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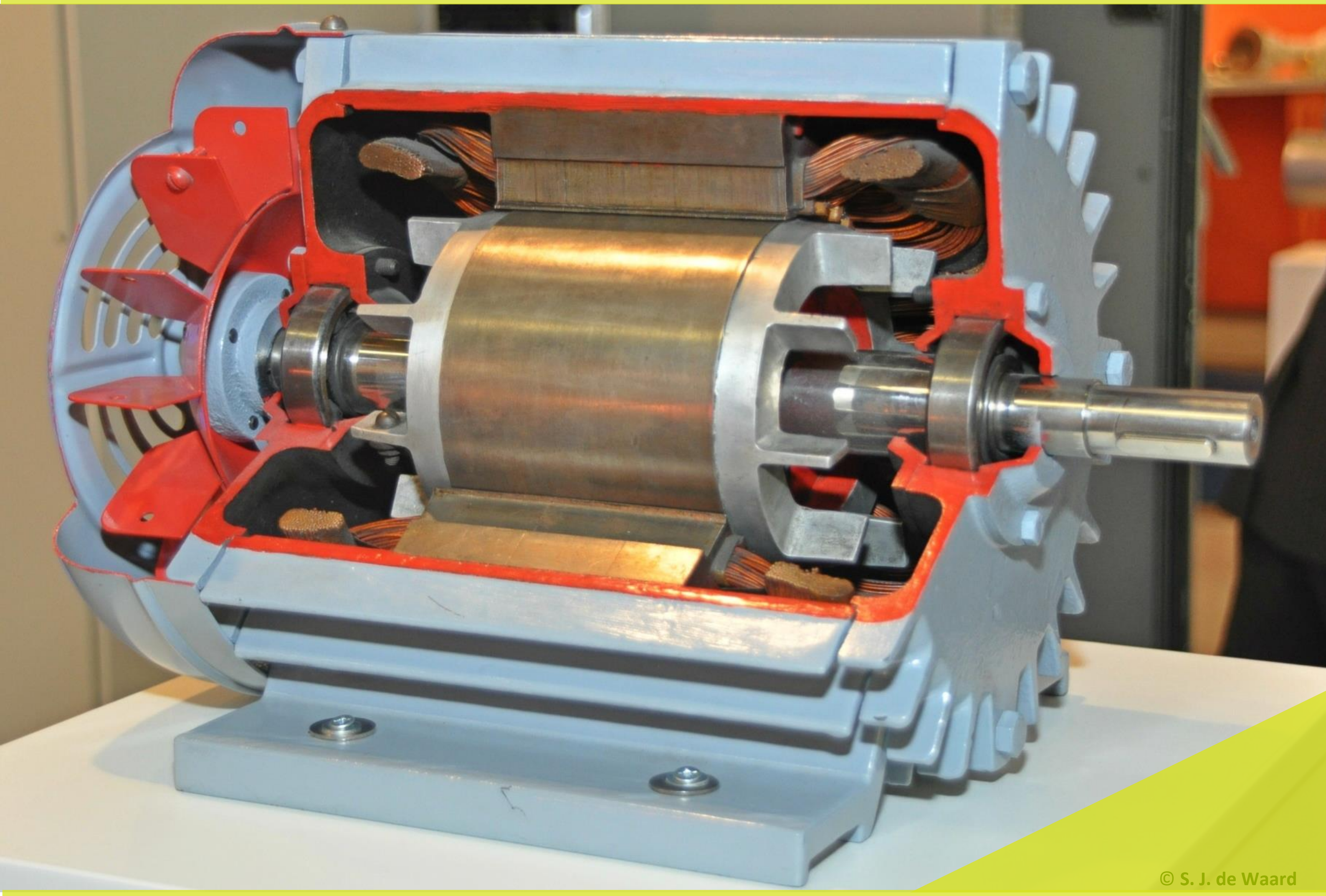
Optimising Electric Motor-Driven Systems

Policy opportunities to reduce electricity consumption of motor systems in Indonesia



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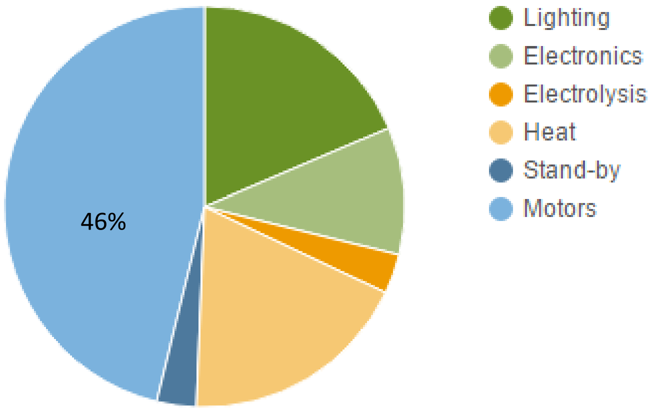
Introduction – Setting the Scene

Across all sectors, every moving mechanical part and cogwheel is driven by a motor, most likely powered by electricity. It should not be surprising, therefore, that almost half of the world's electricity is consumed by electric motors (Figure 1).

