1 Technology description

Some technologies serve as the base load in the heating systems, while others generate peak loads. Waste-based heat and cogeneration have historically generated the base load for many major district heating systems in Denmark. Cogeneration will increasingly be replaced by renewable energy-based heat generation over the coming years.

Peak load facilities have historically been based on oil, while the vast majority of peak load technologies in Denmark today operate using natural gas. Peak load facilities typically generate less than 10% of the total generation demand, while the base load covers approximately 90%, although this is dependent on electricity and fuel prices, etc.

The following chapter describes the technologies that are currently competitive in terms of supplying district heating and cooling as well as individual heating and cooling. The impact of the energy source on the environment in relation to greenhouse gas emissions and emissions to the surrounding environment, including water and soil, is also assessed.

1.1 Heating

The competitive heating technologies are shown in Table 1, and were identified on the basis of socio-economic costs and an empirical assessment. The table is compiled based on the Danish Energy Agency's Technology Catalogue (Technology Data catalogue concerning generation of electricity and district heating - Updated April 2020), combined with the Danish Energy Agency's socio-economic calculation assumptions for energy prices and emissions. The table's negative emissions occur when CO_{2e}-neutral electricity generation from back-pressure biomass cogeneration replaces CO_{2e} in the Danish electricity system.

Technology
Waste cogeneration
Collective solar heating
Bioenergy cogeneration facilities
Woodchip back-pressure system
Straw back-pressure system
Wood pellet back-pressure system
Generator facilities
Biogas generator
District heating generator: Mains gas
Boiler heaters
Woodchip, district heating facility
Straw, district heating facility
Wood pellet, district heating facility
Mains gas, district heating facility, IFK
Mains gas, district heating facility, UFK
Oil, district heating facility
Large heat pump facility (electricity)

Geothermal, 1 300 m
Cogenerating heat pumps
Surplus heat pump
Ambient heat pump
Individual facilities
Gas boiler 1 0–66 MWh
Gas boiler 2 66–825 MWh
Gas boiler 3 825–3 300 MWh
Gas boiler 4 3 300–8 800 MWh
Gas boiler 5 8 800–110 000 MWh
Oil boiler
Wood pellet boiler
Heat pump
Electric heating/electric water heater

1.2 Cooling

Compressor cooling is used both as individual technology, and as technology which generates for a district cooling network.

'Free cooling' refers to cooling generation without the use of supplied energy other than a small amount of consumption to operate pumps and fans. Free cooling requires a cold source. Examples include the sea, lakes or outdoor air. Free cooling means that a COP of 30–40 is possible.

Additionally, excess heat can be used to produce district cooling via a heat pump This surplus heat may come from industrial processes, data centres, supermarkets, district heating production, etc.

Because data on district cooling and cooling technologies is limited, it has not been possible to quantify the socio-economic costs of the individual technologies.

1.3 Storage of district heating and cooling

Storage may be used to create flexibility in the energy system. The flexibility may be used in relation to generating heat in advance, so that the maximum capacity is not exceeded in the district heating network, thus enabling storage facilities to offset the heat generation over a longer period.

Additionally, electricity-based facilities may for example generate heating or cooling where there is a large amount of green energy and electricity from this source is cheaper.

1.3.1 Accumulation tanks

Tank storage is the most common storage technology used in Denmark, and virtually every district heating company is linked to a storage tank. Tank storage facilities are used to offset production for shorter periods, usually within 24 hours.

Cooling storage tanks are similar in design to heat accumulation tanks, except that measures are required to prevent external rust due to condensation. The planned expansion of fluctuating electricity generation, including wind turbines and photovoltaic cells means it is believed there will be a greater need for storage in the future.

1.3.2 Groundwater cooling and seasonal storage

Seasonal heat storage involves storing energy from the summer until the winter. Large-scale seasonal storage exists in Denmark, which serves to balance a district heating system that includes a number of electricity-based heat generation facilities. A storage facility can optimise the operation of a district heating system.

Groundwater storage uses groundwater for both heating and cooling storage purposes; see Figure 1. This type of cooling and groundwater storage is known internationally as ATES (Aquifer Thermal Energy Storage).

