TECHNOLOGY DATA

Heating installations

Technology descriptions and projections for long-term energy system planning.

Danish Energy Agency

Technology Data for Heating Installations
ISBN 978-87-94447-09-6
First published 2016 by the Danish Energy Agency and Energinet,
Current version published by:
Danish Energy Agency
Carsten Niebuhrs Gade 43
1577 Copenhagen
E-mail: teknologikatalog@ens.dk,
Internet: https://ens.dk/technologydata
Design and production: Danish Energy Agency
Front cover photo: Adobe Stock
Version number: 0006

Amendment sheet

Publication date

Publication date for this catalogue "Technology Data for Individual Heating Plants and Energy Transport" is august 2016. A comprehensive review and update of the catalogue has been carried out during Q4 of 2020.

The newest version of the catalogue will always be available from the Danish Energy Agency's web site.

Amendments after publication date

All updates made after the publication date will be listed in the amendment sheet below.

Date	Ref.	Description
2025		Comprehensive update has been undertaken during Q2 and Q3 of 2025. Primary focus is on data sheets. The chapter texts have been edited for consistency and otherwise only updated to a minor degree. Cost and efficiency data updated especially for heat pumps, new chapter about electrical boilers added. Minor update to guideline.
12-04-2024	Guideline/cover	Updated guideline in terms of scenario projection reference, price year, and further minor updates / new cover
24-08-2022	207	Updated the chapter to more clearly convey the SCOP value
24-06-2021	208	Added new chapter on hybrid heat pumps
24-06-2021	207	Capacity of heat pumps have been revised to match heat capacity assessed at -7/55 °C
20-01-2021		Comprehensive update has been undertaken during Q4 of 2020. Primary focus is on data sheets, but text has been revised as well.

Preface

The *Danish Energy Agency* publishes a catalogue containing data on technologies for individual heating. The first edition of the catalogue was published in 2016. This current catalogue includes updates of several technologies. The catalogue will be updated continuously as technologies evolve, if data change significantly or if errors are found. All updates will be listed in the amendment sheet on the previous page and in connection with the relevant chapters, and it will always be possible to find the most recently updated version on the Danish Energy Agency's website, as well as an archive of older versions.

The primary objective of publishing technology catalogues is to establish a uniform, commonly accepted and up-to-date basis for energy planning activities, such as future outlooks, evaluations of security of supply and environmental impacts, climate change evaluations, as well as technical and economic analyses, e.g. on the framework conditions for the development and deployment of certain classes of technologies.

With this scope in mind, it is not the target of the technology data catalogue to provide an exhaustive collection of specifications on all available incarnations of energy technologies. Only selected, representative, technologies are included, to enable generic comparisons of technologies with similar functions.

Finally, the catalogue is meant for international as well as Danish audiences in an attempt to support and contribute to similar initiatives aimed at forming a public and concerted knowledge base for international analyses and negotiations.

Danish preface

Energistyrelsen udarbejder teknologibeskrivelser for en række teknologier til brug for individuel opvarmning. Første udgave af kataloget blev offentliggjort i 2016. Dette nuværende katalog indeholder opdateringer af en stor del af teknologibeskrivelserne. Kataloget vil blive opdateret løbende i takt med, at teknologierne udvikler sig, hvis data ændrer sig væsentligt eller hvis der findes fejl. Alle opdateringer vil blive registreret i rettelsesbladet først i kataloget, og det vil altid være muligt at finde den seneste opdaterede version på Energistyrelsens hjemmeside.

Hovedformålet med teknologikataloget er at sikre et ensartet, alment accepteret og aktuelt grundlag for planlægningsarbejde og vurderinger af forsyningssikkerhed, beredskab, miljø og markedsudvikling hos bl.a. de systemansvarlige selskaber, universiteterne, rådgivere og Energistyrelsen. Dette omfatter for eksempel fremskrivninger, scenarieanalyser og teknisk-økonomiske analyser.

Desuden er teknologikataloget et nyttigt redskab til at vurdere udviklingsmulighederne for energisektorens mange teknologier til brug for tilrettelæggelsen af støtteprogrammer for energiforskning og -udvikling. Tilsvarende afspejler kataloget resultaterne af den energirelaterede forskning og udvikling. Også behovet for planlægning og vurdering af klima-projekter har aktualiseret nødvendigheden af et opdateret databeredskab.

Endelig kan teknologikataloget anvendes i såvel nordisk som internationalt perspektiv. Det kan derudover bruges som led i en systematisk international vidensopbygning og -udveksling, ligesom kataloget kan benyttes som dansk udspil til teknologiske forudsætninger for internationale analyser og forhandlinger. Af disse grunde er kataloget udarbejdet på engelsk.

Med dette omfang i tankerne er det ikke målet for teknologidatakatalogerne at give en udtømmende samling af specifikationer for alle tilgængelige inkarnationer af energiteknologier. Kun udvalgte, repræsentative teknologier er inkluderet, for at muliggøre generiske sammenligninger af teknologier med lignende funktioner i energisystemet.

Table of contents

Guideline/Introduction

This catalogue presents technologies for heating installations used in buildings and households. Some technologies are presented for different sizes and/or for existing and new buildings. The section Definitions defines sizes and types of buildings and describes the specific assumptions.

The main purpose of the catalogue is to provide generalized data for analysis of energy systems, including economic scenario models and high-level energy planning.

These guidelines serve as an introduction to the presentations of the different technologies in the catalogue, and as instructions for the authors of the technology chapters. The following sections (Qualitative description and Quantitative description) explain the formats of the technology chapters, how data were obtained, and which assumptions they are based on. Each technology is subsequently described in a separate technology chapter, making up the main part of this catalogue. The technology chapters contain both a qualitative description of the technologies and a quantitative part including a table with the most important technology data. Quantitative data is published in separate Excel file for Data sheets.

All products are covered by the EU framework regulation for setting ecodesign requirements for sustainable products (Regulation (EU) 2024/1781) and by the EU framework regulation for energy labelling of energy-related products (Regulation (EU) 2017/1369)[11]. Under these frameworks, specific implementing regulations have been adopted for the performance requirements of various heating technologies. These regulations are essential resources for readers seeking detailed data on particular technologies.

Qualitative description

The qualitative description describes the key characteristics of the technology as concise as possible. The following paragraphs are included where relevant for the technology.

Contact information

Containing the following information:

- Contact information: Contact details in case the reader has clarifying questions to the technology chapters. This could be the Danish Energy Agency or the author of the technology chapters.
- Author: Entity/person responsible for preparing the technology chapters

Comments, criticisms or suggestions for changes can be sent to teknologikatalog@ens.dk.

Brief technology description

Brief description for non-engineers of how the technology works and for which purpose. An illustration of the technology is included, showing the main components and working principles. As a default any heating installation includes a hot water storage tank unless otherwise specified in the brief technology description. Hence, unless otherwise noted in this section, the data from the datasheet always includes a hot water storage tank.

Input

The main fuel and/or energy carriers, e.g. biomass or electricity, used by the technology.

Output

The forms of generated energy i.e. heat.

Typical capacities

The stated capacities are for a single unit or, in case of e.g. solar heating, for a typical system size. This section includes a description of the relevant product range(s) in capacity (kW).

Regulation ability

Description of how the unit can regulate, e.g. a gas boiler is very flexible whereas a solar heating system depends on the solar radiation.

Regulation abilities are particularly relevant for electricity generating and consuming technologies. This includes the part-load characteristics, start-up time and how quickly it is able to change its production or consumption when already online.

Advantages/disadvantages

A description of specific advantages and disadvantages relative to equivalent technologies. Generic advantages are ignored; e.g. renewable energy technologies mitigating climate risks and enhance security of supply.

Environment

Particular environmental characteristics are mentioned, for example special emissions or the main ecological footprints. The scope of this footprint ranges from production of materials and fuel to decommissioning of the installation.

Research and development perspectives

This section lists the most important challenges to further development of the technology in the context of this catalogue: Heating supply of buildings in Denmark. Also, the potential for technological development in terms of costs and efficiency is mentioned and quantified if possible. Danish research and development perspectives are highlighted, where relevant.

Examples of market standard technology

Recent commercially available units, which can be considered market standard, are mentioned, preferably with links. If possible, this list includes at least three examples from different suppliers. A description of what is meant by "market standard" is given in the introduction to the Quantitative description. For technologies where no market standard has yet been established, reference is made to best available technology in R&D projects.

Prediction of performance and costs

Cost reductions and improvements of performance can be expected for most technologies in the future. This section accounts for the assumptions underlying the cost and performance in the first technology year (base year) 2025 as well as the improvements assumed for the future years. The specific technology is identified and classified in one of four categories of technological maturity, indicating the commercial and technological progress, and the assumptions for the projections are described in detail.

In some cases, new technological developments might substantially change the function and/or efficiency of a technology, for example by a radically new design or by using a new material with better properties. This can happen to such a degree that it is more reasonable to talk about a technology jump, rather than a technological improvement or development. In this case, it is recommended to create a new data-sheet for the substantially changed technology, rather than simply updating the technology with the new values, in order to avoid confusion about radically different data sheets from one year to the next.

The following background information is considered:

Data for the base year 2025

In case of technologies where market standards have been established, performance and cost data of recent installed versions of the technology in Denmark or the most similar countries in relation to the specific technology in Northern Europe are used for the 2025 estimates.

If consistent data are not available, or if no suitable market standard has yet emerged for new technologies, the 2025 costs may be estimated using an engineering-based approach applying a decomposition of manufacturing and installation costs into engineering components, labour costs, financial costs, etc.

Assumptions for projecting cost into future years

According to the IEA [3]:

"*Innovation theory describes technological innovation through two approaches: the technology-push model, in which new technologies evolve and push themselves into the marketplace; and the market-pull model, in which a market opportunity leads to investment in R&D and, eventually, to an innovation*"

The level of "market-pull" is to a high degree dependent on the global climate and energy policies. Hence, in a future with strong climate policies, demand for e.g. renewable energy technologies will be higher, whereby innovation is expected to take place faster than in a situation with less ambitious policies. This is expected to lead to both more efficient technologies, as well as cost reductions due to economy of scale effects. Therefore, for technologies where large cost reductions are expected, it is important to account for assumptions about global future demand.

The **IEA's Announced Pledges Scenario (APS)** is used as a central estimate for projections in the Technology Catalogue, whenever possible. The IEA describes the Announced Pledges Scenario in their 2022 version as follows:

"The Announced Pledges Scenario introduced in 2021 aims to show to what extent the announced ambitions and targets, including the most recent ones, are on the path to deliver emissions reductions required to achieve net zero emissions by 2050. It includes all recent major national announcements as of September 2022 for 2030 targets and longer term net zero and other pledges, regardless of whether these have been anchored in implementing legislation or in updated NDCs. In the APS, countries fully implement their national targets to 2030 and 2050, and the outlook for exporters of fossil fuels and low emissions fuels like hydrogen is shaped by what full implementation means for global demand. […] Non-policy assumptions, including population and economic growth, are the same as in the STEPS."

According to the IEA, the less ambitious **Stated Policies Scenario (STEPS)** *"provides a more conservative benchmark for the future, because it does not take it for granted that governments will reach all announced goals. Instead, it takes a more granular, sector-by-sector look at what has actually been put in place to reach these and other energy-related objectives, taking account not just of existing policies and measures but also of those that are under development. The STEPS explores where the energy system might go without a major additional steer from policy makers."*

The STEPS Scenario may be used as an upper bound and to assess the expected development of technologies based on a frozen-policy approach. Previous versions of the Technology Catalogue before updating the guideline in April 2024 have used the outdated New Policies Scenario, relatively equivalent to the current STEPS, as a central framework for projections (and supplemented by other outdated scenarios of the IEA). This scenario corresponds to the frozen-policy approach that the Danish Energy Agency uses to project international fuel prices and CO_2-prices and technologies may be assessed in that regard when suitable.

Technologies updated before this cutoff date and which do not contain any explicit methodological description within the chapter regarding alternative supplementary scenarios have been updated based in this previous methodology.

As a more ambitious projection, the **Net Zero Emissions by 2050 Scenario (NZE)** may be used as a lower bound for the technology development. According to the IEA, the NZE *"is a normative IEA scenario that shows a pathway for the global energy sector to achieve net zero CO2 emissions by 2050, with advanced economies reaching net zero emissions in advance of others. This scenario also meets key energy-related United Nations Sustainable Development Goals (SDGs), in particular by achieving universal energy access by 2030 and major improvements in air quality. It is consistent with limiting the global temperature rise to 1.5 °C with no or limited temperature overshoot (with a 50% probability), in line with reductions assessed in the IPCC in its Sixth Assessment Report."*

By using this approach, the quantitative data in the Technology Catalogue provides a sample space that is consistent with the IEA's Global Energy and Climate Model, encompassing relevant outcomes for policy assessments of technologies as well as technology developments in compliance with national targets, and international treaties.

1) ***Learning curves and technological maturity***

Predicting the future costs of technologies may be done by applying an engineering-based approach, as mentioned above, decomposing the costs of the technology into categories such as labour, materials, etc. for which predictions already exist. Alternatively, the development could be predicted using learning curves. Learning curves express the concept that each time a unit of a particular technology is produced, learning accumulates, which leads to cheaper production of the next unit of that technology. The learning rates also consider benefits from economy of scale and benefits related to using automated production processes at high production volumes.

The potential for improving technologies is linked to the level of technological maturity. The technologies are categorized within one of the following four levels of technological maturity in Denmark. As an example, fuel cell mCHP is in widespread use in Japan, but is only installed in limited no. in Europe. Hence, in a Danish context, mCHP is considered a technology in the pioneer phase.

Category 1. Technologies that are still in the *research and development phase*. The uncertainty related to price and performance today and in the future, is highly significant.

Category 2. Technologies in the *pioneer phase*. The technology has been proven to work through demonstration facilities or semi-commercial plants. Due to the limited application, the price and performance is still associated with high uncertainty since development and customization is still needed. The technology still has a significant development potential.

Category 3. *Commercial technologies with moderate deployment*. The price and performance of the technology today is well known. These technologies are deemed to have a certain development potential and therefore there is a considerable level of uncertainty related to future price and performance (e.g. solar heating or electric heat pumps)

Category 4. *Commercial technologies, with large deployment*. The price and performance of the technology today is well known, and normally only incremental improvements would be expected. Therefore, the future price and performance may also be projected with a relatively high level of certainty. (e.g. gas boilers & district heating units)

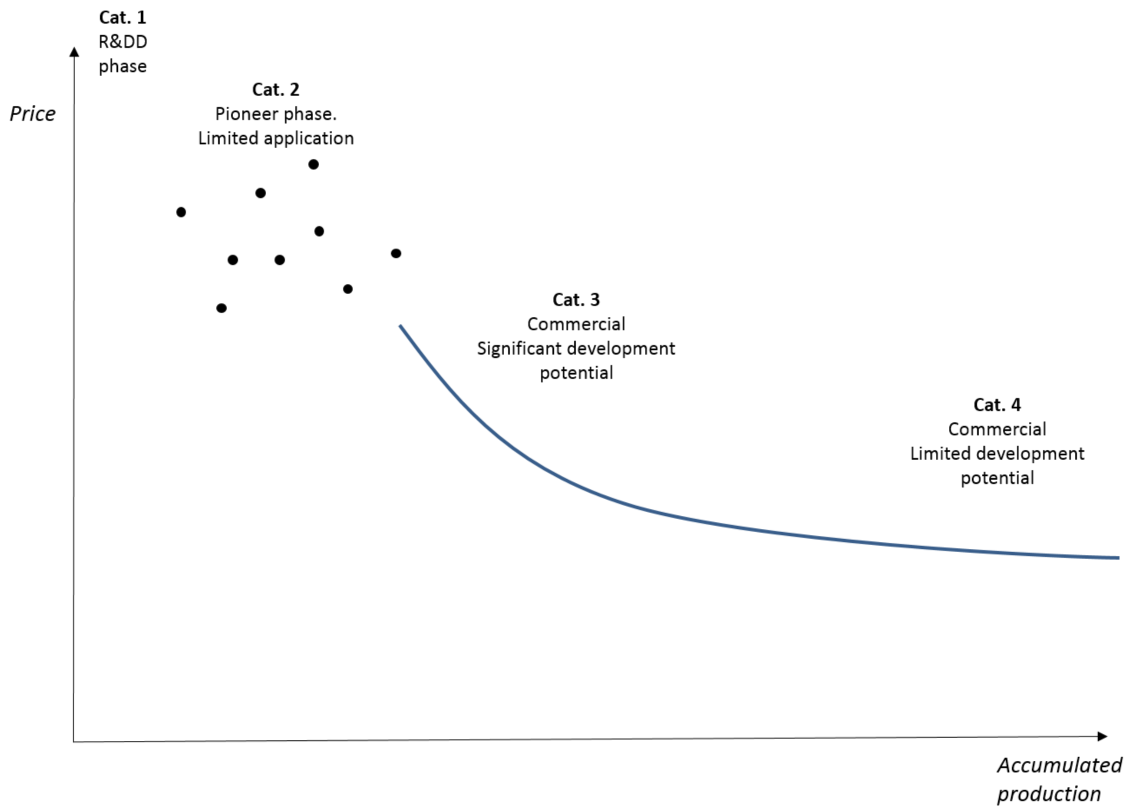

Figure 1 Technological development phases. Correlation between accumulated production volume (MW) and price.

Uncertainty

This catalogue covers both mature technologies and technologies under development. This implies that the price and performance of some technologies may be estimated with a relatively high level of certainty whereas in the case of others, both cost and performance today as well as in the future are associated with high levels of uncertainty.

This section of the technology chapters explains the main challenges to precision of the data and identifies the areas on which the uncertainty ranges in the quantitative description are based. This includes technological or market related issues of the specific technology as well as the level of experience and knowledge in the sector and possible limitations on raw materials. The issues should also relate to the technological development maturity as discussed above.

The level of uncertainty is illustrated by providing a lower and higher bound beside the central estimate, which shall be interpreted as representing probabilities corresponding to a 90% confidence interval. It should be noted that projecting costs of technologies far into the future is a task associated with very large uncertainties. Thus, depending on the technological maturity expressed and the period considered, the confidence interval may be very large. It is the case, for example, of less developed technologies (category 1 and 2) and long-time horizons (2050).

Economy of scale effects

The per unit cost of larger units is usually less than that of smaller plants. Similarly, there is a per unit cost reduction due to mass production. This is called the ‘economy of scale’. This section assesses the economy of scale effect for the specific technology, preferably by means of examples.

Additional remarks

This section includes other information, for example links to websites that describe the technology further or give key figures on it.

References

References are numbered in the text in squared brackets and bibliographical details are listed in this section. It is important that sources used are referenced in a way that they can be found by the reader, i.e. that both the full title of the report, together with author and year where applicable, and a direct link are provided. Reference numeration between references used in the qualitative and the quantitative descriptions must be consistent.

Quantitative description

To enable comparative analyses between different technologies it is imperative that data are comparable: All cost data are stated in real 2025 prices excluding value added taxes (VAT) and other taxes. The information given in the tables relate to the development status of the technology at the point of final investment decision (FID) in the given year (2025, 2030, 2035, 2040 and 2050, where applicable). FID is assumed to be taken when financing of a project is secured, and all permits are at hand. The year of commissioning will depend on the construction time of the individual technologies.

A typical table of quantitative data is shown below, containing all parameters used to describe the specific technologies. The datasheet consists of a generic part, which is identical for all technologies and a technology specific part, containing information, which is not relevant for all technologies. The generic part is made to allow for easy comparison of technologies.

Each cell in the table contains only one number, which is the central estimate for the market standard technology, i.e. no range indications.

Uncertainties related to the figures are stated in the columns named *uncertainty*. To keep the table simple, the level of uncertainty is only specified for years 2025 and 2050.

The level of uncertainty is illustrated by providing a lower and higher bound. These are chosen to reflect the uncertainties of the best projections by the authors. The section on uncertainty in the qualitative description for each technology indicates the main issues influencing the uncertainty related to the specific technology. For technologies in the early stages of technological development or technologies especially prone to variations of cost and performance data, the bounds expressing the confidence interval could result in large intervals. The uncertainty only applies to the market standard technology; in other words, the uncertainty interval does not represent the product range (for example a product with lower efficiency at a lower price or vice versa). The level of uncertainty is stated for the most critical figures such as investment cost and efficiencies. Other figures are considered if relevant.

All data in the tables are referenced by a number in the utmost right column (Ref), referring to source specifics below the table. The following separators are used:

; (semicolon)	separation between the time horizons (2025, 2030, etc.)
/ (forward slash)	separation between sources with different data
+ (plus)	agreement between sources on same data

Notes include additional information on how the data are obtained, as well as assumptions and potential calculations behind the figures presented. Before using the data, please be aware that essential information may be found in the notes below the table.

Energy/technical data

The generic parts of the datasheets for individual heating technologies are presented below:

Heat production capacity for one unit

The heat production capacities, preferably typical capacities (not maximum capacities), are stated for a single unit or, in case of e.g. solar heating, for a typical system size.

Any auxiliary electricity consumption for pumps etc. is not counted in the capacity.

The unit kW is to determine heat production capacity.

The relevant range of sizes of each type of technology is represented by a range of capacities stated in the notes for the "capacity" field in each technology table.

Energy efficiencies

Efficiencies for all heating plants are expressed in decimal per unit (p.u.). at lower calorific heat value (lower heating value) at ambient conditions in Denmark, considering an average air temperature of approximately 8 °C. Efficiencies are calculated under the assumption of a correct installation. For some technologies this matters less, whereas for other technologies, such as heat pumps, the quality of the installation can have a substantial effect on the efficiency and should be discussed where relevant.

The evaluations of the energy efficiencies of the technologies described in the Technology Catalogue, may inspire from the methodologies from the energy-related products directives developed by the EU Commission.

The loss from the hot water storage tank is included in the calculation of the efficiency under the assumption that 50% of heat loss is recuperated. The impact on the total efficiency therefore depends on the size of the storage tank. Some heating installations do not necessarily use a storage tank, when this is the case, this is explicitly specified in the notes.

The heat efficiency equals the net delivery of heat divided by the fuel consumption. The auxiliary electricity consumption is not included in the heat efficiency but stated separately in kWh/year.

For heat pumps, heat efficiency (annual average) is represented by the SPF (Seasonal Performance Factor). SPF (Seasonal Performance Factor) measures the real-life, annual efficiency of a heat pump, typically about 10% lower than the SCOP (Seasonal Coefficient of Performance), which is based on standardized laboratory tests. SCOP for average climate zone is relevant for use in Denmark. SCOP values are listed in product data sheets for the specific model.

The energy supplied by the heat source for heat pumps is not counted as input energy.
If nothing else is stated in the technology description, the heat efficiency reflects the total heat efficiency covering both space heating and hot tap water.

The efficiencies reflect annual average efficiencies as experienced by the consumer, assuming that the heat installations are installed correctly. The boundary of annual efficiency is shown in the figure below.

Often, the efficiencies decrease slightly during the operating life of a plant. This degradation is not reflected in the stated data, and users will have to make such corrections themselves, based on their assumptions about the rate of deterioration of the technology. As a rule of thumb 2.5 – 3.5 %-points may be subtracted during the lifetime (e.g. from 90 % to 87 %).

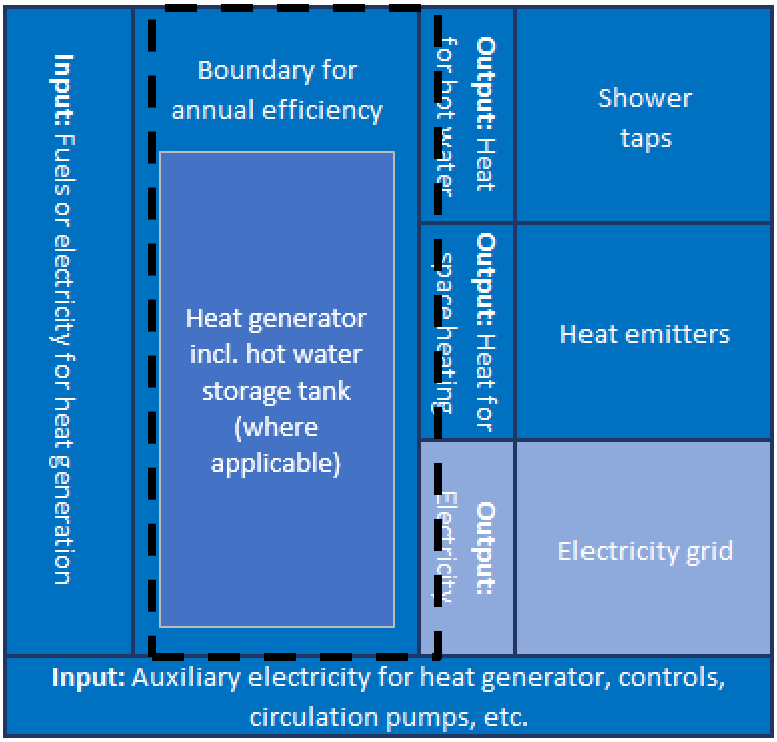

Figure 2 The dotted line shows the boundary for annual efficiency

Expected share of demand covered by unit

The expected share of total demand, both for space heating and for hot tap water, covered by the technology is specified in decimal (p.u).

Auxiliary electricity consumption

A specification of the annual auxiliary electricity demand for the heat installation is given in kWh/year. It accounts for the consumption of electricity from auxiliary systems such as circulation pumps, other pumps, ventilation systems, controls etc. For heat pumps, internal consumption (inside the unit) is considered part of the efficiency (seasonal coefficient of performance, SCOP), while other electricity demand for external pumping is stated under auxiliary electricity consumption. The auxiliary electricity consumption is not included in the efficiencies, as it is possible to see from the boundaries in Figure 2.

Lifetime

The lifetime is defined as the technical-economic lifetime [5], which refers to the expected time for which an energy plant can be operated within, or acceptably close to, its original performance specifications, provided that normal operation and maintenance takes place. As such, the technical-economic lifetime of the technology is found by comparing the on-going costs of repairing and maintaining against the expected costs of re-investing in a similar technology. This should not be mistaken with economic lifetime, which instead evaluates the alternative cost of competing technologies.

During this lifetime, some performance parameters may degrade gradually but still stay within acceptable limits. For instance, efficiencies often decrease slightly (few percent) over the years, and O&M costs increase due to wear and degradation of components and systems.

Towards the end of the technical-economic lifetime, the frequency of unforeseen operational problems and risk of breakdowns is expected to lead to unacceptably low availability and/or high O&M costs. At this time, the installation is decommissioned or undergoes a lifetime extension, which implies a major renovation of components and systems as required to make the installation suitable for a new period of continued operation. The technical-economic lifetime stated in this catalogue is, therefore, a value inherent to each technology and based on experience. If possible, the lifetime is based on statistics/studies done on appliances lifetime. The expected technical-economic lifetime takes into account a typical number of start-ups and shut-downs.

In practice, specific plants of similar technology may operate for shorter or longer times. The strategy for operation and maintenance, e.g. the number of operation hours, start-ups, and the reinvestments made over the years, will have a large influence on the actual lifetime.

Electric regulation ability

This section is only relevant for power consuming technologies. Three parameters describe the electricity regulation capability of the technologies:

A. Primary regulation (% per 30 seconds): frequency control
B. Tertiary regulation (% per minute): balancing power
C. Minimum load (percent of full load).

For several technologies, these parameters are not relevant, e.g. if the technology is regulated solely in on/off-mode.

Parameters A and B are the ability to regulate when the technology is already in operation.

Environment

All plants are assumed to be designed to comply with the regulation that is currently in place in Denmark and planned to be implemented within the 2030 time-horizon.

The emissions below are stated in mass per GJ of fuel at the lower heating value.

CO_2 emission values *are not stated*, as these depend only on the fuel, not the technology.

SO_2 emissions, assuming that all sulphur is converted into SO_2.

NO_x emissions NO_x equals NO_2 + NO, where NO is converted to NO_2 weight-equivalents.

Particles includes the fine particle matters (PM 2.5).

The emissions of CH_4 and N_2O can be converted to CO_2-equivalents by multiplying the CH_4 emission by 25 and the N_2O emission by 298.

Financial data

Financial data are all in Euro (€), fixed prices, at the 2025-level and exclude value added taxes (VAT) and other taxes. Several data originate in Danish references. For those data, a fixed exchange ratio of 7.46 DKK per € has been used.

Investment costs

The investment cost is also called the engineering, procurement, and construction (EPC) price or the overnight cost. Infrastructure and connection costs, i.e. electricity, fuel, and water connections inside the household/building, are also included. The investment cost includes the total costs of establishing the technology for the consumer. Where possible, the investment cost is divided on equipment cost and installation cost. Equipment cost covers the heat generation facility and other major components like water tank and environmental facilities if relevant, whereas installation cost covers counselling on unit design by the installer, grid connection, fittings and commissioning of equipment. The catalogue's investment costs are based on expected average national costs of the technology. However, there may be significant variations in investment and installation costs depending on the location in Denmark. If this is the case, the consultant should specify the impact on the cost in a note to the financial data.

Technologies and scope of investment

The catalogue is intended to work as a tool for energy planners including municipalities in their assessment, comparison, and identification of future energy solutions for heat production in households etc. Hence, it is important to stress that the specific technical and economic data for each technology presented in the catalogue are not in all cases directly comparable, as data/figures cover different aspects of the energy supply of a building and the needed investment costs, respectively.

Table 1 includes the technologies, the scope of the technology definition used within the catalogue and direct and accompanying investment costs. The aim is to outline the different elements that have to be taken into consideration when using the catalogue data for a fair comparison of technologies. The elements included in the technology data sheets are presented in the fourth column, 'Installation of primary heat production technology'. In the case of existing buildings, the premise for an installation is that there is already a worn-out heating installation in place. The cost of dismantling of the existing heat installation is included for most of the technologies since this is typically part of the installation costs. Additional installation costs covering expenses listed in column 1 – 3 and 5 in table 1 are not included in the data sheets. These accompanying costs are instead listed in table 2 and should be considered when relevant. No cost projections have been made for the cost of accompanying investments. As a rule of thumb for mature technologies, it can be assumed that cost expressed in real terms will decrease by approx. 0.5 per cent per annum due to general improvements in productivity. O&M costs related to service pipes and meters for district heating units and gas boilers are not covered by this catalogue, since these costs are assumed to be covered by the distribution tariff.

Possible additional investment cost

Where relevant, a line with possible additional specific investment is included in the data sheet. An example of this is fluid-to-water heat pumps in city areas where it is necessary to establish vertical tubes (by use of drilling holes) instead of horizontal tubes.

