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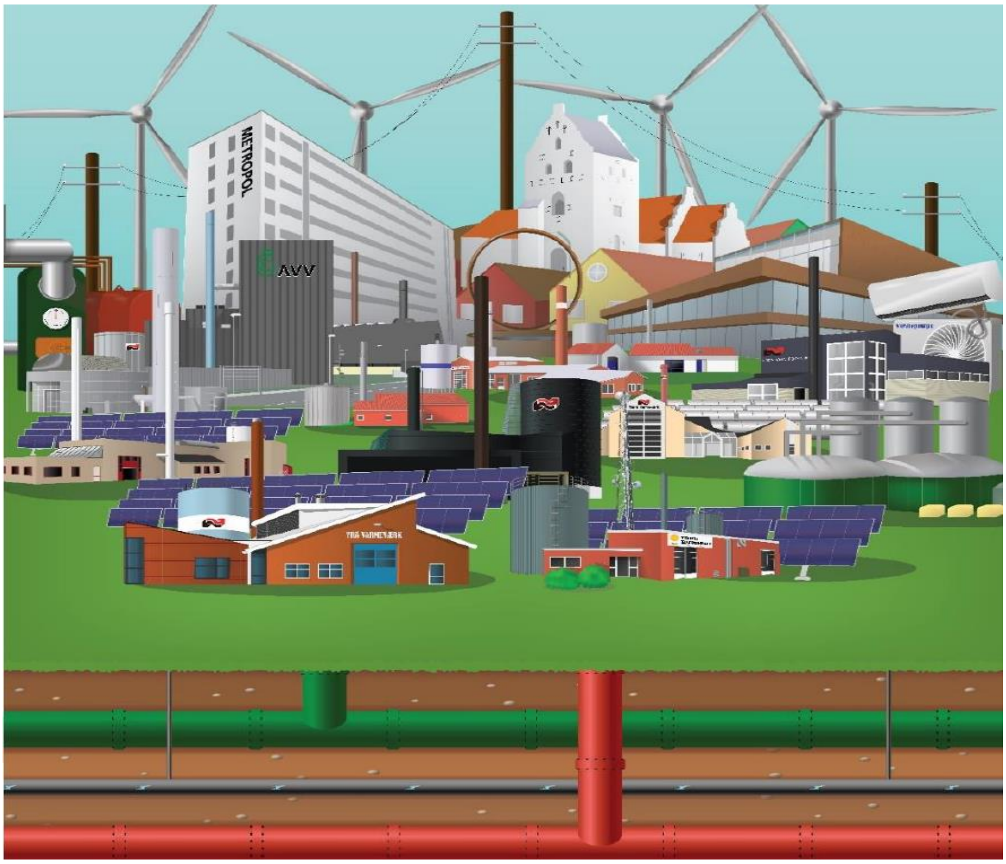
DISTRICT HEATING AND COOLING



IEA DHC ANNEX TS5
INTEGRATION OF RENEWABLE ENERGY SOURCES INTO EXISTING DISTRICT HEATING AND COOLING SYSTEMS

STATE-OF-THE-ART COUNTRY REPORTS

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1 EXECUTIVE SUMMARY OF COUNTRIES

The state-of-art task aims to report the transition status for the participating countries in the DHC sector towards the RES technologies. This also should identify existing examples of integration of RES technologies and applications for transition. The document is to elaborate the following topics according to the existing knowledge in each country:

- The DHC history in the country.
- Political objectives.
- Status of shares of RES divided in fuels: biomass, solar thermal, heat pumps, geothermal heat, waste incineration, surplus heat from industries, etc.
- Obstacles and opportunities for RES transition.
- Status for sector coupling (power to heat, integration of electricity in the heating sector).

The key findings regarding the status and perspectives for development of RE systems have been summarised and compared between the individual countries in the table below. This provides a brief overview of the current situation in the energy sector and country's position in implementing 'green' technologies in the DHC supply. The objectives, motivation techniques and encountered obstacles show a better understanding of how advanced each nationality is in realising own goals and aims set by the international policy, such us EU climate targets to tackle climate change. Moreover, an approach for integrating sector coupling in the energy transition strategy is given, as this plays a crucial role in utilising fluctuating RE with the aim of reaching carbon neutrality.

Country	Energy mix in DHC and political objectives	RES development status, plan and obstacles	Sector coupling
Austria	The DH networks in Austria have been a popular solution for heat supply from 1950s reaching in 2016 the capacity able to supply 7% of total heat demand. Almost a half of heat in DH is produced by biomass plants, the second major energy source at approx. 40% is natural gas.	The national objectives in the energy sector are to increase the share of renewables by 2030 from 45% to 50% of gross final energy consumption and generate electricity using only renewable energy sources by 2030. Moreover, the heat production should also be 100% based on RES by 2050 while the transport sector should be CO2-neutral by 2050.	By 2018 24 large-scale heat pumps in DH have been implemented mostly utilising industrial waste heat and driven by flue gas condensation. The further development is anticipated with use of sewage and wastewater as heat source, however this is limited by lacking mapping of sources and incentives supporting this integration.
Canada	Large DHC systems are somewhat rare, common only in the urban core of the largest cities, and for serving campus and institutional installations. Under Canada's 2030 Emissions Reduction Plan released in March 2022, Canada has committed to reducing overall national GHG emissions by 40-45%, relative to 2005, by 2030, and with a long-term goal of achieving net zero emissions by 2050. More strict targets are common in large cities as Toronto.	CO2 price increase was launched by federal government to encourage the green transition. Currently majority of the heat production in DH is, however, based on natural gas which low prices even with increasing carbon pricing on fossil fuels, still make it challenging to cost-effectively integrate renewables into Canadian networks without significant subsidy.	Consideration for DHC and electricity sector coupling as part of the increased electrification effort is largely absent from any policy directives. There are only a few newer DHC utilising electric heat pumps based on sewage heat recovery or central geoexchange borefields.

		There is a potential in electrification of DH using the relatively green electricity generation, with over 82% of production from non-emitting sources (mostly hydroelectric, also nuclear and wind). The coal-based electricity production constitutes only 9% of total production and is planned to be phased out by 2030.	

Country	Energy mix in DHC and political objectives	RES development status, plan and obstacles	Sector coupling
China	DH supplies in China play a major role in the heating sector with tremendous annual consumption of 6 billion GJ. 77% of heat is produced using coal fuels including CHP and coal fired boilers. China strives for "carbon neutrality" by 2060 with the interim goals of 65% carbon emission reduction, an increase of share of non-fossil energy in primary energy consumption to about 25% and increase of forest stock by 6 billion m^3 all mentioned figures compared with the 2005 levels.	The current proportion of RES in DH supply is only 3%. Solar, geothermal energy or air source heat pump cannot fully meet the heating needs of dense construction and large population mostly due to the requirement for high temperature in the heat networks and fluctuating heat production from RES: Therefore, the first phase of phasing out coal fuel is relying on excess heat from industry and cogeneration. Low-carbon and RES based heat supply has more potential in rural areas in individual heating. The carbon emission motivation initiatives have been introduced so far only in largest agglomerations. The subsidies in RES are limited.	Electric heating has become one of the means to reduce heating air pollution in cities, especially in recent years, with the increasing price of natural gas, electric heating shows more and more advantages than natural gas heating

Denmark	DH become gradually a critical strategy in efficient heat supply to all type of consumers ending with 64% of all Danish buildings (58% of total heat demand) being supplied from approximately 400 district heating utilities. This was initially driven by fuel independence and currently is mostly triggered by ambition for ceasing coal and oil heat production by 2030 and reduction of biomass consumption.	The heat supply to DH more than doubled over the last decade, replacing natural gas, oil and coal supply. with the parallel general demand growth. The main objectives include technological development which needs years of implementation and maturing. This process entails a cost which on the other hand is in Denmark highly regulated in order to protect the final user. The political incentives have also some 'holes' which profit one target group and disadvantage another. This affect for example faster development of flexible DH systems.	The investment in electric heat pumps and boilers has boomed in the last few years due to a favourable incentive on electricity tax exception for these technologies. The concept is still lacking right motivation for the DH to become flexible systems and to use RES electricity?

Country	Energy mix in DHC and political objectives	RES development status, plan and obstacles	Sector coupling
France	The heating demand in France is supplied only at 5% via DH networks of which 60% is based on RES, however the national policy targets aim at circa doubling the capacity by 2030. The energy mix is predominated by biomass, geothermal and domestic waste incineration. There are 32 DC networks supplying 0.82 TWh of chilled water to 1401 buildings.	The major pillar laws at national level target five times increase of waste and RES in DHC networks, reduction of GHG by 75% by 2050 in relation to 1990. By 2028 the DC networks should double or triple (depending on scenario) the cooling capacity.	The sector coupling is considered as prospective at this stage. The demonstrations plants include heat pumps based on geothermal energy and DHC systems. The evolution of DHN energy mix implies further electrification of DH and utilisation of geothermal energy and waste heat sources through development of heat pumps.

		The key obstacles include high temperatures and pressure of the currently operated DHC networks. There is also lacking expertise and subsidies for smooth development of these alternative energy production plants. The economic and environmental advantages of further DHC deployment act substantiate the national goals are in right place.	
Germany	Currently DH systems are widespread in urban areas which corresponds to 14% of total heat demand in the country and 196 DH operators. The federal objectives include a few-step CO_2 emission reduction to reach carbon neutrality by 2045 across all sectors. This initiative is supported with subsidy programmes towards support measures in the energy, industry buildings, transport, agriculture and waste management sectors and phasing out coal.	Nearly 70% of DH supply come from fossil fuel-based production while pure RES account for circa 18%. The key obstacles in further development of RE systems are similar with previous countries which includes inconsistence of supply temperatures from RES to high-temperature DH networks, competitive prices of fossil fuels (gas, oil), sometimes also space limitations especially in urban areas and cost of constructing DH networks between sparse users in rural areas.	Germany in majority has installed CHP systems which continuously expand are planned to spread even further which is partially due to national incentives. The application of large-scale heat pumps and P2H systems is inhibited in Germany by taxes, levies, surcharges and grid fees, as well as the lack of consideration of P2H in existing law.

Country	Energy mix in DHC and political objectives	RES development status, plan and obstacles	Sector coupling

Italy	The DH share in total heat supply is only about 3% with active 413 networks, present in the coldest areas of the country in North. Most of the heating needs is satisfied by fossil-fuelled boilers, mainly based on natural gas. The central and south regions have on the other hand a large potential for DC. However, only 1,5% of the cooling demand is supplied already centrally. Italy has strong funding initiatives focusing in on modernisation and expansion of transmissions grids and new power plant capacities. This should help to reach the European targets of 55% reduction in CO2 emissions and 32% proportion of RES by 2030.	The 'green' heat supply through DH accounts currently for nearly one quarter of total heat production. 22% out of the produced heat comes from biomass, biofuel and municipal waste-based CHPs. The majority of DH is served by natural gas fired boilers and engines. The last decade shows an increase of heat production from municipal waste, while consumption of coal and oil dropped. The major obstacles in development of RE systems include competitive natural gas-fired installations for which short winter periods act only to their favour. DC on the other hand is lacking sufficient funding subsidies.	The electrification of the systems has no sufficient incentives in form of electricity tax exemptions for heat pumps etc. This reduces the economic sustainability of the implementation of heat pumps both to recover low temperature waste heat or ambient heat. The potential of merging several sectors is, however, noticed and is expected to gain an increasing weight in the thermal renewables mix.

Country	Energy mix in DHC and political objectives	RES development status, plan and obstacles	Sector coupling
Sweden	Today, all major cities and towns in Sweden have DH systems and, most often, at very high connection rates in the densest urban areas which accounts for overall 53% share in total heat production. The political objectives for the energy sector are strict aiming at carbon neutrality by 2045 and electricity production in 100% based on RES by 2040.	The heat supply in DH sourced from green energy sources in last 30 years nearly tripled reaching now almost 70% of total heat demand. This includes a large proportion of solid biofuels and renewable municipal waste. One of challenge in development of further RE systems/maintaining existing ones is the current reliance on biomass fuels which will likely become exclusive goods and would need alternative. Incorporating further heat pumps depends on the electricity price development.	Current P2H systems rely on excess electricity from the nuclear power plants serving electric boilers and heat pumps connected to DH systems.
Switzerland	Switzerland similarly to Austria has about 7% share of DH in total heat demand and most larger cities have a DH network I operation for decades. The hat is mainly generated in WIP which lately was replaced with biomass and wastewater-based heat pumps.	The national regulations promote DH development mostly in context of promoting waste heat recovery. The federal government aims at ceasing utilisation of fossil fuels by 2050. This can increase share of DH up to between 14% and 24%. The key obstacles in decarbonisation of DH systems include high investment costs, long implementation periods and lacking experience in deployment of RES. On the other hand, there exists subsidies and dedicated programmes supporting ‘green’ transition investments. Moreover, new development areas and heat potential sources create an opportunity for further expansion of DH.	Heat pumps have undergone strong growth over the last few years; however the majority of the ongoing installations are individual domestic applications.

2 AUSTRIA

Authors: Salzmann M., Leusbrock I., AEE - Institut für Nachhaltige Technologien

DH networks are supplying customers in Austria since the 1950s.

In 2016, 22 TWh/a, equating to 7 % of the total Austrian energy demand (311 TWh/a, including electricity, industry and transportation), was provided by DH. Although the final energy demand for space heating and domestic hot water in Austria is expected to decline, a huge potential for further growth in size and numbers exists. Considering only supply areas with heat densities >10 GWh/km², heat consumption for the year 2012 for heating and warm water of 80 TWh/a was estimated, thus showing huge potential for DH expansion. In the past two decades, DH in Austria has been extensively expanded and currently, with approximately 5400 km track length, it represents an important component in Austrian heat supply. In 2016, 25 % of all apartments in Austria were heated with DH.

Approx. 55 % of total DH sales occur in the nine largest Austrian DH supply areas (Vienna, Graz, Linz, Salzburg, St. Pölten, Klagenfurt, Lienz, Wels, Villach) while the remaining systems are smaller DH networks. The statistics from 2013 show a high diversity in energy sources used in plants across Austria. This includes around 1,000 biomass heating plants with a heating capacity of 400 kW up to 1 MW, 9,000 small-scale DH systems of up to 400 kW and further 316 biomass heating plants and biomass CHP plants in the range from 1 to 5 MW_{th}. (Fladenhofer, et al., 2022)

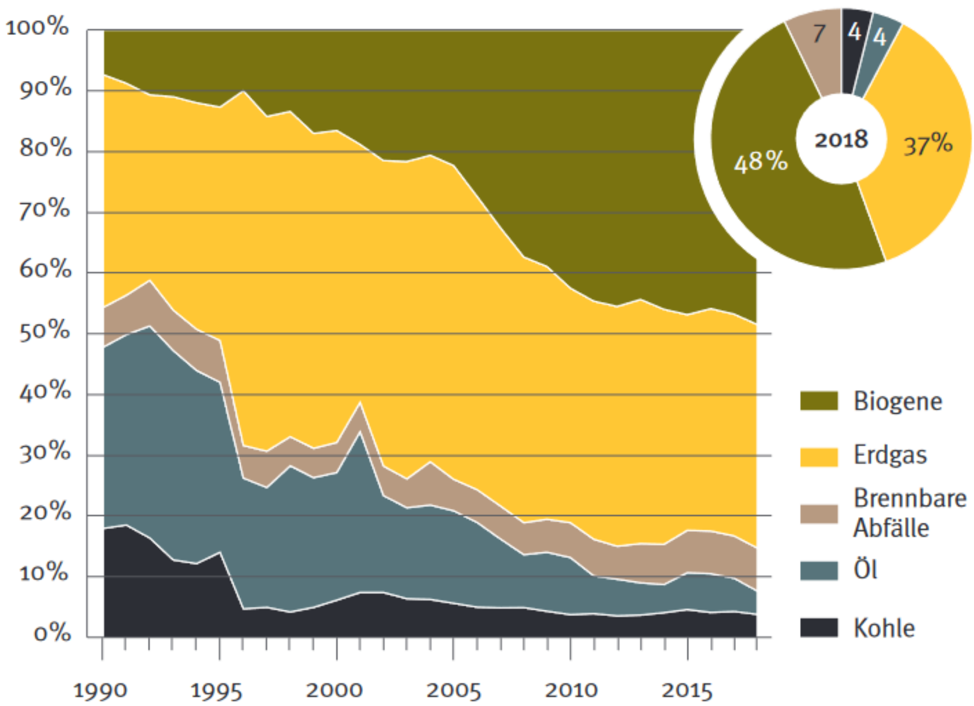

Figure 1 DH generation by energy source (FGW 2020)

These networks are usually operated at temperatures from 80-130°C, representing 2nd and 3rd generation DH networks which are powered by different energy sources. The fuel input for heat generation in 2016 consists of almost 50 % from renewable sources such as biomass, waste and solar thermal.

In 2018 nearly half of the generation was produced with biomass (see Figure 1).

Currently, 27 % of heating customers in Austria are supplied with district heating. This corresponds to over one million homes. (FGW 2020)

The following map (Figure 2) shows an overview of DH systems in Austria sorted by number of connections of residential units supplied.

