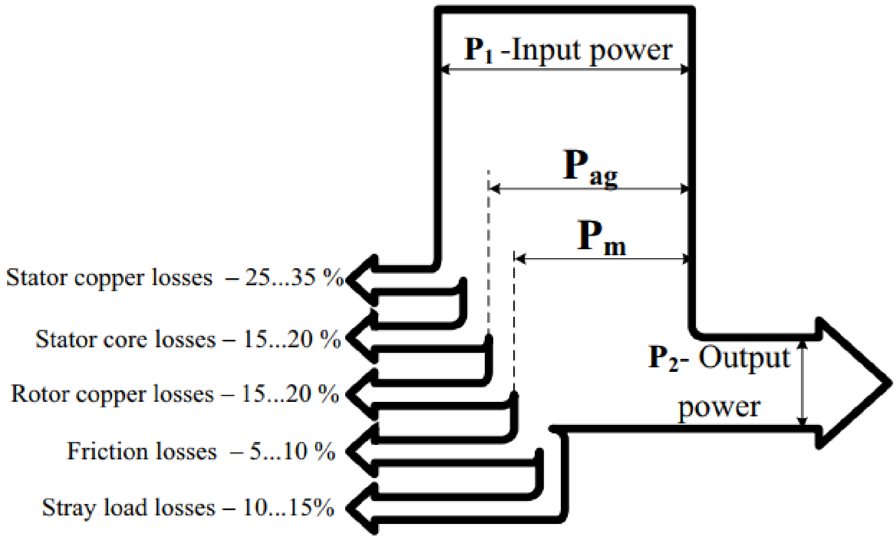


Figure 2-4: Distribution of the losses in the induction motors (Tsybikov, Beyerleyn and Tyuteva, 2016)

2.2. Energy Efficient Electric Motors

Energy-efficient motors (EEM) are the ones in which design improvements are incorporated specifically to increase operating efficiency over motors of standard design. Design improvements focus on reducing intrinsic motor losses. Improvements include the use of lower-loss silicon steel, a longer core (to increase active material), thicker wires (to reduce resistance), thinner laminations, smaller air gap between stator and rotor, copper instead of aluminum bars in the rotor, superior bearings and a smaller fan, etc.

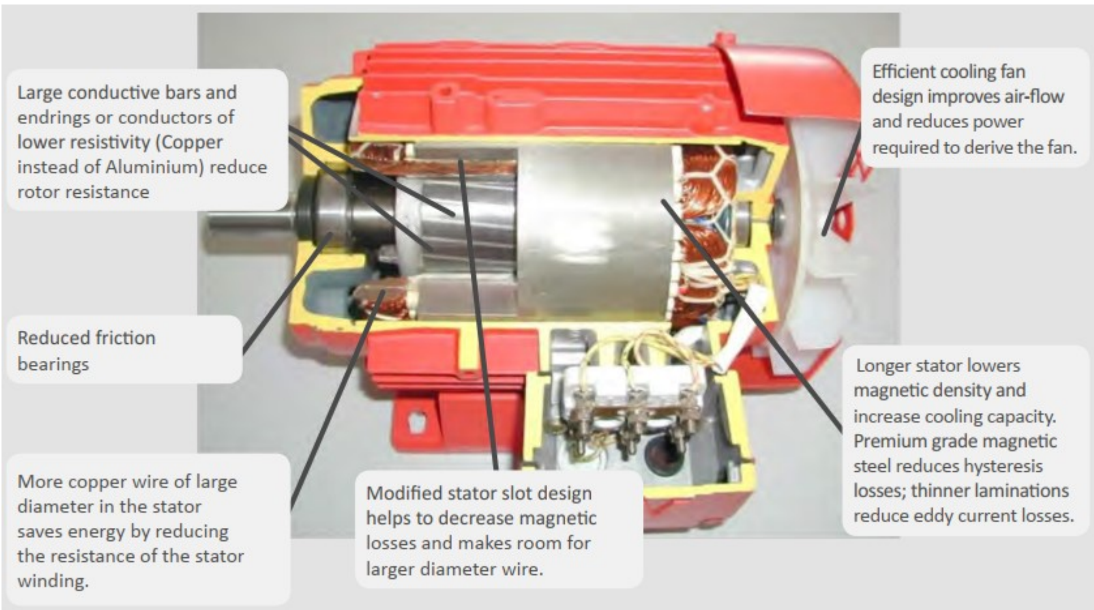


Figure 2-5: Energy Efficient Electric Motor Features (UNIDO, 2018)

A summary of energy efficiency improvements in EEMs is given in Table 2-1.

Table 2-1: Summary of energy improvement in EEM

No.	Power Loss Area	Efficiency Improvement
1	Iron	Use of thinner gauge, lower loss core steel reduces eddy current losses. Longer core adds more steel to the design, which reduces losses due to lower operating flux densities.
2	Stator I^2R	Use of more copper and larger conductors increases cross sectional area of stator windings. This lowers resistance (R) of the windings and reduces losses due to current flow (I).
3	Rotor I^2R	Use of larger rotor conductor bars increases size of cross section, lowering conductor resistance (R) and losses due to current flow (I).
4	Friction and Windage	Use of low loss fan design reduces losses due to air movement.
5	Stray Load Loss	Use of optimized design and strict quality control procedures minimizes stray load losses.

The International Electro Technical Commission (IEC) has contributed to the definition of energy-efficient electric motor systems through the internationally relevant test standard IEC 60034-2-1 for electric motors and the IEC 60034-30-1 classification scheme. The IEC energy efficiency classification: IEC 60034-30 in 2012 was based on the advanced efficiency measurement standard in IEC 60034-2-1 and defined the new IE code with three levels of motor efficiency classification: IE1 Standard Efficiency, IE2 High Efficiency and IE3 Premium Efficiency. It is applicable for electric motors operated on a grid frequency of 50 Hz or 60 Hz, with an output power ranging from 0.75 kW up to 375 kW, and with 2-, 4- and 6-poles. In its revised edition IEC 60034-30-1, enlarges the scope to smaller motors with 0.12 kW up to larger motors with 1000 kW; it also includes 8-pole motors and defines now also the IE4 Super Premium Efficiency level.

Figure 2-6 shows the efficiency improvement of electric motors with higher IE ratings. IE1 is defined as a ‘standard motor’. From IE2 onwards, motors are defined as ‘high efficiency’. From this figure, we can see that the difference between IE-classes efficiency level is larger for smaller motors. If an IE1, 1 kW motor is replaced by IE3 motor, the gain in efficiency is about 13%. For a 10 kW motor, this would be about 6%. Note that in reality the efficiency of, for example, IE1 lies between the curve that represents IE1 until IE2 has been reached. So, the average efficiency for IE1 electric motors will be somewhere halfway between IE1 and IE2. The same counts for the other IE classes.

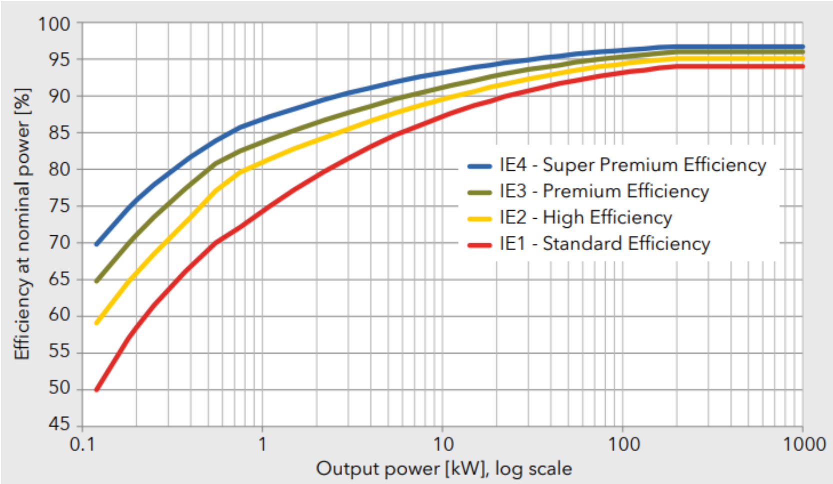


Figure 2-6: Classes of efficiency of motors according to IEC 60034-30-1, 4 pole, 50 Hz

2.3. Minimum Energy Performance Standard

Energy-efficiency standards are procedures and regulations that prescribe the energy performance of manufactured products, sometimes prohibiting the sale of products that are less efficient than a minimum level. “Standards” encompasses two possible meanings:

a) Well-defined protocols (or laboratory test procedures) by which to obtain a sufficiently accurate estimate of the energy performance of a product in the way it is typically used, or at least a relative ranking of its energy performance compared to that of other models; and
b) Target limits on energy performance (usually maximum use or minimum efficiency) based on a specified test protocol.

Minimum energy performance standards prescribe minimum efficiencies (or maximum energy consumption) that manufacturers must achieve specifying the energy performance but not the technology or design details of the product. Ability to establish and enforce MEPS, however, depends:

a) On a standardized testing and
b) Classification system for motor efficiency (CLASP, 2005).

Minimum Energy Performance Standards specify the required efficiency levels for electric motors used in residential, commercial, and industrial applications. MEPS are implemented to increase energy efficiency, promote energy savings, and reduce operating costs for electric motors. There are global efforts to harmonize electric motor efficiency classifications.

MEPS vary among countries and regions, based on local markets, technical needs, and product availability. Although being one of the leading motor specifications in the world, IEC 60034 does not set MEPS efficiency levels other than specifying the efficiency classes and the test methods to prove the actual efficiency of motors.

2.4. Timeline of Global Mandatory MEPS for Electric Motors

The first country to introduce ambitious MEPS for electric motors was the USA. MEPS were passed into law as early as 1992, but it was not until 1997 when the standards were applied. This gave motor manufacturers a five-year period to adapt to the standards and redesign their motors. This so-called Energy Policy Act of 1992 (EPAct 92) standard is comparable to the international IE2 definition from the IEC. More ambitious MEPS were discussed in 2007 and were implemented as law in December 2010. The USA, together with Canada, are the first countries to base MEPS on IE3 (Boteler, 2009, as cited in Tobias and Wolfgang, 2012)

Figure 2-7 provides an overview of the implementation dates of the different standards by country. It should be noted that the implemented standards do not fully correspond to the IEC testing and classification standards in most cases. For example, the standard in Taiwan, which was introduced in 2003, is considerably higher than IE1 for smaller motors and relatively close to IE1 for larger motors. Large developing countries like Brazil, Mexico and China have also implemented MEPS. In practice, countries can go over time through stages of IE-classes when introducing MEPS.

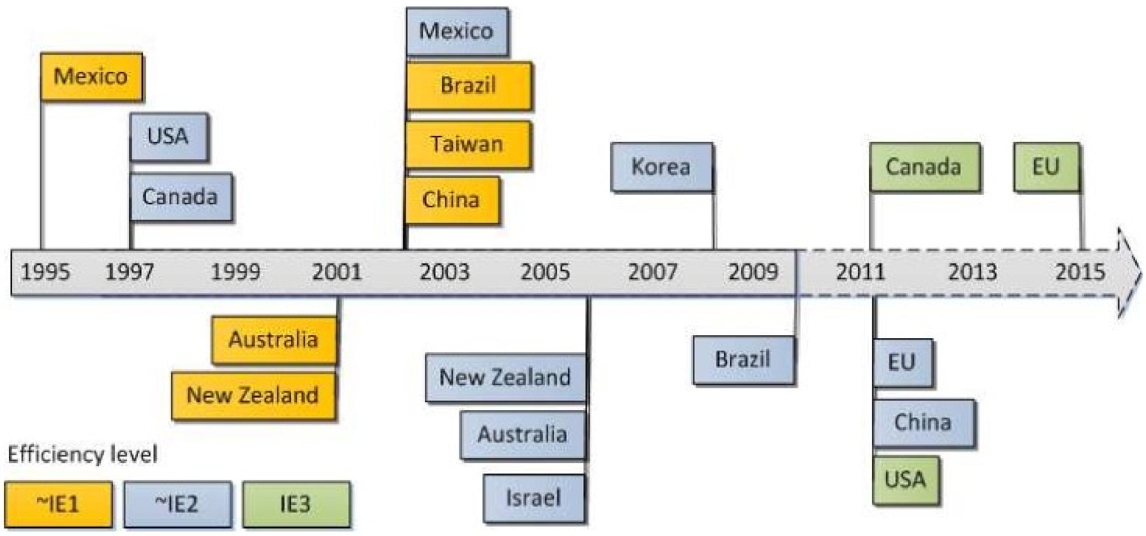


Figure 2-7: Implementation of mandatory MEPS for electric motors worldwide (Almeida et al., 2008; Brunner et al., 2009, as cited in Tobias and Wolfgang, 2012)

2.5. Electric Motors Policy Focus

a) Estimated share of global electricity demand by end-use

IEA estimated share of electric motors in 2006 is about 46% of all end-use electricity consumption globally. With a share of 64%, industry consumes the most power for electric motorized applications, the next most important sectors being the commercial sector (accounting for 20% of all motor-electricity consumption) and the residential sector (accounting for 13%).

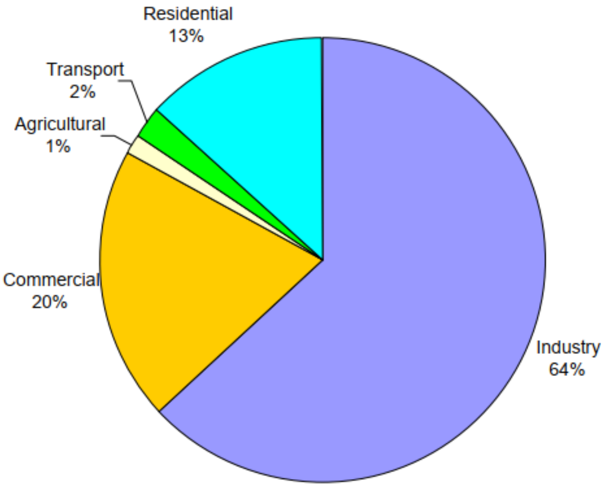


Figure 2-8: Electric motor energy use by sector (Waide and Brunner, 2011)

b) Policy focus on medium sized electric motors

Motors range from a few watts up to many hundreds of kilowatts in terms of power output, though almost all policy debates have focused on mass produced (medium-sized) motors which consume the most power and offer the greatest saving opportunity. The large amount of energy used by medium-sized electric motor systems explains proposed policy focuses.

Table 2-2: Size, percentage of quantity in use and percentage of energy consumption of electric motors, generally world-wide, adopted from (Waide and Brunner, 2011; Sipma, Cameron and Ambarita, 2015)

Size of electric motor	Small (<0.75 kW)	Medium (0.75 kW to 375 kW)	Large (>375 kW)
% Of quantity in use	90%	10%	0.03%
% Electricity consumption	9%	68%	23%
Priority for this project?	-	High priority	-
Strategy	-	MEPS	-

Small motors with a power rating of 10 W to 750 W account for about 90% of all electric motors, but these motors use only about 9% of the total electricity consumed by electric motors. They are used in small appliances, to drive pumps and fans.

These motors are often single-phase and are induction, shaded-pole, or shunt-wound motor types, which are typically custom made in large series to be integrated into specific machines or appliances. They often operate at, or at less than, mains voltage.

In contrast, medium motors in the power range 0.75 W to 375 kW account for 68% of the electricity used by electric motors. For the most part, these are asynchronous AC induction motors of 2, 4, 6 or 8 poles, but some special motors (such as direct current, permanent magnet, switched reluctance, stepper and servo motors) are poly-phase motors operating at voltages of 200 V to 1 000 V. They are manufactured in large series, usually with short delivery lead times and according to standard specifications that can be ordered from catalogues. These motors account for about 10% of all motors sold and are used with pumps, fans, compressors and conveyors, primarily for industrial handling and processing applications.

Large motors, defined as electric motors with a rated power of from 375kW up to 100MW, are poly-phase, high voltage motors operating in the 1kV to 20kV range. They are custom designed; some are of the synchronous type and are generally assembled on site and used in industrial and infrastructural applications. They account for only about 0.03% of the stock of all electric motors, but account for about 23% of the electricity used by electric motors.

From Figure 2-9 and Table 2-2, we see that the medium size motors only make up 10% of the total quantity, but are responsible for 68% of total electricity consumption. These are the electric motors that often have the focus of a project like ours.

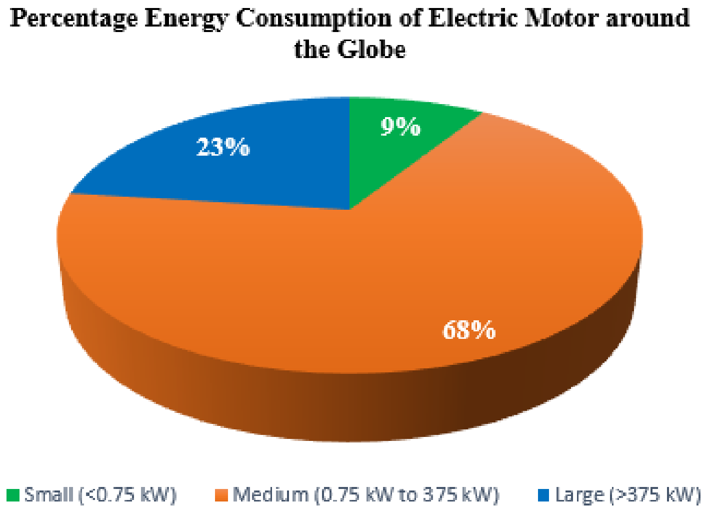


Figure 2-9: Percentage energy consumption of electric motor around the globe, adopted from (Waide and Brunner, 2011; Sipma, Cameron and Ambarita, 2015)

3. METHODOLOGY AND TECHNICAL APPROACHES

3.1. Types of Relevant Data Collected

The data collection team collected the following relevant information from all the entities of the survey.

- The survey included types, country of origin, power rating, cost, market share, import growth and IEC standard classes of imported and electric motors installed at factories.
- The levels of rewinding, repair and maintenance practice on motors.
- Energy consumption by tariff group, losses of the country.

