ENERGY EFFICIENCY MOVEMENT

10 key energy efficiency actions for industrial leaders

The Case for Industrial Energy Efficiency:
Economic and Climate Impacts

Action 1

Audits for energy efficiency

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 summarises the potential benefits associated with the implementation and widespread adoption of Action #1: auditing operations for energy efficiency.

Rationale for Action 1

As stated in the IEEP, one of the fastest and most cost-effective sources of gains in energy efficiency is conducting an energy audit by an established, independent energy service company. Such audits can provide a clear baseline of current energy consumption in buildings and industrial processes, as well as identifying potential 'easy wins' in terms of gains in efficiency of usage.

While the audit itself does not usually create efficiencies, measures can be identified through the audit process that can contribute to reductions in energy costs and use.

According to the IEEP, a basic energy audit can reduce energy usage and costs by between 5% and 10%. More detailed audits can typically identify savings in usage up to 20%, although in some cases savings of up to 40% can be achieved.

The assessment in this paper focuses on two types of energy widely used by industrial and commercial users: electricity and natural gas.

Approach and data sources

The approach taken was to review the objectives and analysis provided in Action #1 in the IEEP and then to proceed to estimate the potential environmental and financial outcomes that stand to be delivered if significant progress is achieved in implementing the action.

The assessment of impact is based on three levels of energy audit, in line with the hierarchy identified by the American Society of Heating, Refrigerating and Air-conditioning Engineers (ASHRAE).[1]

- **Level 1:** involves measures such as a walk-through assessment, a review of energy bills and other applicable operating data, and interviews with operating staff. The process is designed to identify glaring energy usage problems and low-cost measures. The measures may involve improvements in operating methods as well as revealing whether a more in-depth audit could be justified.
- **Level 2:** builds on Level 1 with more detailed energy calculations and financial analyses of proposed intervention options that can be used for business case purposes.
- **Level 3:** provides a more detailed assessment than Level 2, including sub-metering of major system elements. The additional effort of a Level 3 audit would usually be justified for interventions with a substantial capital cost implication.

Scenarios for the delivery of Action #1 are based on the scale of gains identified in the IEEP paper, coupled with baseline data on energy usage identified by the International Energy Agency (IEA). Where available, the approach taken here was to use the most recent available equivalent IEA datasets. In practice, the most recent data was generally for the year 2019.

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

Baseline energy consumption and efficiency scenarios

According to IEA data[2], 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. According to the same source (IEA), global natural gas consumption in 2019 amounted to 68 exajoules (EJ), with 37.6% accounted for by industry and 12.8% by commercial users.

The overall potential scale of savings from audits envisaged by IEEP Action 1 is assumed to range from 5% to 10% for Level 1 audits, up to 20% for more detailed audits, such as for buildings and production systems that are more than 10 years old.

These savings are assumed to be potentially realizable over a short-to-medium-term timeframe, such as two years.

The table below summarizes the savings in energy consumption assumed to be associated with the scenarios developed in this paper.

Table 1: Targets for reduction in energy reduction from audits (industry & commercial) by 2025

Audit	Moderate ambition scenario	High ambition scenario
Level 1 audits	5%	10%
Level 2 and 3 audits	15%	20%

The IEEP indicates that in some circumstances larger savings (beyond 20%) may be achievable. However, for the purposes of this paper it has been assumed that the maximum level of savings that is achievable is 20%. This implies that the overall estimate of savings presented in this paper might be slightly conservative.

Scenario results: scale of potential energy savings

The first consideration is the scale of energy savings that could be achieved in the short to medium term through the implementation of energy audits, based on the scenarios above. The results presented here are based on a 100% roll out of audits among industrial and commercial energy users. These results therefore provide an estimate of the overall 'size of the prize' from the implementation of audits, which would be expected to be self-funding from financial savings achieved through implementation of measures identified through the audit process.

The table below summarizes the potential range of annual energy savings that could be achieved through energy audits (Levels 1 to 3) globally in the short to medium term (for instance by 2025).

Table 2: Potential annual savings from energy audits undertaken by industrial and commercial energy users

Use type	Moderate ambition scenario	High ambition scenario
Industrial electricity use (TWh)	1,157	1,975
Commercial electricity use (TWh)	643	1,086
Overall electricity use (TWh)	1,801	3,062
Industrial gas use (EJ)	3.5	6.0
Commercial gas use (EJ)	1.1	1.9
Overall gas use (EJ)	4.7	7.9

The overall savings that could be achieved through the implementation of energy audits range from around 1,800 to 3,060 TWh of electricity consumption and between 4.7 EJ and 7.9 EJ of natural gas usage.

The remainder of the paper focuses on quantifying the associated carbon emissions and financial savings that would be associated with this scale of energy usage reduction.

Scenario results: scale of potential carbon savings

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

The potential range of annual global carbon reductions that could be delivered in the short to medium term (by 2025) range between 1,489 and 2,527 Mt of CO2 equivalent.

Table 3: Potential annual carbon savings from energy audits undertaken by industrial and commercial energy users by 2025 (MtCO2e/per annum)

Use type	Moderate ambition scenario	High ambition scenario
Industrial electricity use	789	1,347
Commercial electricity use	439	741
Overall electricity use	1,228	2,088
Industrial gas use	198	333
Commercial gas use	63	106
Overall gas use	261	439
Overall industrial and commercial use	1,489	2,527

Around 83% of overall potential emissions savings are associated with electricity usage, with around 17% from gas. Industrial usage dominates the potential for overall emissions savings, accounting for around two-thirds of the overall potential for savings compared to one-third for commercial uses.

Scenario results: scale of potential financial benefits

The table below provides estimates of potential aggregated financial savings for industrial and commercial users that are associated with the energy use savings summarized above (i.e., those that could be delivered from a full rollout of energy use audits). Note: table row sub-totals and overall totals may not sum exactly due to rounding.

The estimates presented here are based on 2021 data for the average global price of energy, from IEA and other industry sources. The savings are presented in terms of 2021 US dollars (billions) and the potential future effects of price inflation over the 2023-2025 period are excluded. It should also be noted that the price data excludes the average incidence of tax on energy use. A 'with tax' estimate would be around 20% greater, on average.

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

Use type	Moderate ambition scenario	High ambition scenario
Industrial electricity use	113	194
Commercial electricity use	63	106
Overall electricity use	177	300
Industrial gas use	9	15
Commercial gas use	3	5
Overall gas use	11	19
Overall industrial and commercial use	188	319

The potential for annual financial savings by industrial and commercial energy users ranges from around $188 billion to $319 billion per annum on a global basis. Around 94% of these savings relate to electricity use, with the use of natural gas accounting for 6%. Around 65% of overall savings are associated with industrial users, with commercial users accounting for the other 35%.

Scenario results: scale of potential economic benefits

Financial savings to industrial and commercial users of electricity and gas would also be expected to generate increases in gross domestic product in host economies. The scale of these economic gains has been estimated based on standard ratios between gross value added[3] 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 energy consumption by industrial and commercial uses (USD billions)

Year	Moderate ambition scenario	High ambition scenario
Industrial electricity use	48	82
Commercial electricity use	48	45
Overall electricity use	75	128
Industrial gas use	4	6
Commercial gas use	1	2
Overall gas use	5	8
Overall industrial and commercial use	80	136

By 2025, the annual boost to global output from energy efficiency activities of the type envisaged by IEEP Action #1 would be expected to lie in the range $80 billion and $136 billion a year at 2021 prices.

Relationship between Action 1 and the other IEEP actions
The assessment presented in this paper indicates that substantial emissions savings could be achieved through the energy audit process. Changes in industrial and commercial practices and behaviors also have the potential to deliver large and valuable financial savings and wider economic benefits to companies, industries and national and global economies.

However, many of the specific interventions and investments that would capture and realize these potential benefits would likely be achieved through specific actions and investments that fall under the other actions contained in the Industrial Energy Efficiency Playbook. Examples include greater use of digital control systems in industrial processes (covered by Action 3) or in the management of heating, ventilation, air conditioning and lighting systems in commercial buildings (Action 9).

Therefore, because of the potential risk of double-counting, it would not be appropriate to add the potential emissions savings and other benefits identified for Action 1 to the similar types of gains that are identified for each specific action in papers prepared for the other actions in the IEEP.

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[1] What are ASHRAE Energy Audits? - Better Buildings (betterbuildingsbc.ca)

[2] Final consumption – Key World Energy Statistics 2021 – Analysis - IEA

[3] 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.

Action 2

Rightsize industrial assets and processes

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 new research is to create a set of models that provide estimates of the financial, wider economic and environmental gains that could be achieved by adoption of various technologies and approaches to more efficient use of energy in industrial processes. This paper outlines a potential approach to identifying the benefits associated with Action #2: Rightsizing industrial assets and processes.

This is a preliminary stage of work that is intended to explore the potential data and evidence sources that could be used to undertake such an assessment.

Rationale for Action 2
Industrial audits often reveal that equipment setups are often larger than needed for the function being performed. This could be because the equipment specification was over-specified in the first place, or more likely because operating conditions have evolved over time. Oversizing components can result in excessive energy use and inefficient loadings.