- 735 networks between 1 and 50 connected residential units
- 252 networks between 50 and 250 connected residential units
- 34 networks between 250 and 1000 connected dwelling units
- 7 networks with more than 1000 connected housing units

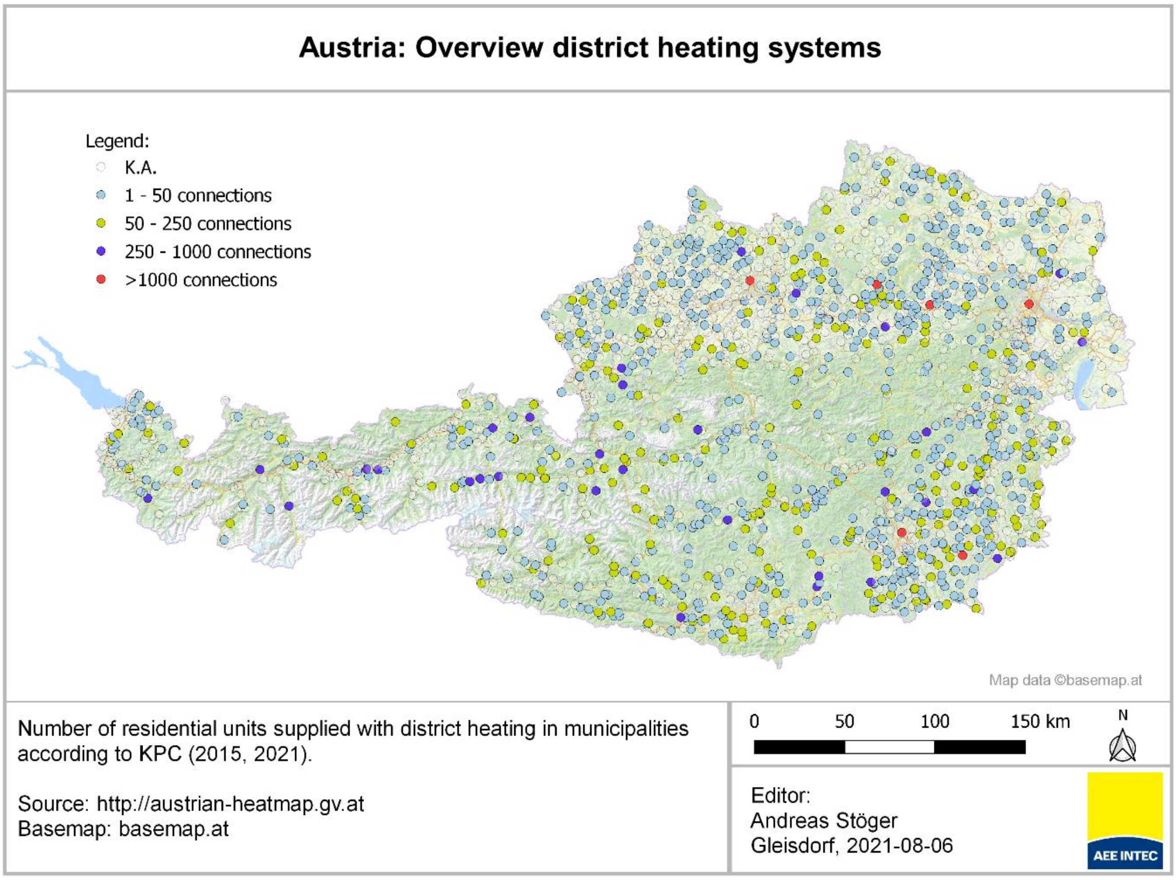

Figure 2 Overview of DH systems in Austria.

Large networks can be found in Austria's biggest cities. In rural areas DH networks tend to have a small structure and only few connected residential units.

The five biggest thermal plants are driven by natural gas followed by a large-scale waste incineration plant.

2.1 POLITICAL OBJECTIVES

On May 28, 2018, the Austrian federal government adopted a new climate and energy strategy entitled "#mission2030". This shows the way to achieve the 2030 climate goals. Austria shall reduce its greenhouse gases by 36% by 2030 compared to 2005.

The strategy #mission2030 has the following national goals (see Figure 3):

- Increase the share of renewables by 2030 from 45% to 50% of gross final energy consumption for all sectors.
- Electricity consumption shall be (balance sheet?) covered by 100% renewable energy sources by 2030.
- By 2050, the heat requirement is to be 100% covered by renewable sources.
- The transport sector should also be CO_2-neutral by 2050.

Moreover, the Austrian government has planned to increase the average share of renewable energy in district heating by at least 1.5 percent every year until the year 2040.

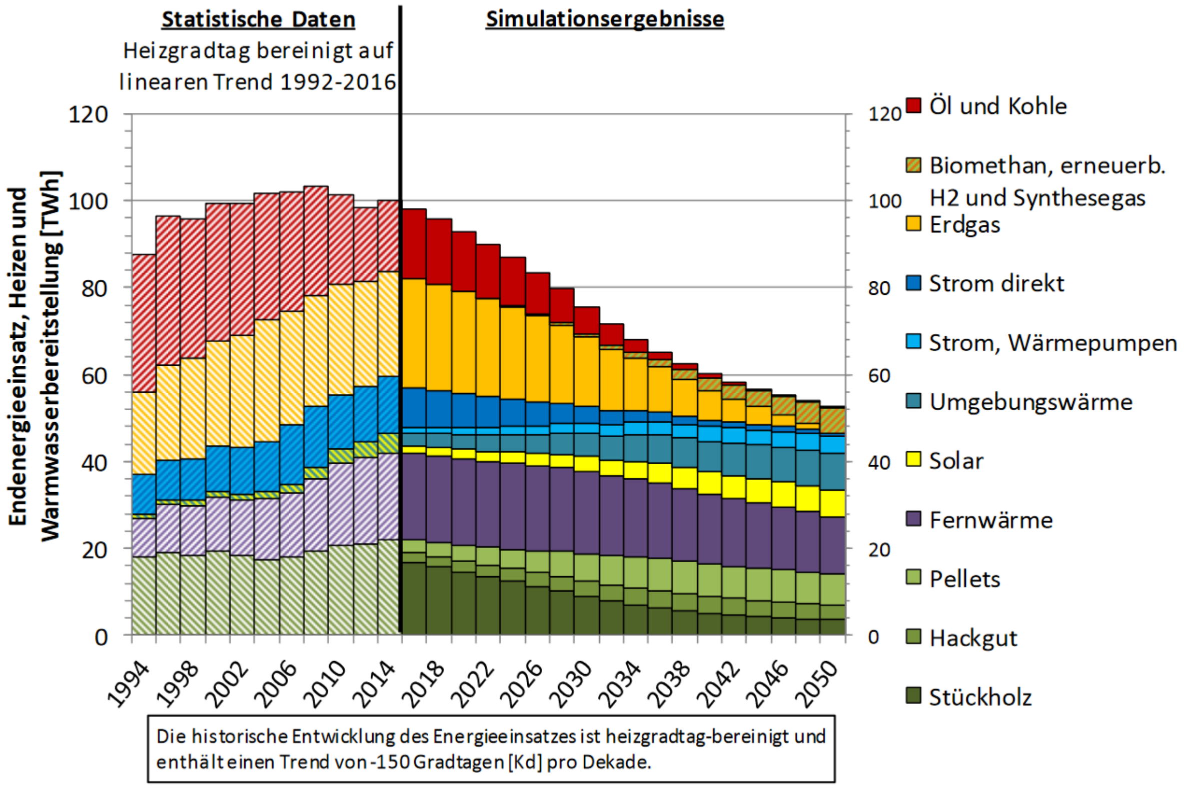

Figure 3 Development of final energy use in the heat transition scenario

The Energy Economics Group of Vienna Technical University examined several simulations to enlighten possible ways for the decarbonisation of DH in Austria.

The energy demand in the heat transition scenario is halved from currently almost 100 TWh to 52 TWh by 2050, of which decentralised biomass technologies, district heating and heat pumps (total of ambient heat share and electricity) each provide about 25 % of the energy. Half of the remaining energy will be provided by decentralised solar technologies solar technologies (solar thermal and PV electricity).

In addition, the energy source natural gas is gradually replaced by other renewable and CO_2-neutral energy sources such as biomethane and renewable hydrogen.

To completely replace natural gas as a fossil fuel in the building sector, such a CO_2-neutral gas mixture would have to provide about 5,855 GWh/a (in terms of calorific value) of final energy in 2050. (EEG 2018)

2.2 CURRENT STATUS OF RES SHARE IN DH

In 2017 the energy supply composition of district heat (see Figure 4 and Figure 5) consisted of 59% cogeneration and 41% heat only generation. Cogeneration could be divided in 33% fossil, 20% renewable and 6% other sources. Heat only generation was done by 13% fossil, 27% renewable and 1% other heat sources. (EHP 2021)

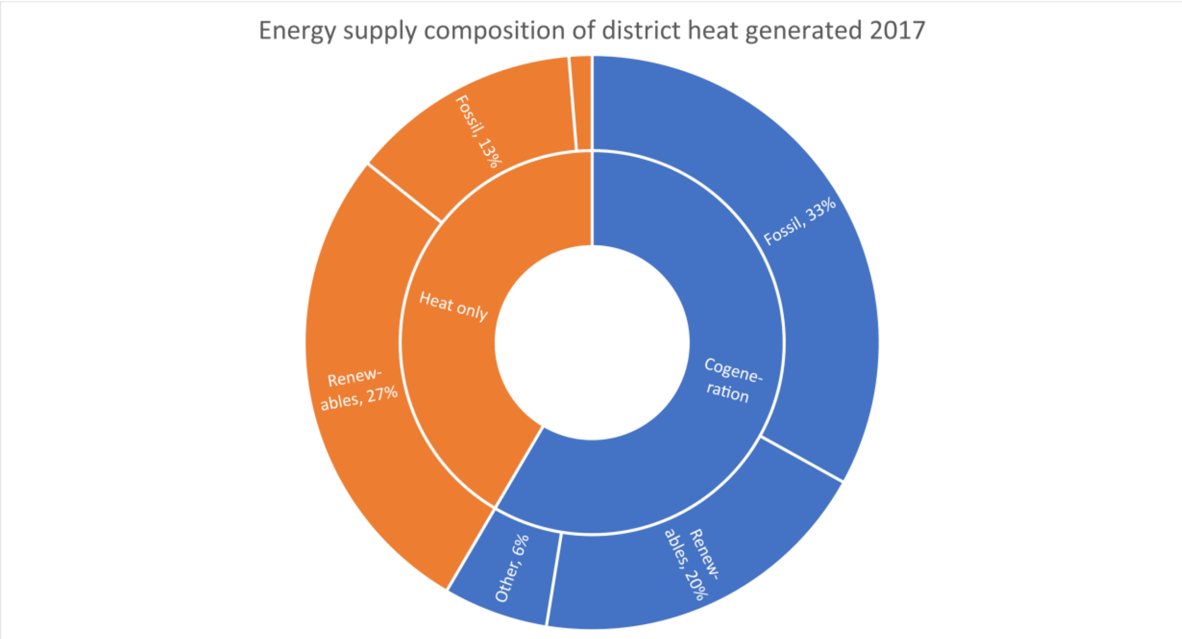

Figure 4 Energy supply composition of DH generation in 2017

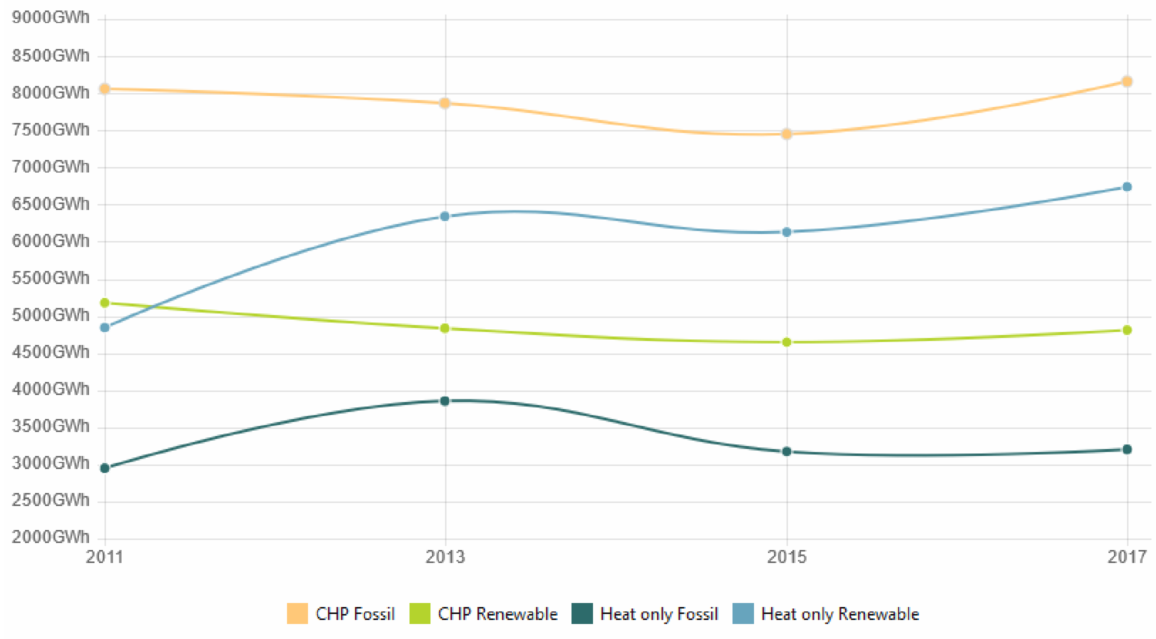

Figure 5 Development of energy supply composition of district heat generated in Austria (EHP 2021)

By RES it is meant the energy sources based on wood pellets, wood chips, biomass and firewood, "Waste" in cogeneration includes both biodegradable fraction and non-renewable waste, solar thermal, E-boilers & heat pumps (output) all subsumed under geothermal.

2.3 OBSTACLES AND OPPORTUNITIES FOR RES

2.3.1 OBSTACLES

Existing barriers to the expansion of district heating are:

- The critical situation of CHP due to fuel prices – high gas price versus low electricity price, determined by import instead of national production.
- High (preliminary) investment costs
- High system temperatures
- Time-consuming administrative procedures for permits
- Not enough support allocation as foreseen by WKLG and UFI
- Future energy savings obligations
- Lack of planning and legal security

For district heating to be able to continue to make its important contribution to a modern, resource-saving, eco-friendly energy supply and to the decarbonization strategy of the Austrian Federal Government by 2050, it is necessary to have the strong support of the Federal Government and political groups.

Moreover, the district heating sector would like to have further subsidy incentives for decarbonization projects, as these are foreseen in the Government Program. Existing funding pools such as WKLG and UFI should be sufficiently allocated in order to reduce the subsidy backlog and to promote the incentives for new investments in district heating and district cooling infrastructure. Biomass and eco-electricity-based power plants that are also part of the district heating supply should be equipped with a system that ensures a long-term continuous operation. Furthermore, new action plans for the further development and use of new technologies such as storage technologies and sector coupling can further enhance the use of these technologies or facilitate their inclusion, so that the exploitation of these sources can be made easier and possible for all the stakeholders.

Against the background of the energy transition and due to the growing share of renewables in the energy system, power-to-heat will become more important in the medium and long term.

2.3.2 OPPORTUNITIES

The new climate and energy strategy "#mission2030" clearly favours the expansion of efficient and/or renewable DH in Austria, especially in urban areas. Still, this takes place without real political commitment besides 'lip services', while a robust legal framework and incentives (taxes, subsidies) are crucial for the expansion of DH.

Within the framework of a future heat supply according to #mission2030, the Austrian climate and energy strategy relies primarily on district heating based on renewables (biomass, geothermal energy, solar thermal energy, photovoltaics, etc.). (EHP 2021)

2.4 STATUS FOR SECTOR COUPLING

In 2018 there were 14 DH networks with in total 24 implemented large-scale HPs with a capacity of 108 MW. Approximately 52% of heat source is supplied by industrial waste heat, while 42% is supplied by flue gas condensation. The other heat pumps use e.g. waste heat from cooling applications as a source. 9 HPs are implemented in 6 DH networks <20km net length, 4 HPs are implemented in 4 DH networks with a length between 20 km and 100 km and 11 HPs are implemented in 4 DH networks with a net length of more than 10 km (IWT 2018).

Examples are:

- P2H Vienna 20MW, 2017
- P2H Vienna 2x5MW in 2022
- P2H Salzburg 2x15MW, 2015 and 2016

Decarbonisation of the different energy sectors is only possible with the help of renewable electricity (from hydropower, wind power, photovoltaics and biomass) and using green heat for the district heating grids. It is important to focus on a broad diversity of energy sources and generation, storage and conversion technologies in order to maintain Austria's energy supply. The great added value of sector coupling lies in guaranteeing the necessary security of supply and flexibility of the energy system.

While the integration of the electricity sector in DH is increasing (mainly via compression heat pumps), the integration in other sectors is currently limited. Few attempts have been made to use sewage or wastewater infrastructure, but it is far from being state-of-the-art. Low-temperature waste heat from industry, data centres for LT systems in combination with heat pumps is not considered frequently as suitable heat (or cold). This is due to lack of mapping for potential waste heat and the knowledge about technical feasibility to utilize this. Furthermore, no clear regulation and subsidy schemes support this integration.

3 CANADA

Author: Boulter R., CanmetENERGY - Natural Resources Canada.

District heating and cooling (DHC) in Canada started as far back as the late 1800s, with several central steam systems initiated in major cities. Uptake increased steadily as universities, military bases and hospitals adopted DHC as a means of reducing energy costs. The technology advanced in the 1970s as the result of the oil crisis, with the Government of Canada becoming involved in demonstration projects. In the 1980s, Canada looked to Europe for guidance and moved to hot water networks. However, with no federal or provincial energy policies on the DHC use, growth of the Canadian industry was slow and relied heavily on niche markets. From 1980 onwards, there has been steady interest in the application of DHC across Canada. Newer systems tend to be strategic in their design and implementation, addressing key issues within their community, whether environmental or urban planning oriented.

As DHC is a relatively minor contributor to the overall building energy supply in Canada, limited operational data exists for DHC systems. The federal government does not collect or maintain data holdings specifically for DHC systems. In recent years, the Canadian Energy and Emissions Data Centre (CEEDC), with support from Natural Resources Canada – CanmetENERGY, has created and maintained a national District Energy (DE) system inventory, recognized as the largest central dataset for DHC in Canada. In the latest CEEDC system survey completed in 2019, 217 DHC systems were identified as operating in Canada, although many of these systems are quite small, serving only a handful of buildings in some cases.

Approximately two-thirds of the Canadian systems are associated with campus and institutional installations, including universities, healthcare centres, military bases, correction institutions, and other government operations. The remaining systems are either private or municipal utilities serving private and public facilities. The table below summarizes some key DHC system data from the CEEDC (2019) inventory survey.

Table 1 Aggregated data about DHC systems in Canada.

2019 Survey Responses	Total Capacity (MW)	Energy Supply (GWh/yr)	Network Length (km)	Building Area (million m^2)
District Heating (Steam)	**4,062** (52)	**3,222** (28)	**200** (36)	**30.4** (87)
District Heating (Hot Water)	**1,333** (51)	**1,056** (49)	**119** (49)	**9.2** (49)
District Cooling	**1,144** (39)	**1,202** (28)	**170** (33)	**22.5** (32)
CHP Electric	**535** (32)	**844** (21)	-	-

*Number of survey responses (n) shown in parentheses

As indicated, most installed heating capacity is associated with older, central steam systems. Figure 6 also from the survey responses collected in CEEDC (2019), shows the gradual trend over time moving away from steam toward hot water systems. It also highlights the relatively high number of new systems that have been commissioned since 2000, most of which are municipal or private utilities. Key market areas of growth include Vancouver and the surrounding metro area, and the greater Toronto area.