The relevant data collected from industrial sub-sectors is indicated in Table 3-1.

Table 3-1: The relevant data collected from industrial sub-sectors

Facility level observation • Year of Establishment • Location of facility • Total electric consumption and costs
Department level observation • Operating schedule
Motor data • Size (KW) • Motor age • Nameplate speed • Nameplate amps • Nameplate power factor • Nameplate efficiency • Voltage rating • Manufacturer/ Model • IEC Standard class • Country of origin • Annual operating time • Number of times motor rewound

3.2. Survey Methodology

3.2.1. Target population and study area

The target population to assess and define the quantity and energy efficiency of existing and newly imported induction electric motor are end-users, importers and maintenance service providers of electric motors in the country. These are factories under the different industrial sub-sectors, grain milling houses, maintenance service providers, and importers. The sampled industrial electric motor end-users are located in Addis Ababa and other areas in Oromia, Amhara, Afar and Southern Nations Nationalities and People (SNNP) Region. The number of establishments of grain milling houses in the country was collected from the Central Statistics Agency of Ethiopia. But, for the survey of number of electric motors installed in the grain milling houses, the study area was limited to Addis Ababa, Bahir Dar, Adama and Hawassa. The importers and most of maintenance service providers of electric motors are located in Addis Ababa.

3.2.2. Sample size determination

The purpose of determining the sample size is to ascertain a representative number of induction electric motors in the country. The induction electric motors in the country are aggregated in twenty five major industry and engineering sub-sectors namely: sugar factory, cement factory, textile factory, tire factory, ceramics factory, marble and granite factory, glass and bottle factory, furniture and wood products factory, fertilizer and petrochemical factory, beverage factory, soft drink factory, bottled water factory, soap and detergent factory, paint and chemical factory, elevator and escalator industry, leather processing factory, pharmaceutical factory, flour grinding mills, EGA sheet factory, pulp and paper factory, plastic factory, metal factory, water supply system, edible oil factory, and apparel and garment. The type and quantity of motors in factories under the same industrial sub-sectors are similar, except for individual variations due to the ages and sizes of the factories. Considering this, the consulting firm surveyed forty-three industry and engineering establishment considering one old and one new establishment from the twenty-five major industry and engineering sub-sectors.

In addition to the industry and engineering sub-sectors, grain milling houses are major induction electric motor end-users. Regarding the number of establishments, the consulting firm acquired a raw data from Central Statistics Agency's report on small-scale manufacturing industry survey in the 2010 Ethiopian fiscal year.

The consulting firm surveyed forty representative milling houses in the country to estimate the number of electric motors installed in each milling house. The major electric motor importers and maintenance service are very small in number; hence eight importers and four maintenance service providers were surveyed to achieve the objective of the study.

3.2.3. Sampling frame

The sampling frame for the study was constructed based on the pieces of information collected from

- Ethiopian Ministry of Trade and Industry
- Ethiopian Investment Commission
- Central Statistics Agency of Ethiopia
- Regional bureaus of trade and industry
- Addis Ababa city administration trade and industry development bureau
- Addis Ababa Water and Sewerage Authority

Based on the above sampling frames, about seven hundred fifty establishments were considered as a sampling frame for conducting Energy Efficiency Assessment on Induction Electric Motors in Ethiopian Market study and were ready for use.

3.2.4. Sampling technique

For electric motors installed at factories the study employed a non-probabilistic quota sampling technique. In order to do such a sampling scheme, the sampling frame was grouped into twenty-five major industrial sub-sectors. Out of which, two representative factories were sampled based on the reason that the electric motors in the same industrial sub-sectors either old or new are rated and assigned to drives based on the specific motor drive and production requirement of the industrial-sub-sectors. Among the same industrial sub-sector, the factory establishment dates vary, there are old factories as well as recently commissioned ones. Therefore, to deal with this situation and to obtain the eligible number of factories for the study, one old and one new factory were sampled from the same industrial sub-sector.

An utmost care was undertaken to collect relevant data from electric motor importers and maintenance service providers. The first necessary step was carefully collecting a fresh list of these established firms from the Addis Ababa city administration trade and industry development bureau. However, the fresh list presented all-electric and electrical appliance importers and maintenance service providers and it was difficult to draw samples of electric motor importers and maintenance service providers only. To properly address this issue and to get the eligible number of electric motor importers and maintenance service providers, the consulting firm interviewed one renowned electric motor importer and one renowned maintenance service provider to refine the list of major importers and major maintenance service providers in the country.

A considerable number of grain mill service providers in the country were surveyed by the Central Statistics Agency of Ethiopia in the 2010 Ethiopian fiscal year. The consultant acquired this raw data from the agency and surveyed the number of electric motors installed per a single grain mill service in these firms through questionnaires and interview at grain mill motor suppliers.

3.2.5. The sample for the study

The consulting firm collected relevant data from different entities such as factories under different industrial sub-sectors, grain mill service providers, importers and distributors, and maintenance service providers.

a) Industry and Engineering sub-sectors

Taking into account time and resource constraints, and the production structure of the sub sectors, the consulting firm surveyed forty-three sample industrial and engineering establishments in the country.

Table 3-2: Number of sampled industrial sub-sectors

No.	Type of factory	Sampled
1	Sugar factory	2
2	Cement factory	2
3	Textile factory	2
4	Tire factory	1
5	Ceramics Factory	2
6	Marble and granite factory	2

No.	Type of factory	Sampled
7	Glass and bottle factory	2
8	Furniture and wood products factory	1
9	Fertilizer and petrochemical factory	1
10	Beverage factory	2
11	Soft drink factory	2
12	Bottled water factory	2
13	Soap and detergent factory	2
14	Paint and chemical factory	2
15	Elevator and escalator industry	2
16	Leather processing factory	1
17	Pharmaceutical factory	2
18	Flour grinding mills	2
19	EGA sheet factory	1
20	Pulp and paper factory	1
21	Plastic factory	2
22	Metal factory	1
23	Water supply system	3
24	Edible oil factory	2
25	Apparel and Garment	1
Total		**43**

b) Grain mill service

Considering the time allotted for the study and homogeneity of the service provided at the grain mill houses, the consulting firm decided to survey forty representative milling houses in Addis Ababa, Adama, Hawassa and Bahir Dar. These cities were selected considering the size of their population and the penetration of the grain milling service providers.

c) Imports, importers and distributors

Taking into account time constraints, the consulting firm surveyed eight electric motor importers in the country.

d) Electric motor maintenance service providers

In addition to industrial sub-sectors, grain milling houses and importers, the consulting firm surveyed four representative electric motor maintenance service providers in the country.

3.3. Data Collection Approach

The survey collected both primary and secondary data sources to assess and establish induction electric motor efficiency levels in the county.

3.3.1. Primary data

The primary data for this study was collected through field assessment of industrial facilities and grain milling houses. Questionary and interview were made to key stakeholders such as importers, distributors, wholesalers and electric motor maintenance service providers.

3.3.2. Secondary data

The secondary data sources were collected from Ethiopian Custom Commission, relevant literature, scientific articles, official policy documents, reports and proceeding of development organizations, previous studies, study reports, and industrial development strategy.

3.4. Technical Approach

There are basically two technical approaches that could be used to make a best estimate of number of electric motors and the associated energy consumption from the available data sets. These approaches are: a top-down approach and a bottom-up approach (Waide and Brunner, 2011).

3.4.1. Top-down approach

The methodology applied involves estimating all non-motor electricity uses and assuming the residual part of total electricity consumption of the country is that used by electric motors. Explicitly, the approach looks at sector-level electricity use in the country and assumes an average fraction of electric motor usage in each sector.

The country's statistics of electricity production and annual electricity consumption for all end use industry sub-sectors will be estimated first, and information about non-motor electricity consumption will also be estimated. Deducting these figures from total electricity consumption results in an estimate of total electricity use for electric motors in all sectors.

3.4.2. Bottom-up approach

In this approach, the national energy use of electric motors is calculated based on available data and estimates of the average size, efficiency, running hours and load factor of the motor stock, which is then used to calculate electric motor system power demand and efficiency. Electric energy consumption of the country stock of electric motors can be estimated from the bottom-up by multiplying the electric power of the installed motor stock by the number of full- load hours per year.

$$E_m = \sum_{k} n_{r,k} \times P_{m_k} / eta_{p,k} \times h_k \times LF_k$$

Where:

E_m	Electricity use by motors
P_m	Nominal mechanical output power (by k or weighted average over all sizes)
n_r	Running stock of electric motors in installed base
h	Average annual operation time (by k or weighted average over all sizes)
LF	average load factor during operation time (by k or weighted average over all sizes)
eta_p	average annual effective motor efficiency in partial load
K	index for the size classes

4. RESULTS AND FINDINGS

4.1. Electric Motors Installed at the Factories and Milling Houses

4.1.1. Number of electric motors

There are different types of electric motors installed at the factories in Ethiopia having years of service ranging from three to fifty years. Based on the survey made, the number of three phase induction electric motors ranging from 0.75kW to 375kW on existing and newly established factories and milling houses in the country is assessed to be 126,912. Appendix A shows the summary of estimated number of electric motors in Ethiopian industries by sector. The power capacity and quantity of major electric motors are 11kW – 17.45%, 18.5kW – 14.58%, 4kW – 9.06%, 1.5kW – 7.93%, 1.1kW – 7.91% and 7.5kW – 6.21%. The estimate is based on motor count at the sample factories per industrial sub-sector and the number of such factories. The data for grain milling houses is obtained from the Central Statistics Agency's report on small-scale manufacturing industry survey in the 2010 Ethiopian fiscal year. From Figure 4-1, 69.40% are 4 pole electric motors whereas 22.2% and 7.90% are 2 pole and 6 pole electric motors respectively.

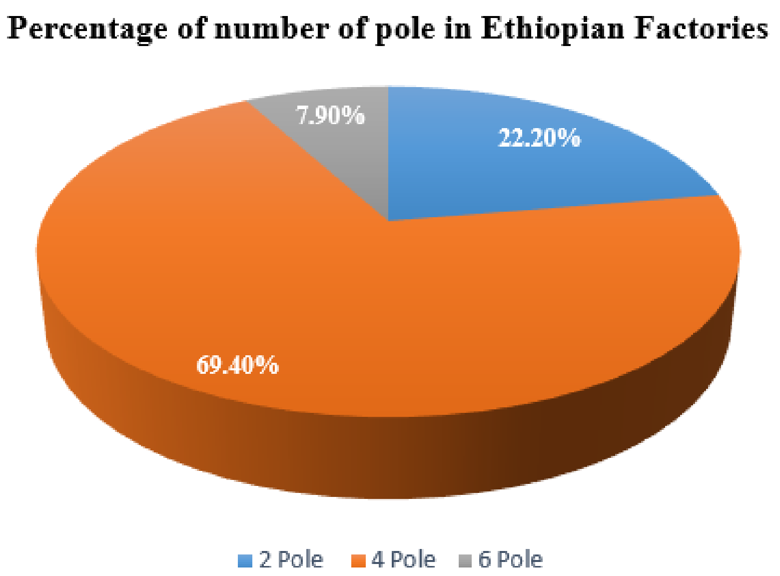
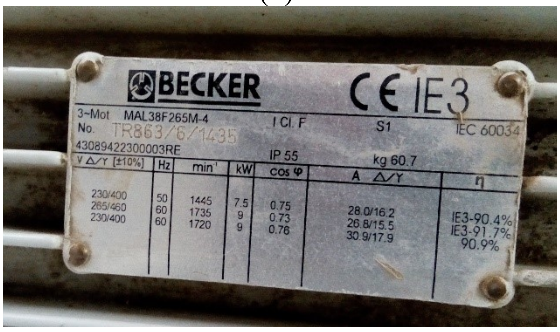


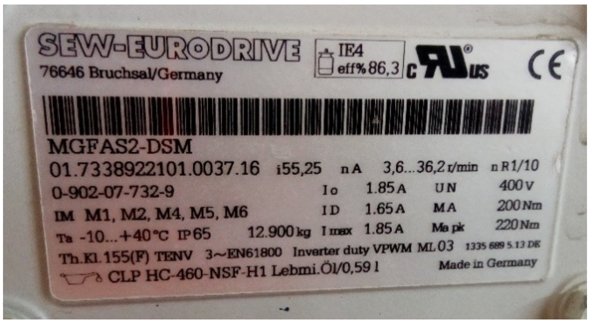
Figure 4-1: Percentage of number of poles in Ethiopian Factories

(a)

(b)



(c)



(d)

Figure 4-2: Nameplate Samples of high-efficient electric motor in surveyed industries (a) IE1, (b) IE2, (c) IE3 and (d) IE4

Figure 4-3: Sample IE5 electric motor in one of surveyed industries

Figure 4-4 shows some electric motors that are found in harsh working environment such as leather processing industries and sugar factories.

Figure 4-4: Electric motor that are found in harsh working environment

Figure 4-5 depicts some electric motor operating environment that were difficult to access the nameplate due to Motors's position in the drives and the production environment.

(a) (b)

Figure 4-5: Sampled Electric motors that were difficult to access the nameplate (a) Motors in milling houses and (b) motors in industries

Even though it was possible to record the name plate readings of all most all motors in sampled factories and milling houses, there were problems of recording nameplate data of few electric motors due to the following problems:

- No nameplates
- Empty name plates
- Damaged nameplates
- Erased nameplates
- Painted nameplates
- Non-English language nameplates

Figure 4-6 shows the nameplates of electric motors for which data recording was difficult.

Figure 4-6: Sample of damaged electric motor nameplates

4.1.2. Efficiency level of electric motors

Energy Efficiency of Electrical motors in Ethiopia vary from below standard (IE0) efficiency motors to IE4 motors. IE0 motor efficiency level is considered to be the efficiency of motors for which IE label has not been assigned or specified on the nameplate. Table 4-1 shows the determined number of electric motors and the respective IEC classes as read from the motor nameplates. Out of the estimated IE0 103,745 electric motors 33.91% are grain milling electric motors. The Efficiency classes of IE2, IE3 and IE4 are found at factories of recent installation which get motor and motor drives supply from Original Equipment manufacturers (OEM). Examples are: recently established Beer and Bottled water factories.

Table 4-1: Estimated number and IEC classifications of electric motors installed at factories.

IE Class	Quantity	Percentage
IE0	103,745	82.16%
IE1	4,496	3.56%
IE2	13,669	10.82%
IE3	4,280	3.39%
IE4	79	0.06%
Total	**126,269**	**100.00%**

4.2. Energy Consumption and Peak Power Demand of Electric Motors

4.2.1. Energy Consumption-Top-down approach

The Top-down approach is employed to calculate the energy consumption of electric motors nation wise. Electric motors are widely used in the industrial and commercial businesses in Ethiopia. Grain milling houses are the main business area using electric motors in the commercial tariff group. A typical grain milling house uses three types of milling machine and drive: Teff milling, Pepper milling, and Shiro milling. Teff is an indigenous crop of which the staple food of Ethiopians, Injera, is prepared and Shiro is a food item of which most Ethiopians favorite stew, ‘Shiro wot’, is prepared.

The recent data available from the EEU/EEP, national electricity consumption by tariff group in the year 2018 is indicated in Table 4-2.

Table 4-2: Electricity consumption by tariff group for the year 2018

Tariff group	Consumption (GWh)
Domestic	4,183.28
Commercial	2,896.20
Industrial	4,272.58
Street lighting	37.02
Total national consumption (GWh)	**11,389.07**

Figure 4-7 presents the percentage electricity consumption in different Sectors in the year 2018.

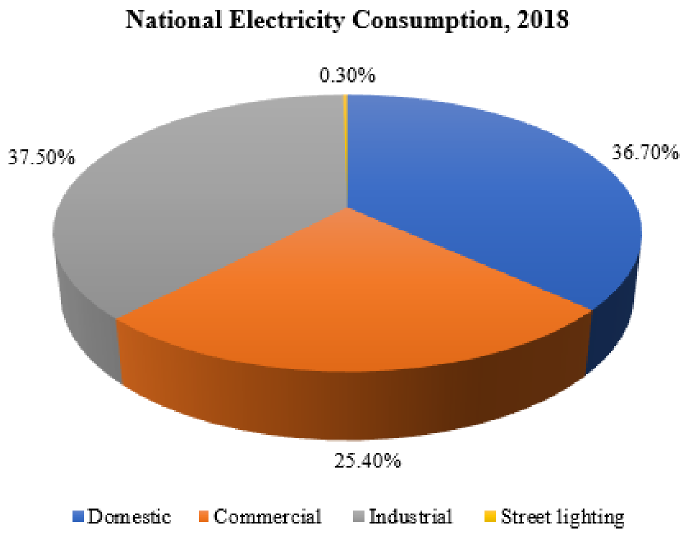


Figure 4-7: National electric energy consumption of 2018 by tariff group

There are no data regarding the consumption of electric motors in the industries and commercial businesses in Ethiopia. International experience indicates that electric motors consume about 68.9% of the Industrial electric consumption and 38.3% of consumptions of commercial premises (Waide and Brunner, 2011). Applying this consumption estimations, the energy consumption of electric motors in Ethiopia is estimated to be 4,044.36 GWh in the year 2018 as in Table 4-3 below.

Table 4-3: Electric motor share of Industrial and Commercial tariff group consumption of 2018

Electricity Tariff group	Energy consumption (GWh)	Estimated share of Electric motor consumption	Electric motor consumption (GWh)
Industrial tariff group	4,272.58	68.9%	2,943.80
Commercia tariff group	2,896.20	38.0%	1,100.55
Total			**4,044.36**

4.2.2. Peak Power demand – Top-down approach

The peak power demand in the year 2018 has been registered to be 2,587.68 MW (EEU/EEP, 2018). Assuming the energy consumption of electric motors is proportional to the power demand with uniform usage hour, the proportional peak power demand for electric motors is estimated as in Table 4-4 below.

