FINAL REPORT

Cost Benefit Analysis to introduce Minimum Energy Performance Standards (MEPS) for Electric Motors in South Africa

Report prepared for CLASP for submission to the Department of Mineral Resources and Energy (DMRE) and the South African National Energy Development Institute (SANEDI)

2021

mineral resources & energy
Department:
Mineral Resources and Energy
REPUBLIC OF SOUTH AFRICA

sanedi
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This report was funded by CLASP
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Efficient Appliances for People & the Planet

December 2021

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Acronyms

BAU Business as Usual
CBA Cost-Benefit Analysis
CEMEP European Committee of Manufacturers of Electrical Machines and Power Electronics
DFFE Department of Fisheries, Forestry, and the Environment
DMRE Department of Mineral Resources and Energy
DTIC Department of Trade Industry and Competition
EE Energy Efficiency
EU European Union
EM Electric Motors
GHG Greenhouse Gases
HVAC Heating, Ventilation, Air Conditioning
INDC Intended Nationally Determined Contribution
IEC International Electrotechnical Commission
kWh kilowatt-hour
$MtCO_2$ Million Tons of CO_2
NEES National Energy Efficiency Strategy
NEMA National Electrical Manufacturers Association (USA)
NRCS National Regulator for Compulsory Specifications
NCPC National Cleaner Production Centre
OEM Original Equipment Manufacturer
PSC Project Steering Committee
S&L Standards & Labelling
SABS South African Bureau of Standards
SANEDI South African National Energy Development Institute
SANS South African National Standard
SDoC Self Declaration of Conformity
StatSA Statistics South Africa
UN United Nations
VC Compulsory Specification

1 Overview and Background to the Study

1.1 Problem Statement

Electric motors (EM) are widely acknowledged as accounting for at least 45-50% of global energy consumption (1). Used in many applications and across all industries, they are commonly referred to as the ‘workhorse of modern industry’. Thus, due to the omnipresence of EM, international best practise is to regulate product efficiency through minimum energy performance standards (MEPS). Here in the South African economy, which is built on energy-intensive industries (mining, chemicals, iron and steel), and where 32 companies consume about 40% of the country’s electrical energy (2), the context is ideal for regulating the energy efficiency (EE) of EM.

However, no such legislation exists in South Africa.

1.1.1 No regulation means the benefits of EE are not being exploited

In many instances, resistance to EE measures has been driven by perceptions that higher efficiency leads only to marginal savings. These should not apply to EM however, where the ubiquity and long operating hours of EM, means that a mere 2% or 3% efficiency improvement is material. For example, in certain economic sectors, it is not uncommon for motors to operate between 4 000 to 6 000 hours per annum (11 to 17 hours per day). Today, this has now been recognised by large energy intensive industrial and manufacturing companies, who see the extensive financial and environmental benefits of efficient motors and have introduced internal policies that mandate minimum efficiency ratings.

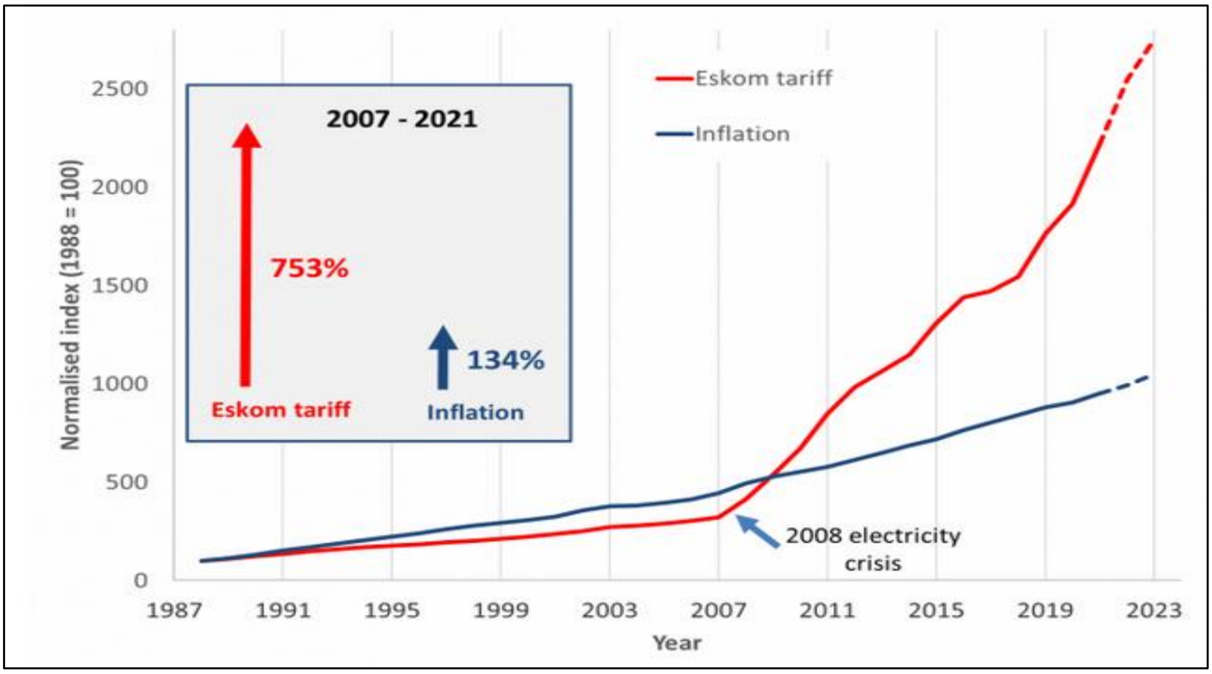
In 2021, five electric motor efficiency standards exist – represented on a scale from 1 through to 5, from lowest to highest, as shown in Figure 1 (1). Notably, motors that do not meet any of these standards – either by not meeting the minimum IEC (International Electrotechnical Commission) efficiency threshold, or not in possession of a test report from an accredited laboratory – are commonly referred to as IE0 motors and have poor efficiency ratings.

Figure 1: Electric motor efficiency classes

IE1	IE2	IE3	IE4	IE5
Standard Efficiency	High Efficiency	Premium Efficiency	Super Premium Efficiency	Ultra Premium Efficiency

Efficiency ratings vary according to motor size, where smaller motors (0.75 to 10 kW range) can deliver savings as high as 15 or 16% between the IE ranges (3), whereas the savings from large motors (300kW) decrease to 3% but remain meaningful, given their size, operational hours, and lifespan. In this, the research has found that the design life target of premium brands is as high as 20 years. Accordingly, there are thousands of motors currently in operation, which have been bought in the last 5-15 years, and that will still be in use for the following 5-15 years. Unfortunately, a high percentage of these are IE1 or below, which will have a negative impact on industrial competitiveness. Inefficient EM make local manufacturers and industries less competitive, due to their increased operational costs – and especially so, given the high electricity tariff increases the economy has endured from 2007 (Figure 2). These have increased by 753%, whilst the inflation climb over this period only totalled 134%.

Figure 2: Electricity tariffs increases versus inflation in South Africa (2007 to 2021)

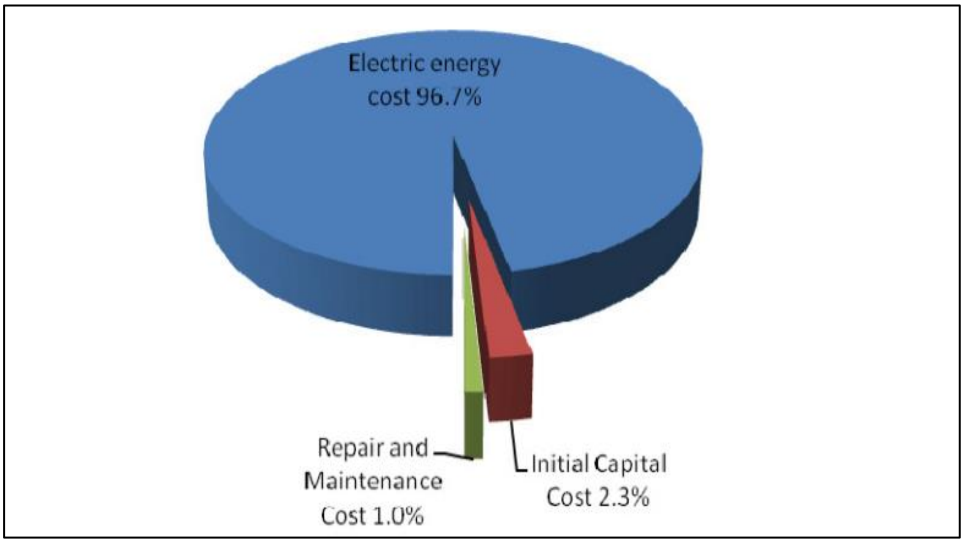


Source: Moolman (2021)[1]

1.1.2 Majority of South African EM sales are in the lower energy performance categories

Purchasing decisions, particularly in distressed economic periods and exacerbated by COVID-19, are primarily price driven. However, especially for EM, this thinking is particularly unwise, because EM-driven systems cost far more to operate over their lifetime, than the initial cost of purchase. This is shown by an EU study of an IE3 11kW motor, graphically illustrated below.

Figure 3: Life cycle cost of 11kW IE3 motor with 4 000 operating hours per year



Source: de Almeida (2008) (4)

[1] https://www.poweroptimal.com/2021-update-eskom-tariff-increases-vs-inflation-since-1988/

In this context, experience in other sectors has already clearly shown that deeper consumer understanding of the long-term cost and savings implications of greater EE, accelerates the penetration of more efficient apparatus into the market. The lack of available information around EM efficiency, is therefore a primary impediment in South Africa. To address this, international best practise uses energy label programmes based on regulated MEPS, which are supported by academic research and awareness campaigns. One such example includes a 2017 United for Efficiency Publication, which was used to advance perceptions on EE, as shown in the box below:

A relatively small improvement in the energy efficiency percentage is equivalent to a substantial reduction of energy losses. By way of illustration, in the example of a 45 kW, 4 pole, 50 Hz motor, the difference in the efficiencies of IE4 and IE1 motors is only 3.7 per cent, but this is equivalent to a 47 per cent reduction in energy losses.

EFFICIENCY CLASS	LOSSES (WATTS)	LOSS REDUCTION (%)	ENERGY EFFICIENCY (%)
IE1	4,073		91.7
IE2	3,335	-18	93.1
IE3	2,771	-32	94.2
IE4	2,170	-47	95.4

U4E (2017) (5)

In South Africa, a DMRE study undertaken in 2018, (further discussed in sections that follow and henceforth referred to as the Urban Econ report), found a strong business case for users to opt for IE3 over IE1 motors, as shown in

Table *1*. The cost premium for an IE3 motor in 2018, was approximately 15%, except for the 300kW (19%); and these figures align with the findings of this research undertaken in 2021. Here, the straight payback period for all models selected was less than one year, assuming a moderate (low) 3 000 hours of annual usage. This clearly illustrates that while IE1 motors have a cheaper purchase cost, they incur higher operational costs (electricity usage) when compared to IE3 motors. This makes standard motors more expensive in the long-term; and higher EE remains attractive, even if a conservative life expectancy of 10 years is assumed for the motor.

Ultimately, a life-cycle-cost (LCC) analysis clearly proves that the cost of owning a motor throughout its operational life, is more important than the initial purchase-cost; and stresses the urgency of this information being communicated to industry and buyers of EM.

Such data also provides a strong driver for formally introducing MEPS for EM in South Africa; and the robustness and validity of research findings is thus a major priority of this study. This is because they provide a strong tool in both justifying the introduction of MEPS and altering market perceptions in favour of higher EE as an operational savings imperative. Their accuracy and veracity must this be impeccable.

Table 1: Straight payback period of IE3 electric motors for selected sizes (2018)

Motor size	IE1 Motor (3 000 hours)			IE3 Motors			Impact IE1 to IE3 Motors			
	Energy Usage (kWh)	**Energy cost (R3/kWh)**	**Average cost (2,4,6 pole)**	**Energy Usage (kWh)**	**Energy cost (R3/kWh)**	**Average cost (2,4,6 pole)**	**Energy Savings (kWh)**	**Energy Savings (A)**	**Add Capital Cost (B)**	**Payback (years) (B/A)**
0.75	2 261	6 783	**R3 601**	2 003	R6 009	**R4 141**	258	R774	**R540**	0.7
5.5	15 796	47 388	**R9 359**	14 954	R44 862	**R10 792**	842	R2 526	**R1 434**	0.56
11	35 080	105 240	**R12 311**	33 635	100 905	**R14 191**	1 445	4 335	**R1 880**	0.43
45	172 304	516 912	**R72 388**	167 977	503 931	**R83 256**	4 327	12 981	**R10 868**	0.83
90	373 049	1 119 147	**R124 918**	364 962	1 094 886	**R143 679**	8 087	24 261	**R18 762**	0.77
300	1 484 043	4 452 129	**R296 832**	1 455 247	4 365 741	**R353 878**	28 796	86 388	**R57 047**	0.66

Source: Urban Econ (2018) (6) and own calculations.

1.1.3 Motor efficiency versus system efficiency – barrier and opportunity

From the outset, it is important to note that total system efficiency, and not merely that of the motor, is the ultimate goal. An EM converts electrical energy into mechanical energy, which is then used to complete tasks for industrial, commercial, residential and personal needs, such as driving fans, pumps, machine tools, household appliances, pool pumps, and even electric wrist watches. Thus, even though EM are a key component of a system, they can serve no function on their own. It therefore follows that, notwithstanding that an EM powers a system, it is not the sole contributor to its functionality, efficiency and overall performance. Indeed, the US Department of Energy (7) identifies three categories to improve system efficiency: power quality; motor and transmission efficiency; and, monitoring and maintenance. This strongly highlights the importance of a system-based approach to maximising energy savings, and completely aligns with the South African experience too.

The importance of a system-based approach was demonstrated during Eskom's demand side management (DSM) Energy Efficiency Motor Roll-out Programme in 2008 and 2009 which retrofitted 1 088 standard motors with higher efficiency motors. To quantify the Programme's benefits Eskom appointed North West University in 2011. A key finding of the report was that: "*Replacing a standard motor with an energy efficient motor did not necessarily result in energy savings. The whole motor driven system must be considered to first make sure that the whole system is optimised*" (8)

Of course, this then begs the question as to whether MEPS is an appropriately effective policy instrument to deliver meaningful energy savings from EM. On the one hand, Section 1.1.1 explains why this is the case – high volumes and long operating hours, with sufficiently sized energy savings. On the other hand, the premium paid for a higher efficiency motor, particularly if still part of a relatively inefficient overall system, may significantly compromise the net economic benefit and deliver significantly reduced cumulative energy savings – possibly making it not a worthwhile investment for the consumer. Fortunately, the motor versus system efficiency issue isn't unique to South Africa. Over 40 countries not only successfully regulate energy performance of EM, but have also strengthened the MEPS, as many as three to four times, IE0 to IE4, over a 20-to-30-year period. And it is thus instructive to gain an understanding of how this barrier is managed internationally, by harnessing insights gained from prior global experience.

Overall, recent academic literature confirms a shift towards system efficiency, in ascertaining how the whole system can be enhanced to achieve even greater efficiency gains (9; 10; 11). This is addressed in the literature review found in Annex 2 (country case studies). This approach was raised by two industry experts during interviews[2], who believe the improvement of overall system design is crucial to realising and maximising energy savings. As already explained above, this comes on the back of instances where the replacement of unregulated EM with highly efficient motors, has not yielded the expected results, and where inefficiencies in the design of motor-driven systems, (pumps, fans, compressors, hoists) negate the realisation of full efficiency benefits. Most importantly however, the projected energy savings are still of a sufficient magnitude to drive countries to continue to implement policies which regulate, and continuously strengthen, motor efficiency – whilst simultaneously seeking to expand their programmes to incorporate system efficiency. The question then is how best to do this. Is it reasonable or practical to regulate overall system design? Given the heterogenous nature of this sector, such an approach would undoubtedly add costs and complexity, and possibly stifle business development and investment. On this basis, it would (understandably) be resisted by industry and the market – manufacturers, distributors and consumers.