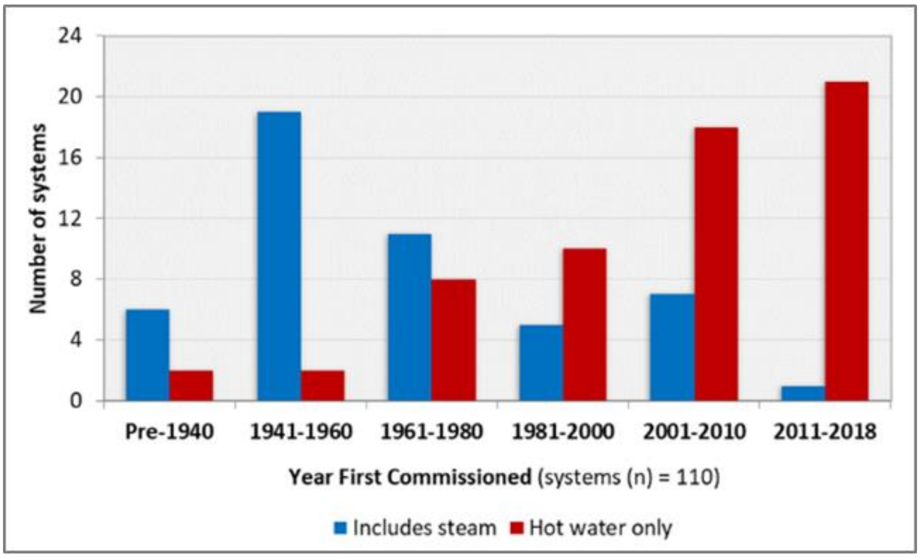

Figure 6 Accrual of steam based and water based DHC systems in Canada.

3.1 POLITICAL OBJECTIVES

DHC is, for the most part, unregulated in Canada. There are no decarbonisation targets applying specifically to the DHC sector, beyond those imposed either federally, provincially, or municipally, or set within institutional operations.

Under the Paris Agreement, Canada committed to reducing overall national GHG emissions by 30%, relative to 2005, by 2030, and with a long-term goal of achieving net zero emissions by 2050. In March 2022, Canada's 2030 Emissions Reduction Plan was released, increasing the reduction target to 40-45% by 2030 (ECCC 2022).

Some cities have adopted local emissions reductions targets that may be more aggressive than federal targets. The city of Toronto, for example, has set within their TransformTO climate action strategy GHG reduction targets of 65%, relative to 1990, by 2030, and net zero by 2050 or sooner (Toronto 2021). Increased integration and growth of low carbon district energy networks is one of the initiatives the city has identified to help achieve those targets.

The federal government has announced that the federal carbon price, applicable as a fuel charge in several provinces on fossil fuel consumption, will increase gradually from $50/tonne in 2022 up to $170/tonne in 2030. As natural gas is the most prevalent fuel used by the majority of DH networks, the carbon price increase is added incentive to decarbonize the heating supply.

Electricity generation is already relatively clean in Canada, with over 82% of production from non-emitting sources (mostly hydroelectric, also nuclear and wind). The remaining coal-fired electricity production (~9% of current national production) is to be phased out by 2030, which will further reduce the overall emissions intensity of the electricity supply. A key policy pathway towards achieving emissions reductions goals includes clean electrification of many sectors, including building heat, transportation and industry.

Applicable specifically to federal government facilities, several directives under the federal Greening Government Strategy (TBS 2020) will have influence on how government owned and operated DHC systems will evolve in the future in terms of potential heating and cooling technologies in use. For example, all new federal government buildings must be constructed to be carbon neutral (i.e. new federal government buildings will not be able to connect to fossil-fired DHC networks). Major facility retrofits, including DHC systems, require a 40-year GHG reduction life-cycle cost analysis using a shadow carbon price of $300/tonne to assess technology options (i.e. a higher weighting applied to carbon reduction potential will benefit low carbon sources for heating technology selection). As well, all federal government departments must use 100% clean electricity by 2025 at the latest, by producing or purchasing renewable electricity (i.e. heating technologies that use electricity, integrated where possible, have potential for significant emissions reduction).

There is no current Canadian-specific industry association for the DHC sector, thus no industry imposed GHG reduction targets. The previous Canadian District Energy Association (CDEA) merged with the US-based International District Energy Association (IDEA) in 2012.

3.2 CURRENT STATUS OF RES SHARE IN DH

As collected in the CEEDC (2019) inventory, over 80% of systems utilize at least one fossil fuel (natural gas or oil) as the primary fuel source, and essentially all systems (178 of 179 reporting systems) indicated use of natural gas or oil in some capacity. 34% of system respondents indicated integration of at least one non-fossil / low-carbon heat source, such as solar, biomass, and waste heat recovery. A summary of the CEEDC (2019) system fuel type information is shown in the table below.

Table 1 A breakdown of DH systems by fuel type.

Fuel Type	Count of fuel types used: Single Fuel Systems	Multi-fuel Systems	Total Systems	% of Systems
Natural Gas	76	46	122	68.2%
Oil & Diesel	11	45	56	31.3%
Biofuel	13	24	37	20.7%
Geoexchange	14	10	24	13.4%
Heat Recovery & Cooling Water	2	2	4	2.2%
Waste	1	2	3	1.7%
Solar	0	4	4	2.2%
Other	0	1	1	0.6%
Total Number of Systems	117	62	179	

Fuel consumption data was only collected from 53 systems in the CEEDC (2019) inventory. As shown in the table below, the vast majority of fuel consumption from reporting systems was by natural gas (88%). Only ~7% of the total energy reported by those 53 systems was from renewable sources, most of which was from biomass/biofuels.

Table 2 Fuel consumption in DH systems by fuel type.

Fuel type	Energy used: TJ	% of total energy
Natural gas	18,287	88%
Oil & Diesel	985	5%
Biofuel	1,013	5%
Geoexchange	27	0%
Heat Recovery & Cooling Water	69	0%
Waste	274	1%
Solar	0.3	0%
Other*	33	0%
Total energy	**20,688**	
Total systems (n)	**53**	

3.3 OBSTACLES AND OPPORTUNITIES FOR RES

3.3.1 OBSTACLES

As noted, a large portion of the installed DHC capacity in Canada is with legacy steam networks. Thus, for these systems in particular, there are compatibility challenges between existing high temperature operations and potential lower temperature renewable energy sources. Modernizing networks to operate at lower temperature to enable integration of renewables often also requires cost-prohibitive retrofits to the heating systems of connected buildings. Available government funding dedicated specifically for DHC network infrastructure and system modernization, as well as consideration for DHC within Canadian energy policies in general, is limited. As well, even with increasing carbon pricing on fossil fuels, the very low natural gas prices still make it challenging to cost-effectively integrate renewables into Canadian networks without significant subsidy.

3.3.2 OPPORTUNITIES

However, there are opportunities to align renewable integration initiatives with overall system modernization investment, such as steam to medium temperature (3rd Gen) hot water network conversion. Many newer DHC systems in Canada have been designed to operate at lower temperatures and with renewable sources, such as biomass and heat pumps, from the start, and have been planned with a long-term vision of low carbon operation in mind.

Canada is fortunate to have good access and availability of potential low carbon resources for DHC, including clean electricity and biomass, as well as geothermal and solar in certain locations. DHC provides an opportunity to integrate energy sources and technologies not typically available and/or cost effective at the individual building level, such as heat recovery from sewage wastewater and large-scale seasonal thermal energy storage. Recent priority areas of RD&D focus in Canada have also included development of a national Hydrogen Strategy, as well as increasing R&D efforts on carbon capture, utilization and storage (CCUS), including bio-energy carbon capture and storage (BECCS). These emerging technology areas could be an additional opportunity for transitioning the heating sector toward low carbon operation.

3.4 STATUS FOR SECTOR COUPLING

Much of the federal climate action plan focus, along with significant government investment, includes electrical grid modernization and advancement of smart renewable generation, as well as support for clean electrification of the broader economy in general, including for building heating, transportation, and industry. However, consideration for DHC and electricity sector coupling as part of the increased electrification effort is largely absent from any policy directives.

Large-scale combined heat and power (CHP) is generally not common in DHC in Canada. From the CEEDC (2019) reporting, 32 DHC systems indicated operations that included CHP, with a total installed electrical capacity of 535 MW.

There are several newer system DHC examples whereby electric heat pumps are used as the primary heat generator for the networks, generally using sewage heat recovery or central geoexchange borefields as the heat source/sink.

4 CHINA

Author: Rong L., Beijing District Heating Group - China District Heating Association

China stretches over 9.6 million km^2. In the 1950s, China was extremely suffering significant energy shortages, therefore it was decided to prioritise the boundaries for regions with the necessary heating needs in winter which was defined by annual average daily temperature to be lower than 5°C for more than 90 days. These 'heating area' cities are placed north to the Qinling Mountains and Huaihe River as indicated in Figure 7.

Figure 7 Boundary of the heated area in China.

By the end of 2019, the total area of heating in northern China was 21.1 billion building m^2 which the heat load is about 6 billion GJ. Out of the total heating area, 14.1 billion m^2 were used for heating in urban areas and 7 billion m^2 in rural areas. Currently the Chinese government is promoting clean heating which means transition to non-fossil energy or remaining fossil energy-based heat generation, however by introducing solutions for clean combustion and ultra-low emissions.

The expected area covered by clean heating program consists of 11.6 billion building m^2, accounting for about 55% of the total. DH in China is basically localised in urban areas, supplied in total by 8,200 heating related enterprises in China, with a total income of 890 billion yuan and more than 1.17 million employees. Heating utilities are owned by municipalities or private entities. Clean heating industry is becoming a rapidly growing emerging industry and an integral part of the national economy.

4.1 POLITICAL OBJECTIVES

- On September 22, 2020, China proposed at the United Nations General Assembly that its carbon dioxide emissions should peak by 2030 and strive to be "carbon neutral" by 2060.
- On December 12, 2020, China further announced at the Climate Ambition Summit that by 2030, China will reduce carbon dioxide emissions per unit of GDP by more than 65 percent from 2005 levels, increase the share of non-fossil energy in primary energy consumption to about 25 percent, and increase forest stock by 6 billion m^3 over the 2005 levels. The total installed capacity of wind and solar power will reach more than 1.2 billion kW.

4.2 CURRENT STATUS OF RES SHARE IN DH

4.2.1 CHINA ENERGY STRUCTURE

Coal consumption in the electricity mix has remained relatively constant in the last decade and the continuous rapid growth of the total energy consumption is led by non-fossil energy sources

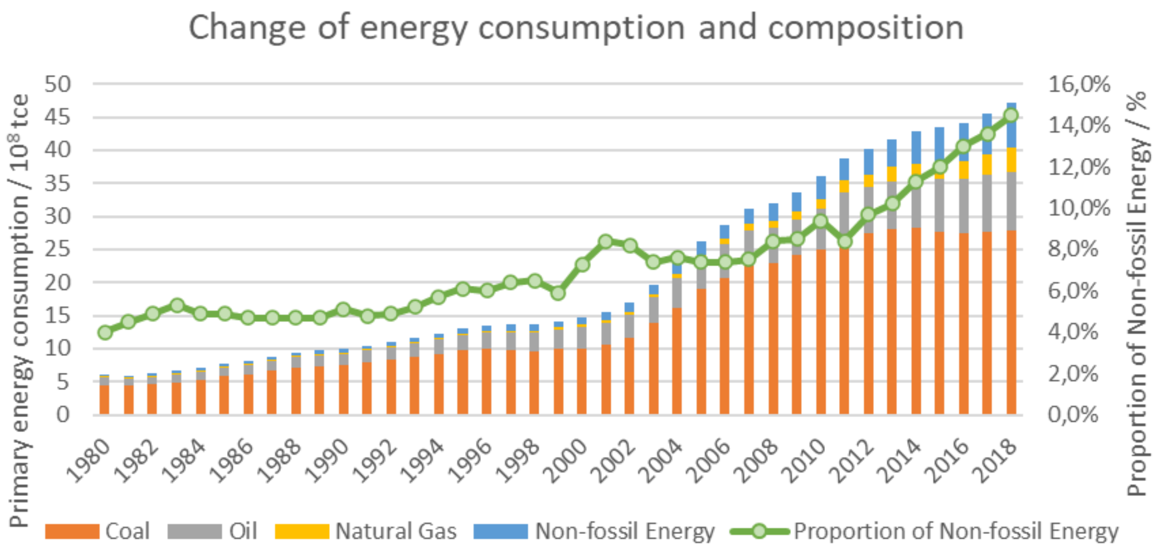

Figure 8 Development of fuel consumption to electricity production with highlighted proportion of non-fossil fuel-based electricity.

The proportion of low-carbon energy sources in the electricity generation is mainly represented by hydropower, with the remaining production evenly split between wind, nuclear and solar (Figure 9).

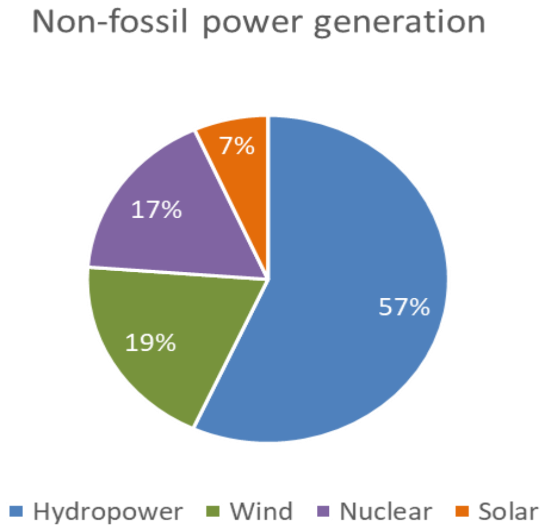

Figure 9 Detailed percentage breakdown of non-fossil electricity generation.

4.2.2 CHINA DH ENERGY CONSUMPTION:BY THE END OF 2019

Figure 10 shows the heating energy structure in China urban including proportion of the DH. It has the following characteristics:

- DH accounts for 91% of the total urban heating energy which consists of coal-fired cogeneration 45%, gas-fired cogeneration 3% , coal-fired boiler 32% and gas-fired boiler 11%.
- RES accounts for only 3% of the total urban heating energy which is mainly used to provide scattered and individual heating.
- China urban heating heavily relies on fossil fuels, especially coal which the coal fired cogeneration covering 45% and coal fired boilers covering 32%.

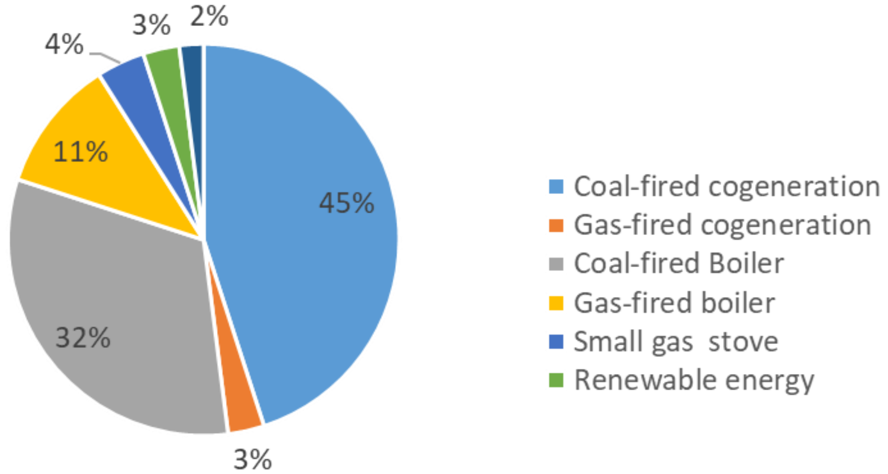

Figure 10 The heating energy structure in China urban including proportion of the DH

4.3 OBSTACLES AND OPPORTUNITIES FOR RES

4.3.1 TECHNICAL OBSTACLES AND OPPORTUNITIES.:

The utilization of RES in China is mainly concentrated in the power generation industry. By the end of 2019, the total installed capacity of RES power generation in China reached 794 million kW, accounting for 39.5% of the total. However, the application rate of RES in the field of heating is still very limited. The main reasons are discussed in this chapter.

The history of developing urban district heating utilizing fossil fuel to co-generation and boiler heat production in northern China has over 60 years. At present, 90% of the cities and towns in northern China have a large-scale district heating network built underground.

The total length of the underground pipe network for DH in China is more than 540 thousand km. The largest diameter of the heating pipeline is DN1600, and the heating stations are usually also very large to supply heating for several buildings or more than a dozen buildings together rather than substations in a single building as in northern Europe.

In the past decade, coal or natural gas has been the main energy source of heating. Thus, China's clean heating strategy, as not able to rapidly replace the carbon intensive heat production and co-generations plants is aiming at increasing their efficiency and filtration of emissions. Remarkable achievements in energy conservation and emission reduction have been proven as show figures after 61% increase of DH supply in the urban areas (corresponding to 2/3 of all urban and rural building footage) noted in 2019 compared with 2013. This significant step in DH deployment caused total energy consumption to increase by only 20%, and the carbon emissions increase by only 17.3%.

However, in the future, China will adjust the development direction of clean heating in the way that fossil energy should be reduced after reaching its peak. Therefore, many small inefficient generators and coal-fired boilers will face elimination and shutdown.

So, seeking clean and low-carbon new energy with a certain scale to replace coal will become a key issue that China's heating industry urgently needs to solve in the future.

In northern urban in China, the distribution of RES is different between the regions. Solar, geothermal energy or air source heat pump cannot fully meet the heating needs of dense construction and large population. Thus, the preliminary alternative for fossil energy will be the industrial waste heat, not only from cogeneration but also from chemical plants or paper mills. Some industrial plants are located far from urban areas, and the government has begun to build long-distance pipelines to transport industrial waste heat to urban centres. At present, the largest project has been completed, which transports waste heat from power plants 50 kilometres away to the city centre through four underground pipelines with a diameter of ND1400mm. It can provide a heat load of 3040 MW for an area of 60 million m^2 of building space and has replaced 300 coal-fired boilers in the city centre. Meanwhile, the government will vigorously develop waste incineration heating, sewage heating, excess heat from data centres, and geothermal or solar heating in areas where conditions allow for it. These RES heating is a supplement to the large-scale urban heating system.

In northern rural in China, people will use a variety of renewable energy sources for direct heating because of the scattered rural houses and the low population density. These renewable energy sources mainly include solar, geothermal, biomass or biogas and green power.

The Chinese government has formulated a series of policies to promote RES heating. For example:

- Promote the significance of making full use of RES In the whole society.
- In the process of designing, planning and renovating the heating network, the RES scheme is optimized.
- In the area covered by the DH network, it is not allowed to build new coal-fired boilers for heating. The newly increased heating demand should give priority to various RES heating systems and give tax incentives and subsidies for renewable energy heating.

The technical obstacles in implementation of the described strategy include:

- How to combine RES with the existing DH network coupling in cities.

Due to historical reasons, both of the urban DH system temperature in primary and the secondary are very high. The main problem is that the temperature gradient of the energy source does not match when we integrate the heat of renewable energy into the urban central heating system. Therefore, currently renewable energy cannot be coupled with the urban heating network but can only supply heat to independent buildings.

- How to solve the problems of RES in rural areas, such as small-scale plants and scattered demand, instability in demand profile and low level of COP etc.
- When the lowest outdoor temperature drops below minus 20°C in winter in northern China, the COP value of air source heat pump is particularly low and even will not start up because of frost.
- Large scale thermal storages, where high temperature membranes and corrosion protection still can perform better.
- Geothermal heat pump requires a large area, and the underground space in the central area of the city is tight, so it is difficult to build.
- There are still many old buildings in urban and rural areas which standard systems for energy-saving have not been fully established yet.

