Heat pump technologies

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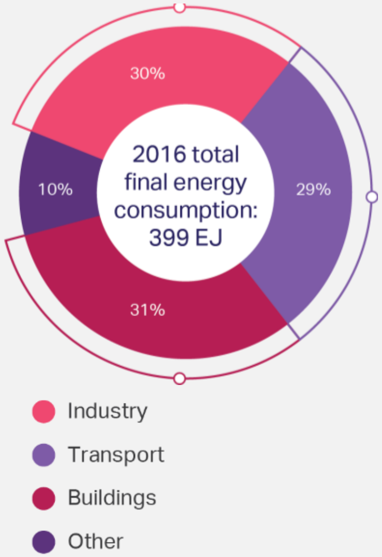
1. Background

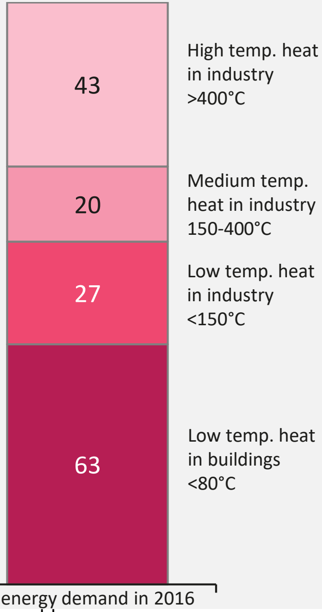
Heat represents a large share of energy demand from buildings and industry

World energy demand[1]



Heat application[1,2]

38% of world energy demand is for heat applications



Possible solutions to decarbonize heat

- **Demand-side energy efficiency measures** such as building envelope improvements, appliance efficiency and process improvements.

- **Efficient heat delivery/generation** including **electric heat** pumps – which typically provide heat to temperatures up to 100°C, or 160°C for the next generation of heat pump[3]– and **district heating**.

- **Renewable heat*** including solar thermal, concentrated solar heat, geothermal.

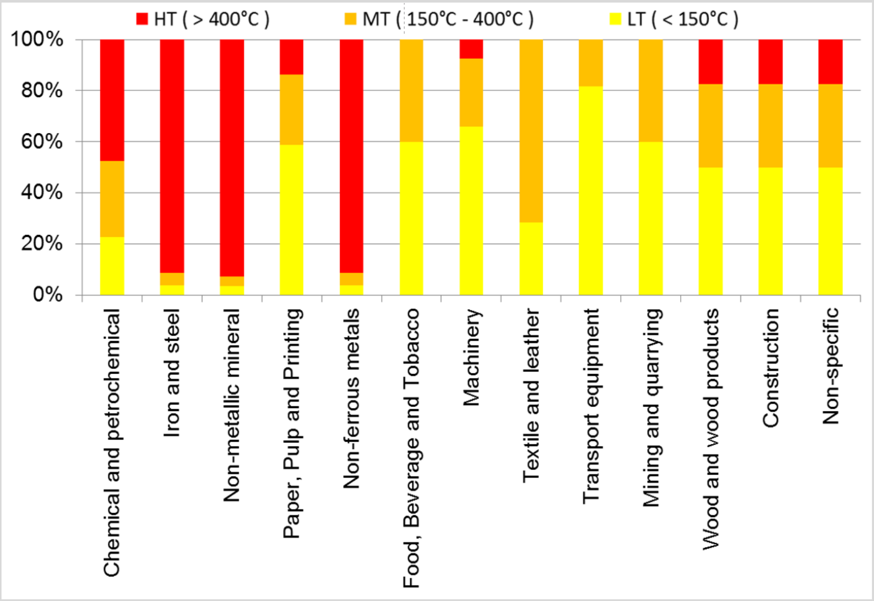
- **Low carbon fuels** such as bioenergy, waste, and green hydrogen.

*In the EU, heat extracted from sources by heat pumps are considered as renewable energy

Sources: [1] IEA, 2017: *Energy Technology Perspectives 2017*; [2] IEA, 2017: *Renewable Energy for Industry – From green energy to green materials and fuels*; [3] *European Heat Pump Association*.

1. Background

Heat temperature requirements for a selection of industrial sectors



Source: Fraunhofer ISE, 2017: *Solar Heat for Industrial Processes*.

- Many industrial processes require **low-temperature heat, which can be met by heat pumps.**
- Some processes require very high temperature heat, which may be linked to chemical processes. Sometimes, the primary source of energy is used for both its energy content and carbon content e.g. in steelmaking.

1. Background

An overwhelming reliance on conventional fossil fuels for heating in industry and buildings