To date, the Chinese government stands alone in introducing regulations that target overall system design efficiency; implementing a minimum standard for three types of motor-driven systems in 2010. This system is attributed to have removed 60GW of old and inefficient motors by 2015, with a total target of 450 GW to be replaced or removed (12). The American NEMA indicates that while system efficiency is beneficial, it is incredibly difficult to regulate and would be problematic for multiple reasons (13; 14). This view was also confirmed by local industry experts[3] and is discussed in more detail in the annex of case studies. However, the case studies also found that all countries agree that an effective and regularly updated communication and awareness campaign, which provides easily accessible information to all buyers of EM about the importance and economic benefits of overall system design, goes hand in hand with successfully regulating energy performance.

Finally, it is important to note that globally, EM regulation was first introduced in the early 1990's. Most countries therefore now have more than 20 years of experience in MEPS, energy labels, communication campaigns, energy saving analysis etc. This has now informed the view that MEPS are a necessary but insufficient condition, and that an overall system efficiency approach is needed, if the energy savings from EM are to be maximised. And today, South Africa, as a new entrant, has the opportunity to leverage from this global experience, which has generated significant research, best practise experience and insight, and that will be incorporated in the research findings and recommendations.

1.1.4 Other barriers - Winding of motors

As with all MEPS programmes, regardless of appliance type, the repair and pre-used sales sectors slow the speed at which government S&L policy objectives, usually aimed at transitioning the national market to higher efficiency equipment, can be achieved. Energy conservation targets are compromised if old and inefficient equipment finds its way to smaller and marginal businesses/households, who opt for lower upfront capital investment, and in so doing condemn themselves to substantially higher LCC, as demonstrated in Figure 3 in section 1.1.2.

Typically, S&L programmes do not seek to regulate the pre-used market, and governments make use of energy labels, awareness programmes and swop out incentive programmes, to accelerate the transition. However, these complementary are generally a function of available resources, and it must

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[2] Interview held with Mr K Steyn (formerly of Eskom) and Mr L Middelburg (electric motor expert and founding member of SANS technical committee)

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be accepted that this process must be managed, and that it takes time for older and inefficient stock to work its way out through natural attrition.

In this regard, a unique feature of the EM industry, is the common practise of rewinding. EM come with substantial capital investment and high operational costs and must be maintained. Rewinding is required when a motor's winding fails; with two possible outcomes: The first is to replace the motor, and the second, is to unwind the old rotor and stator windings, and to replace them with new ones. The capital cost of a new motor, especially larger sized motors (>20kW), may be prohibitive; making rewinding a cost-effective option. Rewound motors however, tend to lose efficiency performance; but recent technology advances in materials, process discipline and stringent quality assurance, can dependably match – and often improve – such electric motor efficiency. Moreover, repairs to an efficient motor (IE3 or better) provide a sensible, environmentally responsible, and economically preferable option. Yet not all repair shops follow these rewinding process protocols, or have the equipment needed to ensure that efficiency is maintained (or even enhanced). Those that do, will naturally charge more for their service, to cover the costs of new machinery, training and certification (15) (16).

In this, the research undertaken[4], noted the low levels of accredited and reputable motor repair businesses, while raising concerns about the common practise of motors being resold through the 2[nd] hand market after multiple repairs' rewindings. An unintended consequence of this practise is that it recycles old motors through the South African economy and allows for motors to be used well below their advertised performance standards. And it was highlighted that this industry trend may be due to the lack of knowledge regarding the cost of ownership of EM. This barrier, however, is not wholly insurmountable; and the successes and failures of international trade partners, will be adapted to the local context and used to inform the recommendations of this study. This ensures that the best possible options are made available to the DMRE, and thus enable South African industry to realise the benefit of improved EM EE.

1.2. Rationale for the study

The rationale for this study must be understood within the context of the South African electricity crisis. This has been ongoing since 2007; with the prevalence of load-shedding, blackouts, supply shortages and continuous above-inflation electricity tariff increases (Figure 2) having a far-reaching impact on the South African economy. Here, addressing the electricity crisis, ultimately requires a combination of supply and demand-side interventions. For the former, the Integrated Resource Plan (IRP) is government's official schedule for generation expansion, with a 2020 determination by the DMRE Minister, now calling for the procurement of 11 813 MW of new generation (17). Regarding the latter, the DMRE has long recognised the meaningful contribution that EE and conservation can make to the country; and it is a key feature of the 1998 Energy White Paper, which specifically identifies S&L as a methodology. This was actualised in the 2005 National Energy Efficiency Strategy (NEES), which targeted a residential S&L programme as a key mechanism to achieve the energy efficiency target set for the residential sector.

South Africa's residential S&L programme commenced in earnest from 2010 when international funding was secured and used to establish MEPS and create appropriate EE labelling for multiple domestic electric appliances – namely, air conditioners (A/C), fridges and freezers, dishwashers, electric ovens, tumble dryers, storage water heaters and washing machines (18). These appliances are

[4] Interviews industry experts and major importers and distributors of electric motors in South Africa

covered by two Compulsory Specifications: VC9006 *Compulsory Specification for Hot Water Storage tanks for domestic use* and VC9008 Compulsory *Specification for Energy Efficiency and Labelling of Electrical and Electronic Apparatus*, which have been in place since 2016 and 2014 respectively.
The energy label then serves as the "public face" of the MEPS as set down by regulation, which through its mandatory display on appliances, is used to provide consumers with accurate information regarding the energy efficiency of an appliance before purchase (18). MEPS for light bulb have also been set and are covered by an optional energy label.

In this, MEPS create the regulatory 'push' for manufacturers to enhance EE performance of appliances, while labelling and consumer education create consumer 'pull' to promote EE product market penetration.

MEPS as a Policy Instrument

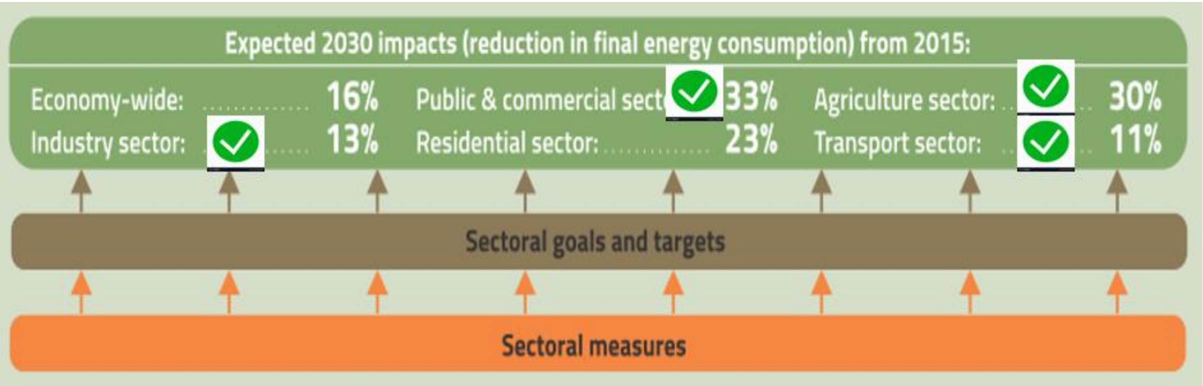
MEPS are a proven policy tool, adopted in developed and developing countries for their ability to deliver tangible energy savings. Indeed, in 2014 some 75 countries had legislated MEPS and energy labelling (66)**, of these as many as forty** (5) **having implemented some form of electric motor MEPS as a tool to transform the efficiency of their industries. The improved efficiency of electric motors is internationally accepted as an important component of efforts to reduce national energy consumption, realise the associated cost savings, and environmental benefits. Wiel and McMahon (1999)** (68) **identify the typical steps in the process of developing consumer product energy efficiency labels and standards:**

1. **Decide how to implement an S&L Programme**
2. **Develop testing capacity**
3. **Design and implement a labelling programme**
4. **Analyse and set standards**
5. **Design and implement a communication campaign**
6. **Ensure programme integrity**

1.2.1 EM as a priority candidate for MEPS

Based on the established success of the initial S&L programme, the post-2015 NEES, which set a final economy-wide energy consumption reduction target of 16%, has prioritised the expansion of the Programme. EM are integral to this expansion, as they are prevalent in four of the five sectors (Figure 4 below) – with the post-2015 NEES having set sector-specific targets for energy intensity improvements; including manufacturing and industry, which are expected to realise a 13% reduction in average specific consumption by 2030, relative to the 2015 baseline.

Figure 4: Post-2015 National Energy Efficiency Strategy 2030 Targets (19).



To achieve these targets, MEPS for EM are crucial, not only in the industrial sector, but also in the agricultural, commercial and transport sectors. Indeed, the preliminary findings of an existing DMRE study, (discussed further in the next paragraph below), acknowledge that EM in the 0.75 to 375kW range, only represent one tenth of the total range, but are responsible for more than two thirds of global industrial electricity consumption. This makes them the proverbial "low-hanging fruit" and a valid entry point for a national MEPS programme. Here, the DMRE in identifying EM as a key intervention in the post-2015 NEES, recommended several measures to work alongside the proposed MEPS, including: improved regulation of the EM repair industry; the use of import tariffs to reduce price differences between high and low efficiency motors; and the application of well-recognised S&L system for high efficiency motors, alongside an educational / information-sharing campaign, to inform consumers of benefits and enhance overall optimisation of system (19). These recommendations are supported by international EE policy literature and best practise methods; and will be proposed for use in South African national MEPS rollout.

Ultimately, this CBA market study thus takes direction from formal national government policy and has been commissioned to update and further inform the findings and recommendations of the DMRE study undertaken in 2018, mentioned in previous paragraphs. Titled, "*Review of South Africa's appliance energy classes and identification of the next set of electrical equipment for inclusion in the national standards and labelling project: New electrical appliances*" (6) it considered:

1. National policy objectives
2. Potential local manufacturing and job impacts
3. National, industry and consumer economic benefit analysis
4. Projected energy and greenhouse gas (GHG) savings.

Thus – based on the outcome of current analysis and as a furthering of the 2018 report's insights – EM MEPS recommendations, with an implementation schedule, will be proposed in this report.

1.2.2 Climate change as an overarching factor driving the need for MEPS

With 2021 as the year of the seminal COP26 climate summit – coming at a time where environmental calamities from floods, to droughts, unprecedented storms, coral bleaching and rampant wildfires, are exponentially escalating – the need to rapidly tackle climate change and its effects, is now top-of-mind in global awareness. South Africa is no exception, and government's commitments via the Nationally Determined Contribution (NDC) mechanism, are in line with the contemporary UN framework on Climate Change and ensure that GHG emissions reductions are now of national importance (20).

As regards EM in this domain, the EU has estimated that their rollout of MEPS for EM, will result in annual CO_2 savings of 40 million tonnes by 2030 (21); with similar savings achieved in other countries, as shown in the case studies discussed below. These results demonstrate that electric motor MEPS are quintessential to achieving CO_2 and GHG emissions reduction targets; while the EU estimates provide strong evidence for the implementation of electric motor MEPS in South Africa, by illustrating the scale of savings to be achieved (21).

GHG reductions from the DMRE's S&L programme are making, and can continue to make, a significant and growing contribution to reducing GHG emissions as per the NDC, which the DFFE released in September of this year. In this, the NDC mitigation targets are set in two periods: 2021-2025 and 2026-2030. This means that in September 2021, the DFFE updated the country's NDC target range for 2025, from its original value of 398-440 Million t CO2-eq, to a range of 350-420 Million t CO2-eq (20). And while this ambition is to be applauded, it does mean that every little bit of GHG emissions savings will be needed, due to the nature of local electricity production. To this end, the implementation of EM MEPS, provides a proven method to do so, whilst also improving the energy intensity of the South African economy, further unpacked in the next sections.

1.2.3 Advanced perceptions: Energy intensity and EE as the fundamental "First Fuel"

A fundamental concept that underpins all forms of generating savings, be they financial or in energy, is that seeking responsible ways to make more, should also be strongly partnered by intelligent ways of spending less. For too long however, the former has been centre stage as regards energy, with EE having taken a backseat to fossil fuel transitional technologies (such as gas) and renewables in contemporary energy debates. Indeed, prior to being known as the "first fuel", EE was referred to as the "hidden fuel".

This changed in 2013, when International Energy Agency (IEA) executive director, Maria van der Hoeven, rephrased EE from the "hidden fuel" into the "first fuel" during her report at the World Energy Congress in Korea (22). The IEA inaugural report argued that due the immense scale of the energy savings potential, EE should be regarded as the first fuel, ahead of the traditional order of fossil fuels, nuclear, and renewables (22). And today, advocates continue to contend, that with sufficient policy efforts and investments, large-scale energy and emissions savings can be achieved on an unprecedented scale.

Originally, the name "first fuel" stems from the idea that efficiency losses, if harnessed correctly, could nullify the need for new energy generation capacity (23; 22) – while simultaneously reducing the electricity consumption costs of existing industries and services. Here, the IEA reports that between 2000 and 2017, global energy savings related to improved efficiency, were equivalent to the total annual consumption of the EU (23). Most importantly, this improved efficiency reduces pressures on national governments to ensure energy security, while negating the need for large capital investments in new generation capacity. Crucially, EE improves overall energy intensity, which is a measure of the amount of energy consumed per unit of GDP and indicates the efficiency of a country's economic output (23). This is of particular importance, because high energy intensity will become increasingly prohibitive to exports, as blocs such as the EU begin to create trade barriers to products of countries with inordinately high energy intensity levels and GHG emissions.

1.2.4 The road ahead

Ultimately, the urgent need for, and immense advantages of, regulating the EE of EM, is in no doubt; and the DMRE has the advantage of being able to both advance its own previous research findings, while leveraging off over two decades of global insights and experience in this regard. And this then, is the core purpose of this report: To empirically demonstrate the financial benefits of efficient motors through a CBA (Cost Benefit Analysis) and harness available contemporary knowledge to tackle market barriers, and in so doing accelerate the transition.

2 Methodological Approach

The assessment was conducted following a Cost Benefit Analysis (CBA) framework, which is an internationally accepted methodology for the economic evaluation of the potential impacts of new regulations. This method uses quantitative data to model predicted impacts and account for variables in the decision-making process (24). CBA is a comparative approach; and the impacts of the proposed regulation to establish MEPS for EM have been defined as the 'policy option' scenario. This is then modelled against the baseline or 'business-as-usual' (BAU) to quantify the impact of the draft policy measure. Here, two policy scenarios will be modelled to illustrate the differing impacts of policy proposals (24). This is a data-driven decision-making process, which enables the evaluation of precise costs and benefits; and is done to determine the extent of overall net gain to be derived from the project. In addition to economic modelling to assess the potential impact of MEPS, the CBA uses inputs from a market analysis, stakeholder consultations and laboratory testing of motors sold in the market.