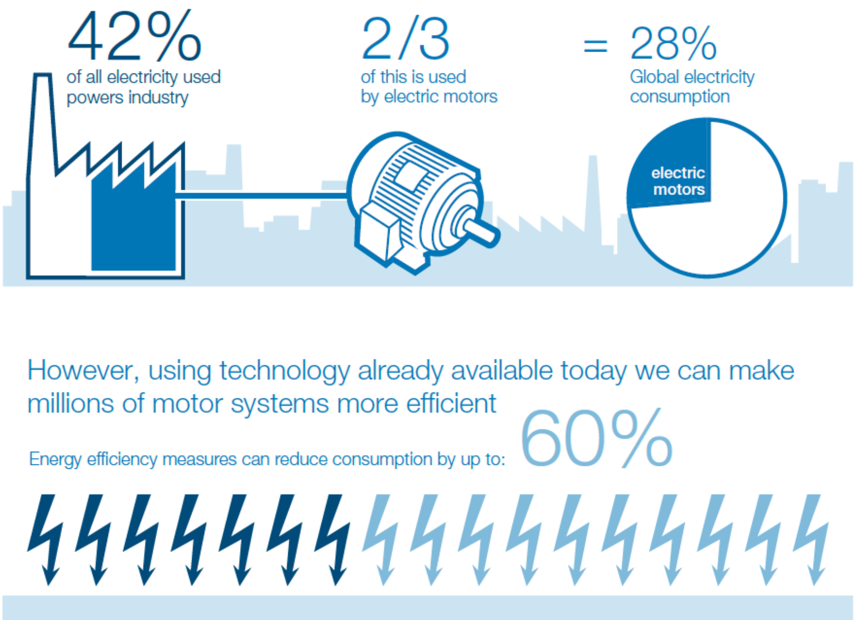
Figure 1: Estimated global electricity demand by sector and end-use (2006)



Source: Institute for Industrial Productivity, adapted from IEA, 2011

In industry, electric motors account for two thirds of electricity consumption, attributing over a quarter of global consumption to this sector alone (see Figure 2).

Figure 2: Global electricity consumption of motors in industry



Source: ABB Group, 2011

There is huge potential to increase energy efficiency of electric motor systems that power the industry sector in particular, but also across a vast number of appliances used in buildings and households. However, the International Energy Agency (IEA) projects that as much as two thirds of this potential will remain untapped without favourable policy change (IEA, 2014). In many developing countries such as Indonesia, most electric motors are out-dated and their long lifetimes often extended through the rewinding industry. The result is widespread reliance on inefficient systems and a significant waste of electricity.

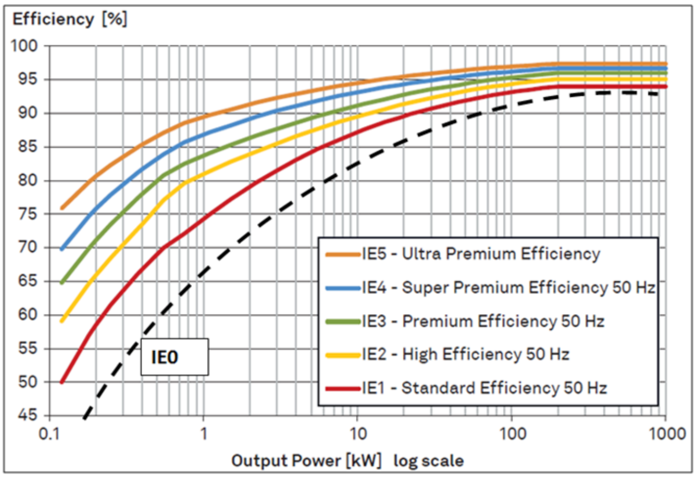
One tried and tested option to achieve efficiency gains makes use of energy efficiency standards. Furthermore, taking a wider electric motor-driven system approach, as illustrated by Figure 5, can easily double or triple savings. Many countries have already achieved large power and cost savings by implementing respective policies (McKane & Hasanbeige, 2010; UNIDO, 2011).