	Abolition/removal of prior heat production system/unit	Improvements of building envelope	Accompanying heat supply installations	Installation of primary heat production technology – **elements included in the technology data sheets**	Installation of secondary heat production technology
Oil boiler	Often necessary in existing buildings • removal of oil tank, etc.	Existing buildings: not directly needed but in many cases recommendable	• Water based supply system • Oil tank • Chimney/flue	Investment/installation cost of boiler incl. pumps, hot tap water production and hot water tank. Dismantling of existing heat installation.	
Gas boiler	Often necessary in existing buildings • removal of oil tank etc.	Existing buildings: not directly needed but in many cases recommendable	• Water based supply system • Service pipe	Investment/installation cost of boiler incl. pumps, hot tap water production, hot water tank. Dismantling of existing heat installation.	
District heating unit	Often necessary in existing buildings • removal of oil tank, etc.	Existing buildings: not directly needed but in many cases recommendable	• Water based supply system • Branch pipe	Investment/installation cost of DH unit incl. pumps, hot tap water production, hot water tank. Dismantling of existing heat installation.	
Biomass boiler	Often necessary in existing buildings • removal of oil tank, etc.	Existing buildings: not directly needed but in many cases recommendable	• Water based supply system • Fuel storage facility • Chimney/flue	Investment/installation cost of boiler incl. pumps, hot tap water production and hot water tank. Dismantling of existing heat installation.	
Wood stove			• Fuel storage facility • Chimney/flue	Investment/installation cost of stove (and water tank). Dismantling of existing stove.	• Supplementary heat supply system • Water heater and possibly storage
Electric heat pumps – air/fluid to water	Often necessary in existing buildings • removal of oil tank, etc.	Existing buildings: energy saving measures often needed in order to optimise heat pump installation	• Water based supply system Existing buildings: measures to reduce radiator temperatures often needed	Investment/installation cost of heat pump incl. pipes, pumps, back-up electric heater, hot tap water production and hot water tank. Dismantling of existing heat installation.	
Heat pumps – air to air/ventilation	Often necessary in existing buildings (ventilation heat pump only) • dismantling of existing boiler, • removal of oil tank, etc.	Existing buildings: energy saving measures often needed in order to optimise heat pump installation	• Existing buildings: measures to reduce radiator temperatures often needed (ventilation heat pump only)	Investment/installation cost of heat pump incl. hot water storage tank.	• Back-up heat e.g. electrical radiators • Hot tap water supply needed
Electric boiler		Existing buildings: not directly needed but in many cases recommendable	• Extra power capacity could be necessary especially for apartment buildings	Investment/installation cost of boiler incl. pumps, hot tap water production and hot water tank. Dismantling of existing heat installation.	
Solar heating		In some cases, improvement of roof construction		Investment/installation cost of panel incl. pipes, pumps and hot tap water tank	• Supplementary heat supply system and water heater and possibly storage
Direct electrical heating		Existing buildings: not directly needed but in many cases recommendable		Investment/installation cost of electrical radiators, hot tap water production and hot water tank	

Table 1 Overview of investment costs included in technology data sheets and possible accompanying investment costs

Table 2 shows some of the general costs of needed accompanying investment (presented in the first three columns in table 2), which potentially could be added when comparing the different technology solutions.

Accompanying element		Costs (EUR2025)
Dismantling of existing boiler	Single-family houses:	
(Note: this is part of installation costs for most technologies, see Table 1)	Wall hung natural gas fired boiler: 2,400 DKK ex. VAT	320 EUR
	Floor standing oil-fired boiler: 3,700 DKK ex. VAT	490 EUR
Dismantling of existing stove	Single-family houses:	
(Note: this is part of installation costs for wood stoves, see Table 1)	Old stove : 1,000 DKK ex. VAT	320 EUR
Removal of oil tank	Single-family houses:	
	1,200 litre tank (standing tank) including removal of old oil: 4,800 DKK ex. VAT	640 EUR
	Underground tank, removal of old oil, sealing of connections (no removal): 4,800 DKK ex. VAT	640 EUR
Building envelope improvements	Costs depend on the building standard etc. More information and tools to estimate costs can be found at e.g. http://www.byggeriogenergi.dk (The Danish Centre for Energy Savings in Buildings).	
Water based heat supply system in building	Existing single-family house (150 m^2):	
	Radiator system: 61,100 DKK ex. VAT	8,100 EUR
	New single-family house (180 m^2):	
	Radiator system: 54,300 DKK ex. VAT	7,280 EUR
	Floor heating (in concrete slap): 42,300DKK ex. VAT	5,670 EUR
	Floor heating (with diffusion plates): 54,300 DKK ex. VAT	7,280 EUR
	All prices include manifolds, piping, insulation, heat emitters/surfaces, thermostats and man hours.	
Additional radiator surface	2.5 DKK ex. VAT pr. Watt (standard radiators, 300-1,000 Watt)	
	Radiators installed including thermostats:	
	Existing single-family house (150 m^2): 6,100 DKK ex. VAT	810 EUR
	New single-family house (180 m^2): 5,800 DKK ex. VAT	770 EUR
Oil tank	1,200 litre standing tank including installations: 9,700 DKK ex. VAT	1,300 EUR
Flue	Single-family houses:	
	5 meter stainless steel flue including fittings: 8,500 DKK ex. VAT	1,130 EUR
	5 meter vertical flue, balanced coaxial split installed in existing chimney: 4,800 DKK ex. VAT	640 EUR

Table 2 Cost of accompanying investments

Operation and maintenance (O&M) costs

The fixed share of O&M (€/unit/year) includes all costs, which are independent of how the heating installation is operated, e.g. service agreements, chimney sweeping, spare parts and possibly insurance.

Any necessary reinvestments to keep the technology operating within the lifetime are also included, whereas reinvestments to extend the life beyond the lifetime are excluded. Reinvestments are discounted at 4 % annual discount rate in real terms. The cost of reinvestments to extend the lifetime of the technologies may be mentioned in a note if the data has been readily available.

Variable O&M costs (€/MWh) are seldom relevant for heating installations but include consumption of auxiliary materials (water, lubricants, fuel additives), treatment and disposal of residuals, spare parts and output related repair and maintenance (however not costs covered by guarantees and service contracts).

Planned and unplanned maintenance costs may fall under fixed costs (e.g., scheduled yearly maintenance works) or variable costs (e.g. works depending on actual operating time) and are split accordingly.

Fuel costs (including transportation costs and tariffs) are not included.

Auxiliary electricity consumption is included. The electricity price applied is specified in the notes for each technology, together with the share of O&M costs due to auxiliary consumption. This enables corrections from the users with own electricity price figures. The cost of auxiliary electricity consumption is calculated using the following electricity prices in €/MWh:, 2025: 85, 2030: 101, 2035: 105 2040: 109, 2050: 117. These prices include production costs and transport tariffs, but not any taxes or subsidies for renewable energy.

It should be noticed that O&M costs often develop over time. The stated O&M costs are therefore average costs during the entire lifetime.

Primarily relevant for stoking of biomass boilers, an estimation is given of how many hours of work is spent a year on maintaining and operating the installation for a household with a given heating installation.

Statistical data on O&M costs for heat technologies are often not available. Maintenance contracts proposed by leading installers and companies may in these cases provide a good source for estimating the O&M costs.

Business cycles

Historic energy technology costs often fluctuate with business cycles. This was seen in 2007–2008 and again in 2021–2022, when global raw material prices and supply chain disruptions exacerbated by the COVID-19 pandemic and energy crisis led to sharp cost increases for many energy generation technologies. While markets began stabilizing in 2023–2024, continued demand for clean energy technologies and geopolitical tensions have kept some costs volatile. The catalogues do not attempt to reflect fluctuations in technology costs due to fluctuations in costs of labour and materials driven by e.g. global/regional crises or major events affecting short term supply or demand. The technology cost developments in the catalogues thus intend to reflect an average business cycle situation and macroeconomic environment in a general long-term equilibrium.

Contingency

Project owners often add a contingency to a project's capital cost estimate to deal with project overruns due to uncertainties and risks caused by uncertainties in the project definition. The Association for the Advancement of Cost Engineering International *(*AACE International) has defined contingency as "An amount added to an estimate to allow for items, conditions, or events for which the state, occurrence, or effect is uncertain and that experience shows will likely result, in aggregate, in additional costs. Typically estimated using statistical analysis or judgment based on past asset or project experience.". AACE International further describes contingency as "…planning and estimating errors and omissions…..design developments and changes within the scope, and variations in market and environmental conditions"*. The Technology Catalogues represent general techno-economic data for different technologies; and are not intended as basis for investment decisions. Therefore, the data in the Technology Catalogues aim at not including contingency.

**Source: AACE (2022) Cost engineering terminology (https://library.aacei.org/terminology/welcome.shtml).*

Technology specific data

Additional data is specified in this section, depending on the technology.

Definitions

Building types and heat demand

Some of the heating technologies are described for different unit sizes and/or for existing and new buildings, respectively. This is shown in the table below. It should be noticed that some technologies, for example wood stoves, air to air electric heat pump and solar heating, do not offer a full heating solution providing both space heating and domestic hot water.

	Existing buildings		New buildings	
	Single-family houses	Apartment complex	Single-family houses	Apartment complex
Oil boiler (including bio oil)	X	X	X (bio oil)	X (bio oil)
Gas boiler	X	X	X	X
District heating substation	X	X	X	X
Biomass boiler, automatic stoking	X	X	X	X
Biomass boiler, manual stoking	X		X	
Wood stove	X		X	
Electric heat pump, air to air	X		X	
Electric heat pump, air to water	X	X	X	X
Electric heat pump, brine to water	X	X	X	X
Electric ventilation heat pump			X	X
Hybrid heat pump	X	X	X	X
Electric boiler	X	X	X	X
Solar heating system	X	X	X	X
Electric heating			X	X

Table 3 Technology descriptions - relevant combinations technology and building

The catalogue considers existing and new single-family houses and apartment complexes. The size of buildings, the annual net heating demand and the peak-load demand is shown in the table below.

Since year 2025 is the base for the present status of the technologies, new buildings are supposed to comply with the current Danish building code, BR2018. Often the actual figures are higher as in the normative calculations. Hence, the peak load and energy demand of new buildings have been adjusted to reflect actual rather than theoretical use. The annual heating demand for new single-family houses is estimated at 65 kWh/m^2 and the annual heating demand for new apartment complexes is estimated at 55 kWh/m^2 based on information from SBi[1] [9] and [12]. However, in July 2025, an updated building code BR25 came into force; the update is not expected to have a significant impact on heating demand, therefore, the specific consumption of the new single-family house is not updated in the 2025 revision.

[1] This assessment is based on SBi 2016, "FORSKELLEN MELLEM MÅLT OG BEREGNET ENERGIFORBRUG TIL OPVARMNING AF PARCELHUSE" and dialog with SBi staff.

A new single-family house is defined to have an annual heat demand of 11.7 MWh inclusive of domestic hot water and a peak demand of 4.1 kW exclusive of domestic hot water. The peak load for domestic hot water in an individual house depends on whether the hot water is produced instantaneously or if it is stored in a hot water storage tank. This is a design issue, and the preferred solution will depend on the characteristics of the specific heat supply technology, including its capital costs per kW of heat capacity. Instantaneous production of water for a single-family house involves a max load of approx. 25-35 kW. If a storage tank is used, the max load is 2-7 kW dependent on the size and heating capacity of the tank[2].

Since 1980 there has been a gradual reduction of the net heating demand of buildings as a response to the strengthening of building codes, therefore the demand of the existing single-family house is updated in the 2025 revision. Today (2025), an average existing single-family house is defined to have an annual heat demand of 13.4 MWh inclusive of domestic hot water and a peak demand of 6.0 kW, exclusive of domestic hot water[3].

An existing apartment complex is defined to have an annual net heat demand of 780 MWh and a peak demand of 320 kW for room heating. The peak demand for domestic hot water is 70 – 115 kW for storage tank system inclusive of 15 kW pipe losses and 230 kW for instantaneous heating of domestic hot water by a heat exchanger without storage[4].

A new apartment complex is defined to have an annual net heat demand of 440 MWh and a peak demand of 160 kW for room heating. The peak demand for domestic hot water is 60 – 105 kW for storage tank system inclusive of 5 kW pipe losses and 220 kW for instantaneous heating of domestic hot water by a heat exchanger without storage.

Net heating demand in this section is based on the average Danish weather for the period 2017-23 with in average 2931 Degree Days per year[5].

New single-family houses are expected to have an average size of 180 m^2, whereas the average size of existing single-family houses is around 125 m^2. The figures include both detached and terraced houses. An apartment complex is assumed to house 100 apartments.

[2] DS 439, Norm for vandinstallationer
[3] Data from SBi 2016:15 and SBi 2017:16 and Analyse:
"Opdatering af repræsentativt varmeforbrug Tabel 5. Forbrug af energi til opvarmning i enfamilieshuse, særskilt for opvarmningsform, median (MWh pr. år)", 8 May 2025, Danish Energy Agency.
[4] SBi/BUILD based on data from HOFOR and FSB, DS439 og Videncenter for energibesparelse i bygninger, Energiløsning: Udskiftning af varmtvandsbeholder
[5] The estimate is based on the DMI's standard calculation method

	Existing buildings		New buildings BR18	
	Single-family house	Apartment complex	Single-family house	Apartment complex
Size	125 m^2	8,000 m^2	180 m^2	8,000 m^2
Peak load for space heat	6.0 kW	320 kW	4.1 kW	160 kW
Additional capacity for hot tap water	4.0 kW	90 kW	4.0 kW	80 kW
Annual heat demand incl. hot tap water	13.4 MWh	780 MWh	11.7 MWh	440 MWh
- hereof hot tap water	3.0 MWh	265 MWh	2.7 MWh	190 MWh

Table 4 Annual net heating demand and capacity in peak load

The net heat demand for heating of domestic hot water to needed temperature is approximately 900 kWh/ann. per person in a household. To this, pipe losses must be added. Hot water consumption is calculated from the number of people in a household and the type of residence they live in. Table 5 below presents the average number of inhabitants in single-family households and apartments respectively based on 2025 numbers.

Type of residence	Single-family houses	Apartments
Avg. number of inhabitants	2.5	1.7

Table 5 Average no. of inhabitants in residences, source: "*Statistikbanken*" table BOL106, Danmarks Statistik 2025,

Inclusive of pipe losses the annual net heating demand for domestic hot water is typically 15 kWh/m^2 in new single-family houses and 24 kWh/m^2 in new apartment complexes. In existing single-family houses, the annual net heating demand for domestic hot water inclusive of pipe losses is typically 24 kWh/m^2. In existing apartment complexes with domestic hot water circulation, the annual net heating demand for DHW inclusive of pipe loses is typically 33 kWh/m^2.

In the case of specific projects, the annual net heating demand and peak demand should be estimated more precisely, depending on the specific types of buildings and sizes.

In case a project is in need of technical and financial data for an installation with an installed capacity different from the standard sizes listed in table 4, an estimate can be found by interpolating technical data, while financial data can be found by interpolating the equipment costs and O&M costs. Installation cost are assumed to remain unchanged. As an example, data on the replacement of a 100 kW gas boiler in an existing apartment complex can be found by interpolating data between the 7.5 kW (existing single-family house) and the 160 kW boiler (new apartment complex), while using the installation (but not equipment) costs of the 320 kW (existing apartment complex).

Requirements for Space Heaters and Domestic Water Heaters and Combinations

The efficiency, noise level, and emissions of space heaters are regulated by several ecodesign regulations, which can be found in the "Product List" for ecodesign and energy labelling regulations. These regulations set minimum efficiency requirements and maximum limits for noise and emissions.

For example, for fuel fired boilers (except biomass boilers) with a rated heat output ≤ 70 kW, the seasonal space heating energy efficiency (based on GCV, gross calorific value) must not be below 86%.

For boilers with a rated heat output between 70 kW and 400 kW, the requirements are that efficiency (based on GCV, gross calorific value) must be higher than 86% at 100% load and higher than 94% at 30% partial load.

The ecodesign requirements specify that the rated heat output must not fall below 36% for electrical boilers, 110% for heat pumps (except low-temperature heat pumps and air-to-air heat pumps), and 125% for low-temperature heat pumps.

The efficiency requirements are related to primary energy. Therefore, when calculating the seasonal space heating energy efficiency for electrical heaters, the electricity consumption must be multiplied by a conversion coefficient (CC) of 2.5. This means that to comply with the ecodesign regulation, the electricity-to-heat efficiency must not be lower than 90% for electrical boilers, 275% for heat pumps (except low-temperature heat pumps and air-to-air heat pumps), and 313% for low-temperature heat pumps.

References

Numerous reference documents are mentioned in each of the technology sheets. Other references used in the Guideline are mentioned below:

1. Danish Energy Agency:"Forudsætninger for samfundsøkonomiske analyser på energiområdet" (Generic data to be used for socio-economic analyses in the energy sector), November 2019.
2. "Konvergensprogram Danmark 2015". Social- og Indenrigsministeriet. March 2015.
3. "Energy Technology Perspectives", International Energy Agency, 2012.
4. International Energy Agency. https://www.iea.org/commentaries/understanding-the-world-energy-outlook-scenarios. Accessed: 20/10/20202.
5. Construction Reliability, Safety, Variability and Sustainability, Edited by J. Baroth, F. Schoefs, D. Breysse, iSTE & WILEY, 2011, ISBN: 978-1-84821-230-5
6. SBi 2016:15. SMART ENERGI I HJEMMET EVALUERING AF FORSØG MED INTELLIGENT TEMPERATURREGULERING I ENFAMILIEHUSE
7. SBi 2017:16. VARMEBESPARELSE I EKSISTERENDE BYGNINGER
8. Videncenter for energibesparelse i bygninger, Energiløsning: Udskiftning af varmtvandsbeholder
9. SBi 2016, "FORSKELLEN MELLEM MÅLT OG BEREGNET ENERGIFORBRUG TIL OPVARMNING AF PARCELHUSE
10. DS 439, Norm for vandinstallationer
11. Product list Energy labelling and ecodesign requirements for heating appliances, European Commission, Product List - European Commission
12. SBI, 2020, conversation

201 Oil boiler (including bio oil)

Contact information

Danish Energy Agency: Emil de Bekker Steffensen, teknologikatalog@ens.dk
Author: Original chapter from 2016 made by COWI.
Update in 2021 and 2025 by Ea Energy Analyses.

Publication date

2016

Amendments after publication date

Date	Ref.	Description
01-10-2025		Minor update has been undertaken during Q3 of 2025. Primary focus is on data sheets, and text has been revised accordantly.
20-01-2021		Comprehensive update has been undertaken during Q4 of 2020. Primary focus is on data sheets, but text has been revised as well.

Qualitative description

Brief technology description

Oil-fired boilers are made for hot water and steam production. In the following, only hot water boilers are considered. The boilers are made in a power range from 15 kW to several MW. The oil qualities considered are:

1. Domestic mineral fuel oil.
2. Domestic oil with added bio-oil up to 10 % (fatty acid methyl ester, FAME).
3. Raw bio-oil, e.g. rapeseed oil.
4. Hydro treated vegetable oil (HVO), [10].
5. Rapeseed oil Methyl Esther (RME)

The complete oil-fired system includes a boiler, a burner, an oil tank and a chimney or an exhaust system. In the case of a condensing boiler, a floor drain for the condensate should be available.

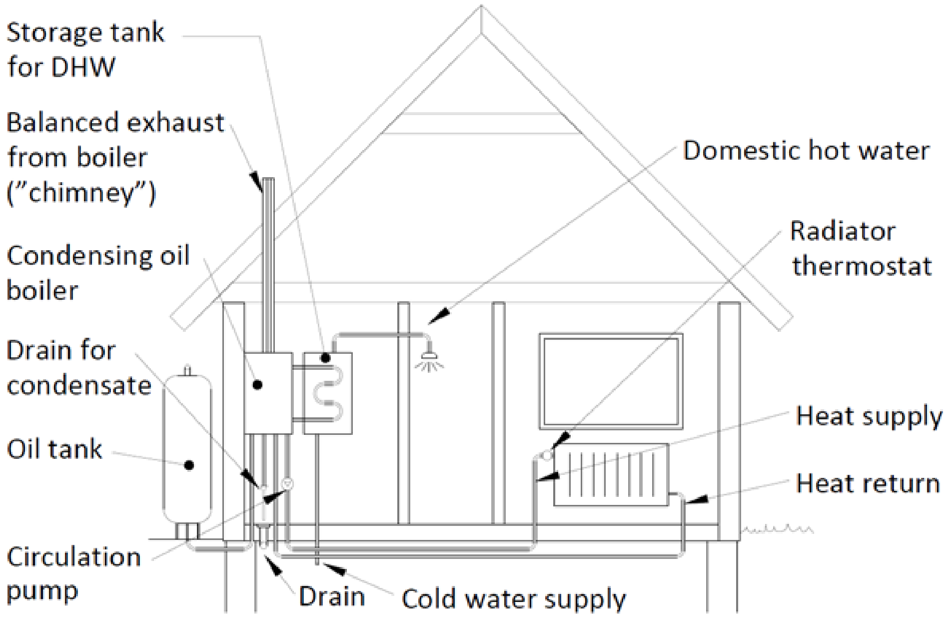

Figure 3 A typical installation of a condensing oil-fired boiler in a single-family house

The burner technology is atomisation by a high-pressure oil nozzle for minor boilers. For very large boilers, other technologies are available, for instance atomisation by a rotating cup. Some advanced recently developed small boilers are also using some rotating cup technology, which allows for modulating burner control. The burners may be yellow flame burners giving a small emission of soot or blue flame burners without soot emission but with a tendency to emit CO instead of soot. For the different fuels, the burner technologies are somewhat different - e.g., some fuels require preheating of the oil.

The boilers for all oil types are of almost similar design: a water-cooled combustion chamber and an integrated convection part. The materials are steel, cast iron or stainless steel. Modern boilers can be delivered with a corrosion resistant flue gas cooler that allows for condensation of the water vapor in the flue gas.

In previous editions, oil boilers were assumed to be condensing to meet EU ecodesign rules and Danish building regulations. However, a 2025 review shows that many non-condensing models—now improved and compliant with efficiency requirements—are available on the Danish market. These models are significantly cheaper than condensing boilers, and it is assumed that most consumers would opt for a non-condensing oil boiler, which, including installation, costs roughly half of a condensing model.

Small domestic boilers (15-70 kW)

The small boilers are used for domestic heating in single family houses. The 15kW boiler heats up to 200-300 m^2 of building area under Danish climate conditions. Very often, the boilers are built with an integrated hot water system, normally a tank of 80-150 l for the domestic tap water.

By Danish law it is not allowed to install oil boilers in new-builds. In existing buildings, it is not allowed to install oil boilers, if district heating or natural gas heating is an option. Previously, it was assumed that only condensing oil boilers could meet EU ecodesign requirements and, consequently, the Danish building code. Therefore, it was assumed that, only condensing oil boilers could be sold and installed legally in Denmark and the EU. Today, however, many non-condensing boilers are available on the market in both regions, as their efficiency has improved enough to meet regulatory standards. Non-condensing oil boilers are generally much cheaper than condensing models, making them the most popular choice and the typical type expected to be installed in Denmark in 2025.

For boilers with a rated heat output between 70 kW and 400 kW the requirements are that efficiency (based on GCV, gross calorific value) shall be higher than 86% at 100% load and higher than 94% at 30% partial load. Based on lower calorific value this corresponds to 92 % respectively 100 %. This efficiency includes electricity consumption and some adjustment due to automatic control. Ecodesign demands correspond reasonably to former demands in the Building regulations - BR 10. [13] as with the assumptions in the tables.

About 60,000 [9] oil boilers for domestic heating are installed in Denmark, the largest part in single-family houses in areas where natural gas or district heating are not available. The variation in the statistics reflect that many of the registered oil boilers are not used in practice or only used for supplementary heating. The number of oil-fired boilers has been declining steadily for several decades, and the number is expected to be reduced by more than 50% in 2030.

Larger boilers (70 kW - 1 MW)

These boilers are used in apartment complexes, institutions, workshops etc. If the connected heating system can deliver return temperatures below 45 °C, a condensing flue gas cooler will often be added. Units with integrated condensing flue gas cooler are also available. The efficiency is influenced by the flue gas temperature - in best cases only few degrees higher than the return temperature. In large boilers, the heat loss from the boiler can be reduced to only a fraction of a percent. Oil-fired boilers can have annual efficiencies around 100 %, if the return temperature from the heating system is sufficiently low, meaning lower than 48 °C, [1], [2], [3].

Most biooil-fired boilers are of this size. The main difference between a conventional boiler and a biooil boiler is a different burner, which is typically twice as expensive as a traditional burner. It is possible to convert from a conventional oil-fired system to a bio-oil system only by changing the burner and very few minor changes to storage tank and boiler. A different burner is needed as bio-oil does not have any lubrication effect and needs higher pressure to operate smoothly.

Input

Domestic fuel oil. Bio oil (FAME) can be added up to approximately 10 % without severe problems.

Bio-oils can be used without blending with conventional mineral fuel-oil, but this requires a specific burner built for the purpose. Bio-oils are exempt from CO_2-taxes.

Output

Heat for central heating and for domestic hot water.

Typical capacities

The heat output ranges from 15 kW to 1 MW.

Regulation ability

The ability to reduce the heat output is excellent for most modern boilers. It should be emphasized that a boiler with a nominal heat output of 15 kW is able to operate at part load, many types will be able to operate down to almost zero heat output still obtaining a high efficiency. The reason for this is that the heat loss from the boiler typically is low because of insulation and low-temperature operation.

Advantages/disadvantages

Advantages

The oil-fired boiler is a simple, reliable technology and operates with a high thermal efficiency. Also as stated above, the control ability of oil-fired burners is excellent.

Today, there are burners for pure bio-oil on the market, operating with acceptable levels of problems, although some enthusiasm may be required.

Normally regular service is made on oil-fired boiler-burner combinations. This is recommended by the authorities. The manufacturers normally recommend annual service.

Disadvantages

The reliability and the maintenance (regular cleaning of the burner as an example) of bio-oil burners cannot be compared with burners of mineral oil [10]. Some research and developments are still needed in case of pure liquid bio fuels. The problems mostly concern practical issues with components (rubber gaskets), storage, sensibility to ambient temperature variations, preheating of the bio-oil, electricity consumption of the burner etc. Burners for raw bio-oil may also have difficulties when running on condensing boilers. Nonetheless these issues are considered to be solvable. Hydro treated vegetable oil (HVO) is almost pure hydrocarbon and can be burnt almost without emission of pollution.

For large plants - in MW size - burning of 100% bio-oil gives no problems. For domestic use, some problems still remain.

Environment

A boiler fired with modern domestic fossil fuel oil with low content of sulphur and nitrogen will - except from the greenhouse gas CO_2 – give rise to the same level of pollution as a natural gas boiler. The pollutants in concern are:

- Unburnt hydrocarbon (only traces),
- CO (less than 100 ppm in the flue)
- NOx (less than 110 mg/kWh ~ 30 g/GJ)
- Soot (Soot number 0 – 1), see [8].
- Voluntarily most boilers are cleaned, adjusted and then inspected once a year for flue gas loss, soot and CO (for blue flame burners).

In Denmark, boilers with an input capacity larger than 100 kW must fulfil "Luftvejledningen", [6], which includes "OML" (Danish abbreviation: Operationelle Meteorologiske Luftkvalitetsmodeller) calculation of immissions (The pollution concentration in the landscape around the plant).

Research and development perspectives

The R&D in 60 years in combustion of mineral oil has resulted in very efficient, cheap and simple technology. Burner/boiler combinations with low emissions and efficiency close to the thermodynamic limits are common on the market [13].

Examples of market standard technology

The best modern boilers operate with annual efficiencies in the range of 100 % (lower calorific value), dependent on the heating system to which the boiler is connected. At the same time, the boiler/burner can be chosen with very low emissions of pollution. Burning of biooils require a different burner in the boiler, and this bio-oil burner is about twice as expensive as a conventional one.

The installation of a bio-oil fired boiler is exempt from the ecodesign requirements for boiler efficiency. The exemption means that it is legal to install oil boilers with a bio-oil burner that have a lower efficiency.

Figure 4 Bosch olio Condens 8000F 19kW[16]

Figure 5 Kroll UB20 biooil burner [18]

Figure 6 Viessmann vitoradial 300T 101 to 545 kW[19]

Prediction of performance and costs

Oil boilers are mature and commercial technology with a large deployment (a category 4 technology). Yet improvements are still possible and possible refinements of oil boilers are:

- Flue gas heat exchanger with exit temperature close to the return temperature from the heating system
- The connected heating system shall be able operate with return temperatures close to room temperature
- The connected hot tap water heat exchanger shall operate with return temperatures close to the cold tap water temperature.
- The boiler shall be placed inside the building so most of the heat loss from the boiler parts will be used in the building.
- The electricity consumption for burner, controls, preheating of oil etc. is to be minimized.

While the cost of oil boilers has decreased during the last 60 years, it is considered unlikely that this trend will continue with any significance – albeit smaller cost reductions are expected due to a general increase in productivity.

Uncertainty

The expected development in thermal efficiency is assumed to be driven by increasing oil prices. If the expectations to the oil prices are not fulfilled, it is likely that the above-mentioned technological improvements will be delayed or not occur at all.

Economy of scale effects

A typical price for 15-30 kW boiler of best quality is in the range of 5,000-6,000 Euros, and a 400 kW boiler costs in the range of 30,000-35,000 Euros. So, the small ones cost around 275 Euros per kW and a 400 kW cost around 85 Euros per kW, hence oil boilers display a significant economy of scale effect.

Additional remarks

Quantitative description

See separate Excel file for Data sheets.

References

[1] Study "Ecodesign of Boilers and Combi-boilers "http://www.ecoboiler.org/". 2006-2007 by Van Holsteijn en Kemna (VHK) for the European Commission, DG Transport and Energy (DG TREN).

[2] RECENT PROGRESS (AND APPLICATION) ACHIEVED IN THE WAY TO ESTIMATE REAL PERFORMANCES OF DOMESTIC BOILERS ONCE INSTALLED Jean Schweitzer, Christian Holm Christiansen Danish Gas Technology Centre, Denmark Martin Koot Gastec, Holland Otto Paulsen DTI, Denmark. SAVE Workshop Utrecht 2000.

[3] BOILSIM http://www.boilsim.com/

[4] Sparolie.dk with a list of high efficiency oil-fired boilers and with a list of the status for existing oilfired boilers.

[5] http://www.blauer-engel.de/_downloads/publikationen/erfolgsbilanz/Erfolgsbilanz_Heiztechnologien.pdf (Rules for NO_X). This is not present at the Blauer Engel Homepage, but can be found at the Internet.

[6] Luftvejledningen fra Miljøstyrelsen. http://www2.mst.dk/udgiv/publikationer/2001/87-7944-625-6/pdf/87-7944-625-6.pdf.

[7] Rapsolie til opvarmning,Teknik, økonomi og miljø. Videncentret for biomasse 2001.

[8] Miljøstyrelsens vejledning nummer 3 1976. Gives a relation between soot number and soot concentration.

[9] Estimated from Climate status and outlook 2025, KF 2025 - Tal bag figurer, Figure 28.6: Olie og gas som primær opvarmningsform Danish Energy Agency, 2025

[10] Paulsen, O.: Calculation of electricity consumption of small oil and gasfired boilers – based on Laboratory test data. Annex F in Schweitzer, Jean: SAVE report 2005: http://www.boilerinfo.org/infosystem_el/webelproject/wp_reports/WP1.pdf

[11] Commission regulation (EU) NO 813/2013, 2. August 2013.

[12] Christiansen. C. H.: Ecodesignkrav for fyringsanlæg – input til BR2015, Notat til Energistyrelsen Teknologisk Institut dec. 2014.

[13] Kedeleffektiviteter for oliefyr og naturgaskedler i enfamiliehuse. DTU BYG, Teknologisk institut, Dansk Gasteknisk Center A/S, 2005

[14] Cilaj Energi. 2020. https://cilaj-energi.dk/om-bioolie/#.X5fcTIhKiUk

[15] OK. 2020. https://www.ok.dk/erhverv/hjaelp/braendstof/hvo-biodiesel/kan-jeg-faa-hvo-biodiesel-leveret-af-ok

[16] Bosch. 2020. https://www.bosch-thermotechnology.com/dk/da/ocs/privat/olio-condens-8000f-1098812-p/

[17] Cheminor. 2020. http://cheminor.dk/

[18] Rapsoliefyr.dk. 2020. https://www.rapsoliefyr.dk/index.php/produkter

[19] Viessmann. 2020. https://www.viessmann.dk/da/beboelsesejendom/oliekedler/kondenserende-oliekedler/vitoradial-300t.html

[20] Study "Ecodesign of Boilers and Combi-boilers http://www.ecoboiler.org/. 2006-2007 by Van Holsteijn en Kemna (VHK) for the European Commission, DG Transport and Energy (DG TREN).