To illustrate the impacts on consumers and the economy, two models that were previously developed by Urban Econ were used. These include a model to calculate the energy savings at an individual product level (i.e., a 0.75kW motor with its own specifications), as well as estimating the potential benefits for the projected annual sales volumes. Additionally, a model to measure the macro benefits to the South African economy from an energy saving and carbon emissions reduction perspective was also utilised. To ensure the models were appropriate for use, an extensive review was undertaken, including desktop research to validate the use and appropriateness of input data, as well through rigorous discussions with the Urban Econ team to understand the methodological approach. Whilst not all information could be validated, due to the elapsed time period, the team has made every effort to update the input data and assumptions for the model. These updates have been informed by desktop research, stakeholder / industry consultations and customs reports from the South African Revenue Service. To this end, the researchers are satisfied that the current models produce results which can be used to support policy discussions and future implementation of S&L. However, where possible, the team has simplified the previous approach to enhance the intuitiveness and use of the model.

Prior to the undertaking of Testing, Evaluation, and Assessment (TEA), it is vitally important to understand the factors which influenced the decision-making process of MEPS programmes internationally. This enables current modelling to account for trends and variables that may not have initially featured in calculations. Additionally, it allows the CBA to have built-in solutions to address issues experienced internationally.

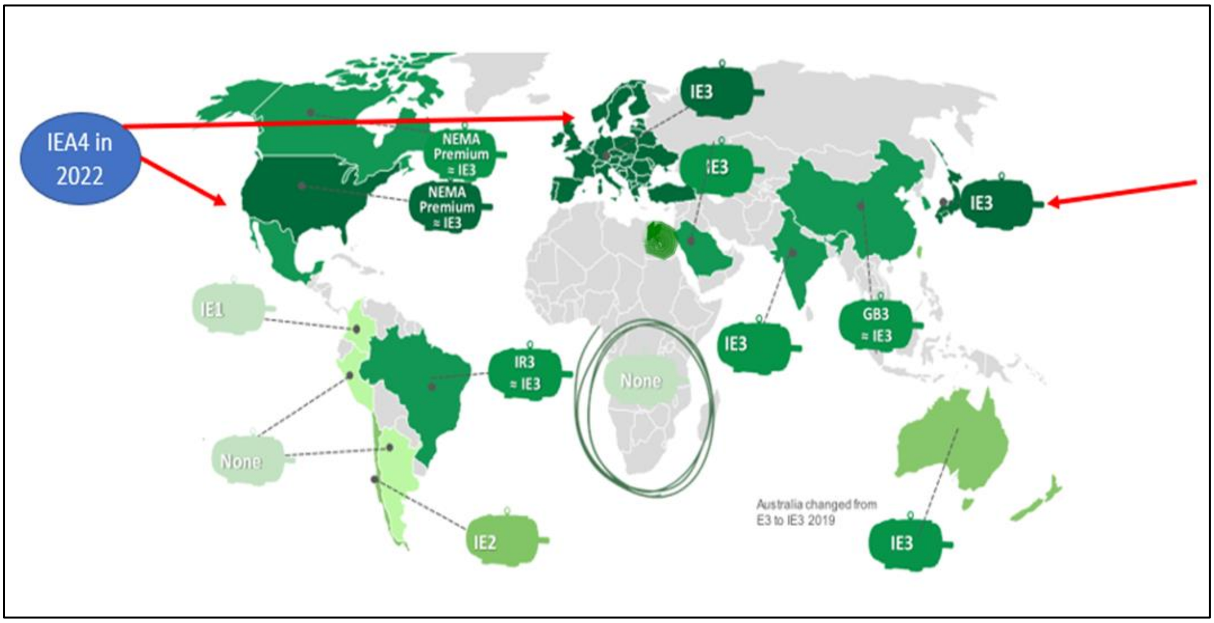
2.1 International context

An overview of the international standards and global trends of MEPS for EM has been undertaken. This informs and provides input into the recommendations that will ultimately be made for the suggested MEPS to be adopted by South Africa. In this, a case study approach of selected countries is used to reflect successful implementation, economic benefit, as well as challenges, as outlined below:

- The analysis of MEPS in other countries (Figure 5) will enable South Africa to identify and adapt successful implementation strategies, consider certification programmes and develop testing methods and facilities. Countries chosen for comparison are those with significant trade relations with South Africa and those from which most electric motors are imported.
  The agreed case study country list: EU, USA, China, and Australia..

- Recommendations will be made in line with international standards and adjusted to suit South African conditions. If products are mostly imported, local implementation of MEPS should consider aligning with those of products' country of origin. This avoids becoming a market for inefficient motors that manufacturers cannot sell elsewhere. Of course, adjustment periods are expected for clearance of noncompliant stock and securing stock that meets new efficiency standards, as well as the rollout of the new testing and certification programme. Simultaneously, cognisance should be given to establishing stricter MEPS for larger motors in the short-term, if initial MEPS implementation is successful.

Figure 5: Global Electric Motor MEPS Programmes



Kenya (IE1) and Egypt (IE3) both run EM MEPS programmes, since 2013 and 2021 respectively.

2.2 Local market analysis

An analysis of the South African Market forms the basis of the cost benefit modelling; and is broken down into four sub-categories:

1. The collection of the core relevant information of EM available in South Africa. (The various ranges and configurations of motors, i.e. efficiency standard/ size -kW/number of poles/ country of origin/ variable speed drive.)
2. Product market description, to ascertain the total number of retailers, brands available in the country, retail product prices, and consumers.
3. Product industry analysis, which will show the size of the industry, average annual sales by EM size, the ratio of imported products to those locally manufactured, and the point of origin of imported products.
4. Product usage and applications, to build an understanding of the industries and sectors that various products operate in, together with the regularity and duration of operation.

As a proviso, market data collection of this nature is a notoriously challenging undertaking; and this is not unique to South Africa. Some of the primary challenges include: no centralised repository being maintained (government or industry association); customs data being grouped by tariff codes and presented at a group level with other non-related products – thus making it very difficult to extract the deeper detail required by the CBA model; manufacturers and distributors being generally unwilling to participate in research that seeks to introduce MEPS, and those that are, not providing detailed information for market competitiveness reasons; internet web scraping is expensive, and for EM, would yield sub-optimal results, because distributors do not post detailed product specification price lists on their sites; market intelligence reports (GfK, Euromonitor etc.) are expensive (and beyond the affordability of this research) and would not provide the level of detail and accuracy required.

In response to the above challenges, data has been collected from multiple sources, and to the greatest extent possible, has been verified through a process of triangulation. This procedure has provided sufficiently robust data, but must also rely on reasonable assumption, particularly in cases where information is unavailable. Within this context, the data for the CBA has been gathered through combined desktop research, which builds on prior market appraisals (6), government studies, customs data, and academic literature. The collected data and market intelligence has then been tested and supplemented through interviews held with industry stakeholders. The interviews followed a semi-structured approach and a stakeholder engagement table (see Annex 1).

Ultimately, engagement with relevant industry players and associations, sought to understand the dynamics of EM use in South Africa; and the stakeholders were carefully selected to ensure inclusivity. These include:

- Major distributors of EM in South Africa (Zest-WEG, Siemens, ABB, Hudaco, HydroMobile, and Motorelli, to name a few).
- Large users of EM, including, mining, agriculture, steel and cement production, and petrochemicals, amongst others.
- EM industry experts, including mechanical engineers, members of the South African Bureau of Standards (SABS) technical committee, Eskom, National Cleaner Production Centre, and the authors of the Urban Econ report.
- Industry associations, namely Business Unity South Africa and the Energy Intensive Users Group.
- National ministries and agencies, such as NRCS and SABS testing and standards.

2.3 Impact assessment

In conducting an impact assessment, the data from the local market analysis, then undergoes a five-step impact analysis (Table 2), to model potential impacts to the country as a result of MEPS, in both the short and long term. This is structured as follows:

- The estimated total annual electricity consumption of EM is modelled, to estimate the annual electricity consumption of three scenarios – business as usual (BAU) and two MEPS classes. The forecast period is up to 2040, to display long-term cumulative electricity and GHG savings.
- The above information is also used to estimate the impact on the national load demand for the two scenarios, thus demonstrating the potential reductions in peak load and baseline demand, compared to the BAU scenario.
- Utilising the energy savings achieved under the different scenarios, a similar BAU and MEPS comparative model is derived to estimate the annual carbon emissions totals for EM.
- The potential annual cost savings for consumers are demonstrated with the same comparative model. This is also forecast for the period up to 2040, to display long-term cumulative savings.
- The study demonstrates the impact of MEPS on the existing EM trade (increased/reduced percentage imports, potential change of product/s' country of origin, trade tariffs and increased costs). Furthermore, the subsequent impacts on local manufacturing / assembly capacity are included. Here, it is important to note that there is no local manufacturing in the 0.75 to 375kW range being considered for MEPS. Consequently, the impact on jobs will be minimal if any at all.

- As regards product registration and market surveillance, the existing certification process is assessed, to ensure that the existing S&L regulatory approach, led by the NRCS, has the capability to regulate this product. Finally, the existence and availability of accredited local test laboratories is also examined.

Table 2: The impact analysis is summarised in the following table

Approach	Key parameters	Data sources
Impact on electricity consumption	Baseline •Number of EM sold •Growth per annum •Lifetime of electric equipment • Usage pattern	• Industry associations •Manufacturer / import data •Literature review •Consumer interviews • Eskom data
	Consumption before MEPS • Energy intensity of EM •Total electricity consumption - current baseline	•Manufacturer / import data • Modelled/calculated
	Consumption after MEPS • Energy intensity after proposed MEPS for EM • Total electricity consumption - after	• Modelled/calculated
	Potential savings and analysis • Difference between before and after	
Impact on peak load	Typical usage profile • Time of use	• Consumer & manufacturer interviews • Eskom • Modelled/calculated
	System load profile • Summer and winter data	
	Impact analysis	
Environmental impact	GHG intensity levels - current and future • Intensity figures	• Eskom • Modelled/calculated
	Energy saving potential • As per impact on electricity consumption	
	Impact analysis	
Market (consumer) impact	Cost implications (once-off) • Prices of most typical EM (up to 3) in use • Expected additional cost of higher EE units	• Consumer & manufacturer interviews •Literature review •Modelled/calculated
	Energy savings/bill reduction (long-term) • Current tariffs & expected real annual increases • Energy savings - LCC benefit to consumers and SA economy	
Impact on trade, manufacturing, and employment	Case study analysis • International case studies, which consider the prices of EM after introduction of MEPS	• Literature review • Workshop/interviews with manufacturers
	Impact analysis • Perceptions regarding the introduction of MEPS • Barriers to trade	

2.4 Findings and dissemination of results

The findings and recommendations of the CBA were presented, in an iterative proves, to government and industry stakeholders for their comments and input. The final report, having considered comments and inputs, is submitted to the DMRE's S&L project office, to decide on how to proceed.

3 Literature Review

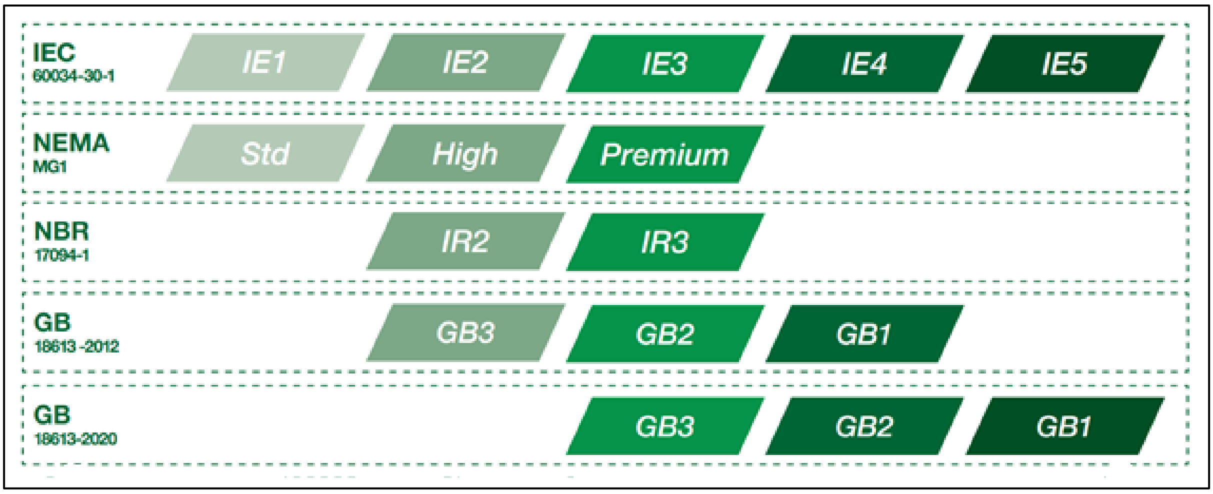
3.1 The evolution of EM efficiency

EM MEPS programmes first appeared in North America and Europe in the mid to late 1990s (1). In the European case, this took the form of a voluntary agreement between regulators and motor manufacturers, to reduce the sales of inefficient motors (25). As stated earlier in section 1, but bearing reiteration, EM were especially targeted for MEPS regulation globally, because of their omnipresence in multiple domains, from heavy industry, to mining, agriculture, and commercial buildings, amongst others. Indeed, EM are reported to represent between 40-45% of annual global electricity consumption and at least two thirds of annual global industrial electricity consumption (1). This indicates that the enforcement of improved efficiency, even by seemingly minimal percentages, would have a profound impact, not only on annual electricity consumption, but also GHG emissions (23). Critically, this factor has become increasingly important in the last thirty years, as climate change concerns have escalated into a pressing issue. Thus, EM MEPS regulations have a dual purpose: fighting energy wastage through improved efficiency; and achieving GHG emissions targets set out by international climate accords such as Copenhagen 2009 and Paris 2015 (23).

To this end, the North American trio was led by the United States, which implemented mandatory EM MEPS in 1997, with Canada and Mexico following soon thereafter (26). These policy moves were not surprising, as similar MEPS programmes had been successfully implemented for other appliances such as refrigerators and lighting. In Europe, the EU agreement with CEMEP lasted almost a decade, before then being replaced by mandatory regulation, in 2009 (1). And at the turn of the millennium, countries such as China, Brazil, Japan, Australia, New Zealand, South Korea and India, also began developing electric motor MEPS programmes (27; 28).

Due to the lack of an international standard at the time though, most regions and countries began developing their own standards for efficiency, motor design and testing. This resulted in the CEMEP standards being used in Europe, NEMA in North America (29), and China having their GB 18613 (12; 30). This accumulation of differing standards and testing methods created many trade problems, as there was no globally accepted hegemonic regulation for EM production or testing. Thus, in 2008, the IEC introduced the IEC 60034-1 and its corresponding testing methodology IEC 60034-2-1; and while initial acceptance has been slow, the IEC standards are being adopted more frequently, as countries realise the benefits of international harmonisation (1). Indeed, it has been observed that some countries such as China, although not formally adopting the IEC standards, have moved to adjust their national standards to an IEC equivalent (12). This is illustrated in Figure 6 below, which lists the various international standards against the IEC efficiency standards – appearing in the following order: NEMA (North America), NBR (Brazil), and GB (China). Here, NEMA Super Premium was added in 2017, as an IE4 equivalent.