This learning paper explains how these best practices from other countries have been used to design a suitable policy programme for Indonesia within the frame of a project funded by the Climate Development and Knowledge Network (CDKN). In turn, the lessons learned from the policy programme for energy-efficient motor systems in Indonesia can inform replication in other countries. In the following, this learning paper introduces selected efficiency measures implemented more globally, before presenting the situation specific to Indonesia, including the savings potential, policy options, and other benefits of a policy programme aiming at energy-efficient motor-driven systems. The paper concludes by giving a quick overview of the mitigation measure developed in the Indonesian concept and where to find more information on the topic.

Standards, MEPS and Motor Systems

Similar to the standards used for a range of household appliances such as fans, refrigerators and irons, electric motors can be classified into five international categories, ranging their performance from 'standard efficiency' to 'ultra premium efficiency' (see Figure 3).

Figure 3: Efficiency of IE-classes electric motors

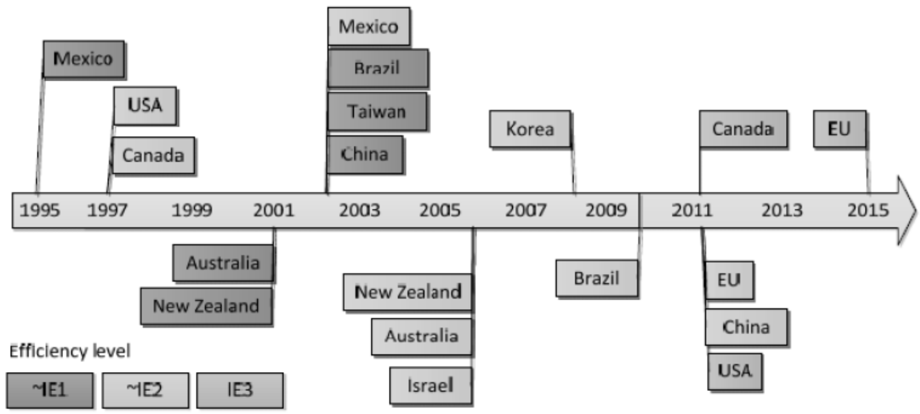


Source: EMSA, 2014

In Indonesia and other developing country contexts, motors may perform at a 'below standard' International Efficiency (IE) level, illustrated in Figure 3 as 'IE0'.

In practice, countries can effectuate a system-wide transition to more efficient technologies by introducing (mandatory) Minimum Energy Performance Standards (MEPS) for motors and other appliances. Under MEPS programmes, government or state legislation and regulations apply mandatory standards for certain products manufactured in or imported into the respective country. Over time, this can lead to a phase out of technologies that do not meet the set efficiency standard and governments can readjust their regulations to promote a higher efficiency level.

Figure 4: Mandatory IE-levels over time for several countries



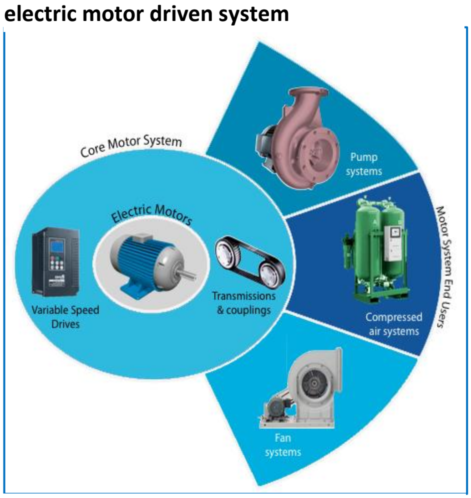
Source: UNIDO, 2011

Mexico, for instance, introduced the IE1 standard in 1995 and progressed to IE2 in 2003. The European Union (EU) initially set the standard at IE2 in 2011 and has recently raised the efficiency requirements to IE3 level. China set the standard at IE2 in 2012 and is planning to progress to IE3 in 2016.

A change in performance standards does not necessarily lead to the need for new technologies. Rather, electric motors are relatively simple devices where a few simple adjustments in design and operation can already affect equipment efficiency. The difference between IE-classes is relatively larger for smaller motors.

As mentioned, to have a larger impact on energy use, it is important to go beyond the electric motor itself. Most country policies look at complete electric motor-driven systems (EMDS) to capture meaningful savings potential. In most cases, improving

