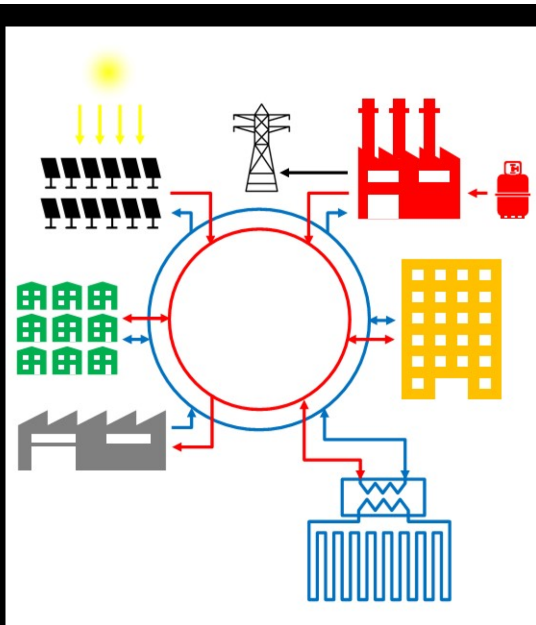
FACTSHEET8 Managing Urban Shallow Geothermal Energy

SGE IN DISTRICT HEATING AND COOLING NETWORKS



District heating and cooling (DHC) grids are large projects (1 - 100 MW_{th}) where thermal power sources/sinks of different types are shared by a network of nearby buildings (office buildings, dwellings, hospitals, factories, etc.). Heat can be supplied and rejected to and from the buildings, but also between them (smart grids). In this context, shallow geothermal energy (SGE) can play a major role due to the versatility and high efficiency of its different exploitation schemes.

1 PROVEN CONCEPTS

The concept of district heating (DH) has evolved since the nineteenth century, always obeying the same principle: **the economy of scale applied to efficiency**. 4 different generations (G) of systems are identified throughout history:

- **1st GDH: Pressurised water steam at temperatures < 200 °C**. The most famous and largest example is in Manhattan (New York, USA), operative since 1882.
- **2nd GDH: Pressurised water at temperatures 100 - 200 °C**. Mostly deployed in Eastern Europe. Combined heat and power (CHP) plants (Fossil fuel-fired) were the most common heat source.
- **3rd GDH: Hot water at temperatures 80 - 100 °C**. Renewable sources such as geothermal (direct heating or driven by large heat pumps) or solar energy.
- **4th GDH: Hot water at temperatures 50 - 70 °C**. Fancoils, modern radiators and radiant floors allowed reducing significantly the minimum temperature needed for the heat carrier fluid. Consequently, transport losses were greatly reduced, more renewable energy sources and other heat sources present in urban environments could be incorporated (waste heat from a wider range of industries and CHP plants burning waste). Absorption chillers were also used to create the first DHC networks. **Centralised SGE installations such as large heat pumps as well as underground thermal energy storage (UTES) systems** for seasonal energy storage are among the many possibilities of conceiving a modern DHC.

2 FUTURE CONCEPTS

5th GENERATION DHCs

In the current energy transition context, a growing complexity is observed due to:

- Increase in renewable energy generation
- Distributed generation of energy
- Energy efficiency pushed to its very limits

All these issues converge in a recent category: **the 5th generation of DHC (5GDCH) networks**. 5GDHC networks are those where the heat exchanger fluid is water at a neutral temperature (close to that of the medium through which is transported, between 10 and 25 °C), and small-to-medium size water-to-water heat pumps are installed at each building of the network. The changes with respect to previous schemes are remarkable:

- **Change from centralised generation to distributed generation**. Easier extension of the network, although at a higher investment cost per connection point.
- **Almost null heat losses due to transport** in cost-effective pipe circuits.
- **Buildings both provide and consume heat** as so called **"prosumers"**. A recent example is the project Minewater 2.0, in Heerlen (The Netherlands).

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- **Heating and cooling to different eras of buildings** (old/retrofitted or new) can be done in the same network through heat pump tailored solutions.

POWER TO HEAT

It is well-known that **100% renewable-based power systems are non-viable without a large storage infrastructure** supporting them, due to the intermittence of important sources like wind and solar energy. SGE facilities combined with UTES offer an efficient and cost effective alternative for managing district heating and cooling grids. **Heat pumps in DHC can be driven by the surplus electricity** from intermittent wind and solar photovoltaics with the use of batteries (essentially during low-price hours), which **stores the heat or cold generated in the UTES** system for its later use.