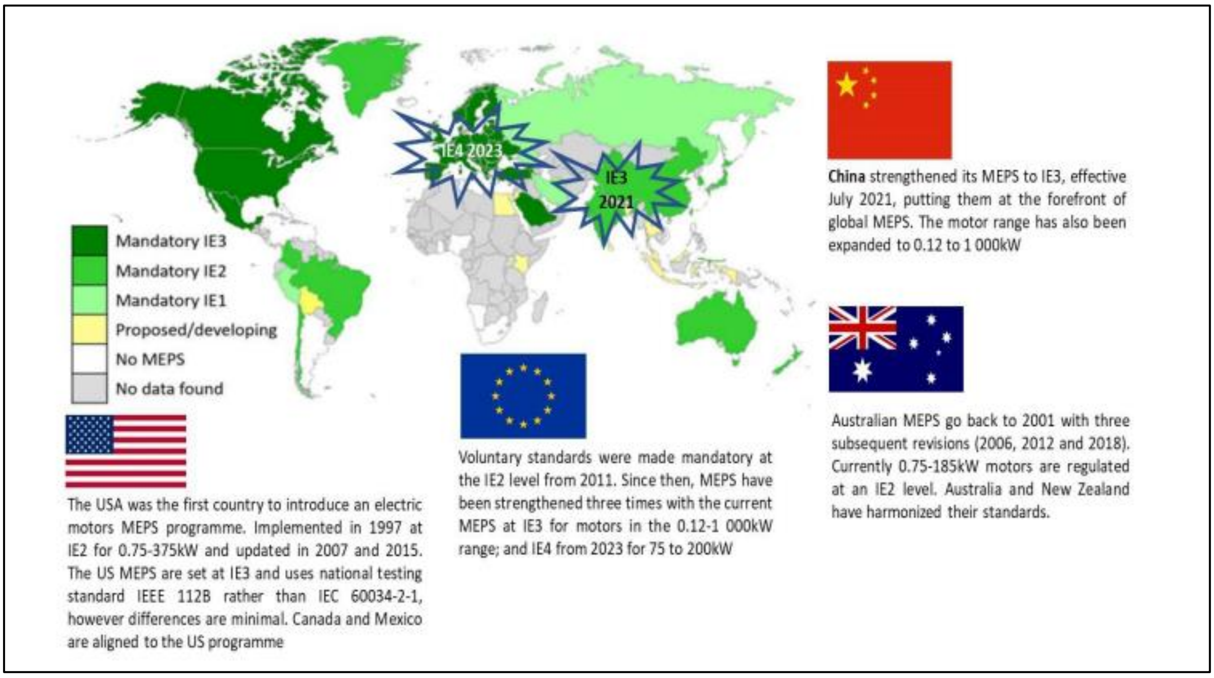
Figure 6: Global International Efficiency Standards for EM



3.2 International case studies

As previously mentioned, four country case studies were undertaken (Annex 2). These are summarised in Figure 7, and the key findings consolidated below.

Figure 7: Summary of Electric Motor Market in the US, EU, China and Australia



- Globally, there are more than 300 million EM; of which less than half, are energy efficient.
- MEPS for EM have reduced annual electricity consumption by over 600 TWh in the case of study countries.
- MEPS programmes are more effective when supported with energy labels, and awareness / educational campaigns that explain the benefits of a system approach.
- Countries should seek to match their MEPS levels to those of their motor suppliers (where there is no local manufacturing) and/or major trading partners.

- Carefully considered and targeted short-term financial incentives can accelerate the rate of replacement.
- Voluntary standards are insufficient. Market forces on their own, will not drive a transition.
- Regular MEPS revisions (3 to 5 years) are necessary as technology improves – thus ensuring that economic, energy and GHG emissions benefits are maintained and improved.
- A grace period of up to 2 years, allows distributors and retailers time to clear stock.
- The motor range of 0.75 to 375kW for MEPS is acknowledged as the international norm. Mature programmes have started regulating motors <0.75kW.
- Harmonizing global test standards (IEC-60034) reduces trade barriers.
- MEPS for Variable Speed Drives (VSD) and Variable Frequency Drives (VFD) create complexity and are not recommended.

4 South Africa's EM Market

4.1 Market overview

As per the recommendation of the Urban-Econ pre-feasibility study undertaken in 2018/19 (6), which was accepted by the DMRE, the range of EM to be considered for MEPS, falls within the following parameters: 0.75kW-375kW three phase induction motors, including those with variable speed drives, including 2,4,6 and 8 pole motors[5]. The recommended international efficiency standard is the IEC 60034-1: rating and performance, and the corresponding testing method is the IEC 60034-2-1: Rotating electrical machines-Part 2-1. These are standard methods for determining losses and efficiency from tests (excluding machines for traction vehicles). Here, the cast study findings are at odds with the recommendation to include VSD's.

The above-mentioned 2019 pre-feasibility impact analysis estimated that 200 000 EM units are sold in South Africa annually. This figure has been triangulated through comparison with relevant SARS import statements and further verification by stakeholders. These point to as many as 23 electric motor brands available in South Africa, with the overwhelming majority being supplied by WEG, Siemens, ABB, Motorelli and Hudaco. There are innumerable models available on the market, due to the multiple varying configuration factors of EM. Investigation also found that there are no EM manufacturers in South Africa, although there is a significant OEM (original equipment manufacturer) industry, which services the mining and agriculture sectors in both South and Southern Africa. This indicates there is little to no risk of job losses as a direct result of introducing MEPS in South Africa, as was confirmed in the stakeholder interviews.

The breakdown of the South African EM market in terms of motor size percentages, then indicates that 69% of motors sold in South Africa are between the 0.75-11kW size range, totalling approximately 128 000 units annually. The data suggests that only 3 percent, or 6 000 units, of motor sales are above 160kW (6). The 2019 study found that between 40 to 50% of EM sold in South Africa were noncompliant with efficiency standards, and referred to as IE0, while another 40 percent of motor sales are in the IE1 category (Table 3). Without prejudice to the Urban Econ report or its research approach, this study could not find data to support this share allocation, with the revised figures provided in Table 4. Moreover, IE0 is a misnomer and is not defined in IEC60034-30, it does however provide a useful term to categorise non-compliant and motors that have been rewound which invariably have lower efficiency than a new motor with an unadulterated magnetic circuit, which have re-entered the market.

With an estimated 150 000 - 200 000 EM being sold in South African annually, volume variations do occur between years for sector specific reasons, but SARS figures confirm the statistics used in the Urban Econ analysis and the annual growth rate of 2%. However, the COVID-19 pandemic has resulted in little growth for the period 2019 to 2021, and the model assumptions take cognisance of this. The full list of assumptions used for the CBA are listed in Section 5.2.

Finally, having provided an overview of the EM market in South Africa, a synopsis of the primary sectors is provided below.

[5] The pole count of a motor is the number of permanent magnetic poles, north and south, on the rotor. There is always the same number of north and south poles on the rotor. For example, in a 12 pole motor, there are 6 north poles and 6 south poles. This motor would also be considered a 6 pole-pair motor.

4.1.1 Agricultural sector

In the agricultural sector, predominant EM use is in irrigation pumps and water storage systems. Produce packhouses, HVAC, and mills, contain most of the remaining applications for EM in agriculture. Overall, irrigation pumps are estimated to run 2 000 hours/pa, while common motor sizes for this application are in the range of 20 - 50kW, with a 50kW motor being very common. Motors found in packhouses tend to be slightly smaller and run between 1 000 - 1 500 hours/pa. Interestingly, these running hours differ noticeably from the average running hours/pa for 20 - 50kW motors, with the average estimated at 4 500 hours/pa for 45kW motors and 4 000 hours/pa for 18kW motors. Also, the practise of farmers purchasing second-hand motor driven systems for irrigation was raised, as it allows old and potentially inefficient motors to be kept in circulation past their expected end-of-life. Additionally, EM and pump systems are sold at auction by large commercial farmers to smaller farmers. This supports the understanding that electric motors can have lifespans of much as 15-20 years.

Consultation found that internal policy regarding EM efficiency, VSDs, repair and replacement is becoming common practise amongst the largest commercial farmers in South Africa. This is being driven by the dual benefit of increasing competitiveness from an environmental and cost containment perspective. These farms are well resourced (skills and finance) allowing for detailed analysis which has demonstrated the benefits of lifecycle over capital costing for efficient motors. Consequently, internal policy is shifting to IE3 EM as the standard, with a concerted effort to phase-out lesser efficiency motors over time. By example, one of the country's largest vegetable farmers stated that all motors over 37kW were being replaced immediately with IE3 and all motors below this size were already IE3, while a move to IE4 was being investigated. Here again the scale of EM use indicates huge savings potential with 1 800 EM being operated by a single commercial farming operation. With 60% of these motors being below the 7.5kW threshold.

Relatively recently, the South African Irrigation Institute (SABI) in its 2017 Norms for the Design of Irrigation Systems, recommend that IE2 electric motors should be used to drive irrigation pumps (31). During the current research, it was found that updated SABI norms, set to be published before the end of 2021, will set a minimum standard of IE2 plus a VSD in line with IEC 60034-30-1.

4.1.2 Mining sector

The mining industry makes use of motors for crushers, grinders, hoists, dewatering pumps, mills, ventilation, and conveyor belts. Industry interviews revealed that 80% of motors in the mining industry are below the 180kW level, with half of those being below 37kW. Moreover, it is commonplace for mining companies to have internal policies on motor efficiency standards, and accordingly, will only purchase motors above that standard, typically IE3. Minimum annual usage hours for a standard duty motor, are estimated at 5 600 hours. These running hours differ noticeably from the 2018 assumed national average running hours/pa for 20 - 50kW motors, the average has thus been revised upwards 5 500 hours/pa for 18 and 45kW motors (Table 4). Also, motor lifespans in mining operations vary tremendously, depending on application and environment. Here, it must be noted that no junior mining operations were engaged; but feedback provided by a large mining operation, indicated that motor lifespan can vary from 3 months, for special application motors, to 8 years for standard duty motors used in processing applications.

4.1.3 Commercial sector

Following direct engagement with major motor suppliers it was found that the split of IE1/IE2/IE3 EM sold by them, is one of 75/25 between IE1 and IE3 respectively. It is understood that IE2 sales are negligible, due to their in-between nature - being neither cheap nor efficient enough. IE1 purchase decision simply present the cheapest purchase option with no consideration of LCC, due to a price premium between IE1 and IE3 motors being in the order of 15 - 20%, depending on motor size

Interviews with large industrial EM users indicated that it is common for such consumers to have internal procedures on issues such as motor repair and replacement, the use of VSD, minimum motor standards, and the discarding and recycling of old motors. This comes alongside direct partnerships with major motor suppliers; and it was found that the use of IE3 motors is becoming increasingly common amongst large industry. This is because it has the financial resources to pay an upfront premium, as well as the internal capacity to understand the benefits of LCC, while increasingly having to respond to corporate pressures to improve sustainability and reduce its carbon footprint.

4.1.4 Summary of Findings

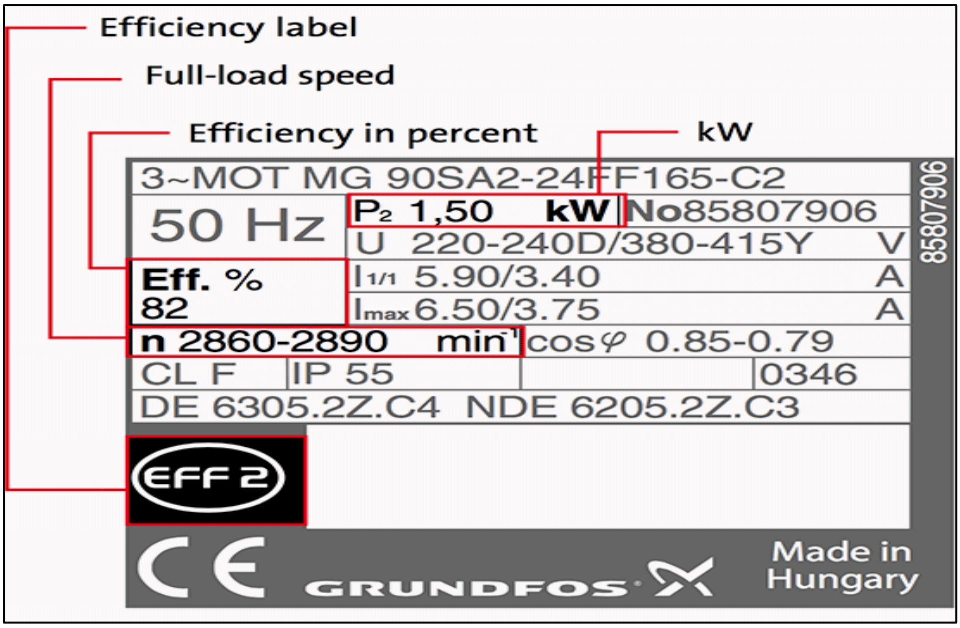
In compiling price data for the EM market of South Africa, data was gathered from 7 sources, both major manufacturers, online distributors, and smaller OEM-orientated distributors. This included extensive analysis of available motor data from across 15 websites. The purpose of this was to establish a database of EM available in South Africa. This allowed for comparative analysis to determine the ranges and variations of motors to be found on the South African market. This enabled the team to access information on hundreds of relevant electric motors. While another 3 major suppliers and 2 distributors were approached for research purposes, they however were not forthcoming with pricing information. It must be noted that only three of the 7 sources stocked motors above 11kW. Motors above 11kW are found to be available in far fewer variations and configurations This is indicative of the characteristics of the market. Due to the high volume of sales between 0.75-11kW this portion of the market was found to be highly competitive, offering the most product variations.

While there is limited available data on 6- pole and 8- pole motors, a pattern can be discerned that there is a positive correlation between the motor pole count and price. The research found that while 2- and 4- pole motors are similarly priced, 2-pole motors are generally cheaper. This is followed by a price increase at 6- pole motors and a further substantial increase at 8-pole motors.

Only two of the available seven surveyed distributors stocked 6- pole and 8- pole motors, indicating a lower market demand for these motors, which was confirmed during the interviews. Additionally, it was found that there are no 8- pole motors available from 300kW and above. The reduced number of 6- and 8- pole motors can be related to the reduced efficiency that is offered by high pole motors (32). As such they are not as popular as 2- and 4- pole motors. The increased pole number reduces the speed, measured in revolutions per minute (RPM), of the motor. However, these motors provide greater torque and are more suitable to heavier applications. This further supports the understanding that 6- and 8- pole motors are bought for specialised applications.

The research established that one motor manufacturer has a market share of approximately 50%, supplying competitively priced IE1 motors of all configurations in cast iron and a limited range of IE1 motors in aluminium, which are substantially more affordable. Furthermore, they sell the most affordable IE3 EM in South Africa and are one of the few to offer IE3 motors across all sizes and configurations. A thorough market comparison of price data, motor sizes and configurations across the brands available found that the company is a market proxy of the EM available in South Africa.

In conclusion, the in-depth engagement with relevant industry players and associations sought to understand the dynamics of EM use in South Africa. This represented a broad range of key commercial activities including, mining, agriculture, steel and cement production, and petrochemicals amongst others. This was done to understand the trends, practises, and decision-making factors of EM consumers. Additionally, the interviews held with motor distributors sought a response on government's intention to introduce MEPS regulations and any potential impacts that this could have on their business. All responded positively and gave their support for an EM MEPS programme in South Africa, with many stating that it was long over-due. All EM distributors surveyed stated that that they stopped stocking EM below IE1 and are now focusing on the shift to IE3 motors. Suppliers also confirmed that total annual sales were in the order 200 000 units, while highlighting that a fifth of electric motor sales in South Africa are shipped into Africa. A common theme that was raised was one of the purchase-cost versus cost-of-ownership debate. Motor suppliers believe there is a knowledge gap in South Africa surrounding LCC and exacerbated by the decade long weak economic conditions which reduces available CAPEX in business. The established trend in South Africa is that EM are bought with purchase-cost being the primary deciding factor. Name-plating and counterfeit products, which bring unregulated motors into the country at prices much below market norms, was raised as a minor concern.