Figure 5: Most common elements of an electric motor driven system



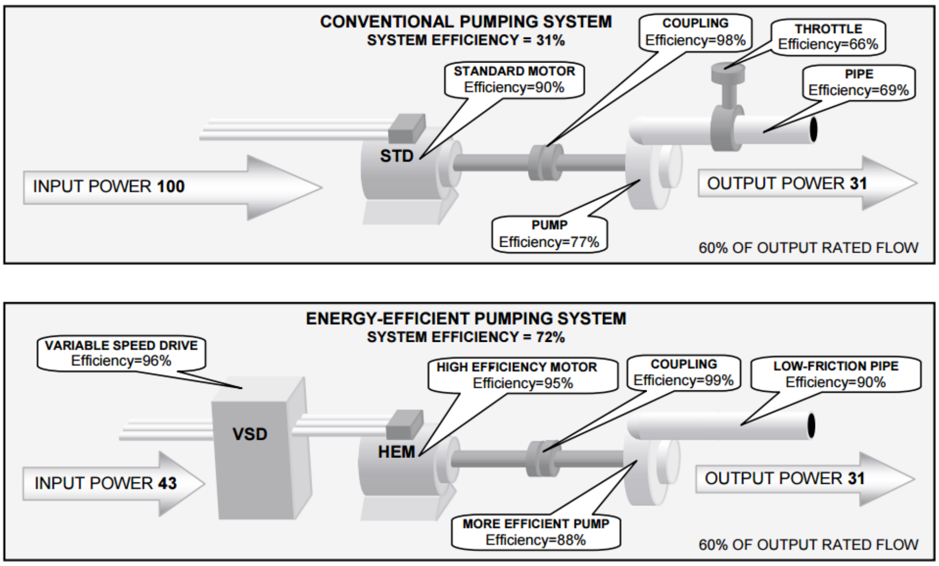
Source: IETD, 2015

the efficiency of a motor system includes the following (see Figure 5):

1. Use of energy-efficient motors;
2. Selecting highly efficient surrounding core components like pumps, fans, compressors, transmissions, variable speed drives as well as appropriate type and size for the system;
3. Optimisation of the design and operation of the complete system.

Widespread experience has shown that retrofits can result in savings ranging from 5% to as much as 60%. Figure 6 illustrates a common retrofit of a pumping system, resulting in an efficiency improvement of 41%.

Figure 6: Retrofitting an electric motor driven pumping system

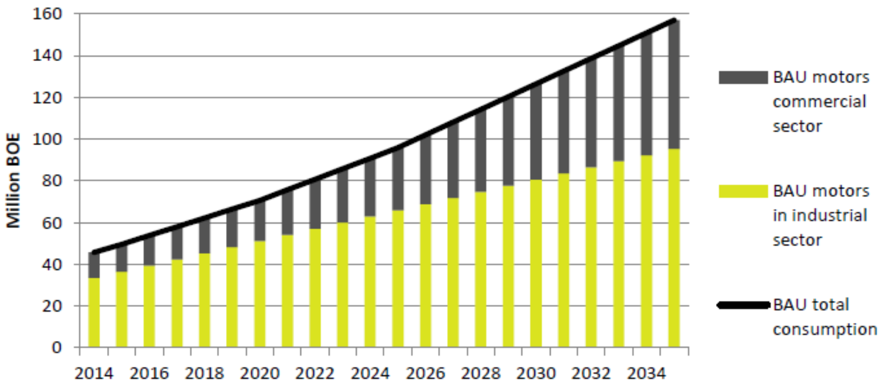


Source: ECI, 2004

Indonesian baseline study and the effect of introducing MEPS

In Indonesia, we used customs import data (bottom-up approach) and national statistics (top-down approach) to calculate the present electricity consumption of the motor stock, as shown in Figure 7. Making use of several scenario studies, we predicted the future consumption, which is expected to rise by more than a factor of three in the coming two decades based on conservative growth assumptions.