It may be possible to improve loadings by adjusting settings or by system reconfiguration. In other situations, it may be more advantageous to replace existing assets with appropriately specified equipment. However, rightsizing in most factory situations is most likely to be viable as part of the continuing process of lifecycle management within the facility.

One of the key considerations is the availability of accurate data concerning equipment loadings. The increasing use of digital sensors in process systems opens considerable opportunities for a flow of data that can be used to identify inefficient equipment loadings.

The link between available data and digital sensors suggests that it would be appropriate to consider the estimation of gains from Action #2 in parallel with consideration for Action #3, bringing connectivity to physical assets.

Action 3

Bringing connectivity to physical assets

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 benefits 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 3: bringing connectivity to physical assets.

Rationale for Action 3

The Internet of Things refers to a network of equipment, apparatus and other physical objects that are embedded with sensors, software and network connectivity so they can collect and share data. Any device that can collect and transmit data can be considered part of the IoT. In factories, there are many benefits associated with greater use of the IoT. According to McKinsey & Company, the largest opportunities for the generation of additional economic value linked to the IoT include the following:[1]

- Operations optimization.
- Human productivity growth.
- Efficiency savings in condition-based maintenance.
- Inventory management.

However, the McKinsey research also recognizes that IoT can deliver other benefits in industrial situations, including energy efficiency and savings. In an industrial setting, connecting physical assets in industrial settings using the IoT creates great potential for business leaders to obtain a clearer view of where energy is used, and wasted, in their operations.

Despite the benefits, research from ABB has revealed that just 35% of industrial organisations have so far implemented IoT at scale.[2]

Action 3 therefore focuses on the potential for value that could be added by the further rollout of IoT, specifically with respect to energy efficiency in factories and other industrial settings.

The potential for IoT to deliver energy efficiencies for commercial businesses, specifically in offices and other commercial buildings, is considered separately as part of an additional IEEP Action (Action 9, deploying smart building management systems).

Approach and data sources

The approach taken for the assessment for Action 3 was to review the objectives and analysis provided in the IEEP and then estimate the potential environmental and other outcomes that could be delivered if significant progress is achieved in implementing the action.

The work programme involved a review of references and data sources cited in the IEEP paper, including a desk-based review of academic and non-academic literature.

Baseline data on energy use by industry, covering both electricity and natural gas, was obtained from the International Energy Agency (IEA) and various other sources.

Design parameters for the development of hypotheses and were agreed through discussion with representatives from EEM partners. The assessment undertaken in this report focuses on the potential impacts in the period up to 2030.

Carbon emissions trends and forecasts

Based on extrapolation of IEA data, industrial electricity usage by 2025 is likely to be around 11,400 terawatt-hours (TWh).[3] Use of natural gas by industry could reach 12,400 TWh in the same year.[4]

Proponents of IoT have identified greater energy efficiency as a significant potential benefit in the industrial sphere. Experts and commentators in organizations including the American Council for an Energy-Efficient Economy andMcKinsey have estimated potential savings ranging from 10% to 30% of annual energy consumed by industry.[5]

The approach taken here is to model two scenarios for levels of efficiency captured by industrial organizations that have not yet deployed IoT on a widespread basis (i.e., circa 65% of industrial businesses, based on analysis undertaken by ABB referred to in the Introduction). The scenarios here explore, respectively, a lower-bounded and an upper-bounded range of energy savings potential offered by widespread adoption of IoT technology by industrial businesses, as follows:

Type of energy	Lower-efficiency scenario	Higher growth scenario
Electricity	10%	22%
Natural gas	5%	11%

The results for these scenarios are then compared with a reference case, which is predicated on no further growth in the adoption of IoT technology for energy efficiency management purposes compared to 2022 levels. Given the huge scale of benefits offered by IoT across a range of business indicators (i.e., not just energy efficiency) this reference case is not considered plausible, but it serves the purpose of providing a baseline against which changes expected under future energy efficiency scenarios can be measured.

Both scenarios assume that the deployment of IoT in industrial situations progresses from the current 35% to 90% by 2030. This growth rate is considered plausible because of the powerful operational benefits offered by IoT across a range of operational themes, of which energy efficiency is but one.

Estimates of the savings in aggregate global electricity use by industrial companies achievable through greater use of IoT over the period to 2030 are set out in the table below. It is reiterated that the potential savings exclude those made by industrial businesses that had as of 2022 deployed IoT on a widespread basis in their organizations.

Annual electricity usage savings from increased use of IoT by industry, 2022-2030

Year	Lower efficiency scenario (TWh)	Higher efficiency scenario (TWh)
2023	416	916
2024	487	1,072
2025	571	1,255
2026	668	1,469
2027	782	1,720
2028	915	2,013
2029	1,071	2,357
2030	1,254	2,759

Annual savings in electricity usage by industrial companies from adoption of IoT achieved by 2025 could range from 571 TWh to 1,255 TWh. By 2030, these savings could range from 1,254 TWh under the lower efficiency scenario to 2,759 TWh under the high scenario.

The table below provides estimates for savings in gas usage by companies that have not already deployed IoT widely in their organizations. Note: gas usage, measured in billions of cubic meters, has been converted to TWh using a standard conversion factor.

Annual natural gas usage savings from increased use of IoT by industry, 2022-2030

Year	Lower efficiency scenario (TWh)	Higher efficiency scenario (TWh)
2023	201	442
2024	232	510
2025	268	589
2026	309	680
2027	357	784
2028	411	905
2029	474	1,044
2030	547	1,204

Annual savings in gas usage from adoption of IoT technology for energy management could range from 268 TWh to 589 TWh by 2025. By 2030, these savings could range from 547 TWh under the lower efficiency scenario to 1,204 under the high scenario.

The energy usage savings set out above would also deliver carbon emissions benefits. The table below presents the results that could be achieved by industrial users adopting IoT for energy management from 2023 onwards (amongst the 65% of industrial organisations that have yet to deploy IoT technology widely). Note: the emissions savings include the potential for gas and electricity use savings in combination, millions of metric tons of carbon equivalent produced annually (MtCO2e).

Carbon emissions savings from increased IoT usage for industrial energy management

Year	Lower efficiency scenario (MtCO2e)	Higher efficiency scenario (MtCO2e)
2023	284	624
2024	331	729
2025	387	851
2026	452	994
2027	528	1,161
2028	616	1,356
2029	720	1,584
2030	841	1,850
2023-2030	4,158	9,148

Under the lower efficiency scenario, annual savings in carbon emissions could amount to 841 MtCO2e per annum by 2030. Cumulative emissions savings over the 2023-2030 period under this scenario could amount to 4,158 MtCO2e.

Under the higher efficiency scenario the emissions savings would be substantially larger, at an estimated 1,850 MtCO2e per annum by 2030. Cumulative emissions savings under this scenario could amount to 9,148 MtCO2e over the 2023-2030 period.

Financial benefits from adoption of IoT

Adoption of IoT for energy efficiency purposes has the potential to deliver significant financial savings for industrial operators. These savings have been estimated using the results for savings in electricity and gas outlined above, coupled with assumptions regarding the average price of electricity and gas. Data on electricity and gas price trends for non-domestic consumers was sourced from:

- The European Union for electricity.[6] The data used was for the first quarter of 2020, predating the price spike linked to the invasion of Ukraine by Russia. The euro price was converted to dollars using September 2023 exchange rates.
- Financial markets for gas. It is worth noting that the international price as of early September 2023 was close to the price that prevailed in the first quarter of 2020. The price of gas per million British thermal units was converted to a price per kilowatt-hours using standard conversion factors.

The table below sets out the potential range of financial savings that could be expected if all industrial companies that have not yet adopted IoT technology were to do so to manage their energy consumption.

Financial savings from increased IoT usage for industrial energy management (USD billions)

Year	Lower efficiency scenario	Higher efficiency scenario
2023	39.3	86.6
2024	46.0	101.2
2025	53.8	118.4
2026	62.9	138.4
2027	73.6	161.9
2028	86.1	189.3
2029	100.6	221.4
2030	117.7	258.9

Annual financial savings could reach between around $54 billion and £119 billion per annum by 2025, rising to between around $118 billion and $259 billion by 2030.

Wider economic benefits from adoption of IoT

The adoption of IoT for energy efficiency purposes also has the potential to deliver substantial benefits in the form of additional economic output. The scale of these economic gains is calculated based on standard ratios between gross value added[7] and procurement expenditure for businesses in the manufacturing sector for major industrialized countries, based on data published by the Buretau of Economic Analysis in the United States, and the U.K.'s Office for National Statistics. The estimates produced are summarized in the table below.

Potential GDP increases from increased IoT usage for industrial energy management (USD billions)

Year	Lower efficiency scenario	Higher efficiency scenario
2023	16.8	36.9
2024	19.6	43.1
2025	22.9	50.4
2026	26.8	59.0
2027	31.3	69.0
2028	36.7	80.7
2029	42.9	94.3
2030	50.1	110.3

By 2025, the annual boost to global output from expanded use of IoT technology for energy management by industrial businesses could lie in the range from around $23 billion to around $50 billion. By 2030 the annual increment to global GDP could lie in the range from around $50 billion to around $110 billion per annum.