Table 4-4: Peak power demand of electric motor 2018

National Peak power demand 2018 (MW)	Tariff group	Sector's share of National energy consumption	Estimated share of Electric motor demand	Electric motor share of peak Power demand (MW)	Electric motor share of National peak demand
2,587.68	Industrial	37.5%	68.9%	668.85	26%
	Commercial	25.4%	38.0%	250.05	10%
Total				**918.91**	**36%**

4.3. Electric Motors in the Market

All the electrical motors sold in the Ethiopian market are imported. New Factories import motors through investment process along with drives and thereafter import motors from Original Equipment Manufacturers (OEM). Old factories either directly import or directly purchase from the local market for replacements. Grain milling houses purchase motors directly from local suppliers or importers. There are no motor manufacturing or assembling firms.

4.3.1. Import data from Ethiopian Customs Commission (ECC)

The data from ECC doesn't contain details such as specific power capacity, number of poles and efficiency classifications of electric motors. Electric motors in Ethiopia are imported from different countries. The major volume of import in the years 2016 to 2020 is from China – 80.8%, Turkey – 7.35% and India – 5.62%. According to the value of motors imported motors, 49.48% is from China, India – 9.53%, Italy – 8.98%, Germany – 6.6% and Turkey – 5.9%.

Imported electric motors are recorded by Ethiopian Customs Authority for Tax assessment purpose by type and quantity and International HS code for range of motor powers. These ranges are: (a) Less than 0.75 kW, (b) 0.75kW to 75kW and (c) >75kW. Table 4-5 below shows volume, country of origin, and value of three phase and single-phase electric motors imported to the country during 2016 to 2020.

Table 4-5: Volume of import, CIF and total value (in millions birr) of Electric Motors Imported over the Years 2016-2020

HS Code	HS Description	Qty	% of Qty	Value (in Millions Birr)			%Value
				CIF *	Tax	Total	
85015100	Motor power <750W	14,068	13.3%	138.3	19.2	157.5	10.5%
85015200	Motor power 750W<75kW	60,279	56.9%	543.6	149.9	693.5	46.4%
85015300	Motor power >75kW	3,401	3.2%	380.8	89.3	470.1	31.5%
85014000	Single phase	28,185	26.6%	158.2	14.7	172.9	11.6%
Total		**105,933**	**100%**	**1,220.9**	**273.1**	**1,494.1**	**100%**

*CIF - Cost, Insurance, and Freight

Table 4-6: Country of Origin (CoO), Volume and Value of Electric Motors Imported in the Years 2016-2020.

No.	Country of Origin	Quantity and Value (1000s Birr)								Total Qty	% Qty	Total Value	% Value
		Single Phase		Three Phase									
				Motor power <750W		Motor power 750W<75kW		Motor power >75kW					
		Qty	Value	Qty	Value	Qty	Value	Qty	Value				
1	Brazil	0	0	15	1,108	230	5,879	1	592	246	0.23%	7,579	0.51%
2	China	17,073	56,338	12,663	47,125	53,612	485,435	2,244	150,340	85,592	80.80%	739,238	49.48%
3	Czech Republic	42	183	15	969	245	8,029	5	10,584	307	0.29%	19,765	1.32%
4	Denmark	0	0	0	0	70	5,518	0	0	70	0.07%	5,518	0.37%
5	France	40	627	113	4,494	48	4,048	12	7,544	213	0.20%	16,713	1.12%
6	Germany	14	570	348	25,253	663	64,477	44	8,294	1,069	1.01%	98,594	6.60%
7	India	2,360	2,600	228	3,759	3,008	9,766	362	126,308	5,958	5.62%	142,433	9.53%
8	Italy	1,066	3,285	205	57,289	1,110	51,787	196	21,865	2,577	2.43%	134,225	8.98%
9	Japan	4	17	7	318	8	1,075	30	74	49	0.05%	1,483	0.10%
10	Kenya	21	358	42	52	4	115	1	253	68	0.06%	778	0.05%
11	New Caledonia	16	6,814	0	0	0	0	0	0	16	0.02%	6,814	0.46%
12	Romania	442	328	0	0	9	179	1	5,075	452	0.43%	5,582	0.37%
13	Singapore	46	194	0	0	0	0	0	0	46	0.04%	194	0.01%
14	Spain	1	14	1	36	108	4,660	60	72,017	170	0.16%	76,727	5.14%
15	Taiwan	254	973	77	265	3	1,243	0	0	334	0.32%	2,481	0.17%
16	Turkey	6,455	4,100	58	1,620	994	32,241	278	50,120	7,785	7.35%	88,080	5.90%
17	UK	21	548	65	1,165	20	1,590	5	4,162	111	0.105	7,466	0.50%
18	United States	199	66,954	62	8,589	34	9,958	7	2,561	302	0.29%	88,061	5.89%
19	Viet Nam	69	27,304	0	0	0	0	105	65	174	0.16%	27,368	1.83%
20	Others	62	1,725	169	5,494	113	7,514	50	10,253	394	0.37%	24,986	1.67%
Total										**105,933**	**100%**	**1,494,086**	**100%**

4.3.2. Import and sales data from importers

Eight major importers have been contacted for data collection on sales of imported motors as per the questionnaire presented in Appendix C. Data in the year 2012 E.C (2020/21), as declared by the importers, is presented by capacity, IE classification and market share in Table 4-7. Table 4-8 shows motors sold in the year by quantity of import, sales, number of poles, and market share of the poles.

Table 4-7: Type and quantity of Electric motors in the Ethiopian Market with corresponding IE classifications

No.	Power (kW)	Quantity Imported	IE Efficiency Classification					Quantity Sold	Market Share (%)
			IE0	IE1	IE2	IE3	IE4		
1	1.5	80	40	3	0	0	0	43	5.6%
2	2.2	135	50	14	0	0	0	64	8.4%
3	3	156	57	10	0	0	0	67	8.8%
4	4	122	33	25	0	0	0	58	7.6%
5	5.5	97	59	8	0	0	0	67	8.7%
6	7.5	57	30	5	0	0	0	35	4.6%
7	11	145	65	9	0	0	0	74	9.6%
8	15	296	131	21	0	0	0	152	19.8%
9	18.5	238	161	4	0	0	0	165	21.5%
10	22	13	7	2	0	0	0	9	1.2%
11	30	32	30	2	0	0	0	32	4.2%
Total		**1,371**	**663**	**103**	**0**	**0**	**0**	**766**	
Percentage		**100%**	**86.6%**	**13.4%**	**0.0%**	**0.0%**	**0.0%**	**55.9%**	

Table 4-8: Quantity of electric motors Imported in 2012 EC (2019 – 2020 GC) in ascending order by number of poles

No	No of Pole	Quantity imported	Quantity sold	Market share (%)
1	2	441	251	32.8%
2	4	809	425	55.5%
3	6	121	90	11.7%
4	8	0	0	0.0%
Total		**1,371**	**766**	
Percentage		**100%**	**55.9%**	

Table 4-9 presents the price of electric motors in the Ethiopian market. Motor labelled as IE1 are claimed ratings as read from the nameplates. IE0 motor efficiency level represents the efficiency of motors for which IE label has not been assigned or specified on the nameplate. Many of the Importers import specific power ranges of motors. Motors having no IEC label, classified as IE0, are imported from a specific country whereas IE1 motors are being imported from two countries including the country of origin of the IE0 motors.

Table 4-9: Price of electric motors in the Ethiopian market

Power (kW)	Price (Birr)								Incremental price between Average IE0 and IE1 prices (%)
	IE0					IE1			
	CoO A					CoO A	CoO B	CoO A & B	
	IM 1	IM 2	IM 3	IM 4	Average price	IM 5	IM 6	Average price	
3		7,000	6,130	8,500	7,210	12,966	15,245	14,105.5	96%
5.5		9,000	10,350		9,675	18,975	21,900	20,437.5	111%
7.5			12,270		12,270		26,900	26,900	119%
11		15,000	16,800	28,000	19,933		42,150	42,150	111%
15	15,000	18,000	21,000	32,000	21,500	34,155	56,530	45,342.5	111%
18.5	19,000		24,525	35,000	26,175		66,620	66,620	155%

*CoO – Country of origin and ** IM – Importer

The following have been noted during the data collection on motors in the market.

a) There are no databases regarding sales of motors in the country. Importers' sales data obtained appears to be very small in quantity, access to their recent import and sales documents was not possible presumably due to import information security, and tax related issues. The few data obtained couldn't be verified from their import declarations.

b) The price of electric motors of the same kW or HP vary significantly for the range of motor power. For example, an 18.5 kW (20 HP) motor price ranges from 15,000.00 Birr to 55,000.00 birr. Such issues raise questions regarding the quality of the electric motors in the market. However, the price difference between average price of IE0 motors and IE1 motors for the 18.5KW motor is about Birr 23,842.50.

c) Allegedly, importers claim that motor nameplates of significant motors on sale are not real and do not reflect the correct specification of the motors. Power rating on name plate is quite higher than internal design capacities, and for internal components such as windings. Windings may not be made using pure copper and nameplates are made according to buyer’s requirement and do not reflect actual values of motor parameters. These problems are exhibited when customers buy the motors and apply near rated load and motors burn away.
d) Most importers are unaware of efficiency requirements, regulations and standards of electric motors they provide to the market. They claim motors are and shall be imported based on customer needs and efficiency is not an issue. Power and speed are the most parameters given weight.
e) Some importers are in custody of two type quality motors: better quality and poor quality. The reason behind is that they are being driven out of the market as the market is flooded with inferior quality motors. Hence, they provide their customers both options of quality and leave the decision to them.
f) Concerns and opinions of the importers regarding Pre-Export Verification of conformity (PVoC)
    - Providing PVoC as a means of standard verification is a good idea to build trust in the customers' choice and penetrate the market. However, the process of PVoC is time-consuming and makes the supplier less interested, will incur additional costs, and this in turn affects the end-users who are barely surviving with the current inflation.
    - Some of them suggested the importance of random checking rather than providing PVoC to save time and additional costs.
    - Getting a standard verification conformity paper from the supplier requires additional expenses, and because of this, it will be difficult to compete with other importers who supply low-quality electric motor.
g) Concerns and opinions of the importers regarding standardization
    - If standardization is a mandatory, the regulatory body should make market surveillance and require all importers to provide quality assurance certificates both from abroad and domestically. Otherwise, the competition would be unhealthy as a result of supplying a motor with locally produced counterfeited nameplate similar to that of the standards provided by the regulator.

- The regulatory body should consider the purchasing capacity and return on investment of small-scale manufacturing enterprises such as milling houses, hollow block manufacturers, edible oil producers, and wood workshops before requiring importers to supply standardized and high-quality electric motors for the local market.

h) Concerns and opinions of the importers regarding problem and challenges on the import, distribution and sales of electric motors

- Getting foreign currency and Letter of Credit (LC) approval are so difficult to import electric motors.
- Choosing the best supplier according to the local market interest and the importer requirement is so difficult.
- Regarding the sales, the main problem is customers' attitude towards low priced motors and lack of awareness about the high-quality electric motor supplied by some importers. Most customers are confused by low-quality electric motors in the market, which are both very cheap and have minimum quality. Due to this, some reputable importers are forced to abandon the business and some started supplying low-quality electric motors to survive in the market competition.
- Allegedly, as the local small and medium manufacturers couldn't afford the current market price of electric motors due to the increase in the global price of copper wire, some importers import copper painted or thinner copper wound electric motors.

4.3.3. Import of motors integrated into motor drives

Recently motors integrated into motor drives are being imported into the country as part of investment projects. These motors are found to be made by Original Equipment Manufacturers (OEM) and have got efficiency levels of IE2, IE3 and IE3.

4.4. Electric Motor Repair and Maintenance Service Providers

Five major electric motor maintenance service providers have been contacted for data collection on maintenance service of electric motors as per the questionnaire presented in Appendix D. The summary of results of data collection from representative electric motor maintenance service providers in the country is presented in Table 4-10.

Table 4-10: Types and quantity of electric motors rewound in 2012 E.C

No.	Power (kW)	Quantity repaired	Price of single motor Rewinding (Birr)
1	0.75	420	3,105
2	1.1	270	3,200
3	1.5	340	3,538
4	2.2	470	3,900
5	3	40	4,675
6	3.7	5	4,675
7	4	730	6,500
8	5.5	20	6,900
9	7.5	802	10,733
10	11	787	13,500
11	15	495	15,000
12	18.5	787	18,500
13	22	300	19,200
14	37	180	35,900
15	55	120	66,360
16	110	96	112,900
17	150	24	144,700
Total		**5,886**	

From the survey conducted:

- Most of the capacity of motors placed for maintenance are 0.75kW to 150kW motors.
- Motors coming for repair are mostly 2 pole motors.
- The most common causes of motor failures are: open phase, overload, mechanical failure and loose connections.
- Average price of motor repair for 7.5kW and 18.5kW is 10,733 birr and 18,500 birr respectively. The repair fee for a motor of a reputable supplier costs as much as 50% of the price of the original motor whereas the repair fee for inferior quality motors is estimated about 100% of the purchase price as the purchase price of these motors is very low. The main problem in the repair business is that customers prefer to buy new inferior quality motors of same capacity with price equivalent to that of the rewinding price. These inferior quality motors fail within a short period of time.
- Few of former electric motor repair and maintenance service providers have changed their line of business due to the low prices of new electric motors, high effort and cost of repair/maintenance services and high prices of repairs.

4.5. Industrial and Commercial Electricity Tariff

The Ethiopian electricity tariffs are among the lowest in Africa, very cheap in energy saving value and insufficient to offset the additional capital cost of a highly efficient electric motor relative to a standard motor. Table 4-11 shows working Tariffs for the Tariff groups.

Table 4-11: Industrial and commercial electricity tariff in Ethiopia, 2018-2021

Tariff category	As of Dec, 2018 onwards (Birr/kWh)	As of Dec, 2019 onwards (Birr/kWh)	As of Dec, 2020 onwards (Birr/kWh)	As of Dec, 2021 onwards (Birr/kWh)
General (Commercial)	1.0352	1.3982	1.7611	2.124
Low voltage Industry	0.8161	1.0544	1.2927	1.531
Medium Voltage Industry	0.6047	0.8008	0.9969	1.193
High Voltage Industry	0.5174	0.654	0.7911	0.928

Figure 4-8 shows a simple comparison of electricity tariff of selected Africa countries. The tariff is for Business rates: Small firms (30,000 kWh annual consumption), medium-sized firms (150,000 kWh annual consumption), large firms (1,000,000 kWh annual consumption) and extra-large firms (7,500,000 kWh annual consumption). The average electricity tariff prices in Africa vary widely across the continent from 0.5 U.S. dollars per kilowatt hour in Burkina Faso to 0.02 U.S. dollars per kilowatt hour in Ethiopia.

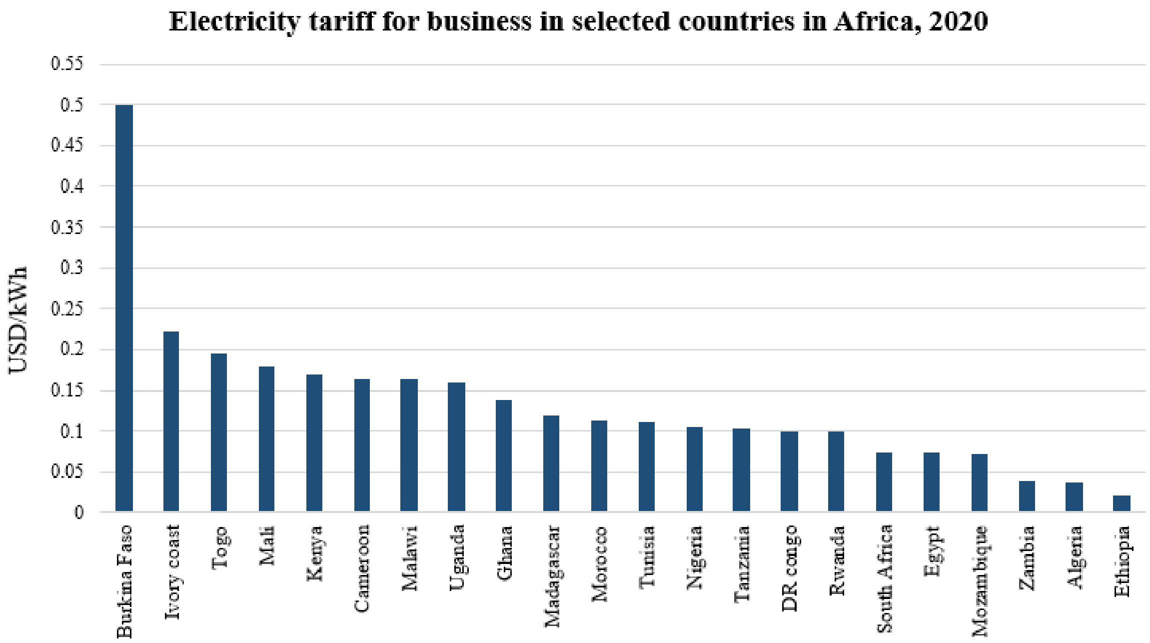


Figure 4-8: Electricity tariff of selected countries in Africa, 2020 (adopted from Global petrol prices, 2020)

5. INDUCTION MOTOR EE STANDARDS AND REGULATIONS, ETHIOPIAN AND GLOBAL EXPERIENCES

5.1. Ethiopian Standards and Regulations

5.1.1. Electric motor energy efficiency standards and labelling in Ethiopia

A study on electric motor, Project document on Electric Motor Energy Efficiency Standard and Labelling, was conducted in 2015 with the objectives of reducing the following impacts of electric motors in the country on power and energy demand.

- Power demand on electric power generating, transmission and distribution networks,
- Cost of building and operating additional electric power generating, transmission and distribution networks,
- Power outages, interruptions and voltage drops.
- Cost of electricity bill on consumers (Danas Electrical Engineering, 2015)

5.1.2. Standard development by Standards Agency

The Ethiopian Standards Agency is an authorized government organ working on standardization of electric motors in Ethiopia through development of standards or adoption of international standards. Ethiopia has adopted IEC electric motor standards, one of the leading standard motor specifications in the world which can be used for electric motor EE standards. These are:

a) ES IEC 60034-1:2012 1 Edition, Rotating Electrical Machines - Part 1: Rating and Performance
b) ES IEC 60034-2:2012 1 Edition, Rotating Electrical Machines - Part 2-1: Standard Method for Determining Losses and Efficiency from Tests (Excluding Machine for Traction Vehicles)
c) ES IEC 60034-30:2012 1 Edition, Rotating Electrical Machines – Part 30 - Efficiency Classes of Single Speed Three Phase Cage Induction Motors (IE - Code), and
d) ES IEC 60034-31:2012 1 Edition, Rotating Electrical Machines – Part 31 - Selection of Energy Efficient Motors Including Variable Speed Application - Application Guide.