[21] RECENT PROGRESS (AND APPLICATION) ACHIEVED IN THE WAY TO ESTIMATE REAL PERFORMANCES OF DOMESTIC BOILERS ONCE INSTALLED Jean Schweitzer, Christian Holm

Christiansen Danish Gas Technology Centre, Denmark Martin Koot Gastec, Holland Otto Paulsen DTI, Denmark. SAVE Workshop Utrecht 2000.
[22] BOILSIM http://www.boilsim.com/
[23] Sparolie.dk with a list of high efficiency oil-fired boilers and with a list of the status for existing oilfired boilers.
[24] http://www.blauerengel.de/_downloads/publikationen/erfolgsbilanz/Erfolgsbilanz_Heiztechnologien.pdf (Rules for NOX). This is not present at the Blauer Engel Homepage, but can be found at the Internet.
[25] Luftvejledningen fra Miljøstyrelsen. http://www2.mst.dk/udgiv/publikationer/2001/87-7944-625-6/pdf/87-7944-625-6.pdf.
[26] Rapsolie til opvarmning,Teknik, økonomi og miljø. Videncentret for biomasse 2001.
[27] Miljøstyrelsens vejledning nummer 3 1976. Gives a relation between soot number and soot concentration.
[28] Hvordan er landets boliger opvarmet og hvor ofte skiftes opvarmningsform? - Resultater fra en spørgeskemaundersøgelse. https://ens.dk/sites/ens.dk/files/Statistik/opvarmningsundersoegelsen.pdf
[29] Aatola, H. et al.: Hydrotreated Vegetable Oil (HVO) as a Renewable Diesel Fuel: Trade-off between NOx, Particulate Emission, and Fuel. Consumption of a Heavy Duty Engine: http://www.biofuelstp.eu/downloads/SAE_Study_Hydrotreated_Vegetable_Oil_HVO_as_a_Renewable_Diesel_Fuel.pdf, Helsinki University, 2008
[30] Paulsen, O.: Calculation of electricity consumption of small oil and gasfired boilers – based on Laboratory test data. Annex F in Schweitzer, Jean: SAVE report 2005: http://www.boilerinfo.org/infosystem_el/webelproject/wp_reports/WP1.pdf.
[31] Commission regulation (EU) NO 813/2013, 2. August 2013.
[32] Christiansen. C. H.: Ecodesignkrav for fyringsanlæg – input til BR2015, Notat til Energistyrelsen Teknologisk Institut dec. 2014.
[33] Kedeleffektiviteter for oliefyr og naturgaskedler i enfamiliehuse. DTU BYG, Teknologisk institut, Dansk Gasteknisk Center A/S, 2005
[34] Klimarådet 2020, Kendte veje og nye spor til 70 procents reduktion

202 Gas boiler

Contact information

Danish Energy Agency: Emil de Bekker Steffensen, teknologikatalog@ens.dk
Author: Original chapter from 2016 made by COWI.
Update in 2021 and 2025 by Ea Energy Analyses.

Publication date

2016

Amendments after publication date

Date	Ref.	Description
01-10-2025		Minor update has been undertaken during Q3 of 2025. Primary focus is on data sheets, and text has been revised accordantly.
20-01-2021		Comprehensive update has been undertaken during Q4 of 2020. Primary focus is on data sheets, but text has been revised as well.

Qualitative description

Brief technology description

Gas boilers are burning gas (natural gas, biomethane etc.). The energy delivered by the combustion is used to heat water through a heat exchanger that is built into the boiler.

In a gas fired boiler, gas is burnt in a combustion section. It may be a traditional flame or a specially designed low-NOX burner. The heat is transferred to water through water cooled walls and through a water heat exchanger after the combustion section. Gas boilers can be wall hung or floor standing.

The hot water from the gas boiler is circulated in the radiators of the house (a pump is, therefore, required on the installation or in the boiler).

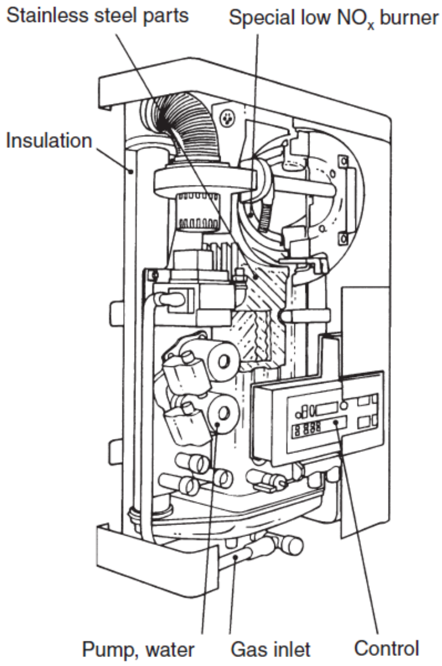

Figure 7 A wall hung gas boiler for a one-family house (Source: VarmeStåbi®, Nyt Teknisk Forlag)

A gas boiler is often called a "central heating (CH) boiler", as it is one of the elements of a central heating installation including boiler(s), a heat distribution system, heat emitters (radiators, convectors etc.) and a control system for the appliances.

Condensing gas boiler

A condensing boiler is a boiler designed for recovering the latent heat from water vapour produced during the combustion of the fuel. The condensing boilers include two stages of heat transfer, compared to traditional boilers (non-condensing boilers), which only include one stage. In the condensing boiler, a second heat exchanger is placed before the flue gas exit to collect the latent heat contained in the flue. Most gas-fired boilers also allow for condensation in the combustion chamber.

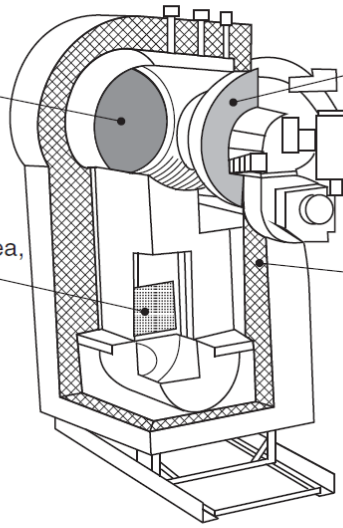

Figure 8: A floor standing medium size condensing gas boiler for apartment blocks etc. (Source: VarmeStåbi®, Nyt Teknisk Forlag)

Condensing flue gas recovery heat exchangers can also be installed as auxiliary equipment after the boiler. Traditional gas boilers (non-condensing boilers) can no longer be installed in houses/buildings (because of minimum levels of energy efficiency required in the ecodesign regulation for space heaters and combination heaters [32] and the requirements of the Danish building regulations [22]). Most gas boilers will accommodate a large variety of natural gas compositions or LPG's with slight technical changes to the burner. New combustion control systems are increasingly used in new boilers allowing, without burner adjustment, burning of very large variation of gas quality. This ranges from low calorific value gases to high calorific LPG gases, including biomethane [34]. Gas boilers are generally covering heating and domestic hot water production. For the latter, hot water storage is mostly used (in Denmark). A minor market share is to appliances producing hot water instantaneously, the main advantage here is a lower space requirement of the equipment.

Efficiency of gas boilers

Gas boiler's energy efficiency is mainly depending on water temperature and load. The improved insulation of boilers and new burner technologies makes it possible to come close to the theoretically achievable efficiency. Annual energy efficiencies in real installations are today close to 100% and up to 104% (based on lower calorific value) [9], [10]. This is also supported by recent field tests in Denmark [41]

As the water temperature and load has a great influence, the boiler heating efficiency will very much depend on installation including the heat distribution system and the right sizing of the boiler to cover the building heat demand. Furthermore, the user behaviour will also influence the efficiency. In general, the efficiency for hot water production is lower than the efficiency for heating. This means that users having high hot water demand may have lower seasonal efficiency.

Normally, the efficiency is rather stable throughout the boiler's lifetime. Statistics made on boiler servicing are showing rather constant flue gas losses between two services [38]

Input

Gas boilers are using natural gas as fuel. They can also use LPG gases (in general with minor burner changes).

Biomethane (upgraded biogas where the CO_2 component has been removed) is increasingly being injected into the gas. In 2024, the average mix of biomethane in the Danish gas grid was approx. 40% and the share is predicted to increase in the future. Biomethane has a composition similar to natural gas and is fully compatible with boiler utilisation without any change on the appliance. It can be injected into the gas grid and mixed with natural gas or used directly. Raw biogas is not suited to injection in the grid, but can be used in specifically designed appliances

Hydrogen may also be injected into the gas grid, and this is already done in several countries (mostly in Germany). New condensing boilers with premix burners can burn high % of hydrogen (60% or higher); however, the long-term impact of hydrogen is not very well known and other sensitive applications in the grid (engines, cookers, etc.) make scenarios with high concentration of hydrogen in the main grid unrealistic. It is generally admitted that a rate of 20 to 30% injection could be the norm in 10 to 20 years [34].

Output

The form of energy generated by gas boilers is heat transferred to heated water. Thus, the output is hot water either used for heating or directly for domestic hot water.

Typical capacities

For the domestic market, most of the gas boilers (single units) have a nominal heat output of about 20 kW and are modulating (see next section) down to 1 kW for very new technologies. Up to 20/35 kW are needed to cover the domestic hot water production (especially in the case of boilers without water tank) [24], whereas for heating 10 kW or less would be sufficient for most of the single family houses [25]. There is no real differentiation between boilers for the new buildings compared to the existing buildings because most of the boilers are designed to cover the domestic hot water demand which is not depending on new or existing buildings. In general, gas boilers are produced as a series of similar appliances having different capacities. Examples of nominal capacities are 10, 20, 30 and 50 kW. For apartment blocks and other large buildings, where the heat demand is larger than for one-family houses, larger boilers of several hundred kW are used, but alternatively the combination of several domestic appliances connected in so-called "cascade" is a possible solution. In that case, the number of appliances in operation is determined by the heat demand.

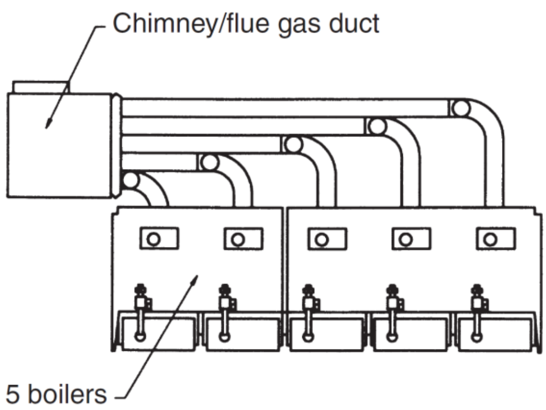

Figure 9: Cascade installation of boilers (Source: VarmeStåbi®, Nyt Teknisk Forlag)

Regulation ability

Boilers are generally sold with controls that enable the optimal matching between the user demand and the appliance's heat production and the actual hot water demand. For example, in case the user needs hot water, the control system will give production priority to that demand. The control systems are able to communicate with components such as external temperature sensors or pumps. The control system may also adapt to other control elements such as radiator thermostats etc. Some control systems are auto-adaptive: they will learn from the recent past to optimize the control of the boiler. Most of the boilers on the present market are so-called "modulating" boilers. This feature allows the appliance to deliver reduced heat output without stopping the burner (the gas and air flows to the burner are reduced). Most of such boilers are able to modulate down to about 20% of the nominal maximum output. For example, for domestic boilers modulating ranges from 4 to 20 kW are typical, and technologies allowing very low minimum range are available (starting from 1 kW). The modulation feature reduces the too frequent start-stop of the boiler and improves the user's comfort and the lifetime of the appliance. Even though boilers have controls systems, it is important to match well the boiler capacity with the building heat demand so to avoid for example frequent start stops.

Advantages/disadvantages

Advantages

- Gas boilers offer an efficient way to use directly primary energy in homes and are designed to cover the entire heat and hot water demand of end users.
- CO2 and NOx emissions of gas boilers are the lowest compared to any other fossil fuel boilers.
- The transport of natural gas to the buildings through the gas grid is less "energy costly" than the transport of oil.

Disadvantages

- The laying of the branch pipe requires extra construction work compared to other heating technologies especially in urban areas where pavements must be broken to establish the required infrastructure

Environment

Gas boilers have low NOx emissions (lower than oil boilers, due to the nature of the fuel) [4] and low CO emissions. Gas boilers have a net emission of CO_2 if fuelled with fossil-based gas. With increasing injection of biomethane (about 40% in 2024) into the grid the carbon footprint of gas boilers is reducing.

About 60% of the CO_2-emissions from a gas-boiler comes from the natural gas it uses during its lifetime, and 21% from extraction of the raw materials [33].

Research and development perspectives

Gas boilers is a mature and commercial technology with a large deployment (a category 4 technology according to the definition presented in the introduction). Today, gas condensing boilers have almost reached the highest possible energy efficiency and only a few per cent improvement is to be expected in the future. Still, improvements are possible to further decrease the electrical consumption and emissions. The electrical consumption has decreased due to the development of low-energy modulating pumps and labelling systems for gas boilers in Denmark [21]. NOx emissions have also been reduced with the introduction of the same label. Further improvements have been observed when the ErP requirements entered into force in 2018 [32].

Gas boilers can be combined with other technologies in order to optimise the performances and to give more flexibility to adapt to the increasing production of versatile renewable energy. Hybrid systems are combining different technologies:

- Gas boilers can be used in combination with solar thermal energy. Gas solar boiler kits are available on the market.

Examples of market standard technology

A typical example of market standard technology would be a modulating, condensing boiler with a range of 2 to 18 kW. The efficiency is rather constant over the range of modulation, and NOx emission is low (low-NOx burner technology). Most of the condensing boilers on the market have now reached the highest achievable efficiency (with this technology) and can be considered to be best available technology.

Figure 12: Bosch condens 5000 W, 2-28kW. [35]

Figure 11: Valliant ECOTEC PLUS VC 156 5-5 with 75L hot water storage tank, 3-15KW.37]

Figure 10: Bosch condens 5000W CBR 100-3, 17-100kW. [36]

Predictions of performance and costs

Gas boilers have been used for several decades and are a mature and commercial technology with a large deployment (a category 4 technology). Further development in the area of individual gas boilers is mainly focusing on:

- Low-NO_X burners
- Combustion controls enabling appliances to self-adapt to variations in gas composition
- Integration in smart grid [18]
- Conversion to hydrogen (pure H2 boilers and boilers for H2 natural gas blends)

While the cost of gas boilers has decreased, it is considered unlikely that this trend will continue with any significance – albeit smaller cost reductions are expected due to a general increase in productivity.

Uncertainty

- **Heat efficiency, annual average, net (%)**: The uncertainty on the figures given in the table is rather low as the variation on Best Available Technology (BAT) boilers is quite small. The variations of annual efficiencies mostly depend on the way to use and install the boilers and especially the design of the radiator system (low-temperature or traditional), but for the BAT installed in a new building, the radiator system will be a low-temperature system resulting in the highest energy efficiency.
- **Auxiliary Electricity consumption (kWh/year)**: As domestic gas boilers have in general integrated circulators, the circulator consumption is accounted for in the tables of the data sheets. The uncertainty is larger, as the components and way to control them (after run time of pumps and ventilator) can be quite different.
- **NO_x (g per GJ fuel)**: Large variations are possible, but regulations are now limiting the emissions to a quite low level (Ecodesign).

Economy of scale effects

The price of boilers for small houses (<35 kW) is decoupled from the capacity of the boiler, instead the cost of small boilers depends on other features like material selection etc. In other words the cost of boilers is not directly proportional to the power (a 24 kW boiler is not twice as expensive as a 12 kW boiler) but in a serial of boilers of the same construction, there will be an increasing of the price with the increase of the power. For the large boiler, there is a clear impact of the size on the price, and average values /8/ are indicating a more or less linear growth of 50 Euro/kW for boilers above 35 kW (but below 700 kW).

Additional remarks

Fossil-based natural gas boilers are generally only allowed in new buildings if the supply per 1.1.2013 is a dedicated “natural gas area” [22]. Gas boilers have a documented average lifetime of about 20 years [38], [39]. It is assumed that larger gas boilers used in apartment buildings have an average lifetime of 25 years, due to better maintenance and higher equipment quality.

Quantitative description

See separate Excel file for Data sheets.

References

[1] Annual efficiency calculation method for domestic boilers. SAVE Contract XVII/4.1031/93-008.

[2] Gaskedlers naturlige overlevelse, Gasenergi nr. 5 2015,

[3] Study "Ecodesign of Boilers and Combi-boilers http://www.ecoboiler.org/. 2006-2007 by Van Holsteijn en Kemna (VHK) for the European Commission, DG Transport and Energy (DG TREN). Task 4 Section 3.1.

[4] DGC project: Evaluation of the NOx emissions of the Danish population of gas boilers below 120 kW.

[5] Start stop emissions of domestic appliances. H. Hüppelshäuser and F. Jansen. Ruhrgas. IGRC 1998.

[6] HMN: http://salg.naturgas.dk

[7] DGC project: Evaluation of the NOx emissions of the Danish population of gas boilers below 120 kW

[8] Average cost information from Viessmann and Weishaupt.

[9] RECENT PROGRESS (AND APPLICATION) ACHIEVED IN THE WAY TO ESTIMATE REAL PERFORMANCES OF DOMESTIC BOILERS ONCE INSTALLED Jean Schweitzer, Christian Holm Christiansen Danish Gas

Technology Centre, Denmark Martin Koot Gastec, Holland, Otto Paulsen DTI, Denmark. SAVE Workshop Utrecht 2000.

[10] Test of more than gas 100 boilers tested in laboratory at DGC. Application of BOILSIM model.

[11] BOILSIM projects (EU work on models for boiler efficiency)

[12] Annual efficiency calculation method for domestic boilers. SAVE Contract XVII/4.1031/93-008.

[13] Framework for a European method to determine the energy consumption for domestic hot water production. SAVE Contract XVII/4.1031/Z/95-052.

[14] Annual Efficiency: Pilot operation for the use of the harmonised method BOILSIM. SAVE Contract XVII/4.1031/Z/9674

[15] Estimation of energy savings by replacement of fuel oil and gas boilers. SAVE Contract XVII/4.1031/D/97-072.

[16] Energy consumption calculation method for domestic hot water and combined systems. SAVE Contract XVII/4.1031/Z/97-048

[17] Example of hybrid technology: manufacturer: Gloworm; Product: Clearly Hybrid: http://www.glow-wormheating.co.uk/clearly-hybrid/clearly-hybrid.php

[18] Paper IGRC 2014: Domestic gas hybrid technologies and their interaction with the Danish energy system, Author: Jean Schweitzer, Karsten V. Frederiksen, Danish Gas Technology Centre and Svend Vinter Pedersen, Emil Jacobsen, Danish Technological Institute.

[19] God økonomi i boligopvarmning med naturgas, Henrik Iskov og Jan K. Jensen, DGC 2013

[20] Bygningsreglementet: http://www.bygningsreglementet.dk

[21] Labelling systems for gas boilers in Denmark: www.dgc.dk/energimaerkede-kedler

[22] DS 439:2009 Norm for vandinstallationer

[23] DS 469:2013 Norm for Varme- og køleanlæg i bygninger

[24] Example of cost of a boiler: http://www.billigvvs.dk/Varmesystemer-Gasfyr.html

[25] NGF Nature Energy 2014 Statistics on replacements of 226 boilers

[26] Facts and figures about domestic gas boilers. Compilation of results covering 25 years of testing at DGC's laboratory. Report, January 2016. Jean Schweitzer, DGC

[27] Drift- og vedligeholdelsesomkostninger for små gaskedler (villakedler), HMN GasNet, 2016

[28] DGC Statistics, Efficiency and Emission test reports from district heating plants, up to and including 2014

[29] Danish District Heating Association, information given to the 2012 survey for the report

[30] Installation costs of new condensing gas boilers in NGF Nature Energys distribution area from 2012 - 2015, NGF Nature Energy (in Danish: Priser for installation af ny kondenserende gaskedel i Nature Energys distributionsområde i perioden 2012-2015)

[31] Operation and maintenance costs of small gas boilers, HMN GasNet 2016 (in Danish: Drift- og vedligeholdelsesomkostninger for små gaskedler (villakedler)

[32] Commission Delegated Regulation (EU) No 811, 812, 813, 814 /2013 with regard to the energy labelling & ecodesign requirements of space heaters and water heaters.

[33] Life cycle assessment of domestic hot water systems: a comparative analysis. University of Brighton. 2014.

[34] Personal communication with Jean Schweitzer, DGD, October 2020

[35] Bosch. https://www.bosch-thermotechnology.com/dk/da/ocs/privat/condens-5000-w-758023-p/ 2020.

[36] Bosch. https://vvsproffen.dk/shop/vvs-varme-gas-gaskedler-342124100-1366p.html 2020
[37] Valliant. https://www.vaillant.dk/professionelle/produkter/ecotec-plus-vc-156-5-5-h-246-5-5-h-31104.html 2020
[38] Facts and figures about domestic gas boilers. Compilation of results covering 25 years of testing at DGC's laboratory February 2016, updated 2017. Jean Schweitzer, DGC
[39] Investigations on 25 gas boilers lifetime with HMN boiler statistics. 743-48 Jean Schweitzer, DGC Sept. 2016
[40] Where is the gas heating market, and where is it going? Steven Ashurst, DeltaEE. EGATEC 2019 Conference, Groningen, the Netherlands
[41] Dokumentation af villagaskedlers faktiske virkningsgrad, Kunderapport, DGC, November 2020, forfatter: Karsten V. Frederiksen/Mamadou Koné.

203 District heating substation

Contact information

Danish Energy Agency: Emil de Bekker Steffensen, teknologikatalog@ens.dk
Author: Original chapter from 2016 made by COWI.
Update in 2021 and 2025 by Ea Energy Analyses.

Publication date

2016

Amendments after publication date

Date	Ref.	Description
01-10-2025		Minor update has been undertaken during Q3 of 2025. Primary focus is on data sheets, and text has been revised accordantly.
20-01-2021		Comprehensive update has been undertaken during Q4 of 2020. Primary focus is on data sheets, but text has been revised as well.

Qualitative description

Brief technology description

District heating is a hydraulic system of pipes with the purpose of distributing heat to end users of space heating and domestic hot water. The heat may come from several sources, including heat from combined heat and power production (CHP), surplus heat from industry, large heat pumps and heat from waste incineration plants and boilers.District heating companies are increasingly investing in large scale heat pumps and electric boilers for heat production. More than 60% of Danish households are supplied with district heating by more than 400 district heating networks and in most major Danish cities, typically more than 95% of the end users are connected.

The district heating sub-station is placed at the end user with the purpose of making domestic hot water and delivering heat for the space heating system. Each building with a district heating sub-station is supplied from a branch pipe connecting the building to the overall distribution network.

District heating units are categorised as either direct units, where the water from the district heating network is circulated directly through the radiators of the end consumer, or indirect units, where the water from the district heating network is led through a heat exchanger. **Fejl! Henvisningskilde ikke fundet.** Figure 13 shows a sketch with typical components included in a direct substation for single-family houses [1], and Figure 14 shows the design of an indirect district heating unit. It is estimated that there is an even share of direct and indirect district heating units in Denmark.

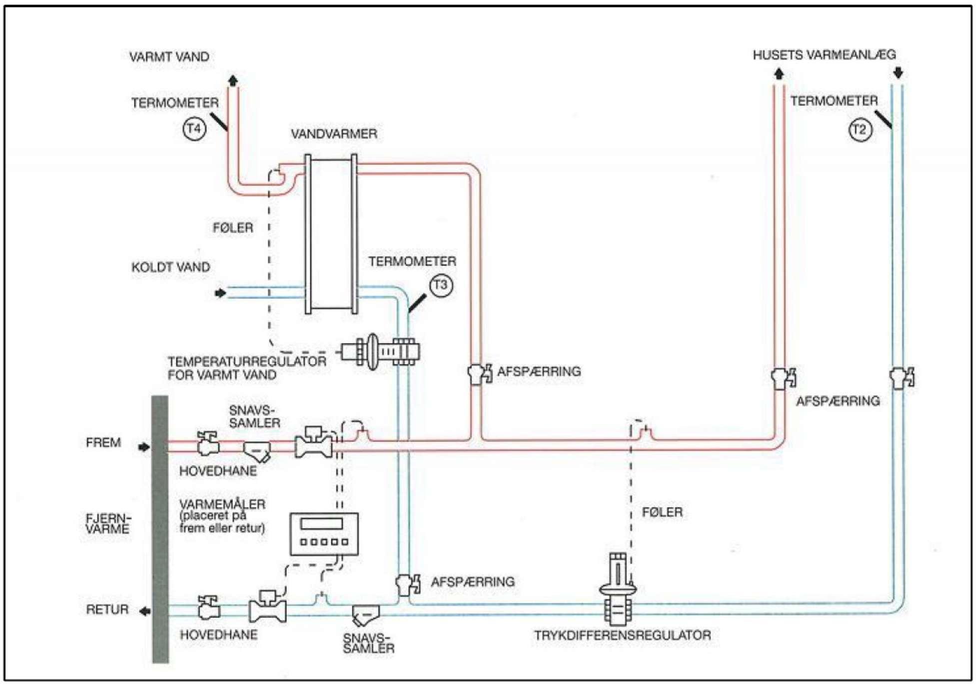

Figure 13 **Direct district heating substation with domestic hot water heater and heat exchanger for space heating in a one-family house.**

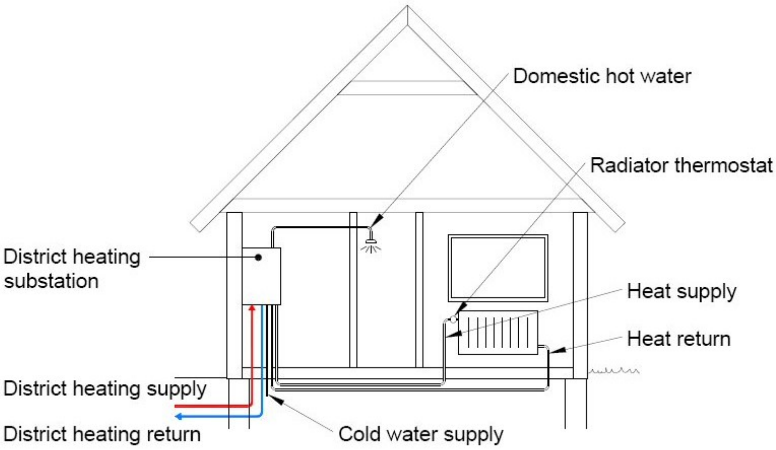

Figure 14 District heating substation with domestic hot water heater and heat exchanger for space heating

In apartment complexes, the standardized and prefabricated substation is placed centrally.

Small substations, the so-called flat stations that can be placed in each apartment, are available on the market but are virtually not used at all in Denmark. The substation is equipped with a domestic hot water heater based on either a storage tank with a heat exchanger embedded or a heat exchanger without storage, e.g. a plate heat exchanger. It is common to use plate heat exchangers without a storage tank in newer installations. New storage tank installations are typically only seen when replacing existing storage tanks, where the branch pipe capacity is not sufficient for plate heat exchangers. In some cases, a combination of an external heat exchanger and a storage tank is seen. The space heating is delivered by direct supply of district heating water or via a heat exchanger placed in between the district heating water (primary side) and the space heating water (secondary side). Further, the substation includes all valves, controllers, filters, pumps, etc. that are necessary for the operation. The substation also includes a heat energy meter. For substations constructed as units the unit is ready for convenient installation of the heat meter.

Input
Heat in the form of hot water supplied from the district heating pipeline.

Output
Heat (space heating and domestic hot water).

Typical capacities
The substation space heating capacity is dimensioned based on district heating temperatures and maximum allowable pressure drop. In single-family houses, the space heating capacity is typically in the range of 10 kW for district heating temperatures 70/40 °C and a maximal allowable pressure difference in the main pipes in the range of 0.3 bar. If the domestic hot water is prepared by an instantaneous water heater (normally including a plate heat exchanger) the heating demand for this is set to 33 kW for a single-family house. For large buildings, the capacities typically range from 70 kW to 250 kW for standardized wall-hung products. Above 250 kW, the substations will be individually designed and manufactured. The capacities of large buildings refer to district heating temperatures 70/40 °C in the following.

Regulation (control) ability
A district heating substation can go from 0 – 100 % almost instantaneous.

On a component level, the design criteria include the ability to control domestic hot tap water temperature, flow temperature to the heating system, pressure loss and ability to maintain a low return temperature. The present building regulation in Denmark states that the flow temperature shall be controlled according to the outdoor temperature. Radiator thermostats shall be installed at all radiators in the building.

Advantages/disadvantages
It is essential to realize that the district heating substation in itself cannot be compared to individual heating options like gas boilers or heat pumps. In order to make a whole techno-economic comparison, the whole district heating system must be taken into consideration, including distribution network and heat source. However, in this chapter, the advantages and disadvantages of district heating are evaluated in comparison to individual heating solutions.

Advantages

- Compact design - small installation space requirements
- Low maintenance costs
- Very low noise level
- No pollution produced locally
- District heating allows for a high degree of security of supply and fuel flexibility

- District heating makes utilization of surplus heat from industries and power production possible and allows for cheap and large-scale energy storages, which may contribute to integrate solar and power through flexible electricity consumption in heat pumps and electric boilers and flexible power generation from combined heat and power plants

Disadvantages

- The laying of branch pipes requires significant construction work compared to other heating technologies especially in urban areas where pavements must be broken to establish the required infrastructure
- Distribution network losses increase energy consumption and operation and maintenance costs
- Specific capital costs and distribution network losses of the district heating system increase with decreasing population density. This is a barrier which prevents district heating companies from providing district heating to customers in areas with low heat density.

Environment

The environmental characteristics are dependent on the heat input to the specific district heating network. Therefore, no such characteristics are presented. Environmental declarations exist for specific district heating networks, e.g. the declaration of the Greater Copenhagen DH system.

Research and development perspectives

Research and development are mainly taking place in the following areas:

- Plate heat exchanger design
- Control strategies such as flexible district heating by HOFOR
- Low-temperature operation (< 55°C district heating flow temperature)
- Reduction of standby losses (primarily in new single-family houses)
- Integration or combination with other technologies (mainly outside Denmark). In Denmark, low temperature district heating combined with electric immersion heating elements or heat pumps for hot water production in some cases combined with smart grids are new research areas

Low-temperature district heating substations have been demonstrated e.g. in the low-energy buildings of the housing association "Boligforeningen Ringgården". The substations incorporate efficient plate heat exchanger technology and can supply domestic hot tap water at 47 °C with a district heating supply temperature of 50 °C and return temperatures below 25 °C [3].

Examples of market standard technology

Figure 15: Metroterm 3 20kW direct DH unit [7]

Figure 16: Metroterm Metro VXT Large direct DH unit 88-420kW [8]

Figure 17: Termix VVX indirect DH unit 4-22 kW [9]

Prediction of performance and costs

The substations have been used for several decades and are a mature and commercial technology with a large deployment (a category 4 technology). Some district heating utilities are working on decreasing the district heating supply temperature and have set new requirements for district heating substations [6]. In low-energy houses, low standby losses of technical installations are essential to comply with the Danish building code. Also new electronically controlled water heaters have entered the market and are expected to improve efficiency and comfort further [5]. Only smaller cost reductions are expected due to a general increase in productivity.

Uncertainty

The technology is well established, and it is likely that production cost for a district heating unit will decrease moderately in the future: improved and cheaper technology for producing heat exchangers, valves, electronics, new fitting and pipe systems will help this process.

