Action 4

Using high-efficiency motors

Introduction and context

A program of 10 potential actions to deliver significant levels of energy efficiency in industrial and commercial applications has been identified in the Industrial Energy Efficiency Playbook (IEEP). The purpose of this research is to attempt to create a set of models that provide estimates of the financial, wider economic and environmental gains that could be achieved by adopting various technologies and approaches to more efficient use of energy in industrial processes.

The focus of this paper is IEEP Action 4: installing high-efficiency motors in industrial and commercial applications.

Rationale for Action 4

As stated in the IEEP, powertrains are used in a range of industrial and commercial applications, from pumps, fans and compressors on productions lines to motors used in refrigeration systems and the ventilation and cooling of buildings. According to the IEEP, as much as 46% of the world's electricity is used to produce mechanical energy through electric motor-driven systems, and in the industrial sector the proportion is around two-thirds.[1]

An electric motor converts electrical energy into mechanical energy. Improved energy efficiency in electric motor-driven systems can be interpreted as the reduction in losses inherent in the mechanical and electrical components of the system. The potential benefits can be expressed as reductions of several types, such as lower financial costs or reduced carbon emissions.

The energy efficiency of motors is indicated by International Efficiency (IE) classes, with IE1 the lowest and IE4 the highest. There is a fifth class, IE5, that is expected to be introduced in the future. For the purpose of assessing the potential impact of IEEP Action 4, we focus on the potential benefits that would be associated with the transition from IE1 to IE4, notwithstanding the expectation that the greatest benefits are likely to be delivered by the introduction of motors reaching IE5.

Approach and data sources

The approach taken was to review the objectives and analysis in Action 4 in the IEEP and update and broaden the assessment to allow for estimation of the environmental, financial and wider economic outcomes that stand to be delivered if significant progress is achieved in implementing the action.

The IEEP cites two particularly useful research papers:

- Ferreira and Almeida, IEEE Industry Applications Magazine, January/February 2018: Reducing Energy Costs in Electric-Motor Driven Systems.
- Waide and Brunner, International Energy Agency (IEA) Working Paper, 2011: Energy Efficiency Policy Opportunities for Electric-Motor Driven Systems.

These papers highlight the proportion of energy usage attributable to electric motor driven (EMD) systems, disaggregated by sector. The papers also highlight the scale of energy efficiency improvements that are potentially achievable using high-efficiency motors and linking these with electromechanical solutions cost-optimized for the end user. The scope for energy efficiency improvements through such interventions could amount to between 20% and 30% of energy used to drive powertrains in industrial and commercial situations.

According to Waide and Brunner, the main routes for achieving enhanced energy efficiency in EMD systems are:[2]

1. Using properly sized and energy-efficient motors.
2. Using adjustable-speed drives to match motor speed and torque to the system's mechanical load requirements
3. Optimizing the complete system, including a correctly sized motor, pipes and ducts, efficient gears and transmissions, and efficient end-use equipment to deliver the required energy service with minimal losses.

The second of these routes, use of variable speed drives, is the subject of a separate IEEP Action (Action 5), so the potential implications of this route are not included as part of this paper.

Baseline descriptions and future scenarios referred to in both the Ferreira and Almeida and Waide and Brunner papers are based on energy usage and trends sourced from data obtained from the International Energy Agency (IEA), but in some cases using datasets that are up to 17 years old (2006). Where available, the approach taken here was to use the most recent available equivalent IEA datasets: in practice, the most recent data was for the year 2019.

Design parameters for the development of new scenarios, such as sector coverage and time periods, were agreed through discussion with representatives from Energy Efficiency Movement partners.

Additional data for the estimation of wider economic impacts were obtained from the U.S. Government's Bureau of Economic Analysis (BEA) and the U.K.'s Office for National Statistics (ONS).

Baseline electricity consumption and future scenarios

According to IEA data, global final electricity consumption in 2019 amounted to 22,848 terawatt-hours (TWh), with 41.9% accounted for by industrial uses and 21.2% by commercial end uses that are ‘in scope’ for the assessment being undertaken here.

Based on the analysis contained in the Ferreira and Almeida paper, it is estimated that around 37% of global electricity usage in 2019 was associated with powering EMD systems in industrial and commercial sectors.[3]

Table 1: Estimated baseline EMD system electricity consumption, 2019

Sector	Overall electricity consumption by sector (TWh)	EMD system electricity consumption (TWh)	EMD system electricity consumption (% of total)
Industrial	9,566	6,601	69%
Commercial	4,849	1,843	38%
Total (in scope)	14,415	8,443	59%
Other sectors	8,433	2,256	27%
Overall total	22,848	10,699	47%

Source: Development Economics analysis, based on Ferreira and Almeida (2018) and IEA data.