Current heat provision and associated CO_2 emissions	• Even the most efficient fossil fuel heating technologies emit substantial amounts of CO_2:[1] condensing gas boilers ~210gCO_2/kWh$_{th}$ and condensing oil boilers ~280gCO_2/kWh$_{th}$. Emissions from electric heating technologies depend on the used power mix: for the average EU generation mix, emissions are ~315gCO_2/kWh$_{th}$ for electric resistance heaters and 90gCO_2/kWh$_{th}$ for heat pumps (COP3.5); 0gCO_2/kWh$_{th}$ for both technologies if the power sector is decarbonized. • Total direct emissions from industry amount to 8.5 GtCO_2 (24% of global energy-related CO_2 emissions), and space and water heating in the buildings sector is responsible for 2.2 GtCO_2 (6% of global energy-related CO_2 emissions).[2]
Forecasted developments in a business-as-usual scenario	• In the IEA's Reference Technology Scenario[2], final energy demand grows by 1.2% p.a. until 2050 with the share of fossil fuels in the final energy demand decreasing slightly but remaining substantial at a rate of 67%. Direct emissions increase to 10.3 GtCO_2 in 2050. • Under the same scenario, final energy demand for space heating and cooling in buildings grows by 0.1% p.a. until 2050, while the share of fossil fuels in the final energy demand decreases to 42%, a 20% reduction from 2014 levels. Under the reference scenario, direct emissions decrease to 1.6 GtCO_2 in 2050.
Obstacles to decarbonizing this energy use	• The development of direct renewable heat in industry is hindered by barriers such as: lack of nearby land space (for solar heat), long distances to high-value resources (e.g. geothermal heat) and high costs e.g. of sustainable biofuels. • Upfront costs of low-carbon solutions are often higher than fossil fuel-based options. • Electrification of heating is hindered by relatively low fossil-fuel prices compared to electricity prices. • Fossil fuel subsidies and an inadequate carbon price levels provide little incentive for decarbonization.

Sources: [1] Emission factors calculated assuming 95% condensing boiler efficiency and *IPCC emission factors*; assumes 100% efficiency for electric resistance heating; [2] IEA, 2017: *Energy Technology Perspectives 2017*.

2. Description of heat pump technology

Overview

Description of the new solution concept	• Heat pumps use energy (electric or thermal) to extract heat from an external, often renewable source and deliver it to the heat sink. • While heat pumps can provide both heating and cooling services to buildings and industry, this business case focuses on electrically-driven heat pumps for heating only, with a focus on applications in the commercial and industrial (C&I) sector.
Rationale for developing this solution	• Heat pump efficiency is typically 2-4 times higher than that of conventional technologies such as natural gas boilers or electrical resistance heating.* • Zero-emissions at point of use. • Can be used to deliver flexibility services to the grid via heat storage. • IEA and IRENA project that heat pumps combined with decarbonized electricity will be one of the key levers for decarbonizing heat.[1] In the IEA's beyond 2°C scenario, electric heat pumps account for about 50% of the total heating stock in 2060.[2]
Assessment of technology readiness status	• Heat pump technologies are already mature. • IEA's Technology Collaboration Programme on Heat Pumping Technologies[3] seeks to further develop heat pumps for multiple applications and operating conditions. Research is being undertaken to further develop hybrid and fuel-driven sorption heat pumps, cold-climate and industrial heat pumps, heat pumps for water heating, and heat pumps for district energy systems.

*The efficiency of a heat pump depends on the heat pump technology and operating conditions.

Sources: [1] IEA, 2017: Energy Technology Perspectives 2017; [2] IEA and IRENA, 2017: Perspectives for the energy transition; [3] IEA: Technology Collaboration Programme on Heat Pumping Technology.

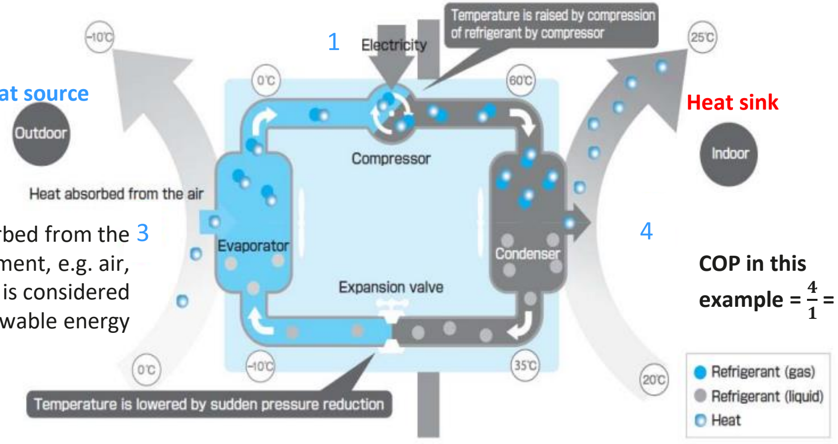
2. Description of heat pump technology

Physical principles and efficiency terminology

- A heat pump moves heat from a lower temperature “source” - ground, air or water - to a higher temperature “sink”, where it is used for space, water or process heating. It uses energy – typically either electricity or thermal energy – to transfer the heat using a refrigerant as a heat transfer medium. Hybrid heat pumps also exist, where heat pumps are combined with e.g. natural gas or solar thermal systems. This business case focuses only on electrically-driven heat pumps.
- A heat pump can provide heating or cooling, depending on whether the objective is to warm the sink or to cool the heat source. Heat pumps can also provide both services in parallel.
- The lab-based efficiency of a heat pump is described by the COP (coefficient of performance). It is the ratio of the useful heat to the amount of electricity consumed. The smaller the difference in temperature between the heat source and the sink, the higher the COP.
- Because the efficiency depends on thermal energy requirements of the sink and the local climate zone, a better way to compare efficiencies is using the seasonal COP (sCOP). This is determined using standardized operating conditions, such as under European standard EN 14825.
- On-site efficiency is referred to as the seasonal performance factor (SPF).