Figure 7: Electricity consumption of electric motors Indonesia



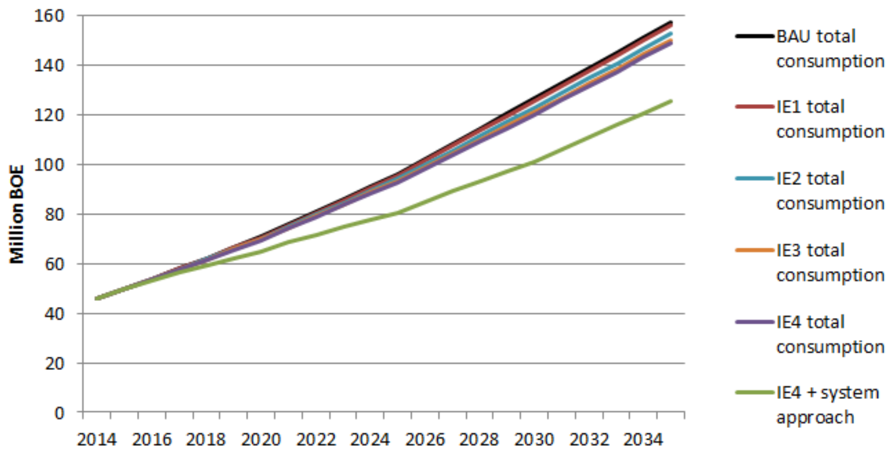
Source: Sipma et al, 2015

For a number of years, Indonesia has been preparing to introduce MEPS for electric motors, at the IE1 level. The import data, together with a survey conducted with industrial companies, gave us an estimate of the present motor stock in Indonesia along IE-classes. It seems that around 40% of the motor stock performs at an efficiency level that can be considered equivalent to IE0, meaning even below IE1 standards, and this percentage is higher still for smaller motor sizes. As a result, analysis shows that the benefits of a MEPS system at IE1 level will be modest, if this is the sole measure to reduce energy use from electric motor systems. Mere savings of 0.7% will be reached at IE1 level compared to the business as usual (BAU) scenario. If MEPS were instead introduced at IE4 level, for instance, the electricity savings and related greenhouse gas (GHG) emission reduction would be 7 times higher (5.1%). In practice, Indonesia could only progress its MEPS level to IE4 over a longer period of time, so this 7-fold efficiency increase could only be realised over very long time frames.

As shown in the above, an effective energy efficiency programme must take into account not only individual motor performance, but also the EMDS as a whole. Since a vast number of different systems exist, it’s much harder to estimate the *average* savings potential, against a BAU scenario, of retrofitting complete systems. To meet this challenge, the project based its assumptions on data describing the savings potential of the three main EMDS in the industrial sector as compiled by a United Nations Industrial Development Organization (UNIDO) report (McKane & Hasanbeige, 2010). Based on these findings, we estimate that a policy approach that combines an electric motor driven system programme and the introduction of MEPS in Indonesia, will increase the savings potential by a conservative additional 15 percentage points. That is, if efficiency improvements are achieved using cost effective retrofits with a maximum simple pay-back time of around 3 years’ time.

The lower graph in Figure 8 shows the savings potential of MEPS at the level of IE4 that is combined with a system approach. Compared to MEPS at the level of IE1 only, the ‘full system approach’ would yield almost 30 times more electricity savings and related reductions of GHG emissions.

Figure 8: Effect of introducing MEPS at several IE-classes, followed by the system approach



Source: Sipma et al, 2015

Policy Options to Effectuate Change

A system approach is more challenging than implementing motor MEPS alone, but offers much larger benefits. To achieve these, successful best practices from other countries can inform the design of a suitable policy programme for Indonesia. A number of reports and resources[1] give guidance on developing a policy package (EMSA, 2011; EMSA, 2014; EMSA, 2015; UNIDO, 2011; and Waide & Brunner, 2011). Besides MEPS and related labelling programmes, the following policy tools are often part of such a programme, targeting several stakeholders:

- Voluntary agreements with industry;
- Energy management programmes;
- Energy audit programmes;
- Company motor policies;
- Financial incentives;
- Raising awareness and providing information.

[1] For more resources, visit the motorsystems.org platform.

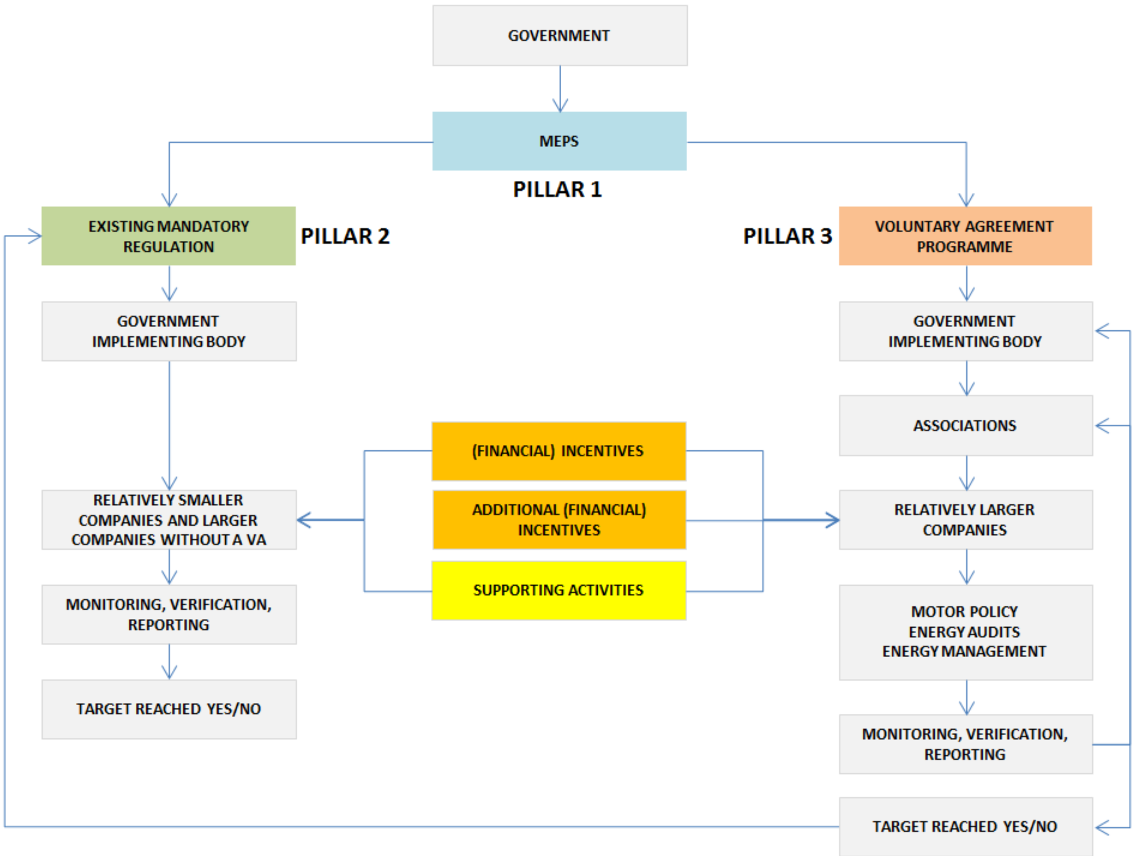
Figure 9: Three pillars of a motor policy programme in Indonesia