Economy of scale effects

For the small indirect unit in an existing single-family house, the price is in the range of 3700 Euros incl. installation, equal to 300 Euros per kW. For a 320 kW indirect unit in an existing apartment complex the price is in the range of 23500 Euros equal to 70 Euros per kW.

Additional remarks

Many district heating companies are implementing measures for consumers to utilize the heat in the district heating system better and thereby making it possible to supply a lower temperature and obtain a better cooling of the district heating water. This will allow for a better business case for geothermal heating and heat pumps.[10]

Quantitative description

See separate Excel file for Data sheets.

References

[1] Forslag til Forskrifter for godkendte standardunits, Teknologisk Institut, 2005.

[2] Communication with Gemina Termix, www.termix.dk.

[3] Delrapport 2 - DEMONSTRATION AF LAVENERGIFJERNVARME TIL LAVENERGIBYGGERI I BOLIGFORENINGEN RINGGÅRDENS AFD. 34 I LYSTRUP. Energistyrelsen - EUDP 2008-II, 2011.
[4] Communication with Danfoss Redan, www.redan.danfoss.com.
[5] www.metrotherm.dk.
[6] Krav til fjernvarmeunits I VarmeTransmission Aarhus, December 2011.
[7] Metroterm, Metrosystem 3 . https://www.metrotherm.dk/produkter/fjernvarme/fjernvarmeunits/metro-system-3, 2020
[8] Metroterm, Metro VXT. https://www.metrotherm.dk/produkter/fjernvarme/store-fjernvarmeunits/metro-vxt 2020, 2020.
[9] Termix, Termix VVX, https://termix.dk/produkt/termix-vvx-med-tpv/, 2020
[10] Enersparerådets anbefalinger vedrørende lavtemperaturfjernvarme, Energisparerådet, 2018.

204 Biomass boiler, automatic stoking

Contact information

Danish Energy Agency: Emil de Bekker Steffensen, teknologikatalog@ens.dk
Author: Original chapter from 2016 made by COWI.
Update in 2021 and 2025 by Ea Energy Analyses.

Publication date

2016

Amendments after publication date

Date	Ref.	Description
26-09-2025		Minor update has been undertaken during Q3 of 2025. Primary focus is on data sheets, and text has been revised accordingly.
20-01-2021		Comprehensive update has been undertaken during Q4 of 2020. Primary focus is on data sheets, but text has been revised as well.

Qualitative description

Brief technology description

The most common fuel used in small scale biomass boilers with automatic stoking is wood pellets. See Figure 18. However, some boilers may be designed for firing of other types of biomass such as wood chips and grain.

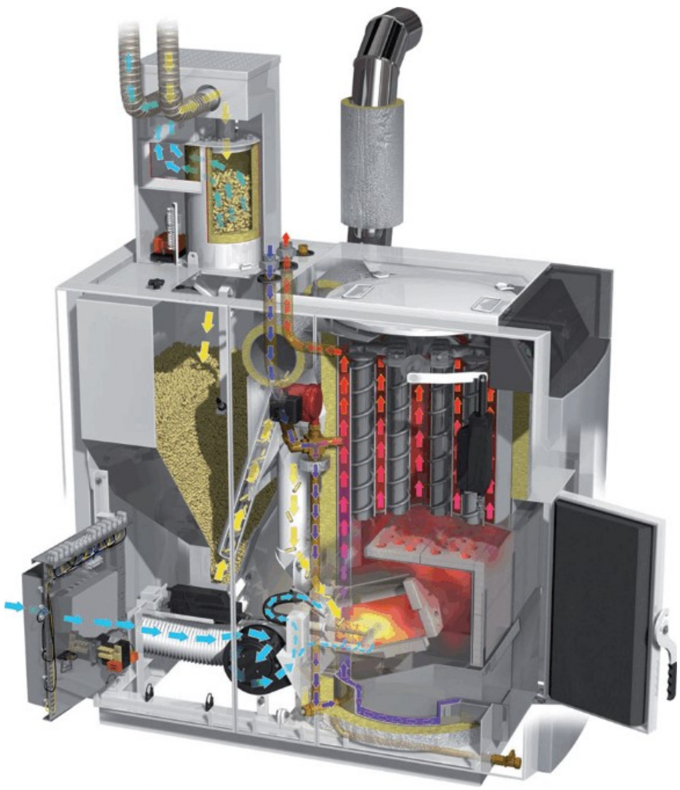

Figure 18 Biomass boiler, automatic stoking

The fuel is typically conveyed via an auger feeder from the fuel supply to the burner unit. In the burner, the combustion takes place during supply of primary and secondary air. The boiler is often a steel sheet boiler with a convection unit consisting of boiler tubes or plates.

Recent developments comprise smaller boilers that are able to modulate to very low load and thus are applicable in modern low energy housing. Incorporation of advanced combustion technologies, such as gasification or pyrolysis steps, have enabled higher efficiency and cleaner combustion. Condensing pellet boilers are able to reach very high efficiencies while lowering the exhaust temperature below 100 degrees C. Innovations in emission control systems have been important to improving the environmental performance of pellet boiler systems. Also, application of secondary technologies is emerging - catalytic converters and electrostatic filters help capture and minimize harmful pollutants released during the combustion process. [16]

Fuel can be supplied from an external earth storage tank, storage room or similar, or it can be supplied from an integral fuel hopper that is part of the boiler unit. Fuel is available in bags and can be added to the silo or hopper manually, or - in case of wood pellets - the fuel can be blown or tipped into the storage tank or room.

Within automatic biomass boilers, there are two plant types: compact plants consisting of a boiler and a burner in the same unit, and boilers with a detachable burner. Detachable burners can be approved up to 70 kW and are exclusively applicable for stoking with pellets.

Automatic biomass boilers can be a stand-alone solution, but a hybrid system like solar/biomass can be an attractive combination because biomass boilers are typically less suited for low-load operation than for example gas and oil boilers. In the summer period hot tap water is produced from the thermal solar heater, while the biomass boiler unit covers the heat demand for hot tap water and space heating during the rest of the year.

Some suppliers offer systems with advanced interfaces that allows for system control via a telephone app or online via an internet browser.

Input

Wood pellets or wood chips. Another possible fuel depending on the boiler type is non-woody biomass such as grain. See additional remarks for detailed description of wood pellets.

Output

Heat for space heating and hot tap water.

Typical capacities

From 8 kW to 500 kW, or even larger, detachable pellet burners from 8 kW to 70 kW.

Regulation ability

All boilers can be operated from less than 30% to 100% of full capacity, without violating emission requirements. The best models can be operated from 10 to 120% of the nominal heat output, according to the manufacturers’ boiler specifications.

Advantages/disadvantages

Advantages

- Biomass boilers provide a reliable heat production, and they use an accessible energy source for homeowners
- A biomass boiler is a means of reducing GHG emissions from residential heat supply
- The extra investment required for a new biomass boiler as opposed to an oil boiler is often limited if the existing oil boiler needed to be replaced anyway
- Biomass for heating purposes is exempted from energy tax in Denmark.

Disadvantages

- Biomass boilers often take up more space than modern wall hung gas boilers and thus require an appropriate boiler room
- Depending on the desired fuel storage capacity room space or an outdoor spot may be required if the storage is not placed underground
- For larger boilers, and in case of firing with other types of fuels than pellets (e.g. straw or wood chips), the labour needed for maintenance must be considered
- For small scale systems, some effort must be put into regular cleaning and ash removal by the owner and, if there is no large fuel storage included in the system, handling of the fuel. A modern boiler would require 5-10 h/y for ash removal [12]
- Local emission of air pollutants e.g., particulate matter.

Environment

Use of high fuel quality and advanced technological combustion concepts ensure that automatic combustion systems are environmentally sound and efficient residential heating technologies. The legislative requirements have been tightened continuously and cover safety, efficiency, emission limits etc.

Secondary emission abatement systems such as electrostatic precipitators have been developed and marketed and are being deployed. In neighbouring countries, boiler investments are subsidised according to the application of secondary abatement systems. This technology might spread to Denmark where we will then see a further decrease in emission levels from future boiler systems.

Research and development perspectives

Biomass boilers with automated stoking have in recent years undergone significant advancements in terms of low emission release, high energy efficiency, user friendliness, system integration as described in [16]. It is now possible to acquire boilers that offer a high automation level in combination with efficiencies as high and emission levels as low as much larger plants – such as large district heating plants. Also, more simple boiler systems are marketed and suit lower budget.

It is fair to assume that biomass boiler system will undergo further development within:

- Further efficiency improvement and low-emission operation
- Automation and comfort
- Improved system design of biomass heating systems
- Hybrid options
- Further cost reduction to improve deployment

Examples of market standard technology

Figure 19: Efficient, integrated 12 kW pellet boiler from Rotec by KS Bioenergi [14]

Figure 20: Integrated 30 kW pellet boiler Phoenix from NBE A/S [15]

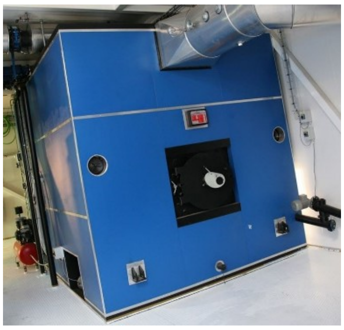

Figure 21: 250 kW pellet boiler for large buildings from LIN-KA [16]

Danish manufacturers of market standard technology can be found on web lists at [4]. The products on this list are boilers tested by the DTI that comply with the latest regulation of biomass boilers.

Prediction of performance and costs

Biomass boilers with automatic stoking are in development and commercially available with a moderate deployment (a category 4 technology).

Price and performance of the technology is today well-known, and only incremental improvements are expected. Therefore, the future price and performance projected is considered to be of fairly high certainty. Hence, technological improvements are expected to be realized without any significant increases in costs.

Use of biomass boilers can be a relevant option for the approx. 500,000 households in Denmark found in rural areas or in areas without legal requirements of connecting to a district heating network or the natural gas grid. Biomass boilers are common in Denmark and in the rest of Europe. In 2023, a survey showed that in almost 100,000 households, an automatically fired biofuel boiler would be the primary heating device [13].

Uncertainty

The cost of smaller units varies and depends on design, brand and options more than on the capacity of the boiler. In general, the prices of small units reflect the level of combustion design and automation meaning the higher automation the higher the costs. Prices of larger-scale units also depend on the fuel flexibility e.g. whether the units only are able to convert wood pellets or also can handle wood chips etc.

As mentioned in the previous section, only incremental improvements are expected and the future price and performance may be projected with high certainty.

Economy of scale effects

The costs vary also with other parameters than capacity. An example from one manufacturer: In small scale, e.g., from 10-50 kW, the unit price less than doubles. The reason is typically that different capacities come in the same physical size with only minor changes to key components. Above that, prices increase in steps.

Additional remarks

Wood pellets are small, compressed pellets made of e.g., wood shavings and sanding dust compressed under high pressure and with none or a maximum of 1% binding agents. Wood pellets have typically a diameter of 6 mm or 8 mm and a moisture content of about 6-8 %. The length varies but is typically up to 5 times the diameter. Wood chips consist of wood pieces of 5-50 mm in the fibre direction, longer twigs (slivers), and a fine fraction (fines). There exist three types of wood chips: Fine, coarse, and extra coarse. The names refer to the size distribution only, and not to the quality.

Quantitative description

See separate Excel file for Data sheets.

References

[1] Vurdering af brændekedlers partikelemission til luften i Danmark, Miljøprojekt nr. 6 2008, Kim Winther, Teknologisk Institut

[2] Emissioner fra træfyrede brændeovne og -kedler, Miljøprojekt nr. 1324 2010, Johnny Iversen, Thomas Capral Henriksen og Simon Dreyer, Carl Bro.

[3] Brændeovne og små kedler – partikelemissioner og reduktionstiltag, Miljøprojekt nr. 1164, 2007, Jytte Boll Illerup, DMU et al.

[4] Listen over godkendte biobrændselsanlæg: Godkendte biobrændselsanlæg - Godkendte kedler https://www.teknologisk.dk/godkendte-biobraendselsanlaeg/39501,2 , Teknologisk Institut, visited July 2025.

[5] Strategic Research and Innovation Agenda for Renewable Heating & Cooling; RHC-Platform 2013; Renewable heating & Cooling; European Technology Platform.

[6] Energibesparelser - det behøver ikke være så svært; Energibranchen.dk, nr. 3, september 2009.

[7] Lot 15: Solid fuel small combustion installations-Base Case definition.

[8] Konvertering fra olie og el til fast biobrændsel; 2012; Videncenter for Energibesparelser

[9] Danish Emission Inventories for stationary combustion plants, inventories until 2011, Scientific Report from DCE n0. 102, 2014

[10] www.bios-bioenergy.at/en/electricity-from-biomass/

[11] Estimate by the Danish Energy Agency and Energinet, 2017

[12] ProBiomass BV, conversation, 2020-10-26

[13] Færre brændeovne, men højere brændeforbrug, Brænde og anden biomasse til opvarmning 2023 https://www.dst.dk/da/Statistik/nyheder-analyser-publ/nyt/NytHtml?cid=54566, Danmarks Statistik, 2023

[14] Roteq, 12 kW pillefyr, https://roteq.dk/. 2020.

[15] NBE A/S, pellet boiler Phoenix, https://www.nbe.dk/rtb-phoenix-dk/, 2020

[16] Linka, 250 kW Boiler. https://www.linka.dk/da/produkter/traepilleanlaeg-250---5000-kw/, 2020

[17] IEA Bioenergy Task 32 Biomass Combustion, Residential Biomass Boiler Systems - State-of-the-art and recent Innovations, June 2025 (Soon to be published on https://task32.ieabioenergy.com/)

205 Biomass boiler manual stoking

Contact information

Danish Energy Agency: Emil de Bekker Steffensen, teknologikatalog@ens.dk
Author: Original chapter from 2016 made by COWI.
Update in 2021 and 2025 by Ea Energy Analyses.

Publication date

2016

Amendments after publication date

Date	Ref.	Description
26-09-2025		Minor update has been undertaken during Q3 of 2025. Primary focus is on data sheets, and text has been revised accordingly.
20-01-2021		Comprehensive update has been undertaken during Q4 of 2020. Primary focus is on data sheets, but text has been revised as well.

Qualitative description

Brief technology description

Modern manually fed boilers for combustion of wood logs typically have downwards draught or down-draught. The principle is that the fuel is heated, dried and gasified in the combustion chamber, after which the gases are led downwards (or down in case of down-draught) through a crevice in the bottom of the combustion chamber into the chamber where combustion takes place during supply of secondary air. This type of boiler is often provided with an air fan for supply of combustion air or a flue gas fan.

Figure 22: Double duty wood log boiler (manual stoking) prepared for mounting of pellet burner (automatic stoking)

Recent developments include a much larger level of automation regarding start-up and operation of these boiler types. Many brands also provide hybrids including a pellet stoker ensuring flexibility and heat supply even when the manual feeding of wood logs is paused.

Older types of boilers are up-draught boilers and do not comply with the current environmental requirements. Manual boilers should be installed with an accumulation tank of appropriate size. A building's heat demand can be covered solely with a manual biomass boiler with a well-insulated accumulation tank.

Input
The input is log wood of different sizes, depending on the boiler. For some boilers, also wood pellets.

Output
Heat for space heating and hot tap water.

Typical capacities
Log wood boilers are available from a few kW up to 100 kW.

Regulation ability
The boilers are installed with a heat storage tank. Few log wood boilers have regulation abilities.

Advantages/disadvantages
Advantages

- A biomass boiler with manual stoking is a simple and robust design
- It provides the opportunity for decarbonizing residential heat supply using local/proprietary resources.

Disadvantages

- Some effort must be put into regular cleaning and ash removal as well as feeding of the fuel. An estimate is 10 h/y for ash removal and cleaning and 50 h/y for fuel handling and feeding (avg. 10 min. per fire)
- Local emission of air pollutants e.g., particulate matter.

Environment
Examinations show that newer boilers with accumulation tanks cause considerably less pollution compared to old up-draught boilers. The legislative requirements have been tightened continuously and cover safety, efficiency, emission limits etc.

Research and development perspectives
Biomass boilers with manual stoking have in recent years undergone significant advancements improving combustion performance in terms of primary and secondary air distribution, combustion control and load control paving the way for low emissions at higher energy efficiency, and with a higher degree of automatic functions providing higher user friendliness.

- Future developments will likely entail improvements along the same lines and potentially also within cost reductions to promote further deployment.

Examples of market standard technology

Figure 23: Recent type 40 kW log wood boiler r counter current combustion**, Vedex 4000 from Vølund Varmeteknik [15]**

Figure 24: 50 kW Solo Innova classic firewood boiler from Baxi [14]

Figure 25 Firewood boiler with advanced gasification/combustion concept S4 Turbo from Fröling [13]

Danish manufacturers of market standard technology can be found on web lists at [4]. The products on this list are boilers tested by the DTI that comply with the latest regulation of biomass boilers.

Assumptions and perspectives for further development

Manually fired biomass boilers are common in Denmark as in the rest of Europe. In 2010, the population of manually fired boilers in Denmark was estimated to 48,000. In 2021, a survey showed that in around 25,000 households, a log wood boiler would be the primary heating device [12].
Costs and performance of the technology is today well-known and only incremental improvements are expected. Therefore, the future price and performance may also be projected with fairly high certainty. Biomass boilers with manual stoking are commercially available with a moderate deployment (a category 4 technology).

Uncertainty

Costs depend on designs and brands as well as the level of automation more than on the capacity.

Economy of scale effects

Biomass boilers with manual stoking are only produced within a very small range of capacity, hence the economy of scale is considered limited if applicable at all.

Additional remarks

Quantitative description

See separate Excel file for Data sheets.

References

[1] Vurdering af brændekedlers partikelemission til luften i Danmark, Miljøprojekt nr. 6 2008, Kim Winther, Teknologisk Institut

[2] Emissioner fra træfyrede brændeovne og -kedler, Miljøprojekt nr. 1324 2010, Johnny Iversen, Thomas Capral Henriksen og Simon Dreyer, Carl Bro.

[3] Brændeovne og små kedler – partikelemissioner og reduktionstiltag, Miljøprojekt nr. 1164, 2007, Jytte Boll Illerup, DMU et al.

[4] Listen over godkendte biobrændselsanlæg: Godkendte biobrændselsanlæg - Godkendte kedler https://www.teknologisk.dk/godkendte-biobraendselsanlaeg/39501,2 , Teknologisk Institut, visited July 2025.

[5] Strategic Research and Innovation Agenda for Renewable Heating & Cooling; RHC-Platform 2013; Renewable heating & Cooling; European Technology Platform.

[6] Energibesparelser - det behøver ikke være så svært; Energibranchen.dk, nr. 3, september 2009.

[7] Lot 15: Solid fuel small combustion installations-Base Case definition.

[8] Konvertering fra olie og el til fast biobrændsel; 2012; Videncenter for Energibesparelser

[9] Danish Emission Inventories for stationary combustion plants, inventories until 2011, Scientific Report from DCE n0. 102, 2014

[10] www.bios-bioenergy.at/en/electricity-from-biomass/

[11] Estimate by the Danish Energy Agency and Energinet, 2017

[12] Brændeforbrug i Danmark 2021- Undersøgelse af brændeforbruget og antallet af brændeovne, pejse, masseovne og brændekedler i danske boliger og fritidshuse, https://ens.dk/media/3923/download, Danish Energy Agency, 2022

[13] Froling, http://www.froling.dk/froeling-produkter/froeling-s4-turbo/s4-turbo/, 2020

[14] HS Tarm https://hstarm.dk/produkter/biokedler/braendekedler/solo-innova/solo-innova-50-lc-mk2 , 2025

[15] Vølund Varmeteknik , https://volundvt.dk/faa-hjaelp/brugervejledninger, 2025

206 Wood stove

Contact information

Danish Energy Agency: Emil de Bekker Steffensen, teknologikatalog@ens.dk
Author: Original chapter from 2016 made by COWI.
Update in 2021 and 2025 by Ea Energy Analyses.

Publication date

2016

Amendments after publication date

Date	Ref.	Description
26-09-2025		Minor update has been undertaken during Q3 of 2025. Primary focus is on data sheets, and text has been revised accordingly.
20-01-2021		Comprehensive update has been undertaken during Q4 of 2020. Primary focus is on data sheets, but text has been revised as well.

Qualitative description

Brief technology description

A wood stove is an enclosed room heater used to heat the space in which the stove is situated. Some stoves are used in connection with ducts and fans that move heated air to other rooms adjacent to the living room. Some stoves are fitted with a water jacket where water is heated for use in radiators in other rooms or in the central heating system of the house. Usually, the wood stove is fired with a batch of 2-3 pieces of new firewood at a time. The refiring typically takes place when there are no more visible flames from the previous basic fire bed, and when a suitable layer of embers has been created. Modern wood stoves have up to three air inlet systems in order to achieve the best possible combustion and to ensure that the glass pane in the front door does not get covered by soot: primary air up through the bottom of the combustion chamber, secondary air as air wash to keep the combustion alive and to maintain the glass clean, and tertiary air in the back of the combustion chamber for after-burning of gases. Some stoves need to have the air inlet dampers manually adjusted in connection with each new fired batch (maximum 3-5 minutes after each charge); others are more or less self-regulating.

Figure 26: Wood stove

The chimney serves as the motor of the stove and is essential to the functioning and performance of the stove. The chimney draught draw air through the air dampers to the combustion chamber. Recent developments include a more common use of suction fans to ensure the draught in all weather conditions and thus an efficient combustion process at the lowest emission levels.

Heat from a wood stove is usually a supplement to other kinds of heat supply. The biannual firewood consumption survey from the Danish Energy Agency assesses the average wood consumption in stoves in Danish households. In 2021, the average consumption was 19 GJ [10].

Some stoves are fitted with an integrated boiler and can be connected to the central heating system and thus cover a larger percentage of the heat demand.

Input

Wood logs of different species such as beech, birch and pine wood. The moisture content should be of 12 to 20 %, and the size of the wood logs depends on the stove but usually about 250 to 330 mm with a weight of 700 to 1000 g.

Output

Space heating by convection and radiation. If the wood stove includes a water tank, it can also produce a certain amount of hot water to be used in radiators elsewhere in the house or to produce hot tap water.

Typical capacities

Typical capacities are 4 to 8 kW nominal output. In recent years smaller stoves have been developed to match the heat demand in modern energy efficient houses and to prevent overheating.

Regulation ability

By regulating the air dampers, the stove's heat output can be minimized or maximized within a few minutes, however, this can result in an increased emission level.

Advantages/disadvantages

Advantages

- Wood stoves are usually independent of electricity supply
- Can supplement primary heating unit, which in turn can reduce the dependency of the primary heating supply.
- It provides the opportunity for decarbonizing a part of the residential heat supply using local resources. Some users have the opportunity to gather firewood at low cost from their own premises at no cost apart from labour

Disadvantages

- Effort must be put into handling of the fuel wood and feeding the unit
- Potential effort to be put into gathering wood. As the stove is typically just a supplement, this work is often seen as a hobby more than a duty. Some argue that firewood provides heat three times: chopping, stacking, firing

- High level of local emission of air pollutants e.g., particulate matter. Potentially also immission of particles indoor due to operation of stove.

Environment

Woodstoves emit a high level of air pollutants e.g. particulate matter at local level.

Air pollution from wood stoves is dependent on series of factors such as stoking conduct, the individual stove design, the controlling of the combustion and the chimney in relation to the surrounding topography. The chimney is the engine for the combustion, and where the draught is an essential part of how much air is reaching the combustion, this can be affected by the height of the chimney, and the surroundings e.g. other buildings, hills, forests as well as wind and wind direction. If the draught is not sufficient, it will lead to poor combustion and higher emissions. A solution may be to install a draught stabiliser - a fan - that provides a stable draught and greatly improves the combustion while reducing emissions.

Apart from the mandatory EU energy label**Fejl! Henvisningskilde ikke fundet.**, different voluntary environmental labelling schemes of woodstoves exist e.g., the Blue Angel (DE) and the Nordic Swan-labelling. The Swan label emerged in 2005, is well accepted and can be seen as the consumer guarantee that the stove meets certain environmental requirements. Still, the emission from a modern wood stove is much higher than from gas, oil or biomass boilers.

R&D is going on nationally and internationally to improve the design of the combustion physiology as well as to develop secondary measures to abate emissions such as electrostatic filters. Optimal stove design is described in a design guideline from IEA Bioenergy Task 32 Biomass Combustion [16]. Electrostatic filters are supplied by a few suppliers but are becoming standard in neighbouring markets [12].

In 2021, the Danish Change of Ownership Order (BEK no. 1449) [13] came into force. This regulation stipulates that wood-burning stoves and fireplace inserts manufactured before 1 January 2003 must be replaced or removed when a property is sold or changes ownership. The regulation applies to wood stoves and fireplace inserts with a capacity of up to 1 MW. Importantly, there are currently no exemptions from this requirement, even if the appliance is fitted with a particle filter.

In 2023, an announcement on municipal regulations for the replacement or scrapping of older wood stoves and fireplace inserts in areas with collective heat supply came into force, allowing municipalities with collective heat supply to set requirements about replacement or scrapping of wood-burning stoves and fireplace inserts installed before 1 June 2008 [14], [15].

The ecodesign regulation for solid fuel boilers **Fejl! Henvisningskilde ikke fundet.** sets the minimum level for emissions, applies throughout the EU, and has been in force for new boilers since 2020. The Danish wood stove statutory order (latest update 2022) applies to new installations and replacements in Denmark, is based on (or matches) the ecodesign regulation for emission limits, and may include additional or stricter local requirements on emissions. **Fejl! Henvisningskilde ikke fundet.**.

Research and development perspectives

There is a continuous need for development of stoves with the purpose of reducing the particle emissions and design of stoves with lower capacity suited for low-energy houses. Recent developments have had a tremendous effect on emission levels as it has been shown in a Task 32 fact sheet [17]. Stoves are now capable of reaching very low emissions. Achieving these levels requires careful operation (probably including user education) with specific focus on air control and refueling patterns etc. and/or further automation. Please see more about emission abatement above.

Examples of market standard technology

Some Danish manufacturers produce swan-labelled products, a list of which can be found at [6].

The swan label is a voluntary agreement, and labelled stoves must comply with relative stringent efficiency and emission requirements.

Figure 27: Morsø 6843 wood stove, swan-labelled. [7]

Figure 28: Lend wood stove with 8,7L water tank. 7-15kW. efficiency 80%. [8]

Figure 29. Hwam 30/55s insert with advanced control system

Prediction of performance and costs

Wood stoves are commercially available with large deployment (a category 4 technology). Wood stoves are widely used in Denmark, and the number of installed stoves is around 700,000 [10]. Price and performance of the technology is well-known today, however, significant improvements with respect to emission performance are expected due to improved design of combustion chamber topology and combustion air supply control as well as draught stabilisation and secondary emission abatement measures such as an electrostatic filter. The societal attention as to emission of particles can be seen as a driver of this development. The technologies are closer to the market and are being implemented in neighbouring countries like Germany. Thus, it can be expected that the future performance will improve and - as a consequence - that the investment cost will increase.

Uncertainty

Prices vary very little with the capacity of the stove compared to the variation that is related to designs and brands. Price and performance of the technology is well known today. It is however expected that from 2030 more automatic stoves will be marketed to overcome the legislation and future demands as mentioned above. Therefore, an increment in investment is expected. After this period, it is expected that the technology becomes generic and as a result of mass production investments are expected to drop somewhat again.

Economy of scale effects

Wood stoves are only produced within a very small range of capacities, hence it is not relevant to talk about economy of scale.

Additional remarks

Wood stoves without integrated boilers / heat storage will currently often be oversized for use in new low energy houses. However, they can be used for peak load and for heating up the building after the room temperature has been lowered e.g., during holidays. Units with lower capacity have been developed.

Quantitative description

See separate Excel file for Data sheets.

References

[1] Brændeovne og små kedler – partikelemissioner og reduktionstiltag, Miljøprojekt nr. 1164, 2007, Jytte Boll Illerup, DMU et. al.

[2] Emissioner fra træfyrede brændeovne og -kedler, Miljøprojekt nr. 1324 2010, Johnny Iversen, Thomas Capral Henriksen og Simon Dreyer, Carl Bro.

[3] Lot 15: Solid fuel small combustion installations-Base Case definition.

[4] Danish Emission Inventories for stationary combustion plants, inventories until 2011, Scientific Report from DCE n0. 102, 2014

[5] http://www.ecolabel.dk

[6] https://www.svanemaerket.dk/en/products/wood-stove-pt100067

[7] Morsø, https://pejsen.com/produkt/braendeovne/morsoe-braendeovne/morsoe-6843-braendemagasin/?gclid=Cj0KCQjwreT8BRDTARIsAJLI0KL5yvWUCZ99w83ZEKGyk4TIMB2fnVBipCtAYVvPTseTOtnCBKBjO1caAtuUEALw_wcB, 2020

[8] Stendesign.dk. https://www.sten-design.dk/shop/braendeovne-med-vandtank-145/lend-braendeovn-med-vandtank-7-15-kw-5-forskellige-farver/. 2020

[9] Hwam, http://www.hwam.dk/hwam-i-30-55s.html

[10] Færre brændeovne, men højere brændeforbrug, Brænde og anden biomasse til opvarmning 2023 https://www.dst.dk/da/Statistik/nyheder-analyser-publ/nyt/NytHtml?cid=54566, Danmarks Statistik, 2023

[11] Statutory Order no. 199 of 2022 on Wood-burning Stoves and Wood-fired Boilers, https://www.retsinformation.dk/eli/lta/2022/199

[12] Workshop on residential heating, IEA Bioenergy Task 32 Biomass Combustion, January 22nd 2020, Graz, Austria, http://task32.ieabioenergy.com/ieaevent/iea-workshop-residential-wood-combustion/

[13] Ordinance on the replacement or abandonment of certain solid fuel combustion plants under 1 MW by change of ownership of real estate. https://www.retsinformation.dk/eli/lta/2021/1449, Danish Ministry of the Environment, 2021

[14] Executive Order on Municipal regulations on the replacement or dismantling of older wood stoves and fireplace inserts in areas with collective heating supply, 2023. https://www.retsinformation.dk/eli/lta/2023/64

[15] Inventory of National Strategies for Reducing the Impact on Air Quality from Residential Wood Combustion, https://task32.ieabioenergy.com/wp-content/uploads/sites/24/2025/05/National-Strategies-Report-Air-Quality-Residential-Wood-Combustion_2nd-edition2025.pdf, IEA Bioenergy, Task 32, May 2025

[16] Design of Low Emission Wood Stoves – Technical guidelines, IEA Bioenergy Task 32 Biomass Combustion, October 2022, https://task32.ieabioenergy.com/publications/design-of-low-emission-wood-stoves-technical-guidelines/

[17] IEA Bioenergy Factsheet: Residential solid biofuels combustion – continuous improvement over time, IEA Bioenergy Task 32 Biomass Combustion, January 2025, https://task32.ieabioenergy.com/publications/iea-bioenergy-factsheet-residential-solid-biofuels-combustion-continuous-improvement-over-time

[18] Danish Technology Institute, interview 2020-10-26

[19] Solid Fuel Boilers- Energy labelling and ecodesign requirements apply to this product, https://energy-efficient-products.ec.europa.eu/product-list/solid-fuel-boilers_en

207 Electric heat pumps, air-to-water, brine-to-water, air-to-air and ventilation

Contact information

Danish Energy Agency: Emil de Bekker Steffensen, teknologikatalog@ens.dk
Author: Original chapter from 2016 made by PlanEnergi.
Update in 2021 and 2025 Ea Energy Analyses

Publication date

2020

Amendments after publication date

Date	Ref.	Description
26-09-2025		Update has been undertaken during Q3 of 2025. Primary focus is on data sheets, and text has been revised accordingly. Data for low price heat pump removed
24-08-2022		Updated the chapter to more clearly convey the SCOP value
24-06-2021		Capacity of heat pumps have been revised to match heat capacity assessed at -7/55 °C
20-01-2021		Comprehensive update has been undertaken during Q4 of 2020. Data for low-price air-to-water heat pumps added.