Heat source

Heat absorbed from the environment, e.g. air, ground, water, is considered to be renewable energy 3



Heat sink

4

COP in this example = $\frac{4}{1}$ = 4

1 3 4

Figure adapted from IEA-ETSAP & IRENA, 2013: *Heat pumps*.

2. Description of heat pump technology

Different types of heat sources

Heat pumps can use the air, water or ground as heat sources, as well as waste energy from buildings and industrial processes to provide heating and cooling:[1,2]

- **Air-source heat pump (ASHP):**
  - ASHPs can use outdoor air or ventilation air in residential and commercial buildings (recovering waste heat in the process) as the heat source.
  - Typical COP between 3-4.
- **Ground-source heat pump (GSHP):**
  - Can be installed as either a horizontal shallow-grid system, where the heat exchanger is installed in the surface layer of the ground, and mainly relies on stored solar heat; or a vertical borehole system, which extends deeper underground.
  - The performance of a GSHP is not influenced by outdoor air temperatures, and there is limited temperature variation a few meters below ground.
  - GSHPs have a higher efficiency than ASHPs, typically with a COP above 4.
- **Water-source heat pump (WSHP):**
  - Natural water heat sources include ground, surface and sea water. Other sources include raw or cleaned sewage water, industrial waste water or other industrial liquid flows.
  - The performance of a WSHP is not influenced by outdoor air temperatures, and there is limited temperature variation at the bottom of water source.
  - WSHPs have a COP typically above 4.


Air source heat pump

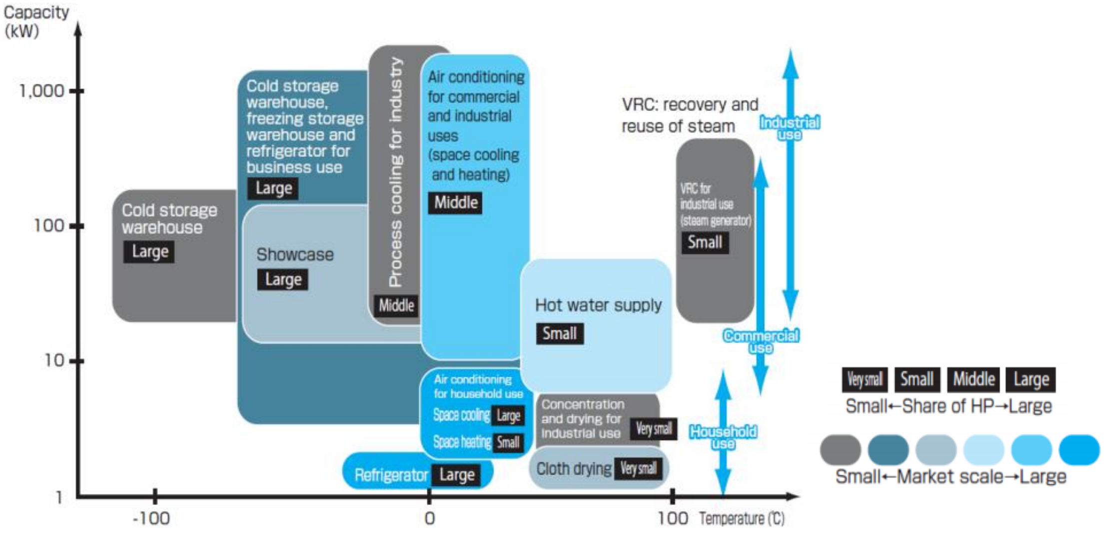

Ground source heat pump


Water source heat pump

Sources: [1] IEA, 2013: *Transition to Sustainable Buildings. Strategies and Opportunities to 2050*; [2] EHPA, 2010: *Heat pump technology and application overview*.

2. Description of heat pump technology

Applications in buildings and industry



- Heat pump technologies can provide temperatures from below -100°C to 160°C.
- The capacity of heat pumps can range from several kW to over 1000 kW.
- Heat pumps are already used in many cooling applications, but potential exists to expand the use of heat pumps for heating applications in industry and buildings. There is also a large potential in application fields where both heating and cooling demand exists, as high efficiencies can be realized.

Source: IEA-ETSAP & IRENA, 2013: *Heat pumps*.

2. Description of heat pump technology

Applications in commercial buildings

- Heat can be distributed in commercial buildings using an **air or water-based system**:
  - Water-based systems: heat is transferred to radiators, floor heating or wall-based emitters. This is typically used only for heating.
  - Air-based distribution systems: conditioned air is transported directly or via ducts to heat, cool and/or dehumidify rooms.
  - A mix of both is also possible, where energy is distributed throughout the building in water-based systems but disseminated in the room via fan coils.
- Heat pumps with an energy management system can **reduce energy demand by recycling waste heat**. Waste heat from one part of the building can be distributed to other parts where heating is needed or can be used as the heat source to heat water.[1]

- **The ideal buildings for heat pump applications** are those that are well insulated with sufficient heat distribution surface (e.g. underfloor heating or floor to ceiling radiators) to allow comfortable indoor temperatures at comparatively low temperatures for the heat distribution system. This is because the heat pump output temperature is typically lower than that of gas boilers. For water-based distribution systems, a typical heat pump output temperature is below 55°C*, whereas radiators fed by central heating systems typically operate at 60-80°C.[2] For this reason, the ideal building for heat pumps are near-zero energy, passive or positive energy buildings. Heat pumps are also suitable to replace boilers in buildings that have undergone deep renovation (i.e. where energy savings of 60-90% are realized).