4.3.2 ECONOMICAL OBSTACLES AND OPPORTUNITIES.

In order to promote the application of renewable energy in China's heating, three parties of government, heating enterprises and consumers should pay certain responsibilities. The huge challenges are:

- How long can the national fund subsidies continue?
- Whether enterprises can have the ability to operate and put out funds to do the transformation of renewable energy.
- How much expenses the customers can bear?

4.3.3 LEGISLATIVE OBSTACLES AND OPPORTUNITIES.

China has formulated a series of laws or regulations on carbon emissions trading. Tax on carbon emissions is also being implemented. However, at present, these measures have been well implemented in large cities throughout the country, but not yet fully implemented in small and medium-sized cities and rural areas.

4.3.4 ORGANIZATIONAL OBSTACLES AND OPPORTUNITIES.

Winter heating in northern China belongs to the government's guarantee project for people's livelihood. The price of heating charges is generally set by the government. If the enterprise cannot make a small profit because of the high cost of purchasing energy in the operation process, the government will provide some subsidies. But recently, with the intensification of carbon reduction taxes, the funding of government subsidies is becoming more and more difficult.

4.3.5 SOCIAL OBSTACLES AND OPPORTUNITIES.

In China, not all people have a clear understanding of low-carbon emission reduction. Especially in some remote mountainous areas, where people just solved the problem of poverty. The desire to live a better life is very strong. With the improvement of living standards, people's demand for energy consumption will also increase. How balancing the economic development and reduction of energy consumption is a huge challenge. Chinese government has stepped up publicity to promote low-carbon emission reduction and green life. More and more people are having a better understanding of low-carbon green now.

4.3.6 KNOWLEDGE AND PERCEPTION OBSTACLES AND OPPORTUNITIES.

RES knowledge among customers, authorities, suppliers and industry is being at acceptable level as it is growing constantly.

4.4 STATUS FOR SECTOR COUPLING

Electric heating has become one of the means to reduce heating air pollution in cities, especially in recent years, with the increasing price of natural gas, electric heating shows more and more advantages than natural gas heating. Direct heating from coal-fired power or gas-fired power is generally prohibited in China. Heating industry electrification is one of the green development trends in the future. High energy efficiency of heat pump is the best way of electric heating.

By the end of 2018, the heating area of various types of heat pumps in heating area in northern China had reached about 670 million building m^2. Between 2017 and 2018, about 208 million m^2 of new heating area was added by heat pumps, accounting for 60% of the increase in non-coal and non-gas areas.

5 DENMARK

Author: PSørensen P.-A., PlanEnergi

District heating has a long tradition in Denmark. It started in Copenhagen and larger cities 100 years ago with utilization of excess heat from power production and later on from waste incineration. Until the 1960ties fuels for individual heating was coke and peat. Since then oil fuel was introduced, however, in many cities, district heating operated by consumer-owned district heating companies took the priority over individual oil boilers. This became the second round of implementation of district heating. A third round came when natural gas fired CHP was introduced in the 1990ties.

Today 64% of all Danish buildings are supplied from approximately 400 district heating utilities. Of those circa 350 are consumer-owned and 50 belong to municipalities. District heating utilities are by law non-profit companies.

5.1 POLITICAL OBJECTIVES

The Danish Parliament agreed on the 16th of June 2020 upon a 2030 plan including:

- No coal, oil and natural gas in the district heating sector in 2030 (and in the heating sector in total).
- Wooden biomass for district heating must be certified and wood as fuel in the DH sector must be reduced.

5.2 CURRENT STATUS OF RES SHARE IN DH

The Danish Energy Agency produces every year energy statistics. The latest is for 2019 and has the following results showing more than doubling of heat generation from RES over the last decade: This is mostly due to boom of all different low-carbon and green heat production plants including solar thermal, geothermal, biomass, biogas and in the recent years electric heat pumps sourced from wind-based electricity.

Fuel consumption for district heating production			Ændring i pct. Change %
Direct energy contents [TJ]	1990	2019	'90 - '19
Total fuel consumption	**69 833**	**88 115**	**26,18**
Oil	4 766	867	-81,8
- Orimulsion	-	-	
Natural gas	12 131	13 416	10,6
Coal	30 898	7 619	-75,3
Electricity (Heat pumps, electric boilers etc.)	-	1 610	
Waste, non-renewable	6 289	8 384	33,3
Renewable energy	**15 749**	**56 219**	**257**
Solar	6	2 270	37740
Geothermal	48	69	43
Biomass	15 611	50 902	226
- Straw	3 640	8 443	132
- Wood	3 541	32 069	806
- Biooil	744	143	-80,8
- Waste, renewable	7 686	10 248	**33,3**
Biogas	84	2 567	2956
Heat pumps	-	411	

Figure 11 Energy statistics for the annual fuel consumption to heat production in District Heating in Denmark (Danish Energy Agency 2019).

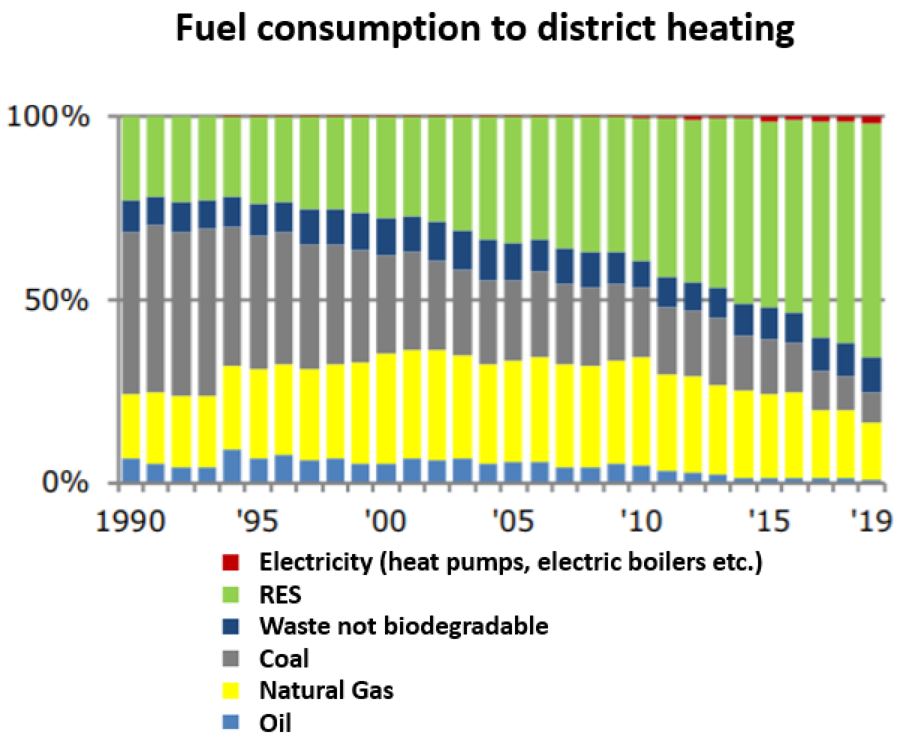

Figure 12 The graphical demonstration of annual fuel consumption by fuel type to DH heat production in Denmark (Danish Energy Agency 2019).

5.3 OBSTACLES AND OPPORTUNITIES FOR RES

5.3.1 TECHNICAL OBSTACLES AND OPPORTUNITIES.

The technical obstacles are few since we already know and have full scale projects including technologies, that can bring us to the 2030 objectives. Still technologies are under development, as for instance

- Large scale thermal storages, where high temperature membranes and corrosion protection still can perform better.
- Excess heat from data centers, where liquified cooling of CPUs could bring the excess heat temperature from 25-30°C to 60°C.
- PtX, where excess heat amount and temperatures differs very much from hydrogen production by use of alcaline electrolyzers to methanol production by direct conversion of biogas.

5.3.2 ECONOMICAL OBSTACLES AND OPPORTUNITIES.

According to the Danish Act for Heat Supply district heating companies are obliged to find the cheapest production price when implementing new production units. If CO_2 taxes are too low, this can prevent them from the most long term economical efficient investments.

5.3.3 LEGISLATIVE OBSTACLES AND OPPORTUNITIES.

Taxes on carbon emission are not giving DH utilities motivation to be flexible, since nearly all electricity tax for heating is removed also in periods, where the electricity is produced partly or totally by use of fossil fuels.

Obligations to use of excess heat from for instance data centres and economical motivations are missing. Can be solved by a high CO_2 tax.

5.3.4 ORGANIZATIONAL OBSTACLES AND OPPORTUNITIES.

The Danish district heating sector consist of app. 400 utilities. Most consumer owned. The sector can be more efficient by cooperating more and by helping the most expensive utilities through fusion with cheaper utilities.

The electricity distribution companies are working for highest sale of electricity not sale of green electricity.

5.3.5 SOCIAL OBSTACLES AND OPPORTUNITIES.

DH prices differs quite much resulting in areas where DH is less popular, but in general district heating is well known in Denmark and the social acceptance is high in general.

5.3.6 KNOWLEDGE AND PERCEPTION OBSTACLES AND OPPORTUNITIES.

Knowledge among customers, authorities, suppliers and industry is very high making export of solutions and technology possible.

5.4 STATUS FOR SECTOR COUPLING

Power to heat is implemented and under implementation (electric boilers and electric driven heat pumps). 750 MW heat capacity from electric boilers and heat pumps were installed in 2019 (85 plants). 70 MW of new heat pump capacity has been added in 2020 and this will develop in the coming years since heat produced by electrical driven heat pumps are now producing cheaper heat than for instance biomass.

The development in amount of heat pump installations and heat production capacity is illustrated below:

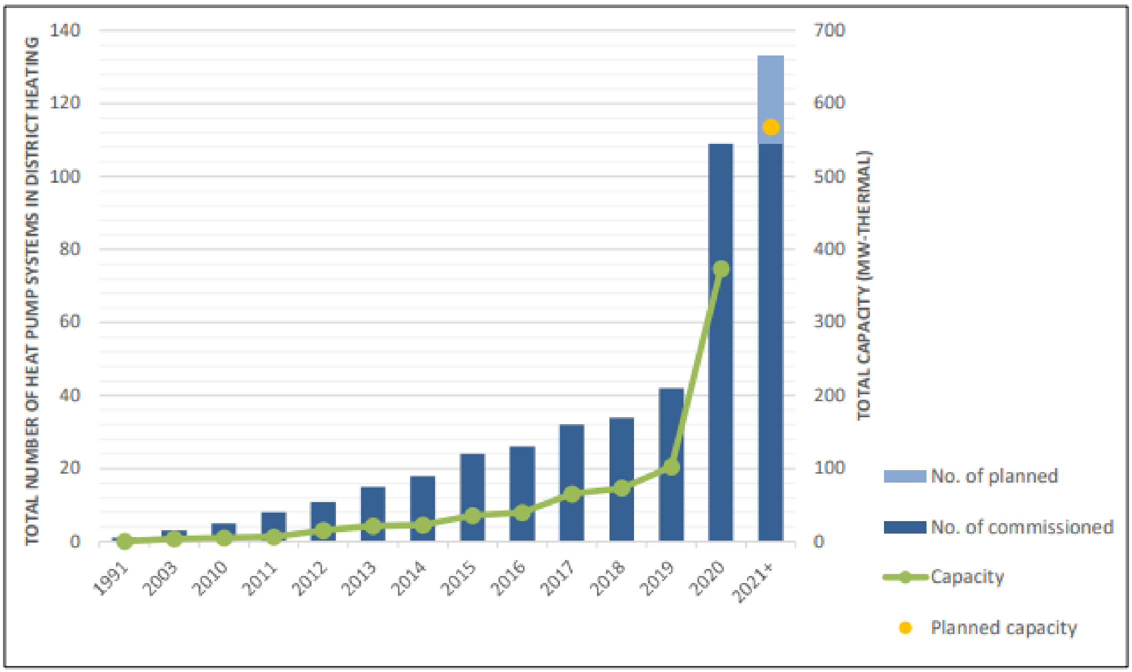

Figure 13 The status of the installed large scale heat pump capacities in Denmark (PlanEnergi Varmepumpeoversigten, 2021).

Still the sector coupling should motivate utilities to use renewable electricity. This is not the situation in DK at present as explained above under legislative obstacles.

6 FRANCE

Author: Bourdon D., CEA | The French Alternative Energies and Atomic Energy Commission

French heating networks, in terms of covering national heating needs, are ranked at the 20th place of the European chart, with only 5% of the heating needs covered by district heating networks. France has thus significant development potential for these networks.

Nevertheless, despite their limited deployment, regarding the energy mix and carbon content, French networks are among the most diversified in Europe. Current state of the French DHC is presented in Table 3:

Table 3 Status for the DH and DC in France

DH:	DC:
833 DH networks	32 DC networks
25.4 TWh supplied	0.81 TWh supplied
60.5% from renewables and heat recovery	0.011 kg/kWh (average CO_2 content)
0.101 kg/kWh (average CO_2 content)	225 km of total piping length
6199 km of total piping length	1401 connected buildings
43945 connected buildings	

The potential for the development of heating networks in France seems significant, but the current trajectory of the projects does not allow the objectives set by the French National policy targets (Multi-annual Energy Programs - *Programmations Pluriannuelles de l'Energie - PPE* and Energy Transition law for a Green Growth - *Loi de Transition Energétique pour la Croissance Verte – LTECV,* detailed in §6.1) to be achieved (as shown in Figure 14)

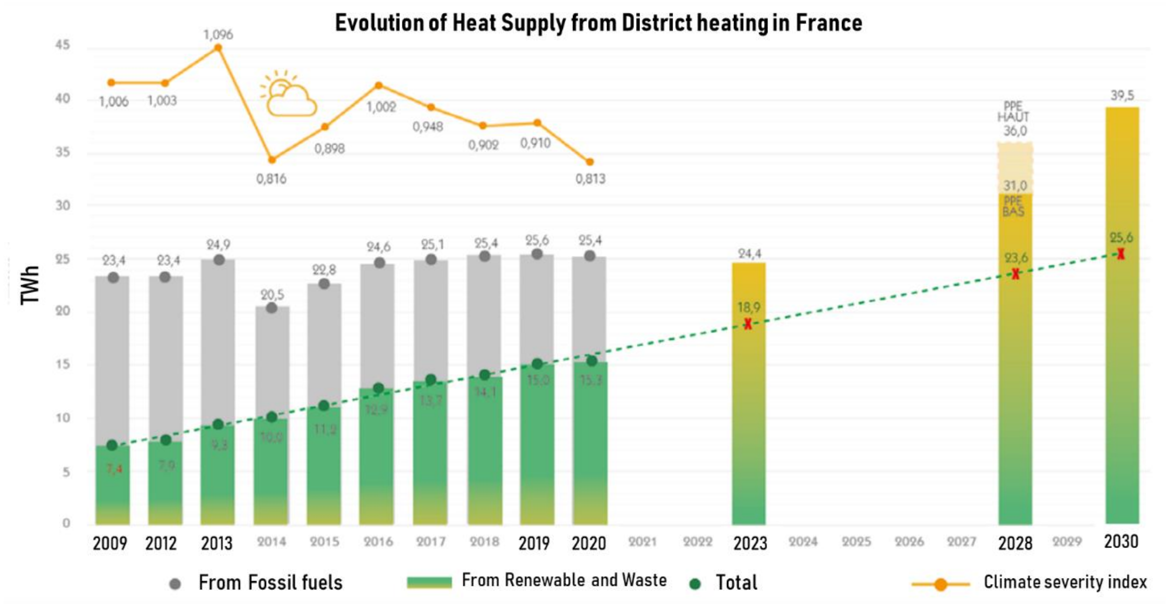

Figure 14 Evolution of heat supply from district heating networks in France.

The scenarios established by the French national Funding Agency for Environment and Energy Control *(Agence Nationale de l'Environnement et de la Maitrise de l'Energie - ADEME)* are shown in Figure 15.

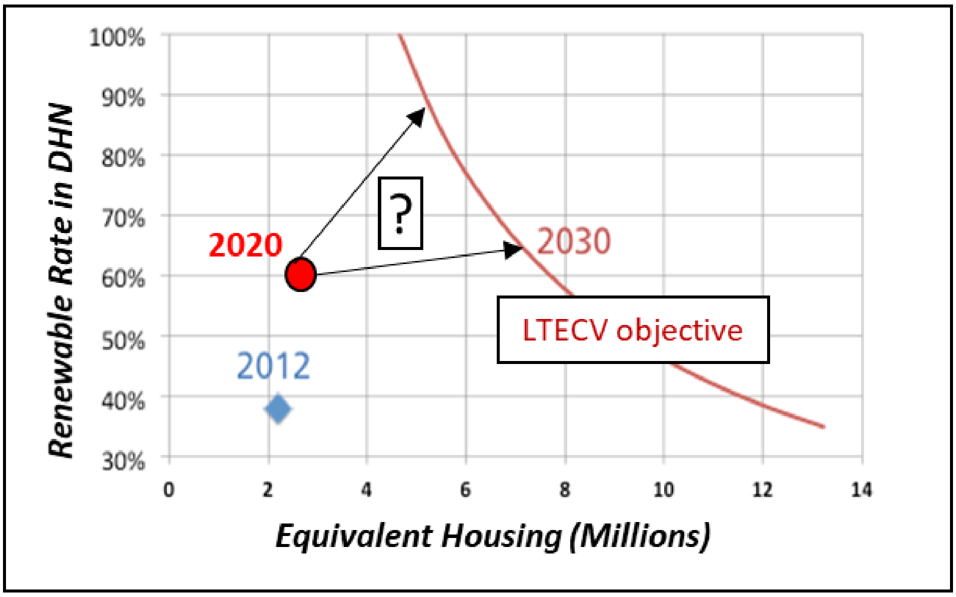

Figure 15 Increase of DHN and its share of renewable energy-based supply.

6.1 POLITICAL OBJECTIVES

The EC objectives set a framework for the various energy carriers, including heat. The European target is to increase a proportion of renewable energy into DHC by 1% per year. District Heating networks are an integral part of the means identified by Europe to achieve carbon neutrality by 2050.