A 2021 report by McKinsey identified that by 2030 IoT technology in the industrial sector could generate between $1.43 trillion and $3.32 trillion per annum globally. The results presented in the table above suggest that energy savings would account for around 3.5% of the value generated by IoT across all industrial applications.[8]

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[1] Where and how to capture accelerating IoT value | McKinsey & Company

[2] IEEP, page 6

[3] IEA: World electricity final consumption by sector

[4] Gas Market Report, Q2-2023 – Analysis - IEA

[5] International Society of Automation: available here: Combining IoT, Industry 4.0, and energy management - ISA

[6] Statistics | Eurostat (europa.eu)

[7] 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.

[8] The largest shares of the overall contribution of IoT to the industrial sector identified by McKinsey were in the areas of operations optimization, human productivity and condition-based maintenance.

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.

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.

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[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.

Action 6

Electrifying industrial fleets

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 set of models and reports 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.

This paper summarizes the potential benefits associated with the implementation and widespread adoption of Action 6: electrifying industrial fleets.

Rationale for Action 6

Transportation of people, goods and raw materials accounts for around 25% of the world's total energy consumption and around 30% of societal carbon dioxide emissions.[1] Increasing efforts are being made to electrify private car and some light commercial vehicle fleets, but electrification of medium and heavy duty commercial and industrial fleets has so far proceeded slowly.

The electrification of vehicles in industrial and commercial fleets offers considerable potential in contributing to carbon emissions reductions as well as other pollution associated with internal combustion engines. The emergence of electric vehicles also offers an increasingly compelling set of financial benefits to the owners and operators of industrial fleets, with potential for wider productivity and output generation benefits.

The purpose of this paper is to identify and quantify the potential benefits of accelerating progress towards electrification of industrial and commercial fleets, with a particular focus on the scale of benefits that might be available in the short-to-medium term and on to 2030.

Approach and data sources

The approach taken was to review the objectives and analysis provided in Action 6 in the IEEP and then estimate the potential environmental and financial outcomes delivered if significant progress is achieved in implementing the action.

Baseline descriptions and potential future scenarios were obtained from various sources, including:

- Data and insight published by organizations such as Lawrence Berkeley National Laboratory and CALSTART.
- White papers produced by ABB.
- Topic and briefing papers produced by other industry analysts and commentators, such as EY and McKinsey & Company.

Design parameters for the development of new scenarios, such as sector coverage and timeframes, were agreed through discussion with representatives from ABB.

Additional data for the estimation of wider economic impacts were obtained from the International Energy Agency (IEA), the US Government's Bureau of Economic Analysis, Eurostat and the UK's Office for National Statistics.

Decarbonization of truck and van fleets

Baseline position

Worldwide sales of electric light commercial vehicles (LCVs) in 2022 accounted for just 2% of sales in their vehicle segment, compared to 6% for electric passenger vehicles.[2]

However, the share of electric vehicles (EVs) within commercial fleets is increasing, driven by mutually reinforcing factors including improved technology, decreasing total cost of ownership (TCO) compared to internal combustion engine (ICE) vehicles and improvements in charging infrastructure availability. According to an assessment undertaken by EY, the purchase costs of EVs are expected to reduce by around 30% in real terms by 2025 compared to 2020 levels, driven in part by expected falls in battery prices.[3]

Most comparisons of costs between EVs and ICE vehicles are dependent on battery pack costs, which typically account for around 30% of the purchase cost of a medium-duty commercial vehicle depending on the weight and purpose of the vehicle.[4]

Research indicates many fleet operators are preparing to invest in greater electrification of fleets. In industry surveys in the United States, almost 50% of fleet operators purchased an electric vehicle in 2022, and more than 50% plan to operate fully carbon-free fleets by 2027—with 90% planning to fully decarbonize eventually.[5]

Lighter commercial vehicles have reached TCO parity with diesel vehicles in the <6 tons class. However, it is widely recognized that comparative performance is affected by a range of variables. ‘Average’ performances reported for different vehicle use classes may differ from typical performance achieved by individual users depending on factors such as daily range, average mileages per vehicle and the availability or density of charging infrastructure.

Nevertheless, McKinsey & Company expects battery electric LCVs to be 5% to 10% cheaper to operate than equivalent ICE vehicles by 2025.[6] It also expects the TCO for medium-duty trucks, from six to 16 tons, to achieve parity during 2023, with parity for heavy-duty trucks (over 15 tons) expected by 2025.

However, in some situations cost parity for heavy-duty vehicles appears to have been achieved already. Researchers at Lawrence Berkeley National Laboratory (LBNL) identified that a heavy-duty (US Class 8) truck with a 375-mile range running a 300 mile-per-day route can already achieve a 13% lower TCO than an equivalent diesel vehicle.[7]

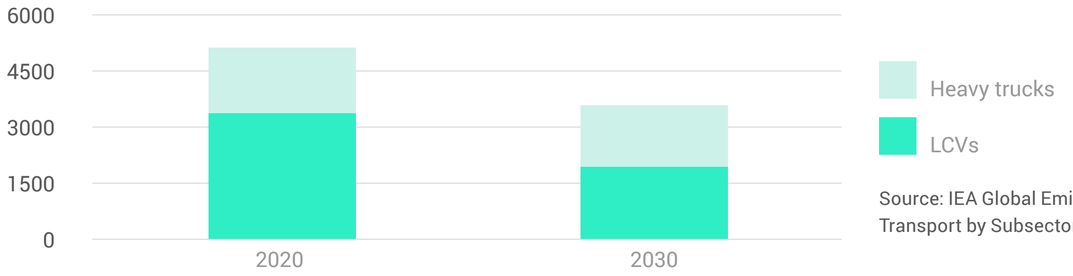
Benefits from reduced carbon and other emissions

Transportation of goods and raw materials accounts for a significant proportion of global energy consumption and carbon emissions. According to the IEA, around 55% of global carbon emissions from the transportation sector is accounted for by light-duty vehicles and heavy trucks, with the combined volume from these sources accounting for slightly over 5 billion metric tons of CO2 equivalent in 2020.[8]

Electrification of a substantial proportion of the world’s commercial and industrial vehicle fleet has a crucial part to play in the eventual realization of a successful net-zero transition. Indeed, the trajectory for compliance with the IEA’s ‘net zero emissions by 2050’ scenario requires that carbon emissions from light- and heavy-duty vehicles and trucks would need to reduce to 3.5 billion metric tons of CO2 equivalent by 2030.[9]

The scenario explored here implies a reduction in annual emissions amounting to 30% of 2020 levels by 2030, which is equivalent to an average annual reduction of about 3.5% over the 2020 to 2030 period. The importance of addressing emissions from trucks and buses is underlined by the fact that despite comprising just 4% of the world’s fleet of vehicles, buses and trucks contribute 40% of global transport emissions.[10]

Figure 1: Annual carbon emissions from road transport: 2020 levels versus 2030 (net zero trajectory), millions of metric tons of CO2 equivalent (MtCO2e) per year.



Source: IEA Global Emissions from Transport by Subsector, 2020-2030

This scenario aligns with market predictions from sources such as EY and LBNL, whose assessment is that battery-electric LCVs are already competitive with ICE equivalents and that the cost differential on a TCO basis will continue to improve over the decade as the cost of battery packs decreases.

The annual savings in carbon emissions from the transition of light vans and delivery vehicles, as well as modest numbers of heavy trucks, expected under this scenario are summarized in the table below.

Carbon emissions savings from the transition to EVs by industrial fleets

Year	MtCO2e
2024	38.2
2025	44.1
2026	51.0
2027	58.9
2028	68.1
2029	78.7
2030	91.0

This growth rate assumes an increase in the rate of adoption of commercial EVs averaging 16% per annum over the 2022 to 2030 period.

Apart from a reduction in carbon emissions, reduced use of diesel fuels in freight transportation can also deliver local environmental benefits and benefits to human health from reduced levels of pollutants associated with ICEs, such as sulfur dioxide, nitrous oxides and particulates.

Benefits from financial savings to operators

As already noted, using electricity instead of fossil fuels to power vehicles can significantly improve energy efficiency and the overall cost of transport to owners and operators of commercial fleets. For example, when operating in the optimal load range, electric motors can achieve about 95% efficiency, which is more than twice the typical efficiency of diesel engines (45%) and nearly three times the efficiency of petrol engines (33%).[11]

Financial modelling undertaken by McKinsey & Company predicts that on a cost-per-mile basis, battery electric LCVs will be 5% to 10% cheaper to operate than equivalent ICE vehicles by 2025.[12] The cost advantages of LCVs are mainly driven by savings in fuel costs, reduced maintenance costs and higher residual asset values. Moreover, savings in these areas are more than sufficient to offset higher average purchase costs, the cost of investing in charging infrastructure and the costs associated with insuring a higher-value asset.

An additional financial advantage for operators of EVs is their relative resilience to price fluctuations in fuel costs, compared to diesel and petrol vehicles.[13]

However, it is important to point out that the financial incentives for transition to electrified fleets differ by industry segment. In general, savings will be greater and achieved sooner for operators with fleets with a high proportion of LCVs compared to medium- and heavy-duty trucks.

According to McKinsey & Company, a parcel delivery fleet operator with a fleet of 70% LCVs should expect savings of 13% by 2030, whereas a food products distributor with a fleet of 80% medium-duty trucks and 20% LCVs could expect savings amounting to 9% compared to an equivalent 100% ICE powered fleet.