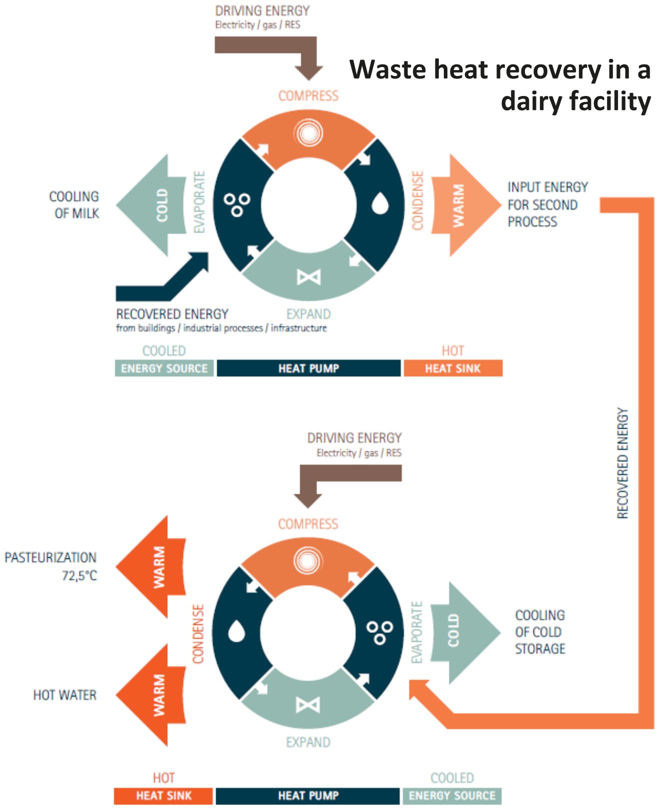
*While this is typically the case, some heat pumps on the market are specifically designed to substitute boilers, and can heat water efficiently up to 80°C.
Sources: [1] European Copper Institute, 2018: *Heat Pumps. Integrating Technologies to Decarbonise Heating and Cooling*. [2] YouGen: *Heating and hot water – energy saving information*.

2. Description of heat pump technology

Applications in industry

- Heat pumps can be used for industrial processes which require **low temperature heat**. Commercially available heat pumps can provide heat up to 160°C.[1]
- **Typical industrial applications** for heat pumps include drying, washing, and pasteurization. Industrial heat pumps are most **often bespoke systems** designed for specific process needs.
- Many industrial facilities both consume heat and also have low temperature **waste heat flows** which cannot be exploited directly using traditional heat exchangers. Heat pumps can be designed to increase this waste heat to a useful temperature.
- For example, in the dairy industry (see right)[2],milk needs to be cooled before transport and consumption. On the other hand, heat is needed for the pasteurization process. The waste heat from the cooling process can be recovered and used as a heat source for the pasteurization process.
- The **main challenge** is that in many industries steam is most often used to transfer heat across a site, resulting in high temperature system designs. Shifting this to air or liquid water requires new pipes and pumps and different process designs. This leads to high investment costs and potentially disrupted operations.

Waste heat recovery in a dairy facility



Sources: [1] Viking Heat Engines; [2] European Copper Institute, 2018: Heat Pumps. Integrating Technologies to Decarbonise Heating and Cooling.

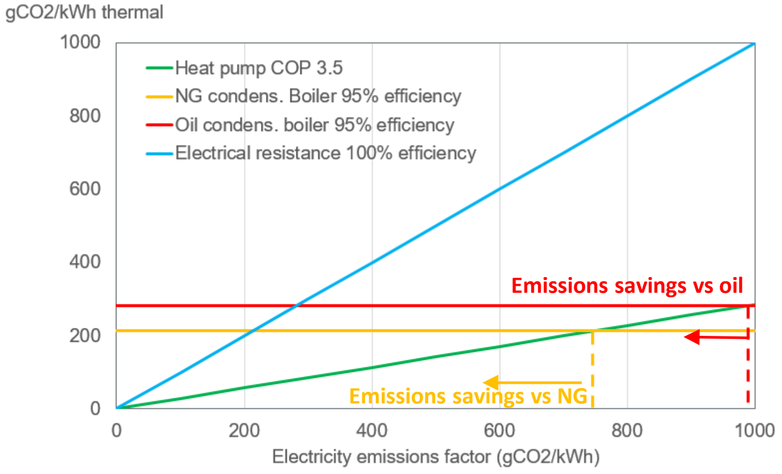
3. GHG reduction potentials of heat pumps

GHG emissions assessment of current and new solution

- **Avoided emissions compared to conventional heating** depends on the electricity emissions factor.
- Due to its higher efficiency, heat pumps are always more carbon efficient than electrical resistance heaters. For example, a heat pump with a COP 3.5 emit less CO_2/kWh_{th} compared to:
  - Natural gas condensing boilers when the electricity grid factor is below 740gCO_2/kWh.*
  - Oil condensing boilers when the electricity grid factor is below 980gCO_2/kWh.
- The avoided emissions that could be realized by **heat pumps powered by zero-carbon electricity** are shown below:

Technology	Avoided emissions (gCO_2/kWh_{th})
Natural gas condensing boiler	210
Oil condensing boiler	280
Electrical resistance heater powered by zero-carbon electricity	0

Relationship between grid electricity emissions factors and carbon emissions of the heat pump



*For comparison, the EU electricity grid factor is about 300gCO_2/kWh, meaning that the heat pump is always more carbon efficient than natural gas boilers

Source: Own calculations based on *IPCC emission factors*.