PILLAR 1	PILLAR 2	PILLAR 3
STRENGTHEN MOTOR MEPS	**MANDATORY REGULATION**	**VOLUNTARY AGREEMENT (VA) PROGRAMME**
Increase the level of the planned Minimum Energy Performance Standard (MEPS) for electric motors from IE1 to IE4 over time. Include more motor types and sizes.	Increase the scope and effectiveness of the current *mandatory* regulation that says that companies with a certain minimum energy consumption should implement an Energy Management System (EMS)	Start a *voluntary* agreement (VA) programme with industrial and commercial branches, and negotiate, together with relevant associations, energy saving targets with government. Assistance and incentives will be provided to help meet those targets.

Source: (ECN, 2016)

These tools don't work independently from each other, but are highly complementary and have their own interactions with several stakeholders such as manufacturers, trading companies and end-users. Further steps include collecting information on existing policies and discussing barriers and most appropriate incentives with government partners and industry. For the project in Indonesia, we designed a policy programme that includes three pillars (see Figure 9 and 10).

Figure 10: Elements of a 3-pillared approach in Indonesia



Source: ECN, 2016

Note that *voluntary* doesn't mean that companies have no obligations in meeting those targets, but can be asked to leave the VA programme. Figure 10 shows how the three pillars could relate to each other in practise and where supporting activities such as financial incentives come into play.

Benefits of Taking a System Approach

A system approach doesn't only increase the electricity savings and related GHG reduction by a factor of 25[2], there are also additional benefits to achieve that are equally important.

1. *Reduced government spending on subsidies*

   In Indonesia and many other developing countries, electricity is heavily subsidised, providing little incentive for end-users to reduce energy consumption or invest in efficient appliances. However, the government of Indonesia has begun to reduce subsidies for electricity, which represent a significant financial burden. A reduction in energy consumption from more efficient motor systems will also reduce the amount of subsidies spent by the government on electricity consumption. At the same time, reduced subsidies will increase the incentive to invest in efficient technologies. We calculated the related governmental financial savings for the reference year 2014. Since subsidies will be reduced further over time, this figure will change over time, however, it shows the large magnitude of possible governmental savings. Independent of the speed of subsidy reduction, the system approach will yield 25-fold reduction in governmental subsidy expenses (see Table 1).

2. *Prevented losses during electricity production*

   In Indonesia, there is a relatively large difference between average production costs of electricity and (unsubsidised) electricity tariffs, due to inefficiencies. Any electricity savings will contribute to reducing these losses in a magnitude equivalent to the energy savings generated through a system approach. Similar to other energy efficiency measures on a larger scale, reducing energy consumption from motor-driven systems can therefore have a positive impact on a country's energy security and dependence on fossil fuel resources such as coal. This is particularly relevant in many developing country contexts where domestic electricity production may not cover rising demand and dependence

[2] The formerly mentioned '30-fold higher savings' is now reduced to '25-fold higher savings', since the relatively smaller companies are excluded from the policy approaches of pillar 2 and 3. By targeting e.g. the 20% largest energy consumers, pillar 2 and 3 will cover around 80% of the total electricity consumption. The smaller companies, responsible for the remaining 20% electricity consumption, will only be targeted with the MEPS approach of pillar 1. Although motors consume 65% to 75% of industrial and commercial electricity, one cannot separate the impact of the complete policy programme from the broader energy use in these sectors. It is therefore anticipated that the overall effect will be larger than the savings mentioned in this document, related to motor system impacts only, but this has not been calculated.

on energy imports is often paired with grid and transmission losses and insecure access. In these cases, the goal of increasing energy security – inter alia through energy efficiency measures – can be an important driver for policy development[3].