French legislation derives from European directives. The major pillar laws are established at national level:

- Energy Transition law for a Green Growth *(Loi de Transition Energétique pour la Croissance Verte - LTECV)* : target to x5 on waste and renewable heat in DHC in 2030 ; 39.5 TWh of heat supply from waste and renewable resources in 2030.
- Low Carbon National Strategy *(Strategie Nationale Bas Carbone – SNBC) :* target *a* reduction by 75% GHG in 2050 (reference of 1990)
- Multi-annual Energy Programs *(Programmations Pluriannuelles de l'Energie - PPE) target for* DHC energy supply in TWh. 2023 : 24.4 (heat) / 1.4 (cold) ; 2028 : 31 (heat - scenario A) – 36 (heat - scenario B) / 2 (cold -scenario A) – 2.7 (cold - scenario. B)

These laws set objectives which are then broken down in the territories via planning documents such as:

  - at regional level: the regional planning, sustainable development and territorial equality plans (*Schéma Régional d'Aménagement, de Développement Durable et d'Egalité des Territoires :SRADDET*)[2]
- at inter-municipalities and metropolitan areas level :
    - *Territorial Climate Air Energy Plans (Plans Climat Air Energie Territoriaux – PCAETs)*
    - Departemental Energy Associations (S*yndicat Départemental de l'Energie-SDEs*).

6.2 CURRENT STATUS OF RES SHARE IN DH

In France, heat production accounts for nearly half of the final energy consumption and 20% of the greenhouse gas emissions. It is a central component of the ecological transition. By mobilizing local renewable and recovered energies (R&R), district heating networks have demonstrated their ability to quickly decarbonize their energy production. In ten years, district heating networks have doubled their heat production from renewable energy to exceed a rate of 60% in 2020.

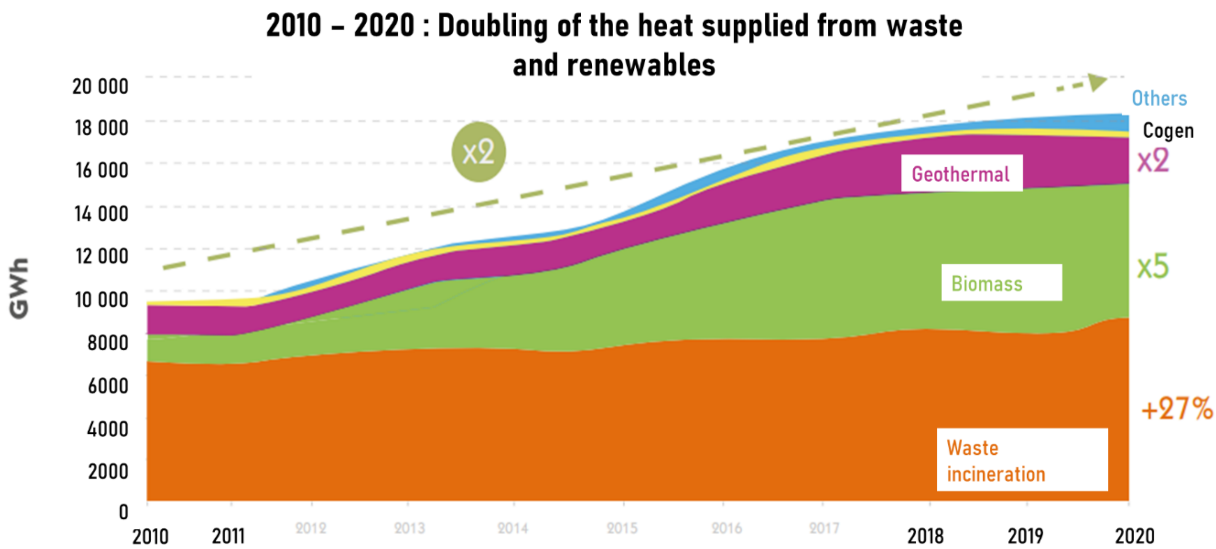

Figure 16 The development of renewable energy share in DHN over a decade.

DH networks have increased their production of heat from renewable energy mainly thanks to heat from waste incineration and introduction of renewable energies.

Heat from domestic wastes incineration is the primary source of renewable energy for heating networks (8,605 GWh in 2020), i.e., 28.3% of network production.

The DH networks generated 6,457 GWh of heat from biomass in 2020, i.e. 21.2% of the sector's production. The Auvergne-Rhône-Alpes (AURA) region has the largest production with 1,345 GWh.

In ten years, the quantity of geothermal heat supplied by DH networks has doubled to reach 1,859 GWh in 2020. Ile de-France concentrates 87% of this production.

6.3 OBSTACLES AND OPPORTUNITIES FOR RES

6.3.1 OBSTACLES

The main limitations for a massive introduction of RES into DHC are:

- Too high temperature and pressure level of the current operating conditions which are not compatible with the introduction of RES (as solar thermal or heat pumps). In addition, end users' installations are outdated and hinder operators to reduce their operating temperature levels. Even if operators are willing to reduce their operating temperature to be more sustainable, it can be achieved along with the potential refurbishment of the end-user's installations. This is, however, not be supported by national and regional funding.
- In case of potential tools to support decision makers, these are either under development or already developed but poorly disseminated.
- Lack of support on how to claim subsidiaries and national and regional funding to help communities and operators in installation of the renewable resources and storages in the DHC.

6.3.2 OPPORTUNITIES

The main opportunities are:

- **A strong opportunity to lower carbon footprint**: To lower the global carbon footprint on the new buildings, a recent modification of the environmental regulation on buildings (RE2020) was implemented. This targets all GHG emissions, even from the construction phase, and set a carbon content of the energies supplying the building. In 2020, operation of DH systems instead of individual gas boilers allowed to save 5.65 million tons of CO2, (i.e. the equivalent of 2.7 million cars withdrawn from circulation in one year! DHC networks also improve air quality and reduce greenhouse gas emissions thanks to high-performance technologies and optimized operation. Within last ten years, heating networks have practically halved their CO_2 content (-48%) thanks to the significant development of energy systems based on renewable energy which replace fossil fuels-driven plants. With an average CO_2 content of 101 g/kWh in direct emissions and 129 g/kWh in Life Cycle Analysis - LCA emissions, heating networks emit 43% less CO_2 than natural gas (227 g/kWh in LCA). ADEME assesses the abatement cost of DHC networks at €37/teqCO2 avoided. The DHC are then less expensive than wind power, photovoltaic on the ground or on the roof and heat pumps to reduce greenhouse gas emissions.

- **Adaptability to local wastes & renewable resources**: Anchored in the heart of the territories, the DHC networks make it possible to mobilize and exploit the renewable energies available locally, mostly heat recovered from domestic wastes incinerators and biomass. The diversity of energy mixes in the region reflects the ability of DHC networks to adapt to local resources.
- **Stable and controlled costs**: heating networks use local wastes and renewable resources, the prices of which are more stable than fossil fuels. They provide diversified and competitive heat prices for domestic, public and commercial customers.
- **Incentive scheme for the creation of diversified DHC:** In addition, the creation of new networks is not sufficient to meet these 2030 objectives, while there is significant potential in communities with fewer than 50,000 inhabitants. To move from raising awareness to the launch of concrete projects, the District Heating National Association (*Syndicat National du Chauffage Urbain – SNCU*) is working with the public authorities and its partners to set up a system of calls for projects to create diversified DHC networks. By 2030, this system should facilitate the creation of nearly 1,000 diversified DHC networks (i.e. one DHC network per department and per year).
- **DHC classification to valorise virtuous networks**: Finally, the classification of diversified public DHC networks will become automatic in 2022: any new or renovated building located near a classified network must now connect to it. This major development will stimulate the densification of diversified networks and will switch a large number of subscribers to a sustainable heating mode.
- **Development of urban cooling supply**: With acceleration of global warming, the cooling of cities is a health issue! By using renewable and recovered cold sources, the DHC networks provide a sustainable response to ‘heat island’ phenomena. We must make every effort to accelerate the growth of effective cooling. The public authorities must seize the subject without a delay!

6.4 STATUS FOR SECTOR COUPLING

Sector coupling is considered as prospective at this stage. Very few demonstration plants are present in France. For example: the DHC of Paris Saclay has launched a sector coupling initiative through introduction of geothermal resources (coupled to Heat Pumps) on a multi loop DHC system for both heat and cold production and distribution, in which coupling to the gas network with additional gas boilers (Lesechos) is also to be implemented in the future.

Trends of temperature reduction for the DH loops will support the coupling to other energy carriers as electricity through usage i.e., of heat pumps on heat recovery resources, as to ensure the best overall energy balance.

Collective adaptation of the energy transport and distribution network is also currently studied (including gas and electricity) with interconnection with local DHC.

According to Table 4 the development of heat pump in DHNs in France is gradually progressing.

Table 4 Development of DHN with heat pumps.

Date of National Survey	**2018**	**2019**	**2020**
Date of Data collection	2017	2018	2019
Number of DHC integrating Heat Pumps	27	26	31
Thermal Energy from RES provided (GWhth)	97	202	255
Increased compared to the previous year (%)	-15	+108	+26,2
Share in the DHC energy mix (%)	0,32	0,7	0,8

Also, since the development of DHN in France at 2050 horizon is expected to be more and more dependent on waste heat and geothermal energy (see Figure 17), heat pumping and thus sector coupling will also be strongly necessary.

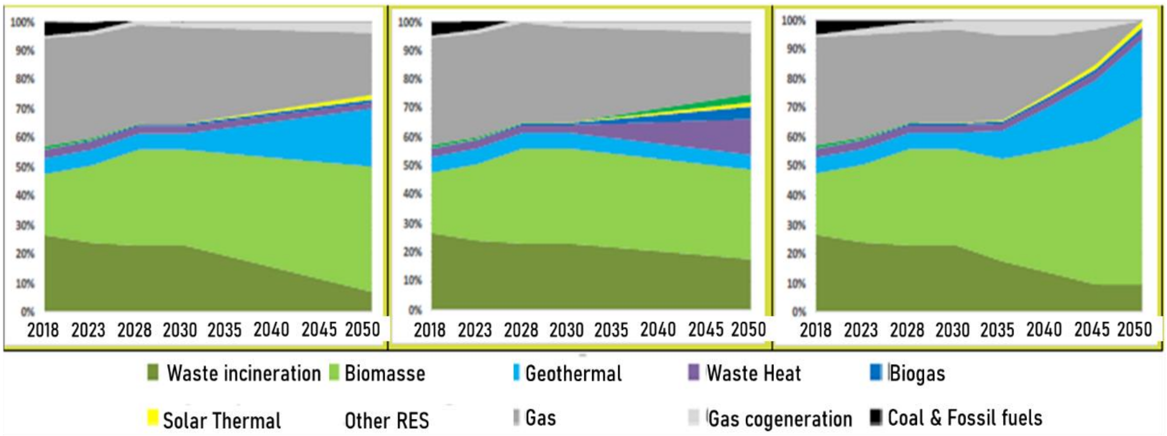

Figure 17 Evolution of the DHN energy mix in three potential scenarios (left: trends, mid: alternative, right: regulatory) (Source: ADEME, 2020)

7 GERMANY

Author: Hay S., AGFW | Energy Efficiency Association for Heating, Cooling and CHP

The first District Heating systems in Germany were installed in 1901. Today DH systems are widespread in urban areas and these historically grown DH systems are predominantly hot water networks with design temperatures higher than 110°C. The market share of DH in Germany is round about 14 %.

The description of the status quo of district heating supply in Germany is based on the data of the AGFW Main Report 2020. The AGFW statistics, which have been collected annually since 1971, most recently included 196 district heating supply companies:

The route length of the heating networks in Germany amounts to 21,482 km, which are again differentiated into hot water networks (20,938 km) and steam networks (544.4 km). The total of 1207 heat networks provide 377,305 customer installations (hot water networks 353,455 installations, steam networks 6,850 installations) with the required amount of heat. In 2019, the heat supplied by all district heating utilities to customers amounted to 255,661 TJ, which, in combination with the necessary heat input into the networks of 290,374 TJ, results in an average heat loss of the heating networks of 12 %.

7.1 POLITICAL OBJECTIVES

On 12 May 2021, the Federal Government of Germany passed a draft amendment to the Federal Climate Protection Act including (Political goals 2021):

- Increase the greenhouse gas reduction targets:
  - 2030: (from minus 55 % to) minus 65 % compared to 1990.
  - 2040: 88 % greenhouse gas reduction compared to 1990.
  - 2045: reach greenhouse gas neutrality.

The Federal Government of Germany adopted the Climate Protection Programme 2030 in October 2019. Cornerstones of the programme are (Political goals 2021):

- National emissions trading in the areas of heat and transport.
- A gradual phase-out of coal-fired power generation.
- Relief for citizens and the economy.
- Comprehensive support measures in the energy, industry buildings, transport, agriculture and waste management sectors.

7.2 CURRENT STATUS OF RES SHARE IN DH

Based on the current statistics and estimates of the BDEW (BDEW 2021), 67.9 % of the district heating supply in Germany is generated from fossil fuels. A further 8.5 % is accounted for by non-biogenic waste utilisation, 5.5 % by waste heat and 0.5 % by other energy sources. The statistics show a renewable share in the district heating supply of 17.6%, which is further differentiated into biomass (9.4%), biogenic municipal waste (7.5%) and geothermal and solar thermal energy (0.8%).

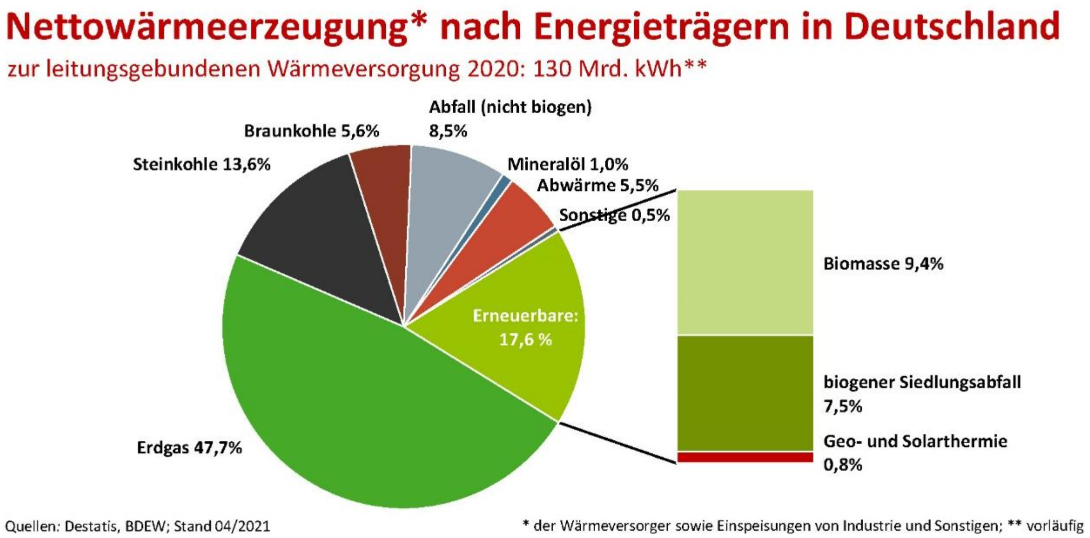

Figure 18 Net heat generation by energy source in Germany for pipeline-based heat supply 2020 (BDEW 2021)

7.3 OBSTACLES AND OPPORTUNITIES FOR RES

7.3.1 OBSTACLES

- Space requirement, especially in urban areas.
- High supply temperatures in existing DH systems.
- Low prices for gas and oil are a barrier to investment, especially for heating networks with a high share of renewable heat generation.
- The reduction of the operating temperatures in existing systems requires an adjustment of the building-side installations and depends on the modernization of the buildings in the supply area.
- In urban areas, the installation costs for DH grids are also very high. Building new grids in order to connect RES heat producers outside the city fails because of these high investment costs.

7.3.2 OPPORTUNITIES

- Climate goals of federal government, partly more ambitious in local areas and cities.
- Development of CO_2 prices, making RES in DHC more competitive.
- Transformation processes in existing DH systems.
- Process of digitalization, needed to operate a more distributed heat production in a DH system.
- Funding programmes like "Bundesförderprogramm Effiziente Wärmenetze (BEW)"or „innovative KWK-Systeme (iKWK)" (innovative CHP systems).

7.4 STATUS FOR SECTOR COUPLING

According to the statistical data of the AGFW, Power to Heat plants with a total thermal output of 870 MW are installed in Germany. Vattenfall Berlin's largest plant can provide 120 MW_{th} for district heating. Exact heat quantities or shares of heat generation of the installed plants are currently not statistically recorded. Figure 19 shows the installed plants in Germany with their capacity and additionally the plant future development of capacity.

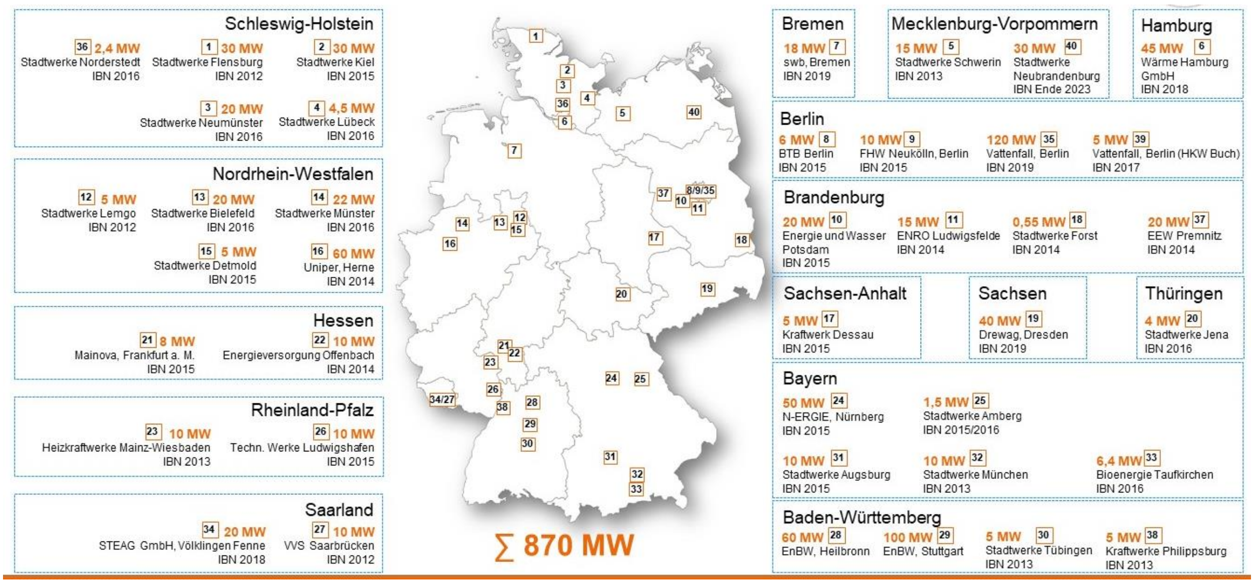

Figure 19 Power to Heat installations in Germany, Source: AGFW

In addition, the increase in the installed capacity of power-to-heat plants in Germany since 2012 is shown in Figure 20.

The application of large-scale heat pumps and P2H systems is inhibited in Germany by taxes, levies, surcharges and grid fees, as well as the lack of consideration of P2H in existing law. A recommendation to adapt the existing laws based on the principle "benefit-instead-of-shut-down"? is highly appreciated.