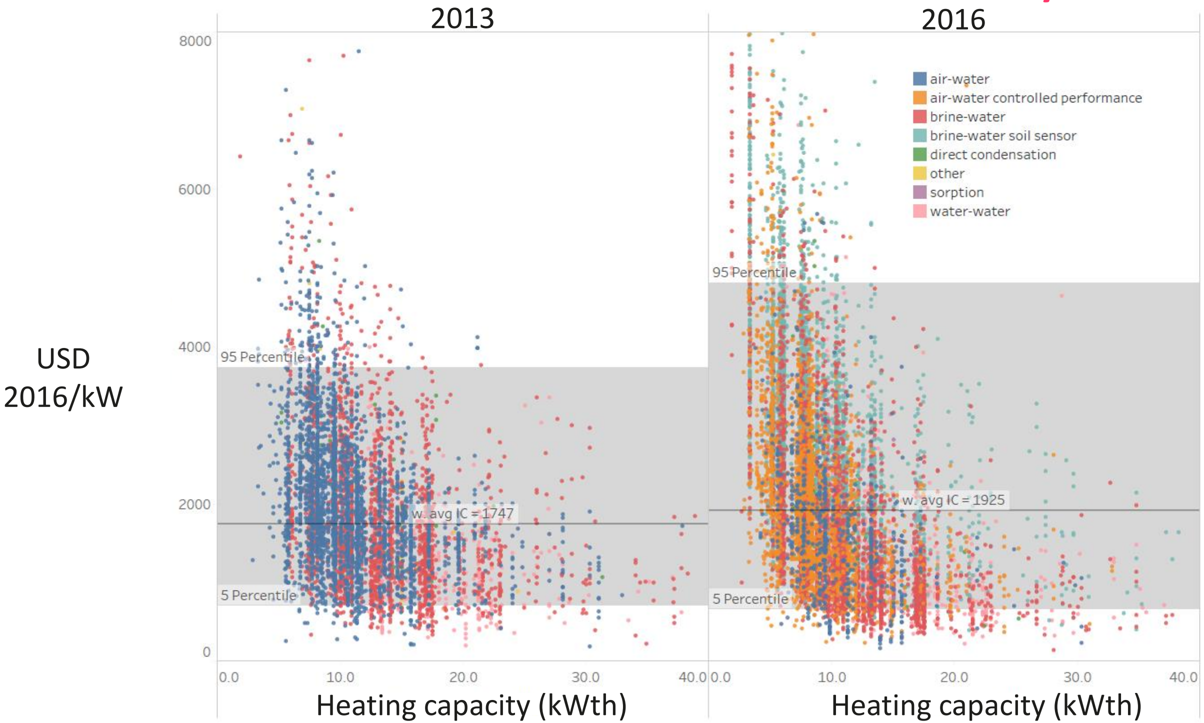
4. Cost assessment and sensitivity analysis

Investment costs & LCOH	• No information publicly available on the levelized cost of heating (LCOH) of C&I heat pumps. • Investment costs depend on country, application and brand: in 2016, the average installation cost of a small-scale heat pump in buildings in Germany was USD $1,925/kW, while the average equipment cost (excluding installation) of a large-scale heat pump in Europe/MENA was USD $699/kW in 2015.[1] • The LCOH for domestic heat pumps in the EU over 2008-2012 ranged from EUR €95-150/MWh_{th}.[2]
Return on Investment (ROI)	• Limited information exists on the ROI and comparison of LCOH of heat pumps compared to fossil fuels. • Heat pumps in new buildings are cost-competitive compared to fossil fuel-based alternatives in certain cases, including in applications when heating and cooling is needed and when stringent energy efficiency standards for buildings are in place. • In general, heat pumps are not yet competitive in the like-for-like replacement case, where an existing fossil fuel boiler is replaced without any upgrade to the building. However, in some regions, the cost of use may be competitive due to electricity prices being lower than natural gas prices. • Heat pumps are competitive in some industrial applications, but constraints such as long payback periods limit deployment.
Sensitivity analysis	• The competitiveness of heat pumps vs fossil-based conventional technologies is sensitive to the **price of electricity compared to the price of fossil fuels**. • **Energy and climate policies** such as carbon pricing, fossil fuel subsidies, energy efficiency targets and technology-specific incentives can greatly improve the cost competitiveness of heat pumps. These vary by geography and therefore research needs to be conducted for the region of installation. • The upfront capex cost can **vary across technologies**: GSHPs and WSHPs have higher installation costs than ASHPs. However, GSHPs and WSHPs have higher efficiencies than ASHPs. • The **price per kW decreases with increasing heat pump size**. The typical price of a small-scale heat pump is in the range of USD $1000-2000/kW. The typical cost of an industrial scale heat pump in Europe/MENA is about USD $600/kW in 2015.[1] • **Operating conditions** affect the efficiency of heat pumps and hence cost of heating. Heat pumps in cold climates may operate at a lower efficiency, and high heating demand also reduces the efficiency.