The IEC has contributed to the definition of energy-efficient electric motor systems through the internationally relevant test standard IEC 60034-2-1 for electric motors and the IEC 60034-30-1 classification scheme comprising four levels of motor efficiency ("IE-code"):

- IE1 Standard Efficiency
- IE3 Premium Efficiency
- IE2 High Efficiency
- IE4 Super Premium Efficiency

These IE-codes serve as a reference for governments who specify the efficiency levels for their minimum energy performance standards (U. Brunner, Werle and Werkhoven, 2012).

5.1.3. The regulatory body EEA

EEA is mandated by the proclamation on Energy, No. 810/2013 and regulation 447/2019, on EE regulations and conservation works. To set a Minimum Efficiency Performance Standard (MEPS) for electric motors, EEA shall prepare and ratify a directive regarding the level of MEPS and associated mandatory and non-mandatory standards clauses. The directive shall be reviewed every few years.

Energy-efficiency labels, informative labels that are affixed to imported motors and describe motor 's energy performance (usually in the form of energy use, efficiency, or energy cost) to provide consumers with the data necessary for making informed purchases, should be developed by the Ethiopian Energy Authority, in accordance with the procedures laid out in the National Standard for Labelling. The lowest level of efficiency on the label should match that of the MEPS for the electric motor. Compared to MEPS, a labelling scheme offers fewer guarantees of energy savings, but it can be used to complement MEPS. Energy efficiency labelling is being implemented for products like Electric Mitad and stove.

The labelling for electric motors shall be designed to match Ethiopian labelling scheme and that of the standard to be followed in testing and classifying efficiency levels.

5.1.4. Testing of electric motor for conformity with the standards

In Ethiopia, testing of products for conformity with standards is generally carried out by the Ethiopian Conformity Assessment Enterprise (ECAE) in accordance with the organization's scope. However, ECAE is currently working on few products and there are no testing facility and trained manpower for testing electric motors. Hence, Pre-Export Verification of Conformity (PVoC) to standard and testing procedures is necessary to confirm the performance parameters of Imported motors. PVoC has been applied successfully in many countries to fast-track enforcement of MEPS. EEA is currently preparing the PVoC Manual for three phase AC Cage Induction Motors.

The Energy Regulations give EEA the power to request product samples from manufacturers for energy efficiency testing; the future EEA's activities may involve establishing laboratories or structures for testing energy performance. In all cases, this should be aligned with the Conformity Assessment Enterprise, which should ideally be responsible for oversight and control of performance testing in the country.

5.2. Electric motor National and International Regulations and Standards

5.2.1. Analysis of MEPS, regulations and standards in other countries

There are different national and international electric motor regulations, standards, MEPS, output power ranges, number of poles, voltage levels and frequency levels. MEPS vary among countries and regions, based on local markets, technical needs, and product availability. MEPS for two major global regions: the EU and the U.S. is presented below.

a) MEPS for the EU market

IE2 (High Efficiency) MEPS was specified for motors from 0.75 to 375 kW beginning June 2011, and the requirement was increased to IE3 (premium efficiency) in January 2015, for motors with power ratings from 7.5 to 375 kW and the range was extended to 0.75 to 375 kW in January 2017.

Variable speed drives (VSD, frequency converters) provide efficiency improvements by matching the motor operation to the load requirements, motors controlled by VSDs are allowed to meet the lower IE2 efficiency rating.

According to the European Commission (EC), from July 2021, the current regulation will be repealed and replaced by Regulation on electric motors and variable speed drivers (EU) 2019/1781. Under the new rules, several induction motors that were previously not covered will be regulated, including

- Smaller motors between 120W and 750W
- Larger motors between 375kW and 1000kW
- 60Hz motors, 8 poles motors and single-phase motors (the latter only as of July 2023)

The level of requirement will moreover increase, as three-phase motors with a rated output between 0.75kW and equal to or below 1000kW must reach the IE3 level by July 2021. Motors between 75kW and 200kW must meet the IE4 level as of July 2023 (EU, 2019).

b) MEPS for the U.S market

MEPS was introduced first in the US back in 1997. NEMA Energy Efficient standards were required to be met by general-purpose motors from 1 to 200 hp. But in 2010, the EISA (Energy Independence and Security Act of 2007) increased the requirement for general-purpose motors to NEMA Premium Efficiency. Other 1 to 200 hp motors, along with motors from 201 to 500 hp, were still required to meet Energy Efficient standards.

Electric motor efficiency standards in the U.S. were increased in June 2016 with the Integral Horsepower Motor (IHP) Rule. NEMA Premium Efficiency levels are required to be met for almost all single-speed induction motors under this final rule (Danielle, 2020).

Table 5-1 below shows current and latest global electric motor regulations, standards and MEPS of economy countries and countries of origin of electric motors imported to Ethiopia for three phase low voltage system motors (U. Brunner, Werle and Werkhoven, 2012).

Table 5-1: Global electric motor regulations, standards and MEPS

No.	Country	Regulation	Standard	MEPS	Range of kW of Application	Number of Poles
1	Australia	GEMS Act of 2019	IEC 60034-30-1	IE2	0.73 - 185 kW	2,4,6,8
2	Brazil	Portaria no 01/2017	ABNT NBR 17094-1	IR3	0.12 - 370 kW	2,4,6,8
3	Canada	Amendment 13 to Energy Efficiency Regulations - Electric Motors	IEEE Std 112-2004, CSA C390-10	NEMA Premium	1 - 500 HP (0.75 - 375 kW)	2,4,6,8
		Amendment 14 to Energy Efficiency Regulations - Small Electric Motors	IEEE Std 114-2010, IEEE Std 112-2004, CSA C390-10, CSA C747-09	Premium	0.25 - 3 HP (0.18 - 2.2 kW)	2,4,6
4	China	Decree no 35	GB 18613-2012	GB3	0.75 - 375 kW	2,4,6
5	EU	EU 1781/2019	IEC 6003-30-1	IE3	0.75 - 1000 kW	2,4,6,8
		EU 1781/2019	IEC 6003-30-1	IE2 with inverter frequency	0.12 - 0.75 kW	2,4,6,8
6	India	The Gazette of India S.O.178	IS 12615:2018	IE2	0.12 - 1000 kW	2,4,6,8
7	Japan	Energy Saving Act / Top Runner Program	JIS C 4034-30	IE3	0.75 - 375 kW	2,4,6
8	South Korea	MKE-2017-206	KS C IEC 60034	IE3	0.75 - 375 kW	2,4,6,8
9	USA	DOE 10 CFR Part 431 - Subpart B - Electric Motors	IEEE Std 112-2004, CSA C390-10	NEMA Premium	1 - 500 HP (0.75 - 375 kW)	2,4,6,8
		DOE 10 CFR Part 431 - Subpart X - Small Electric Motors	IEEE Std 114-2010, IEEE Std 112-2004, CSA C390-10, CSA C747-09	Premium	0.25 - 3 HP (0.18 - 2.2 kW)	2,4,6

The Global alignment of country's efficiency classes, performance standard and testing standard with IEC standards is presented in Table 5-2.

Table 5-2: Nationally Required MEPS; IEC Efficiency Classes and Testing Standards (IEC, 2016)

Efficiency Levels **3-phase induction motors** **(Low Voltage < 1000 V)**	**Efficiency Classes** **IEC 60034-30-1, 2014** **IE-Code I**	**Testing Standard** **IEC 60034-30-1, 2014** **incl. stray load losses**	**Performance Standard** **Mandatory MEPS** **National Policy Requirement**	
Super Premium Efficiency	IE4	Preferred Method II	EU 28 **	(75-200 kW)
Premium Efficiency	IE3	Summation of losses With load; Additional losses P_{LL} determined from residual loss	Canada	(0.75 - 375 kW)
			Mexico	(0.75 - 375 kW)
			USA	(0.75 - 375 kW)
			USA*	(0.18 - 2.2 kW)
			South Korea	(0.75 - 375 kW)
			EU 28 **	(0.75 - 1000 kW)
			Switzerland **	(0.75 - 375 kW)
			Turkey	(0.75 - 375 kW)
			Japan Toprunner	(0.75 - 375 kW)
			Israel	(7.5 - 375 kW)
			Singapore	(0.75 - 375 kW)
			Taiwan	(0.75 - 200 kW)
			Brazil	(0.12 - 370 kW)
			Ukraine ***	(0.75 - 375 kW)
			Saudi Arabia	(0.75 - 375 kW)
High Efficiency	IE2		Australia	(0.75 - 185 kW)
			Chile	(0.75 - 375 kW)
			China	(0.75 - 375 kW)
			Peru	(0.75 - 375 kW)
			Colombia	(7.5 - 373 kW)
			Iran	(7.5 - 375 kW)
			EU 28**	(0.12 - 0.75 kW)
			Israel	(0.75 - 5.5 kW)
			India	(0.37 - 160 kW)
			New Zealand	(0.75 - 185 kW)
			Israel	(0.75 - 375 kW)
			Taiwan	(0.75 - 375 kW)
Standard Efficiency	IE1		Costa Rica	(0.75 - 375 kW)
			Vietnam	
	I) output power: 0.12 kW - 1000 kW, 50 and 60 Hz, line operated 2,4,6 and 8 poles	II) for 3-phase machines direct online < 1 kV rated output power < 1000 kW	*) Polyphase: e.g., to IE3; single phase: IE2 levels or above **) Tier1: per 15/7/21; option IE2+VSD removed (0.75-375 kW) Tier2: 1/7/2023; 1-phase > 0.12 kW IE2; 0.75-75 / 200-1000 kW IE3 ***) IE3 or IE2+VSD, per 1/9/2019 + 2 years for implementation	

Figure 5-1 shows the World-wide MEPS settings for induction motors.

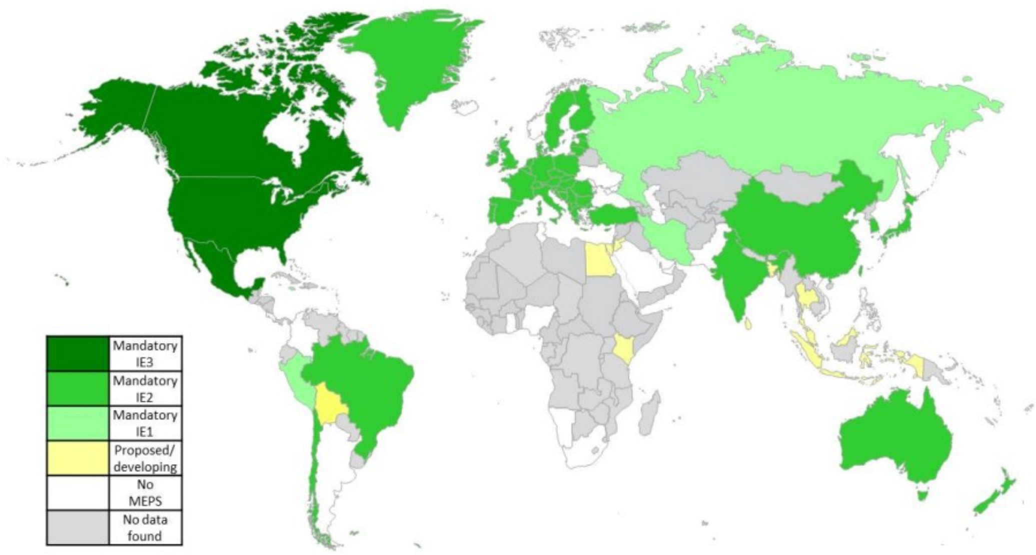


Figure 5-1: Minimum energy performance standards worldwide for electric motors (Almeida *et al.*, 2015)

5.2.2. World market for induction motors

The global motor markets are shifting towards highly efficient motors and new efficient technologies are emerging. Figure 5-2 below shows the shifting of global market from IE1 motors to increasingly more efficient IE2 and IE3 motors.

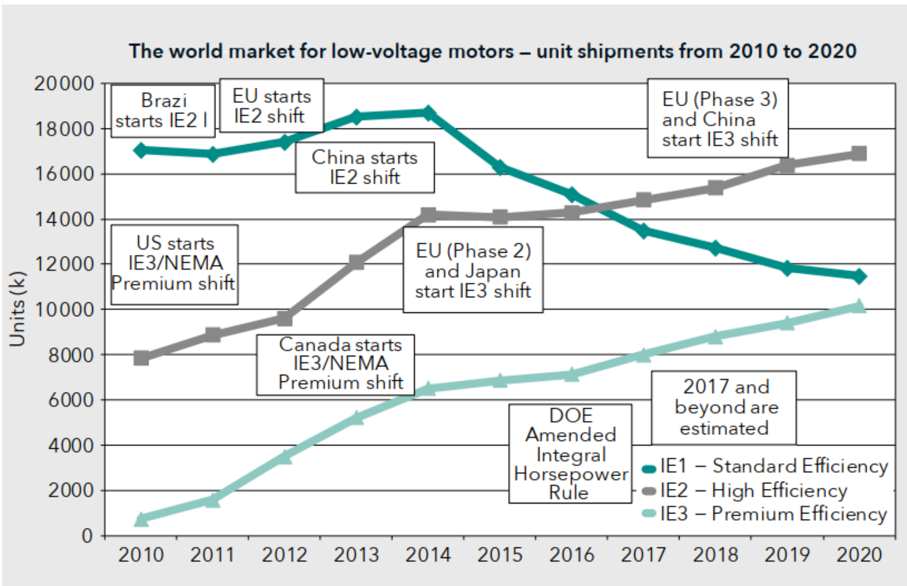


Figure 5-2: Evolution of the global motor markets: until 2016: market survey; from 2017: estimation (Preston Reine,2017, as cited in TopMotors, 2019)

6. PROPOSED POLICY OPTION FOR ETHIOPIA

6.1. Basis for Setting MEPS

The following are deemed basis for the proposed MEPS.

- The number of electric motor importers in the country is quite few, about 10 in number, and current imports are limited to IE1(13.4 %) and IE0 (86.6%) motors, i.e., majority of the importers have IE0 in their stock.
- As per the data from Ethiopian Customs Authority, the total quantity of imported electric motors in the last five years, from 2016 to 2020 is about 106,000 pieces, annual average import size is about 21,000 motors. As per Table 4-5, Out of the total imported motors, 73.4% are multi-phase (Three phase) and 26.6% are single phase. These figures indicate that the demand for electric motors is at a very low level and few importers are engaged in the import business for various reasons.
- Thus far, there are no testing facility and trained manpower for testing electric motors in Ethiopia. Hence, Pre-Export Verification of Conformity (PVoC) to Standard and Testing procedures is necessary to confirm the performance parameters like Power, speed, efficiency and efficiency class of motors indicated on motor nameplates of Imported motors. EEA is currently preparing the PVoC Manual for three phase AC Cage Induction Motors which can be used as a basis on which MEPS could be referenced. The cost and processing time impacts of PVoC reflects on the value of imported electric motors, and hence on the consumer.
- There are no directives as to control the types of motors imported during the importing of motors and through investment processes. The MEPS to be issued will be the first of its kind in the country for electric motors.
- Most importers and factory technical managers, electric motor technicians are unaware of the existence of higher energy efficiency classes of motors. There is a need for strong public awareness campaign before the implementation of MEPS.
- The number of poles of electric motors at importers show rooms and installed at factories surveyed are limited to 2, 4 and 6 poles.

- The market of induction motors in the country is driven by the needs of customers without due regard to efficiency and the nameplate data on some motors are allegedly importer declared specifications. Furthermore, electric motor prices for same power of motor vary as much as three to four times, which cannot be justified by any pricing standard. Allegedly, there are fraudulent operations in the import and distribution of electric motors which is significantly affecting the motor market and energy efficiency in this regard. Hence, the market of electric motors in the country is not in good shape.
- The quantity of imported electric motors has declined in the year 2020 due to the economic slowdown of the Corona Pandemic effect in trade and business and lack of foreign currency in the country. Hence, importers may have additional difficulties of importing if the MEPS requirement is set higher in a short period of time.
- There shall be adequate time for the transition from existing efficiency level of electric motors to higher energy efficient types due to the time required for awareness creation, imported stock clearance and import duration and import situation of the country.
- Ethiopian has adopted IEC standards on classification, testing methods and performance and rating of electric motors.

6.2. Approaches for the MEPS setting

MEPS can be set at a lower or higher level. At the lower end of the scale, MEPS levels would eliminate only part of the current market, the least efficient models currently on sale, or even set to preclude any lower efficiency models from entering the market. When set to higher levels, the MEPS can eliminate all current models from the market and/or mandate the adoption of new technology and designs that are at the current leading edge to meet the prescribed efficiency levels. Capability of importers, importing costs, local electricity prices, and incomes will be the range of factors to decide the MEPS level selected.

There are two most widely used analytical approaches to determine MEPS levels: the statistical approach and the engineering/economic analysis of potential technologies. Efficiency levels are set so that the market impact is manageable in terms of the number of models eliminated (typically 20 -50%) in the statistical method. In this approach, the range and characteristics of products currently on the market define the MEPS. In the engineering approach, the range of MEPS level is based on the technical analysis of product efficiency.

For the engineering analysis, base case market product is used as a reference to assess a range of measures and their incremental cost. The optimum efficiency level is determined based on the assessment on each additional measure. Factors such as energy prices, and likely impact on retail product prices after MEPS are also considered.

Harmonization of MEPS levels with International IEC efficiency classes and standards which Ethiopia has adopted would reduce restrictions to free trade as the test procedures and product types in each of the relevant market are similar or related (Harrington and Waide, 2004).