Qualitative description

Brief technology description

Heat pumps are utilized for individual space heating, industrial processes, and district heat production.

Heat pumps employ the same technology as refrigerators, moving heat from a low-temperature level to a higher temperature level. They draw heat from a heat source (input heat) and convert the heat to a higher temperature (output heat) through a closed process. There are two main technology groups: compression heat pumps powered by electricity and absorption heat pumps powered by thermal energy from, for example gas. In the Danish individual heating sector today, generally only electric compression heat pumps are utilised, thus this chapter will focus on the different types of compression heat pumps commonly installed in Denmark today. The different types of heat pumps differ mostly with regard to the medium from which they absorb heat, for example ambient air or the ground, and the medium they deliver heat to.

The main advantage of heat pumps is their ability to provide more heat than electricity consumed. The energy flow is illustrated in the Sankey diagram in Figure 30. The heat delivered to the building is the sum of the heat absorbed from the environment and the electrical energy added. The heat pump efficiency, also called "Coefficient Of Performance" (COP), can be calculated by the formula below.

$$COP = \frac{Delivered\ heat}{Electricity\ consumed} = \frac{6\ kW}{2\ kW} = 3$$

The COP denoted by the heat pump producer is often in the interval 3-5, meaning they deliver 3-5 times more heat energy than electricity consumed.

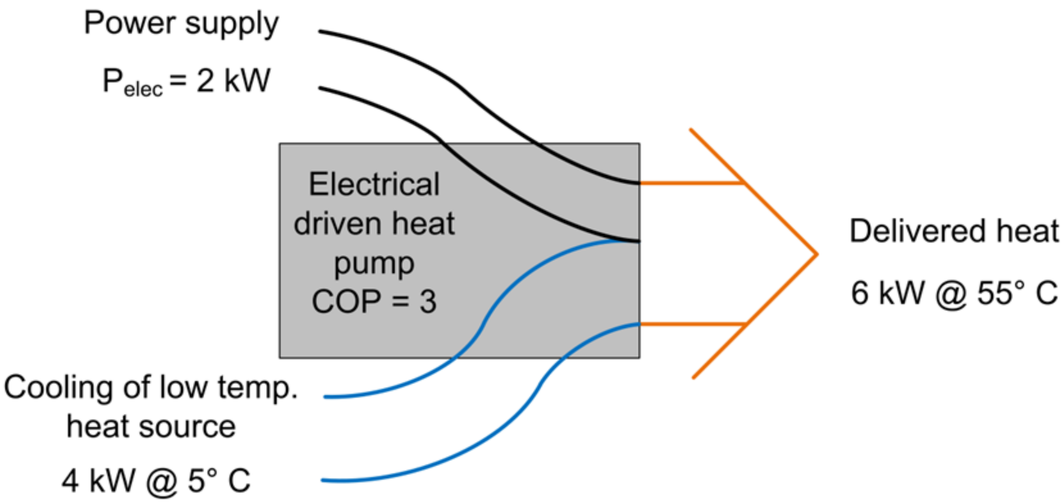

Figure 30 Sankey diagram for a heat pump.

The temperature difference between the temperature of the heat source and the temperature level of the heat delivered influences the COP. When the difference in temperature between the heat source and heat delivery decreases, the COP will increase and vice versa. This implies that the COP will vary according to the season – a low outdoor temperature implies a higher temperature difference, and a high outdoor temperature implies a low temperature difference. Likewise, the efficiency of a heat pump is also higher with lower delivered temperature, meaning a heat pump combined with floor-heating will generally have a higher efficiency than a heat pump combined with radiators.

The COP is the efficiency in certain predetermined operating conditions, but when considering the efficiency in an annual context, it is more correct to consider the *Seasonal Coefficient of Performance* (SCOP). The SCOP is calculated as defined in the European standard EN14825 [7] and expresses the weighted average annual efficiency. It takes the annual temperature variations and temporal correlation with the heat demand into account.

The following will present the main differences between different types of heat pumps.

Air-to-water heat pumps draw heat from ambient air using an outdoor unit. The heat from the ambient air is boosted by the heat pump and supplied as heat through a water-based heat distribution system (radiator, floor heating). Air-to-water heat pumps are also capable of providing the full demand of domestic hot water, as newer heat pumps can deliver the necessary temperature without the use of direct electric heating in the water tank. This is due to technological development during recent years allowing heat pumps to heat water to 55-65°C. The necessary temperature of hot domestic water is 55°C to eliminate bacterial growth such as Legionella in the hot water storage tank. Figure 31 is an illustration of a typical heating system based on an air-to-water heat pump.

Newer heat pumps still include direct electric heating, to assist the heat production if needed. The air-to-water heat pump is generally dimensioned to cover 95-98 % of the total heat demand and the remaining heat is provided by an electric water heater. This results in a more cost-effective solution while also providing security of supply in unusually cold periods or if the heat pump should suffer technical challenges. The electric water heater in a 7 kW heat pump defined at -7/55 degrees, typically has a capacity of 9 kW [10].

Several manufacturers now offer air-to-water heat pumps – particularly models designed for the Nordic market – with technologies such as Enhanced Vapor Injection (EVI) or, in the case of Panasonic, T-CAP. These solutions enable the unit to maintain full or near-nominal heating capacity at low ambient temperatures, in some cases down to –20 °C or below. This can reduce the need for supplementary heat from direct electric heaters during colder periods, although electric backup will still be required in extreme cold or during defrost cycles.[28],[35].

Air-to-water heat pumps can be split into two groups: monobloc and split units. In a monobloc unit all components related to the heat pump cycle are grouped inside a heat pump unit situated outside the home. This includes the compressor, the refrigerant, etc. Two pipes carry either water or a mixture of water and antifreeze between the outdoor unit and the indoor unit. The indoor unit contains the hot water tank, expansion tank, and all components related to storing heat and interaction with the heating system.

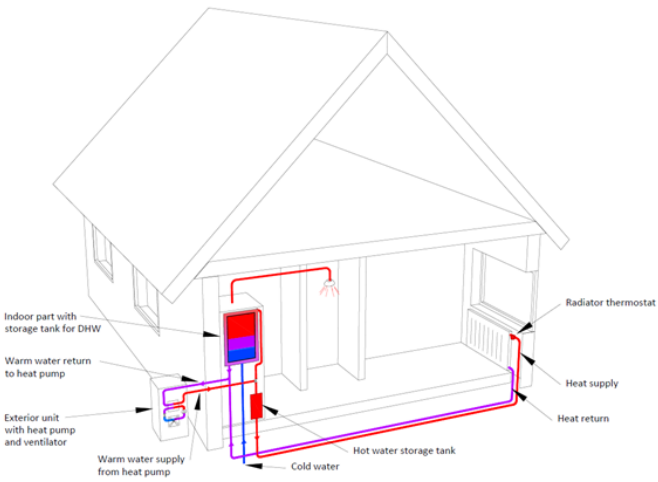

Figure 31 Illustration of a heating system based on an air-to-water heat pump (monobloc).

A split heat pump system consists of an outside unit, containing the heat exchanger, and an in-door unit, where refrigerant lines connect the outdoor unit and the indoor unit. In this type of system, the components related to the heat pump cycle are split between the indoor and outdoor unit.

The benefit of a monobloc configuration is that it comes with a fully charged refrigeration system, which means that there is no need to connect refrigerant lines and add refrigerant on site. The disadvantage is that the water in the outside piping and condenser presents a risk of freezing if the circulation should stop. This is unlikely though.

Generally, there has been more focus on improving the outdoor unit of a monobloc system, compared to split units, and therefore monobloc units typically generate less noise and are of higher quality.

A new type of air-to-water heat pump, known as "full mono," is gaining popularity in Denmark. This compact system is well-suited for smaller houses with limited indoor space. In a full mono design, key components typically located indoors—such as the circulation pump, electric backup heater, and expansion vessel—are integrated into the outdoor unit. As a result, only minimal indoor installation is required, usually a hot water tank and a few valves or small buffer tanks.

Heat pumps are not normally dimensioned with sufficient heating capacity to instantaneously provide heat for domestic hot water. For that reason, a heat pump for a typical one-family house would be equipped with a roughly 200 litre water tank which is sufficient to supply four people with hot water.

In some cases, an additional water tank, also called a buffer tank, is installed, to increase the volume of water to be heated for space heating and thereby limiting the number of starts and stops of the heat pump. Even though modern heat pumps are normally inverter-based and able to operate at 20-30 % of their nominal load there may be low load periods with many start-ups. Adding a buffer tank may improve the efficiency and diminish the wear on the heat pump. The buffer tank would typically be dimensioned with a capacity of around 10 litres per kW of heat capacity. [8]

In Denmark, it is possible to acquire an air-to-water heat pump on subscription, where the consumer does not own the heat pump but instead pays per kWh of heat used. [19]

Air-to-water heat pumps also provide a relevant heating option for large buildings and building complexes. These solutions are typically more tailored to the specific needs of the building, and therefore less standardized. Often installers would design a heat pump solution for a large building as a cascade system based on several smaller single-house family size units. In such a system the cost of the outdoor units would be proportional to the cost of smaller sized systems, but the cost of the indoor unit and the water tank would be proportionally lower. For heat demands up to 60–80 kW, standard residential air-to-water heat pump models are often installed in cascade configurations. This approach allows multiple smaller units to operate together, making it suitable for applications such as small commercial buildings or multi-family housing. For larger systems, modular heat pump units in the range of 40–110 kW are commonly used. These can be combined to deliver total capacities of up to 400–500 kW, and in some configurations, up to 1.2–1.4 MW. Beyond this scale, technologies similar to those used in district heating systems are typically applied. These often utilize alternative refrigerants, such as CO_2, to handle the higher capacity requirements efficiently.

Large consumers are more likely to opt for hybrid solutions that combine a heat pump with an existing gas boiler. This approach can help reduce upfront investment costs, in particular if sufficient ampere is not available for the electric boiler providing supplementary heat on very cold winter days.

Brine-to-water heat pumps, often called ground-source heat pumps, absorb heat from the ground using a collector consisting of an underground hose/pipe circulating anti-freeze brine. The liquid absorbs heat from the ground which is boosted by the heat pump. The heat is delivered to the indoor unit which in turn is connected to the water-based heating system (radiators, floor heating, etc.) in the house.

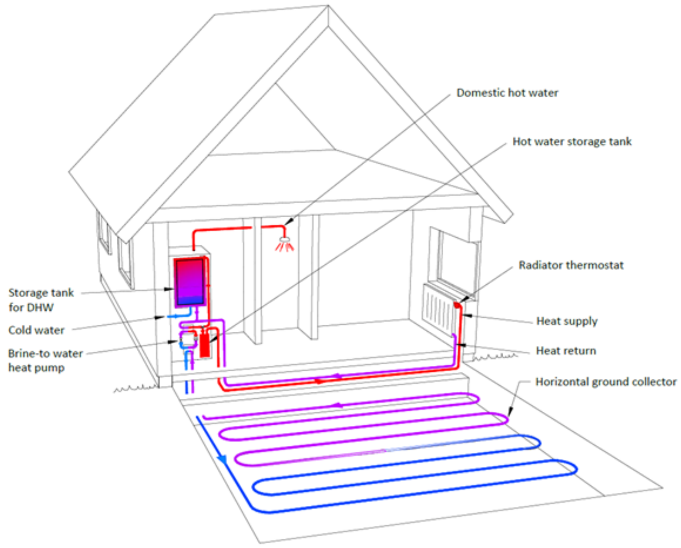

Figure 32 Illustration of a heating system based on a ground source heat pump (horizontal collector).

There are generally two types of collectors ground-source heat pumps can employ: 1) The horizontal collector and 2) the vertical collector, where the horizontal collector is most common and typically the least expensive option, but also requires more space.

The horizontal collector consists of tubing running horizontally at a frost-free depth, where the temperature is relatively stable throughout the year. The longer the collector, the more energy can be absorbed from the ground.

A vertical collector consists of holes drilled vertically deep into the ground and for that reason, it does not have the same space requirements and provides a relevant alternative in densely populated areas. A typical house will require a pair of vertically drilled holes with a depth of 120-160m. Generally, the vertical solution is more expensive than a horizontal collector because the drilling requires a specialist and a drilling rig. This type of collector is also largely affected by the geological properties of the ground. The approval procedure for vertical collector systems is typically longer than for other heat pumps solution due to potential conflicts with drinking water abstraction.

Like air-to-water heat pumps, a ground source heat pump is capable of providing the annual demand of heat and domestic water, but usually the heat pump is dimensioned to provide 95-98% of the annual heat demand, where the heat output is boosted by an electric water heater during the coldest hours. This results in a more cost-effective system.

Ground-source heat pumps are also installed with a water tank, because like air-to-water heat pumps, they are generally not dimensioned with sufficient heat capacity to instantaneously provide the hot water during peak demand.

Ground-source heat pumps can also be used to provide the heat demand of larger buildings, including apartment complexes.

Air-to-air heat pumps draw heat from the ambient air, and supply heat locally through an air heat exchanger. Most air-to-air heat pumps have one outdoor unit and one indoor unit and are often referred to as "split-units". This configuration means that the heat pump can only supply heat at one location in the house and that larger coverage requires an air circulation system or that the doors to adjoining rooms are open.

However, multi-split air-to-air heat pump systems, with more than one indoor unit, for example, 2–5 indoor units placed in different rooms, are also available and can be seen as a mature technology, although they are not yet common in Denmark. This technology could be particularly relevant for low-energy houses, and for buildings without water-borne heating systems, multi-split air-to-air heat pumps offer a more energy-efficient alternative to direct electric heating with panel heaters.

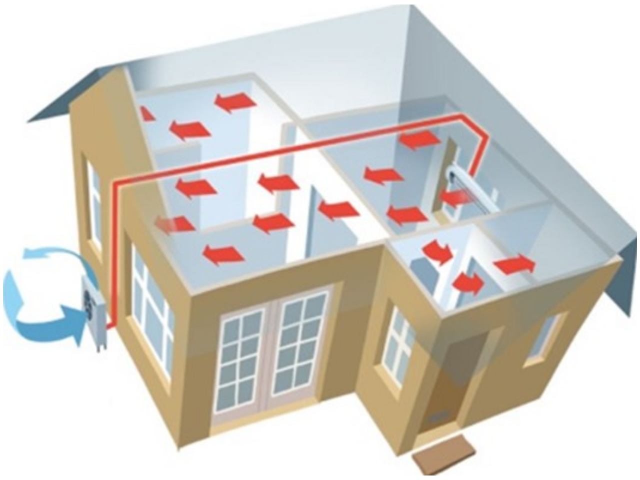

Figure 33 Illustration of a heating system based on an air to air heat pump.

The amount of heat demand which an air-to-air heat pump can supply is highly dependent on its location in the building and the building design. For buildings with large rooms and good air circulation, the heat pump may be able to supply 30 % of the space heating demand, in most buildings the share of the total heat demand is limited by separations within the building which prevent circulation of the hot air. It is possible to install multiple indoor units at different locations in the building, which of course can increase the share of the heat demand which can be provided. Either way, it is not expected that an air-to-air heat pump can provide the full heat demand in a standard building, thus, requiring additional heating.

Air-to-air heat pumps cannot provide hot domestic water and therefore it is always necessary to have another technology installed for this, for example an electric boiler. Often air-to-air is installed as an auxiliary heating unit in combination with an existing primary source of heat, for example a boiler using biomass, gas or oil.

Typically, air-to-air heat pumps are reversible meaning that they can also be used for cooling (air-condition), and it is expected that a portion of installed units are acquired with the intention of primarily using them for air-conditioning.

Air-to-air heat pumps are very common in summer houses, where the main heat is provided by the heat pump and the domestic hot water is provided by an electric water heater. This is due to the fact that many summer houses historically were built with electric heating, where the heat pump is a more economical solution which can also provide cooling.

Ventilation heat pumps, also called exhaust air heat pumps, draw energy from ventilation outlet air and heats up the air intake in the ventilation system or the hot tap water. These heat pumps therefore utilize heat that otherwise would have escaped the building. In theory, a ventilation heat pump can be either air-to-air, air-to-water or a combination of both, but the most common are air-to-water, where the heat is used to produce domestic hot water .

The heat pump can heat the inlet air to a level providing more heat than the ventilation heat losses and can thereby compensate for the transmission loss to some extent. Depending on the ratio between transmission heat losses and ventilation heat losses, this type of heat pump might require a supplementary heat source to cover the heat demand all year around and to make individual room regulation possible.

There are also systems which can be installed in a bathroom, where there is excess heat. This type of system then takes heat from the air in the room and produces hot water but is not a standalone solution. This type of system is typically seen in summerhouses.

The data provided in this catalogue concerns, for one family houses, only ventilation heat pumps used for production of domestic hot water. For apartment buildings data are provided for combination of space heating and domestic hot water production.

Figure 34 Illustration of a heating system based on a ventilation heat pump.

Input

All heat pumps use electricity as an input.

air-to-water and air-to-air compression heat pumps use heat from the ambient air as an input,

ground-source heat pumps use heat absorbed from the ground as an input, and

ventilation heat pumps use excess heat from the building as an input.

Output

Air-to-water and ground-source heat pumps provide domestic hot water and water for heating.

Air-to-air heat pumps provide heated air for space heating.

Ventilation heat pumps usually provide domestic hot water and in some cases space heating as well.

Typical capacities

Air-to-water and ground-source heat pumps typically range from approximately 3-4 kW up to several hundred kW heating capacity, covering the needs for both space heating and domestic hot water in both low-energy buildings and other buildings. Water based heat pumps are normally designed to cover between 95 % and 98 % of the heat demand. The remaining demand would be covered by an electric heater, which is integrated in the indoor unit of the heat pump.

Typical heating capacities for single air-to-air heat pumps are 2-8 kW, which may cover approx. 30% of the space heating demand in a single-family house.

Ventilation heat pumps heating capacities range from 1.5 kW in single family houses to several hundred kW in large office buildings. In private households, the heating capacity is normally up to 3 kW.

Regulation ability

All heat pumps have on/off regulation and many modern heat pumps are also equipped with capacity regulation, using electronically controlled expansion valves, meaning that the heat pump can balance the heat production to the demand continuously down to around 20-30 % of maximum capacity.

The efficiency and lifetime will decrease with increasing numbers of starts and stops and therefore the operation strategy of a heat pump over time has influence on the overall energy consumption and economy. Correct dimensioning and utilization of storage tanks is important to ensure the highest efficiencies. Heat pumps with capacity regulation are more dynamic and operation at partial load allows them to limit the number of starts and stops.

Advantages/disadvantages

Heat pumps are much more energy efficient than electrical boilers and direct electrical heating. Integration of more heat pumps supports the shift towards electrification. A disadvantage of this is an increased strain on the local electric grid.

Environmental impacts are mostly described in the section Environment.

Specific for air-to-water heat pumps:

Air-to-water heat pump can deliver the full heat demand of a building and can therefore directly replace any existing heating system with a water-based distribution system. According to experience among installation companies, there are only few buildings where a heat pump is not technically able to deliver the full heat demand, and in some buildings, it may be necessary to make some changes to the heat distribution system, for example swapping older radiators to newer models. Typically, this concerns larger, older single-family houses or villas with poor insulation, large floor areas, and only limited energy renovations.

Air-to-water heat pumps are easy to install compared to ground-source pumps and do not have large space requirements. The total time requirement for installing a heat pump is estimated at 32-40 hours and the installation typically takes 1.5-2 days with two workers in 2025.

The indoor unit is generally slightly larger than a standard cupboard (60 x 60 cm), meaning it can fit into most utility rooms in place of the previous heating installation, but this can also pose an issue in houses with limited space, especially if the house is converting from a gas boiler which is generally smaller. Furthermore, heat pump installations may require a buffer tank, further increasing the space requirement.

The outside unit of the air-to-water heat pump can generate some noise. During the past 10 years, technological development has greatly reduced the generated noise for example by increasing the size of the fan and decreasing its speed. New units today generate noise in the range 45-70 dB, where the cheaper units generally produce more noise. 60 dB corresponds to a normal conversation while 50 dB corresponds to a quiet office. An increase of 6-10 dB is generally perceived as a doubling of the sound. Therefore, modern heat pumps generally have a noise generation which will not bother most people. However, incorrect installation can greatly increase the noise generation, for example if the piping is under-dimensioned. An under-dimensioned heat pump will also produce more noise because it will operate close to maximum load more frequently.

It should be noted that a heat pump generates most noise while de-icing, which is only necessary infrequently and only during the winter when people are mostly indoors. During warmer months, the heat pump only produces hot water for domestic use and is therefore much less active.

Air-to-water heat pumps are generally associated with a significantly higher investment than competing technologies which can be a deterrent for some consumers, even though the annual cost is significantly lower. The ability to acquire a heat pump on subscription can appeal to consumers who cannot or do not want to pay the full investment cost of the heat pump.

The aesthetics of the outdoor unit can also be a deterrent for some consumers. The demand for better aesthetics is high and many producers today give priority to the design of the unit.

Lack of competition for heat pumps for larger buildings can result in higher prices. This is caused by the fact that the systems for larger buildings are generally designed for the specific needs of the given building and there are few companies with these competencies today. The focus of the market has to a large degree been on heat pumps for smaller buildings, however interest in heat pumps for large buildings is expected to rise. Mass-production of larger heat pumps (>50 kW) and the introduction of new players on the Danish market hold a potential to lower prices of heat pump solutions in large buildings.

Especially large existing buildings may not have sufficient ampere available for a heat pump installation including the electric boiler for supplementary supply in very cold winter days. Acquiring enough ampere can therefore increase the investment costs for some buildings [11].

Specific for ground-source heat pumps:

Like air-to-water heat pumps, ground-source heat pumps can deliver the full heat demand of a building and can therefore directly replace any existing heating system with a water-based distribution system. The indoor unit is generally slightly larger than standard cupboard (60 x 60 cm) but some heat pump installations may require a buffer tank, further increasing the space requirement.

Ground-source heat pumps, unlike air-to-water heat pumps, do not have the same issue with noise, because the outdoor unit is replaced by underground pipes and/or hoses, which cannot be seen or heard. Instead, the ground-source heat pump has a disadvantage regarding space requirements. A horizontal collector requires a large enough property and that this area can be partially dug up under installation. The size of the collector depends on the specific conditions but suppliers report that the required length of the hose in meters is typically double the area of the house in square meters, but generally never less than 400 m^2 for a household [10]. And a common rule of thumb is that about 1 meter of ground hose can be installed per square meter of land, so 100 meters of ground hose typically requires about 100 m^2 of available area. In Denmark, in general the annual heat extraction from a typical ground hose is approximately 40 kWh per square meter. For larger buildings, the required area can be substantial. An 8,000 m^2 apartment complex would by this standard require an area of 125 m by 125 m (approximately 1.6 ha). Newer and/or better insulated buildings may need a smaller collector while older building may need a larger collector. The vertical collector requires less space but is more expensive and more difficult to repair.

The ground source heat pumps access a more stable heat source, with a temperature above freezing, which means the COP is also more stable, and the annual average COP will generally be higher than that of an air-to-water heat pump.

Furthermore, the absence of freezing temperatures means that the heat pump is exposed to less strain, which is reflected in the expected lifetime. Ground-source heat-pumps generally experience fewer problems over their lifetime, and suppliers have examples of systems from the 1980s still operating.

Ground-source heat pumps, like air-to-water heat pumps, require a substantial investment. They are generally more expensive than air-to water heat pumps, but due to the absence of noise and potential for better performance, this can still be an attractive option for some buildings.

Specific for air-to-air heat pumps

Unlike air-to-water and ground-source heat pumps, air-to-air heat pumps have the disadvantage that they cannot provide the full heat demand and must be combined with another heating installation. The owner must therefore maintain and service both heating installations.

Like air-to-water heat pumps, air-to-air heat pumps have an outdoor component that some consumers might find unsightly. This outdoor unit can generate some noise, but the level is highly dependent on the specific product type and quality. Some people will also find the noise from the indoor unit due to the exchange of air by the fan uncomfortable.

The main reasons for the large number of installed air-to-air heat pumps are low investment costs, easy installation, and high efficiency. Air-to-air heat pumps do not require anything of the existing heating system and can be installed in both houses with electrical heating and a water-based distribution system. A drawback of the air-to-air heat pump is that, unless it is installed as a multi-split unit, it is only able to deliver heat in a single location of the house.

Since the air-to-air heat pumps deliver heated air at lower temperatures than the ground-source and air-to-water heat pumps, they generally have a higher SCOP.

Ventilation

The ventilation heat pump considered in this catalogue is only applicable in houses with a ventilation system. In old houses with uncontrolled ventilation due to air infiltration, this technology will not be suitable. In new and more airtight houses, ventilation systems are often applied, meaning that ventilation heat pumps could be a suitable solution.

A disadvantage of ventilation heat pumps is that the heat capacity is limited by the heat that can be drawn from the exhaust air, and they can generally therefore not supply the full heat demand and must be combined with another heat source. This has the disadvantage that the owner must maintain and service both heating installations.

Environment

The environmental impact of heat pumps relates mainly to power consumption, the potential of leaking of synthetic refrigerants and noise.

- Heat pumps no direct emissions during operation.
- The environmental impact due to the use of electricity will depend on the way the electricity is produced.

Refrigerants:

Newer heat pump models for individual heating in Denmark mainly use propane (R290), R32, or R410A as refrigerants, due to the current F-gas regulation. Due to stricter EU F-gas regulations taking effect from 2027, only propane (R290) fully complies with the new requirements for small systems (GWP < 150). R32 and R410A do not meet this threshold and will not be permitted in new products after 2027. Manufacturers are therefore increasingly switching to R290 to ensure compliance with upcoming rules.

In addition to a very low GWP, R290 has the advantage that the gas itself is cheap and that propane systems can supply temperatures up to 75 degrees.

A few years ago, almost all heat pumps for individual heating on the Danish market used synthetic coolants. These are known as HFC's (hydrofluorocarbons) which are fluorinated gases (F-gases), which possess a potent greenhouse effect and are covered by the Kyoto Protocol. There are many different refrigerants based on HFCs.

Five to ten years ago the most common refrigerants based on HFCs had Global Warming Potentials (GWP) of about 1,500 to 4,000.

The Danish Safety Technology Authority (Sikkerhedsstyrelsen) has updated the regulations for mandatory servicing of heat pumps. The requirements now depend on the amount of refrigerant in the system:

- Up to and including 3 kg: No mandatory service inspection
- Between 3 and 5 kg: Mandatory inspection every two years
- Above 5 kg: Mandatory annual inspection

In practice, this means that the vast majority of air-to-water heat pumps currently sold are not subject to mandatory servicing requirements.

Typical R290 refrigerant charges are:

- Approx. 1 kg for systems up to 7–8 kW (at –7 °C)
- Approx. 1.6 kg for systems up to 16 kW

As a result, most air-to-water and ground-source heat pumps used in single-family houses and small buildings fall below the threshold for mandatory inspections under the current regulation.

Because of the GWP of synthetic refrigerants, leaks must be avoided. According to a report by the Ministry of Environment, the total refrigerant in heat pumps in Denmark corresponds to approximately 700,000 ton CO_2 of which the report assumes there is an average leakage of 3% each year [18]. The risk of leakage is higher with split-unit systems, where the refrigeration cycle is assembled on-site as well as from older units. In monobloc heat pumps, the refrigeration cycle is assembled during its production and connections are welded together and tested for leaks. Producers test monobloc systems for leaks and these will generally only leak if physically damaged. There is a risk of leakage when disassembling a heat pump system and the refrigerant should be discarded correctly.

Noise:

Air-to-air and air-to-water heat pumps have an outdoor unit which generates some noise. The indicative maximum noise level is 35 dB during night and max 45 dB during the day measured at the property boundary[36]. Since most heat pumps generate more noise than this, they must generally be placed at some distance from the boundary. The amount of noise generated is correlated with the quality of the heat pump, where low-end heat pumps must be placed farther from property boundaries to adhere to regulations. Heat pumps with low noise can generally be placed within 3-4 meters of the property boundary. The best units on the market today are quieter (40 dB)[30] than five years ago (52 dB).

Additionally, the EU ecodesign regulation of heat pumps [16] includes specification of maximum noise from the heat pump itself. This is a focus of the industry and large improvements are expected.

Ground-source heat pumps do not generate noise from the outdoor unit.

Research and development perspectives

Figure 35 shows the sale of different types of heat pumps since 2009. It is seen that especially the sale of air to water heat pumps has increased significantly. From around 2017, air to water heat pumps is the most commonly sold heat pump type for 100% coverage of annual heat demand. The sales peaks in 2021 - 2023 for air-to-water and ground-source heat pumps are probably due to the high natural gas prices during this period.

Ground-source heat pumps are more commonly installed in new buildings, where the required heat capacity is lower, and the installation is easier.

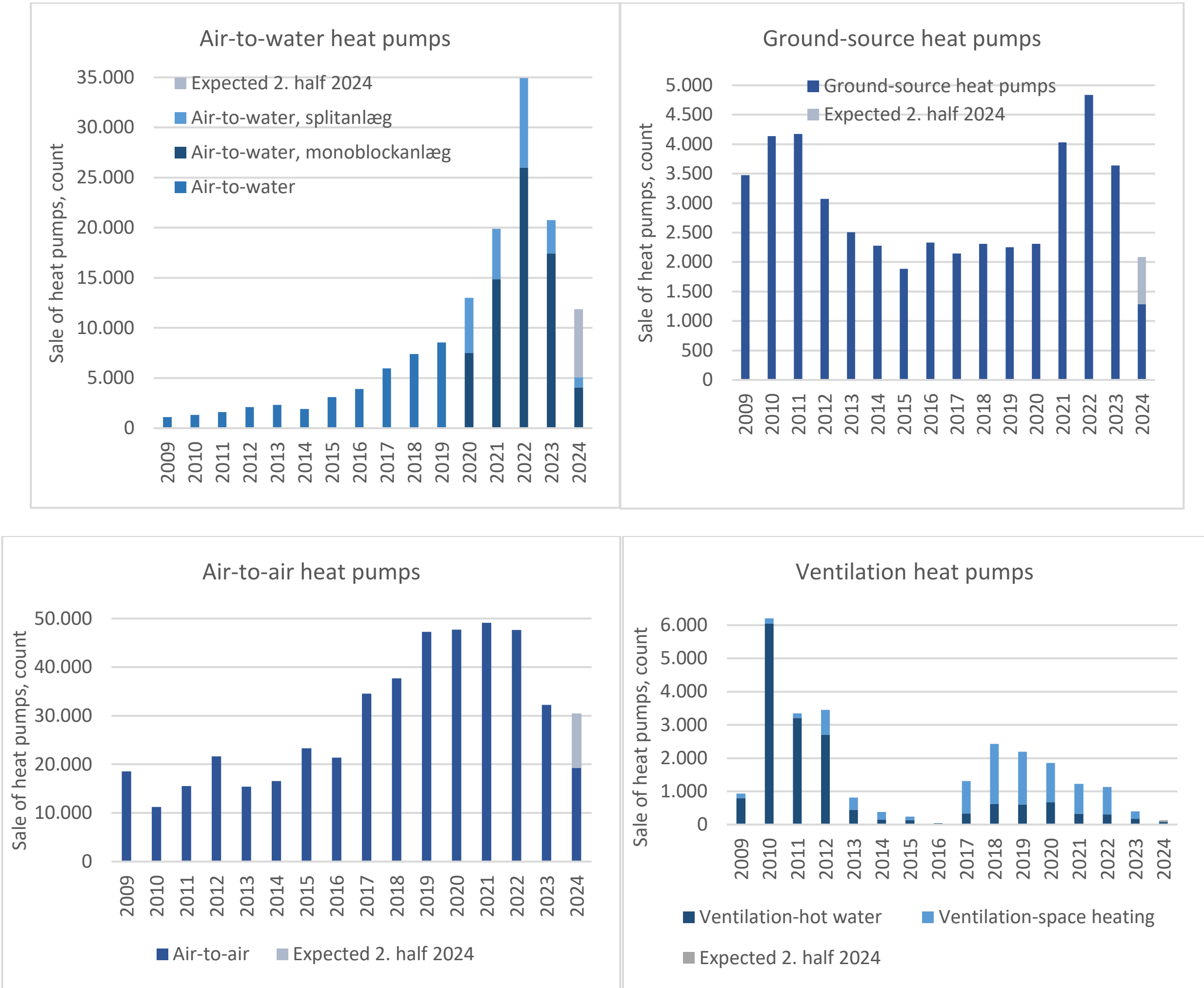

Figure 35: Sale of heat pumps in Denmark 2009-2024. An estimate for the sale in the second half of 2024 is included, which is based on the share of the total 2014 sale registered in the second half of 2019. The sale of ventilation heat pumps includes both those capable of delivering heat to water and air. Source: Historic sale is published by The Danish Energy Agency [13].