3 GOOD EXISTING PRACTICES

A PLAYGROUND FOR ENERGY PLANNERS

SGE in any of its application schemes as a heat source and/or sink has the potential to be implemented almost everywhere in Europe for DHC purposes:

- **Groundwater heat exchangers (GWHEs):** Bound to large aquifers with low hydraulic head (< 50 m) in inland areas.
- **Surface water heat exchangers (SWHEs)**: Ideal heat sources/sinks close to large water bodies (rivers or lakes) or close to the coast areas.
- **Vertical borehole heat exchangers (BHEs)**: Feasible almost everywhere. When water is not present or not exploitable, BHEs still have an opportunity if thermal conductivity shows a minimum reasonable value (1.5 - 2 W/mK).

Concerning **UTES**, DHC networks can benefit mainly from two perspectives:

- Regardless of the heat source or sink of the DHC network, an efficient **seasonal storage allows an effective increase in usable energy with the same installed capacity**.
- When different and **complementary building demands coexist** in the same network (office buildings, households, industries, commercial areas, hospitals or data centres), **cold and warm reservoirs in thermal storage systems of any kind act as large buffer tanks**. This allows an effective heat exchange between the buildings themselves. In this sense, **fast heat charge and discharge systems as ATES and CTES** are the best option from the operational perspective.

4 LESSONS LEARNED

FROM BUILDING TO BUILDING

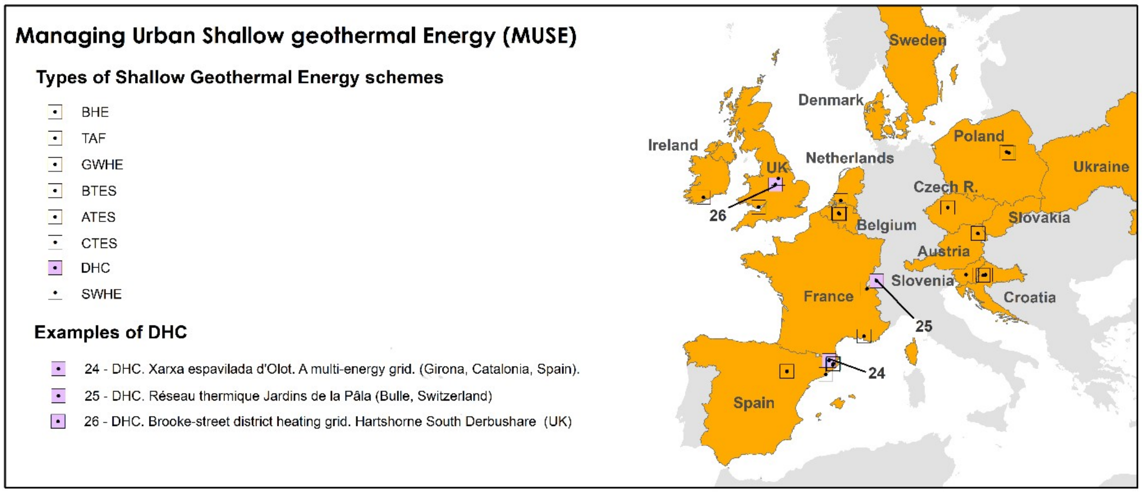
The ideal DHC network should require a minimum heating/cooling infrastructure, favoured by:

- **A smart management of the urban energy metabolism**. At a local scale, it is more efficient to transport heat between different buildings than to produce or reject it from or towards a heat source or sink.
- **Non-simultaneous peak demand patterns among the different buildings**. Peak loads of different buildings taking place at different moments of the day will minimise the required overall installed capacity in centralised DHC networks.

ENERGY AND URBANISATION

Mostly during the second half of the past twentieth century, energy infrastructure planning was characterized by a growing disconnection with urbanisation, due to the centralised production of electrical energy and the reliance on fossil fuels. In other words, **energy infrastructure adapted to urbanisation**. However, in the present context where a circular and de-carbonised economy is pursued, **energy infrastructure planning must be considered an essential piece in future urbanisation patterns**. In this sense, DHC networks will surely gain prominence in the forthcoming years. In particular, **SGE and UTES** systems are postulated as modern and renewable **energy sources and tools**.