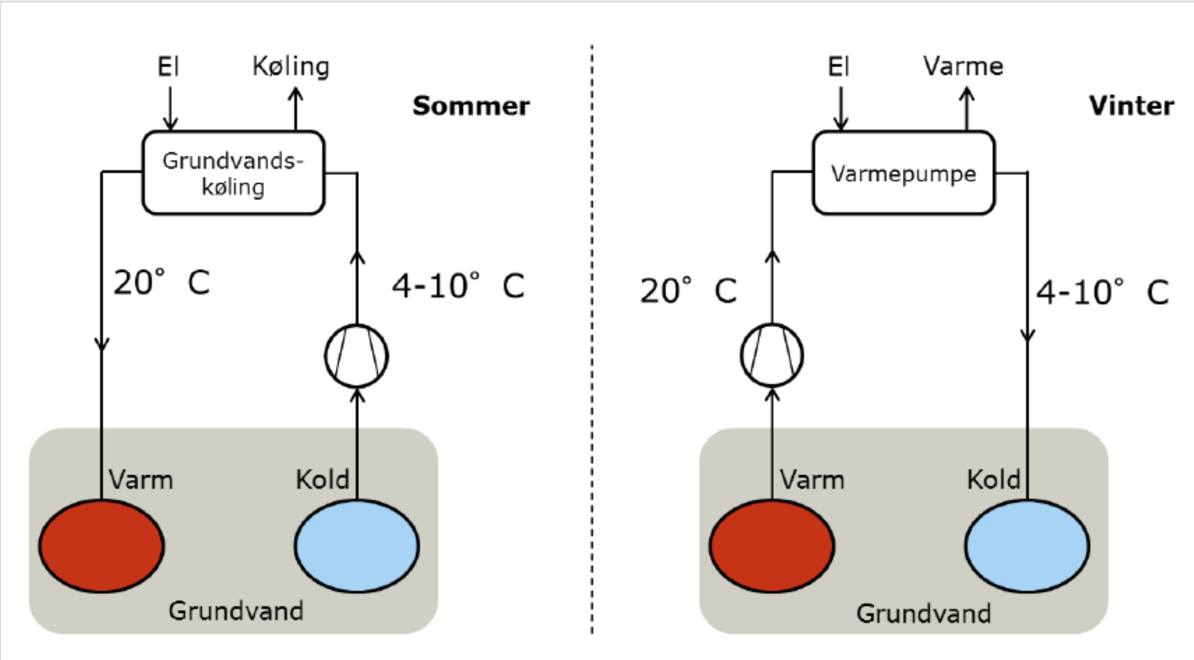

Figure 1 Outline drawing of groundwater storage (ATES).

EI	Electricity
Køling	Cooling
Sommer	Summer
Grundvandskøling	Groundwater cooling
Varm	Heating
Kold	Cooling
Grundvand	Groundwater
Varme	Heating
Vinter	Winter
Varmepumpe	Heat pump

Cold water is pumped up from a cold well in the summer and used for free cooling, and is then returned to a warm well. This is reversed in winter, when the warm water is pumped up from the warm well and cooled via a heat pump at the same time as heat is produced in the heat pump. Groundwater storage therefore has two potential uses.

1.4 Environmental conditions

Table 1 describes the impact of the technologies described on the environment in relation to greenhouse gas emissions and emissions to the surrounding environment, including water and soil.

Technology	Environmental conditions
Electricity-based heat pumps (the environmental assessment applies if the heat pump is used to generate both heating and cooling)	Emissions are not local and are dependent on the emissions contained in the electricity that is generated for the overall Danish electricity transmission network. The use of natural refrigerants in larger refrigeration systems and heat pumps has long been required in Denmark. The limit for the refrigerant's greenhouse gas emissions is set to 5 GWP in Denmark. Natural refrigerants are not harmful to either the ozone layer or global warming, but can be both flammable and toxic, so a raft of safety measures must be implemented, such as refrigerant detection and alarms and ventilation in technical rooms before they are used. The risk of negative impacts on the environment is assessed as low for heat sources such as wastewater, cooling and outdoor air, etc.
Biomass boilers and biomass cogeneration facilities	Biomass is considered CO_2 neutral. Biomass also contributes to both sulphur and NO_x emissions. Central cogeneration facilities are often equipped with purification facilities for both sulphur and NO_x therefore retaining the vast majority of the emissions. The fuels emit a certain amount of dust during combustion. Facilities are therefore generally equipped with filters to reduce emissions. The condensed water vapour is typically fed into the sewage system and treated as wastewater. Biomass as a fuel has no direct environmental impact on soil.
Gas boilers (biogas or green gas)	Natural gas is a fossil fuel and consequently releases CO_{2e}. Sulphur emissions are extremely limited in connection with the combustion of natural gas. However, natural gas releases significant quantities of NO_x. Consequently, cogeneration facilities often have catalysts capable of removing NO_x from flue gases. Natural gas combustion has a limited effect on soil and water. Some of the facilities can be operated in condensing operation mode where the moisture from fuel is condensed out of the flue gas. The condensate is often fed into the sewage system and is treated together with wastewater.
Geothermal	Emissions are not local and depend on the emissions contained in the electricity that is

	used for geothermal heating generation generated for the entire Danish electricity transmission network. If an absorption heat pump is used for geothermal heat generation, driving heat in the form of steam is used, which may be generated from fossil fuels or biomass.
Storage	ATES storage: Drinking water resources in Denmark are a key priority, and municipal environmental authorities have a duty to ensure that no facilities are established that in the worst case could contaminate or heat the groundwater to such an extent that bacterial growth occurs. Authorities are thus particularly concerned with groundwater cooling and geothermal heating in areas important for drinking water.

Table 1 Impact of technologies on the environment in relation to greenhouse gas emissions and emissions to the surrounding environment, including water and soil.