5 Impact Assessment

5.1 Why a Cost Benefit Analysis?

Effective EE programmes, through MEPS, offer substantial economic benefits. This has been clearly demonstrated by South Africa's existing S&L programme, which in 2018 was forecast to achieve 2.15 TWh of savings by 2020 and 5.55 TWh by 2030 (33). These savings are an outcome of a detailed CBA, which was used to inform the MEPS selected for each appliance (see FRIDGE Report (34)). As explained in Section 2.1 of the report, determining the targets of MEPS requires careful consideration and analysis, as several important factors need to be balanced. The primary objective of any efficiency programme is to reduce energy consumption or slow its growth. This provides multiple benefits, such as improved energy security; reduced operating costs; improved productivity; reduced GHG emissions and other fossil fuel pollutants; and the reduction of environmental impacts caused by energy extraction. However, EE implementation comes with costs. First among these is the additional cost needed to improve appliance efficiency, and the costs to manufacturers to retool and modify production lines. These costs are generally passed on to consumers, in the form of increased retail prices. Price impacts have further consequences on manufacturers. They can reduce competitiveness with imports, if imported products already meet efficiency requirements. They can also reduce overall sales, leading to a loss of revenues and jobs. A complete analysis of proposed MEPS should thus take careful consideration of the following impacts:

- Energy Demand Reduction
- Peak Load Reduction
- Environmental Impacts
- Consumer Impacts
- Manufacturer and Employment Impacts (Not applicable for South Africa as all EM are imported)
- Trade Impacts

Of these, one of the most important criteria for setting an efficiency target for MEPS, is the *Consumer Impacts* analysis. Generally speaking, mandatory standards that impose a net financial penalty are undesirable and will be resisted by industry. Conversely, if it can be demonstrated that such action will yield substantial financial benefits, then there is strong justification for MEPS. Therefore, cost-effectiveness analyses ideally provide the primary determinant of MEPS targets. For example, MEPS can be chosen to maximize net financial savings or to maximize energy savings, while still providing an overall net benefit.

5.1.1 Life cycle costing

A variety of metrics are typically used to evaluate the cost-effectiveness of appliance efficiency standards. These include *payback period*, *benefit-cost ratio*, *LCC* and *cost of conserved energy*. Of these, the LCC calculation is most appropriate for capturing overall net financial impacts to consumers. *LCC* is given by:

$$LCC = I + \sum_{n=1}^{L} \frac{OC}{(1+d)^n}$$

In this equation, the I represents the initial investment (equipment price), OC is the annual operating cost, L is the equipment lifetime and d is the discount rate (10% - see Section 5.3.2). The LCC includes the full cost to the consumer of purchasing and operating an appliance over its lifetime. Annual operating cost is the annual energy use, multiplied by the energy price. In general, efficiency improvements reduce operating cost, but increase the initial investment. The change in LCC relative to the base case, can therefore either be positive or negative. If the operating cost decrease outweighs the initial investment increase, the standard imposes a net savings to consumers and is determined to be cost-effective. If on the other hand the initial investment increase outweighs the operating cost decrease, the standard imposes a net cost to consumers and is determined not to be cost-effective. The discount rate parameterizes the difference in present value of initial investment, which is immediate, and operating cost, which is deferred (McNeil in 34).

5.1.2 Total annual energy consumption

The total annual energy consumption for each respective electric motor size in both the BAU and MEPS scenarios, has been computed as follows. This formula was drawn from the original report (6) and has been maintained due to its appropriateness, as well as for consistency.

$$Total\ annual\ energy\ consumption\ = \left(\frac{\text{kW}\ output}{Efficiency * Loading\ Impact}\right) * usage * loading$$

5.2 Data inputs and assumptions used in the CBA

. *Note: The columns IE0, 1, 2 and 3 is the estimated market share and not the motor efficiency*

Table 3 is from the 2018 Urban Econ (6) research report. It provides a snapshot market analysis of South Africa's EM market, clearly showing that the market share decreases as the efficiency class increases, except for IE2, for the reasons provided above. The Urban Econ researchers aggregated the assumed usage hours as a national average, while motor price averages by size (kW) were established through market research. The price premium between IE1 and IE3 motors was found to be between 15-20%, which aligns with prior research indicating a similar price premium of 15% and has been confirmed by this study (Section 1.1.2). *Note: The columns IE0, 1, 2 and 3 is the estimated market share and not the motor efficiency*

Table 3: Attributes of the representative electric motors (2018)

Electric motor size (kW)	Assumed market share	Assumed Usage (Hrs/yr)	Assumed Loading	Assumed current IEC energy efficiency rating shares			
				IE0	*IE1*	*IE2*	*IE3*
0.75	19%	2500	75%	50%	30%	5%	15%
1.5	15%	2500	75%	50%	30%	5%	15%
3	13%	2500	75%	50%	30%	5%	15%
5.5	12%	3000	75%	50%	30%	5%	15%
11	10%	3500	75%	40%	36%	6%	18%
18.5	9%	4000	75%	40%	36%	6%	18%
45	8%	4500	75%	40%	36%	6%	18%
90	6%	5000	75%	40%	36%	6%	18%
160	5%	5500	75%	40%	36%	6%	18%
300	3%	6000	75%	40%	36%	6%	18%

Source: Urban Econ

The model used by Urban Econ was evaluated and the assumptions used for modelling, updated. The revised assumptions are summarised as follows:

- Total annual sales were retained at 200 000 units (6). This figure was triangulated against SARS data and verified by industry stakeholders. It was also determined that approximately 20% of motors imported into South Africa are re-exported to SADC region. The modelling has adjusted the sales volumes accordingly.
- The market share by motor size was revised.
- The annual sales growth rate was also maintained at 2%, due to a combination of South Africa's decade-long stagnated economy, which has had very low or no GDP growth, and more recently, the impact of the COVID-19 pandemic.
- The market share by size (kW) EM categories have been maintained, after extensive consultation with the major distributors and online research.
- Average annual usage hours assumed loaded, and market share by IE classification, were revised, based on the outcomes of the information and data collected from industry interviews and desktop research.
- Market share by poles: The inherited data assumed market shares of 60% 2- pole, 20% 4- pole, and 20% 6- pole (6). Due to the limited available data on 8-pole motors and the feedback received from industry, it is assumed that these motors hold a minimal market share. After in-depth consideration and analysis of the efficiency differences between motor polarity, 8- pole motors were not included in modelling, as savings calculations would see minimal changes. The split by poles is as follows:
    - 2 Pole = 24%
    - 4 Pole = 70%
    - 6 Pole = 5%
    - 8 Pole & others = <1
- The values for the suggested MEPS efficiency classes are taken from the relevant IEC standards: IEC 60034-30-1 *Rotating electric machines: Efficiency classes of line operated AC motors (IE code)* – See Section 6.1.
- The calculations used by the original model for efficiency percentages of IE0 motors, were maintained (6). Moreover, their impact on the energy savings projections was deemed to be minimal, given their almost complete elimination from the market.
- A carbon factor of 0.94kg CO_2e/kWh was applied (35).
- A non-residential electricity tariff of R3.50/kWh was applied, compared to R3/kWh used in the prior study (6).

Table 4 now lists the revised 2021 attributes, which have been informed by the above assumptions, as an outcome of extensive stakeholder engagement and desktop research. Here, discussions with industry prompted a slight downward revision of the assumed loading percentage. This is in light of the over-sizing of EM in various applications and industries, which is driven by two factors: The first, is the innate practise of engineering consultants adding a small percentage for safety i.e. intentionally oversizing motors. The second, is that loads do not always match available motor sizes and it is often not possible/economical to design a special motor for each application. As a result, the next 'size up' is used, which then negatively impacts loading. By way of example, with an 800W motor not being available, such a load must opt for a 1.5kW motor, resulting in it running at 53% loading.

Finally, annual usage hours have been adjusted to reflect the information provided by industry, while the transition to higher efficiency (larger sized) motors by energy intensive industrial companies, is also reflected.

Table 4: Attributes of the representative EM (2021)

EM size: (kW)	Assumed market share	Assumed Usage (Hrs/pa)	Assumed Loading	IE0 (Rewound Motors)	IE1	IE2	IE3
0,75	10%	5 500	72%	5%	75%	5%	15%
1,5	15%	5 500	72%	5%	75%	5%	15%
3	18%	5 500	72%	5%	75%	5%	15%
5,5	18%	5 500	72%	5%	75%	5%	15%
11	15%	5 500	72%	5%	75%	5%	15%
18,5	7%	5 500	72%	5%	75%	5%	15%
45	10%	5 500	72%	10%	70%	5%	15%
90	4%	5 500	72%	10%	70%	5%	15%
160	2%	6 500	72%	10%	65%	5%	20%
300	1%	6 500	72%	10%	65%	5%	20%

5.3 CBA modelling outputs

Scenario analysis is a process of examining and evaluating possible events or scenarios that could take place in the future and predicting the various feasible results or possible outcomes. This has been adopted as the researchers recognise the difficulty of quantifying the average annual hours of usage of a specific motor size both within and across sectors. For example, in the agricultural sector some farms operate all year whereas others are seasonal. And of course, hours of usage in mining, for say a 18.5kW EM, is unlikely to be the same as would be the case in the commercial sector.

To ascertain which is the most suitable path for South Africa to benefit from a change in policy direction, two sets of scenarios are considered, these are differentiated as the high-usage and a low-usage scenarios.

- Set 1 (scenarios 1 & 2): Uses all updated market assumptions found during the research.
- Set 2 (scenarios 3 & 4): Maintains the annual usage hours assumptions used in the Urban Econ study, which are lower and thus more conservative - see Table 3 above.

For both sets of scenarios, a comparison between the BAU scenario and MEPS at the IE2 and IE3 level, is undertaken. For the purposes of the analysis, the IE1 is a proxy for the BAU scenario. Based on stakeholder feedback, setting the MEPS at the IE2 level has been found to present an economically ineffective option for the reasons provided above; namely that these EM are neither cheap nor efficient enough, as reflected by their very low market share. However, it is worth demonstrating this through the CBA. Moreover, it may provide a more acceptable MEPS level, as it would provide consumers a cheaper motor price alternative. Lastly, the study assumes that MEPS will be formally introduced in 2023 – allowing stakeholders a transition period to cost and adopt new technologies / more efficient IE3 motors.

5.3.1 Scenario analysis

In scenario 1 (Table 5 below), the estimated savings from a shift from IE1 to IE2 in 2023 are considered. Here, estimated savings are 274 GWh pa, approximately R959 million savings[6] and GHG emissions reductions of approximately 0.260 $MtCO_2$[7] .

Table 5: Scenario 1: IE1 to IE2 (High usage scenario)

Motor size (kW)	IE1 Motors		IE2 Motors		Impact: IE1 to IE2			
	Energy Consumption (kWh/yr)	Energy cost (based on R3,5/kWh tariff)	Energy Consumption (kWh/yr)	Energy cost (based on R3,5/kWh tariff)	Energy Savings (MEPS savings)	Energy Savings Value (kWh)	Motor sales	Savings (GWh/year)
0,75	4 789	16 758	4 371	15 295	418	1 463	17 318	7
1,5	8 707	30 469	8 159	28 549	549	1 920	25 978	14
3	16 214	56 737	15 498	54 232	716	2 506	31 174	22
5,5	27 949	97 798	27 046	94 638	903	3 160	31 174	28
11	53 273	186 412	52 020	182 029	1 253	4 384	25 978	33
18,5	87 776	307 146	86 020	301 001	1 756	6 145	12 123	21
45	204 045	713 995	201 092	703 662	2 953	10 334	17 318	51
90	397 812	1 392 023	392 866	1 374 716	4 946	17 306	6 927	34
160	833 236	2 915 661	823 833	2 882 755	9 404	32 906	3 463	33
300	1 558 994	5 455 232	1 541 436	5 393 794	17 558	61 438	1 731	30
TOTAL							**173 184**	**274**

In scenario 2 (**Error! Not a valid bookmark self-reference.**) below, the shift from IE1 to IE3 is considered for 2023; with energy savings forecast at approximately 474 GWh per year, thus 200 GWh per year more than scenario 1. The Rand value of the annual cost savings is R1.65 bn and the GHG emission reductions 0.449 $MtCO_2$ (R697 million and 0.189 $MtCO_2$ more than scenario 1, respectively). The modelling results therefore clearly demonstrate the benefits of adopting IE3 as the MEPS.

Table 6: Scenario 2: IE1 and IE3 (High usage scenario)

Motor size (kW)	IE1 Motors		IE3 Motors		Impact:IE1 to IE3			
	Energy Consumption (kWh/yr)	Energy cost (based on R3,5/kWh tariff)	Energy Consumption (kWh/yr)	Energy cost (based on R3,5/kWh tariff)	Energy Savings (MEPS savings)	Energy Savings Value (kWh)	Motor sales	Savings (GWh/year)
0,75	4 789	16 758	4 211	14 734	578	2 024	17 318	10
1,5	8 707	30 469	7 908	27 672	799	2 797	25 978	21
3	16 214	56 737	15 095	52 819	1 120	3 918	31 174	35
5,5	27 949	97 798	26 448	92 545	1 501	5 253	31 174	47
11	53 273	186 412	51 081	178 742	2 192	7 670	25 978	57
18,5	87 776	307 146	84 700	296 383	3 076	10 762	12 123	37
45	204 045	713 995	198 753	695 476	5 292	18 519	17 318	92
90	397 812	1 392 023	388 857	1 360 690	8 954	31 333	6 927	62
160	833 236	2 915 661	816 340	2 856 538	16 896	59 123	3 463	59
300	1 558 994	5 455 232	1 527 447	5 344 844	31 547	110 389	1 731	55
TOTAL							**173 184**	**474**

[6] Using an electricity tariff of R3,5/KWh.
[7] Using a CO_2 emissions factor of 0,9488

In scenario 3 (Table 7) the estimated savings from a shift from IE1 to IE2 in 2023 are considered. Here, estimated savings are 200 GW/h pa, approximately R700 million savings[8] and GHG emissions reductions of approximately 0.190 $MtCO_2$[9] .

Table 7: Scenario 3: IE1 to IE2 (Low usage scenario)

Motor size (kW)	IE1 Motors		IE2 Motors		Impact:IE1 to IE2			
	Energy Consumption (kWh/yr)	**Energy cost (based on R3,5/kWh tariff)**	**Energy Consumption (kWh/yr)**	**Energy cost (based on R3,5/kWh tariff)**	**Energy Savings (MEPS savings)**	**Energy Savings Value**	**Motor sales**	**Savings (GW/h per year)**
0,75	2 177	7 617	1 987	6 952	190	665	17 318	3
1,5	3 958	13 849	3 708	12 977	249	873	25 978	6
3	7 370	25 790	7 045	24 651	326	1139	31 174	10
5,5	15 245	53 344	14 752	51 621	493	1724	31 174	15
11	33 901	118 626	33 104	115 837	797	2790	25 978	21
18,5	63 837	223 379	62 560	218 910	12 77	4469	12 123	15
45	166 946	584 178	164 530	575 723	2 416	8455	17 318	42
90	361 647	1 265 475	357 151	1 249 742	4 496	15733	6 927	31
160	705 046	2 467 098	697 089	2 439 254	7 957	27844	3 463	28
300	1 439 072	5 035 599	1 422 864	4 978 887	16 207	56712	1 731	28
TOTAL							**173 184**	**200**

In scenario 4 (Tables 8) below, the shift from IE1 to IE3 is considered for 2023; with energy savings forecast at approximately 350 GWh per year, thus 150 GWh per year more than scenario 3. The Rand value of the annual cost savings is R1.22 bn and the GHG emission reductions 0.332 $MtCO_2$ (R524 million and 0.142 $MtCO_2$ more than scenario 3, respectively). The modelling results therefore clearly demonstrate the benefits of adopting IE3 as the MEPS.