Incorrect installation results in reduced efficiency, increased noise, etc. For example, installing incorrectly dimensioned pipes can drastically increase the noise, while errors in the physical installation or incorrect settings for the heat curve can lead to suboptimal operation and decreased efficiency. Heat pumps also need to be maintained properly to ensure continued, high performance. For example, gathering debris in the outdoor unit can increase the strain on the heat pump to maintain sufficient airflow.

It is unknown how many heat pumps currently operate sub-optimally since the heat pump owners often do not have a way to know whether this is the case for their system. User errors, where users themselves tamper with the settings, can also decrease the performance and increase wear of the system. For example, when users feel cold their natural response is to increase the heat pumps delivered temperature, but the problem is not necessarily the water temperature but could be a suboptimal heat distribution system. Based on a Carnot-calculation it is estimated that by increasing the delivered temperature by 1 degree, the performance decreases by approximately 3%-points.

An increased focus on education of those installing heat pumps and in turn those operating them, is considered key to reduce the number of errors in installations and increase the number of heat pumps operating optimally. It is important to note that the heat efficiency (annual average, net) values presented in the data sheets reflect a situation with correct installation, considering the average operation pattern under specific Danish conditions and the fact that air-to-water and ground source heat pumps also supply domestic hot water. Therefore, the values in the data sheets are 10-15% lower than the SCOP for space heating (55°C) found by testing in laboratories.

Over the past few years, new air-to-air heat pumps entering the market in Denmark have typically achieved a SCOP of approximately 5. Modern air-to-air heat pumps achieve SCOP of approximately 5 through inverter-driven compressors, advanced refrigerants like R32, optimized heat exchangers, precise electronic expansion valves, smarter defrost cycles, and adaptive control systems that optimize performance under varying conditions. These models benefit from mass production and mature technologies, making them price-competitive with prices comparable to models offering a SCOP of around 4.5. Certain models display SCOP values as high as 5.9, however, models with SCOP >5.5 apply premium components, larger exchangers, and more sophisticated controls, driving up costs by 50% or more.

The air-to-water heat pumps delivering heating at radiator-temperature (55°C) have improved from SCOP 2.5–3.0 (2015) to 3.2–4.0 (2025), driven by better compressors, refrigerants, and controls. Ground source heat pumps, benefiting from stable source temperatures, now achieve SCOPs of 4.0–4.5 for radiator-temperature (55°C), with best-in-class units approaching 5.6 for lower flow temperatures. Future gains will come from digitalization (Wi-Fi is standard), hybridization, and new refrigerants. [21],[22],[23], and [24]

Heat pumps are generally getting more sophisticated with regard to smart controls. This is not expected to be visible in the investment costs but can improve performance by automatically adapting the operation to the needs of the specific building, for example by communicating with intelligent radiator thermostats and adapting production patterns to the varying power prices in the electricity market. Furthermore, remote access and surveillance are becoming more common. Newer models already have many of these smart functions.

Fejl! Henvisningskilde ikke fundet. is based on data from the EU EPREL database[30] and shows the distribution of energy classes for air-to-water and ground source heat pumps in sizes suitable for single-family houses available on the EU market in July 2025. As seen in the table on the left, approximately 92% of these models achieve an A++ label or better for radiator heating (55 °C), thus complying with the current ecodesign requirement. The table in the middle shows that around 98% of these models achieve an A+ label or better for low temperature/floor heating (35 °C) and thus meet the current ecodesign requirements for this type of heating. In the table to the right approximately 90% of heat pump water heaters in the EPREL data are in energy class A or better.

Distribution of the selected 8 699 models out of a total of 45 953 models

Seasonal space heating energy efficiency class (55°) 8 699 models			Seasonal space heating energy efficiency class (35°) 8 258 models			Water heating energy efficiency class 8 699 models		
Class	Entries	%	Class	Entries	%	Class	Entries	%
A+++	272	3,1	A+++	6 889	83,4	A+	4 868	56,0
A++	7 758	89,2	A++	1 218	14,7	A	3 607	41,5
A+	669	7,7	A+	9	0,1	B	212	2,4
A	0	0,0	A	142	1,7	C	12	0,1
B	0	0,0	B	0	0,0	D	0	0,0
C	0	0,0	C	0	0,0	E	0	0,0
D	0	0,0	D	0	0,0	F	0	0,0

Figure 36: Distribution of the heat pumps (air to water and ground source) in the EU EPREL database [30]16 July 2025 with rated heat output from 4-10 kW (55°C) on energy classes. The red lines indicate the ecodesign requirements that came into force in 26 Sept 2017. The current ecodesign requirement for space heating (55 °C) SCOP shall not be lower than 2.75, ecodesign requirement for space heating (35 °C) SCOP shall not be lower than 3.31 and ecodesign requirement for electric water heaters (size medium) the efficiency shall not be lower than 90%.

According to a separate retrieval of energy labelling data from the EPREL database (not shown in any figure), all models of heat pumps with rated outputs of 20 kW (55 °C) and above comply with the current ecodesign requirements.

<u>Specific for air-to-water heat pumps:</u>

Today, the time required for the installation of an air-to-water heat pump in a household is generally 32-40 man-hours, not including the time required for dimensioning. Historically, it has taken longer time, but producers have made their models easier to install, also to decrease the risk of errors.

Replacing a heat pump with a new unit in an existing building is significantly cheaper than converting from a fossil fuel system (e.g. gas or oil) to a heat pump. This is primarily because the existing electrical and plumbing installations can typically be reused. Only the indoor and outdoor units of the heat pump are replaced.

It has become common for manufacturers to design new units to fit the same footprint and pipe connections as previous models. Installers can therefore quickly disconnect the existing heat pump and install the new one, often without needing to modify the pipework. If there are changes in the pipe layout, manufacturers provide adapter kits to simplify installation.

The replacement process typically takes 2–4 hours, with most of the time spent draining and refilling the heating system. Including removal of the old unit and cleanup, the total time spent is around 10 hours. Two workers (a technician and an assistant) are usually involved. The electrical work is limited to connecting the pre-mounted power cable to the existing safety switch. External sensors and bus cables use standard connectors compatible with new units, eliminating the need for an electrician.

Labour costs and material for this type of replacement are generally expected to be about DKK 10,000 excluding VAT. This estimate does not cover the installer's overhead expenses related to sales and marketing, customer support, service, or administration, all of which would also contribute to the overall cost of a heat pump replacement. It is reasonable to assume that the total costs of a replacement heat pump can be reduced by 25-35% compared to a heat pump installed in an existing building converting form a fossil fuel system.

Today, the quietest single family house heat pumps have an outdoor sound power level below 44 dB [30], and it is expected that many models will achieve this level or lower.

Currently air-to-water heat pumps for larger buildings are to a large degree custom solutions, whereas heat pumps for single family houses are standard products. Furthermore, air-to-water heat pump systems for larger buildings are still not common, but interest in this segment is growing. This means that there may be a larger potential for price reductions as solutions become more common and standardized.

Today’s air-to-water heat pumps can deliver heat at temperatures of 65-75 °C where it previously was only possible to reach 45 or 55°C.

There are developments regarding the physical size and design of the heat pumps, where producers are making the units smaller and more aesthetically pleasing, as this factor can affect consumers’ likelihood of choosing a heat pump.

<u>Specific for ground-source heat pumps:</u>

Although ground-source heat pumps have been utilized for space heating for a longer period, the same degree of development as for air-to-water heat pumps could be expected. As with air-to-water heat pumps, ground-source heat pumps are expected to be able to deliver temperatures up to 75 degrees and convert to natural refrigerants, e.g. R290.

<u>Specific for air-to-air heat pumps:</u>

Air-to-air heat pumps are a mature technology and therefore major technological developments are not expected. As for air-to-water heat pumps, there may be developments regarding noise and the physical appearance.

<u>Specific for ventilation heat pumps:</u>

The focus on ventilation heat pumps is less than that of the other types of heat pumps and the segment of buildings where they are relevant is smaller. According to the Danish Energy Agency’s heat pump sale statistics, less than 500 of these types of heat pumps have been sold annually during recent years. But there has recently been an increasing focus on ventilation heat pumps as integrated heating solutions in new, energy-efficient buildings. These systems combine balanced ventilation with heat recovery and heat pump operation, allowing them to cover a large share of space heating in the well-insulated buildings.

Examples of market standard technology

Figure 37: Metrotherm, Metroair I, 16kW heat. Outside unit. Split unit. [1]

Figure 38: Bosch compress 7000i, Air-Water Outside-Unit on the left, inside unit on the right. 7kW split unit. [2]

Figure 39: Compax Brine-Water indoor-unit. 10kW. SCOP 4,61-5,2. [3]

Figure 40: Bosch compress 6000 LW 6kW [4]

Figure 41: Nilan Compact P series ventilation heat pump can be combined with brine-water or air-water unit. 3-9kW [5]

Figure 42: Panasonic CZ25TKE air-air heat pump. 5,2kW. R32 refrigerant. [6]

Prediction of performance and costs

<u>Specifically for air-to-water heat pumps:</u>

The technology maturity of air-to-water heat pumps is between category 3 and 4. Thus, a steady decline in prices was expected. However, external incidents in recent years have affected the price trend in an upward direction, and a significant increase in heat pump prices was seen between 2022 and 2024. As a result, prices in 2025 are higher than in 2020, although a decrease is observed between 2024 and the first half of 2025.

The increase in heat pump prices in 2022 can be attributed to two main factors:

1. Rising raw material costs and restricted access to certain components—some of which are produced in Ukraine—created cost pressure across the supply chain.

2. Changed market dynamics, particularly increased demand due to rising gas prices from mid-2021 and the invasion of Ukraine, allowed manufacturers and installers to raise prices. Public subsidies (e.g., the Danish support scheme for heat pumps) further fueled demand.

This price development was confirmed by interviews conducted in May 2022 and June and July 2025 with stakeholders in the heat pump sector.

Also, new data from 2024–2025 shows that prices have declined since their peak in 2022. We have based the assessment of current costs on three sources:

A. Actual cost data from the Danish Energy Agency's heat pump subsidy scheme for 2025.

B. Market prices collected from both traditional HVAC companies and new online providers, including both package solutions (equipment + installation) and individual components.

C. Interviews with HVAC installers and heat pump suppliers.

Across these sources, we observe an average price of approx. EUR 12,900 (DKK 96,000) excl. VAT (120.000 DKK incl. VAT), for a good-quality monobloc air-to-water heat pump, from a reputable supplier. These heat pumps are typically low-noise and designed for retrofitting in standard Danish single-family houses.

During the past five years, manufacturer focus has been on, a) noise reduction, to meet noise limits and consumer demand, particularly in countries such as Germany, Switzerland, and Austria, where consumer expectations are high, b) refrigerants with low GWP, particularly propane, in line with EU F-gas regulations.

Going forward, we expect a renewed focus on cost reduction, driven by:

- Increasing competition from Asian manufacturers.
- Digitisation and platformisation of sales and design processes, allowing tailored solutions and reducing sales and installation costs through economies of scale.

Labour shortages in the HVAC sector may on the other hand exert upward pressure on installation and O&M (operation and maintenance) costs. This may partly or fully offset the expected cost reductions from improved processes and economies of scale. The net effect will depend on the balance between productivity improvements and the tightening labour market.

Typically, about 30% of the total price of a heat pump is soft cost (installation, sales and marketing, customer support and service, administration etc.) and about 70% is equipment costs. In this equation, installation accessories are considered as equipment costs.

For existing single-family houses, it is assumed that equipment costs will decrease by about 15% through learning effects and increasing competition from Asian manufacturers and soft cost by 10% by 2030 as a result of more efficient workflows and streamlined customers handling. In total we expect cost reduction of 13% meaning that the average price of heat pump installed in Denmark will decrease to EUR 11,100 (DKK 83,000 DKK excl. VAT and 104,000 DKK incl. VAT).

Towards 2050 we anticipate a further reduction of 15% in equipment cost, reflecting learning effects from the expected increase in sales, but no changes to soft costs because we foresee that efficiency gains are outweighed by labour shortage. In total we forecast the air-to-water heat pump to cost EUR 10,000 excl. VAT (DKK 74,500 excl. VAT and DKK 93,000 incl. VAT) in 2050.

For new single family houses, the equipment investment is also expected to decrease by 15% towards 2030 and another 15% between 2030 and 2050. A smaller reduction of the installation costs is expected, because this is already optimised compared to installing heat pumps in existing buildings to a larger degree. A decrease of 5% of the installation cost of air-to-water heat pumps in new households in the period 2025-2030 is foreseen, whereas we do not expect any change in the period 2030-2050.

As mentioned, a simple learning-based analysis has also been conducted to validate the presented price developments. The complete description hereof can be found under Notes in Appendix 2.

Cost development for large heat pumps in apartment buildings

Large heat pumps for apartment buildings have experienced rising costs since 2020. This market is served by only a few specialized suppliers, unlike the more competitive single-family house sector. Limited competition and the need for custom solutions in each project have contributed to higher prices.

New entrants, including manufacturers from Asia, may increase competition for standardized equipment. This is expected to push equipment prices lower. Because experience with large systems is still limited, cost reductions from learning and scaling could be greater than in the more mature single-family segment.

However, opportunities to streamline sales and installation are smaller than for single-family systems. Each project typically requires a solution tailored to the building's layout, existing heating system, peak load, and integration with other energy systems. This reduces the potential for standardization, especially in retrofit projects.

Overall, equipment costs for large heat pumps are projected to fall by about 15% between 2025 and 2030, and by another 15% from 2030 to 2050. Installation costs are expected to drop by around 10% from 2025 to 2030, after which they are likely to remain stable until 2050 for both existing and new buildings.

O&M costs

Projecting the operation and maintenance (O&M) costs of heat pumps is inherently uncertain. The uncertainty relates not only to the future cost of spare parts, labor, and service offerings, but also to the extent to which the heat pump will require maintenance and repairs over its lifetime. Usage patterns, installation quality, and environmental conditions all influence how often service is needed, making generalizations difficult. Furthermore, there is a lack of systematically compiled and publicly available data summarizing actual O&M costs across technologies and usage contexts, which limits the basis for robust projections.

O&M costs are closely linked to the expected lifetime of the equipment. In principle, the lifetime of a heat pump can be extended indefinitely by replacing worn components as needed, but this is typically not financially advantageous. For this reason, O&M costs should be related to the expected economic lifetime of the heat pump — that is, the period during which continued operation is financially preferable to replacement.

To estimate future O&M costs, we have examined service and warranty contracts available in the market. One of the major suppliers offers up to 20 years of warranty conditional on the purchase of an annual service and warranty subscription. This covers the replacement of defective parts and regular maintenance. For the single family house units the subscription costs DKK 800 per year, excl. VAT for the first five years, and DKK 2,500 excl. VAT per year for the following 15 years is expected.

Based on these figures and assuming a discount rate of 3.5% per annum, the average annual O&M costs over the 20-year period amount to approximately DKK 2,300 excl. VAT (about 2.4% of the investment cost). This provides a reasonable estimate for the expected O&M costs of an air-to-water heat pump, assuming regular servicing and part replacement over its economic lifetime.

An annual reduction of 0.5% for the fixed O&M costs including service and spare parts is assumed for all air-to-water and air-to-air systems, corresponding to the expected annual reduction of mature technologies.

Specific for ground-source heat pumps:

Ground-source heat pumps can be categorized between category 3 and 4 regarding technology maturity. For the installation and operation there is a potential for improvement. The time required for an installation is expected to decrease while the quality of the installation is expected to increase, resulting in higher performance of the heat pumps.

For systems installed in existing and new single family houses, the cost of equipment of ground source heat pumps is expected to follow the development of the air to water heat pumps; i.e. a fall by 15% in the period 2025-30 and by another 15% in the period 2030-50. And the development of the cost of large ground source heat pumps supplying apartment buildings are assumed to follow the development of the large air to water heat pump. Hence, equipment costs for large ground source heat pumps are projected to fall by about 15% between 2025 and 2030, and by another 15% from 2030 to 2050. Installation costs are expected to drop by around 10% from 2025 to 2030, after which they are likely to remain stable until 2050.

The installation costs of ground-source heat pumps are largely due to man-hours and rental of equipment, and a reduction like that of air-to-water is expected. Meaning that a decrease of 10% for existing and 5% for new single family houses is assumed for the periods 2025-30 and 2030-50, while a decrease of 10% is expected for larger buildings for the periods 2025-30 and 2030-50.

O&M costs

Like for air-to-water heat pumps, the required service interval for ground-source heat pumps will be reduced to a biannual requirement, where it is expected that 25% of consumers will continue an annual service agreement. To ensure a long operational lifetime, the annual fixed operations and maintenance (O&M) costs are expected to match those of air-to-water heat pumps, based on similar service agreement prices and negligible differences in spare part costs. An annual reduction of 0.5% for the fixed O&M costs including service and spare parts is assumed for all ground-source heat pumps, corresponding to the expected annual reduction of mature technologies.

Specific for air-to-air heat pumps:

Regarding the technology maturity, it is assumed that the air-to-air heat pumps belong to Category 4, i.e. "Commercial Technologies, with large deployment so far".

Air-to-air heat pumps have already seen a dramatic decrease in cost and is deployed to a much larger degree globally, compared to for example ground-source and air-to-water heat pumps. Furthermore, air-to-air heat pumps are very similar to split air-conditioners (often the same appliance can deliver both heating and cooling) meaning that the production numbers are immense, and the production plants are highly efficient.

Therefore, an annual reduction of the total cost by only 0.5% per year is expected. This is the same reduction as expected for other mature technologies such as gas and oil boilers.

Uncertainty

The exact split between installation and equipment for the technologies is subject to uncertainty. This is mainly due to the fact that the definition of what costs are attributed to equipment and installation is not always clear and suppliers may have differing definitions. Examples of the costs which can be interpreted as part of either price component are the mark-up on equipment and the costs of additional piping, fittings, etc. needed for the specific installation.

Prices of fuels as well as carbon and energy taxes affect the competitiveness of heat pumps. E.g. expensive biomass, gas or oil will imply that heat pumps will become more attractive. Alternatively, if the fuel prices drop relative to the electricity prices, then heat pumps will become less competitive.

The demand for heat pumps in both the EU and Denmark is shaped by a combination of climate policy, energy prices and market dynamics. Heat pump deployment is a cornerstone of the EU's strategy to decarbonise the building sector. A rapid roll-out can accelerate cost reductions through learning effects and economies of scale. However, a fast scale-up also risks straining the supply chain, particularly in relation to installation capacity, where labour shortages are already a concern in several countries.

The introduction of the EU Emissions Trading System for buildings and transport (ETS 2) will gradually increase the cost of using fossil fuels such as natural gas and oil in buildings across the EU. This price signal is expected to strengthen the economic case for heat pumps. However, the long-term impact of ETS 2 will depend on how strict the system becomes after 2030, which in turn will be influenced by the EU's climate targets for 2040.

Furthermore, the average COP achieved by any given installation is highly dependent on the specific conditions. Therefore, there is naturally a large uncertainty with regard to this value.

Economy of scale effects

Economy of scale applied to heat pumps within the typical capacity range for single-family houses. A capacity increase of 100 % will typically increase total investment cost for these systems by 15-25 % depending on the brand and supplier.

Regarding the larger heat pumps for apartment complexes, only sources for heat pumps supplying district heating have been found. It is expected that capacity increase of 100 % will increase investment cost by about 65-75 % based on the newest source [31].

Additional remarks

Application of the data in the data sheet for actual calculations of a project should be evaluated according to the specific local conditions.

For further reading about the heat pump technology see [14] (in Danish). For information about the technology, case stories, and the heat pump list[6] see [**Fejl! Henvisningskilde ikke fundet.**].

Appendix 1: Background for energy efficiencies for heat pumps in the Technology Catalogue (in Danish)

This appendix can be found in the previous version of the Technology Catalogue for Individual Heating. A link to the report is available on the Danish Energy Agency's website: https://ens.dk/en/analyses-and-statistics/technology-data-individual-heating-plants. On that page, you can find previous versions of the catalogue under "Previous versions of Technology catalogue for Individual Heating."

[6] Heat Pump List: Testing and Comparison of Heat Pumps (Varmepumpelisten)

Appendix 2: Learning-based projection

The price projections for heat pumps are based on interviews and experience from the sector. To validate the size and speed of these price developments a learning-based projection is also incorporated. The following is not an in-depth analysis of the heat pump market but should be seen as an indicative analysis of the theoretical price development under certain developments and assumptions as described below.

This methodology estimates price trends using the concept of a learning rate, which reflects the reduction in price associated with each doubling of installed capacity or units sold for a given technology.

The Reflex project Technological Learning in Energy Modelling [15] has assessed learning curves for different energy technologies, including heat pumps. Here the heat pump technology is evaluated to have a learning rate of 10% but also concludes that this value is very uncertain and can vary from country to country. For comparison, the same study found the following learning rates for other technologies:

- Solar PV: 18.6-21.4% depending on type
- CCS: 2.1 – 2.2% depending on fuel, but 11-12% for industrial CCS.
- Li-ion battery storages: 12.5-15.2% depending on scale.
- Fuel cell stacks: 18%
- Wind systems: 5.9% for onshore systems and 10.3% for offshore systems

It is assumed that the investment price of heat pumps in Denmark will follow the developments in the EU, and therefore it is necessary to look at the expected number of heat pumps in Europe and not just Denmark. Table 6 shows an estimate of the distribution of individual heating in Europe [16] [17]. Boilers are supplied by either gas or oil. With current climate goals in the EU and individual countries, a shift from boilers to heat pumps and district heating is expected.

Number of heating units	***End 2024***
Air-to-water:	8.045.000
Ground-to-water:	1.740.000
Other heat pumps*:	3.075.000
Air-to-air:	10.950.000
Boilers	86.000.000
Stoves	58.000.000
Electric radiators	28.000.000

Table 6: Estimated distribution of individual heating installations in EU based on statistics from the European Heat Pump association and JRC. Data on stoves and electric radiators are from 2019. *Sanitary hot water heat pumps, ventilation heat pumps and other heat pumps.

An analysis of heat pump sales over the past decade indicates a consistent increase in air/water heat pump purchases. Notably, there was significant growth during 2021 and 2022, which is likely attributable to elevated gas prices throughout that period. However, sales declined slightly between 2022 and 2023, and data from 14 European countries reveal a further decrease of 21% from 2023 to 2024.

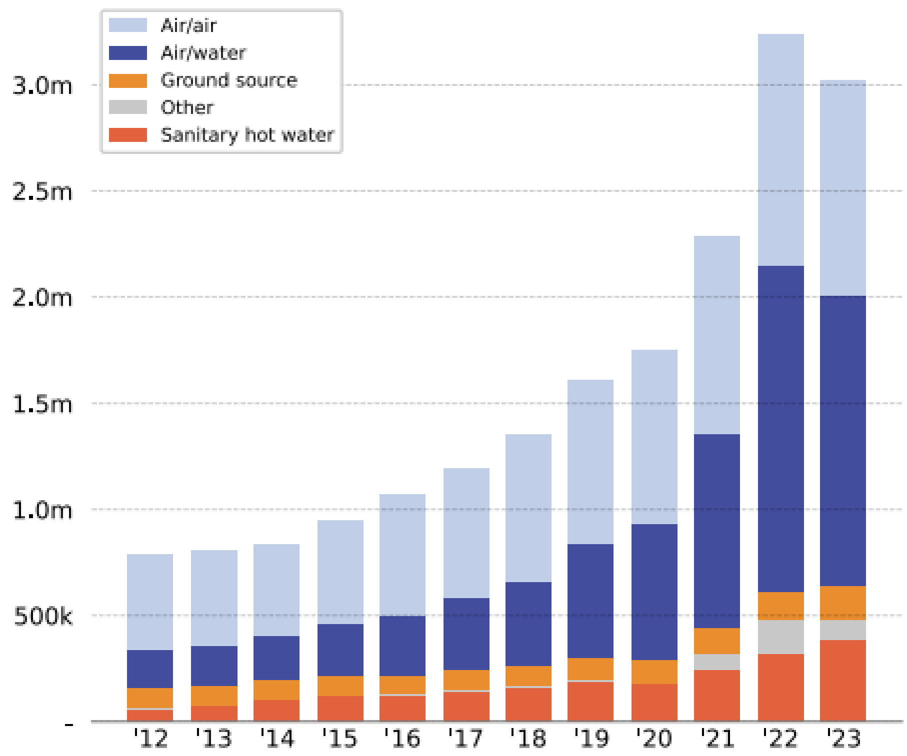

Figure 43: Sales development in EU by year and type of heat pump

Two scenarios are considered regarding the sale of air/water heat pumps.

- Reference scenario: This scenario assumes a continuation of the current sales trend while reversing the decline observed in 2024. Under this scenario, the air/water heat pump stock is projected to reach approximately 30 million units by 2030 in the European Union.
- Target scenario: In this scenario there is a substantial increase in sales in order to meet the European Union’s decarbonization objectives for the heating sector. The air/water heat pump stock is projected to approach 60 million units by 2050, which could potentially replace around 60% of existing boiler capacity. The remaining boilers may be replaced through expansion of district heating systems and the adoption of air/air heat pump systems combined with electric boilers for domestic hot water.

The accompanying graph illustrates the projected sales of air/water heat pump systems under both scenarios. The projection incorporates the need to replace heat pump systems at the end of their operational lifetime. Consequently, the projected increase in sales reflects both the adoption of heat pumps in additional buildings and the replacement of existing units. The considerable rise in heat pump sales between 2021 and 2023 is expected to result in a replacement peak 15–20 years later. In reality, the replacement peak is likely to have a smoother pattern than depicted in the graph. The next figure displays trends in the total stock of air/water heat pumps.

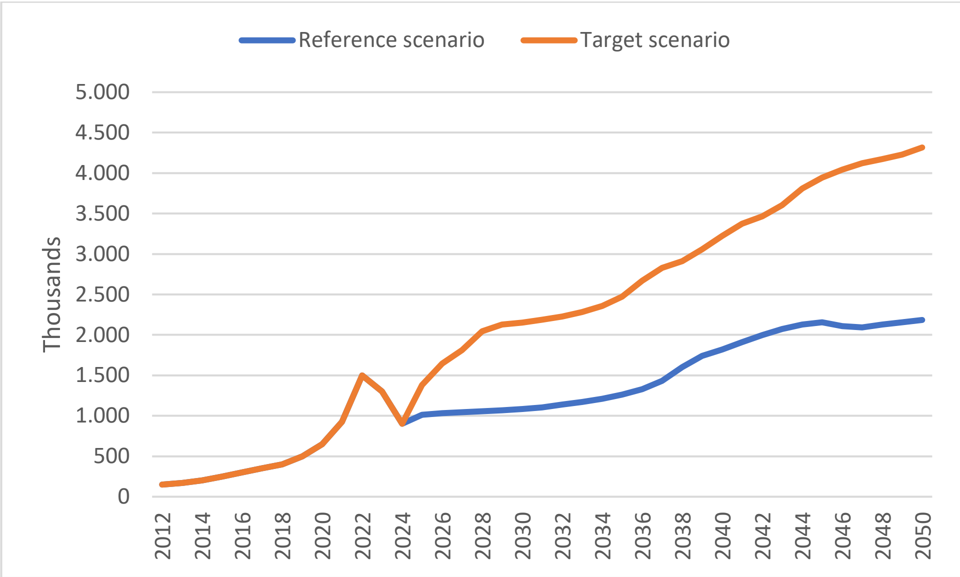

Figure 44: Projection of the annual sale of air/water heat pumps in the two scenarios

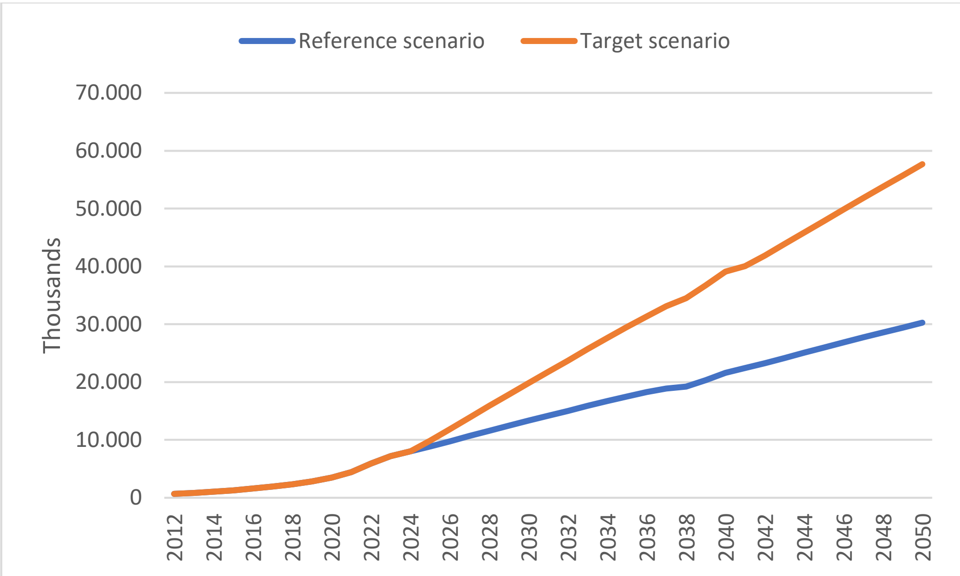

Figure 45: Projection of the stock of air/water heat pumps in the two scenarios

Projections for air/air heat pumps and ground source heat pumps were developed by extending historical sales trends.

Based on the development in accumulated sales over time and a learning rate of 10% we derive the following learning-based price developments for each of the three types of heat pumps.

Heat pump	Scenario	2025	2030	2040	2050
Air/water	Reference	100%	93%	84%	77%
	Target	100%	90%	79%	72%
Ground source	Reference	100%	94%	86%	80%
	Target	100%	94%	85%	79%
Air/air	Reference	100%	94%	85%	79%
	Target	100%	93%	85%	78%

Table 7: **Expected investment price reduction compared to 2025 for each type of heat pump.**

This projection reflects a consistent decline in investment costs across all heat pump types, primarily driven by cumulative sales growth and the application of a 10% learning rate. For air-to-water heat pumps, which are more frequently installed as full replacements for traditional heating systems, the learning effect is most pronounced.