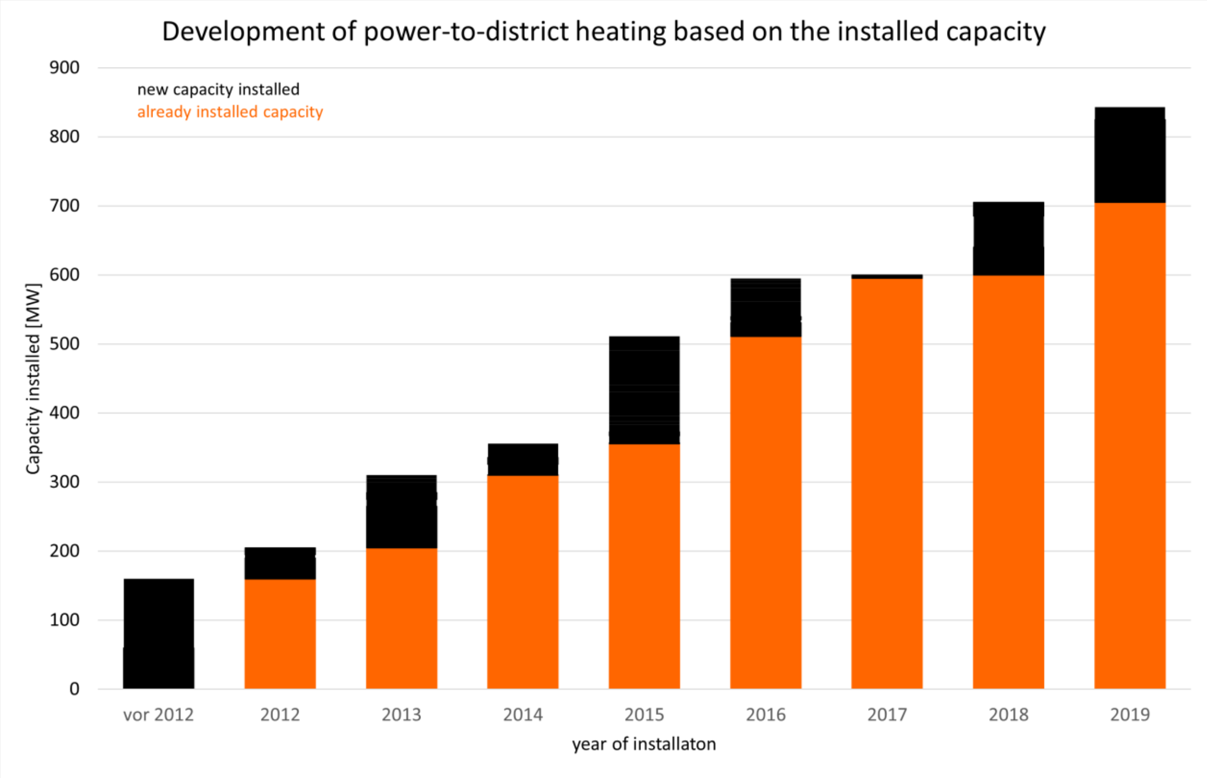

Figure 20 Installed capacity and year of commissioning of Power to Heat plants in Germany, (AGFW)

The national funding programme "innovative KWK-Systeme" enables several more power-to-heat plants to be built in Germany in the next few years. Figure 21 shows projects that have been approved for large-scale heat pumps and power-to-heat plants. These projects will increase the installed capacity of power-to-heat plants in Germany by another 46,8 MW_{th}.

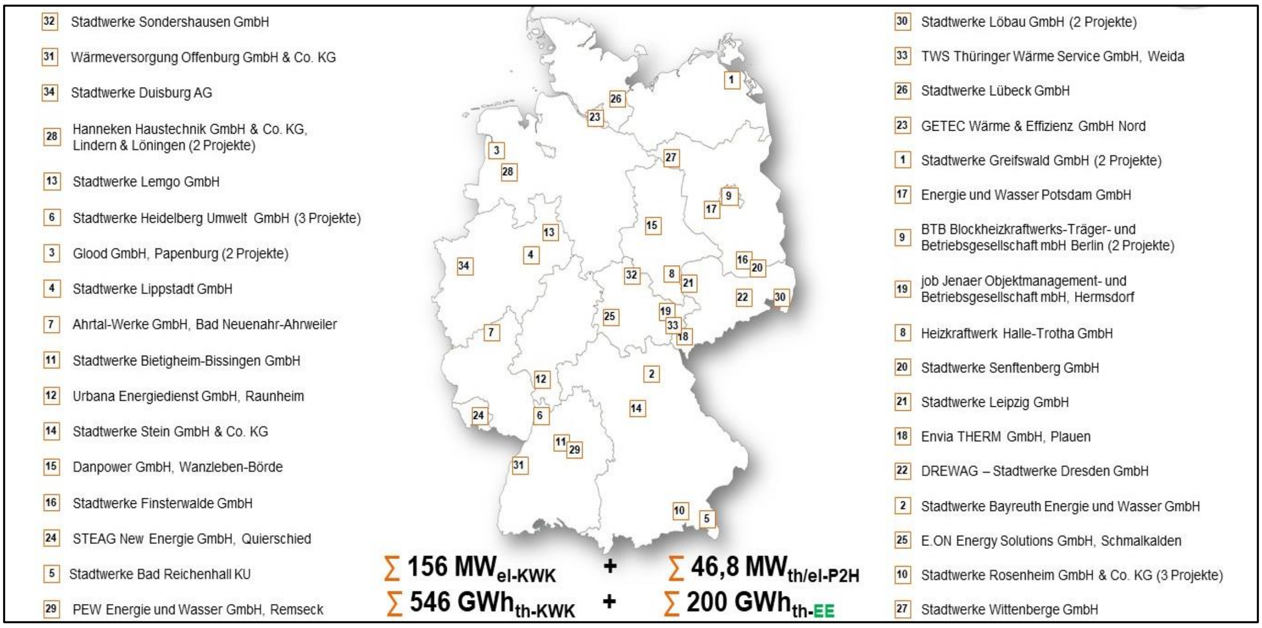

Figure 21 Overview of approved innovative KWK-Systeme (AGFW)

8 ITALY

Author: Spirito G., Dénarié A., Caputo P., Politecnico di Milano & Giannetti D., GSE, AIRU..

Italy is a country of 301,338 km^2. Approximately, half territory is characterized by cold winter (more than 2100degree days), while one third is covered by forests. The estimated country's overall demand for heating and domestic hot water in residential and service sectors' buildings accounts for 329 TWh, according to (Politecnico di Milano e Politecnico di Torino, 2020), and it is dominated by individual heating solutions such as boilers, mainly based on natural gas. According to (AIRU, 2020) and (GSE,2021) only 9.133 GWh of thermal energy is supplied through district heating in Italy, representing 2.7% of the overall heat demand. In 2019, district heating counts 413 networks in operation, with a total length of about 4551 km and a total heated volume of 366 million m^3.

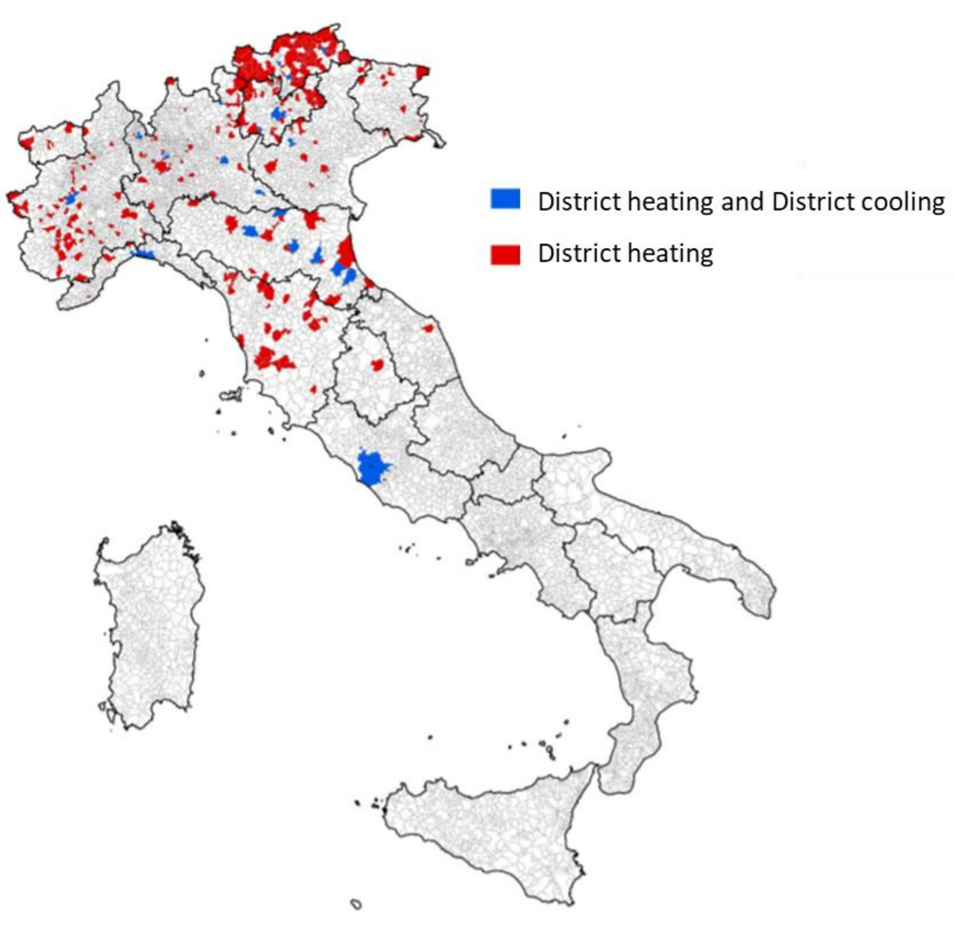

Figure 22 Municipalities with DH (red) and DHC (blu) (GSE,2021)

The existing systems are mainly operating in Northern Italy, especially because of the cold climatic conditions, and they account for 98% of the overall heated volume. In particular, the cities of Brescia, Milan and Turin currently represent 42% of the total national DH, managed under public-private partnerships. Few plants are also operating in the central part of Italy, especially in Tuscany, due to the large availability of geothermal heat.

Regions in central/south part of Italy are promising for the opportunity of providing cooling services during summer. District cooling, however, remains very limited: according to (AIRU, 2020), the cooling energy provided to the users through district cooling networks amounts to 129.6 GWh, representing only 1.4% of the thermal energy distributed for space heating and domestic hot water in the same year. The corresponding installed cooling power is equal to 203.8 MW of which 48% is provided by compression chillers collocated at the central plant and 52% by absorption chillers located in the users' substations.

In 55% of the installed DH networks, the heat carrier is hot water (on average: 90°C supply and 65°C return); in 44% of cases is pressurized hot water (on average: 120°C supply and 70°C return); in the remaining 1% the heat carrier is vapour. Regarding district cooling the average temperatures are 6°C in supply and 12°C in return.

For what concerns the heat fed into DH networks, 52.5% of the overall provided thermal energy is generated by fossil fuel-based CHP plants; 22% is generated by fossil-fuelled boilers, mostly fed by natural gas; 25.5% is thermal energy from renewable sources, namely RES as solar thermal and geothermal energy, bioenergy and biomass-based CHPs, heat pumps and industrial waste heat. An illustration from (AIRU, 2020) is reported below:

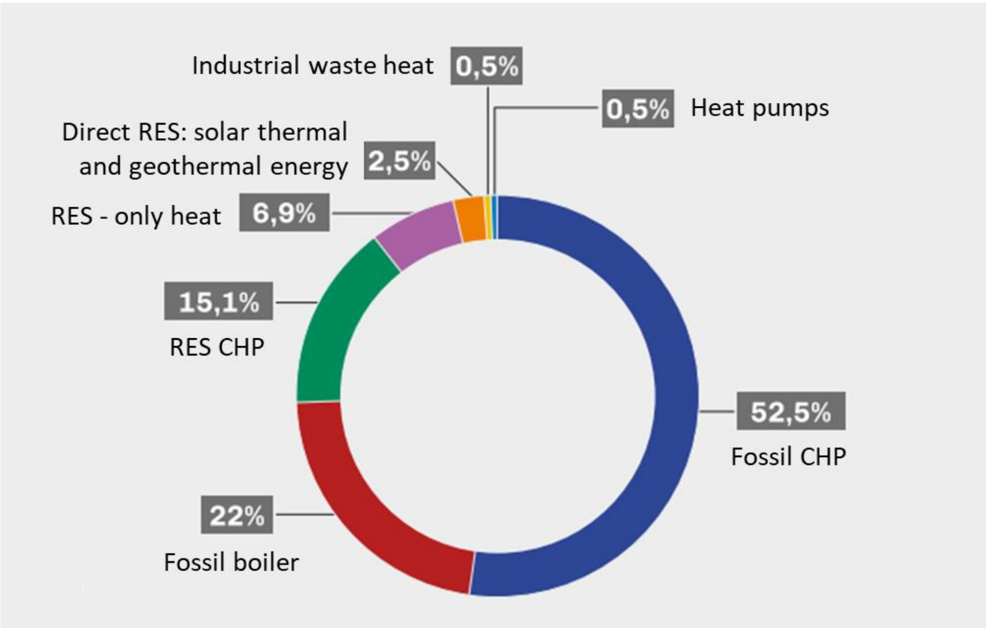

Figure 23 Shares of the technologies installed in 2019 for the production of thermal energy fed into DH networks.

In 2019, thanks to the district heating networks in operation in Italy, 0.5 Mt_{ep} of primary energy has been saved and 1.7 million tons of CO_{2eq} is the estimated number of avoided emissions.

8.1 POLITICAL OBJECTIVES

Italy is the first EU Member State that is receiving funding for the period 2021-2026 in the context of the European programme Next Generation EU (NGEU), aimed at accelerating the ecological and digital transition, improving living and working conditions and guaranteeing gender equity, intra-generational and intra-territorial fairness. In order to achieve the European objectives, Italy has been asked (together with all the other EU Countries) to define a roadmap with the targets and the planned reforms and investments to achieve them. In this context, the National Recovery and Resilience Plan, PNRR? (Italian Council of Ministers, 2021) has been drafted.

The reference European targets aim to a complete decarbonization by 2050. This ambitious goal is to be reached through a reduced utilization of primary energy and a higher energy efficiency, which translate in buildings' refurbishment, increased share of renewable energy sources, deployment of low temperature and RES-based district heating networks, circular economy. By 2030 the intermediate European targets to be reached are: -55% of greenhouse gases emitted, 32% of RES share in the whole system (including heat/cooling generation, the power system and the transport sector), 32.5% of primary energy saved.

Regarding the Italian DHC sector in particular, the target defined in the PNRR requires the development of 300 km of efficient district heating networks and the installation of plants and connections finalized to a thermal production of 360 MW from excess heat sources and RES. Indeed, an efficient district heating system is based on RES, waste heat and high efficiency CHP plants, by definition. It is also defined that the available funding will be allocated to the development of new networks in the share of 65% and to the construction of new generation plants in the remaining 35%. If achieved, these targets will bring to 20 Ktep/year of fossil primary energy saved and 0.04 million tons of CO_2 avoided emissions per year.

8.2 CURRENT STATUS OF RES SHARE IN DH

According to (AIRU, 2020), in 2019 the thermal energy of renewable origin that is fed into DH networks in Italy equals 25.5% of the overall thermal energy provided, showing an overall transition from fossil fuels to renewables, which are mainly utilized to meet base load needs. Of this share, 2.5% is given by geothermal energy and solar thermal; 0.5% is given by recovered industrial waste heat; 0.5% by large heat pumps; 22% is covered by CHPs and boilers fuelled with municipal waste, biomass or biofuels. In particular, the municipal waste represents the second fuel the most used in Italy for district heat generation, while bioenergy, and especially biomass, is the third. The first place is still taken by natural gas.

In the tableTable 5, from (AIRU, 2020), the mix of utilized energy sources is reported.

Table 5 Mix of primary energy sources utilized in the existing DH systems in Italy in 2019

	2019		2009	
	Thermal energy (tep)	%	Thermal energy (tep)	%
Natural gas	1,319,031	69.4	1,032,854	74.3
Municipal waste	287,476	15.1	109,525	7.9
Bioenergy (biomass and biofuels)	188,823	9.9	71,615	5.2
Coal	47,825	2.5	48,534	3.5
Oil	2,351	0.1	42,107	3
Geothermal energy	25,239	1.3	10,905	0.8
Industrial waste heat	5,086	0.3	2,090	0.2
Solar thermal	91	0	-	0
Fossil primary energy from Power System	25,945	1.4	71,974	5.2
Fossil total	1,395,152	73	1,195,469	86
RES total	506,715	27	194,135	14

Natural gas is still predominant but it has slightly decreased in the last period. Also the other fossil sources show a negative trend, as it can be seen in Figure 24.

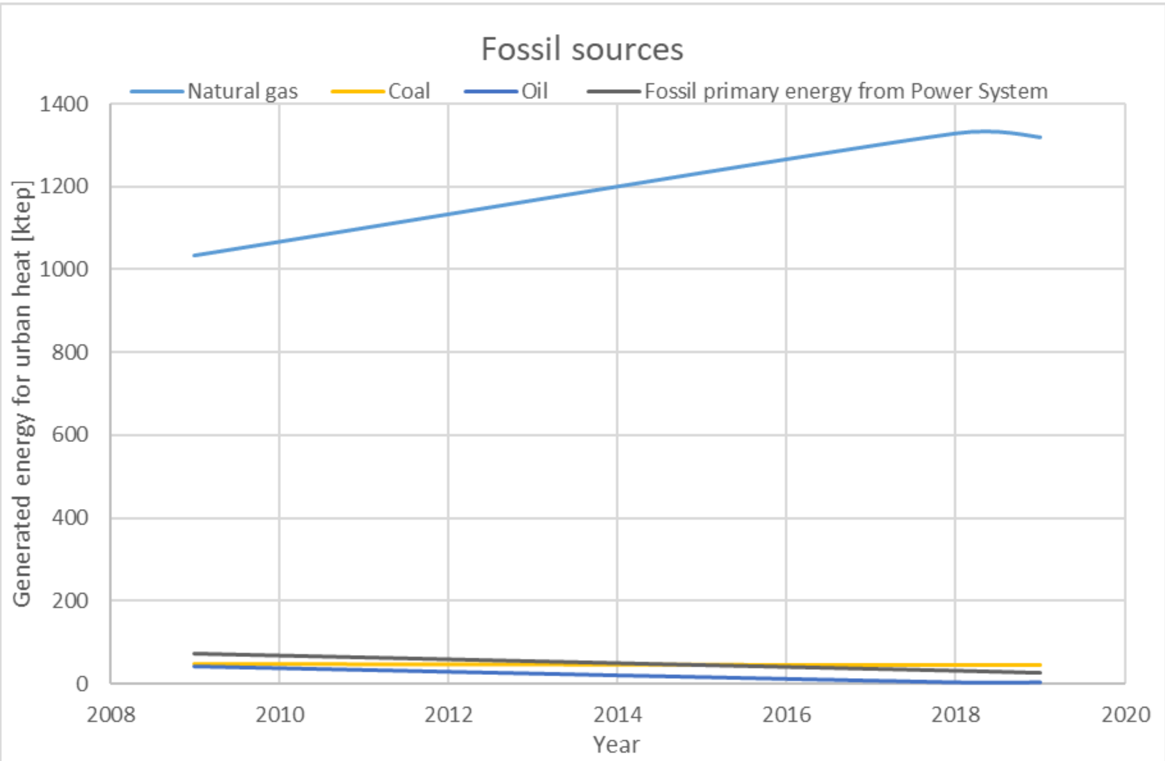

Figure 24 Trends from 2009 to 2019 of primary energy sources of fossil origin utilized in DH systems in Italy.