6.3. Impact Assessment of Setting MEPS to Higher IEC Classifications

In order to set the MEPS for electric motors in Ethiopia the impacts likely to arise in setting the MEPS level to higher IEC classifications on industrial and commercial sector consumers and country level impacts are analyzed in the following sections.

6.3.1. Impact on industrial and commercial consumers

The analysis estimates the usage hours of motors and the load factor as in Table 6-1 for range of motors imported by the importers. Average yearly operating hours of electric motors are estimated based on the working hours of surveyed factories weighted by their number of motors. There are consumers operating for 8 hrs/day, 12 hrs/day and 24 hrs/day. The weighted average operating hours is estimated as 3702 hrs/yr. Motors are estimated to be loaded at the average loading factor of 75% (WSU Energy Program and National Renewable Energy Laboratory, 2014). The analysis is based on electric motors at importers stock of IE0 level representing motors having efficiency levels below IE1.

Table 6-1: Weighted usage hours and loading of electric motors in the market

Power (kW)	Market share	Weighted usage hours	Assumed loading	IEC energy efficiency classification shares of motors at importers' stock				
				IE0	IE1	IE2	IE3	IE4
1.5	5.60%	3,702	75%	86.6%	13.4%	0	0	0
2.2	8.40%	3,702	75%	86.6%	13.4%	0	0	0
3	8.80%	3,702	75%	86.6%	13.4%	0	0	0
4	7.60%	3,702	75%	86.6%	13.4%	0	0	0
5.5	8.70%	3,702	75%	86.6%	13.4%	0	0	0

Power (kW)	Market share	Weighted usage hours	Assumed loading	IEC energy efficiency classification shares of motors at importers' stock				
				IE0	IE1	IE2	IE3	IE4
7.5	4.60%	3,702	75%	86.6%	13.4%	0	0	0
11	9.60%	3,702	75%	86.6%	13.4%	0	0	0
15	19.80%	3,702	75%	86.6%	13.4%	0	0	0
18.5	21.50%	3,702	75%	86.6%	13.4%	0	0	0
22	1.20%	3,702	75%	86.6%	13.4%	0	0	0
30	4.20%	3,702	75%	86.6%	13.4%	0	0	0

The efficiency of IE0 motor is estimated to be less than IE1 by the magnitude of difference between the respective motor capacity efficiencies of IE2 and IE1 levels plus 5.5%, losses to account for country wide electric motors inefficiencies due to several reasons as presented in Table 6-2.

Table 6-2: Electric motor efficiency reductions (Danas Electrical Engineering, 2015)

Causes of Efficiency Limitations	Efficiency Reduction (%)
Power supply quality and level	1.00
Inadequate maintenance procedure	2.50
Absence of match between load and motors	1.00
Unsuitable operating environment	1.00
Total efficiency reduction	5.50%

Table 6-3, shows the IEC efficiency class levels weighted to efficiency levels based on the percentage of number of poles of motors as in Table 4-7. IE0 is an estimated motor efficiency level, which is lower than IE1 and used to account for the fact that the average motor efficiency can be well below IE1 levels in developing countries (UNEP, 2016).

Table 6-3: IEC class levels weighted for efficiency levels based on the percentage of number of poles of motors

Power (kW)	IEC Efficiency Levels												
	IE3			IE3 Weighted by Pole	IE2			IE2 Weighted by Pole	IE1			IE1 Weighted by Pole	IE0
	2 Pole	4 Pole	6 Pole		2 Pole	4 Pole	6 Pole		2 Pole	4 Pole	6 Pole		
1.5	84.2%	85.3%	82.5%	84.6%	81.3%	82.8%	79.8%	82.0%	77.0%	77.0%	75.0%	76.8%	66.1%
2.2	85.9%	86.7%	84.3%	86.2%	83.3%	84.3%	81.8%	83.7%	80.0%	80.0%	78.0%	79.8%	70.4%
3	87.1%	87.7%	85.6%	87.3%	84.6%	85.5%	83.3%	84.9%	82.0%	82.0%	80.0%	81.8%	73.2%
4	88.1%	88.6%	86.8%	88.2%	85.8%	86.6%	84.6%	86.1%	83.0%	83.0%	81.0%	82.8%	74.0%
5.5	89.2%	89.6%	88.0%	89.3%	87.0%	87.7%	86.0%	87.3%	85.0%	85.0%	83.1%	84.8%	76.8%
7.5	90.1%	90.4%	89.1%	90.1%	88.1%	88.7%	87.2%	88.3%	86.0%	86.0%	84.7%	85.8%	77.8%
11	91.2%	91.4%	90.3%	91.2%	89.4%	89.8%	88.7%	89.5%	87.6%	87.6%	86.4%	87.5%	80.0%
15	91.9%	92.1%	91.2%	91.9%	90.3%	90.6%	89.7%	90.4%	88.7%	88.7%	87.7%	88.6%	81.3%
18.5	92.4%	92.6%	91.7%	92.4%	90.9%	91.2%	90.4%	91.0%	89.3%	89.3%	88.6%	89.2%	81.9%
22	92.7%	93.0%	92.2%	92.8%	91.3%	91.6%	90.9%	91.4%	89.9%	89.9%	89.2%	89.8%	82.7%
30	93.3%	93.6%	92.9%	93.4%	92.0%	92.3%	91.7%	92.1%	90.7%	90.7%	90.2%	90.6%	83.6%

Table 6-4 shows the annual energy consumption for electric motors currently on sale in the Ethiopian market if motor is under the IEC efficiency class. Annual energy consumption is computed as:

$$\text{Annual energy consumption} = \frac{\text{Output Power} \times \text{Hours per year} \times \text{Loading}}{\text{Efficiency}}$$

Business as Usual (BAU) or base case scenario is assumed to be based on the IE0 motors as these constitute 87% of the total motor population. Annual energy savings for MEPS scenarios (kWh/yr) is computed as the difference of the energy consumption under the BAU and that of the respective IE MEPS scenarios per motor capacity.

Table 6-4: Typical annual energy consumption if motors is under the efficiency class and energy savings for higher MEPS scenarios

Power (kW)	Typical energy consumption if motors is under the efficiency class (kWh/yr)				Annual Energy consumption for BAU (kWhr/yr)	Annual Energy savings for MEPS scenarios (kWh/yr)		
	IE0	IE1	IE2	IE3		MEPS IE1	MEPS IE2	MEPS IE3
1.5	6,301	5,423	5,079	4,923	6,301	878	1,222	1,378
2.2	8,677	7,655	7,298	7,086	8,677	1,022	1,379	1,591
3	11,379	10,183	9,811	9,541	11,379	1,196	1,568	1,838
4	15,008	13,413	12,899	12,592	15,008	1,595	2,109	2,416
5.5	19,884	18,008	17,492	17,101	19,884	1,876	2,392	2,783
7.5	26,766	24,270	23,583	23,112	26,766	2,496	3,183	3,654
11	38,177	34,905	34,125	33,488	38,177	3,272	4,052	4,689
15	51,227	47,006	46,070	45,318	51,227	4,221	5,157	5,909
18.5	62,717	57,584	56,445	55,590	62,717	5,133	6,272	7,127
22	73,861	68,021	66,830	65,822	73,861	5,840	7,031	8,039
30	99,635	91,937	90,440	89,181	99,635	7,698	9,195	10,454

a) Impact of transition from IE0 to IE1 motor

Table 6-5 indicates the impact on consumers due to the transition from IE0 motors to options of MEPS IE1 for consumers under the Low voltage industrial tariff group rate, i.e., Birr 1.531/kWh and current average market price of motors in Ethiopian market. The analysis is based on electric motors at importers stock.

Table 6-5: Impact on industrial consumer for a transition from IE0 to IE1 motors

Power (kW)	BAU			IE1 motors			Impact of transition from BAU to IE1			Simple pay back (yrs.)
	Energy consumption (kWh/yr)	Energy cost (Birr/yr)	Average price of motor (Birr)	Energy consumption (kWh/yr)	Energy cost (Birr/yr)	Average price of motor (Birr)	Energy savings (kWh)	Energy saving value (Birr)	Difference in motor price (Birr)	
3	11,379	17,421	7,210	10,183	15,590	14,106	1,196	1,831	6,896	7.7
5.5	19,884	30,442	9,675	18,008	27,570	20,438	1,876	2,872	10,763	7.1
7.5	26,766	40,979	12,270	24,270	37,157	26,900	2,496	3,821	14,630	7.0
11	38,177	58,449	19,933	34,905	53,440	42,150	3,272	5,009	22,217	8.4
15	51,227	78,429	21,500	47,006	71,966	45,343	4,221	6,462	23,843	7.0
18.5	62,717	96,020	26,175	57,584	88,161	66,620	5,133	7,859	40,445	8.5

Table 6-6 indicates the impact on commercial consumers (grain milling houses) due to the transition from IE0 motors to options of MEPS IE1 for consumers under the Commercial tariff group rate, i.e., Birr 2.124/kWh.

Table 6-6: Impact on commercial consumer (Grain milling houses) for a transition from IE0 to IE1 motors

Power (kW)	BAU			IE1 motors			Impact of transition from BAU to IE1			Simple pay back (yrs.)
	Energy consumption (kWh/yr)	Energy cost (Birr/yr)	Average price of motor (Birr)	Energy consumption (kWh/yr)	Energy cost (Birr/yr)	Average price of motor (Birr)	Energy savings (kWh)	Energy saving value (Birr)	Difference in motor price (Birr)	
11	38,177	81,088	19,933	34,865	74,053	42,150	3,312	7,035	22,217	6.0
15	51,227	108,806	21,500	46,953	99,728	45,343	4,274	9,078	23,843	5.0
18.5	62,717	133,211	26,175	57,520	122,172	66,620	5,197	11,039	40,445	6.0

b) Impact of transition from IE0 to IE2 motor

Table 6-7 indicates the impact on consumers due to the transition from IE0 motors to options of IE2 MEPS for consumers under the Low voltage industrial tariff group rate, i.e., Birr 1.531/kWh and the current average market price of motors in Ethiopian market. The price for IE2 motor is estimated to be 16% higher than IE1 motors (Rita, 2020). The IE2 motor price does not include PVoC fee of 0.75% of the FOB Value (Kenya Bureau of Standards, 2019).

Table 6-7: Impact on industrial consumer for a transition from IE0 to IE2 motors

Power (kW)	BAU			IE2 motors			Impact of transition from BAU to IE2			Simple pay back (yrs.)
	Energy consumption (kWh/yr)	Energy cost (Birr/yr)	Average price of motor (Birr)	Energy consumption (kWh/yr)	Energy cost (Birr/yr)	Average price of motor (Birr)	Energy savings (kWh)	Energy saving value (Birr)	Difference in motor price (Birr)	
3	11,379	17,421	7,210	9,811	15,021	16,363	1,568	2,401	9,153	6.8
5.5	19,884	30,442	9,675	17,492	26,780	23,708	2,392	3,662	14,033	6.5
7.5	26,766	40,979	12,270	23,583	36,106	31,204	3,183	4,873	18,934	6.4
11	38,177	58,449	19,933	34,125	52,245	48,894	4,052	6,204	28,961	7.9
15	51,227	78,429	21,500	46,070	70,533	52,598	5,157	7,895	31,098	6.7
18.5	62,717	96,020	26,175	56,445	86,417	77,279	6,272	9,602	51,104	8.0

Table 6-8 indicates the impact on commercial consumers (grain milling houses) due to the transition from IE0 motors to options of IE2 MEPS for consumers under the Commercial tariff group rate, i.e., Birr 2.124/kWh.

Table 6-8: Impact on commercial consumer (Grain milling houses) for a transition from IE0 to IE2 motors

Power (kW)	BAU			IE2 motors			Impact of transition from BAU to IE2			Simple pay back (yrs.)
	Energy consumption (kWh/yr)	Energy cost (Birr/yr)	Average price of motor (Birr)	Energy consumption (kWh/yr)	Energy cost (Birr/yr)	Average price of motor (Birr)	Energy savings (kWh)	Energy saving value (Birr)	Difference in motor price (Birr)	
11	38,177	81,088	19,933	34,011	72,239	48,894	4,166	8,849	28,961	5.5
15	51,227	108,806	21,500	45,969	97,638	52,598	5,258	11,168	31,098	4.7
18.5	62,717	133,211	26,175	56,322	119,628	77,279	6,395	13,583	51,104	5.7

c) Impact of transition from IE0 to IE3 motors

Table 6-9 indicates the impact on consumers due to the transition from IE0 motors to options of IE3 MEPS for consumers under the Low voltage industrial tariff group rate, i.e., 1.531 Birr/kWh and current average market price of motors in Ethiopian market. The price for IE3 motor is estimated to be 16% higher than IE2 motors (Rita, 2020). The IE3 motor price does not include PVoC fee of 0.75% of the FOB Value (Kenya Bureau of Standards, 2019).

Table 6-9: Impact on industrial consumer for a transition from IE0 to IE3 motors

Power (kW)	BAU			IE3 motors			Impact of transition from BAU to IE3			Simple pay back (yrs.)
	Energy consumption (kWh/yr)	Energy cost (Birr/yr)	Average price of motor (Birr)	Energy consumption (kWh/yr)	Energy cost (Birr/yr)	Average price of motor (Birr)	Energy savings (kWh)	Energy saving value (Birr)	Difference in motor price (Birr)	
3	11,379	17,421	7,210	9,541	14,607	18,981	1,838	2,814	11,771	6.7
5.5	19,884	30,442	9,675	17,101	26,182	27,501	2,783	4,261	17,826	6.5
7.5	26,766	40,979	12,270	23,112	35,384	36,197	3,654	5,594	23,927	6.5
11	38,177	58,449	19,933	33,488	51,270	56,717	4,689	7,179	36,784	7.9
15	51,227	78,429	21,500	45,318	69,382	61,014	5,909	9,047	39,514	6.7
18.5	62,717	96,020	26,175	55,590	85,108	89,644	7,127	10,911	63,469	8.2

Table 6-10 indicate the impact on commercial consumers (grain milling houses) due to the transition from IE0 motors to options of IE2 MEPS for consumers under the Commercial tariff group rate, i.e., Birr 2.124/kWh.

Table 6-10: Impact on commercial consumer (Grain milling houses) for a transition from IE0 to IE3 motors

Power (kW)	BAU			IE3 motors			Impact of transition from BAU to IE3			Simple pay back (yrs.)
	Energy consumption (kWh/yr)	Energy cost (Birr/yr)	Average price of motor (Birr)	Energy consumption (kWh/yr)	Energy cost (Birr/yr)	Average price of motor (Birr)	Energy savings (kWh)	Energy saving value (Birr)	Difference in motor price (Birr)	
11	38,177	81,088	19,933	33,415	70,973	56,717	4,762	10,115	36,784	5.6
15	51,227	108,806	21,500	45,220	96,047	61,014	6,007	12,759	39,514	4.8
18.5	62,717	133,211	26,175	55,470	117,818	89,644	7,247	15,393	63,469	5.8

6.3.2. Country level impacts: electricity consumption reduction and peak power demand saving

The amount of money could be saved by purchasing an energy efficient motor instead of a standard motor depends on motor size, annual hours of use, load factor, efficiency improvement, and the serving utility's charges for electrical power demand and energy consumed (Gilbert.A and Douglass, 1996).

Table 6-11: Weighted usage hours and loading of electric motors in the market

Power (kW)	Market share	Weighted usage hours	Assumed loading	IEC energy efficiency classification shares of motors at Ethiopian factories				
				IE0	IE1	IE2	IE3	IE4
0.75	6.12%	3,702	75%	82.00%	3.53%	10.72%	3.36%	0.06%
1.1	7.88%	3,702	75%	82.00%	3.53%	10.72%	3.36%	0.06%
1.5	7.90%	3,702	75%	82.00%	3.53%	10.72%	3.36%	0.06%
2.2	5.82%	3,702	75%	82.00%	3.53%	10.72%	3.36%	0.06%
3	4.23%	3,702	75%	82.00%	3.53%	10.72%	3.36%	0.06%
4	9.03%	3,702	75%	82.00%	3.53%	10.72%	3.36%	0.06%
5.5	5.39%	3,702	75%	82.00%	3.53%	10.72%	3.36%	0.06%
7.5	6.18%	3,702	75%	82.00%	3.53%	10.72%	3.36%	0.06%
11	17.38%	3,702	75%	82.00%	3.53%	10.72%	3.36%	0.06%
15	5.17%	3,702	75%	82.00%	3.53%	10.72%	3.36%	0.06%
18.5	14.52%	3,702	75%	82.00%	3.53%	10.72%	3.36%	0.06%
22	2.56%	3,702	75%	82.00%	3.53%	10.72%	3.36%	0.06%
30	2.13%	3,702	75%	82.00%	3.53%	10.72%	3.36%	0.06%
above 30	5.27%	3,702	75%	82.00%	3.53%	10.72%	3.36%	0.06%

Table 6-12, shows the IEC efficiency class levels weighted to efficiency levels based on the percentage of number of poles of motors as in Figure 4-1. The efficiency of IE0 motor is estimated to be less than IE1 by the magnitude of difference between the respective motor capacity efficiencies of IE2 and IE1 levels plus 5.5%, to account country wide electric motors inefficiencies for several reasons as presented in Table 6-2.