By 2030, investment costs are projected to fall by 7–10% for air/water heat pumps, and by 6–7% for both ground source and air/air heat pumps, relative to 2025 levels. These initial reductions reflect moderate learning effects and the gradual uptake of more efficient manufacturing and installation practices. The price reductions continue beyond 2030, with air/water heat pumps reaching a total decline of up to 28% by 2050 in the *target* scenario. Ground source and air/air systems follow with more modest reductions of 15–21%, depending on scenario.

Learning effects are expected to take place not in isolation, but across technologies. Air-to-water and ground source heat pumps share significant technological components, particularly in compressors and control systems. As a result, innovations in one segment are likely to benefit the other. Similarly, air/air heat pumps share a large technological overlap with air conditioning systems. However, because air conditioning is already a mature and globally widespread technology, the scope for further cost reductions may be more limited than the learning rate model implies.

While the long-term cost projections for heat pumps are based on a learning rate of 10%—consistent with cumulative production trends across several energy technologies—recent market dynamics suggest that actual price developments may temporarily deviate from this trajectory.

In particular, if we look back at the development of air-to-water heat pump prices over the past five years, we do not see the price reductions that a straightforward learning-curve model would predict, given the significant increase in sales over the same period. On the contrary, prices have remained relatively high. Several factors can help explain this deviation:

1. **Supply constraints and high demand**: A rapid growth in demand has outpaced the industry's ability to scale up production and installation capacity. This has created bottlenecks across the supply chain, allowing suppliers to maintain elevated prices despite increasing volumes.

2. **Shift in innovation priorities**: Manufacturers have not primarily focused on reducing costs. Instead, they have directed efforts toward improving performance—introducing refrigerants with lower global warming potential and reducing operational noise. These improvements add value but also limit short-term cost reductions.

This pattern is not without precedent. A useful analogy can be drawn from the solar PV sector. During the early 2000s, a similar decoupling between technological progress and price development occurred. As inspiration for assessing the likely duration of the current deviation from expected heat pump learning curves, we refer to developments in PV module pricing from 2003 to 2008. In that period, module prices remained constant—or even increased slightly—despite continued technological improvements, primarily due to strong demand and limited competition:

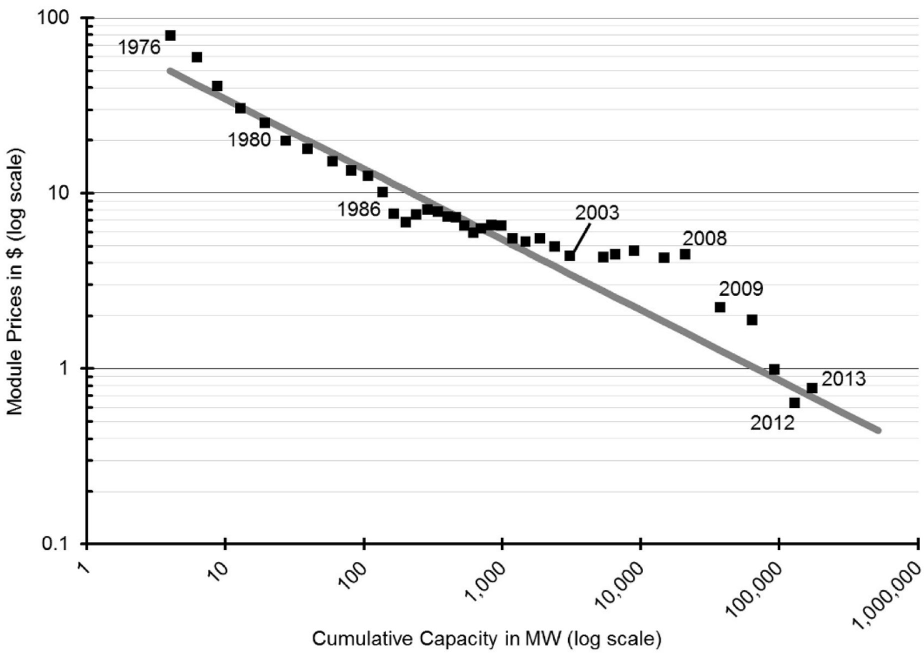

Figure 46: Learning curve of the solar PV module. Data from IRENA [

The authors of the article "Estimating the learning curve of solar PV balance–of–system for over 20 countries: Implications and policy recommendations" explain the development in the following way:

"The pre-crisis period was shaped by high demand of solar systems in Europe, which allowed suppliers to keep prices high and enjoy windfall profits. Although technological progress and cost reductions were achieved by manufacturers during this period, these advancements were not reflected in the module price. It was only after the financial crisis that suppliers had to compete in a shrunken market, and did so by slashing their previously inflated prices."

In light of this, it is likely that current heat pump prices in 2025 still reflect a temporary uplift caused by the energy crisis and the resulting supply shortages. These effects may take several more years to subside, meaning that price levels are expected to gradually return to the underlying learning-based trajectory during the latter half of the 2020s.

It is important to clarify that while the learning rates applied in this analysis primarily reflect equipment costs, learning effects are not limited to manufactured components alone. In principle, learning theory can also be applied to installation and other soft costs—such as design, sale and service—since these too can benefit from accumulated experience and scale. However, in practice, learning rates are generally more pronounced and predictable for factory-produced technologies, where economies of scale, automation, and supply chain optimization can drive down costs in a systematic way. In contrast, installation processes are more labor-intensive, site-specific, and subject to local regulation and workforce skills. Cost reductions here tend to result from incremental improvements: better training, standardization of procedures, improved coordination across trades, and the introduction of digital tools for planning and diagnostics. These gains are often slower, more fragmented, and less easily forecasted using standard learning curve models. This distinction has been observed in other sectors as well—for example, in rooftop solar PV and building retrofits—where hardware costs have declined rapidly, while installation and soft costs have proven more persistent and variable across markets. For heat pumps, we can therefore expect the strongest learning-driven cost reductions in the equipment itself, while installation-related savings are likely to emerge more gradually and unevenly.

Quantitative description

See separate Excel file for Data sheets.

References

[1] Metrotherm. https://www.metrotherm.dk/produkter/varmepumper/luft-vand-varmepumper/metroair-i. 2020

[2] Bosch. https://www.bosch-thermotechnology.com/dk/da/ocs/privat/compress-7000i-aw-758037-p/. 2020

[3] Vvs-eksperten.dk. https://www.vvs-eksperten.dk/varme-og-klima-varmepumpe-jordvarme-jordvarmepumpe-copmax-10-kw-med-siemens-styring-346019210?gclid=CjwKCAjw8-78BRA0EiwAFUw8LHOZWVy_8x0PGtcqpg8AAWVuaStjKAlD4sPsxI6DLT0L6OwLxHz2uxoCQYUQAvD_BwE. 2020.

[4] Vvs-eksperten.dk. https://www.vvs-eksperten.dk/varme-og-klima-varmepumpe-jordvarme-bosch-compress-6000-lw-6-kw-jordvarmepumpe-346737006. 2020

[5] Nilan. https://www.nilan.dk/da-dk/forside/loesninger/boligloesninger/kompaktloesning/compact-p-cts700. 2020

[6] Heat Pump List: Testing and Comparison of Heat Pumps (Varmepumpelisten: Test og sammenligning af varmepumper), https://sparenergi.dk/varmepumpelisten, Danish energy Agency

[7] Energistyrelsen, " Beregning af SCOP for varmepumper efter En14825", 2011

[8] Interview med VS Automatic

[9] COWI, "Evaluering af Abonnementsordningen for varmepumper til boligejere", 2019

[10] Website investigation of various suppliers.

[11] Interviews with various installation companies.

[12] Interview with Bosch.

[13] The Danish Energy Agency, "Varmepumper installeret halvårligt fra 2009 til første halvår 2020", 2020. https://ens.dk/sites/ens.dk/files/Statistik/udvikling_i_salg_af_varmepumper_fra_2009.pdf og "Varmepumper installeret fra 2014 til første halvår 2024" https://ens.dk/sites/ens.dk/files/Statistik/installation_af_varmepumper_2014-2024_q2.xlsx

[14]Dansk Energi, "Den lille blå bog om varmepumper", 2019. https://elforsk.dk/sites/elforsk.dk/files/media/dokumenter/2019-04/Den_Lille_Blaa_Om_Varmepumper.pdf

[15] A. Louwen, M. Junginger, A. Krishnan, "Technological Learning in Energy Modelling: Experience Curves", REFLEX project, 2018. http://reflex-project.eu/wp-content/uploads/2018/12/REFLEX_policy_brief_Experience_curves_12_2018.pdf

[16] S. Pezzutto, S. Croce, S. Zambotti, L. Kranzl, A. Novelli, P. Zambelli. "Assessment of the Space Heating and Domestic Hot Water Market in Europe—Open Data and Results". Energies, 2019.

[17] Statistics from the European Heat Pump association: "European Heat Pump Market and Statistics Report 2024", https://www.ehpa.org/wp-content/uploads/2024/08/Executive-summary_EHPA-heat-pump-market-and-statistic-report-2024-2.pdf

[18] Ministry of Environment and Food of Denmark, "Utilsigtet tab af F-gasser ved demontering af klimaanlæg og varmepumper Udredningsprojekt", 2020. https://www2.mst.dk/Udgiv/publikationer/2020/02/978-87-7038-159-8.pdf

[19] SparEnergi.dk, "Varmepumpe på abonnement", https://sparenergi.dk/forbruger/varme/varmepumper/varmepumper-paa-abonnement

[20] F-gas regulation: REGULATION (EU) 2024/573 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 7 February 2024 on fluorinated greenhouse gases, amending Directive (EU) 2019/1937 and repealing Regulation (EU) No 517/2014; EU parliament, 2024

[21] Example of air – to air HP with SCOP above 5, https://heatnow.dk/produkt/panasonic-hz35zke/, July 2025.

[22]EHPA Market Reports, ehpa.org, 2023, 2024

[23]IEA Heat Pump Technology Collaboration Programme, https://heatpumpingtechnologies.org/, IEA, 2025

[24] Clean Energy Technology Observatory, Heat pumps in the European Union

[25] Toleikyte, A., Roca Reina, J. C., Volt, J., Carlsson, J., Lyons, L., Gasparella, A., Koolen, D., De Felice, M., Tarvydas, D., Czako, V., Koukoufikis, G., Kuokkanen, A., Letout, S, The Heat Pump Wave: Opportunities and Challenges, Publications Office of the European Union, Luxembourg, 2023, doi:10.2760/27877, JRC134045

[26] Amro M.Elshurafaa, Shahad R.Albardia, Simona, Bigernab, Carlo Andrea, Bollinoab, Journal of Cleaner Production, Volume 196, 20 September 2018, Pages 122-134. Estimating the learning curve of solar PV balance–of–system for over 20 countries: Implications and policy recommendations https://www.sciencedirect.com/science/article/pii/S0959652618316652

[27] Status report on technology development, trends, value chains and markets : 2024, https://op.europa.eu/en/publication-detail/-/publication/c1d5104d-a17b-11ef-85f0-01aa75ed71a1/language-en, JRC, 2024

[28] Introducing M Series T-CAP, the latest generation of Aquarea air to water heat pumps with R290, Aquarea T-CAP M Series - Panasonic - heating and cooling solutions, web page visited July 2025

[29] Best Air Source Heat Pump Manufacturers in the UK https://whatcost.co.uk/heat-pumps/manufacturers, WHATCOST-UK 2025

[30] EPREL data base EU, space heaters and combined, https://eprel.ec.europa.eu/screen/product/spaceheaters, EU, 2025

[31] Economic incentives for flexible district heating in the Nordic countries, Sneum, Daniel Møller; Sandberg, Eli, DTU, 2025

[32] HEAT, VENTILATION AND GOOD INDOOR CLIMATE – AS SIMPLE AS THAT, The indoor climate solution of the future, https://livingbetter.dk/wp-content/uploads/2021/06/LivingBetter-brochure-UK.pdf, LivingBetter, visited July 2025

[33] Ventilation, hot water production and heating, Nilan, visited July 2025

[34] A new stylish smart and economical concept for properties with exhaust air heating, https://ctc-heating.com/products/ventilation-solutions/ctc-ecovent-i360f, CTC, visited July 2025

[35] What Is EVI in a Heat Pump? https://www.nulitegroup.com/what-is-evi-in-a-heat-pump?utm, Nulite. 07-17-2025

[36] Danish Environmental Protection Agency Guideline No. 5/1984: "External Noise from Industrial Plants", https://www.retsinformation.dk/eli/retsinfo/1984/14018

208 Hybrid heat pumps, air to water heat pump combined with gas boiler

Contact information

Danish Energy Agency: Emil de Bekker Steffensen, teknologikatalog@ens.dk
Author: Ea Energy Analyses

Publication date

June 2021, update 2025 by Ea Energy Analyses

Amendments after publication date

Date	Ref.	Description
July 2025		Update has been undertaken during Q3 of 2025. Primary focus is on data sheets, and text has been revised accordantly.

Qualitative description

Brief technology description

A hybrid heating solution, consisting of an electric heat pump combined with a condensing gas boiler, is commonly referred to as a hybrid heat pump. It can also be called other names such as hybrid boiler or hybrid heat pump boiler. Hybrid heat pumps have gained increasing interest in recent years as a solution to significantly reduce the use of gas for heating buildings. In hybrid heat pump systems, the heat pump component provides most of the heat demand, where the gas boiler boosts and supports the heat production, when this is beneficial, for example during periods of high electricity prices and/or cold periods. By combining these two technologies, hybrid heat pumps will typically have lower variable heat costs compared to a traditional gas boiler while overcoming some of the disadvantages of heat pumps, for example the decreased COP in cold periods.

The heat pump component must be a type capable of delivering heat to a water-based distribution system, for example an air-to-water, ground-source, or ventilation heat pump. A hybrid heat pump can also vary with regards to the non-heat pump component, which in principle can be any heat producing unit, for example an oil or biomass boiler.

This chapter will focus on the hybrid heat pumps consisting of an air-to-water heat pump and a gas boiler, since this combination is expected to remain the most common, but there are many different types of possible combinations. For an in-depth presentation of the two technologies, consult their respective chapters.

A consumer can acquire a hybrid heat pump system by using one of the following three solutions:

- Add-on solution: The consumer adds a heat pump unit to a heating system consisting of an existing standard condensing gas boiler

- Package solution: The consumer buys a complete system, consisting of a new condensing gas boiler and a heat pump. The two units are separate, like in the add-on solution, but sold as a package where the units are chosen to integrate well and according to the customer needs.
- Integrated solution: The consumer buys a full system, where the gas boiler and the heat pump are combined into a single, integrated, and optimized unit by the manufacturer.

Figure 47 illustrates the three solutions. The choice of solution depends on the consumer's preferences and requirements and the specifics of the building, in which it needs to be installed. For example, the add-on and package solutions will generally require more space but can be tailored to the specific needs of the building, while the integrated solution is a space efficient unit and easier to install but has predefined specifications. Moreover, the add-on solution will typically require the smallest investment, whereas installation costs could be higher. The range of integrated systems available in the Danish market today is limited. Figure 47 illustrates a single-family home, but the same solutions apply to larger buildings.

Often, package or integrated solutions are typically recommended as opposed to add-on solutions to ensure high system efficiency and avoid compatibility challenges. [1]

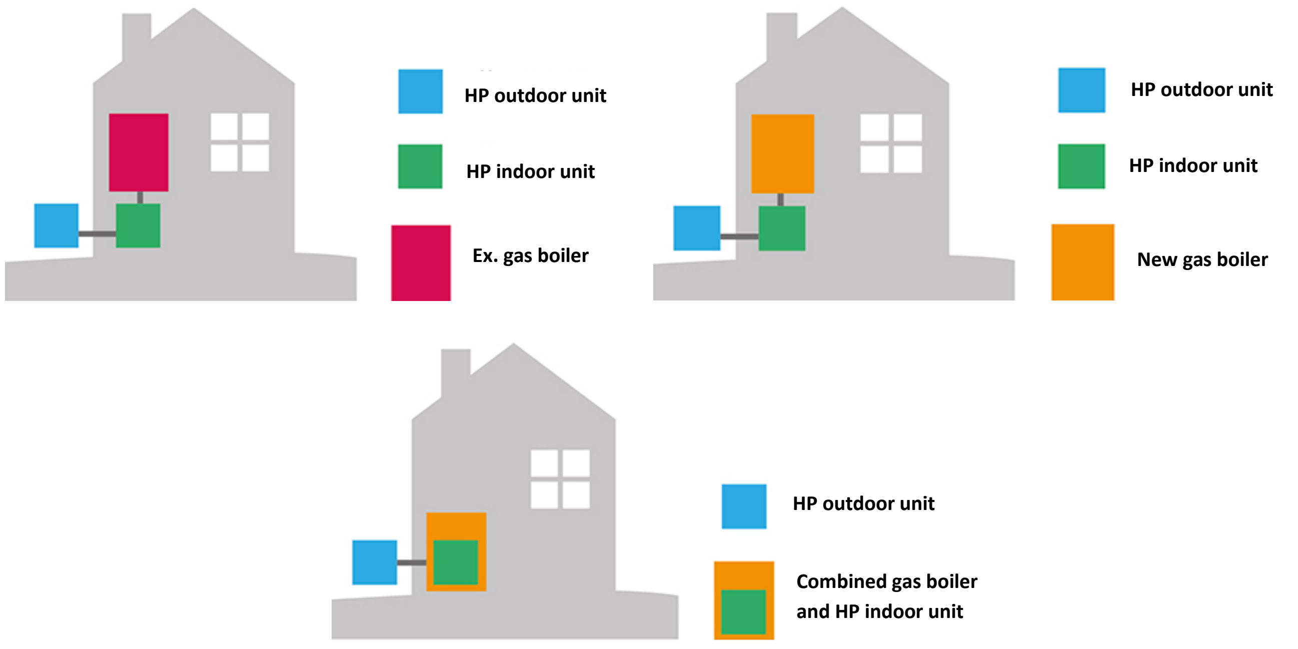

Figure 47: Principle of the three hybrid heat pump solutions. Left to right: add-on, package, and integrated solution [2]

A heat pump's COP, "Coefficient of Performance", describes the heat output per drive energy input, or electricity in the case of electric heat pumps, and is highly dependent on its operating conditions. Heat pumps draw heat from a low temperature source (input heat) and convert the heat to a higher temperature (output heat) through a closed process. The heat delivered is the sum of the heat absorbed from the environment and the electrical energy added via the compressor. The COP can be calculated by the formula below.

$$COP = \frac{Delivered\ heat}{Electricty\ consumed} = \frac{6\ kW}{2\ kW} = 3$$

The COP is often in the interval 3-5, meaning they deliver 3-5 times more heat energy than electricity consumed.

The temperature difference between the temperature of the heat source and the temperature level of the heat delivered strongly influences the COP. When the difference in temperature between the heat source and heat delivery decreases, the COP will increase and vice versa. This implies that the COP will vary e.g. according to the season. During the winter, the low outdoor temperature combined with a higher temperature required by the heating system results in a higher temperature difference and therefore a lower COP compared with milder days.

In a hybrid heat pump system, the heat pump does not have to cover the entire heat demand by itself and will typically not be dimensioned to do so, since the gas boiler can assist, when this is advantageous.

There are many different possibilities for the operation strategy for the hybrid system. Commonly, the heat pump will cover the full demand when the outside temperature is sufficiently high (for example 3°C), whereas the demand will be covered by the boiler when the outside temperature is low (for example less than -3°C [1]). In between these temperatures, the heat pump and boiler will share the heat production. For the heat pump and boiler to operate efficiently they should both be capable of operating at partial load.

Instead of determining the heat production split based on outside temperature, another way is to allow the heat pump to generate heat up until a certain compressor pressure. The compressor is the component in the refrigeration cycle which generates pressure. A larger temperature difference between the input and output increases the required compressor pressure and electricity consumption. If the pressure is limited, the heat pump may not be able to deliver sufficiently high output temperatures when the input temperature is low. In this case, the boiler provides the difference. This operation strategy minimises strain on the heat pump compressor while ensuring high heat pump efficiency.

It can be beneficial for the gas boiler to provide most or all of the domestic hot water heat demand, since the minimum required temperature hereof is 55°C, no matter the season, to avoid bacterial growth such as Legionella. The heat pump can pre-heat the domestic water, while the gas boiler provides the remaining heat, but in some cases the gas boiler will just provide the full domestic hot water demand.

The operation may also be optimized according to price signals from the power market and time-of-use tariffs or local price signals, thereby reducing the strain on the local power grid. This may again diminish or postpone the need for grid reinforcement, while also lowering the electricity costs.

Compared to pure heat pump systems, the hybrid system is more suited for providing regulating power for balancing the electricity grid, because it can shift between two supply options. The benefit of this flexibility is expected to increase as the share of electricity produced by intermittent, renewable energy sources, such as wind and solar, increases – and the loads in the distribution grids surge, as more and more households are equipped with electric vehicles and heat pumps.

The hybrid heat pump is typically dimensioned to ensure that the heat pump can provide approximately half of the expected peak heat demand of the building[7]. A heat pump of this dimension is expected to deliver

[7] Typically calculated for an external temperature of -10°C.

approximately 70-90% of the annual heat demand. Typically, the gas unit is dimensioned to provide the full peak demand.

Input

Inputs for hybrid heat pumps consisting of an air-to-water heat pump and a gas boiler are ambient air, electricity and gas.

Output

Hot water for space heating and domestic hot water.

Typical capacities

The heat capacity of the heat pump component in a hybrid solution for a residential household typically lies in the range of 3 kW to 9 kW, where 5 kW is commonly installed in existing single-family house. This size will be able to deliver most of the heat demand of such a house. For comparison, the same building with a pure heat pump solution is expected to require a heat pump of approximately 7 kW. Heat pump capacities are defined at -7°/55° degrees.

Existing gas boilers are typically larger than strictly necessary, mainly due to gas boilers having relatively small economy of scale effects. In the data sheet, a system including a 20 kW gas boiler for households is assumed, but the costs are not expected to be significantly different for a system with a smaller or larger boiler.

In larger buildings, the dimensions will depend on the specifications of the building, but generally the heat pump is still dimensioned to deliver 80-90% of the heat demand. In larger buildings, cascade heat pump systems are common, where the heat pump component consists of multiple smaller heat pumps connected in series. As in smaller buildings, the gas boiler will often be dimensioned to supply the full heat demand.

Regulation ability

Many modern heat pumps are equipped with an inverter/frequency converter, so they can operate at part load. The fact that the heat pump is supported by a gas boiler means that the heat pump can operate at a lower than maximum load, which decreases the strain on the components. Heat pumps can typically operate at as low as 20-30% of their maximum load. Likewise, most gas boilers are able to modulate down to about 20-25% of the nominal maximum output.

The introduction of more smart controls can increase automatic operation surveillance and communication between the two units, ultimately resulting in a better performing system.

Advantages/disadvantages

The hybrid heat pump can bypass some of the disadvantages of both traditional gas boilers and electric heat pumps.

Hybrid heat pumps consume less gas compared to a traditional gas boiler, and therefore also have lower emissions. The gas boiler typically only delivers 10-20% of the annual heat consumption. Furthermore, the share of green gas in the gas supply is expected to increase, further decreasing the emissions. The combination of a heat pump and boiler enables minimization of heating costs, and these will typically be lower compared to a single boiler and/or heat pump.

Heat pumps have the disadvantage that their efficiency decreases, as the temperature difference between the heat source and delivered heat increases. This effect can be reduced in a hybrid heat pump, because the gas boiler can boost the temperature of the heat delivered by the heat pump, so the bulk of the heat pump operation will be at a lower temperature difference and therefore higher efficiencies. Since the energy not delivered by the heat pump is delivered by the boiler instead, the total system efficiency does not necessarily increase. Below is a calculation example for the system efficiency for a building with a heat demand of 13,4 MWh where the heat pump delivers 80% of the heat demand:[8]

$$Electricity = \frac{HP_{out}}{SCOP} = \frac{13{,}4\ MWh \cdot 80\%}{3{,}5} = 4{,}3\ MWh$$

$$Gas = \frac{GasBoiler_{out}}{Eff.} = \frac{13{,}4\ MWh \cdot 20\%}{91\%} = 3{,}9\ MWh$$

$$Eff_{sys} = \frac{Heat\ demand}{Electricity + Gas} = \frac{13{,}4\ MWh}{4{,}3 + 3{,}9\ MWh} = 223\%$$

As previously mentioned, a hybrid system can also operate based on the electricity price and can support the power grid by reducing or increasing electricity consumption.

Another advantage of a hybrid heat pump is that the individual components do not have to be dimensioned to deliver the full heat demand. As mentioned earlier in this section on gas boilers, the economy of scale effect of gas boilers is small, while it has been found that for the small heat pump a capacity increase of 1 kW increases the price by about 5-15% including installation, as in the section for heat pump. While for the large heat pumps it has been found that doubling the capacity will increase the total investment cost by about 70%. Reducing the capacity of the heat pump reduces the investment cost of the heat pump unit, but since the hybrid solution requires both a heat pump and gas boiler, the total investment cost is a little higher than for simply installing a full air-to-water heat pump solution for an existing single-family house. A package solution (separate, new boiler and heat pump) requires installation of two separate units, which increases the installation time and price compared to the installation of a heat pump or gas boiler alone.

A package solution requires more space indoors than both the gas boiler and pure heat pump solutions, which can pose a challenge in some houses. On the other hand, the indoor unit of integrated solutions generally requires less space than the indoor component of a pure heat pump.

Since the hybrid solution has two different heat producing components, it adds a layer of security for the owner. If the boiler or heat pump is out of operation, the other component can still deliver most if not all of the heat demand. This may also be an important factor for consumers who are hesitant in choosing a full heat pump solution due to the fear of it not being able to deliver enough heat on the coldest days.

The ability of one unit to deliver all or most of the heat demand adds flexibility regarding time-dependent tariffs, where periods with high tariffs can be avoided.

[8] The heat demand does not have to be defined to calculate the system efficiency but is done so in the example for easier understanding. The system efficiency can be calculated without defining the heat demand: $Eff_{sys} = \frac{1}{\frac{Share_{HP}}{Eff_{HP}} + \frac{Share_{boiler}}{Eff_{boiler}}}$

There are a small number of houses where a pure heat pump solution is not well suited, for example buildings with unusually high temperature requirements for the space heating. In these buildings, a hybrid solution may be better suited.

By reducing the HP size in the hybrid technology and supporting heat production with the gas boiler in cold periods, the noise generation is decreased compared to a corresponding pure heat pump system. Therefore, it may be possible to install the solution where a pure heat pump solution would not be suitable.

Since the heat pump does not have to deliver the full heat demand, the strain on its components is less. This can increase the economic lifetime of the system. Similarly, the gas boiler also operates less, meaning its lifetime is expected to be improved.

For newer gas boilers, the add-on solution could be an affordable and cost-effective way to upgrade the heating system, assuming there are no compatibility issues.

Both the gas boiler and the heat pump require maintenance. Some companies offer combined service of both the boiler and the heat pump, but since the amount of work is larger, the fixed O&M cost would typically be slightly higher than that of pure boiler and pure heat pump solutions but can vary depending on the specific company. One source reported that a service of a hybrid heat pump could cost 1.5 times that of a pure air-to-water heat pump system, whereas another source mentioned that the cost of maintaining a hybrid heat pump was almost the same as for an air-to-water heat pump system [8]. In the datasheets the cost of service is set as 25% higher than that of a corresponding air-to-water heat pump.

Environment

The environmental effects of a hybrid heat pump are the sum of the environmental effects of the gas boiler and the air-to-water heat pump. These are shortly summarized below, and it is recommended to read the corresponding section for the two technologies for more details.

Gas boilers have NO_x and CO emissions, but these are quite low. Since gas boilers generally burn natural gas, they also emit CO_2. With increasing injection of biomethane (about 20% in 2020) into the grid, the carbon footprint of gas boilers is declining. Furthermore, increased use of intelligent controls may also reduce the emissions.

The environmental effect of the air-to-water heat pump relates to the electricity consumption, the refrigerant, and the generated noise. The environmental impact due to the use of electricity will depend on the way the electricity is produced.

For details about the environmental impact of the refrigerants, please refer to the section on electrical heat pumps.

The other main environmental impact is the noise the outdoor unit of the heat pump generates. The amount of noise generated is correlated with the quality, type, and size of the heat pump. For details about the sound level of the heat pumps, please refer to the section on electrical heat pumps. The indicative maximum noise level is 35 dB during the night and max 45 dB during the day measured at the property boundary. Since most heat pumps generate more noise than this, they must generally be placed at some distance from the boundary. The heat pump in a hybrid configuration is typically smaller, and therefore the generated noise can be lower compared to a corresponding pure heat pump solution.

Research and development perspectives

The hybrid heat pumps will benefit from the developments in both gas boilers and heat pumps. Gas boilers by themselves are a mature and commercial technology with large deployment, and they are highly efficient. Significant development in the technology is not expected, but there may be optimizations regarding boilers in a hybrid context, for example smart grid and control.

On the other hand, air-to-water heat pumps have developed rapidly in the last 10 years, as the interest in them and sales grows, and they are expected to continue developing. The experience with heat pumps among installation companies has been low, which has resulted in suboptimal installation. This is expected to improve due to the growing market and a focus on increasing competencies of installation companies via measures such as RE-certifications (VE-godkendelsesordning). This also means that the installation costs will decrease, as companies get more experienced with installing these systems.

Besides the installation, the noise of the outdoor unit is expected to continue to decrease. Furthermore, the developments within refrigerants can potentially increase the maximum temperature, the heat pump can deliver, to 75°C.

Examples of market standard technology

Figure 48: Daikin Altherma, integrated hybrid heat pump (unit solution) 5 kw heat pump, 32kW gas boiler [3]

Figure 49: A hybrid heat pump by Panasonic for larger buildings and heat demands.

Figure 50: Package solution consisting of ELCO Thision Mini gas boiler and air-to-water ELCO Aerotop Monobloc heat pump. [4]

Prediction of performance and costs

As mentioned earlier, package or integrated solutions are often preferred to add-on solutions, and therefore the datasheets focus on these solutions.

Costs

There are currently no statistics for the sale of hybrid heat pump systems in Denmark but according to suppliers, the sale is limited.

The demand for hybrid heat pumps is higher and growing in other European countries, including England, the Netherlands, and Austria [6][9], and therefore, despite the lack of activity in Denmark, the costs are still expected to decrease, and the efficiency to increase. Also, as stated earlier, hybrid heat pumps will benefit from the developments within air-to-water heat pumps. Moreover, increased interest in hybrid solutions will increase competition among producers of boilers and heat pumps to create products more capable of efficient integration.

The investment costs of hybrid heat pumps described in the datasheets are based on market research and interviews with companies offering hybrid solutions. Due to the limited market of hybrid heat pumps, this price is validated using data for pure heat pump and gas boiler solutions separately, which is expected to be representative, especially with regards to a package solution consisting of a separate boiler and heat pump.

Since a portion of the cost pertains to the gas boiler, the total costs are not expected to decrease as drastically as pure air-to-water heat pumps. For existing households, it is assumed that the cost of the equipment for the heat pump will decrease by 15% in the period 2025-30 and again in the period 2030-50, while the cost of the equipment for the gas boiler is only expected to decrease 0.5% annually. For this reason, the cost of the equipment of a hybrid heat pump is expected to decrease by 12% towards 2030 and another 13% between 2030 and 2050.

Like air-to-water heat pumps, the relative reduction is expected to be the same for larger buildings. The equipment for the heat pump is expected to see a cost reduction of 15% in the period 2025-30 and again in the period 2030-50, while the equipment for the gas boiler is only expected to decrease 0.5% annually. This gives an overall equipment cost reduction of 12-13% by 2030.