It is also worth noting that the overall consumption of electricity in industrial and commercial sectors has been estimated to be disaggregated by the following applications: pumps (20%); fans (18%); compressors (29%); and mechanical movement (33%).[4]

Waide and Brunner (2011) proposed a policy-driven intervention to encourage investment and optimal deployment of efficient motors and other equipment and components to deliver overall efficiency gains of 20% by 2030. However, the period for the implementation of such a program was envisaged by the authors to be around 17 years, i.e., from 2014 to 2030.

However, the period for the assessment of Action 4 is somewhat less (eight years, from 2023 to 2030). Therefore, achieving the scale of efficiency enhancements envisaged by Waide and Brunner is challenging.

The scale of efficiency enhancements in EMD system electricity usage by 2030 envisaged by Waide and Brunner ranged from 20% to 30% under a reference scenario of expected usage by 2030 if there were no change in the proportion of highly energy efficient motors used globally compared to the levels in 2014.

The future usage scenarios examined here are similar to those assessed by Waide and Brunner, except tha the focus is on industrial and commercial sectors only, with other sectors such as residential and transportation excluded.

Also, an eight-year period (2023 to 2030) is used, with an intermediate date (2025) to highlight the potential for short-to-medium term financial savings that could be achieved by industrial and commercial users adopting highly efficient EMD systems and end-use equipment.

The table below provides a summary of the average targets for EMD system electricity consumption associated with the scenarios developed in this paper.

Table 2: Targets for reduction in EMD system electricity consumption (industry and commercial)

Year	Moderate ambition scenario	High ambition scenario
2025	5%	7%
2030	10%	15%

The approach to assessing the financial and environmental effects of these targets takes into account the estimated 25% of the world's population of motors that already incorporate a variable speed drive. The assessment also assumes that the proportion of the world's fleet of EMD systems that incorporates a variable speed drive will continue to increase: the specific assumption is that the figure will increase to 40% by 2030. The assessment also factors in the (small) proportion of the worlds' population of motors that is already at IE4 standard.[5]

Scenario results: carbon

The performance metric relevant to emissions is millions of tons of carbon equivalent produced annually (MtCO2e/per annum) from EMD systems used by industrial businesses and commercial organisations.

The annual global carbon reductions that could be delivered by 2025 range between 90 and 126 Mt of CO2 equivalent. By 2030, these reductions could increase to between 300 and 450 MtCO2e per annum.

Table 3: Potential annual carbon savings from reduced EMD system electricity consumption from industrial and commercial uses (Mt CO2e/per annum)

Year	Moderate ambition scenario	High ambition scenario
2025	90	126
2030	300	450

These reductions relate to the annual volume of CO2 produced as a consequence of industrial processes and commercial activities involving efficient electric motors combined with optimized end-use equipment compared to carbon produced with the same output using standard equipment and configurations.

Scenario results: financial benefits

The potential annual financial savings associated with reduced levels of electricity use are also likely to be of great interest to businesses. Based on case study evidence, typical levels of benefits from the transition towards high-efficiency motors are attractive financially and from an emissions perspective. For example:

- A payback period for a replacement 2.2-kilowatt (kW) motor used in a heating, ventilation and air-conditioning (HVAC) system is typically seven to eight months depending on the specification and the efficiency of the legacy motor.[6]
- The typical payback period for a 5.5 kW motor used in HVAC systems is one to two years.[7] Additional benefits to users from replacement of more efficient motors of this type are substantial reductions in CO2 emissions: these can amount to over 100 tons per motor over an assumed 20-year operational lifecycle.

These examples are relevant to the goal of achieving substantial improvements in energy efficiency from the use of more efficient motors in industrial and commercial settings. According to Waide and Brunner, although medium-sized motors (0.75 kW to 375 kW) account for only around 10% of the global population of electric motors, this category accounts for around two-thirds of electricity consumption of motors used in industrial and commercial settings.[8]

Moving from benefits to individual end users to a wider perspective, the table below provides estimates of aggregated benefits for industrial and commercial users at a global level.

By 2025, the global financial savings from use of highly efficient EMD systems and optimization of end-use equipment by industrial and commercial users of such systems would be expected to lie in the range $13.8 billion to $19.3 billion a year at 2021 prices.

By 2030, the annual global financial savings would be expected to increase to between $45.8 billion and $68.8 billion per annum at 2021 prices.

Table 4: Potential annual financial savings from reduced EMD system electricity consumption by industrial and commercial uses (USD billions, 2021 prices)

Year	Moderate ambition scenario	High ambition scenario
2025	13.8	19.3
2030	45.8	68.8

The estimates presented here are based on 2021 data for the average global price of electricity per kWh, based on IEA data. It should be noted that the savings are presented in terms of billions of US dollars in 2021 and the effects of price inflation over the 2023 to 2030 period are excluded. It should also be noted that the price data excludes the average incidence of tax on electricity use. If a with-tax estimate is required, then the values in the table could be increased by around 22%, on average.