The scope for industry-wide financial savings from a widespread transition to EVs is correlated to the future size and composition of global and national truck fleets. Based on current data, national truck fleets in high-income economies are approximately evenly distributed between light-, medium- and heavy-duty vehicles.

Based on the scale of predicted operating cost savings by vehicle size category for 2030, we estimate a typical blended average of savings across logistics could amount to 1.4% of industry operating costs by 2030. The table below sets out the estimates of savings by commercial vehicle size category.

Table 1: Potential cost savings

Vehicle size band	Assumed proportion of national fleet	Vehicle costs as % of total annual costs	Assumed vehicle cost savings by 2030
Light	33%	34%	15%
Medium	32%	44%	10%
Heavy duty	35%	59%	5%
Totals	**100%**	**–**	**–**

Potential cost savings are likely to be larger on a per-vehicle basis for light commercial vehicles, but for these vehicles the proportion of overall costs accounted for by vehicle costs tends to be lower: 34% for light vehicles compared to 44% for medium-sized and 59% for heavy duty vehicles. The remaining portion of costs are accounted for by items such as costs associated with the driver and business overheads.

In monetary terms, annual savings per vehicle could amount to an average of around $2,775 for a light commercial vehicle or around $3,250 for a medium-sized vehicle, at 2021 prices. In specific cases the out-turn results would vary according to range, daily mileage and other factors.

The analysis here has focused on savings for delivery vans and trucks used on the highway network. There are also opportunities to achieve savings for vehicles used in some non-road situations. Examples include light vehicles used on construction sites, in freight terminals and many other situations. However, there is little available benchmark information on these types of non-road vehicles, so they have not been included in the assessment.

Potential wider financial and economic benefits from commercial fleet decarbonization
When rolled out across national and global fleets, potential savings to the truck transportation industry from fleet electrification could become very significant.

The average operating cost savings described in the table above, when extended across national commercial vehicle fleets, could result in reductions in industry-wide operating costs of around 1.4% per annum. Based on current fleet sizes, savings to the truck transportation industry in the United States could amount to at least $11.5 billion per annum, using a weighted average of potential savings across different vehicle size categories.

In the United Kingdom, average annual savings could similarly amount to at least £430 million per annum.

The potential for cost reductions in transport fleet operating costs would also be expected to generate wider economic benefits, including a boost to GDP generated by the truck transportation industry. For example, the $11.5 billion reduction in industry operating costs would be expected to result in an increase in the annual GDP generated by the industry worth around $3.8 billion per annum in 2021 prices.

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[1] US Energy Information Administration, International Energy Outlook, 2016

[2] US Department of Energy, Argonne National Laboratory

[3] EY (2020) How commercial fleet electrification is driving opportunities.

[4] CALSTART: Global Roadmap for reaching 100% zero-emission medium- and heavy-duty vehicles by 2040, page 5

[5] McKinsey & Company (December 2022): Getting to carbon-free commercial fleets, page 2

[6] McKinsey & Company (December 2022): Getting to carbon-free commercial fleets, page 3-4.

[7] Phadke et al: Why Regional and Long-Haul Trucks are Primed for Electrification Now, Lawrence Berkeley National Laboratory, March 2021

[8] Global CO2 emissions from transport by subsector, 2000-2030 – Charts – Data & Statistics - IEA

[9] Global CO2 emissions from transport by subsector, 2000-2030 – Charts – Data & Statistics - IEA

[10] ABB E-mobility unveils HVC360, the next evolution in fleet charging solutions

[11] ABB, Sustainable Transport: electrifying the powertrains of industrial vehicles, transportation and marine, June 2022, page 10

[12] McKinsey & Company (December 2022): Getting to carbon-free commercial fleets, page 4

[13] McKinsey & Company (January 2023): Why the economics of electrification make this decarbonization transition different, page 4

Action 7

Using well-maintained heat exchangers

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 IEEP Action 7: the use of efficient, well-maintained heat exchangers.

Rationale for Action 7
Heat exchangers are used in a wide range of industrial and commercial processes to transfer heat from one medium to another: they are typically used to provide heating or cooling to meet a process requirement. Heat exchangers can also be used to enhance a system's energy efficiency by enabling the transfer of heat from locations where it is not needed to situations where it can be used.

Heat exchangers are widely used in sectors such as oil and gas and power generation that are outside of the scope of the IEEP. The assessment provided in this report focuses only on efficiency gains associated with heat exchangers deployed in manufacturing applications, including process industries, and in commercial activities.

The IEEP identifies two strands of intervention that could be deployed by operators of heat exchangers and are likely to yield efficiency and emissions gains almost immediately. These strands are:

1. Keeping a heat exchanger at an optimum performance level through use of appropriate maintenance regimes. A study has identified that between 1% and 2.5% of global CO2 emissions are associated with unmaintained heat exchangers.[1]
2. Selecting the right exchanger technology. Some types of exchangers can be up to 25% more efficient than others, so matching the right exchanger for the situation can yield significant gains. In addition, there are opportunities to replace older, less-efficient heat exchangers with modern, more-efficient models when legacy equipment approaches the end of its life cycle.

Each of these strands are explored in this paper.

Approach and data sources

The approach taken was to review the objectives and analysis provided in Action 7 in the IEEP and to broaden the assessment to allow for estimation of potential environmental, financial and wider economic outcomes delivered if significant progress is achieved in implementing the action.

The work involved a review of references and data sources cited in the IEEP paper. The work also included a desk-based review of other relevant information and data, including academic and non-academic literature.

Design parameters for the development of hypotheses and scenarios, including sector coverage and appropriate applications of heat exchangers, were agreed through discussion with representatives from Energy Efficiency Movement partners including Alfa Laval.

Baseline data on industrial and commercial energy use was obtained from the International Energy Agency and various national government statistical agency sources. Additional data needed for the estimation of wider economic impacts were obtained the US Government's Bureau of Economic Analysis (BEA) and the UK's Office for National Statistics (ONS).

Strand 1: Gains from a regular cleaning and maintenance program

Emissions savings from improved cleaning and maintenance

A starting point was to estimate the current extent of CO2 emissions associated with the inefficient operation of heat exchangers already deployed in industrial and commercial situations. As cited above, research estimates identify that between 1% and 2.5% of global emissions are linked to poorly maintained heat exchangers.

The sources for this estimation were:

- UK data on CO2 emissions, broken down by business sector, obtained from the UK's Office for National Statistics.
- A study of the global market for heat exchangers, to ascertain deployment of the technology across markets including[2] chemicals, petrochemicals, oil and gas, heating and ventilation, air conditioning and refrigeration, food and beverage manufacturing, power generation and others. This data was filtered to focus on sectors that are in scope for the purposes of the IEEP.
- Data from the IEA on global emissions of CO2 by segment, including industrial, commercial and other uses.

The results of this assessment were that between 271 million metric tons of carbon equivalent (MtCO2e) and 678 MtCO2 was estimated in 2019 as a result of unmaintained heat exchangers in industrial and commercial situations. The mid-point estimate was 474 MtCO2e and 83% of this figure is associated with industrial users.

Table 1: Estimated annual global CO2 emissions associated with unmaintained heat exchangers in industrial and commercial situations (MtCO2e)

Sector	Low-end estimate	Mid-point estimate	Top-end estimate
Industrial	225	394	563
Commercial	46	80	114
Overall total	271	474	678

Source: Development Economics analysis

All of these emissions could be removed simply and cheaply through the implementation of a regular cleaning regime as part of a planned maintenance program. The scenario results assume that 100% of currently unmaintained heat exchangers are brought into regular maintenance by 2030.

Financial savings from improved cleaning and maintenance

The introduction of a regular cleaning regime would also be expected to result in commensurate savings in energy usage and energy bills for users.

The table below provides estimates of aggregated benefits from the deployment of improved cleaning and maintenance of heat exchangers. The mid-range estimates amount to annual savings of $55.28 billion for industrial and commercial users of heat exchangers.

Table 2: Potential annual global financial savings from addressing unmaintained heat exchangers in industrial and commercial situations (USD billions, 2021 prices)

Sector	Low-end estimate	Mid-point estimate	Top-end estimate
Industrial	24.12	42.21	60.30
Commercial	7.47	13.07	18.68
Overall total	31.59	55.28	78.98

Source: Development Economics analysis

Economic benefits from improved cleaning and maintenance

Financial savings to industrial and commercial users of heat exchangers would also be expected to generate increases in gross domestic product in host economies, from reduced costs to manufacturers and commercial organizations. The scale of these economic gains is based on standard ratios between gross value added[3] 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 are summarized in the table below.

Table 3: Potential annual global economic output gains associated with reduced energy expenditure via addressing unmaintained heat exchangers in industrial and commercial situations (USD billions, 2021 prices)

Sector	Low-end estimate	Mid-point estimate	Top-end estimate
Industrial	10.27	17.98	25.69
Commercial	3.18	5.57	7.96
Overall total	13.46	23.55	33.64

Source: Development Economics analysis

The mid-point value of expected output gains would amount to $23.55 billion annually if all unmaintained heat exchangers were subject to a regular cleaning regime.