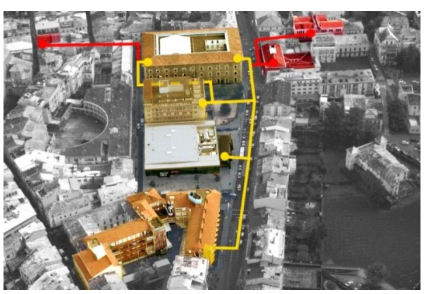
5 EXAMPLES



DHC-1. Xarxa Espavilada (Smart Grid) in Olot (Girona, Spain)

GIRONA PILOT AREA

Location (WGS84 coordinates): N 42.180841 E 2.487193



	heating (15/18)	cooling (21/24)
Degree-days$_{2017-18}$ [ºC·days/year]	1718	219

SGE contribution: multi-grid energy DHC (geothermal, biomassa and PV)

Number of Boreholes: 24

T_{gr0} [ºC]: 15

Total length [m]: 2400

T_{flow}/T_{return} [ºC]: 90/60 (heating), 5/15 (cooling)

	Heating	Cooling
Capacity installed [kW]	180	180
Demand [MWh]	~3400	No data
Seasonal performance (SPF_{H2})	No data	No data

The "Xarxa Espavilada d'Olot" is a District Heating and Cooling (DHC) multienergy grid located in the town of Olot (Girona, Spain) that combines: Shallow geothermal energy (60 kW_{th} ground source heat pumps x 3 = 180 kW_{th}) + Biomass boilers (600 kW_{th}) + Solar PV panels (28.8 kW_p), i.e. it is a trigenaration thermal energy grid based on three renewable energy sources. It is the first of its class in Catalonia and has a very important side-objective in promoting the use of renewable energy sources in the city of Olot and beyond. There are two storage tanks of 8 m^3 each and has back-up unit is a gas boiler of 700 kW_{th}, that at the moment never has been used. The DHC supplies simultaneusly heating and cooling to several public buildings in the city centre (a market, a hospital and a regional museum, among others).

DHC-2. Jardins de la Pâla in Bulle (Switzerland)

BULLE

Location (WGS84 coordinates): N 46.6151 E 7.0393

	heating (15/18)	cooling (21/24)
Degree-days$_{2017\text{-}18}$ [ºC·days/year]	4000	50

SGE contribution: De-centralised GWHEs (3+3 prod. and inj. wells)

T_{gw} [ºC]: 8-12 Depth of extr./inj. [m]: 50-65

T_{flow} [ºC]: 35-40 (heating), 60 (Domestic Hot Water)

	Heating	Cooling
Capacity installed [kW]	2000	NA
Demand [MWh]	No data	No data
Seasonal performance (SPF_{H2})	No data	No data

According to Buffa et al (2012*), this is an example of the new concept 5th Generation District Heating and Cooling (5GDHC) network comprising a set of new residential, industrial and commercial buildings. Groundwater is used as the only heat source/sink by means of individualised heat pumps. While heating is carried out by heat pumps, cooling is passive (de-centralised heat exchangers separating groundwater flow from building brine flows). Up to 240 m^3/h can be extracted from the 3 extraction wells, in total.

(*) Buffa et al 2012. 5th generation district heating and cooling systems: A review of existing cases in Europe. Renewable and Sustainable Energy Reviews 104 (2019) 504–522. https://doi.org/10.1016/j.rser.2018.12.059

DHC-3. Brooke Street - South Derbyshire (UK)

Hartshorne South DERBYSHARE

Location (WGS84 coordinates): N 52.7888 W - 1.524723

	heating (15/18)	cooling (21/24)
Degree-days$_{2017\text{-}18}$ [ºC·days/year]	3077	0

SGE contribution: Centralised ground source heat pumps (GSHPs)

T_{ground} [ºC]: 6-12 Number of Boreholes: 28

$T_{condenser}$ [ºC]: 60 Total length [m]: 2800

	Heating	Cooling
Capacity installed [kW]	120	NA
Demand [MWh]	No data	No data
Seasonal performance (SPF_{H2})	3.2. (design)	No data

Brooke Street is an off-gas grid area on the edge of a rural village: Hartshorne, in South Derbyshire. A small heat pump in district heating installation was implemented in 2012 to serve 18 existing local authority flats (built in 1982). The previous heating strategy had been carried out by all-electric storage heaters. Due to numerous complaints about the high running cost of these systems and the low level of control, it was decided to explore renewable energy solutions and obtained an RHPP grant to cover part of the cost of the heat pump in district heating installation. The system provides space heating and domestic hot water (DHW) to each flat. The flats were all retrofitted with low temperature radiators so that the space heating supply temperature can be kept as low as 55 °C. The system temperature is raised to 60 °C for a period every night to heat the DHW cylinder to mitigate Legionella risks. Two plant rooms have been installed, one serving six flats and the other serving twelve flats. Each heat pump also has a 100 l thermal store. Three blocks of six flats (18 falts in total) are served from three ground source heat pumps (40 kW$_{th}$ each) coupled to a common ground loop served by 28 boreholes, each 100 m deep.