Table 6-12: IEC class levels weighted for efficiency levels based on the percentage of number of poles of motors

Power (kW)	IEC Efficiency Levels													
	IE3			IE3 Weighted by Pole	IE2			IE2 Weighted by Pole	IE1			IE1 Weighted by Pole	IE0
	2 Pole	4 Pole	6 Pole		2 Pole	4 Pole	6 Pole		2 Pole	4 Pole	6 Pole		
0.75	80.7%	82.5%	78.9%	81.4%	77.4%	79.6%	75.9%	78.4%	72.1%	72.1%	70.0%	71.6%	59.3%
1.1	82.7%	84.1%	81.0%	83.1%	79.6%	81.4%	78.1%	80.3%	75.0%	75.0%	72.9%	74.5%	63.2%
1.5	84.2%	85.3%	82.5%	84.4%	81.3%	82.8%	79.8%	81.8%	77.2%	77.2%	75.2%	76.7%	66.1%
2.2	85.9%	86.7%	84.3%	85.9%	83.2%	84.3%	81.8%	83.4%	79.7%	79.7%	77.7%	79.1%	69.3%
3	87.1%	87.7%	85.6%	87.0%	84.6%	85.5%	83.3%	84.7%	81.5%	81.5%	79.7%	81.0%	71.8%
4	88.1%	88.6%	86.8%	87.9%	85.8%	86.6%	84.6%	85.8%	83.1%	83.1%	81.4%	82.6%	73.9%
5.5	89.2%	89.6%	88.0%	88.9%	87.0%	87.7%	86.0%	87.0%	84.7%	84.7%	83.1%	84.2%	75.9%
7.5	90.1%	90.4%	89.1%	89.8%	88.1%	88.7%	87.2%	88.0%	86.0%	86.0%	84.7%	85.5%	77.5%
11	91.2%	91.4%	90.3%	90.8%	89.4%	89.8%	88.7%	89.2%	87.6%	87.6%	86.4%	87.1%	79.5%
15	91.9%	92.1%	91.2%	91.5%	90.3%	90.6%	89.7%	90.0%	88.7%	88.7%	87.7%	88.2%	80.9%
18.5	92.4%	92.6%	91.7%	92.0%	90.9%	91.2%	90.4%	90.6%	89.3%	89.3%	88.6%	88.8%	81.5%
22	92.7%	93.0%	92.2%	92.4%	91.3%	91.6%	90.9%	91.0%	89.9%	89.9%	89.2%	89.4%	82.3%
30	93.3%	93.6%	92.9%	93.0%	92.0%	92.3%	91.7%	91.7%	90.7%	90.7%	90.2%	90.2%	83.2%
above 30	93.7%	93.9%	93.3%	93.3%	92.5%	92.7%	92.2%	92.2%	91.2%	91.2%	90.8%	90.7%	83.7%

Table 6-13 shows the annual energy consumption for electric motors currently on sale in the Ethiopian market if motor is under the IEC efficiency class. Business as Usual (BAU) or base case scenario is assumed to be based on the IE0 motors as these constitute 82% of the total motor population. Annual energy savings for MEPS scenarios (kWh/yr) is computed as the difference of the energy consumption under the BAU and that of the respective IE MEPS scenarios per motor capacity.

Table 6-13: Typical annual energy consumption if motors is under the efficiency class and energy savings for higher MEPS

Power (kW)	Typical energy consumption if motors is under the efficiency class (kWh/yr)				Annual Energy consumption for BAU (kWhr/yr)	Annual Energy savings for MEPS scenarios (kWh/yr)		
	IE0	IE1	IE2	IE3		MEPS IE1	MEPS IE2	MEPS IE3
0.75	3,512	2,908	2,656	2,558	3,512	604	856	954
1.1	4,833	4,100	3,803	3,675	4,833	733	1,030	1,158
1.5	6,301	5,430	5,091	4,935	6,301	871	1,210	1,366
2.2	8,814	7,722	7,324	7,111	8,814	1,092	1,490	1,703
3	11,601	10,283	9,834	9,574	11,601	1,318	1,767	2,027
4	15,028	13,446	12,944	12,635	15,028	1,582	2,084	2,393
5.5	20,120	18,136	17,553	17,177	20,120	1,984	2,567	2,943
7.5	26,869	24,355	23,663	23,189	26,869	2,514	3,206	3,680
11	38,417	35,065	34,239	33,636	38,417	3,352	4,178	4,781
15	51,480	47,219	46,275	45,516	51,480	4,261	5,205	5,964
18.5	63,025	57,844	56,695	55,832	63,025	5,181	6,330	7,193
22	74,220	68,326	67,124	66,107	74,220	5,894	7,096	8,113
30	100,114	92,345	90,834	89,565	100,114	7,769	9,280	10,549
above 30	122,737	113,264	111,421	110,108	122,737	9,473	11,316	12,629

From Table 6-14, the total energy consumption savings for MEPS IE1, MEPS IE2, MEPS IE3 scenarios are computed to be 334.57 GWh, 415.57 GWh, and 472.74 GWh respectively.

Table 6-14: Total annual energy consumption for BAU and energy savings for higher MEPS scenarios

Power (kW)	Total surveyed Qty of IE0 motors in the country	Total Annual energy consumption for BAU (GWh/yr)	Total Annual energy savings for MEPS scenarios (GWh/yr)		
			MEPS IE1	MEPS IE2	MEPS IE3
0.75	3,829	13.45	2.31	3.28	3.65
1.1	4,476	21.63	3.28	4.61	5.18
1.5	8,413	53.01	7.33	10.18	11.49
2.2	6,575	57.95	7.18	9.80	11.20
3	4,561	52.91	6.01	8.06	9.25
4	10,573	158.89	16.73	22.03	25.30
5.5	5,517	111.00	10.95	14.16	16.24
7.5	6,492	174.43	16.32	20.81	23.89
11	19,540	750.67	65.50	81.64	93.42
15	6,136	315.88	26.15	31.94	36.60
18.5	17,505	1,103.25	90.69	110.81	125.91
22	2,727	202.40	16.07	19.35	22.12
30	2,235	223.75	17.36	20.74	23.58
above 30	5,140	630.87	48.69	58.16	64.91
Total	**103,719**	**3,870.09**	**334.57**	**415.57**	**472.74**
Percentage saving of total energy consumption for the MEPS scenarios			**8.6%**	**10.7%**	**12.2%**

Applying the energy saving percentages in Table 6-14 above, to the Top-down approach Energy and peak power demand estimation of Table 4-3, the Energy saving for the MEPS scenarios is presented as in Table 6-15 below.

Table 6-15: Country level energy saving under IE1, IE2 and IE3 MEPS scenarios

Description	MEPS Scenarios		
	IE1	IE2	IE3
Energy saving potential %	8.60%	10.70%	12.20%
Energy consumption of electric motors 2018(GWh/yr)	4,044.36	4,044.36	4,044.36
Energy saving (GWh/yr)	347.81	432.75	493.41
Energy saving (GWh/yr) including 25 % losses	434.77	540.93	616.76

The monetized country level energy saving under the IE1, IE2 and IE3 MEPS scenarios for consumers under the Low voltage industrial tariff group rate, i.e., Birr 1.531/kWh and is presented in Table 6-16 below.

Table 6-16: Monetized country level energy saving under the IE1, IE2 and IE3 MEPS scenarios

MEPS scenarios	Energy saving (GWh)	Rate (Birr/Kwh)	Monetized energy saving (Mill Birr/yr)
IE1	347.81	1.531	532.5
IE2	432.75	1.531	662.5
IE3	493.41	1.531	755.4

Applying the energy saving percentages in Table 6-16 above, to the Top-down approach peak power demand estimation of Table 4-4, the peak power demand saving for the MEPS scenarios is presented as in Table 6-17 below.

Table 6-17: Country level peak power demand saving under IE1, IE2 and IE3 MEPS scenarios

Description	MEPS Scenarios		
	IE1	IE2	IE3
Peak power demand saving potential %	8.60%	10.70%	12.20%
Peak power demand of electric motors 2018(MW)	918.91	918.91	918.91
Peak power demand saving (MW)	79.03	98.32	112.11
Peak power demand saving (MW) including 25 % losses	98.78	122.90	140.13

Currently most factories in Ethiopia are charged significant amount of money, some paying 10% to 50% of total electricity bill per month, for power demands exceeding the allowable limit. The peak power demand savings in Table 6-17 above reduce the power demand charges. Demand charges are fees applied to the electric bills of commercial and industrial customers based upon the highest amount of power drawn during any (typically 15-minute) interval of the billing period, monthly in this case. The saving on power demand charge will be proportional to the power demand savings under the respective MEPS scenarios above. The Peak power demand saving, Demand charge rate set by EEU as of December 2021 onwards and the corresponding monetized savings on demand charge for the MEPS scenarios, are presented in Table 6-20 below. The peak power demand saving in Table 6-19 is assumed to relive the monthly exceeded power demands.

Table 6-18: Monetized demand charge savings under IE1, IE2 and IE3 MEPS scenarios.

MEPS scenarios	Peak power demand saving (MW)	Low voltage Industrial Tariff group Demand Charge rate as of December 2021, (Birr/Kw)	Monetized power demand charge saving (Mill Birr/month)
IE1	79.03	200.00	15.80
IE2	98.32	200.00	19.67
IE3	112.11	200.00	22.42

6.3.3. Other macro-economic impacts

The implementation of MEPS IE2 or IE3 would not affect local electric motor manufacturers or assemblers since these establishments are nonexistent and as all-electric motors nowadays are imported from abroad. However, establishments that use electric motors for a short period of time (minimal usage hours) might be negatively affected by the implementation of the MEPS IE2 or IE3 due to the relatively higher purchase cost associated with these electric motors. For these establishments, the use of high-priced energy-efficient electric motors might not be economically attractive. Therefore, such establishments might be forced to inflate their prices to accommodate the relatively higher costs of the mandated IE2 or IE3 electric motors, and this in turn affects the end-users who claim they are barely surviving with the current situation of inflation.

6.4. Proposed MEPS and Implementation Schedule

6.4.1. Proposed MEPS

Importers in the country import 87%, IE0 and 13 %, IE1 motors. Setting MEPS to IE1 level requires the 87%, IE0 importers to shift to IE1 motor imports whereas setting MEPS to IE2 level subjects the same importers to import IE2 motors without having prior introduction to transitioning to IE1 motor imports. The same holds true for setting MEPS to IE3 level. Furthermore, there will be a newly to be introduced PVoC process under both scenarios.

From the impact analysis of industrial and commercial application motors, it is revealed that setting the MEPS to IE1 motors will have slightly higher simple payback of 7.0 to 8.5 years for industrial consumers and 5.1 to 6.1 years for commercial consumers (Milling houses).

In the scenario of transition from IE0 to IE2, the payback period reduces to 6.4 to 8.0 for industrial consumers and 4.8 to 5.8 years for commercial consumers. This indicates that transitioning either to IE1 or IE2 MEPS has no significant payback time difference and acceptable considering the service life time of efficient electric motors of 10 to 15 years in developing countries. The payback periods for the IE0 to IE2 transition are lower due to the fact that the incremental energy savings of transition from IE0 to IE2 outweighs the relative price increment of same motors by proportion.

For transition to IE3 MEPS, the simple payback period is almost the same as that of IE2 MEPS. However, there is estimated significant price difference between the two scenarios. For example, for the most prevalent milling motor of 11 kW, the average price difference is estimated to be Birr 22,000 between IE0 and IE1, Birr 29,000 between IE0 and IE2, and Birr 36,717 between IE0 and IE3 motors. This shows there is a need for higher up front capital cost in the transition scenarios, that of MEPS IE3 being the highest. The milling houses, as presented in previous sections, are engaged in processing basic flour of Teff, Shiro and Pepper, staple food and basic ingredients of Ethiopian stew ('Wot'). Figure 6-1 shows the payback period versus cost difference for the MEPS scenarios.

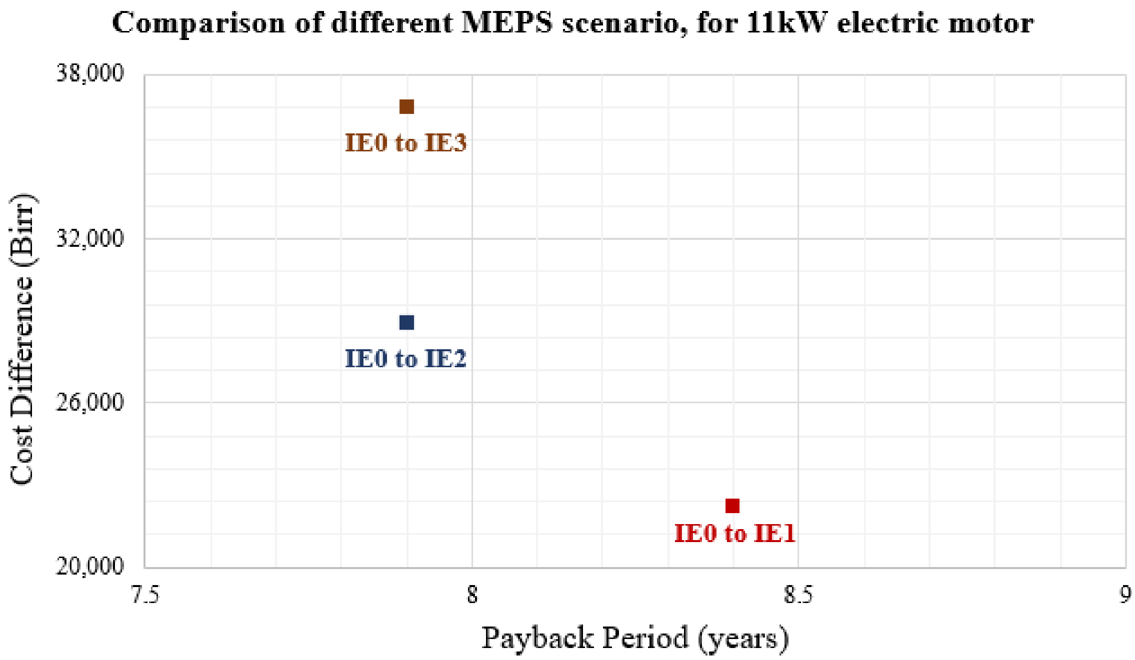


Figure 6-1: Comparison for different MEPS scenario, for 11kW electric motors

Considering the above, it is proposed to set the MEPS to IE2 level instead of IE1 or IE3 levels as the payback period is better than that of IE1 MEPS and equal to that of IE3 MEPS and the upfront cost of acquiring the electric motors is between that of IE1 and IE3.

6.4.2. Sensitivity analysis IE2 MEPS

The sensitivity analysis helps to analyze the sensitivity of the simple payback period to the change in the electricity tariff rate in implementing MEPS IE2 in the country. The sensitivity analysis indicated that increasing the electricity tariff by 125% decreases the payback period by a higher value. The change in the electricity tariff rate beyond 125% only changes the payback period by a small value.

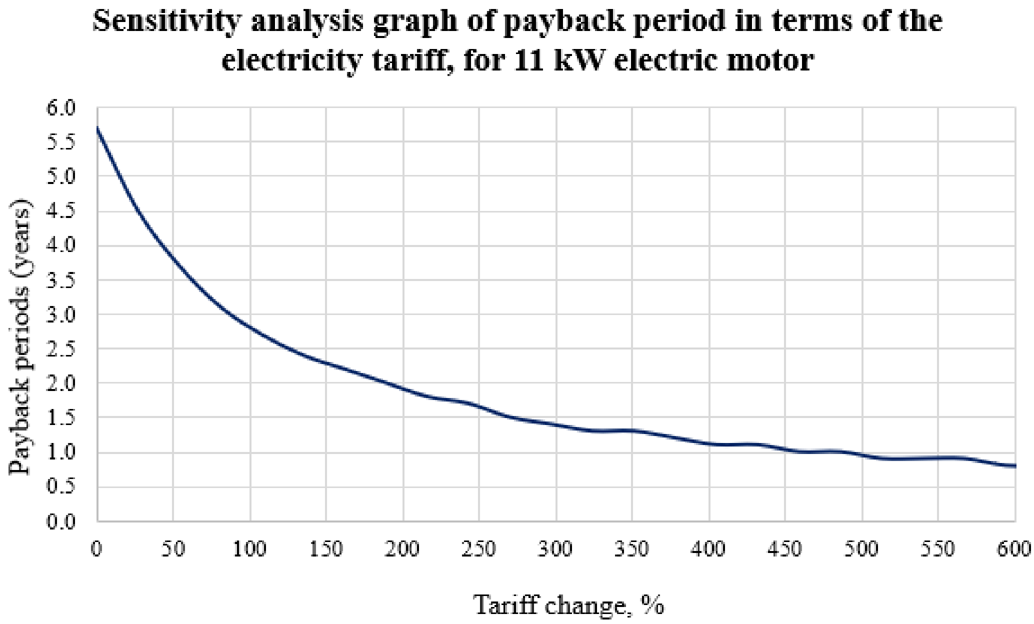


Figure 6-2: Sensitivity analysis graph of payback period in terms of electricity tariff, for 11kW electric motor based on commercial tariff rate

The electricity tariff for Ethiopian industrial and commercial consumers is quite low as compared to other African countries and international references. The Ethiopian commercial tariff charges 2.124 Birr/kWh (USD 0.053/kWh, at 40.09 birr per USD).

The comparison in Figure 6-2 indicates transitioning to IE2 MEPS for the 11kW motor could have shorter payback period, for example 2 years, had the electricity tariff been around 6.06 Birr /kWh at the current time. However, tariff increase by such amount has significant impact on the end user and is not acceptable. Hence, the simple payback period 5.5 years for IE2 MEPS of commercial consumers, is sound as indicated in Table 6-8.

6.4.3. Life Cycle Cost (LCC) of IE2 MEPS

The Life Cycle Cost has been calculated and compared for both IE2 electric motor and IE0 electric motor. This analysis is based on the total annualized system costs that consists of the capital cost, maintenance cost as well as energy cost through an electric motor's life time of fifteen years. The expected inflation rate and nominal discount rate are accounted for in the real discount rate in the LCC calculation. The real discount rate is computed to be 2% (Kebede, Bouyguet and Olivier, 2020). Table 6-19 presents life cycle cost analysis of MEPS IE2 and IE0 electric motor.