Sources: [1] Taylor, M., 2018: A sustainable energy future: the role of heat pumps in a fossil-free system; [2] Ecofys, 2014: Subsidies and costs of EU energy.

4. Cost assessment and sensitivity analysis

Total installed costs in the residential and commercial sectors in Germany

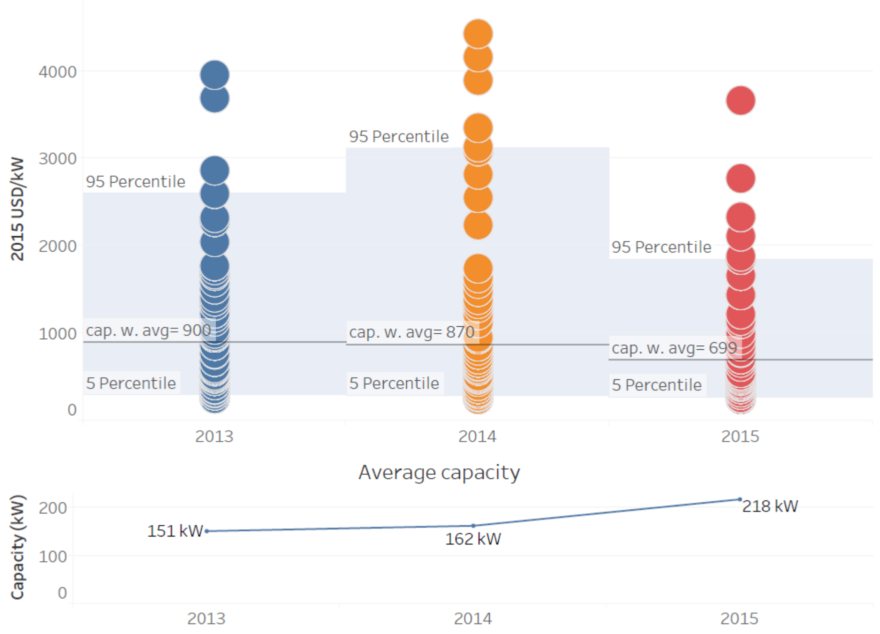


- The average price of a heat pump has increased in Germany over 2013-2016, however there has been an 18% increase in the efficiency of the installed systems.

Source: IRENA Renewable Cost Database 2018

4. Cost assessment and sensitivity analysis

Large scale heat pump equipment costs* in Europe/MENA



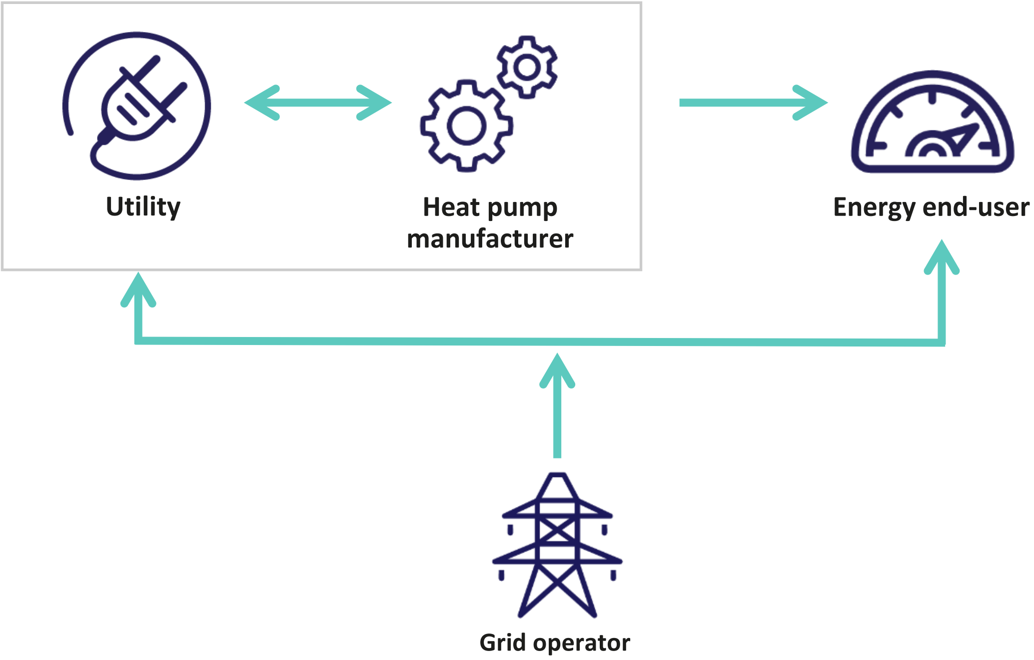
- Weighted average costs decrease as system sizes increase.

* Equipment costs exclude installation costs
Source: IRENA Renewable Cost Database 2018

5. New partnership opportunities

Utilities and heat pump manufacturers can partner so that utilities become heat pump vendors. This opens up opportunities for ESCO (energy service company) business models, where the utility sells heating (rather than simply electricity or a heat pump). This would overcome the barrier of comparatively high upfront investment costs.

Utilities can aggregate heat pump users. This would enable heat pump users to participate in demand response programs and be remunerated for providing demand side response flexibility services to the grid operator.



