Action 5
Using variable speed drives

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 create a model that produces 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.

This paper summarizes the potential benefits associated with the implementation and widespread adoption of Action 5: using variable speed drives in electric motor-driven systems. This paper shares some of the background information and assumptions that also underpin Action 4: installing high-efficiency motors.

Rationale for Action 5
Motors are sometimes sold (or later matched) with variable speed drive (VSD) technology to enable greater efficiency when operating at partial loads.

VSDs are used in various applications, with the following three being primary examples:[1]

- Use in driving pumps, fans and similar equipment with changing loads.
- Use with escalators, hoists, cranes and similar types of equipment where torque is largely independent from speed.
- Equipment with minimal changes in load and speed but where use of a VSD can deliver benefits in terms of reduced wear and tear on machinery involved.

The focus in this paper is on the first two applications only, with a particular focus on industrial and commercial applications where a user would likely benefit from the use of a VSD and where a motor without a VSD is currently being used

It is not known with precision what proportion of the world's industrial and commercial motors are matched with a VSD, but various sources estimate that it is probably between 25% and 30%.[2] Discussions with Energy Efficiency Movement (EEM) experts indicate that an appropriate longer-term target for the adoption of VSDs in industrial and commercial situations is around 60%.

Approach and data sources

The approach taken was to review the objectives and analysis in Action 5 in the IEEP and to update and broaden the assessment to allow for estimation of the potential environmental, financial and wider economic outcomes if significant progress is achieved in implementing the action.

References cited in the IEEP included two research papers that were particularly useful in yielding insights relevant to the research tasks. These were:

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

These papers highlighted the proportion of energy usage attributable to electric motor-driven (EMD) systems, disaggregated by sector. The second paper also explores the issues and opportunities associated with the use of VSDs in EMD systems.

According to Waide and Brunner, the three main routes for achieving enhanced energy efficiency in EMD systems are:[3]

1. The use of properly sized and energy-efficient motors.
2. The use of adjustable-speed drives to match motor speed and torque to the system's mechanical load requirements.
3. The optimization of the system, including 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 first and third of these routes is the subject of a separate IEEP Action (Action 4), so the potential implications of these two routes are not included as part of this paper.

Baseline descriptions and potential future scenarios referred to in the Ferreira and Almeida and Waide and Brunner papers are based on energy usage and trends sourced from data obtained from the IEA, but in some cases using datasets that are up to 17 years old. 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 EEM partners.

Additional data needed for the estimation of wider economic impacts were obtained from the US Government's Bureau of Economic Analysis (BEA) and the UK'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 here.

Based on the Ferreira and Almeida paper, it is estimated that around 37% of global electricity usage in 2019 was associated with EMD systems in industrial and commercial sectors.[4]

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%).[5]

Waide and Brunner (2011) proposed a policy-driven intervention promoting transition towards optimized use of electricity in EMD systems. The policies were intended to encourage investment and use of 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, from 2014 to 2030.

The future usage scenarios examined here are like those assessed by Waide and Brunner except that:

- The focus is on industrial and commercial sectors only, with other sectors such as residential and transportation excluded.
- An eight-year period (2023-2030) 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 a greater proportion of VSDs when appropriate.

These scenarios take into account the estimated 25% or so of the world's 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 could realistically increase to 40% by 2030.

Discussions with EEM partners identified a possible range of efficiency gains associated with greater use of VSDs in industrial and commercial applications. The table below provides a summary of the adopted average targets for reduced EMD system electricity consumption associated with expanded use of VSDs in the scenarios developed in this paper.

Table 2: Targets for reduction in EMD system electricity consumption from expanded use of VSDs (industry and commercial)

Year	Moderate ambition scenario	High ambition scenario
2025	4.8%	6.4%
2030	9.6%	12.8%

The targets in the table above consider the range of efficiency enhancements potentially available in different applications. For example, a VSD in a system driving a pump or fan will usually offer greater efficiency gains than a system driving a crane or hoist.

Scenario results: carbon emissions

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

The annual global carbon reductions that could be delivered by 2025 range between 40 and 70 Mt of CO2 equivalent. By 2030, these reductions could increase to between 141 and 188 MtCO2e per annum through expanded usage of VSDs in industrial and commercial applications.

Table 3: Potential annual carbon savings from enhanced use of VSDs in industrial and commercial applications (MtCO2e/per annum)

Year	Moderate ambition scenario	High ambition scenario
2025	40	70
2030	141	188

Scenario results: financial benefits

The table below provides estimates of aggregated benefits from increased use of VSDs in appropriate industrial and commercial applications at a global level, from around 25% currently to a target of 40% by 2030.

By 2025, the annual global financial savings from increased use of VSDs by industrial and commercial users could range from $6 billionn to $10.7 billion at 2021 prices. By 2030, the annual global financial savings could increase by between $21.5 billion and $28.7 billion per annum at 2021 prices.

Table 4: Potential annual financial savings from enhanced use of VSDs in industrial and commercial applications (USD billions, 2021 prices)

Year	Moderate ambition scenario	High ambition scenario
2025	6.0	10.7
2030	21.5	28.7

The estimates here are based on 2021 IEA data for the average global price of electricity per kilowatt-hour. It should be noted that the savings are presented in terms of 2021 US dollars, therefore 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.

Financial savings from greater use of VSDs can be achieved across all industrial and commercial sectors, with the potential for savings especially apparent in sectors that are the most intensive users of motors. The sub-sectors sectors with the greatest opportunities for savings are expected to include the following:

- Production of fuels and chemicals: around 20% 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%).

Installing VSDs can improve the energy efficiency of motor-driven systems by up to 30%, although savings of 10% to 15% are more typical. Payback periods for many applications are within one or two years.

Scenario results: economic benefits

Financial savings from expanded use of VSDs would also generate increases in gross domestic product. The scale of these gains is based on standard ratios between gross value added[6] and procurement expenditure for businesses in the non-financial business economy for major industrialized countries, based on data published by the BEA and the UK's ONS. The estimates produced are summarized in the table below.

Table 5: Potential annual GDP increases from enhanced use of VSDs in industrial and commercial applications (USD billions)

Year	Moderate ambition scenario	High ambition scenario
2025	2.6	4.6
2030	9.2	12.2

By 2025, the annual boost to global output from expanded use of VSDs in EMD systems by industrial and commercial users could lie between $2.6 billion and $4.6 billion at 2021 prices.

By 2030, the annual increment to global output could lie between $9.2 billion and $12.2 billion at 2021 prices.

[1] De Almeida et al., Motors with Adjustable Speed Drives: Testing Protocol and Efficiency Standards, (2009)

[2] EU: Possible requirements for electric motors and variable speed drives (undated), page 4

[3] Waide and Brunner, p13

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

[5] De Almeida et al Motors with Adjustable Speed Drives: Testing Protocol and Efficiency Standards (2009)

[6] 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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