Table 6-19: LCC comparison of IE0 and IE2 motors

	IE0 Motor	IE2 Motor
Power (kW)	11	11
Purchasing Cost (Birr)	19,933	48,894
Life (Years)	15	15
Salvage Value (Birr)	0	0
Efficiency	80.0%	89.5%
Loading	75% (0.75)	75% (0.75)
Real Discount rate (%)	2.0%	2.0%
Energy Cost (Birr/kWh)	2.124	2.124
Annual Operating Hours	3,702	3,702
Annual Energy Usage (kWh)	38,175	34,123
Annual Energy Cost (Birr)	81,084	72,477
Annualized capital cost	1,551	3,805
Equivalent Annual Cost	82,635	76,282
Cost per kWh (Birr/kWh)	2.165	2.236
Annualized Incremental Capital Cost (Birr)	**2,254**	
Annualized Incremental Energy Saving (Birr)	**8,607**	
Annualized Revenue (Birr)	**6,353**	

Table 6-19 indicates that at 3,702 annual operating hours, it will cost the end-users an annualized additional 2,254 birr to transition to IE2 motor and save energy amounting to 8,607 birr resulting in a 6,353 birr net revenue per motor.

6.4.4. Implementation schedule

Based on the existing imported types and status of electric motor market in the country, it is recommended that PVoC implemented in 2023, efficiency class of imported motors to be IE2 in 2023 and amended to IE3 five years or later after the date of enforcement of IE2. The IEC classifications and standards shall be based on IEC 60034-30: Efficiency classes of single speed three phase cage induction motors (IE-code); IEC 60034-2-1: Standard methods for determining losses and efficiency; and EC 60034-1: Rating and performance standards. Labeling on imported motors would assist the consumer to easily identify the efficiency class of the motors and to provide them with the data necessary for making informed purchases. Hence, it is proposed the labelling for electric motors be adapted from labelling design already approved and being used for other products/appliances in the country.

The following are specifications for the proposed IE2 MEPS or specifications to be mandatory in the Ethiopia Standards indicated above.

- Single speed squirrel cage three phase induction motor
- For operation on Sinusoidal voltage supply
- Number of poles :2, 4, 6 Pole
- Power rating from 0.75Kw to 375 KW.
- Rated voltage 50V to 1000V

Implementation of the MEPS requires strong awareness creation to the importers, factory owners, technical managers and technicians. Considering the current slowdown in the economy of the country, clearing the stock of IE0 motors at importers' stock requires some time before the implementation of IE2 MEPS. Parallel to the implementation of PVoC, ratifications of directives for IE2 MEPS for industrial and commercial motors and for new factory installation is needed. Depending on the outcome of the implementation of IE2 MEPS, ratification of IE3 MEPS and subsequent implementation of MEPS IE3 shall follow. The proposed implementation schedule is presented in Table 6-20 below.

Table 6-20: MEPS Implementation schedule

No.	Activity	Year							
		2021	2022	2023	2024	2025	2026	2027	2028
1	Awareness creation to stake holders								
2	Stock Clearance Imported below IE0& IE1								
3	Implement PVoC								
4	Directive MEPS IE2 industrial and commercial users								
6	Implementation MEPS IE2 on imported motors								
7	Directive new factory installation MEPS IE2								
8	New factory installations and motor replacement at industrial and commercial users MEPS IE2								
9	Directive MEPS IE3								
10	Implementation MEPS IE3								

7. BUSINESS MODEL AND FINANCING MECHANISMS FOR ENERGY EFFICIENCY OF ELECTRIC MOTORS

7.1. Business Models and Financing Options

Business models for investments in energy efficiency provide policy makers and investors with alternative business methods for the deployment of new technologies, or for the application of well-established technologies and practices in new settings.

There are many barriers inhibiting investments in energy efficiency currently, including high upfront costs, lack of access to finance, high perceived risk, lack of trust in new technologies, competing investment priorities, lack of knowledge and awareness, and split incentives. Many of these barriers can be overcome, at least in significant part, with well-designed financing mechanisms, incentives and business models, together with complementary measures such as policies, regulations, awareness raising activities and behavior change initiatives.

Common types of financing and funding sources for commercial sector energy efficiency include banking institutions, Private equity Funds, ESCOs (Energy Service Companies), Insurance companies, Guarantee institution, and On-bill financing and rebates. There are also national and international entities for source of financing such as, National development banks, Bi/Multilateral development banks providing credits, credit guarantees and grants.

There are few business models and financing mechanisms which are currently being exercised in many countries for energy efficiency and could be applied to energy efficiency improvement of electric motors. These include: loans, revolving loan funds, dealer or trade financing, leasing, pay-per-service models, Energy Performance Contacts (EPC) - shared and guaranteed savings models (ESCOs), Financial incentives (e.g., rebate or subsidy programs), guarantees and insurance, and Energy savings insurance models (Magallón et al., 2019). However, most of the business models and financing mechanisms require the availability of banks, insurance companies, micro finance institutions, and leasing, and Energy Service Companies who are familiar with energy efficiency projects.

Studies show that the combination of revolving loan fund, EPC with Credit Guarantee business models have been successfully implemented in developing countries during initial stages of energy efficiency financing.

Revolving loans funds work similar to commercial loans. Special purpose revolving loan funds are sometimes established where fit for purpose commercial mechanisms are not available to a specific market sector (such as micro, small or medium sized enterprises), or are not considered appropriate. Revolving loan funds start with a fixed pool of capital, which is lent to clients for projects that fit a specific purpose, and then repaid, often with a small amount of interest, to the fund. The replenished money can be re-lent to new clients. Revolving loan funds are typically managed by a government entity or in some cases are administered by a commercial financial institution such as a bank.

Energy Performance Contracts (EPCs) enable funding of energy efficiency improvements from the earnings of energy cost reductions. In the EPC model Energy Service Company (ESCO) implements an energy efficiency project, and uses the stream of income from the cost savings to repay the project costs. The ESCO only receives full payment if the project delivers predicted energy savings; this transfers project technical, financial and operational risks from the client to the service provider.

The two major contracting models defining the relationships and risk allocations among the ESCO, customer and lender are the shared savings model and the guaranteed savings model. Under the shared savings models, the ESCO invests in the project. The cost savings resulting from the energy efficiency improvement are quantified, and for the duration of the contract a pre-determined share of this amount will be used to remunerate the ESCO. The ESCO thus takes over both the performance and the customer credit risk, and acquires financing. In guaranteed savings models, the ESCO guarantees a certain level of energy savings by covering, in case of underperformance, the monetary value of the difference between predicated and actual energy bill savings based on a specified utility rate. This shields the customer from any performance risk. The customer is directly financed by a financial institution, repays the loan and assumes the investment repayment risk. Small businesses and creditworthy commercial customers are good potential clients for EPCs. The feasibility of EPC projects depends on the predictability of energy use, the level in energy efficiency, the price of energy, the size of the investment, the complexity of the project, and the legal, financial and regulatory rules.

7.2. Proposed Business Model and Financing Mechanism

The Energy regulation No 447/2019, chapter 6, provides for the establishment of Energy efficiency and conservation fund (Revolving fund), partial or full fund, partial or full credit guarantee or on cost sharing basis to energy efficiency and conservation activities in Ethiopia. This fund may include budget allocation from government, loans and grants from financial institutions, grants from non-governmental organizations. The regulation stipulates the establishment of Energy board which directs and controls the fund and the Nominated trust agent to administer the fund. The EEA directive 006/2012, Energy efficiency service providers and Energy auditor licensing of Nov 2019, Item 6, Licensing of Energy Service Companies (ESCOs), provides for the establishment of ESCOs for implementation of energy efficiency projects in industries. The energy efficiency strategy for industries, buildings, and appliances, directive No 005/2012, under Strategic energy efficiency frame work for industries, energy efficiency financing programs, states that barriers in financing energy efficiency projects can be addressed by the development of financial products such as Partial Credit Guarantees (PCG). Under this scheme, EEA will use the fund from the revolving fund to provide partial credit guarantees for 50% of the project cost to the financial institution. If the customer or ESCO defaults, the financial institution will be guaranteed to be paid 50% of the payments due to the ESCO.

Considering the above, it is proposed that at the early stage of financing energy efficiency of electric motors, the revolving fund business model in conjunction with Partial Credit Guarantee (PCG) and guarantee fee raised either by the customer or ESCO be applied to reduce financial institutions' perceived risks. Under this circumstance, even with loan guarantee programs in place, borrowers should still satisfy loan conditions that are commercially viable, like providing collateral as security. If claims are made under guarantees, guarantee issuers are forced to repay the amount of those claims to the guarantee beneficiaries. After the implementation and maturing of the energy efficiency financing of electric motors with the revolving fund & PCG model above, the EPC - shared and guaranteed savings models (ESCOs) may be introduced without the revolving fund and PCG mechanisms. Figure *7-1* shows the revolving fund along with PCG business model while the EPC – shared and guaranteed savings models (ESCOs) are presented in Figure 7-2 and Figure 7-3 respectively.

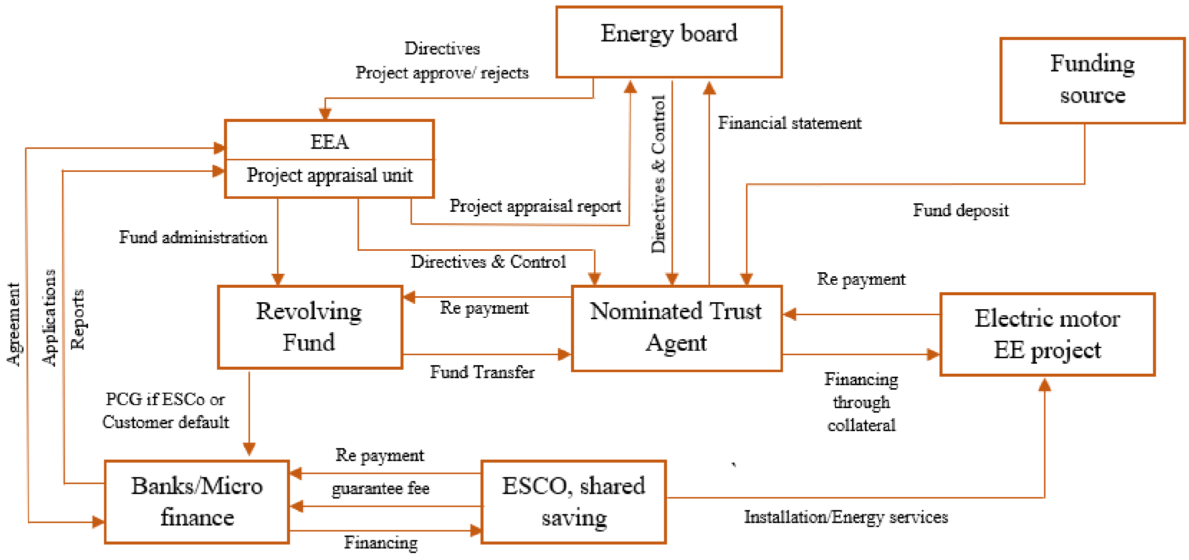


Figure 7-1: Revolving fund/PCG business model relationship

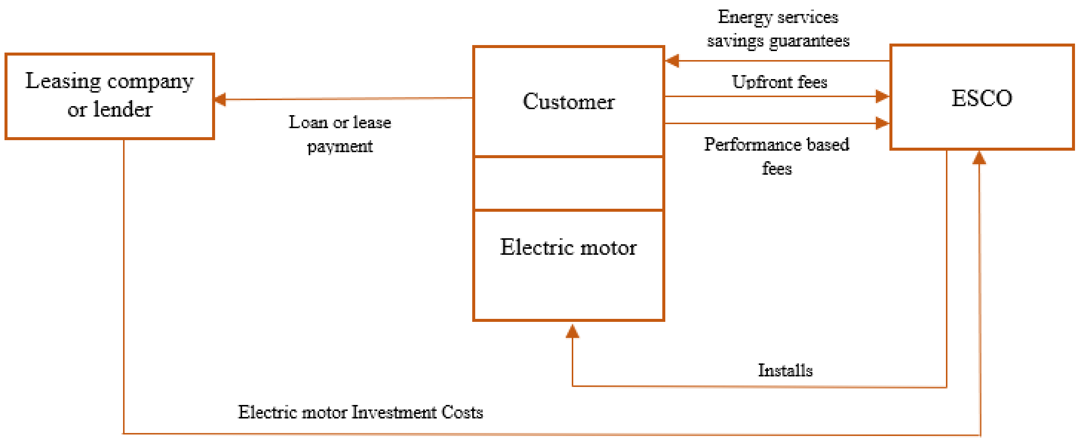


Figure 7-2: Energy Performance Contract business model: Guaranteed-Savings

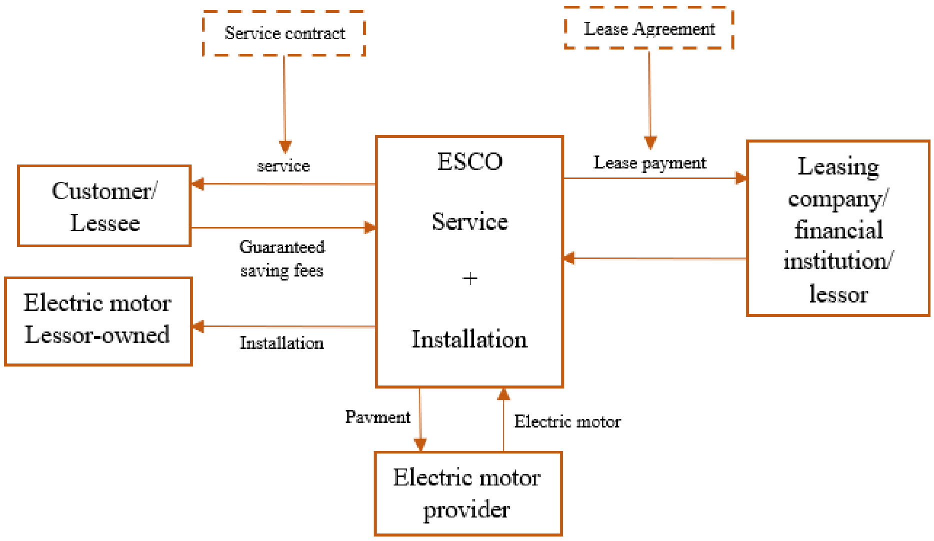


Figure 7-3: Energy Performance Contract business model: Shared Saving (Pay-as-You-Save)

8. RISK AND MITIGATION MEASURES

The risk identified, their impact level and the mitigation measures to taken are indicated in the Table 8-1 below.

Table 8-1: Risks, impact level and mitigation measures

No.	Risks	Rating	Mitigation Measures	Responsibility
1	Lack of awareness in commercial and industry electric motor end-users on the significance of energy savings obtained from the implementation of proposed MEPS	High	▪ Guidebook on savings for motors and help in capacity building. Covering the following topics • Motor lifetime costs • Motor Loading • Higher efficiency models and standards • Loss of efficiency repair and the resulting life cycle cost • Motor management policy (MMP) including o Motor Purchase Policy o Motor Efficiency Standards o Motor Replacement Plan o Rewinding Standards o Motor Inventory Optimization o Predictive/preventive maintenance o Condition monitoring	EEA
2	Unwillingness of electric motor end-users to buy energy-efficient motor due to high initial cost may lead to failure of implementation of the proposed MEPS	High	▪ Encourage and assist electric motor end-users to make real time and informed decision making when buying energy efficient electric motor including Web site support. ▪ Awareness creation on available financing, incentives and government implementation programs. ▪ Introduce a national campaign in the country to encourage greater use of higher efficiency motors through television, radio and social media campaign.	EEA and stakeholders

No.	Risks	Rating	Mitigation Measures	Responsibility
3	Inadequate incentives and lack of financing set aside for importers and end-users investing in an energy-efficient electric motor.	Medium	▪ Establish and look for financing sources and mechanisms for the implementation of MEPS ▪ EEA, MoWIE, and MoF, and other stakeholders such as the development bank of Ethiopia and microfinance institution and revolving fund administration to secure medium to long term financing for the implementation program	EEA, MoWIE MoF, DBE and financial institutions
4	Low technical capacity and ineffective stakeholder coordination	Medium	▪ Series of capacity building activities to help remove technical barriers to the implementation of MEPS and regular meetings with the stockholders to exchange work programs and implementation plans	EEA and stakeholders
5	Increase in Illegal trade/ contraband of inefficient electric motors	Medium	▪ Monitoring illegal or contraband injection of inefficient electric motors in the country through and serious implementation of PVoC and labelling of electric motors	EEA, ECC
6	Poor electricity supply quality that may severely affect energy efficient electric motors resulting in customer dissatisfaction	Medium	▪ Improve the electric supply quality ▪ Motor end-user's protection programs by the government.	EEA and EEU
7	Delay in implementation of MEPS	Low	▪ Include the new MEPS strategy in national agenda papers ▪ Initiate round table discussions with stakeholders	EEA

9. CONCLUSION AND RECOMMENDATION

9.1. Conclusion

This study of energy efficiency assessment and MEPS proposition for induction electric motors has been conducted by collecting data at forty three sample industrial sector and engineering factories, forty commercial premises (Milling houses), eight electric motor importers, four maintenance service providers and government institutions like Ethiopian Customs Commission, Ministry of trade, Ministry of industry, Ethiopian Electric utility, Ethiopian Electric Power and Central statistics Authority. The number, capacity, pole number and efficiency classification of electric motors installed and being imported to the country and their associated energy demand has been assessed based on the current market conditions. Global and national best practices and country experiences on electric motor regulations and MEPS setting have been assessed. MEPS has been proposed based on adopted Ethiopian standards and by assessing the impacts of setting the MEPS to higher efficiency levels on consumers, commercial premises and nation wise.

The number of Induction electric motors ranging from 0.75kW to 375kW on existing and newly established factories and milling houses in the country is estimated to be 126,912. The quantity and IEC efficiency classes of the installed motors is found to be IE0 - 82.16%, IE1- 3.56%, IE2-10.82%, IE3 - 3.39% and IE4 - 0.06%. The energy consumption of electric motors in Ethiopia is estimated to be 4,044.36 GWh/yr in the year 2018. The import data indicated about 105,933 motors have been imported in the years 2016 to 2020. Imported motors constitute 86.6% - IE0 and 13.4% - IE1 in the year 2020. There is a one and half to twofold price difference between same power and country of origin of IE0 and IE1 motors respectively in the market indicating the significant quality differences.