6. Heat pump technologies SWOT analysis

Strengths

- **Can be highly energy efficient** compared to existing conventional heating options. COP of heat pumps has not reached its technical potential and further efficiency gains are anticipated.
- **Can be used for multiple purposes:** heating and cooling of both water and air. Highest efficiency if simultaneous provision of heating and cooling is required.
- **Potential to reduce GHG emissions** and no local air pollutants.
- **Mature technology**, already used at various scales from individual buildings to district heating.
- Heat pumps can be controlled so that they **exploit periods of low electricity prices** thereby reducing operating costs. They can also **provide flexibility services** to the grid by switching on/off when needed.

Weaknesses

- **High upfront CAPEX** and long payback periods compared to conventional heating options.
- Where the **C&I building stock has a low thermal efficiency**, heat pump efficiency is reduced. Fully electric heat pumps have a lower efficiency in regions with challenging climatic conditions (e.g. extremely cold regions). However, hybrid heat pumps may be a bridge solution.
- In some regions, there is **limited public awareness** of the technology and a lack of skilled technicians.
- **Many heat pump refrigerants are F-gases, with a high global warming potential.** With the entry into force of the Kigali Amendment to the Montreal Protocol, such gases are being phased out and replacement refrigerants are being developed.
- **Permits** may be needed to install ground or water-source heat pumps.

Opportunities

- **Regulatory support** specifically for heat pumps exists in a small number of jurisdictions.
- Increasing implementation of **supportive policies** – such as carbon pricing, the phase out of fossil fuel subsidies and the move toward zero energy buildings – increase the competitiveness of heat pumps.
- **New financing models** could reduce the risk and high up-front CAPEX costs heat-pumps, e.g. heat supply contracts/ESCO models.

Threats

- **Deep renovation rates** in buildings are relatively low, hampering the uptake of more heat pumps.

7. Success factors

Industry and building applications

Selection of geography-appropriate HP technology

ASHPs are more suitable for mild climates; for colder climates, ground or water sourced heat pumps are needed for optimal performance.

Policies

Policies such as carbon pricing, removal of fossil fuel subsidies, considering heat pumps as renewable energy and valorising the provision of demand side flexibility all help the heat pump business case.

Financing models

Availability of financing models to reduce high up-front CAPEX costs, e.g. heat supply contracts and ESCO models.

Electricity vs fossil fuel price

The business case is strengthened when the price of electricity is relatively low compared to the fossil fuel alternative used in a boiler (typically natural gas).

Industry applications

Low-temperature heating demand

Commercial heat pump technologies can reach 160°C.

Utilization of waste heat

Capturing waste heat from other industrial processes as a heat source increases system efficiency.

New or extensive facility refurbishment

The business case for heat pumps is best for new facilities or when heat pump retrofit is part of an extensive facility upgrade program.

Building applications

Utilization of waste heat

Capturing waste heat from other parts of the building increases system efficiency.

Cooling and heating demand

Business case is strong, as a heat pump can meet both heating and cooling needs.

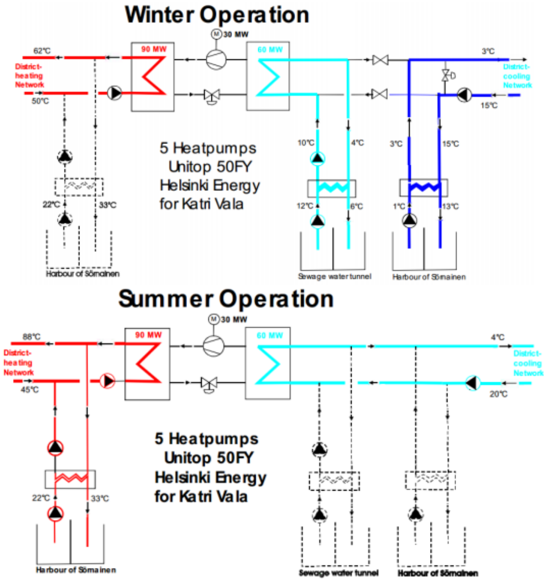
Highly energy efficient buildings

Near-zero energy, passive or positive energy buildings or buildings that have undergone deep renovation are most suitable for heat pumps.

8. Heat pumps: Case studies (1/3)

District heating and cooling system

Katri Vala District heating and cooling (Helsinki, Finland)	
Context	• Helsinki has a well-established district heating and cooling network, supplying 90% of the city's heat demand and an increasing share of cooling. It is mostly heated by gas-fired combined heat and power and cooled by absorption chillers.
Project description & objectives	• Operated by Helen Ltd • Heat pumps to provide district heating and cooling • Commissioned in 2006.
Main technical data	• 5 heat pumps with a total heating capacity of 100 MW and cooling capacity of 65 MW were integrated in 2006 • A 6th heat pump will be commissioned in 2021 with 18 MW heating and 12 MW cooling output, with total investment costs of about EUR €20 million • Heating supply temperature of 62°C/88°C in winter/summer, with waste heat (sewage and return water of district cooling network) as heat sources • Cooling supply temperature of 3°C/4°C in winter/summer, with sea water and district heat network as heat sinks • COP (heating): 3.51 in winter, 2.96 in summer.