Strand 2: Use of modern and efficiency heat exchanger technology

The second strand of the assessment focuses on the use of efficient heat exchanger technology in industrial and commercial applications. Heat exchangers usually have an operational life measured in decades. The analysis here therefore focuses on the potential gains from replacing older equipment (40-plus years) with modern equipment as part of a routine program of replacing obsolete equipment at the end of its life cycle.[4]

While it is possible to achieve efficiency gains of up to 25% through the use of the most appropriate heat exchanger technology, this model explored a range of plausible values for efficiency gains, ranging from 10% to 25%.

Emissions savings from replacement of obsolete equipment with modern heat exchangers
The results of this assessment were that between 136 and 339 MtCO2e could be saved annually through the replacement of obsolete heat exchangers in industrial and commercial situations. The mid-point estimate was 237 MtCO2e.

Table 4: Estimated annual global CO2 emissions associated with replacement of obsolete heat exchangers in industrial and commercial situations (MtCO2e)

Sector	Low-end estimate	Mid-point estimate	Top-end estimate
Industrial	113	197	282
Commercial	23	40	57
Overall total	136	237	339

Source: Development Economics analysis

Financial savings from replacement of obsolete equipment with modern heat exchangers
The next table provides estimates of aggregated financial benefits from the deployment of modern heat exchangers to replace older, obsolete heat exchangers in industrial and commercial settings. The mid-range annual savings amount to $10.91 billion.

Table 5: Potential annual global financial savings associated with the replacement of obsolete heat exchangers in industrial and commercial situations (USD billions, 2021 prices)

Sector	Low-end estimate	Mid-point estimate	Top-end estimate
Industrial	4.95	8.67	12.38
Commercial	1.28	2.24	3.20
Overall total	6.23	10.91	15.58

Source: Development Economics analysis

Obviously, these annual financial benefits will recur annually assuming the new equipment is well-maintained after being installed.

Economic benefits from replacement of obsolete equipment with modern heat exchangers
The final table provides estimates of the GDP gains through cost savings associated with replacing obsolete heat exchangers with modern, efficient equipment.

Table 6: Potential annual global economic output gains associated with replacement of obsolete heat exchangers in industrial and commercial situations (USD billions, 2021 prices)

Sector	Low-end estimate	Mid-point estimate	Top-end estimate
Industrial	2.11	3.69	5.27
Commercial	0.55	0.95	1.36
Overall total	2.65	4.65	6.64

Source: Development Economics analysis

The mid-point annual output gains from replacement of obsolete heat exchangers would amount to $4.65 billion. Obviously, these benefits will continue to be generated annually assuming the new equipment is well maintained after being installed.

Summary of benefits

The table below pulls together the potential annual gains from regular cleaning of extant heat exchangers and replacing one year of obsolete heat exchangers with modern, efficient models.

Table 7: IEEP Action 7: Summary of potential annual global effects (mid-point estimates only)

Sector	Saved CO2 emissions (MtCO2e)	Financial savings for operators (USD billions, 2021 prices)	GDP output gains (USD billions, 2021 prices)
Industrial	592	50.87	21.67
Commercial	120	15.31	6.52
Overall total	712	66.19	28.20

Source: Development Economics analysis

The overall potential of these actions in just one year could be to:

- Deliver 712 MtCO2e of CO2 emissions savings from industrial and commercial users.
- Deliver savings of around $66 billion for industrial and commercial users.
- Generate GDP increases worth more than $28 billion annually.

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[1] H. Müller-Steinhagen, M. R. Malayeri and A. P. Watkinson (2009), Heat Exchanger Fouling: Environmental Impacts, Heat Transfer Engineering, 30:10-11, 773-776

[2] Allied Market Research report, available (behind paywall) at: Heat Exchanger Market Size, Share Analysis - 2030 | Industry Forecast (alliedmarketresearch.com)

[3] 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.

[4] It is acknowledged that even in situations where a heat exchanger has not yet reached the end of its operational life, there may be a business case for replacing an older unit for a more efficient one. However, such cases have not been included in the analysis, so the emissions savings results presented here may be an underestimate of those that are potentially feasible.

Action 8

Using heat pumps

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 IEEP Action 8: switching from gas boilers to heat pumps.

Rationale for Action 8

Heat pumps take advantage of thermal gradients to improve the efficiency of electricity-to-heat generation processes. They can be considered in industrial situations where there is a need for low-to-moderate process heat. They can also be used for the heating or cooling of commercial buildings.

In industry, the generation and use of process heat accounts for just over half of on-site industrial energy use. Heat pumps can be used where the need for process heat is up to 180 C/356 F. More than 95% of energy used for process heat generation comes from fossil fuels, so the substitution of heat pumps for conventional boilers offers a powerful opportunity for decarbonization. Heat pumps are already widely used in industries such as timber processing, food and drink manufacturing, chemicals and water treatment and supply.

Heat pumps also have important applications for owners and occupiers of commercial buildings, such as offices, hotels, restaurants, shops, showrooms and indoor leisure facilities, where they can replace the need for a gas boiler for space heating. Heat pumps are suitable for retrofits and new builds and they can also work alongside existing heating systems in a hybrid situation.

Approach and data sources

The approach taken wasto review the objectives and analysis provided in Action 8 in the IEEP and to broaden the assessment to allow for estimation of the potential environmental and other outcomes delivered if significant progress is achieved in implementing the action.
The work involved a review of references and data sources cited in the IEEP paper and included a desk-based review of other academic and non-academic literature.

Baseline data on industrial and commercial energy use was obtained from the International Energy Agency and various national government statistical agency sources.

Design parameters for the development of hypotheses and scenarios, including sector coverage and appropriate applications of heat pumps, were agreed through discussion with representatives from Energy Efficiency Movement partners including Alfa Laval.

The IEEP identifies that heat pumps are long-lasting equipment with a payback period of less than five years. Additional research reveals that in many cases industrial heat pumps have a payback of less than two years.

However, research identifies that the financial benefits associated with the substitution of heat pumps for gas boilers are dependent on the relative prices of gas and electricity. In places where the electricity-to-gas price ratio is 4.0 or higher, heat pumps are less likely to be adopted. A 2022 study revealed that in the United States, the price ratio exceeded 4.0 in around 40 out of 50 states.[1] A European study also identified that heat pumps are less likely to be adopted in countries or regions that possess highly developed gas supply grids, such as Germany and the U.K.[2] However, in some countries government incentives encourage the adoption of heat pumps amongst residential and non-residential users.

Given the variability of the electricity-gas price ratio in different countries (and, in large countries such as the U.S., between different states and provinces) it is not possible within the scope of this paper to estimate accurately the potential aggregate business savings and associated GDP gains that could be obtained from the substitution of industrial and commercial heat pumps for conventional, fossil fuel powered boilers.

The focus instead is on the carbon emissions savings that can be obtained by users switching to heat pumps. The paper also provides an outline of the types of savings that users in some situations could expect to receive from the use of heat pumps.

Strand 1: industrial process heat

Emissions savings

A review of the market for heat pumps for industry revealed that the principal current and potential future applications are focused on the following industrial sub-sectors:

- Timber drying and preparation.
- Pulp and paper.
- Chemicals and petrochemicals.
- Food and drink manufacturing.
- Other manufacturing activities, including the production of pharmaceuticals, textiles, some types of building materials, and in the printing industry.

There are also uses for heat pumps in other activities, including power generation, district heating and water treatment and supply, but these sectors are out of scope as far as the IEEP is concerned so are not included in this assessment.

A starting point was to estimate the current extent of CO2 emissions associated with the operation of process heat in industries where heat pumps can be effectively used. This estimation utilized the following sources:

- Market studies, interrogated to ascertain deployment of the heat pumps across industrial market segments.[3] This data was filtered to focus on sectors that are in scope for the purposes of the IEEP.
- Data from the IEA on global emissions of CO2 by industrial segment.
- Detailed data published by the UK government on CO2 emissions by disaggregated industrial activities.
- Studies undertaken by various agencies into the potential gains from more widespread use of industrial heat pumps for sourcing process heat.

A report produced by the American Council for an Energy Efficient Economy (ACEEE) was useful in that it produced assessments of the carbon savings in three industries: paper and pulp; food manufacturing; and chemicals. The study identified that the following carbon savings could be realized:

- Paper and pulp: 3.8 million metric tons of carbon equivalent (MtCO2e) a year in 2020, rising to 5.7 MtCO2e by 2050.
- Food manufacturing: 0.5 MtCO2e a year in 2020, rising to 0.9 MtCO2e a year by 2050.
- Chemicals: 9.0 MtCO2e a year in 2020, rising to 11.7 MtCO2e a year by 2050.

These results only cover three of the target industries and only apply to the United States.

When extended to other relevant industries and other countries, the results of the assessment were that between 171 MtCO2e and 205 MtCO2e could be saved through the wider use of heat pumps for process heat in industries such as food and drinking manufacturing, chemicals and textiles. The mid-point estimate was 188 MtCO2e.

Table 1: Estimated annual CO2 emissions saved by introduction of heat pumps in industrial situations (MtCO2e)

	Low-end estimate	Mid-point estimate	Top-end estimate
Total industrial	171	188	205

Source: Development Economics analysis

Examples of financial savings from use of heat pumps: industrial process heat

Research undertaken by ACEEE has identified powerful financial savings from the adoption of heat pump technology in a variety of industrial processes across sectors.[4] The table below summarizes some of the results identified by this research across three industrial sectors: food, paper and pulp, and chemicals.