Meanwhile, renewable sources in Figure 25 show a positive trend: apart from municipal waste and bioenergy which are the most relevant, it is possible to see that geothermal energy more than doubled its former share in 2009, solar thermal appeared in the energy mix and industrial waste heat is not yet relevant in term of percentage but its impact in terms of thermal energy more than doubled.

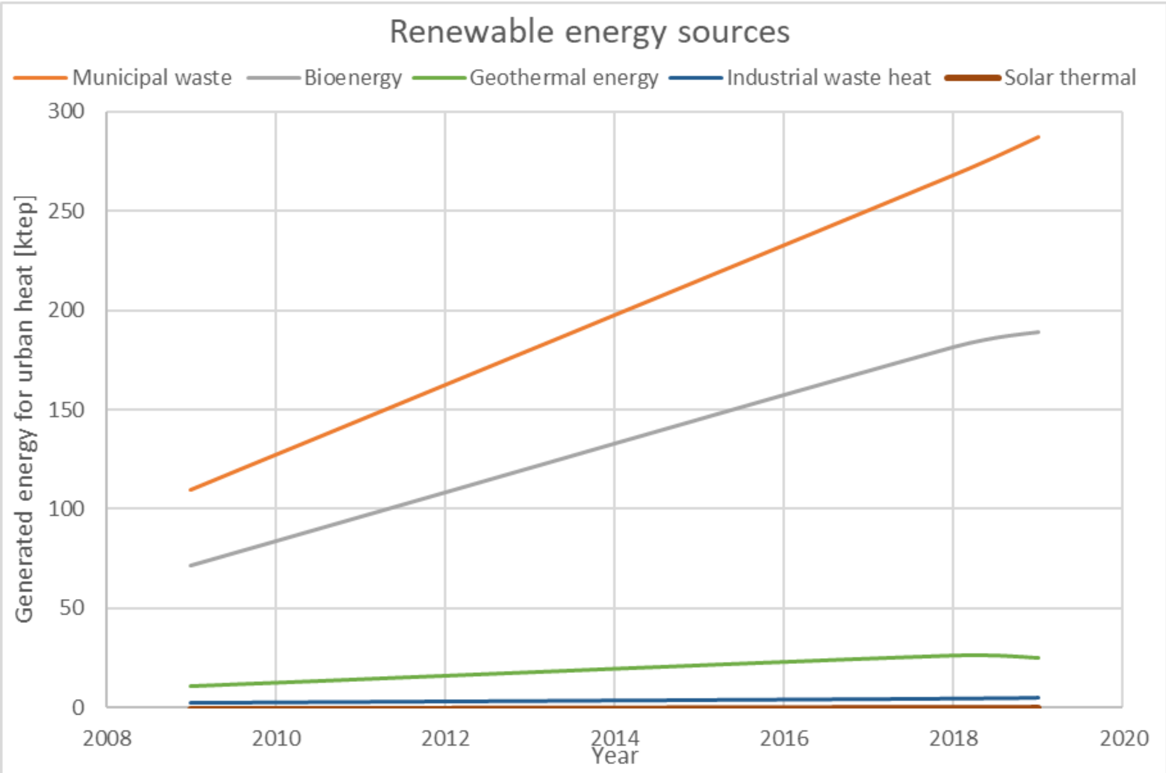

Figure 25 Trends from 2009 to 2019 of primary energy sources of renewable origin utilized in DH systems in Italy.

8.3 OBSTACLES AND OPPORTUNITIES FOR RES

Even though increasing trends can be observed for renewable sources, renewable primary energy sources adopted in 2019 cover only one fourth of the total.

The main identified obstacles for RES transition in Italy are listed in the following:

- RES heating supply sources of district heating are generally more capital intensive than natural gas CHP. DH operation takes place in a highly competitive environment where the choice of heat supplier is principally based on prices. The main alternative to efficient DH is the use of natural gas boilers (or oil boilers in the few areas not yet reached by the natural gas grid), which dominate the heating market.

- There are not many national incentives to DHC, e.g., there are no specific investment grants for DH, despite the long payback time of these systems (above 20 years). Until 2016, district heating and cooling (DHC) projects were supported by white certificates (corresponding to the primary energy saved), but this support scheme has recently been changed and in some cases the incentive has been significantly reduced. As minor support, a reduced Value Added Tax (VAT) is applied to heat sales to residential users supplied with RES or Combined Heat and Power (CHP) and other minor mechanisms are available for particular cases (biomass, geothermal, cogeneration and micro-CHP systems). However, these measures proved to be not so effective.
- The short duration of the winter season and the reduced space availability in many areas of the country often makes the fossil heating solution preferable, especially in the absence of regulatory constraints on its development.
- Stakeholders involved in DH admit that this technology is generally perceived as a rather old and inefficient technology. Actions need to be taken in order to get owners, consumers, industries and public authorities more aware of the environmental and social benefits that DH can bring. In this way they would be able to make informed decisions about heating supply options.
- There is no reduction on electricity taxes for DH compression heat pump; this reduces the economic sustainability of the implementation of heat pump both to recover low temperature waste heat or ambient heat.

A recent study funded by AIRU and conducted by Politecnico di Milano and Politecnico di Torino (Politecnico di Milano and Politecnico di Torino 2020) demonstrates, however, that by only exploiting the existing renewable and excess heat sources in the whole Italian country, 90TWh is the amount of thermal energy that can be conveyed to the buildings through DH networks. By considering that 114TWh is the energy demand from buildings technically connectable to a DH system without required interventions at the substation level, 78% of it can be covered by RES. Currently, the amount of heat distributed through DH networks in Italy equals 9TWh and therefore a ten-fold expansion of efficient DHC system (i.e. based on RES and excess heat sources) can be potentially achieved in a technically feasible and cost-effective way.

8.4 STATUS FOR SECTOR COUPLING

The power sector plays a central role in decarbonizing the whole energy system, thanks to the intrinsic efficiency of electricity and the technological maturity of renewables such as wind and solar (CDP et al.,2019). The electrification of energy consumption and the spread of renewable energy sources emphasize the complexities related to residual load ramp and overgeneration management, confirming the need for flexible technologies such as storage systems, demand-response management, distributed generation management, Power-to-heat, etc. District heating, being an energy infrastructure with a strong local connotation, can be seen as the key technology at the core of sector coupling, facilitating the interconnection between the heating and the power sectors, together with several other energy consuming sectors. From the point of view of DH, these sectors are the heating sector (with the buildings), the power sector (with the large-scale heat pumps and the CHP plants), the industry (through the excess heat recovery in DH networks), the telecommunication network (with datacentres' excess heat recovery), etc.

DH can also be seen as an effective way to balance the electricity system: especially in future scenario with reduced distribution temperatures and increased proportion of intermittent RES, district heating can balance the fluctuating renewable energies' overproduction in integration with large heat pumps. These are expected to gain an increasing weight in the thermal renewables mix because of their high efficiency and the continuous technological progress in the sector. The provided balancing power could then potentially reduce the need for the electrical grid upgrade, that is expected to be necessary in future since electrification and the diffusion of renewables are showing increasing trends in many OECD countries since many years. In Italy, in particular, the share of electricity in final consumption has grown from 17% in 1990 to 22% in 2017 (CDP et al.,2019).

Eventually, DH can be seen as a big thermal reservoir, by avoiding the release in the environment of heat flows at different temperatures and from different sources and, if integrated with thermal storages and power-to-heat systems, by stocking and providing heat when it is more convenient.

9 SWEDEN

Author: Lind J., Sanchéz-García L., Persson U., HU | Halmstad University.

Sweden has quite a long history of developing district heating (DH) and utilising energy efficiency benefits from cogeneration, resource efficiency benefits from industrial waste heat recovery, and other system integration benefits by, for example, utilising excess electricity production in P2H (Power-to-Heat) technologies such as large-scale electric boilers and heat pumps. During the last three decades, from the early 1990s, Swedish DH has also managed to undergo a substantial transformation from an original dependency on fossil fuels (e.g. oil and coal) to a, more or less, complete phase-out of non-renewable energy sources today. This development is presented inFigure 26, which is based on extended energy balances time series data on Swedish heat output from the International Energy Agency (IEA, 2019).

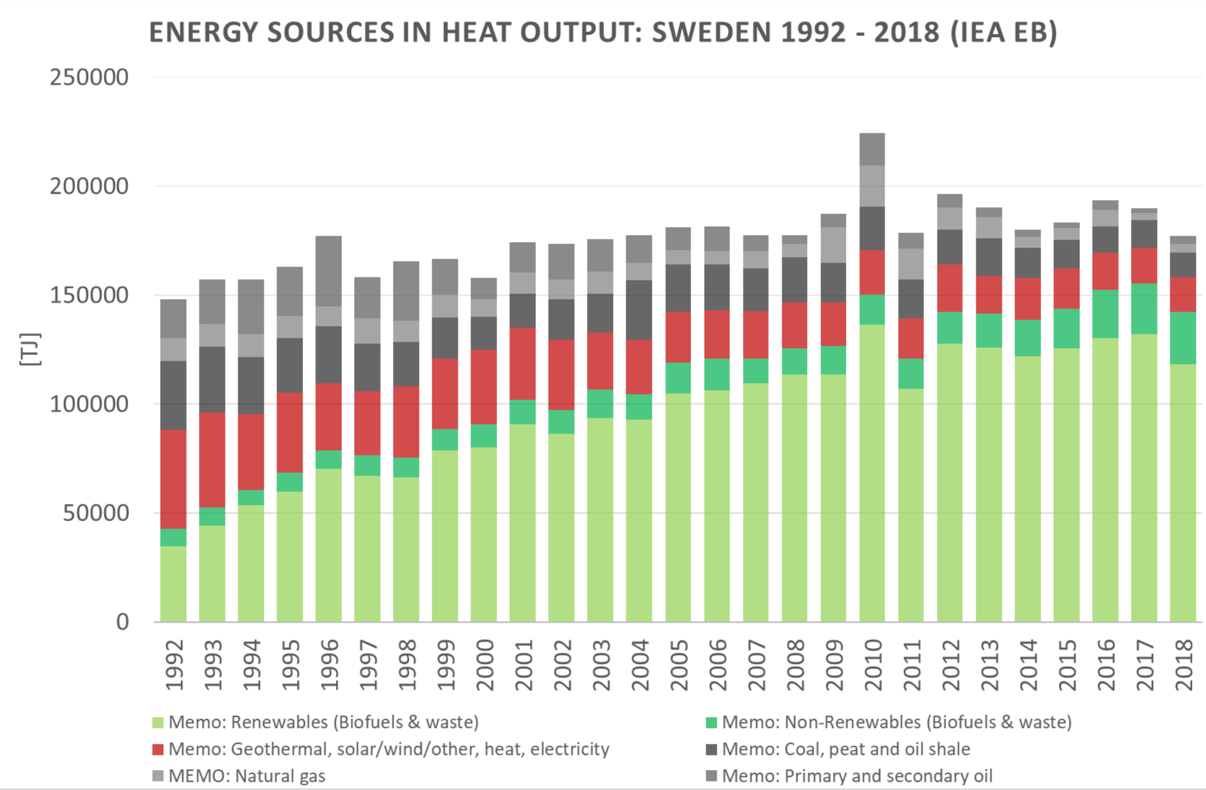

Figure 26 Energy sources in Swedish District Heating (Heat output) from 1992 to 2018 according to IEA Energy Balances 2019 (IEA, 2019).

The first Swedish DH system started 1948 in Karlstad, where heat was delivered from a small municipal thermal power plant to some industrial buildings. The initial driving force for DH was the municipal interest in CHP plants (Combined Heat and Power) in the 1950s and 1960s, as an in-house alternative to electricity purchase from the major power suppliers. The development of DH in Sweden has then been driven by three main additional driving forces: 1) the national housing policy programme to build one million new dwellings during ten years

(1965-1974); 2) the national energy policy programme to reduce the oil dependence (1980s), and; 3) the national climate change policy programme to reduce greenhouse gas emissions (1990s).

Today, all major cities and towns in Sweden have DH systems and, most often, at very high connection rates in the densest urban areas. The heat in these systems is mainly used to cover space heating (SH) and domestic hot water (DHW) heat demands in residential and service sector buildings, but there are also some industrial low-temperature process heat (PH) demands supplied by district heat deliveries.

During the time period from 1992 to 2017, the average share of district heat in the total final consumption of heat has increased from approximately 45% to some 60% in the residential and service sectors, as a rough hand-on assessment. According to a snap-shot for the year 2015, as reported in one of the output reports from Work Package 3 in the Heat Roadmap Europe project (Fleiter et al., 2017), Figure 27 presents the 2015 share of district heating in total final demand for heat among the 28 Member States of The European Union. As can be seen in the figure, Swedish district heat constituted a 53% share during this year, which was short only of neighbouring Denmark (at 58%) and far above the EU28 average at 12%.

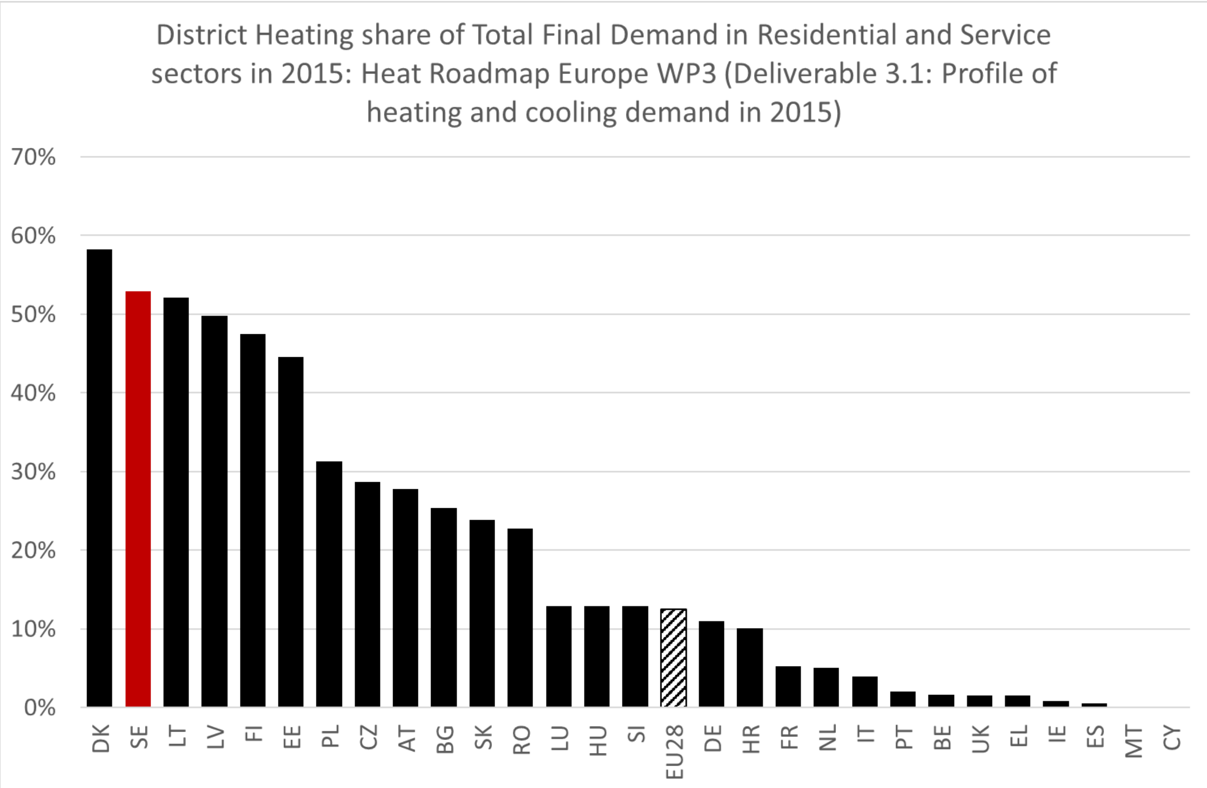

Figure 27 National shares of district heat out of total final demand for heat during 2015, according to the report 3.1: Profile of heating and cooling demand in 2015 from the Heat Roadmap Europe project (Fleiter et al., 2017).

9.1 POLITICAL OBJECTIVES

The current national energy objectives in Sweden include, among other things, the following (Swedish Energy Agency 2020):

- A net-zero emission target by 2045
- 100 % renewable electricity power production by 2040

According to the Swedish government's plan for climate policy from 2020 (Swedish Government (2020), the objective of net-zero emissions implies that the emissions from the electricity and heat sector have to be principally zero by 2045.

9.2 CURRENT STATUS OF RES SHARE IN DH

The energy sources used in Swedish DH systems has changed significantly over the years, from mainly a fossil fuels dominance in the 1980s to a more diversified mix of renewable fuels and heat recycling, dominated by biomass and waste incineration, in the 2010s. This development is visible in Figure 28, which depicts the relative shares of the energy sources in Swedish DH presented above in Figure 25. Renewable energy sources in the form of biofuels and waste have increased from approximately 23% in 1992 to some 67% in 2018, according to a direct analysis of energy statistics (IEA, 2019).