Sources: Helen Ltd: Katri Vala Heating and Cooling Plant; Helen Ltd, 2018: New heat pump to be built again in Helsinki; UK DECC, 2016: Heat Pumps in District Heating. Case Studies.

8. Heat pumps: Case studies (2/3)

Industrial facility

Nutrex (Busswil b. Büren, Switzerland)	
Context	• For quality production of vinegar, two processes are used: fermentation and pasteurization. - Fermentation is an exothermic reaction, and to stabilize the temperature over 10 days at 30°C, the fermentation tanks need to be cooled. - Vinegar pasteurization takes place above 70°C.
Project description & objectives	• Nutrex is a food producer specialized on vinegar and part of the Swiss holding Coop • A heat pump was installed to meet both heating and cooling demands • Commissioned in 2009.
Main technical data	• Cooling capacity of 136 kW and a heating capacity of 194 kW • COP of 3.4 • Water is the heat source • Supply temperature > 70°C • In addition to pasteurization, the produced heat is used to for building heat and to heat the laboratory
Benefit	• The heat pump displaced conventional heating oil, resulting in annual savings of CO_2emissions by 310 tCO_2 and 65,000 liters of fuel.

Source: EHPA, 2017: *Large scale heat pumps in Europe. 16 examples of realized and successful projects*.

8. Heat pumps: Case studies (3/3)

Retail store

IKEA Vantaa (Helsinki, Finland)	
Context	• Store was constructed in 2003 • The store was connected to the district heating system (110°C hot water in winter, 80°C in summer)
Project description & objectives	• Closed loop ground source system • Installation date: March 2018 • 8 years payback period
Main technical data	• 32 boreholes, each 350 meters deep. Quality of soil (very wet/soft) caused some small additional costs. More support piping to wells was required, than had been expected. • Stainless steel connection piping between wells and circulation pumps. Ethanol based geothermal liquid • Three heat pumps (2 x 350 kW for heating and 1 x 40 kW for hot water) • Combination produces around 600 kw continuous heating capacity • System can be used for cooling with free cooling • System has also 2 x 300 kw electrical boilers as a backup (for possible system failures or very cold winter periods).

Sources: Personal Communication with IKEA; Mapio: *IKEA Vantaa*.

9. Summary

Emissions and energy	• Direct emissions from industry account for 24% of global CO_2 emissions, while space and water heating in the buildings sector is responsible for 6%. • 38% of world energy demand is for heat applications.
Solution	• Combined with low-carbon electricity supplies, heat pumps are a key lever in decarbonizing cooling and low-temperature heating. • Heat pumps use electric or thermal energy to extract heat from an external, often renewable source and deliver it to a heat sink. • There are three different types of heat pumps: air-source heat pumps (ASHP), ground-source heat pumps (GSHP) and water-source heat pumps (WSHP).
Avoided GHG emissions and co-benefits	• Heat pumps can substantially reduce emission reductions from heating compared to natural gas or oil boilers, particularly when the electricity generation mix is low-carbon. • Heat pumps can also be used to deliver co-benefits such as flexibility services to the grid via heat storage.
Readiness status	• Heat pumps are mature technologies. They are already widely used in cooling applications, but potential exists to expand the use of heat pumps in heating applications.
Barriers	• High upfront costs and long payback periods compared to conventional heating options. • Low building renovation rates.
Success factors	• New financing models that lower upfront investment costs. • Supportive policy environment. • Low electricity prices compared to fossil fuel energy sources.

10. Key sources and references on heat pumps

- David, A., Vad Mathiesen, B., Averfalk, H., Werner, S., Lund, H., 2017: Heat Roadmap Europe: Large-Scale Electric Heat Pumps in District Heating Systems
- Ecofys, 2014: Subsidies and costs of EU energy
- European Heat pump Association (EHPA)
- EHPA, 2010: Heat pump technology and application overview
- EHPA, 2017: Large scale heat pumps in Europe. 16 examples of realized and successful projects
- European Copper Institute, 2018: Heat Pumps. Integrating Technologies to Decarbonise Heating and Cooling
- Global Sustainable Electricity Partnership, 2018: New Electricity Frontiers. Harnessing the role of low-carbon electricity uses in a digital era
- Helen Ltd: Katri Vala Heating and Cooling Plant
- Helen Ltd, 2018: New heat pump to be built again in Helsinki
- IEA: Technology Collaboration Programme on Heat Pumping Technologies
- IEA, 2013: Transition to Sustainable Buildings. Strategies and Opportunities to 2050
- IEA, 2017: Energy Technology Perspectives 2017
- IEA, 2017: Renewable Energy for Industry – From green energy to green materials and fuels
- IEA and IRENA, 2017: Perspectives for the energy transition
- IEA-ETSAP & IRENA, 2013: Heat pumps
- IKEA: Personal Communication
- IPCC, 2006: Guidelines for National Greenhouse Gas Inventories
- IRENA Renewable Cost Database 2018
- IRENA, 2015: Solar Heat for Industrial Processes
- Mapio: IKEA Vantaa
- REN21, 2017: Renewables 2017: Global Status Report
- Taylor, M. (IRENA), 2018: A sustainable energy future: the role of heat pumps in a fossil-free system
- UK DECC, 2016: Heat Pumps in District Heating. Case Studies
- Viking Heat Engines
- YouGen: Heating and hot water – energy saving information

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