Table 2: Examples of energy and financial cases

Sector	Unit	Carbon reduction (%)	Simple payback (years)
Food	Potato drying	24.3	4.5
Food	Wet corn milling, steepwater	1.2	3.7
Food	Wet corn milling, high fructose syrup	1.9	4.4
Paper	Kraft mill digester	21.7	4.2
Paper	Kraft mill evaporator	34.5	3.8
Paper	Non-integrated mill pulper	5.7	2.5
Chemicals	Ethylene debutanizer	15.1	1.9
Chemicals	Ethylene process water strip reboiler	7.0	2.2
Chemicals	Ethanol fuel, ethyl alcohol, dry mill	52.0	1.9

Source: ACEEE, March 2022

In these examples the simple payback from the deployment of heat pumps was estimated to lie between 1.9 and 4.5 years. The shortest paybacks tended to be found in the chemical sector, with 1.9 to 2.2 years.

Strand 2: Heating and cooling in commercial buildings

The second strand of the assessment focuses on the use of heat pump technology for heating and cooling of commercial buildings. Heat pumps can be used in commercial buildings such as offices, showrooms, retail hotels, hotels and indoor leisure facilities.

Research undertaken by the Carbon Trust identifies that heat pumps have the potential to deliver carbon savings of up to 70% compared to conventional electric heating, and up to 65% compared to an A-rated gas boiler.[5]

The approach taken in this study was to undertake a review of literature to identify data and insight that could be used to develop assumptions with respect to:

- The proportion of energy used in commercial buildings for heating, cooling and ventilation (the balance of energy used is for purposes such as powering office equipment, hot water, cooking and operation of elevators).
- The typical mix of technologies and fuel types used in space heating and cooling in the most common types of commercial buildings.
- Sources such as the Carbon Trust were used to identify the potential range of efficiencies and savings for in-scope energy usage in commercial buildings.

The results of this assessment were that, globally, between 155 MtCO2e and 279 MtCO2e could be saved annually through the substitution of heat pumps for heating and cooling in commercial buildings. The mid-point estimate was 208 MtCO2e.

Table 2: Estimated annual CO2 emissions saved by introduction of heat pumps in industrial situations (MtCO2e)

	Low-end estimate	Mid-point estimate	Top-end estimate
Total commercial	155	208	279

Source: Development Economics analysis

Examples of financial savings from use of heat pumps: heating and cooling of commercial buildings

Research undertaken by ACEEE indicates that around 27% of commercial floorspace in the United States currently heated with fossil fuel systems could be electrified with a simple pay-back of less than 10 years.[6] Buildings with the best paybacks tended to be located in areas with milder winter climates where space-heating needs were more modest, and in building types that tended to have medium-to-high operating hours, such as health care facilities, food and retail outlets, and offices.

Research undertaken by the Carbon Trust in the U.K. found that commercial buildings with the weakest case for retrofitting heat pumps were office buildings with no cooling demand and with relatively simple gas boiler systems.[7] The Carbon Trust identified that the largest factor driving this was the relatively low cost of replacement gas boiler systems. Thus the transition from fossil fuel systems to low-carbon alternative such as heat pumps may need to be supported through incentives and/or regulatory changes.

Summary of benefits

The table below pulls together the potential annual carbon emissions savings from the two strands of Action 8. Column totals may not sum exactly due to rounding of decimals.

Table 3: IEEP Action 8: Summary of potential annual effects (MtCO2e)

Sector	Low-end estimate	Mid-point estimate	Top-end estimate
Industrial	171	188	205
Commercial	155	208	279
Overall total	326	396	485

Source: Development Economics analysis

The overall potential of these actions in just one year could be to deliver savings of between 326 MtCO2e and 485 MtCO2e, with a mid-point value of 396 MtCO2e. In the mid-point scenario, the share of savings between strands is 47% for industrial process heat and 53% for commercial heating and cooling. In the top-end scenario the balance shifts more in favor of commercial, which accounts for 58% of the overall total.

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[1] ihp_fact_sheet_final.pdf (aceee.org)

[2] Electricity, gas, and other fuel prices across Europe | Nesta

[3] Industrial Heat Pump Market Analysis - 2031 | Size, Share (alliedmarketresearch.com)

[4] ACEEE (March 2022), Industrial Heat Pumps: Electrifying Industry's Process Heat Supply

[5] heat-pump-retrofit-in-london-v2.pdf

[6] ACEEE (October 2020): Electrifying Space Heating in Existing Commercial Buildings

[7] Carbon Trust (2020): Heat Pump Retrofit in London

Action 9

Deploying smart building management systems

Introduction and context

A program of 10 potential actions that 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 producing estimates of the benefits 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 IEEP Action 9: deploying smart building management systems.

Rationale for Action 9

A digital building management system (BMS) is used to monitor and regulate a building's electrical and mechanical assets, such as lighting and heating, ventilation and air conditioning (HVAC) systems. HVAC systems alone are associated with over 40% of a typical commercial building's energy load, with around 35% of this energy use usually wasted.[1] A BMS can control up to 70% of a commercial building's energy load if lighting is included.[2] When combining artificial intelligence with a digital BMS, HVAC emissions can be reduced by up to 40% and reduce energy costs up to 25%.[3]

Smart BMSs can save substantial proportions of a building's energy use costs because they provide detection, diagnostic, historical analysis and predictive capabilities.

For example, the deployment of smart BMS in an approximately 30,000-square-meter R&D facility in Bengaluru (Bangalore), India, resulted in building operational and management cost savings of up to 10% and savings in energy management costs of around 19%. The deployment of smart BMS there also resulted in emissions savings of up to 34%.

Similarly, a smart BMS deployed in an assisted living and memory care complex in Florida, integrating HVAC systems, elevators, water systems, heating equipment, fuel systems and switchgear, resulted in savings of 22% for some equipment, achieved by optimizing sequences and lowering maintenance costs.

The use of BMS can also generate benefits for commercial building occupants in terms of improved working conditions for employees, with knock-on impacts for workforce health and productivity. However, benefits of this type have not been quantified in this report.
A principal benefit from implementation of Action 9 is likely to be in increasing the use of digital BMS in older commercial buildings that do not have a BMS system installed. Research undertaken in support of this paper indicates that around 75% of buildings built before the year 2000 fall into this category.

In addition, although most commercial buildings constructed in the past 20 or so years will already have an BMS system installed from the outset, in a significant proportion of these buildings the original systems are ageing and in many cases there would be energy management benefits in upgrading legacy systems.

All types of commercial buildings, including offices, research facilities, hotels and shopping centers, have potential to improve energy management with the introduction of a digital BMS when none is currently used. All of these types of uses are therefore within the scope of Action 9.

Energy usage in industrial buildings is covered by IEEP Action 3, bringing connectivity to digital assets. Energy use in industrial buildings is therefore not included within the scope of Action 9.

Approach and data sources
The approach taken to the assessment was as follows: the objectives and analysis provided in Action 9 was reviewed and the assessment was broadened to allow for estimation of the potential environmental and other outcomes that could be delivered if significant progress is achieved in implementing the action.

The work involved a review of references and data sources cited in the IEEP paper, including a desk-based review of academic and non-academic literature.

Baseline data on energy use by industry, covering electricity and natural gas, was obtained from the International Energy Agency (IEA).

Design parameters for the development of hypotheses and were agreed through discussion with Energy Efficiency Movement partners. The assessment undertaken in this report focuses on the potential impacts in the period up to 2030.

Carbon emissions trends and forecasts
Based on extrapolation of IEA data, commercial electricity usage by 2025 is likely to be around 5,440 terawatt-hours (TWh).[4] Use of natural gas in commercial buildings could reach 2,500 TWh in the same year.[5]

Proponents of the use of smart BMS in commercial buildings have identified greater energy efficiency as a significant potential benefit. Experts such as ABB, Brainbox AI and Frost & Sullivan have estimated the potential for energy savings of up to 30% in annual energy consumed by HVAC and lighting systems used within commercial buildings.[6]

The approach taken here is to model two scenarios covering commercial buildings that have not yet had smart building management systems deployed (circa 75% of commercial buildings that were built before year 2000).

Two scenarios are developed here which respectively explore a lower-bounded and an upper-bounded range of energy savings potential offered by widespread retrofitting of smart BMS technology by occupiers of older industrial businesses, as follows:

Type of energy	Lower-efficiency scenario	Higher growth scenario
Electricity	20%	30%
Natural gas	6%	12%

The results for these scenarios are then compared with a reference case, which is predicated on no further growth in the adoption of smart BMS technology compared to 2022 levels. This reference case is not considered plausible, but it serves the purpose of providing a starting point baseline against which the changes expected under the alternative future scenarios can be measured.

Both scenarios assume that the deployment of smart BMS for older (pre-2000) commercial buildings progresses from the current 25% to 75% by 2030.