Table 8: Scenario 4: IE1 to IE3 (Low usage scenario)

Motor size (kW)	IE1 Motors		IE3 Motors		Impact:IE1 to IE3			
	Energy Consumption (kWh/yr)	Energy cost (based on R3,5/kWh tariff)	Energy Consumption (kWh/yr)	Energy cost (R3,5/kWh tariff)	Energy Savings (MEPS savings)	Energy Savings Value	Motor sales	Savings (GWh/ year)
0,75	2 177	7 617	1 914	6 697	263	920	17 318	5
1,5	3 958	13 849	3 595	12 578	363	1 271	25 978	9
3	7 370	25 790	6 861	24 009	509	1 781	31 174	16
5,5	15 245	53 344	14 426	50 479	819	2 865	31 174	26
11	33 901	118 626	32 506	113 745	1395	4 881	25 978	36
18,5	63 837	223 379	61 600	215 552	2237	7 827	12 123	27
45	166 946	584 178	162 616	569 026	4330	15 152	17 318	75
90	361 647	1 265 475	353 507	1 236 991	8140	28 484	6 927	56
160	705 046	2 467 098	690 749	2 417 071	14297	50 027	3 463	50
300	1 439 072	5 035 599	1 409 951	4 933 702	29120	101 897	1 731	50
							173 184	**350**

[8] Using an electricity tariff of R3,5/KWh.
[9] Using a CO_2 emissions factor of 0,9488

5.3.2 LCC model outputs

The annual energy consumption modelling clearly demonstrates the national benefits of MEPS at the IE2 level, but even more so at IE3. However, these EM have an upfront price premium or a higher capital outlay. Cost effectiveness therefore becomes an important consideration for consumers. To determine if the transition to more efficient motors will provide a net financial benefit, (as detailed in Section 5.1.1 above), requires a comparison of the price differential between an IE1 and IE3 EM, against the expected energy cost savings. The literature review has found that the outcome will be positive, given that the life expectancy of EM averages more than 10 years. However, what becomes crucially important, is the time it takes for this to occur. Typically, the rule of thumb in South African industry, which is conservative by international norms, is that EE investments should have a payback of less than two years for them to be deemed acceptable[10]. Thus, it follows that if the energy cost savings outweigh the initial investment costs in less than two years, IE3 MEPS would hypothetically present an acceptable investment to companies. However, considering that the shift is expected to generate savings over the EM product life, an estimation of energy savings (and a reduction in GHG emissions) over time, is also useful.

The following assumptions have been used for the LCC analysis:

- Annual EM imports are 200 000 (2% annual growth) of which 80% are sold domestically.
- MEPS is to be implemented as of 2023 and assumes that all new EM sold are IE3.
- All motor sizes are assumed to have a minimum product life expectancy of 10 years.
- Prices for each of the motor sizes have been weighted according to the market share per pole.
- An electricity tariff of R3/kWh in 2021 has been adjusted by 8% year on year, to ascertain an annual electricity tariff for the period 2023 to 2033.[11]
- A GHG emission factor of 0.9488 is used for the period 2023 to 2019, and 0.75 from 2030 to 2033, to reflect South Africa's energy transition, as detailed in the Integrated Resource Plan (2019).
- A discount rate of 10% [12] is applied.

Table 9 below provides a summary of the outputs of the LCC model, using the IE1 to IE3 scenarios for the upper and lower usage ranges (scenarios 2 and 4). To determine the duration of the payback period, the difference in initial investment cost was compared to the expected annual savings per motor size. It is observed that across all motor sizes, the payback periods are attractive as they can be recouped within a year. These investments further result in substantial energy savings of about 5.7 TWh, or approximately R30 billion, over the period.[13] Importantly for South Africa's ambitions to reduce climate change impacts, the shift is estimated to reduce GHG emissions by 5 $MtCO_2$ over the 10-year period. This reiterates the need for a shift towards more efficient motors in South Africa, with substantial benefits expected to flow.

Table 9: Scenario 2 (IE1 to IE3) LCC model outputs

Motor size	Payback		2023-2033	
KW	Duration (years)	Year of completion	Energy cost savings (GWh)	GHG reductions ($MtCO_2$)

[10] Researchers experience and confirmed in the stakeholder interviews

[11] The Eskom 2021 tariff increase was 15.06% https://mg.co.za/business/2021-09-05-eskoms-double-digit-tariff-request-unaffordable-for-struggling-consumers/ Eskom continues to operate at a loss and it is likely that tariffs for the foreseeable future will be more than 10%. Given the tariff increases since 2006 an average rate of 8% has been used

[12] EM are a low risk investment and IE3 technology is proven. For the purposes of the analysis, the current Capital Market Rate on a 10 Year Government bond of 9.83% is used (however rounded off to 10%). Rate was obtained from https://www.resbank.co.za/en/home/what-we-do/statistics/key-statistics/current-market-rates, accessed on 11.11.2021.

[13] Calculated using an average electricity tariff for the period 2023 to 2033 - R5,30/kWh.

0.75	0,28	2023	122	0.106
1.5	0,27	2023	253	0.220
3	0,27	2023	425	0.370
5.5	0,29	2023	569	0.496
11	0,38	2023	693	0.604
18.5	0,42	2023	454	0.395
45	0,58	2023	1 115	0.972
90	0,61	2023	755	0.658
160	0,51	2023	712	0.621
300	0,87	2023	665	0.579
		Totals	**5 763**	**5.022**

The expected savings to be yielded in the low-usage scenarios result in energy savings of about 3.6 TWh, or approximately R19 billion, over the period.[14] Importantly for South Africa's ambitions to reduce climate change impacts, the shift is estimated to reduce GHG emissions by 3.1 $MtCO_2$ over the 10-year period. This demonstrates the lower level of savings, and further indicates that all motor sizes realises cost-savings within a year of purchase.

Table 10: Scenario 4 (IE1 to IE3) LCC model outputs

Motor size	**Payback**		**2023-2033**	
kW	**Duration (years)**	**Year of completion**	**Energy cost savings (GWh)**	**GHG reductions ($MtCO_2$) {Adjusted EF)**
0.75	0,62	2023	48	0.41
1.5	0,59	2023	98	0.86
3	0,59	2023	165	0.144
5.5	0,53	2023	265	0.231
11	0,60	2023	375	0.327
18.5	0,58	2023	281	0.245
45	0,71	2023	803	0.699
90	0,67	2023	603	0.526
160	0,60	2023	500	0.435
300	0,94	2023	509	0.443
		Totals	**3 646**	**3.177**

The above LCC models' outputs are, by a sizable order of magnitude, lower than the findings of the Urban Econ study, which calculated that '*about 32.2TWh in aggregate energy savings, with an estimated total energy bill value of around R96.7bn, are forecasted for South Africa during the period 2022-2030, with an estimated 24.2 $MtCO_2$ in emission savings*' (page 59). There are several reasons for this:

1. The market share by motor size and allocation by efficiency were redistributed (see Table 4). Specifically, Urban Econ's market allocation to 90kW, 160kW and 300 kW motors, the biggest EM energy consumption, was 14%. This was reduced to 6% (see pages 28-29). This study also reduced IE0 from 50% to 5%.

[14] Calculated using an average electricity tariff for the period 2023 to 2033 - R5,30/kWh.

2. The Urban Econ study modelled all 200 000 imported EM, whereas this study reduced the 20% of EMs that are exported into Africa.
3. The loading figure was adjusted from 75% to 72%, a 3% reduction in efficiency

The lower figures can also be viewed as a more conservative representation of the potential savings, which offsets some of the motor versus system efficiency concerns.

5.3.3 Conclusions and findings

The scenario analysis findings are summarised in Although these savings may seem small and insignificant, they are not given the declining state and low energy availability factor of the utility's generation plants. Moreover, the MEPS programme represents the proverbial 'low hanging fruit' of improving energy performance in the industrial sector and should be prioritised.

Table 11, which clearly demonstrate that all scenarios offer energy and GHG emission savings benefits, with scenario 2 offering the greatest benefit, especially when the savings are accumulated over a 10-year period.

It is useful to provide perspective as to what an IE3 MEPS would deliver in practical terms. Eskom's Integrated Annual Report (36) reported sales of 191 852 GWh (from all sources) for the one-year reporting period. This implies that IE3 MEPS has the potential to reduced electricity demand by 0.25% in 2023, increasing as the existing EM stock is replaced with IE3 over time. Although these savings may seem small and insignificant, they are not given the declining state and low energy availability factor of the utility's generation plants. Moreover, the MEPS programme represents the proverbial 'low hanging fruit' of improving energy performance in the industrial sector and should be prioritised.

Table 11: Summary of Scenario Analysis Findings

	Savings GWh Year 1	GHG emissions ($MtCO_2$) Year 1	Percentage of Eskom 2020 Generation	Savings GWh. 10 Years	GHG emissions ($MtCO_2$) 10 Years
Scenario 1	274	0.260	0.14		
Scenario 2	**474**	**0.449**	**0.25**	**5 763**	**5.022**
Scenario 3	200	0.190	0.10		
Scenario 4	350	0.332	0.18	3 646	3.177

6. National Standards, Testing Facilities and Regulatory Approach

6.1 National standards (IEC and non-IEC)

There are three existing South African standards pertinent to EM MEPS. The first is the SANS 60034-1: 2010, which aligns with the IEC standard of the same designation, IEC 60034-1: 2017 (Rotating electrical machines - Part 1: Rating and performance). However, as may be noted from the name, the SANS is outdated by several years, with the latest version of the IEC 600034-1 being released in 2017. Consultations with the SABS Standards division and members of the technical committee confirmed that the SANS 60034-1 is in the process of being reviewed and updated, and that this process should be concluded by end 2022. The second national standard is SANS 60034-2: 2014, which again aligns with the corresponding IEC Standard 60034-2-1: 2014 (Rotating electrical machines - Part 2-1: Standard methods for determining losses and efficiency from tests). Currently, neither of these standards are mandatory; but compliance can be demonstrated through the motor's IE level and SABS certification, explained in the next section. Finally, the third standard is the SANS 1804-1: 2012. During the compilation of this study, the research team was invited to partake in the SANS 1804 Series Working Group meetings. The SANS 1804 Series deals with specific requirements for induction motors, in line with SANS 60034 and SANS 60072. The purpose of these meetings was to update the SANS 1804 Series, as it is undergoing revision. After this meeting and further consultation with SABS officials, it was found that this standard does not consider motor efficiency and thus will not hinder the potential implementation of EM MEPS in South Africa.

6.2 SABS Certification, accreditation, name-plating and counterfeit products

The SABS, in addition to testing and the writing of standards, offers a certification scheme for specific products. Certification (mark scheme) provides a third-party guarantee of quality, safety and reliability for consumers, and it applies to locally manufactured and imported products for which technical SANS exist (37). The mark scheme pre-dates the 2008 establishment of the NRCS, which was set-up to administer compulsory specifications, a function previously performed by SABS Regulatory Department. Under the original approach, and in tandem with the compulsory processes, many manufacturers operated under a Type 5 – SABS mark scheme, providing 'proof of compliance' of SABS mark-bearing products (38). Thus, under this process, a product could display the SABS mark (accreditation label) demonstrating quality and regulatory compliance. When the SABS was restructured in 2008 - extracting the SABS Regulatory Department into an independent regulator (NRCS) - all regulated products would need to demonstrate compliance under the newly established LoA process, which does not recognise the mark scheme as demonstrating regulatory compliance. Consequently, mark holders view the mark scheme and LoA certificate as duplicate processes, which increases their compliance costs. A three-year LoA requires an upfront application fee and attracts annual levies based on sales volumes. SABS mark scheme costs are not insignificant and many NRCS regulated products have let their mark scheme certification lapse. A prime example of the financial impact that the introduction of MEPS (VC 9006) had on the SABS mark scheme, was with electric water heaters (geyser) – see (39).

As EM are not regulated, some distributors make use of the SABS mark scheme to demonstrate compliance to the national standard, which in effect is the adopted IEC standard, as detailed above. The research has also found that over time the number of EM models bearing the mark scheme has decreased, for a variety of reasons. These include costs; declining SABS testing capacity and competence; and market perceptions that the SABS mark does not provide the 'value-add' it did in the past, with consumers placing greater value on brand names. Discussions with the SABS Certification department confirmed their apprehension to the introduction of MEPS, as a major risk to their business model. In their view, SABS provides a valuable service, and EM distributors certify their products due to the large number of counterfeit products and the high incidence of name plating (the practise of deliberately mislabelling products and especially misrepresenting IE levels). Although this practise may occur, no evidence was found to suggest that it is endemic or a threat to the EM market; and it could be addressed through the implantation of a South African Energy Label. The SABS test laboratory acknowledged that their test equipment is aging and unreliable, but remains functional (see next section).

The introduction of MEPS for EM will provide both opportunities and risks for the SABS. On the one hand, S&L programmes require robust MVE, which would generate new business. However, this may not materialise, as the NRCS has undertaken very limited post-compliance activities for existing S&L regulated products and almost no product testing; raising concerns that this will be the case for EM. Moreover, as detailed above, mark scheme holders are less likely to renew their contracts, due to the additional costs associated with the LoA compliance, which is mandatory.

6.3 SABS testing capacity

Consultations with officials from the SABS determined that there is limited EM testing capacity. The laboratories can only test motors up to 80kW, while the testing process can take up to three weeks, with some of the tests being outsourced. This long turnaround time further reduces interest in companies certifying their motors, as many businesses are not willing and/or able to afford being without their equipment for extended periods. As mentioned, the SABS testing infrastructure is aging and in need of refurbishment. However, with more than 90% of EM being within the 80kW testing range, the SABS is confident of their capacity to serve the South African market if the equipment upgrade is limited to this range, as it alleviates the need for substantial investment. The unit has motivated internally for capital funding to upgrade the test laboratory. At the time of writing this report, a funding decision had not been made and is likely to await the final MEPS outcome.

6.4 Regulatory approach

S&L programmes have proven to be highly effective in stimulating the development of cost-effective, energy-efficient technologies, over many decades and in multiple countries. However, their success is dependent on the implementation of sets of procedures that ensure suppliers and products comply with the programme rules. These procedures and their corresponding activities are geared to monitor, verify and enforce (MVE) the regulations and rules of individual programmes. They aim to maximise energy savings and to help safeguard the programme's integrity, thus building the confidence of consumers and industry participants (40). Indeed, this has been confirmed by numerous research studies; and is best captured by Zaelke (41):

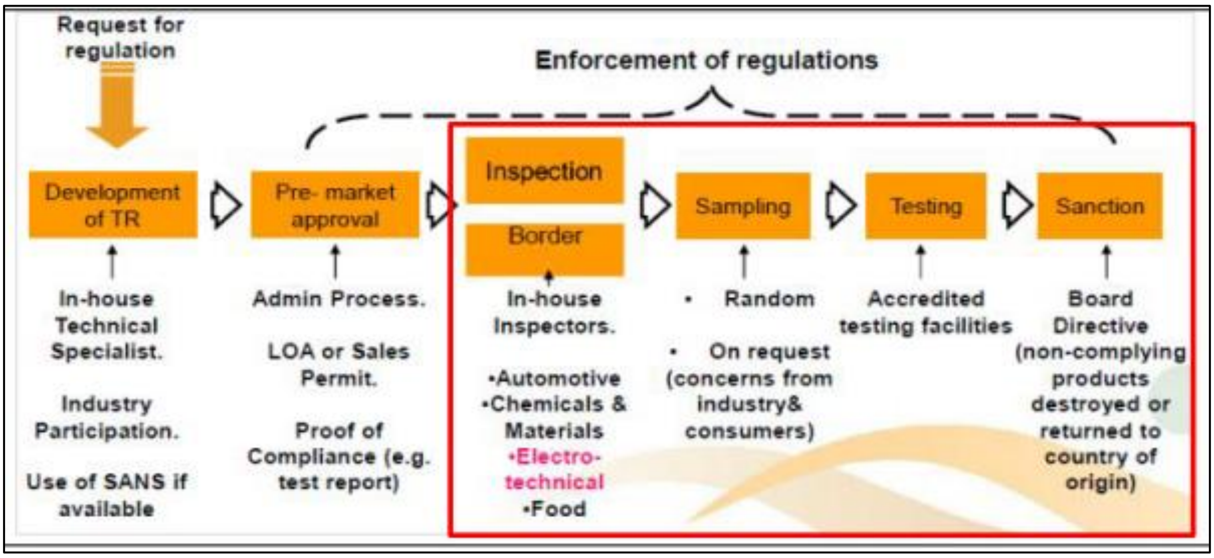
> "*In most markets, 20% of the regulated population will comply with any regulation; 5% will attempt to evade it; and the remaining 75% will comply as long as they think that the 5% will be caught and punished*."