The impact analysis of transition of import motors to MEPS of higher efficiency classes indicated that IE2 MEPS shows equal simple payback period as compared to IE3 MEPS and better than that of IE1 MEPS. The upfront cost of electric motors for IE2 is between that of IE1 and IE3. The country level impact of setting the MEPS indicated that there will be energy savings of 334.57 GWh/yr, 415.57 GWh/yr, and 472.74 GWh/yr for the IE1 MEPS, IE2 MEPS and IE3 MEPS respectively.

The peak power demand savings under the IE1 MEPS, IE2 MEPS and IE3 MEPS scenarios are estimated to be 79.0, 98.3 and 112.1 MW respectively. This level of power demand reduction will reduce the Maximum demand charge currently being paid by almost all industrial consumers.

The monetized benefits of IE1 MEPS, IE2 MEPS and IE3 MEPS for energy consumption saving are estimated to be Birr 532.5 Mill/yr, Birr 662.5 Mill/yr, Birr 755.4 Mill/yr respectively. The peak power demand charge saving for the IE1 MEPS, IE2 MEPS and IE3 MEPS is about Birr 15.8 Mill/month, Birr 19.67 Mill/month and Birr 22.42 Mill/month respectively.

IE2 MEPS is proposed as it is the modest MEPS having better simple pay back, and higher energy and peak demand savings. There will be saving from 1,568 kWh/yr (for 3 kW motor) to 6,272kWh/yr (for 18.5 kW Motor) per motor if MEPS is set to IE2. The sensitivity analysis for IE2 MEPS for the 11Kw motor showed that the simple payback period decreases significantly for increase of electricity tariff up to 125% while it changes by a small value for tariff changes beyond this value. The Life Cycle Cost analysis indicated that 3,702 annual operating hours, it will cost the end-users an annualized additional 2,254 birr to transition to IE2 motor and save energy amounting to 8,607 birr resulting in a 6,353 birr net revenue per motor.

Revolving fund business model in conjunction with Partial Credit Guarantee (PCG) is proposed at the early stage of financing energy efficiency of electric motors and guarantee fee raised either by the customer or ESCO is applied to reduce financial institutions' perceived risks. After the implementation and maturing of the energy efficiency financing of electric motors with the revolving fund & PCG model above, the EPC - shared and guaranteed savings models (ESCOs) may be introduced without the revolving fund and PCG mechanisms.

Implementation schedule of IE2 MEPS by mid-2023 for both imported motors and new factory installations have been proposed. Setting the MEPS for electric motors to IE2 level saves significant amount of energy for consumer and the nation. Based on the assessment made, there is an urgent need to implement MEPS on electric motors in the county as the efficiency of 82.16% of installed electric motors are below standard efficiency and the current electric motor market is not in a good shape.

9.2. Recommendations

The following recommendations have been made regarding data collection for energy efficiency assessment and future MEPS determinations.

- Most factory owners, technical managers, technicians, importers and maintenance service providers are no aware about Energy Efficiency in electric motors. These stakeholders shall update with the benefits of energy efficient electric motors and the current international trends and regulations underway in the country.
- In order to have a proper data base of imported electric motors in the country, an arrangement shall be made between EEA and ECC in that an importer shall secure detailed Commercial invoice from suppliers (including Efficiency and Efficiency class) and ECC shall transfer Customs declarations to EEA after customs processing is completed. This data shall indicate types, ratings, speeds, no of poles, efficiency and efficiency classes of electric motors imported to the country per import.
- EEA shall have agreement with Ethiopian investment commission, Ministry of trade and Ministry Industry to have control and prior approval of efficiency classes of motors attached to motor drives before importation of factory machineries.
- In order to assess the status of electric motors in the country when and as needed factories and major business premises employing electric motors shall be directed to keep proper and updated inventory of electric motors to be delivered to EEA per year. This shall include Power, no of Poles, speed, IEC Efficiency classifications, operating hour, and rewinding made per motor.
- Factory and commercial premises shall be directed to conduct motor load and efficiency analysis for each motor operating more than 1000 hours per year. Motor load and efficiency analysis shall be made on all major working motors as part of preventive maintenance and energy conservation program. As a result:
  - Motors that are moderately oversized and underloaded shall be replaced with more efficient, properly sized models.
  - Motors that are properly sized but standard efficiency shall be replaced with energy-efficient models when they fail.
- Issuance of Regulation/Directive regarding rewinding of electric motors is necessary in order to keep the quality of electric motor rewinding services.

- Government purchased electric motor shall comply with the implementation schedule of the proposed MEPS. EEA and the Public Procurement & Property Administration Agency shall define procedures that government purchases are aligned with the electric motor energy efficiency program of the country.
- Import of improved efficiency motors will be promoted if market completion among importers is strengthened and importers are incentivized through different mechanisms. This includes annual recognitions, web site advertisements, announcing to the end user the types of energy efficient motors available in the market.
- The availability of online reference and guideline on EEA web site on the regulation, benefits and frequently asked questions on acquiring Energy efficient motors.
- The establishment of electric motor testing facility in Ethiopia in the future would avoid any fraudulent PVoC operations and assures self-sufficiency of the country.
- It is recommended that the recurrent MEPS updated every five years, depending on technology trends and the global market.

REFERENCE

Almeida, A. T. De *et al.* (2015) 'From laggard to world leader – the role of policies in the EU motors and drives market transformation', *Eceee 2015*, pp. 1549–1557.

CLASP (2005) *Energy-Efficiency Labels and Standards: A Guidebook for Appliances, Equipment, and Lighting*.

Danas Electrical Engineering (2015) *Project document on Electric Motor Energy Efficiency Standards and Labeling.*

Danielle, C. (2020) *What are current and future MEPS for electric motors ?* Available at: https://www.motioncontroltips.com/what-are-current-and-future-meps-for-electric-motors/.

EU (2019) 'COMMISSION REGULATION (EU) 2019/1781', pp. 48–119.

Falkner, H. and Shane, H. (2011) *WALKING THE TORQUE: Proposed work plan for energy-efficiency policy opportunities for electric motor-driven systems*, *IEA*. Available at: http://www.abhatoo.net.ma/index.php/fre/content/download/18421/330602/file/TRANSPORT_ENERGY_EFFICIENCY.pdf.

Gilbert.A, M. and Douglass, J. G. (1996) *Energy efficient electric motor selection handbook*, *Motor Challenge Program (U.S.)*.

Global petrol prices (2020) *Electricity prices*. Available at: https://www.globalpetrolprices.com/electricity_prices/.

Grundfos Motors (2004) *Motor book*.

Harrington, L. and Waide, P. (2004) 'Labels and Standards for Energy', *Encyclopedia of Energy*, 3, pp. 599–611. doi: 10.1016/b0-12-176480-x/00471-x.

IEA (2016) 'World Energy Outlook 2016'.

IEA (2019) 'Multiple Benefits of Energy Efficiency', *International Energy Agency*, (30), pp. 1–9.

IEC (2016) *Electric motors: Increasing the efficiency of electric motors - one of the biggest energy efficiency opportunities*, *IEC*. Available at: https://www.iec.ch/government-regulators/electric-motors.

Kebede, F. S., Bouyguet, S. and Olivier, J. C. (2020) 'Photovoltaic System Sizing for Reliability Improvement in an unreliable Power Distribution System', *2020 15th International Conference on Ecological Vehicles and Renewable Energies, EVER 2020*, 2020-Janua. doi: 10.1109/EVER48776.2020.9243063.

Magallón, D. *et al.* (2019) *Manual of financing mechanisms and business models for energy efficiency*.

Rita, W. (2020) *Topmotors Market Report Switzerland 2020*.

Sipma, J. M., Cameron, L. R. and Ambarita, H. (2015) *Energy efficient electric motor systems in Indonesia*.

Tobias, F. and Wolfgang, E. (2012) *Energy efficiency in electric motor systems: Technology, saving potentials and policy options developing countries*, *UNIDO*.

TopMotors (2019) 'New motor technologies', pp. 1–10.

Tsybikov, B., Beyerleyn, E. and Tyuteva, P. (2016) 'Comparison of energy efficiency determination methods for the induction motors', *MATEC Web of Conferences*, 91. doi: 10.1051/matecconf/20179101034.

U. Brunner, Werle, R. and Werkhoven, M. van (2012) *Electric motors: Increasing the efficiency of electric motors - one of the biggest energy efficiency opportunities*, *IEC*. Available at: https://www.iec.ch/government-regulators/electric-motors.

UNIDO (2018) *Manual for Industrial Motor Systems Assessment and Optimization*.

Waide, P. and Brunner, C. U. (2011) *Energy-Efficiency Policy Opportunities for Electric Motor-Driven Systems*, *Internationale energy agency*.

WSU Energy Program and National Renewable Energy Laboratory (2014) *Continuous Energy Improvement in Motor Driven Systems: A GuideBook For Industry*.

APPENDIX

Appendix A: Summary of Electric Motors by Quantity, No of Poles, And IE Classifications in Ethiopian Factories

Power (kW)	Qty	% Qty	Number of poles	Qty by pole	IE Efficiency Classification				
					IE0	IE1	IE2	IE3	IE4
0.75	7803	6.15%	2	514	514	0	0	0	0
			4	6731	3070	352	1784	1525	0
			6	420	126	0	294	0	0
			8	103	103	0	0	0	0
			unknown	35	16	0	0	0	2
1.1	10038	7.91%	2	680	560	0	65	56	0
			4	7837	2766	409	4630	32	0
			6	529	529	0	0	0	0
			8	0	0	0	0	0	0
			unknown	992	622	0	0	0	39
1.5	10069	7.93%	2	1544	1314	178	33	19	0
			4	7253	5850	626	234	543	0
			6	1070	1046	0	24	0	0
			8	20	20	0	0	0	0
			unknown	183	183	0	0	0	0
2.2	7414	5.84%	2	2817	2629	23	125	40	0
			4	3522	3136	273	67	47	0
			6	772	687	10	10	66	0
			8	0	0	0	0	0	0
			unknown	304	123	0	0	0	19
3	5393	4.25%	2	2046	1769	24	213	40	0
			4	2260	1752	302	193	13	0
			6	894	884	0	10	0	0
			8	40	40	0	0	0	0
			unknown	154	116	0	0	0	4
4	11503	9.06%	2	7622	7056	203	182	182	0
			4	2593	2314	42	235	3	0
			6	277	277	0	0	0	0
			8	16	16	0	0	0	0
			unknown	996	910	0	0	0	9
5.5	6869	5.41%	2	2306	1802	148	155	201	0
			4	4094	3254	191	466	184	0
			6	314	306	8	0	0	0
			8	18	18	0	0	0	0
			unknown	138	138	0	0	0	0
7.5	7878	6.21%	2	3866	2919	19	451	469	1
			4	2947	2508	85	261	93	0
			6	947	947	0	0	0	0

Power (kW)	Qty	% Qty	Number of poles	Qty by pole	IE Efficiency Classification				
					IE0	IE1	IE2	IE3	IE4
			8	44	44	0	0	0	0
			unknown	74	74	0	0	0	0
11	22147	17.45%	2	1451	1016	185	108	142	0
			4	20038	17916	38	2036	48	0
			6	555	552	0	3	0	0
			8	6	6	0	0	0	0
			unknown	98	50	0	0	0	5
15	6589	5.19%	2	1196	1027	60	43	67	0
			4	5063	4800	60	175	29	0
			6	200	179	10	12	0	0
			8	48	48	0	0	0	0
			unknown	82	82	0	0	0	0
18.5	18505	14.58%	2	279	142	0	41	96	0
			4	16905	16539	151	193	22	0
			6	1234	776	0	458	0	0
			8	40	0	0	40	0	0
			unknown	48	48	0	0	0	0
22	3267	2.57%	2	856	416	55	337	49	0
			4	1569	1470	77	10	13	0
			6	767	767	0	0	0	0
			8	48	48	0	0	0	0
			unknown	27	27	0	0	0	0
30	2720	2.14%	2	677	537	0	67	73	0
			4	1498	1194	201	79	24	0
			6	491	449	0	42	0	0
			8	0	0	0	0	0	0
			unknown	55	55	0	0	0	0
37	1315	1.04%	2	161	107	0	25	29	0
			4	954	786	129	24	16	0
			6	170	118	0	53	0	0
			8	0	0	0	0	0	0
			unknown	30	30	0	0	0	0
45	1204	0.95%	2	195	152	0	18	26	0
			4	981	967	6	8	0	0
			6	16	16	0	0	0	0
			8	4	4	0	0	0	0
			unknown	8	8	0	0	0	0
55	1313	1.03%	2	160	58	0	103	0	0
			4	816	394	418	4	0	0
			6	224	224	0	0	0	0
			8	0	0	0	0	0	0

Power (kW)	Qty	% Qty	Number of poles	Qty by pole	IE Efficiency Classification				
					IE0	IE1	IE2	IE3	IE4
			unknown	114	114	0	0	0	0
75	993	0.78%	2	285	154	55	38	38	0
			4	596	510	65	10	12	0
			6	0	0	0	0	0	0
			8	47	47	0	0	0	0
			unknown	67	67	0	0	0	0
90	306	0.24%	2	30	10	0	11	10	0
			4	195	172	9	10	4	0
			6	49	49	0	0	0	0
			8	0	0	0	0	0	0
			unknown	33	33	0	0	0	0
110	565	0.44%	2	70	8	0	53	10	0
			4	379	207	32	75	66	0
			6	116	78	0	38	0	0
			8	0	0	0	0	0	0
			unknown	0	0	0	0	0	0
132	284	0.22%	2	117	57	0	60	0	0
			4	118	91	6	21	0	0
			6	50	50	0	0	0	0
			8	0	0	0	0	0	0
			unknown	0	0	0	0	0	0
160	206	0.16%	2	33	33	0	0	0	0
			4	159	142	9	8	0	0
			6	6	5	1	0	0	0
			8	5	5	0	0	0	0
			unknown	3	3	0	0	0	0
185	75	0.06%	2	16	0	0	16	0	0
			4	38	38	0	0	0	0
			6	21	21	0	0	0	0
			8	0	0	0	0	0	0
			unknown	0	0	0	0	0	0
200 up to 375	460	0.36%	2	44	34	0	10	0	0
			4	321	275	42	4	0	0
			6	76	60	0	16	0	0
			8	20	20	0	0	0	0
			unknown	0	0	0	0	0	0
Total	126912			126912	103745	4496	13669	4280	79
Percentage	100%			100%	81.75%	3.54%	10.77%	3.37%	0.06%

Appendix B:Motor name plate and field data collection form

Employee Name ________________________ Facility/Location __________________

Company _____________________________ Department ______________________

Date _________________________________ Process __________________________

General Data

Serving Electrical Utility _____________________________________

Energy Rate ____

Application ____

Coupling Type ____

Motor Purchase Date / Age ____________________________________

Rewound Yes No

MOTOR NAME PLATE DATA

1. Manufacturer ____
2. Serial Number ____
3. Manufacturer/Model ___________________________________
4. IEC Standard class______________________________________
5. Size (kW) ____
6. Speed (rpm) ____
7. Voltage Rating ____
8. Amperage ____
9. Power Factor ____
10. Annual Operating Time __________________________________
11. Country of Origin ______________________________________
12. Number of times motor rewound __________________________________

Appendix C: Questionary on Electric Motor Energy Efficiency Assessment in Ethiopian Market, data from Importers

Electric Motor Energy Efficiency Assessment in Ethiopian Market data from Importers

1. Name of Importer: ____
2. Address of Importer: City_____________, Woreda__________, House No.___________, Tel. No________________
3. Contact person. ________________________________. Tel ______________________
4. Types and quantity of electric motors Imported in 2012 EC (2019-2020GC) in ascending order by Power of motors and market share.

No	Motor Power		Quantity imported	Efficiency of motors	IEC ratings on Nameplate					Quantity Sold	Market share (%)	Average price of single motor (Birr)
	KW	HP			IE0	IE1	IE2	IE3	IE4			
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												

5. Quantity of electric motors Imported in 2012 EC (2019-2020GC) in ascending order by number of Poles.

No	No of Poles	Quantity imported	Quantity sold	Market share (%)
1	**2**			
2	**4**			
3	**6**			
4	**8**			

6. Country of origin of motors in descending order for quantity of motors imported
   a. ______________________
   b. ______________________
   c. ______________________
   d. ______________________

7. What is your opinion on Pre-Export Verification of Conformity to Standards on electric motors?
____
____
____
____
____

8. Most common application of the motors imported in descending order for quantity of motors imported
    e. ____________________
    f. ____________________
    g. ____________________
    h. ____________________

9. What are the most common problems and challenges faced on the import, distribution and sales of electric motors?
____
____
____
____
____
____
____

10. Does the Importer believe that standardizing of Electric Motors is useful to his/her business?
    i. Yes
    j. No
    k. Indifferent

Appendix D: Questionary on Electric Motor Energy Efficiency Assessment in Ethiopian Market data from Maintenance/Repair Service Providers

Electric Motor Energy Efficiency Assessment in Ethiopian Market data from Maintenance/Repair Service Providers

1. Name of Maintenance Service Provider: ______________________________________
2. Address: City____________, Woreda_________, House No.__________,Tel. No_______________
3. Contact person. ______________________________. Tel ____________________
4. Types and quantity of electric motors rewound in 2012 EC (2019/2020GC) in ascending order by Power of motors.

No	Motor Power		Quantity repaired	Average price for single motor rewinding (Birr)
	KW	HP		
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				

5. Quantity of electric motors rewound in 2012 EC (2019-2020GC) in ascending order by number of Poles.

No	No of Poles	Quantity repaired
1	**2**	
2	**4**	
3	**6**	
4	**8**	

6. Country of origin of motors in descending order coming for repair.
   a. ____________________
   b. ____________________
   c. ____________________
   d. ____________________

7. Most common application of the motors repaired in descending order.
    a. ____________________
    b. ____________________
    c. ____________________
    d. ____________________

8. What are the most common problems and solutions of motors coming for repair?

No	Most common Motor problem	Solutions

9. Does the repair service provider believe that standardizing of Electric Motors is useful to his/her business?
    a. Yes
    b. No
    c. Indifferent

10. Additional Notes
    ____
    ____
    ____
    ____
    ____