Based on the baseline information introduced earlier and the assumptions set out above, estimates of the potential savings in global electricity use by occupiers of older commercial buildings (built before 2000) achievable through greater use of smart BMS over the period to 2030 are set out in the table below. It is reiterated that the potential savings exclude those occupiers that have already (as of 2022) deployed smart BMS in their buildings, either in more recently built premises or in buildings that have already been retrofitted with smart BMS technology.

Annual electricity usage savings from retrofitting of smart BMS by commerce, 2022-2030

Year	Low scenario (TWh)	High scenario (TWh)
2023	295	442
2024	347	521
2025	425	637
2026	525	787
2027	654	981
2028	796	1,195
2029	892	1,338
2030	994	1,491

Average annual electricity usage savings achieved by 2025 could range from 425 TWh to 637 TWh under the two scenarios. By 2030, these savings could range from 994 TWh under the low scenario to 1,491 under the high scenario.

The table below provides equivalent estimates for potential savings in gas usage offered by commercial occupiers. Note: gas usage measured in billion cubic meters has been converted to TWh using a standard conversion factor.

Annual natural gas usage savings from retrofitting of smart BMS by commerce, 2022-2030

Year	Low scenario (TWh)	High scenario (TWh)
2023	40	81
2024	48	96
2025	58	116
2026	71	141
2027	87	174
2028	104	208
2029	115	230
2030	126	252

Annual savings in gas usage by commercial occupiers from the retrofitting of smart BMS in older buildings achieved by 2025 could range from 58 TWh to 116 TWh. By 2030, these savings could range from 126 TWh under the low scenario to 252 under the high scenario.

The energy usage savings set out above would also deliver significant carbon emissions savings benefits.

The table below presents the combined results that could be achieved through the retrofitting of smart BMS in older commercial buildings from 2023 onwards. Note: the emissions savings include the potential for gas and electricity use savings in combination, in millions of metric tons of carbon equivalent (MtCO2e).

Carbon emissions savings from retrofitting of smart BMS for commerce building management

Year	Low scenario (MtCO2e)	High scenario (MtCO2e)
2023	176	269
2024	208	316
2025	254	386
2026	314	477
2027	391	595
2028	475	723
2029	532	809
2030	593	901
2023-2030	2,942	4,477

Under the low scenario, annual savings in carbon emissions resulting from the retrofitting of smart BMS in older commercial buildings could amount to 593 MtCO2e per annum by 2030. Cumulative emissions savings over the 2023 to 2030 period under this scenario could amount to 2,942 MtCO2e.

However, under the high scenario the emissions savings would be substantially larger, at an estimated 901 MtCO2e per annum by 2030. Cumulative emissions savings over the 2023 to 2030 period under this scenario could amount to 4,477 MtCO2e.

Financial benefits

Adoption of smart BMS for energy efficiency purposes has the potential to deliver significant financial savings for occupiers of older (pre-2000) commercial buildings. These savings have been projected using the estimated results for savings in electricity and gas usage outlined above, coupled with assumptions regarding the average price of electricity and gas.

For electricity, data was sourced from the European Union (Eurostat).[7] The data used was for the first quarter of 2020, predating the price spike linked to the invasion of Ukraine by Russia. The euro price was converted to dollars using September 2023 exchange rates.

For gas, the international price was sourced from financial markets data. It is worth noting that the international price as of early September 2023 was close to the price that prevailed in the first quarter of 2020. The price of gas per million British thermal units was converted to a price per kilowatt-hour using standard conversion factors.

The table below sets out the financial savings expected if up to 75% of occupiers of commercial properties that have not yet adopted smart BMS technology were to do so, and in particular were they to use this technology to manage and optimize their energy usage in operating HVAC and building lighting systems.

Financial savings from retrofitting of smart BMS for commerce building management (USD billions)

Year	Low scenario	High scenario
2023	11.3	17.0
2024	13.3	20.0
2025	16.2	24.5
2026	20.1	30.2
2027	25.0	37.7
2028	30.4	45.9
2029	34.1	51.4
2030	38.0	57.2

Annual financial savings from retrofit of smart BMS in 75% of older commercial buildings where this has not already occurred could reach between $16.2 billion and $24.5 billion by 2025, rising to between $38 billion and $57.2 billion by 2030.

Wider economic benefits from increased use of smart BMS for commercial building management

A greater level of deployment of smart BMS technology to enable enhanced energy management in older commercial buildings also has the potential to deliver substantial benefits in the form of additional economic output. The scale of these economic gains is calculated based on standard ratios between gross value added[8] and procurement expenditure for businesses in the commercial sector for major industrialized countries, based on data published by the United States Government's Bureau of Economic Analysis and the U.K.'s Office for National Statistics. The estimates produced are summarized in the table below.

Potential GDP increases from retrofitting of smart BMS for commerce building management (USD billions)

Year	Lower efficiency scenario	Higher efficiency scenario
2023	13.9	21.0
2024	16.4	24.8
2025	20.1	30.3
2026	24.8	37.4
2027	30.9	46.6
2028	37.6	56.7
2029	42.1	63.5
2030	46.9	70.8

By 2025, the annual boost to global output from expanded use of smart BMS technology for energy management retrofitted to older premises occupied by commercial enterprises could lie in the range of $20.1 billion to $30.3 billion.

By 2030, the annual increment to global GDP could lie in the range of $46.9 billion to $70.8 billion per annum.

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[1] BrainBox AI website, 2022: Making buildings smarter, greener, and more efficient

[2] Faruque Hossain, Chapter Seven - Best Management Practices, Sustainable Design and Build, Butterworth-Heinemann, 2019, Pages 419-431

[3] BrainBox AI

[4] IEA: World electricity final consumption by sector

[5] Gas Market Report, Q2-2023 – Analysis - IEA

[6] Frost & Sullivan (March 2023) – Global Building Automation System Growth Opportunities

[7] Statistics | Eurostat (europa.eu)

[8] 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.

Action 10

Moving data to the cloud

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 benefits that could be achieved by adopting various technologies and approaches to more efficient use of energy in industrial processes.

This paper summarises the potential benefits associated with the implementation and widespread adoption of IEEP Action 10: moving data to the cloud.

Rationale for Action 10

Global demand for data processing has been growing fast, with internet traffic growing by around 600% between 2015 and 2022. Meanwhile, data center workloads have grown by around 340% over the same period.[1] Despite huge growth in data traffic, energy use by data centers (excluding data transmission networks) is estimated to have grown by only around 20%. The moderate increase in energy usage by data centers (compared to the rate of growth in demand for services) has been facilitated by rapid improvements in energy efficiency on the part of data center operators.

Part of the trend towards efficiency gains has been the migration of a significant share of data storage from enterprise data centers towards large-scale, multi-tenanted cloud data center operations.

According to data from Thales, between 2015 and 2022 the proportion of corporate data held in the cloud doubled, from 30% to 60%.[2] Based on recent (2015 to 2022) growth rates, the proportion of corporate data held in the cloud by 2027 is likely to be between 77% and 87%.

Cloud data storage providers recognize that electricity consumption is one of their largest operating expenses, and all the major operators are aggressive in seeking energy efficiency improvements. On the other hand, companies operating their own servers in local facilities may not know their server-related energy costs in isolation. They may also not have a strong incentive to enhance the energy efficiency of on-premises data storage operations unless this is a specific priority for management.

There are at least three drivers for cloud data center operators to drive greater efficiency savings compared to what is generally possible for an individual on-premises data storage facility:

- **Operational efficacy:** the large economies of scale offered by cloud computing can usually operate at a much higher level of efficiency compared to smaller, on-premises servers. In cloud data centers, prediction and monitoring of demand can help ensure that over-provisioning of supply, where equipment is sized to meet a customer's peak load, can be more easily avoided compared to on-premises provision. Multi-tenancy also allows a cloud facility to balance fluctuating demand and power load from a wide base of customers, thereby increasing average utilization rates and creating energy use efficiencies.
- **Equipment efficiency:** energy usage accounts for a significant percentage of a cloud operator's overall operating expenses, so there is a strong financial incentive to optimize IT equipment operational efficiency.
- **Infrastructure efficiency:** advanced infrastructure technologies in hyperscale data centers also reduce the energy requirement for operating systems for lighting and cooling the facility.

An additional factor is that hyperscale data center operators also have the potential to purchase large quantities of renewable energy. Major cloud data center operators including Microsoft, Equinix, CyrusOne and Digital Realty have all made public commitments to 100% purchase of energy from renewable sources by 2030 at the latest, and Google already claims to be 100% reliant on purchases of electricity from renewable sources. However, the ambition for cloud-based data center operators to source the majority of their electricity needs from renewable sources is not included in the assessment undertaken for this report.

Approach and data sources

The approach taken was to review the objectives and analysis provided in Action 10 and broaden the assessment to estimate the potential environmental and other outcomes that could be delivered if significant progress is achieved in implementing the action.

The work involved a review of references and data sources cited in the IEEP paper. There was also a desk-based review of other academic and non-academic literature. Baseline data on energy use by data centers was obtained from the International Energy Agency (IEA) and various other sources.

Given the expected continuing strong growth in demand for data services, particular attention was placed on obtaining a range of forecasts for future demand for services, future energy needs and future levels of carbon emissions relating to data centers.

Design parameters for the development of hypotheses and scenarios, including sector coverage and appropriate applications of heat pumps, were agreed through discussion with Energ Efficiency Movement partners.