This was then monetised by a more recent EU study (2015) that found that *one euro invested in market surveillance, led to €13 saved because of improved energy efficiency* (42).

A recent study (43) (reviewed and endorsed by the NRCS and its parent ministry the dtic) confirmed that effective market regulation (3rd party conformity approach) is only possible if both pre-approval and MVE are present. Without the latter, compliance levels average 40%, while increasing to 80% when both are effectively in place. The alternative approach is the self-declaration conformity approach (SDoC), where the supplier or manufacturer simply declares that the apparatus fulfils the specified national requirements. Thus, the 3rd party method is most appropriate where there is a higher risk associated with non-compliance, and especially so when there are limited market surveillance activities (MSA).

The DMRE has allocated the regulatory function of its S&L programme to the NRCS, which applies the 3rd party conformity approach (Figure 8). This has been in operation since 2015 and is well understood by government and industry. The DMRE has no direct influence or oversight over the NRCS

Figure 8: NRCS Third Party Conformity Approach



Source: NRCS

Simultaneously, the research findings point to a market in transition. Large, well-resourced companies, across all economic sectors, have recognised the benefits of EE EM; and have, or are in the process of, implementing internal programmes to shift their existing stock to IE3. This has two benefits: The first, as would be expected, is reduced electricity consumption and in turn improved profitability. The second, is reduced stockholding of spare parts and maintenance variability, i.e. IE3 only. This then raises the question as to how old, but still functional, EM are disposed of. The research found that many companies sell their old motors to a thriving second-hand EM market, either via dealers or through auctions, which any simple online search confirms. The outcome of this practice is that smaller companies, with fewer resources, get 'trapped' into a low efficiency EM replacement cycle. Here, it is important to recognise the South African government's stated commitment to small businesses by establishing a dedicated ministry:

> *The Ministry of Small Business Development (DSBD) was established in 2014, marking a turning point in history of SMMEs and Co-operatives development in South Africa, demonstrating Government's commitment to place SMMEs and Co-operatives at the centre of economic growth and job creation. –* www.dsbd.gov.za

Given this context - and noting the estimated sizable energy savings of IE3 MEPS - the challenge is to structure MEPS such that they liberate, rather than further supress, SMMEs caught in the inefficient EM trap. Here, two factors are crucial.

1. **Robust and functional MSA to maximise market compliance**. This is an outcome which currently cannot be assumed. In 2021, six years into the S&L programme, the Regulator's MSA have been low – creating growing industry discontent and resistance. Industry is justifiably concerned that the S&L programme has introduced costs and lengthy application timeliness, but that without MSA, their products are not protected – potentially losing market share to cheaper (non-compliant) products and / or impacting on their profitability – see (44) (45) and (46). As a result, industry is increasingly lobbying against the current 3rd party conformity process (47) and challenging government efforts to introduce regulations to maintain and administer compulsory specifications and technical regulations. Examples include the strengthening of MEPS for VC 9008, and the introduction of MEPS for general service lamps (VC9109 and 9110), and streetlights.
   Indeed, meetings with the NRCS parent ministry (dtic) recognised these challenges and proposed that alternate conformity approaches, such as SDoC, be evaluated as a mechanism to overcome this challenge.
2. **Awareness.** As per the international case study learnings, it is important to devise an active awareness campaign, which communicates the benefits of MEPS to industry and provides them with appropriate technical information – thus creating awareness around LCC, system design efficiency, VSD etc.

7 Findings and Recommendations

7.1 Overview and reflections

The CBA has unequivocally demonstrated that the DMRE should implement MEPS for EM. This view was shared almost universally by all stakeholders interviewed. The one exception came from a senior engineer from a large industrial energy user, even though the company had implemented IE3 as an internal standard several years ago. It was his view that efficiency should not be regulated; especially given the country's current tough economic conditions. In stark opposition, the dtic's National Cleaner Production Centre stated it has been lobbying its ministry and the DMRE to introduce MEPS for over a decade. Indeed, decades of S&L experience have demonstrated that MEPS drive efficiencies, reduce prices and ultimately benefit consumers.

A key consideration when introducing MEPS, is whether they should be phased in or if a 'big bang' can be absorbed by industry. The latter would maximise savings and simplify implementation, but valuable stakeholder input, for and against, is worth considering – some of it technical and some of it strategic.

Introduce MEPS at the IE3 level for motors in the 10kW to 375 kW range

This would delay MEPS for EM whose size is less than 10kW by two years or so, because although this category makes up the majority of total annual sales, the savings are lower (Table 9). This is due to the combination of shorter annual operational hours and lower efficiencies possible. Such an approach thus seeks to provide the industry with more time to prepare for the regulations, which it is likely to be more amenable to, as the MEPS will not affect most of the smaller distributors, who operate almost exclusively in this range. And MEPS, for EM greater than 10kW will still deliver substantial energy savings. Indeed, once large users recognise the financial benefits, they are likely to shift all their motors to the MEPS level or higher – resulting in a market-driven transition that will pave the way for a more straightforward introduction of the regulations.

Introduce MEPS at the IE3 level for motors in the 0.75 to ~120 kW range

EM greater than 120kW are predominantly driven via VFD, which creates different system dynamics. These make it imprudent to go beyond IE2, for technical reasons like the amount of copper needed for low voltage motors, the voltage change over time requirement for insulation, together with other factors that will negatively affect the magnetic circuit and reduce efficiency and performance.

Although several thresholds were provided, it has been ascertained that it is cheaper to buy new, rather than to rewind, an EM for sizes up to 10kW. The introduction of MEPS in the <10kW range will ensure that the use of inefficient motors is not perpetuated by users, who will benefit most from LCC, and who either do not have sufficient understanding thereof or are unable to resist the upfront cost saving of 15 to 20%. At this motor size, it is typically between R500 to R2 000, and thus not overly prohibitive.

7.2 Report recommendations

In Section 5.1 it was stated that '*a complete analysis of proposed MEPS should take careful consideration of specific impacts*.' These are now assessed in Table 12, based on the outcomes of the CBA.

Table 12: Impact analysis findings

Impacts	Research Finding
Energy Demand Reduction	Significant. 474 and 351 GWh for Scenario 1 and 3 in year 1, 2023. This equates to 0.25 and 0.20% of total electricity sold in 2021
Peak Load Reduction	Limited impact due to the nature of application i.e. continuous use
Environmental Impacts	Significant, due to South Africa's high coal usage, with an emission factor of 0.9488, as well as high particulates of NOx and SOx emission. And 1.1 billion litres of water saved per year (Scenario 2)
Cost Savings (Rands) pa	Payback of less than one year for all motor sizes and R2.94 billion per annum for Scenario 1
Consumer Impacts	As above
Manufacturer and Employment Impacts	Limited impact, as all EM are imported
Trade Impacts	Minimal, but must be managed through awareness and communication
Education Campaign and S&L	A well designed and adequately funded communication and awareness campaign will be a key driver of maximising savings
Government Incentive Scheme	Subject to available funds, an incentive scheme could yield immediate energy savings

Ultimately, the CBA has demonstrated that an effective EM MEPS programme has the potential to offer meaningful electricity savings. This will assist Eskom with its current supply challenges and make a sizable contribution towards meeting the DMRE's post-2015 NEES targets. It will also deliver on the DFFE's NDC targets, which are relying on GHG emissions savings from the S&L programme. And it will improve the competitiveness of the South African industrial base, by reducing the risk of load shedding (albeit by small measure) and reducing operational costs. Industry concerns can, and should be, managed through a well-developed communication and awareness campaign. Reliable literature regarding the rewinding of EM must be disseminated and this sub-industry supported, as it has an important role to play. Indeed, if left alone, it poses a major risk and may undermine energy savings. Finally, companies should be discouraged from selling their old and non-MEPS compliant EM; especially to the agricultural sector. Emerging farmers are the most likely recipients, which only places them under greater financial stress. Here, a targeted incentive programme may provide a solution.

Implementing MEPS for EM is not however without risks. Even though it is a policy priority for the DMRE and DFFE, there is an implementation gap and needs to be strengthened and supported. A well-considered institutional regulatory oversight framework does exist, and an adequate first check (LoA) under the 3rd party conformity approach is present. Unfortunately, limited MSA has resulted in sub-optimal results from the existing S&L programme and is increasingly creating industry displeasure – leading to active resistance against government attempts to introduce regulations, under any means possible. This is evident with the stalled VCs under consideration, as detailed in Section 6.4. – with these events and outcomes having strong potential to compromise EM efforts. Therefore, before proceeding, it is recommended that the importance of energy savings through a proven programme approach, be communicated to the requisite officials at the dtic – thus ensuring that the NRCS and SABS (testing facilities) have the required technical capacity, financial resources and management support and commitment. In this way, the MEPS regulation can deliver on its full potential, while strengthening market security and confidence for companies operating legally in South Africa. SDoC is not recommended as a viable conformity approach for the reasons cited by Covary (43).

Finally, based on the research findings, it is recommended that the DMRE move forward and implement MEPS at the IE3 level for EM in the 0.75 to 375 kW range for 2, 4, 6 and 8 pole motors, in line with international standards. VSD and VFD, which are used in specialist applications, should not be regulated at this time. Also, industry must be allowed a reasonable period to sell existing stock - no longer than 18 months - while clearly communicating from the outset that the determined start date is non-negotiable.

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Annex 1 – Stakeholder Engagement, Questionnaire and Decision Tree

The interview list is presented in **Error! Reference source not found.**, which includes all individuals and companies contacted. The research questions for the semi-structured interviews are also provided, followed by the decision tree used to interrogate the usage patterns, operational hours, motor sizes etc. The questions and schematic presented below are for the petrochemical sector but were customised for each interview.

Interview list

Figure 9: Stakeholder Interview List

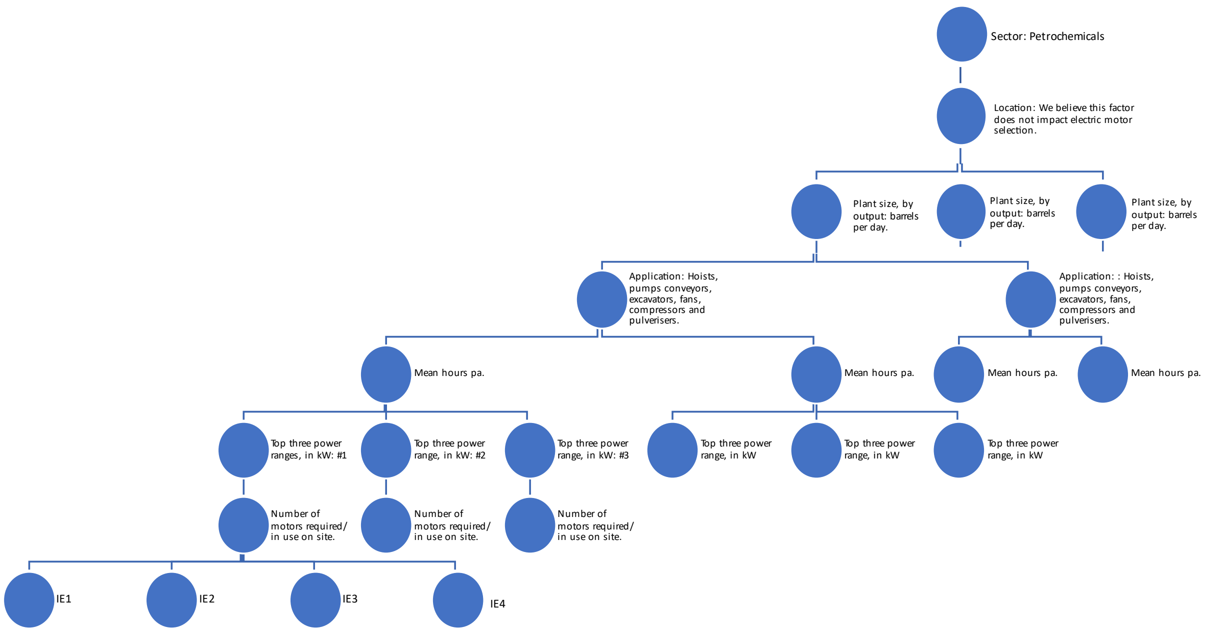
RESPONSES TO ELECTRIC MOTORS CALL FOR STAKEHOLDER PARTICIPATION		
Company	**Activity**	**Outcome**
Distributor	Maxeff Motor Seminar	Attended - 13/09/2021
Distributor	Major EM supplier.	Invite sent - 13 Sept - no response.
Distributor	Major EM supplier.	Meeting - 06/10/2021
Distributor	South African OEM and motor distributor.	Invite sent - 14th Oct - no response
Distributor	Accredited EM supplier in country.	Meeting - 26/07/2021
Distributor	South African OEM and motor distributor.	Invite sent - 14th Oct - no response
Distributor	EM Distributor	Meeting - 26/08/2021
Distributor	Major EM supplier	Meeting - 1/07/2021
Distributor	Electronics and motor supplier.	Invite sent - 26/08/2021 - no response.
Distributor	South African OEM and motor distributor.	Meeting - 13/07/2021
European Copper institute: Copper Alliance	10th International Motors Workshop	Attended - 16/10/2021
Industry Association	Industry Association	Meeting - 24/08/2021
Industry Expert	Agricultural Sector	Meeting 08/09/2021
Industry Expert	Retired Eskom Eng.	Meeting - 22/07/2021
Industry Expert	Industry Association	Meeting - 06/10/2021
Control Techniques	Webinar: Efficiency in pump applications	Attended - 26/08/2021
SABS	SANS 1804 WG meeting -	Meeting - 19/08/2021
SABS	Discussion around SANS	Meeting - 07/07/2021 & 13/10/2021
Large Commercial Agriculture	Agriculture	Meeting - 02/11/2021
Large Mining & Industrial	Petrochemicals	Meeting - 20/09/2021
Large Mining & Industrial	Mining - PGMs / Coal	Meeting - 23/09/2021
Large Mining & Industrial	Mining-	Invite sent - 13/09/2021 passed on to colleague - no response.

Research questions (mining and chemicals Sector)

1. Do you agree with the logical flow of the decision-making factors as they appear in the diagram shown? Please indicate the steps you would change if any.
2. Are the mining subsectors displayed, an accurate assumption of subsectors relevant to the electric motor study?
3. Aside from those listed, are there other major applications for electric motors that we should consider?
4. Following this, what size motors, in kW, are most commonly used for these applications? This question is dependant of factors decided prior. We are looking for at least three sizes.
5. Could you indicate how many motors your company purchases a year?