The smallest decrease in installation costs is expected in both the short and long term. This is because the shortage of skilled workers with experience in hybrid systems is projected to grow, despite an overall increase in the total number of workers.

Similar to air-to-water heat pumps, the installation costs in households are expected to decrease by 25% in existing buildings and 15% in new single-family households. The installation is more expensive than for a pure air-to-water heat pump system, since a gas boiler also needs to be installed. For integrated solutions, the installation cost may be closer to that of a pure heat pump system. For both new and existing building complexes, the installation costs are expected to decrease by 25%.

Performance

When installed in a hybrid context, it is expected that the boiler will achieve lower total efficiency compared to the same gas boiler alone. This is due to the fact that a boiler in a hybrid context generally produces heat when higher water temperatures are required, ie. during cold periods and domestic water. According to a study performed by DGC, the efficiency of a gas boiler during the summer season is estimated as 91%[9] and a similar efficiency is expected for a boiler in a hybrid solution [5].

The heat pump efficiency is highly dependent on the specific conditions and the operation strategy. There are no in-depth analyses or studies of how much the heat pump efficiency improves in a hybrid set-up

[9] Net Calorific Value (NCV)

compared to a non-hybrid set-up, but it will be higher. Due to the lack of sources, the average heat pump efficiency is therefore constructed based on knowledge from pure heat pump solutions.

If it is assumed that the heat pump provides the full heat demand while the gas boiler provides the full domestic hot water demand, the heat pump's annual average efficiency is estimated to increase by 6-8%, for an existing household with radiators. This is not a completely accurate representation, because in reality, the heat pump and boiler will support each other more dynamically. For example, this calculation does not take into account that the heat pump in a hybrid context will not produce the full heat demand in the coldest periods.

Therefore, it is expected that the average annual efficiency of the heat pump will be increased further. To account for this, it is assumed that the heat pump will not produce during the 300 lowest COP-hours[10] (assuming same COP (2.2) as for producing domestic hot water), where the gas boiler provides the full heat demand instead. This increases the annual average efficiency of the heat pump by 10-13% compared to a pure air-to-water solution in an existing single-family home with radiators. This is under the assumption that when the heat pump assists the boiler with domestic hot water production, it only pre-heats the water to a degree where it does not affect the annual average efficiency of the heat pump. This value is very uncertain, and there will also be variation between systems, due to differences in the buildings, system configuration and operating strategy.

Uncertainty

The political environment has a large effect on the future of hybrid heat pumps. Currently, the focus is on pure heat pump solutions and looking at a future with less gas used for heating buildings. The lack of focus on gas-hybrid solutions is partly due to the political targets of reducing the use of fossil gas, and that the available amount of green gas in the future is uncertain. Therefore, other sectors, without relevant alternatives to gas, may be prioritized for this resource [7]. Consequently, it is uncertain if and when the sale of hybrid heat pumps will increase in Denmark.

On the other hand, it is unclear how the load on the power system will develop. The integration of large numbers of pure heat pump solutions and electrical vehicles can strain local power systems, which may increase the interest in hybrid solutions in such areas.

It is uncertain how the available models will develop, and which types will be most in demand. The price of gas versus the price of electricity, as well as the taxation structure, can also affect whether consumers choose a hybrid solution, a pure heat pump solution or a purely gas-based solution.

Therefore, the development of costs and efficiencies are uncertain.

As described in the chapter for heat pumps, their efficiencies are also uncertain, and more so for heat pumps in hybrid solutions, because the operating strategy also plays a role.

[10] Estimated number of hours with average of 0 degrees or less in Denmark.

Economy of scale effects

Due to the economy of scale effects of air-to-water heat pumps, hybrid heat pumps will also have a considerable cost reduction with increasing system size. This effect is expected to be less than that of pure air-to-water systems, since the gas boiler component does not have a significant economy of scale effect.

Additional remarks

A key point regarding application of the data sheet is that the efficiency may vary considerably depending on the specific temperature parameters.

Application of the data sheet for calculations of a concrete project should be evaluated according to the specific local conditions. Some guidelines based on experience from existing applications of heat pumps are provided in the data sheets.

Quantitative description

See separate Excel file for Data sheets.

References

[1] ”Udskiftning af ældre gaskedel til gashybridvarmepumpe”, Videnscenter for Energibesparelser i Bygninger, 2019, https://www.byggeriogenergi.dk/media/2001/gashybridvarmepumpe_ok.pdf
[2] www.Hybridvarme.nu
[3] https://www.viessmann.dk/da/viden/teknologi-og-systemer/hybridanlaeg.html
[4] https://www.gastech.dk/luft-til-vand-varmepumper/hybridloesning-varmepumpe-gasfyr/
[5] DGC, ”Dokumentation for villagaskedlers faktiske virkningsgrad”, November 2020.
[6] Workshop about hybrid heat pumps organized by TEKNIQ, September 2020.
[7] Danish Energy Agency, ”Spørgsmål 263”, march 2020. https://www.ft.dk/samling/20191/almdel/kef/spm/263/svar/1643963/2165926.pdf
[8] Interviews with installation companies.
[9] https://www.greenmatch.dk/varmepumpe/hybridanlaeg

209 Electric boiler

Contact information

Danish Energy Agency: Emil de Bekker Steffensen, teknologikatalog@ens.dk

Author: Ea Energy Analyses, 2025.

Publication date

2025

Qualitative description

Brief technology description

Electric boilers heat water for space heating and domestic hot water by converting electrical energy into heat through immersed resistance elements. These systems are valued for their reliability, simplicity, and ability to supply heating in single family houses and apartment buildings.

Electric boilers are a mature and reliable technology for space heating and hot water production in single-family houses and apartment buildings, offering a straightforward path to electrification. However, **not common in** Denmark e.g. due the high energy factor for electricity in the Danish building regulation making it difficult to comply with the requirements in the energy performance if using electric heating.

Electrical boilers for residential heating, which are typically resistance element boilers, are common in other countries. They can be wall-mounted or floor-standing and are typically compact, requiring minimal installation space.

Electric boilers are available in various configurations; as standalone units for space heating, combined units for both space heating and hot water (combi-boiler), or as auxiliary/supplementary units in hybrid systems (e.g., with heat pumps or solar thermal). The circulators, for distributing the heat in the radiator system, may be integrated into the boiler or installed separately. Electric boilers up to 6 kW are typically single-phase, while those over 6 kW are three-phase. Tubular sheathed heating elements are the foundational technology for the resistance element in most electric boilers for residential heating. These elements are highly versatile and can be assembled into different mounting forms, notably as both screw-in/cartridge elements and flanged immersion elements. Tubular sheathed heating elements consist of a resistance wire (commonly nichrome) inside a metal sheath, often stainless steel, copper, or nickel-iron-chromium alloys. The sheath protects against corrosion and ensures long-term durability. The industry standard for insulating the resistance wire within the element is pressed magnesium oxide (MgO). MgO provides good thermal conductivity and electrical insulation while withstanding high temperatures. It is used in nearly all tubular and immersion elements for both small and large boilers. Alternatives to magnesium oxide are rare in standard domestic and central heating boilers due to MgO's superior balance of conductivity, insulation, and cost. As mentioned, tubular sheathed heating elements come in different forms where screw-in/cartridge elements are common in smaller, single-family house boilers and hot water tanks, these elements are threaded and can be easily replaced, making them convenient for decentralized or domestic settings. Flanged Immersion Elements are used in larger boilers (such as those for apartment buildings), these elements are bolted to a flange on the boiler tank. Flanged heaters are robust, offer higher wattages, and facilitate maintenance. They are ideal for central, high-capacity or commercial-scale applications. The tubular elements are designed for ease of maintenance and replacement.

Other types of electric heating are electrode and induction heating. Electrode boilers heat water by passing current directly through the liquid between immersed electrodes. Induction boilers use electromagnetic induction—an electrical current in a coil generates heat in a metal core or pipe, transferred to the water. Both are less common in residential settings due to complexity, higher cost, and safety considerations. References for the above technology description are [1], [2], [3],[4],[5], [6], [7], [8].

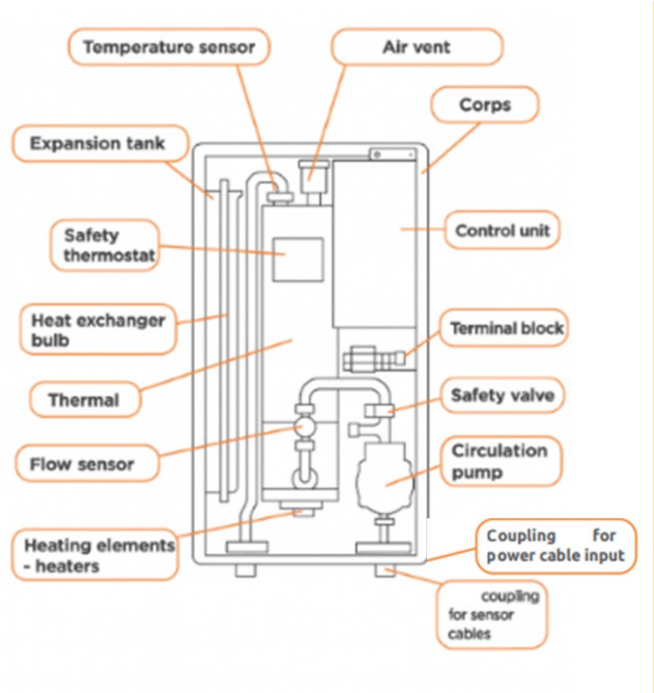

Figure 51: Illustration of an electric heating boiler, inspired by the OPERATING MANUAL figure 1 https://teknix.pro/wp-content/uploads/2023/07/instrukciya_teknix_eng.pdf

Input
Electrical boilers are using electricity as energy source.

Output
Output is hot water for space heating and/or domestic hot water.

Typical capacities
Electric boilers for single-family homes typically have a capacity of 3–20 kW, sufficient to cover the full heat demand of modern, well-insulated single family houses. Larger units (up to several hundred kW) are available for apartment buildings and commercial applications. For domestic hot water, instantaneous electric water heaters may also be used, but these are not covered in this chapter.

Regulation ability
Modern electric boilers are highly flexible and can modulate output from near-zero to full capacity almost instantaneously. They can respond rapidly to changes in heat demand and are well-suited for integration

with smart controls, demand response, and renewable electricity sources. Advanced models offer precise temperature control and can be operated in cascade for larger installations.

Boilers are generally sold with controls that enable the optimal matching between the user demand and the appliance's heat production and the actual hot water demand. For example, in case the user needs hot water, the control system will give production priority to that demand. The control systems can communicate with components such as external temperature sensors or circulators. The control system will also adapt to other control elements such as radiator thermostat etc. Some control systems are auto-adaptive: they will learn from the recent past to optimize the control of the boiler.

Advantages/disadvantages

Environmental impacts are described in the section Environment.

Advantages

Electric boilers have several advantages:

- Relative high efficiency (100%)
- Low investment cost
- Easy and quick installation
- Low space requirements for the boiler, compact design, no fuel feeding systems or fuel storage
- Low maintenance requirements, simple and reliable technology
- Quick start-up and fast load response, fast reheating after night setback
- Provides flexible electricity consumption and can serve as a smart grid technology.

Disadvantages

Electric boilers have some disadvantages:

- High energy costs
- High loss of exergy when converting electricity to heat
- If widespread used, the peak load power demand can prove a challenge for both power production units and the electricity grid.
- A household or an apartment complex heated by electric heating often requires reinforcement of the electricity connection compared to households heated by heat pumps, boilers or district heating.

Environment

- Electric boilers have no local environmental impact
  - Electric boilers produce no direct emissions during operation.
  - Electric boilers produce no noise during operation
- The environmental impact due to the use of electricity will depend on the way the electricity is produced.

Research and development perspectives

Electric boilers are a mature technology (category 4). Future improvements are likely to focus on smart integration (demand response, grid services), reduced standby losses, and higher power density (smaller units with higher output). Hybrid systems combining electric boilers with heat pumps or thermal storage are an area of growing interest.

No major efficiency gains are expected for the core technology, but system-level innovations (control, integration) are relevant.

Examples of market standard technology

Examples of Danish and international manufacturers include Argo, CTC, ThermoGroup, and Bosch. Market-standard electric boilers for residential use typically have modulating output, digital controls, and safety features such as over-temperature and dry-run protection[9], [10],[11],[12],.

Figure 52: Example of market-standard electric boilers for residential use. AT Series C Electric Boiler, copied from : https://argocontrols.com/products/boilers-electric/series-c-electric-boiler. The AT Series C is a 100% efficient, compact wall hung boiler with an advanced microprocessor control and load managing controller. The Argo AT Series C has a proven one piece cast iron heat exchanger backed by a 20 year limited warranty.

Predictions of performance and costs

Electrical boilers offer efficiency close to 100% at the point of use and maintain this level over their lifetime. Furthermore, auxiliary electricity consumption is minimal.

This technology is currently only marginally available on the Danish market, which may result in higher costs than those indicated. The price estimates are based on international experience, and their applicability in Denmark presupposes the establishment of a domestic market of sufficient scale.

As a mature technology, only incremental cost reductions are expected, mainly due to ongoing improvements in manufacturing productivity. The main cost driver is the price of electricity, not the boiler itself. Future cost reductions may result from simplified installation, greater standardization, and integration with smart home systems. Therefore, even though electric boilers are not common in Denmark, their design is so simple, and installation is so straightforward that it is anticipated their total cost will decrease by 0.5% per year, consistent with the trend observed for other mature technologies.

Uncertainty

There is a relative high uncertainty related to predicting the total cost in Denmark in 2025 due to the limited experience, while the uncertainty on the other parameters is low.

Economy of scale effects

For electric boilers for one family houses, the cost per kW remains relatively constant across the typical size range (3–20 kW). This reflects the simple, modular design of the technology.

For the apartment size electrical boilers only examples of electrical boilers supplying district heating have been found. Based on these it is expected that a capacity increase of 100 % will increase investment cost by about 65-75 %.

Quantitative description

See separate Excel file for Data sheets.

References

[1] Electric boilers: what you need to know, https://www.partedonboiler.com/resources/electric-boilers-what-you-need-to-know.html, Partedon group, 2024

[2] Understanding Electric Water Heater Elements, https://www.kingheating.com/blog/understanding-electric-water-heater-elements, visited July 2025

[3] Electric Boiler Heating Element (CALEB Range), https://www.heattec-webshop.com/electric-boiler-heating-elements, Heattec, visited July 2025

[4] Boiler Heating Element: Features, Benefits, and Prices in India 2025, https://www.powerpackelectricals.com/blog/boiler-heating-element, Powerpack, visited July 2025

[5] How To Select To Use Flange Immersion Heater Or Screw plug heater?, https://www.jaye-heater.com/info/how-to-select-to-use-flange-immersion-heater-o-96071637.html, Jaya Heater, May 2024

[6] Electrical Resistance Wire & Tapes, https://www.knight-group.co.uk/products/electrical-resistance-wire-tapes/, knight-group, visited July 2025

[7] Flanged Armoured Heating Elements, Flanged Armoured Heating Elements Reco group, Reco Group, visited July 2025

[8] AT Series C Electric Boiler , https://argocontrols.com/products/boilers-electric/series-c-electric-boiler, Argo, visited July 2025

[9] Heating with an electric boiler options, https://alterair.ua/en/otoplenie/elektricheskiy-kotel-dlya-doma/, Alter Air, visited July 2025

[10] Electric boiler Mini Europe +, An electric boiler with safe values! https://www.thermogroup.nl/v2/pdf/en/mini-europe-plus.pdf

[11] CTC EcoMiniEl https://ctc-heating.com/products/electric-heating/ctc-ecominiel, CTC, visited July 2025

215 Solar heating system

Contact information

Danish Energy Agency: Emil de Bekker Steffensen, teknologikatalog@ens.dk
Author: Original chapter from 2016 made by COWI.
Update in 2021 and 2025 by Ea Energy Analyses.

Publication date

2016

Amendments after publication date

Date	Ref.	Description
X-x-2025		Minor adjustments made in the data sheets.
20-01-2021		Comprehensive update has been undertaken during Q4 of 2020. Primary focus is on data sheets, but text has been revised as well.

Qualitative description

Brief technology description

Solar energy for domestic hot water and space heating is usually based on the principle of pumping a heat transfer liquid (typically a mixture of water and propylene glycol) from an array of roof mounted solar collectors to one or more storage tanks. Solar heating for dwellings has mainly been developed for coverage of the entire hot water demand during the summer period, and to a minor degree for space heating [1]. Because of the mismatch between demand for space heating and available solar heat, there is a need of seasonal energy storage if solar energy should be the only supply. Such storage systems are only feasible at very large scale, and therefore solar heating for single-family houses must be combined with other heating systems, e.g. gas boilers or heat pumps. Small-scale long-term storages based on heat of fusion (heat of melting – the heat used when a substance melts) are theoretically possible, but they are not on the market today.

The main components of a solar heating system are: Flat plate or vacuum tube solar collector, storage tank with heat exchangers, pump and control unit. Self-circulating systems work without pump and control.

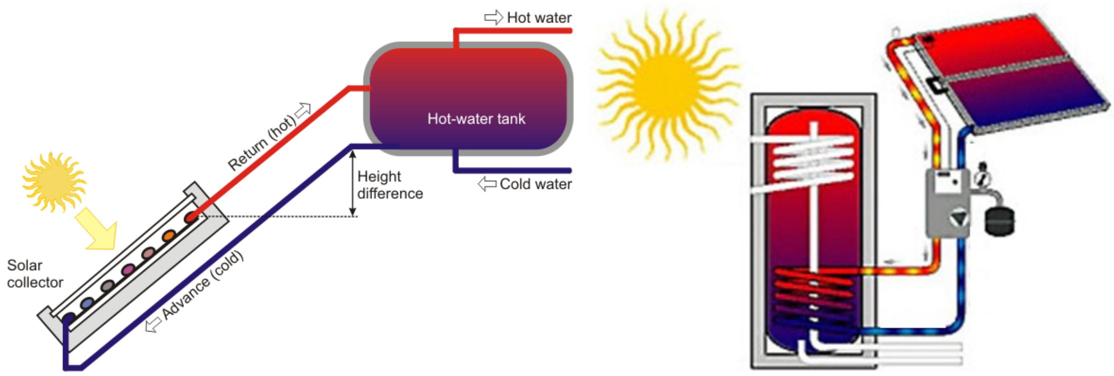

Figure 53: Small solar heating system for domestic hot water. To the rigth a pumped system where auxiliary heat is supplied to the upper heat exchanger coil. To the left a thermosyphon system without pump. In such a system the circulation of the heat transfer fluid is driven by natural convection rather than a mechanical pump. By far the most systems are equipped with a pump.

Input

The primary energy input is solar radiation, of which a part can be converted to thermal energy in the absorber plate. The amount of energy reaching the solar collector depends on geographical site and orientation of the collector as well as possible shadows and ground reflectance. The only non-solar energy input to a solar heating system is the electric energy needed for the pump, controller and optional electric back-up heater. This amounts to up to 5 % of the delivered energy in a typical system, not including electric backup heater.

Output

The output is thermal energy at medium temperature, typically 20-80 °C, depending on operation conditions and collector type. Higher temperatures are possible with special double-glazed solar collectors for district or industrial heating, but they are hardly relevant for domestic hot water (DHW) and space heating.

It is very important to mention that the actual performance of a solar heating system is highly dependent on the energy consumption and its distribution on time. A high consumption per m^2 collector is favourable for the efficiency, because it tends to lower the operational temperature, but it also results in a low solar fraction i.e. the part of the heating demand that is covered by the solar heating system.

Typical capacities

Traditionally, the system size is given in m^2 collector surface. For single-family houses the typical range is from 4 m^2 in case of a small DHW system to 15 m^2 for a combined space heating and DHW system. In order to compare with other technologies, IEA has estimated that 0.7 kW of nominal thermal power can be used as an equivalent to 1 m^2 collector surface [5]{7].

Regulation ability

The thermal efficiency is largely determined by the solar irradiance and the actual operating temperature relative to ambient temperature. As the operating temperature increases, efficiency drops, so in a sense solar collectors are self-regulating and will stop producing heat when it reaches the so-called stagnation temperature. The regulation system in a solar heating plant can switch the available solar energy to be used for hot water or space heating and in some cases to a heat dump (typically the ground circuit in a solar/heat pump combi-system), in order to avoid boiling or temperature-induced damages. Boiling can happen in case of a power failure during periods with bright sunshine. A safety valve will open and it will be necessary to refill the system.

Advantages/disadvantages

Advantages

- No pollution during operation.
- The solar collector can be integrated in the urban environment and will then substitute a part of the building envelope.

- Large energy savings are often possible if the existing heater can be completely switched off during the summer so that standby losses can be substantially reduced.
- No dependency on fuels.

Disadvantages

- Relatively expensive installation, except for large systems.
- Mismatch between heating demand and solar availability.
- Requires sufficient area on the roof with appropriate orientation.
- May compete with photovoltaic systems for the same area.
- Cannot cover the entire heat demand.

Environment

A solar heating system mainly contains metals and glass that require energy in manufacturing. It is estimated that the energy payback time is 1-3 years [4] for a well-functioning system in Denmark. Almost all the materials can be recycled. The special selective surface used on most solar collectors is made in a chemical process that in some cases involves chromium. It is important that the process control is adequate to avoid any pollution from this process. The fluid used in most solar heating systems shall be disposed of as low-toxic chemical waste.

An LCA (Life Cycle Assessment) found that the main part of pollution during the lifetime of a solar heating system is acidification by sulfur produced in combustion processes during production. These emissions accommodate half of the pollution from the system [5] [6].

Research and development perspectives

The most relevant R&D needed for further development of solar thermal systems is:

- Advanced and cost-effective storage systems for thermal energy.
- More cost-effective solar collectors, mainly through improved low-cost manufacturing processes.
- Self-adjusting control systems that are easily adapted to the existing heating system.
- Completely new system designs, e.g. air-based wall solar collectors combined with heat pumps.
- Improved architectural design and smooth integration in buildings.
- Integration with solar photovoltaic and heat pumps (PVT – Thermal PV).
- Cost- effective mounting and installation methods

Examples of market standard technology

The sector is characterized by step-by-step improvements, and areas where there have been improvements within the last 10 years are:

- Vacuum tube collectors with high power/cost ratio
- Hot water heat exchanger modules for Legionella prevention.
- Large-scale solar collectors for district heating and other applications.
- Energy saving pumps for less electricity consumption.

Most systems on the market today are vacuum tube collector modules and are systems with a pump circulating the liquid in the tubes. Most systems are modular, meaning it is possible to add another panel to existing systems. To cover 65% of the hot tap water demand in a system for a new apartment complex described earlier in this catalogue a solar collector area of approximately 300 m^2 is needed, and such a system is not an “off the shelf” product. Two systems for single family houses are shown below:

Figure 55: Complete solar heating system with a hot water storage tank of 300L. Able to supply a new family house with 100% of hot water supply during hot months. [9]

Figure 54: Vacuum solar collector from Sun Power with 380W/m2 capacity and a Solarterm hot water storage tank, 200l. [8]

Prediction of performance and costs

Today, solar heating covers a minute part of the Danish energy supply (less than 1 % of the total heating). In recent years, the dominating market has shifted from individual systems to large-scale systems for district heating due to economy of scale benefits. However, with the increasing demand for energy efficiency of new buildings, individual solar heating plants could become more and more common. The international (European) solar thermal industry was growing rather quickly up to 2008 but has been decreasing since then. It has probably to do with the fact that solar photovoltaic has been growing very quickly in the past years. The major challenge for solar thermal energy is to develop low cost manufacturing and installation processes, which is very difficult in a situation where the markets in Europa and Denmark are declining [3]. A logical way to cope with this challenge is to merge solar thermal with solar photovoltaic into one system or module. There are also many attempts in this respect presently. It should be noticed that compact self-circulating DHW systems are far cheaper than the traditional pumped systems but are not much used in Denmark for aesthetical reasons and risk of freezing. Solar heating systems are a mature and commercial technology with a large deployment (a category 4 technology).

Uncertainty

Small solar systems for DHW are a category 4 technology. It is expected that this technology will continue to develop on market conditions with gradually reduced prices and increased performance.

The future of larger systems for space heating is more uncertain. The competition about roof space with photovoltaic will be a challenge and it could therefore happen that pure solar heating plants will continue to be a declining market.

Economy of scale effects

The scale effect for solar heating systems for buildings mainly comes from installation costs that will be smaller per area for larger plants. The rational mounting or building integration has been the key issue to address for solar thermal heating systems.

Additional remarks

This technology description is limited to traditional (pumped) solar heating systems without exchange of energy with other buildings than the one where the solar collectors are installed. Only domestic hot water and space heating are considered, not solar cooling.

Quantitative description

See separate Excel file for Data sheets.

References

[1] Solvarme faktablade, www.altomsolvarme.dk.

[2] http://www.rhc-platform.org/fileadmin/user_upload/Structure/Solar_Thermal/Download/Solar_Thermal_Roadmap.pdf

[3] http://www.iea-shc.org/data/sites/1/publications/Solar-Heat-Worldwide-2014.pdf

[4] Energiteknologier – tekniske og økonomiske udviklingsperspektiver, Teknisk baggrundsrapport til Energistrategi 2025, 2005.

[5] Life cycle environmental impact assessment of a solar water heater. Koroneos j. Christopher. 2012.

[6] Bygningsintegreret energiproduktion. Det økologiske råd, juni 2011.

[7] Recommendation: Converting solar thermal collector area into installed capacity (m2 to kWth). Technical note, IEA SHC 2004.

[8] Vvs-eksperten.dk. https://www.vvs-eksperten.dk/varme-og-klima-solenergi-solfangersaet-solfangersaet-18-ror-og-200-liter-solvarmebeholder-379997530, 2020

[9] https://dbvvs.dk/produkt/solvarmeanlaeg-pakke-4, 2025

[10] Solvarme pakke https://www.dbvvs.dk/shop/solvarmeanlaeg-pakke-3-2433p.html

216 Electric heating

Contact information

Danish Energy Agency: Emil de Bekker Steffensen, teknologikatalog@ens.dk
Author: Original chapter from 2016 made by COWI.
Update in 2021 and 2025 by Ea Energy Analyses.

Publication date

2016

Amendments after publication date

Date	Ref.	Description
20-01-2021		Comprehensive update has been undertaken during Q4 of 2020. Primary focus is on data sheets, but text has been revised as well.
July 2025		Minor update has been undertaken during Q3 of 2025. Primary focus is on data sheets, and text has been revised accordantly.

Qualitative description

Brief technology description

Electric radiators are mounted in each room. The bathrooms are sometimes equipped with electric floor heating systems. The hot tap water is made by a hot water tank with an electric heating coil. In case the distance to a secondary tapping point is large, more than one water heater can be installed. The radiators are equipped with internal thermostats, but more advanced systems are available, making it possible to program a temperature schedule individually for each room[1]. Electric heating can be a supplement or a complete system. Electric heating can be controlled by external systems, as an example Lauritz Knudsens IHC system including night set back. Also, remote internet control is becoming popular, particular in vacation houses. The installation will normally include a group switch per one or two rooms, making central control very simple to install.

Input

The input is electricity.

Output

The output is room heating and hot water.

Typical capacities

Typical capacities for one-family buildings and apartment complex are 5 to 320 kW. Normally there will be installed 1 or more panels in each room, number and capacity of the panels in the different room depends on the heat demand of room.

Regulation ability

The control is very flexible and the capacity can be regulated fast from 0 to 100 % and vice versa. It should be noted that the heat output is only dependent on the installed nominal power. In most cases, use of night setback or other forms of periodic heating is very efficient, as the reheating of the rooms can be very rapid. Furthermore, adding extra capacity is cheap.

Electric radiators can be built as storage heaters with some energy storage. For such radiators, electricity can be turned off for a period, but heat is still emitted from the radiator. This ability can be used to e.g. fit time varying electricity tariffs.

Advantages/disadvantages

Environmental impacts are described in the section Environment.

Advantages

- Low investment and installation costs [4]
- Distribution heat losses are saved compared to water based heating systems.
- No space requirements for, no boiler, no fuel feeding systems or fuel storage
- Low maintenance requirements, simple and reliable technology
- Precise room temperature control, easy possibility of remote control
- Fast load response, fast reheating after night setback
- Provides flexible electricity consumption and can serve as a smart grid technology.

Disadvantages

- High energy costs
- High loss of exergy when converting electricity to heat
- If widespread used, the peak load power demand can prove a challenge for both power production units and the electricity grid.
- A household or an apartment complex heated by electric heating often requires reinforcement of the electricity connection compared to households heated by heat pumps, boilers or district heating

Environment

- Electric boilers have no local environmental impact
  - Electric boilers produce no direct emissions during operation.
  - Electric boilers produce no noise during operation
- The environmental impact due to the use of electricity will depend on the way the electricity is produced.

Research and development perspectives

Research concerning the future use of direct electrical heating in a smart grid may lead to positive results for this technology. It shall be taken into account that electrical heating historically often showed unexpected low energy consumptions [2]

Examples of market standard technology

A modern electric heating system is an intelligent system, see [3]. Each room can be controlled individually, and the consumption per room can be displayed for the consumer. The bathrooms are heated with floor heating and the rooms with panels. The hot water tank is a 'smart tank' including self-learning controls to maintain the lowest average temperature, while still controlling the risk of Legionella. Storage heaters are used in case of varying electricity tariffs.

The technology is mature and has been in use for many years. However, an important development over the past decade is the capability to control the electric radiator via Wi-Fi, allowing consumers to switch it on or off remotely using a smartphone.

Figure 58: Adax radiator with wi-fi connection, 250-2000W. [6]

Figure 56: Bosch 4500T hot water electric heater, 150l. [7]

Figure 57: DEVI heat mat for electric floor heating, 150W/m2 [8]

Prediction of performance and costs

The deployment of electric heating systems is expected to be limited to housings were the demand of space heating is considerably reduced, such as vacation houses, where water-based heating systems are too costly.

Electric heating systems are a mature and commercial technology with a large deployment (a category 4 technology).

Uncertainty

High certainty of the prediction of the cost and efficiency of the direct electric heating systems is assumed.Economy of scale effects

Economy of scale for the investment cost is assumed to be low not relevant, however it could be assumed the if a very higher number of the electrical panels are bought for an apartment building of 100 households the costs per panel would be lower than per panel for a similar panel for a single family building .

Additional remarks

The prices below include a complete system for space heating and domestic hot water in each living unit.

Quantitative description

See separate Excel file for Data sheets.

References

[1] http://www.dimplex.co.uk/products/domestic_heating/installed_ heating/storage_heaters/index.htm.
[2] Dansk Elforsyningsstatistik 2008.
[3] http://www.lk.dk/Lauritz+Knudsen/privat/det-intelligente-hjem/det-intelligente-hjem.page
[4] Peter Strøm from “EL-Strøm A/S”, personal communication.
[5] Large scale Smart Grids demonstration of real time market-based integration of DER and DR | ECOGRID EU | Project | Results | FP7 | CORDIS | European Commission 2011-2015
[6] Greenline.dk. https://www.greenline.dk/elartikler/elradiator/adax-wi-fi-elradiator. 2020.

[7] Bosch. https://www.completvvs.dk/bosch-tronic-4500t-150-el-vandvarmer-med-elektronisk-display/. 2020

[8] https://store.danfoss.com/dk/en/Climate-Solutions-for-heating/Electric-heating/DEVI-electric-heating/Heating-mats/DEVImat%E2%84%A2/Heating-Mats%2C-DEVImat%E2%84%A2-150T%2C-150-W-m%C2%B2%2C-10-00-m%C2%B2%2C-Supply-voltage-%5BV%5D-AC%3A-230/p/140F0457, 2025.