The cloud computing industry is evolving quickly, so the main focus of the assessment undertaken in this report is on the potential impacts in the short to-medium term, up to and including 2027. However, in order to provide an assessment in line with that undertaken for the other actions, results are also provided for the year 2030.

Carbon emissions trends and forecasts
According to the IEA, data center electricity usage in 2021 was estimated at between 220 and 329 terawatt-hours (TWh).[3] This implies that data centers account for around 1% to 1.5% of global electricity use. Meanwhile, a study of global IT sector energy use and greenhouse gas (GHG) emissions identified that data centers in 2020 consumed 223 TWh of electricity and generated 95 million metric tons of carbon equivalent (MtCO2e) of GHG emissions.[4]

Predicting future energy usage and emissions on the part of the data center industry is challenging for several reasons:

- The high rates of growth expected for future data center services, especially cloud services. With most estimates predicting continuing double-digit rates of growth, a small difference in annual growth rates can lead to substantial changes in end points reached in just (say) five years.
- Uncertainty about data usage and trends in China, which accounts for a significant share of the baseline market and future growth.
- Uncertainty over the future market share of cloud-based services.
- The relative share of alternative cloud-based technologies, which offer a range of comparative efficiencies compared to locally deployed physical servers. Based on data from Microsoft, four alternative cloud services offer efficiencies ranging between 22% and 93% compared to locally deployed physical servers. A simple average of the four technologies suggests a typical range of improvement lying between 56% and 84% compared to locally deployed servers.[5]

Despite the challenges, there are a large number of forecasts and predictions available assessing the potential growth rates of the data centre industry, the share of cloud -based services and aggregate energy use by data centers.

To assess the potential contribution of the expected trend towards increasing levels of cloud data storage over the next five years, three scenarios have been considered: a lower growth scenario, a higher growth scenario and a mid-range scenario at the mid-point between the low and high scenarios.

Based on a distillation of the available evidence, a range of assumptions for key indicators have been used in this paper to predict future trends from 2022 onwards. The table below sets out some of the main assumptions for the three forward-looking scenarios considered in this assessment.[6]

Metric	Lower growth scenario	Mid-range scenario	Higher growth scenario
Average efficiency of cloud data centers versus locally deployed servers	56%	70%	84%
Cloud share of market by 2030	84%	87%	89%
Data center electricity use average annual growth rate	2%	3%	4%

The results for these scenarios are then compared with a reference case, which is based on no further growth in cloud-based data beyond 2022 levels. Of course, this reference case is not considered to be plausible, but it serves the purpose of providing a starting point baseline against which the changes expected under the three forward looking scenarios can be measured.

Based on the information introduced earlier and the assumptions set out above, the following are the estimates of the potential scale of aggregate global electricity usage attributable to the expected growth of cloud service usage, compared to locally deployed physical servers. Results in the first column are based on the lower band estimate of 2021 data center industry energy usage (from IEA figures), at 220 TWh.

Those in second column are based on the higher band estimate of 2021 data center industry energy usage, which is 329 TWh.

Energy savings from continued transition to cloud services by 2027 (per annum)

Scenario	Lower 2021 baseline (TWh)	Higher 2021 baseline (TWh)
Lower growth	183	282
Moderate growth	201	300
Higher growth	219	305

Growth in cloud services over the 2022 to 2027 period would be expected to deliver savings of between 183 TWh and 219 TWh annually by 2027, compared to a situation where there is no further growth in the market share of cloud services. This range is predicated on the baseline data usage figure for 2021 being 220 TWh, which is the low end of the range estimated by the IEA.

Alternatively, annual data use savings achieved by 2027 from transition to cloud services could lie between 282 TWh and 305 TWh if the baseline energy usage figure for 2021 is taken to be 329 TWh, the upper end of the range estimated by the IEA.

Carbon emissions savings associated with the expected continued transition towards cloud services can also be estimated. The approach taken is to apply the emissions-to-electricity-usage ratio identified for the year 2021 to the energy usage savings expected to occur over the period to 2027.

The potential carbon emissions savings associated with the continued transition to cloud services are set out in the table below.

Carbon emissions savings from continued transition to cloud data storage by 2027 (per annum)

Scenario	Lower 2021 baseline (MtCO2e)	Higher 2021 baseline (MtCO2e)
Lower growth	104	161
Moderate growth	115	171
Higher growth	125	174

Assuming that the lower baseline figure for electricity consumption is used as a starting point, then continued transition to cloud services is likely, by 2027, to result in annual carbon emissions savings of between 104 and 125 MtCO2e.

If the higher baseline figure is used instead, the expected annual savings would be likely to amount to between 161 and 174 MtCO2e per annum by 2027.

The results for potential carbon emissions savings can also be extrapolated to year 2030, although the rapid rates of growth and change occurring in the industry mean that these results are more uncertain and should therefore be regarded as indicative.

Carbon emissions savings from continued transition to cloud services by 2030 (per annum)v

Scenario	Lower 2021 baseline (MtCO2e)	Higher 2021 baseline (MtCO2e)
Lower growth	133	218
Moderate growth	155	239
Higher growth	177	244

By 2030, migration to cloud services could result in annual carbon emissions savings of between 133 and 177 MtCO2e if the lower baseline position is used, or between 218 to 244 MtCO2e if the higher baseline is used.

It should be noted that the estimation does not factor in any additional carbon savings associated with the expected increased sourcing of electricity supply from renewable sources. The drive towards renewable energy would generate even greater carbon savings, so the figures in the table above are likely to be an underestimate of what cloud services will ultimately achieve.

Other benefits from transition to cloud services

For businesses that are contemplating cloud services, there may be other advantages to consider, including:

- Other environmental impact benefits, such as reduced water usage.
- Opportunities to address shortcomings in the architecture and technology associated with existing, on-premises data storage.
- Opportunities to address shortcomings in disaster recovery, security and compliance associated with existing, on-premises data storage.

For many companies, cloud services can also be a less expensive alternative compared to continued on-premises computing and data storage. The extent to which financial savings are achievable from a switch to cloud is influenced by a range of variables, including:

- The size of the business making the transition.
- Costs and inefficiencies embedded in the existing on-premises architecture.
- Decisions around whether investment in a single cloud solution or a multi-cloud solution is appropriate for the business.
- Legacy costs associated with on-premises data storage.

A review of available research suggests that while cloud services can be initially more expensive than on-premises facilities because of migration investment costs, the cloud will usually become cost effective over time, especially as organizations become more adept at using and operating cloud services. The break-even point typically occurs at around 18 months.

Direct financial savings achieved by moving to the cloud are principally found in four areas:

- Reduced costs in procurement and configuration of on-premises hardware and software.
- Reduced staff costs for tasks such as backing up, responding to alerts and incidents, and managing infrastructure.
- Reduced personnel and hardware costs associated with migrating systems of upgraded hardware.
- Improved response time in scaling up and scaling down as locations are added or closed.

A recent study undertaken on behalf of Microsoft found that migration to cloud-based apps delivered a return on investment of up to 22% with a payback period of 15 months.[7] Meanwhile, a survey of over 4,000 senior business leaders and executives undertaken by Accenture[8] found that 65% of respondents reported, on average, up to 10% costs savings from moving to the cloud.

However, the Accenture survey also found that around 10% to 15% of businesses moving to the cloud had experienced much more substantial financial savings and operational benefits from the move. The survey found that the businesses that had experienced the greatest benefits were the ones that had capitalized on the potential of cloud computing to evolve business operating practices and culture, and by enhancing and accelerating business innovation, flexibility and productivity growth.

These findings are similar to those identified by the research recently undertaken for Microsoft[9], which found that customers using the Azure cloud platform service could realize a 50% increase in the speed of application development and a 40% decrease in application development-related infrastructure costs.

The extent to which these benefits could be available to businesses switching to cloud-based services may vary by sector, with the most powerful benefits likely to be experienced by companies operating in knowledge and innovation driven sectors such as pharmaceuticals, biotechnology and aerospace.

Additional capabilities that are often enabled by the most successful migrations to cloud services include enhanced abilities to achieve faster and deeper insights into emerging trends in customer behaviors, market opportunities, and to enhance relationships with customers and suppliers.

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[1] IEA analysis based on data from Cisco.

[2] Percent of Corporate Data Stored in the cloud (2023) (explodingtopics.com)

[3] Data centres & networks - IEA

[4] J.Malmodin et al, ICT sector electricity consumption and greenhouse gas emissions – 2020 outcomes (May 2023), available at: ICT Sector Electricity Consumption and Greenhouse Gas Emissions – 2020 Outcome by Jens Malmodin, Nina Lövehagen, Pernilla Bergmark, Dag Lundén :: SSRN

[5] Download Study: Carbon, energy efficiency benefits of the Microsoft Cloud from Official Microsoft Download Center

[6] It should be noted that the lower growth scenario is predicated on rates of growth that would be regarded as very high rates for most other business sectors.

[7] Forrester study finds 228 percent ROI when modernizing applications on Azure PaaS | Azure Blog | Microsoft Azure

[8] 4 Keys to Cloud Continuum Success | Accenture

[9] Forrester study finds 228 percent ROI when modernizing applications on Azure PaaS | Azure Blog | Microsoft Azure

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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