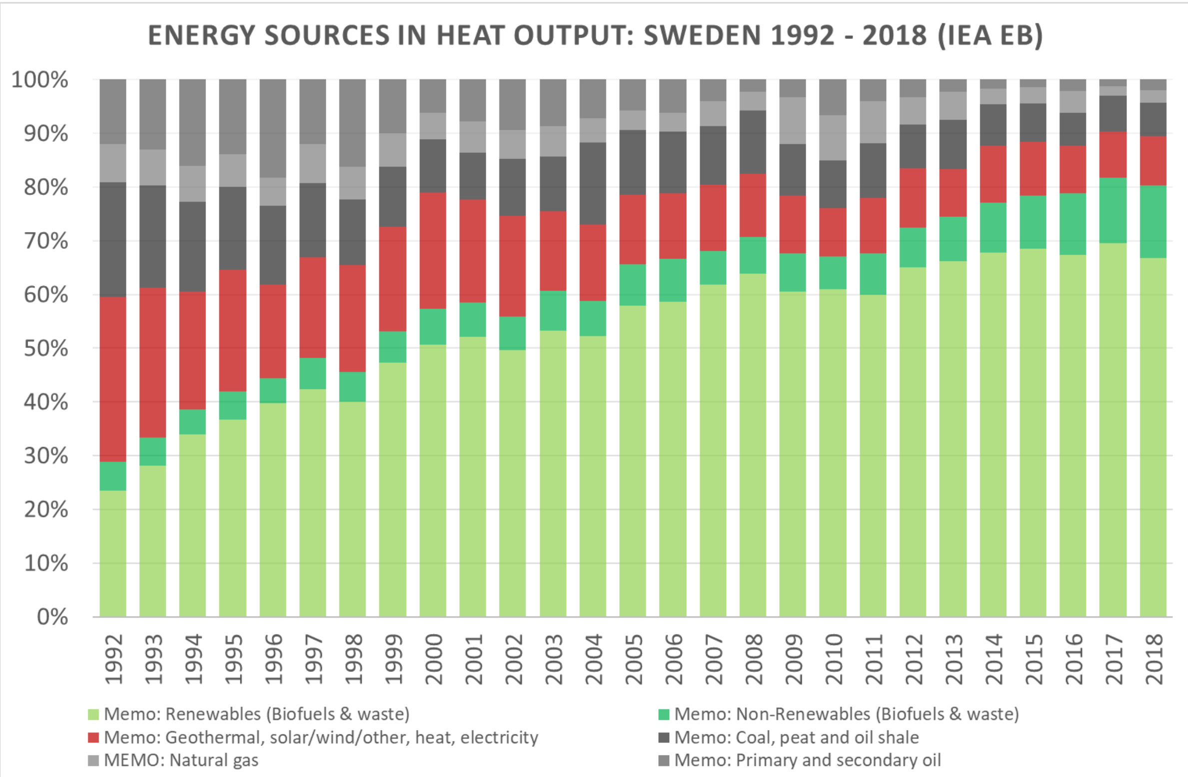

Figure 28 Shares of energy sources in Swedish District Heating (Heat output) from 1992 to 2018 according to IEA Energy Balances 2019 (IEA, 2019).

For the share of dedicated renewables in Swedish heating and cooling, the same development is visible in the national data reported to the European Commission under the SHARES reporting standard[1], as assessed by the specified quota defined in Article 7 of the recast Renewable Energy Directive (REDII), which distinguishes between three main categories for heating and cooling: Derived Heat (DH), Final consumption excluding Derived Heat and Heat Pumps (FE), and Heat Pumps (HP). InFigure 29, the shares of renewables within each of these three main categories, for each of the respective years 2004 and 2019, provides an indication of the success by which the ongoing process of transformation is reforming the Swedish heating and cooling sector.

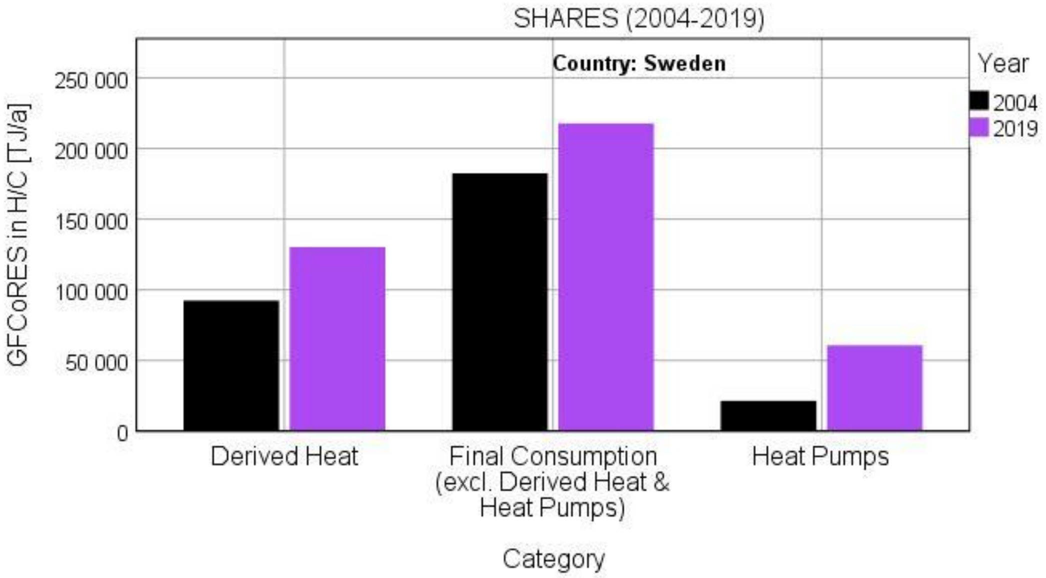

Figure 29 Gross Final Consumption of Renewable Energy Sources in Heating and Cooling (GFCoRES in H/C) for main categories Derived Heat (DH), Final consumption excluding Derived Heat and Heat Pumps (FE), and Heat Pumps (HP), and for the respective years 2004 and 2019. Graph based on SHARES 2019 detailed results for Sweden.

Noteworthy, Sweden is one of a few European countries which enjoys very rich access to domestically available bioenergy, mainly in the form of Solid Biofuels and various residues from forest, paper, and pulp industries. If looking closer at the renewable energy sources used in the main category of Derived Heat (DH), as in Figure 30, which presents the reported SHARES data for the time span from 2004 to 2019, it is clear that Solid Biofuels constitute the main bulk. The only other source categories which makes substantial footprints in the Swedish district heating supply mix, is the renewable fraction of municipal solid waste and renewable

[1] SHARES (Renewables): https://ec.europa.eu/eurostat/web/energy/data/shares

fractions of electricity used in large-scale heat pumps and electric boilers. As shown in Figure 29 the use of large-scale heat pumps has however decreased compared to the 1990s.

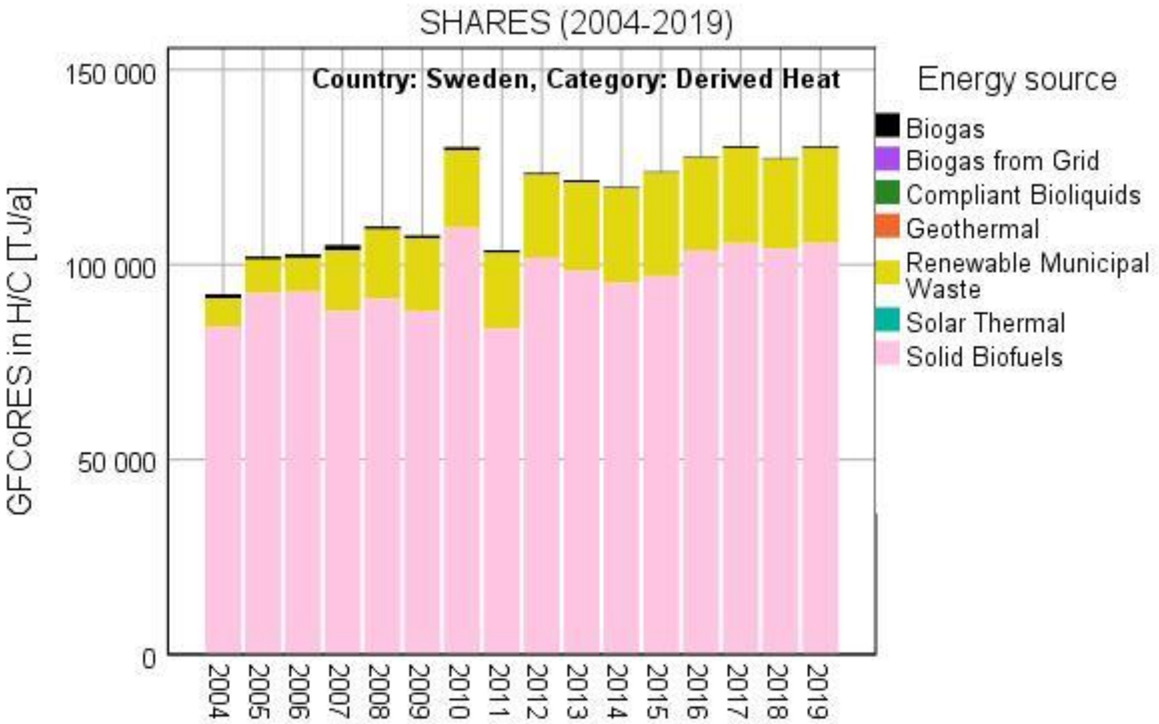

Figure 30 Gross Final Consumption of Renewable Energy Sources in Heating and Cooling (GFCoRES in H/C) for main category Derived Heat (DH), during the time span from 2004 to 2019. Graph based on SHARES 2019 detailed results for Sweden.

9.3 OBSTACLES AND OPPORTUNITIES FOR RES

In this section, some obstacles, and opportunities for the continued integration of renewables in Swedish district heating is presented in a few subsections. However, it might be worth mentioning here that Sweden, by reporting no less than a 66.1% share of renewables in heating and cooling for the year 2019 in the SHARES format, is, firstly, the leading EU Member State in this respect (Finland and Latvia on shared second place at some 57.5%), and, secondly, is hereby relaxed from the formal requirements posed by European Union legislation in this field. Despite this, Sweden will continue its transformation process and seems quite determined to reach net-zero emissions from the electricity and heat sector by 2045.

9.3.1 LEGISLATIVE OPPORTUNITIES

Since 1991 there has been a national carbon dioxide tax in Sweden that greatly has influenced the relative competitiveness of different fuels used in DH systems. This tax has punished fossil fuels for domestic purposes and has improved the opportunities for renewable energy sources, such as biomass.

In 2003, a new long-term green certificate system was introduced in Sweden in order to provide market support for new non-fossil power generation, and in order to give long-term support for biomass CHP plants.

9.3.2 OTHER OPPORTUNITIES

DH systems can balance the electricity power system by using surplus energy from wind and solar in large heat pumps and electric boilers.

The heat demand in buildings will decrease in the future due to improved energy efficiency. This change will probably make it possible to decrease the distribution temperature in DH systems, which will improve the opportunities for new low temperature heat sources.

CHP plants have historically not been very competitive in the Swedish DH sector, and the share of heat from CHP plants in the heat supply is small, compared to many other countries. Nuclear power plants together with hydropower have for long time dominated the electricity generation. During recent years, however, the conditions for CHP plants have been improved for various reasons, and the interest in CHP production has been renewed. One reason is that the Swedish electricity market nowadays is part of an integrated electricity market in Northern Europe. Another reason is that the green certificate system (introduced 2003) gives long-term support for biomass CHP plants.

9.3.3 OBSTACLES

Heat from electric driven individual heat pumps is the main competitor to DH in Sweden. The future competitiveness of DH is strongly dependent on the relative price development between district heat and electricity.

In the future there will be more competition for energy sources such as biomass. The strong dependence on biomass in Swedish DH systems will be challenged by other demands for biomass, for instance from forest-based feedstock in the chemical and petrochemical industry.

9.3.4 ORGANIZATIONAL OBSTACLES/OPPORTUNITIES

There has been an extensive transformation in the ownership of DH utilities in Sweden. Initially, most local DH utilities were run by the municipal administrations, but most of these where later transformed into municipal energy companies. After the deregulation of the energy markets during the 1990s many municipal energy companies have been sold to large national/international energy companies. It is difficult to say whether this development has influenced the investment interest in Swedish DH systems.

9.4 STATUS FOR SECTOR COUPLING

During the 1980s, several new Swedish nuclear power plants were commissioned that resulted in a national electricity surplus. A part of this electricity surplus was absorbed in DH systems by installing large electric boilers and large-scale heat pumps connected to DH. Higher national electricity demand has later reduced the operation of the electric boilers, but many of these large heat pumps are still in operation.

10 SWITZERLAND

Author: Chevillat Y., Deschaintre L., Planair. Caputo P., Politecnico di Milano. Belliardi M. SUPSI

Every major city in Switzerland has thermal network that have been in operation for decades. Initially, these large-scale district heating networks (>50 MW) were mainly supplied with waste heat from WIP; later, wood-fired heating systems and heat pumps were added, which are mainly supplied with water or waste heat.

Many villages and agglomerations also operate their own heating networks mainly based on biomass resources in the form of wood energy and fermentable biomass (average 1.5 MW).

These historically grown DH systems are predominantly hot water networks.

The CO_2-neutral share of heat production in these networks ranges from 60% to about 80%. Fossil fuels are often used to cover peak loads and sometimes also serve as redundancy.

There is a total of about 1000 District Heating systems in Switzerland (the majority are high temperature systems, but there are also about 30 5GDHC systems) which provide circa 25,000 TJ/year heat to customers. The market share of DH in Switzerland is round about 7 %. With an average heat price of 15 ¢ /kWh, the heat sold corresponds to a turnover of about 1.2 billion Swiss francs per year.

10.1 POLITICAL OBJECTIVES

The Energy Act only mentions district heating in the context of promoting waste heat recovery (Art. 50). It is not mentioned in the corresponding ordinance. Only the 1992 Ordinance on Measures for the Rational Use of Energy and the Use of Renewable Energy lists connection to a district heating network as one of the measures for the rational use of energy and the use of renewable energy. In contrast to the electricity sector, the heating sector is poorly regulated at the federal level.

In its Energy Outlook 2050+ however, the federal government mentions that the share of fossil fuels must be reduced to zero by 2050 in order to achieve the climate targets. In its "heat strategy", the federal government therefore focuses on increasing efficiency and expanding thermal networks. Depending on the scenario, the market share of DH in Switzerland in 2050 is seen to reach 14% to 24 %.

The heating sector is regulated at cantonal level, which means that the objectives and norms depend highly on the location. Some cantons have very ambitious objectives regarding the decarbonation of the heat sector. Several very urbanistic cantons specifically include in their strategy the development and decarbonation of DH networks (Basel Land, Zürich, Geneva for example), others have objectives regarding the heat sector, without precising the technological means (individual solutions or DH). The challenge is in keeping high shares of renewable heat while increasing the number of connected buildings.

10.2 CURRENT STATUS OF RES SHARE IN DH

In its annual report, ASCAD 2020, the Swiss association for DH, reports that approximately 36% of the current thermal networks are supplied with waste heat from municipal waste, 27% with renewable energy sources (from biomass or by means of heat pumps), 19% with waste heat from nuclear power plants, other waste heat sources and other renewable energy sources, 17% with natural gas and 2% with geothermal energy.

10.3 OBSTACLES AND OPPORTUNITIES FOR RES

10.3.1 OBSTACLES

As far as is known, no in-depth study of barriers has been carried out in Switzerland.

Swiss association for renewable energies and efficiency, AEE issue 2020 shows in its report that a fully decarbonised heating sector is possible in Switzerland.

However, the following main obstacles for decarbonation of DH were identified in the framework of the Horizon 2020 RES-DHC project:

- For new networks: 100% renewable solutions exist but are still unknown to stakeholders, notably planners.
- Long implementation times and complex procedures.
- High investment costs, financing difficulties.
- No or poor business model with budgeted balance sheet and income statement (basic requirement for external financing).
- Difficulty in achieving cost-effectiveness, particularly in 100% renewable solutions.
- No incentive to increase the share of renewable energy.
- Lack of long-term planning.
- Different regulations between cantons.
- Lack of resources in municipalities.

10.3.2 OPPORTUNITIES

Many opportunities are not specific to Switzerland but are the same than in other countries. A few specific opportunities are:

- Participation of the local governments in the governance of thermal networks in many large cities. On the other hand, contracting opportunities for smaller towns and villages.
- Cantonal subsidies as well as carbon-compensation programmes.

- Development of new business areas for investment in thermal networks and exploitation of renewable energy potential, contracting offers, possibly even in cooperation with large energy supply companies.
- In some cantons, the cities can decide to make the connection to the network mandatory in an area.
- Development of local businesses, in biomass for instance is quite important because a large number of villages own their forest.
- Very recently adopted risk-fund to reduce the risk of using industrial waste heat and incentives for detailed local energy planning with zero-emission goals.
- Another opportunity is related to the possibility to exploit seas, rivers and lakes as thermal sources. This is a promising option also because the most important Swiss cities (in which the heating demand is most concentrated) are located near lakes.

10.4 STATUS FOR SECTOR COUPLING

Heat pumps have undergone strong growth over the last few years (FWS-Statistiken 2021) but the most part of the current installation are of small sizes (domestic appliances). More information is available in publications (Sustainable Cities and Society 2020, Energies 2022).

SYMBOLS, ABBREVIATIONS, INDIZES

ABBREVIATIONS

Abbreviation	Meaning
ACV	Analyse du cycle de vie (Life cycle assessment)
ADEME	French national funding agency
AGFW	Energy Efficiency Association for Heating, Cooling and CHP
AIRU	Associazione Italiana Riscaldamento Urbano
BDEW	German Association of Energy and Water Industries
BMWi	The Federal Ministry for Economic Affairs and Energy in Germany
CanmetENERGY	Natural Resources Canada
CEEDC	Canadian Energy and Emissions Data Centre
CHP	Combined Heat and Power
CO_2	Carbon dioxide
CO_{2eq}	Equivalent of carbon dioxide emission
CPU	Central Processing Unit
¢	Euro cent
DC	District Cooling
DE	District Energy
DH	District Heating
DHC	District Heating and Cooling
DK	Denmark
EU	European Union
FE	Final consumption excluding Derived Heat and Heat Pumps
GFC	Gross Final Consumption
GWh/a	Giga Watt hours per year (annum)
GWh/km^2	Giga Watt hours per square kilometer
HP	Heat Pump
LT	Low temperature
LTECV	Loi de Transition Energétique pour la Croissance Verte (Law on Energy Transition for Green Growth)
Mtep	Mega tonne of primary energy production
MW_{el}	Megawatt electric
MW_{th}	Megawatt thermal
OECD	Organisation for Economic Co-operation and Development

PCAETs	Plan climat-air-énergie territorial (the Territorial climate-air-energy plan)
P2H	Power to Heat
PNRR	Piano Nazionale di Ripresa e Resilienza
PPE	Plan Pluriannuel de l'Energie (the Multiannual Energy Program)
PV	Photovoltaics
SDEs	Syndicat Départemental d'Energies (Departmental Syndicate of Energy)
SNBC	Stratégie Nationale Bas Carbone (the National Low Carbon Strategy)
SNCU	Syndicat National du Chauffage Urbain
SRADDET	Schémas régionaux d'aménagement, de développement durable et d'égalité des territoires (the regional planning, sustainable development and territorial equality plans)
RES	Renewable Energy Source
R&R	renewable and recovered energies
teqCO_2	Tonnes of CO2 equivalent
TWh/a	Terra Watt hours per year
UFI	Environmental Support Scheme
VAT	Value Added Tax
WIP	waste incineration plants
WKLG	Law for expansion of District Heating and Cooling networks

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