# 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.

[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

# 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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