3. *Cost-effective investments that pay back over time*

   From an end-user perspective, standards that promote more expensive efficient motors may seem unattractive. Yet, this cost argument only holds true at the time of purchase. During a motor's lifetime, the cost of buying the equipment makes up less than 5% of expenses; the remaining 95% are dominated by the cost of power. High-efficiency electric motors therefore deliver significant cost savings for firms over time. An electric motor becomes a profitable investment within a few months. Based on average prices of electric motors and estimated investments costs for pumping-, compressed air- and fan systems (McKane & Hasanbeige, 2010), we assume that a system approach requires an investment that is roughly 10 times higher than investing in stand–alone motor improvement measures. This is due to higher costs of additional equipment compared to motor retrofits. These additional system costs also have higher payback times than stand-alone motor investments. For the additional equipment used in a system approach, we assume a simple payback period of maximum three years. It is important to note, that beyond this period the respective company will fully benefit from (additional) yearly energy savings over the remaining lifetime of technical equipment, resulting in a positive return on investment. When a country has an internal manufacturing market for high-efficiency electric motors and the mentioned systems; investments will also boost that segment of the economy (which is not the case in Indonesia, however).

4. *Savings due to avoided additional power plants*

   Future savings are not only related to power production costs through the public utility, but also avoided investment in generation facilities. Figure 8 indicates the possible impact on electricity consumption until 2030 (the year all retrofits can be expected to have taken place), namely a reduction of 25.2 mBOE or 41.1 TWh. This is roughly equivalent to the power generation capacity of 6 to 7 GW of new coal power plants, depending on annual operational hours. This reduced dependence on coal represents a practical avoided investment cost, considering coal power makes up the largest share of new capacity planned by the Indonesian public utility company PLN over the coming decade. Interviews conducted with Independent Power Producers (IPP) focussed on coal power plant development suggest figures of USD 1.2

[3] Read more on energy security and other benefits of low emission development in an outreach brief series developed in the frame of the Low Emission Development Strategies Global Partnership (LEDS GP) here: **http://ledsgp.org/2016/06/presenting-co-benefits-of-leds/?loclang=en_gb**

million of avoided investment cost per MW of installed capacity for Chinese constructions and up to USD 2 million for European and US constructions. On average, the avoided investment is estimated at approximately billion 10 to 11 USD. The avoided GHG emissions of these coal power plants are included in the related GHG emission reduction, mentioned in Table 1, calculated based on aggregate estimate future grid emission factors.

5. *Job creation for equipment installation*
   Installing an electric motor often doesn't require external engineers; only larger motors, that may need to be assembled on-site, might require the hiring of specialised engineers. For other equipment, the changes are more complex and may rely on specialised knowledge. We were able to estimate the *direct* installation workforce needed for Indonesia, to replace the present motor stock and install additional equipment. Taking into account (1) man-hours needed for installation by motor-size and the hourly salary, and (2) the percentage of the investment costs of additional system equipment that goes to labour, we estimate an additional need of 15 times as many engineers to implement a system-based programme. Additional employment opportunities can also be expected within the trading sector and with auditing companies (as part of pillar 2 and 3).

Table 1 summarises all mentioned savings and other benefits in the case of Indonesia. Similar numbers could be calculated for other countries.

Table 1: Impact of pillars 1, 2 and 3 in Indonesia

<table>
<tr><th>Annual effect in 2025: combined industrial & commercial sector</th><th>MEPS IE1 (current proposed policy)</th><th>Pillar 1 in place (MEPS IE4 compared to IE1)</th><th>Full system approach with pillars 1, 2 & 3 in place (compared to IE1 only)</th></tr>
<tr><td>Electricity savings (in % of total)</td><td>0.7</td><td rowspan="6">Up to 7-fold increase</td><td rowspan="6">Up to 25-fold increase</td></tr>
<tr><td>Electricity savings (in million BOE)</td><td>0.5</td></tr>
<tr><td>Electricity savings (in TWh)</td><td>0.9</td></tr>
<tr><td>Electricity savings in the industrial & commercial sector (in USD million)</td><td>60</td></tr>
<tr><td>Governmental subsidy & production savings (in USD million)</td><td>36</td></tr>
<tr><td>Related GHG emission reduction (in Mt)</td><td>0.8</td></tr>
<tr><td>Economy: direct investment equipment (in USD million)</td><td>190</td><td>1.3 times larger</td><td>10 times larger</td></tr>
<tr><td>Employment: workforce for initial installation (in man/years)</td><td>326</td><td>Equivalent</td><td>15 times larger</td></tr>
</table>

