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.

[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.

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.