Although it is expected that financial savings would be achieved across all industrial and commercial sectors, the potential for savings is especially apparent in sectors that are the most intensive users of motors. The industrial and commercial sectors with the greatest opportunities are expected to include the following:

- Production of fuels and chemicals (with around 22% of the overall savings potential across all relevant business activities).
- Manufacture of non-metallic mineral products, such as glass, cement and plaster (13%).
- Manufacture of metals (11%).
- Manufacture of food and drink products (7%).

Scenario results: economic benefits

Financial savings to industrial and commercial users of EMD systems would also be expected to generate increases in gross domestic product in host economies. The scale of these economic gains is calculated based on standard ratios between gross value added[9] and procurement expenditure for businesses in the non-financial business economy for major industrialized countries, based on data published by the BEA and the U.K.'s ONS. The estimates produced are summarized in the table below.

Table 5: Potential annual GDP increases from reduced EMD system electricity consumption by industrial and commercial uses (USD billions)

Year	Moderate ambition scenario	High ambition scenario
2025	5.9	8.2
2030	19.5	29.3

By 2025, the annual boost to global output from the use of highly efficient EMD systems and optimization of end-use equipment by industrial and commercial users would be expected to lie between $5.9 billion and $8.2 billion at 2021 prices.

By 2030, the annual increment to global output would be expected to lie between $19.5 billion and $29.3 billion at 2021 prices.

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[1] IEEP, page 9

[2] Waide and Brunner, p13

[3] That is, 8,443 TWh divided by 22,848 TWh.

[4] De Almeida et al Improving the Penetration of Energy Efficient Motors and Drives, European Commission SAVE Study (2008).

[5] It has been estimated that around 3% to 4% of motor sales in the European Union since 2019 have been for IE4 class motors.

[6] Example based on the substitution of a 2.2 kW motor with 88.7% efficiency at 100% of normal speed for a 92.4% efficiency motor at 100% of normal speed.

[7] Example based on the substitution of a 5.5 kW motor with 88.5% efficiency motor at 100% of normal speed for a 92.9% efficiency motor at 100% of normal speed.

[8] Waide and Brunner, p38.

[9] GVA is an estimate of sub-national contributions to national GDP by individual companies or business sectors. GVA is essential the value of final market value of goods and services minus intermediate consumption.

About the numbers in this model

The figures in this model refer to global amounts, with financial savings net of investment costs.

The results for emissions reduction, industry savings and gross domestic product (GDP) growth are based on modeling commissioned by the Energy Efficiency Movement from Development Economics, an independent economic impact assessment provider.

From May to October 2023, Development Economics undertook rigorous modeling of the economic and emissions outlook for each action in this model.

This modeling incorporated the best available data and included input from subject matter experts at leading industrial players including ABB, Alfa Laval and Microsoft. Expert advice was also provided by the IEA.

The models include optimistic, mid-range and pessimistic scenarios based on ranges in the underlying data. Each model, and the details of how it was developed, can be accessed via links in the respective actions in this model.

The headline figures cited in the introduction are based on mid-range scenarios.

Nevertheless, all totals have been calculated so as to avoid double counting; for actions where an emissions or economic value was difficult to ascertain, the value has been set to zero rather than using an arbitrary estimate.

The approach taken in our assessment is to quantify the anticipated scale of avoided carbon emissions, in line with the GHG Protocol. An “avoided emission” in this case is the difference between carbon emissions that would occur through the implementation of an action contained within the IEEP, and the emissions that would have occurred in the absence of an implemented IEEP action.

Per the World Business Council for Sustainable Development's "Guidance on Avoided Emissions" (published March 2023), "avoided emissions are emission reductions that occur outside of a [solution's] life cycle or value chain, mainly as a result of the use of that [solution]. Due to their forward-looking nature, avoided emissions are the result of a comparative exercise between emissions associated with an identified reference scenario and emissions associated with the solution (the intervention)."

The analysis presented herein relies on the IEA's Stated Policies Scenario (SPS) as the reference scenario.

Every care has been taken to rely on the most authoritative numbers available for modeling, with a particular emphasis on using IEA data current as of September 2023.

The models have been built assuming reasonable technology adoption curves and validated against third-party sources where possible. In cases where our values or definitions differ from those of the IEA, this has been made clear within the modeling documents.

However, no model can ever be definitive. We intend these models to act as an invitation for your business to carry out its own analysis and, where possible, share data on real outcomes through the Energy Efficiency Movement.

We are grateful to the IEA for acting as an expert contributor to this modeling.

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