6. To the best of your knowledge what are the mean hours per annum for these main applications?
7. On average what is the life expectancy of these motors? > 10 years or less
8. Can you roughly indicate the number of motors each mine would require? This question is dependant of factors decided prior.
9. Are there any industry trends regarding EM we should know of? Such as internal policy on rewinding/repairing motors, motor lifespan (periodic replacement), the use of VSD/VFD.
10. What is the practise with old motors, are they disposed of or sold off, we understand the agricultural industry buys old motors?
11. Given the continuous above inflation electricity tariff increases since 2006 has this operational cost become a concern the mines? If so, has there been a shift towards higher efficiency motors such as the IE1,2, and 3?
12. Given the long hours that EM run, do the mines base their purchase decision on life cycle or upfront cost considerations? Please elaborate, i.e. are there internal policy as to motor minimum specs.
13. Our research has indicated that EM nameplates have false information about the efficiency of the EM. For example, IE0 sold as IE2. This is why many distributors get SABS accreditation. Based on your experience is this practise a) not common; b) happens from time to time; c) more than it should; or d) a real concern
14. What would be your recommendation for the starting level for MEPS? IE1, IE2, IE3 or IE4
15. What would be the best way to communicate the benefits of high efficiency motors to the mining and heavy engineering industry? Would concessional financing be useful?
16. Based on your company's experience advice or message you would like to communicate to the DMRE and dtic with regards to the development of MEPS regulations?

Figure 10: Decision Tree



Annex 2 – Country Case Studies

Case Studies were used to identify the best practises of leading EM manufacturing countries, this enables the study to provide recommendations highlighting the lessons learnt internationally and compare and contrast approaches with countries with similarly structured economies, such as Australia.

United States of America – including Mexico and Canada.

Country	Key Indicators
Programme Type	Mandatory MEPS and Energy Label; supported by public awareness campaign.
Start Date and Range	1997 - IE2 0.75-375kW
Subsequent revisions	2010 – IE3 0.75-375kW 2017 – voluntary IE4
Estimated Savings	132 TWh pa as of 2020

The 1992 Energy Policy Act officially launched America's electric motor S&L programme. The Act established nominal efficiency classes for implementation in 1997. Subsequent market demand for standardisation led the National Electrical Manufacturers Association (NEMA) to introduce 'Premium' efficiency motors in June 2001 for the range 1-500 HP (0.75-375kW), at an equivalent of IE2. In 2007 the MEPS was increased to Premium (IE3) and came into effect in 2010. In 2017, voluntary 'Super Premium' (IE4) was introduced (1; 29; 5; 48). The IEC and NEMA efficiency classifications are:

IEC	NEMA	Timeline
IE5	Ultra-Premium	
IE4	Super Premium	Voluntary EPS
IE3	Premium	2017 MEPS
IE2	High	2010 MEPS
IE1	Standard	1997 MEPS
None or IE0	Below Standard	

NEMA publishes national standards and guidelines for electric motors, in line with federal law. However, NEMA is not responsible for certification or compliance, this responsibility lies with the US Department of Energy (DOE).

In 2011, the programme was harmonised with Canada and Mexico so that the continent has one hegemonic system (1; 29; 5; 26). However, the region has never fully adopted the IEC 60034-30-1 (classification) or the IEC 60034-30-2 (testing), the adoption of IEC test standards as a legal requirement is being considered (49; 29; 50).

In 2014, the DOE started publishing information sheets explaining the benefits of purchasing higher efficiency motors and how to maximise energy savings by understanding the link between motor efficiency and system performance. This was done in a simple and illustrative manner which highlighted the annual cost savings in dollars for various motor sizes. Furthermore, the DOE demonstrated why the rewinding of small electric motors was not a worthwhile venture due to efficiency losses, costs, and improved technologies available (50).

Lessons Learnt:	
1	MEPS have achieved significant energy savings and increased industry competitiveness
2	Energy savings are maximised through an effective and adequately funded communication and awareness campaign
3	Regulating VSD and VFD creates unnecessary complexity and compromises MEPS effectiveness, and should be excluded
4	Motor manufacturers should be given time to clear non-compliant stock (up to 3 years). A shorter period for countries that do not have a manufacturing industry
5	The range 0.75-375kW covers 99% of industrial and commercial motors.
6	The DOE advise against rewinding of small EM's due efficiency losses and costs involved.

China

Country	**Key Indicators**
Programme Type	Mandatory MEPS and Energy Label; supported by public awareness campaign and incentive mechanisms.
Start Date and Range	2002 - IE2 0.75-375kW
Subsequent revisions	2009 - incentive scheme 2010 – IE2 Motor Driven Systems IE2 2016 – voluntary energy label 0.75-375kW 2021 – IE3 0.12-1 000kW 2021- mandatory energy label 0.75-375kW
Estimated Savings	400 TWh kWh pa

China's electric motor MEPS programme introduced IE2 in 2002. This was followed up in 2006 when national motor manufacturing standards were adjusted to align with CEMEP (EU) standards. Between 2007-2010 the Chinese government updated their domestic electric motor MEPS as part of motor driven systems (fans, pumps, and compressors) (51; 10).

In 2020, China announced that it would be strengthening its electric motor MEPS from IE2 to IE3, effective July 1st, 2021, and in so doing aligning with the EU and US. (30; 52). In addition to more stringent standards the criteria were expanded by: 1) Expanding the range from 0.75 to 375kW to 0.12 to 1 000kW and including all pole variations; 2) Making energy labelling mandatory; 3) Mandating that motors in the 0.75 to 375kW range be produced with the CEL (Chinese Energy Label), to increase consumer information at time of purchase (30; 12).

Lessons Learnt:	
1	The MEPS programme achieved significant energy savings, largely due to the frequent revision of MEPS and incentives

2.	The incentive programme was carefully planned and well executed, delivering a net economic benefit
3.	Energy labelling is a key component of a successful S&L programme and introduced (belatedly) to improve effectiveness
4.	Government impetus is required to drive continuous transition

European Union (EU)

	Key Indicators
Programme Type	Mandatory MEPS and Energy Label; supported by public awareness campaign.
Start Date and Range	1999 – IE1 0.75-375kW voluntary
Subsequent revisions.	2011 – IE2 0.75-375kW 2015 – IE3 7.5-375kW (VSD motors at IE2) 2017 – IE3 0.75-375 (VSD motors at IE2) 2021 – IE3 0.75-1000kW no exceptions. 2023 – IE4 75-200kW
Estimated Savings	57 TWh pa 2020; 110 TWh pa to 2030 / 40 billion tonnes CO2e pa, as of 2030

Voluntary standards (IE1 equivalent) were introduced in 1999. MEPS were legislated in 2009 (effective 2011) at the IE2 level and covered various motor designs, configurations, sizes (0.75 to 375 kW), and purpose-built motors. The revision also adopted the IEC 60034-30-1 international standard. Simultaneously, various member states introduced national incentive and tax rebate programmes to promote efficient motors. Three subsequent revisions are summarised in the chart below (53).

From July 2021 three phase motors in the range 0.75 to 1 000kW must correspond to IE3 or better; 0.12 to 0.75kW must meet IE2 specifications; and VSD motors greater than 0.75kW must be IE2. From July 2023 the MEPS for single phase motors greater than 0.12kW will be IE2; and motors in the range 75 to 200kW (2, 4 or 6 pole) will be IE4.

Lessons Learnt:	
1	Voluntary programmes have a limited impact
2.	Incentives were used to transition to MEPS.
3.	Government impetus is required to drive continuous transition, this takes the form of regular MEPS revisions and consultation with manufacturers and users
4.	Aligning standards with international best practise reduces trade barriers I.e.: shift from CEMEP to IE
5.	Legislating MEPS for VSD is complicated and has not yielded the expected energy savings and has come under scrutiny from manufacturers and consumers.

Australia

Country	**Australia (Inc. New Zealand)**
Programme Type	Mandatory MEPS and Energy Label; supported by public awareness campaign and incentive mechanisms.
Start Date and Range	2001 – IE1 0.75-185kW
Subsequent revisions.	2006 – IE2 0.75-185kW 2012 – IE2 Adoption of IEC standard 2019 – IE3 Voluntary for ‘high efficiency motors’
Estimated Savings	1 TWh pa, as of 2015 / 1 100 kt CO2e pa, as of 2015

Australia’s electric motor MEPS programme commenced in 2001 (MEPS1) and updated in 2006 (MEPS2). During this time, Australia and New Zealand harmonised their policies and standards to reduce trade barriers. These were subsequently absorbed into the *Greenhouse and Energy Minimum Standards Act 2012 (*GEMS), which also adopted the IEC 60034-30-1 as the national standard. The

MEPS programme was revised in 2019 whereby all motors in the range 0.75 to 185 kW which are IE2 must be labelled as 'standard' and IE3 (voluntary standard) as 'high efficiency' (27; 54; 55; 56; 28; 57).

An additional feature is the mandatory product registration database known as the Equipment Energy Efficiency (3E) Programme, which forms part of the monitoring, enforcement, and verification process. Only products registered on the database may be sold and 3E runs a targeted check-testing programme to ensure legislated products are compliant (54; 55). The programme is supported by a highly visible information and public awareness website, which lists equipment and technology guides to educate the public on energy efficiency best practise in their businesses (58).

Lessons Learnt:	
1.	Government incentives to transition the market were an effective tool.
2.	Aligning standards with international best practise reduces trade barriers
3.	3E runs a very effective and high-profile public awareness and education programme which has been an important support mechanism.
4.	GEMS undertakes regular market surveillance which has contributed significantly to the high levels of market compliance

Kenya

	Key Indicators
Programme Type	Mandatory MEPS and Energy Label; supported by public awareness campaign.
Start Date and Range	2013 – IE1 0.73-185kW
Subsequent revisions.	
Estimated Savings	NA

2013 saw the role out of a S&L programme in Kenya, by the Kenyan EPRA (Energy and Petroleum Regulatory Authority). This programme introduced MEPS for a number of appliances, including refrigerators, electric motors, and air conditioners amongst others (59). EM were regulated by the mandatory KS 2449-1:2013 (rating and performance) and KS 2449-2:2013, (determining losses and efficiency testing) this standard applies to all EM between 0.73-185kW. EM are tested against these standards, then registered with the EPRA and given the Energy Label (59). The Kenyan energy label uses a five-star ranking system to denote level of efficiency, with one being the lowest and five the highest (60; 59).

The EPRA require the Energy Label to be applied to the appliance before it reaches market and conduct market surveillance and inspections with the help of government entities. Further the EPRA display useful educational information regarding energy efficiency benefits and the Kenyan Energy Label on their website here.

Initial analysis indicates that the Kenyan EM MEPS are not yet harmonised with IEC standards and have not been updated since their initial rollout of 2013. However, revisions are expected in following the revisions to MEPS for air conditioners and refrigerators in 2020 and 2019 respectively.

Egypt

	Key Indicators
Programme Type	Mandatory MEPS and Energy Label; supported by public awareness campaign.
Start Date and Range	2021 – IE3 0.75-375kW
Subsequent revisions.	NA
Estimated Savings	NA

Announced in January 2020, the Egyptian Organization for Standardization and Quality announced the rollout of EM MEPS starting July 2021 (61; 62). The Egyptian EM MEPS programme had been in the works since 2015 when it aligned national standards with those of the IEC. The relevant Egyptian Standards, ES 8268-1 for *"Rotating electrical machines - Part 1: - Rating and performance"*, ES 2623-1 *"Standard methods for determining losses and efficiency from tests",* ES 2623-3/ 2017 for *"Rotating electrical machines – part 3: Efficiency classes of line operated AC motors (IE code)"*, which are aligned with the corresponding IEC standards. These standards were revised in line with IEC revisions in 2017 and 2019 (61).

All EM between 0.75-375kW as of July this year must comply with an IE3 equivalent. The Egyptian government also requires EM products to have an energy label designating their efficiency and compliance with the relevant Egyptian Standards (61).

Communication and Awareness

Desktop research indicates that a grace-period, generally 2-3 years, is common in countries and regions who having existing MEPS programmes. During this motor manufacturers and suppliers in-country are allowed to clear their existing stock of motors which fall below the new MEPS. This practise of a grace period continues with the updating of MEPS in line with improving and newer motor technologies. Alongside, the grace-period, it would be beneficial to have an industry awareness and communication campaign which targets product end-users and suppliers (5; 54). This campaign would have to explain the rationale behind the MEPS programme at a national level, and illustrate the long-term cost-saving benefits, to the end-users. Research indicates that this process is crucial to the overall success of the EM MEPS programme (5). All of the countries detailed in the case studies, ran highly public educational campaigns which detailed and illustrated, through the use of graphs and diagrams, how seemingly minor changes can have significant impacts. The US DOE, the Australian and New Zealand governments have well designed and user-friendly websites which cover numerous FAQs around EM efficiency and their MEPS programmes (50; 58). The Australasian case indicates that the effectiveness is improved with a thorough and well-planned campaign.

Incentive programmes

Incentive programmes were used in China, Australasia, and in some EU member states. The Chinese government ran a highly successful short-term incentive scheme for energy efficient appliances between 2009-2011 (51; 12). During this period the market share of MEPS compliant EMs grew significantly. This large-scale funding scheme was used as a kickstart mechanism for the transformation of the EM market in China. The short nature of the scheme ensured EM were motivated to purchase new motors and trade in their old motors while the cost was negligible (51).

The Australasians continue to make funding options available for incentivising energy efficient purchases. However, they did offer direct subsidies for EM during their first MEPS rollout of 2001-2006 (56). The early success of the Australian MEPS programme has been attributed in part to the incentive scheme available at the time. Currently incentives for energy efficient improvements are available through different government entities for qualifying businesses (58).

Energy labels and nameplates.

Research indicates that all the aforementioned countries use energy labels to varying degrees to demarcate the efficiency standards of products sold domestically. The Chinese example is pertinent as energy labels were voluntary when introduced in 2016 for motors 0.75-375kW, known as the Chinese Energy Label or CEL. In June of this year, they were made mandatory as the Chinese government realised the consumer benefits of increased information and awareness brought on by the label programme (51). Both the EU and US have long used Energy Label programmes alongside their MEPS programmes to boost the effectiveness and rapidity of MEPS rollout (29; 26).

Findings and Recommendations

The study of the aforementioned countries has yielded a clear picture as to the best practise surrounding electric motor MEPS internationally. The study has found that the MEPS target range of 0.75-375kW motors is the international norm, with this range being used as a springboard for further MEPS developments (63). This is evidenced by the recent adjustments made by the EU and China who in June/July of this year implemented electric motor MEPS broader than the 0.75-375kW they had been using for some years prior (63).

The use of energy labels has been found to be extremely effective in aiding the market penetration of MEPS programmes, however, are less effective if not mandatory. This was evident in the Chinese MEPS programme with the slow use of energy labels prior to July of this year. Energy labels and nameplates are used to provide end-users with information has to product rating and improved energy efficiency benefits at the time of purchase. The nameplates also work to ensure quality control and avoid counterfeit products entering local markets.

Incentive programmes have been identified has a useful mechanism to kick-start MEPS programme implementation. When used in the short-term to accelerate high-efficiency motor uptake, incentive schemes have proven instrumental to overall MEPS programmes success. These can take various forms but often cover the price premium between the old and new MEPS standards. Another successful incentive model was the trade-in model which granted consumers discounts for swapping out old motors for newer MEPS compliant motors.