Source: ECN, 2016

Steps taken toward a system approach in Indonesia

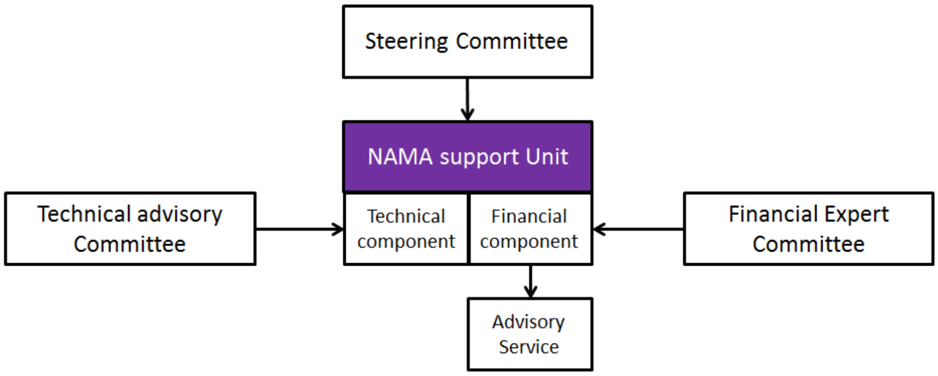
In Indonesia, an important step toward a policy programme to implement an energy-efficient motor-driven system approach, was to develop an evidence-based concept for a Nationally Appropriate Mitigation Action (NAMA). The project team undertook stakeholder interviews, workshops with country partners, and own calculations of savings potential and other benefits where data was available. These findings were quantified in a midterm report and eventually summarised and linked to policy options in a NAMA concept proposal in cooperation with the Indonesian government.

The confidential document covers policy recommendations how to implement and stimulate a respective policy programme. It follows the format of the NAMA Facility[4] (2016) and includes aspects such as (1) an intervention strategy and

[4] The NAMA Facility is a joint programme of the German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB), the UK Department of Energy and Climate Change (DECC), the Danish Ministry of Climate, Energy and Building (MCEB) and the European Commission. The Facility provides financial support for the implementation of NAMAs in developing countries through global competitive calls for proposals. These proposals must include both a technical assistance and a financial assistance component alongside further elements. For more information, see: http://www.nama-facility.org/no_cache/about-us.html

related activities to be developed over the next decade; (2) possible implementing partners; (3) a cooperation structure as shown below; (3) several possible financial supporting mechanisms that may evolve over time; (4) an estimated time frame for implementation; and (5) the assumed necessary workforce and budget. Note that the budget is relatively small compared to the above-mentioned financial savings. The NAMA proposal includes assumptions regarding a growing market of high quality audit companies, access to high quality energy management training, the creation of an advisory service for banks, and access to expert advice regarding energy-efficient project investments in general.

Figure 9: The proposed governance structure to implement a NAMA over the next decade



Source: ECN, 2016

Where to find more information

More information[5] can be found on the **CDKN project website** and the related **ECN website**. Here we have published several presentations and our mid-term report of 2015, that includes aspects not mentioned in this document such as (1) savings potential in industrial subsectors; (2) existing Indonesian policies and activities that are relevant for this subject; and (3) identified existing barriers, as found in literature and based on 17 interviews and several workshops with different stakeholders. Our Excel-based tool for Payback Periods of EE Electric Motors can be downloaded from the website and used to calculate the simple pay-back period of purchasing a more energy-efficient electric motor for different situations. In May 2016, we gave a **webinar** introducing listeners to the characteristics of energy-efficient electric motor systems, their design and the potential savings from

[5] The CDKN project website can be found at: http://cdkn.org/project/indonesia-energy-sector-nama-coordination/?loclang=en_gb; the ECN motors project website can be found at: https://www.ecn.nl/collaboration/ee-motors-indonesia/; the webinar resources can be found on the Low Emission Development Strategies Global Partnership (LEDS GP) website: http://ledsgp.org/resource/energy-efficient-electric-motor-systems-learning-indonesia/?loclang=en_gbhttp://ledsgp.org/resource/energy-efficient-electric-motor-systems-learning-indonesia/?loclang=en_gb

improved systems. The webinar summarises some of the above findings and explains how Indonesia could harvest the calculated savings potential compared to a BAU scenario; building upon existing policies and by introducing some new approaches such as voluntary agreements.

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