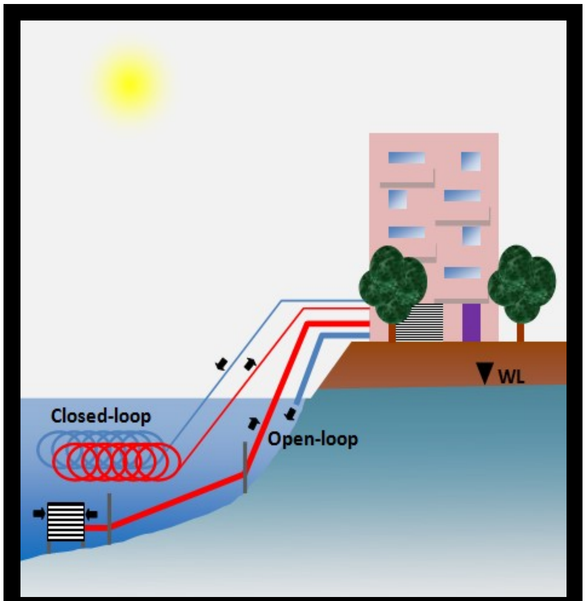
FACTSHEET4

Managing Urban Shallow Geothermal Energy

SURFACE WATER HEAT EXCHANGER SYSTEMS



In surface water heat exchanger (SWHE) systems, thermal energy is exchanged with large water bodies like rivers, lakes or the sea. Heat pumps are necessary mainly for heating. Both open- and closed-loop (OL & CL, respectively) options are possible. Upfront costs are lower than in groundwater heat exchangers (GWHEs), although surface water temperature is more variable.

1 PROVEN CONCEPTS

THE FIRST IN EUROPE

The first documented European project that could be considered as a shallow hydrothermal energy installation **was an OL-SWHE system** that used the water from Limmat River and a heat pump to meet the heating demand of the City Council in Zürich (Switzerland, 1938). **A modern example** can be found in a district cooling network in Tartu (Estonia, 13 $\mathrm{MW_{th}}$).

TAPPING HEAT FROM SEA WATER

Seawater is a natural brine with its freezing point around -2 °C. This makes **OL-SWHEs at seaports a feasible option for heating in cold climates.** Värta Ropsten plant in Stockholm (Sweden) is the biggest of its class (180 $\mathrm{MW_{th}}$). It provides hot water (80 °C), heating and cooling through a district heating network since 1988.

In Drammen (Norway) **the water of the fjord is used as the heat source**. This 60 $\mathrm{MW_{th}}$ district heating network was retrofitted in 2011 with new heat pump equipment (15 $\mathrm{MW_{th}}$) that produces hot water at 90 °C (Fjord water is 8 °C). The refrigerant in the heat pump is ammonia. Thanks to the high outlet temperature, the old buildings did not have to replace their existing radiators.

IT LAYS DEEP IN THE LAKES

OL-SWHEs are the most common option in Europe when the water from lakes is used as the heat source/sink. Geneva (Switzerland) uses cool water from Lake Léman for “free cooling” (23.5 $\mathrm{MW_{th}}$) and heating (3 $\mathrm{MW_{th}}$).

Although **CL-SWHEs are far more common in North America**, in Europe a few examples can be found. Possibly the biggest one is King’s Mill Hospital in Mansfield (UK, 5 $\mathrm{MW_{th}}$).

2 FUTURE CONCEPTS

SEWAGE IS NASTY. HEAT IS NICE

Waste heat from the urban sewer network is **a yet little exploited resource,** although its recovery is not a novel concept. Average sewage temperature can be easily above 15 °C, and compared with surface water bodies, sewage temperature variations along the year is lower. Hence, **it is an ideal source for efficient heating**. Three exploitation schemes are identified:

- **In-place heat recovery**. The residual heat contained in wash water (grey water or sullage) from households can be recovered and upgraded by heat pumps before being thrown into the sewer. It is the most efficient option at small scale from the nearly zero energy building (nZEB) perspective.
- **Embedded heat exchangers in sewer pipes.** There are commercial solutions already available consisting of large concrete sewage pipes with embedded heat exchanger probes in their lower part of the wall. However, it means that an additional water flow is required to recover the residual heat. It is the best solution for new constructions or retrofitting old sewer pipes. Oriented to district heating networks.

- **Advanced heat exchangers.** They consist of intake stations at the desired location, where part of the sewage flows via a bye-pass to a heat exchanger. Heat exchangers operating with sewage are challenging, since sludge must be filtered first. Oriented to large buildings or district heating networks.

3

GOOD EXISTING PRACTICES

SENSIBLE HEAT IN A SENSITIVE RESOURCE

Leaving aside regulatory aspects, managers and project planners must be concerned about the following aspects (quantity and quality of the resource **influencing feasibility, profitability and limitations of use**):

- **Water balance:** Water inflows and outflows (rainfall, groundwater connections) and yearly volumetric variations in lakes (surface evaporation) and rivers.
- **Water temperature:** In-depth profiles of average temperatures along the year in lakes, rivers and the sea. This also influences the most suitable location for intake and outtake. In lakes also solar irradiation, night sky radiation, surface freezing and heat exchange with the ground influence the temperature.
- **Water quality** (pH, hardness, alkalinity, calcium content) is a bigger concern in OL-SWHE (more in seawater) than in groundwater heat exchangers (GWHE), due to dissolved oxygen and biological activity. Non-metallic CL-SWHEs avoid most of water-related problems except for fouling.
- **Biological activity** gains extra importance in SWHEs. Interaction with living creatures should cause minimal or no damage to them and keep equipment deterioration under an admissible level.

DESIGN PARALLELISMS

Conceptually, the **methodology involved in the design of an OL-SWHE and a GWHE are analogous**. Pumping power (Q_{pump}) and water temperature "jump" (ΔT_w) are the main drivers of optimization (see Factsheet 3). In contrast, the **design of CL-SWHEs (coiled pipes) has many points in common with borehole heat exchangers (BHE)** (see Factsheet 1). The main conceptual difference is in the heat exchange mechanism. Convection dominates in CL-SWHEs while conduction does in BHEs.

4

LESSONS LEARNED

LAKES ARE "PICKY"

Lakes require a deeper characterization than any other water body, mainly because it is a very static system, compared to rivers and the sea, and because water is a unique liquid. Its solid phase is lighter than the liquid one, and maximum density is achieved at about 4 °C. These two features drive water thermal patterns (Figure 1). As a result, **the intake should be placed at the bottom regardless of the season**.

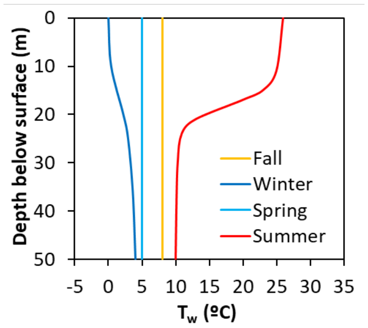


Figure 1. Ideal T_w depth profiles in a European lake.

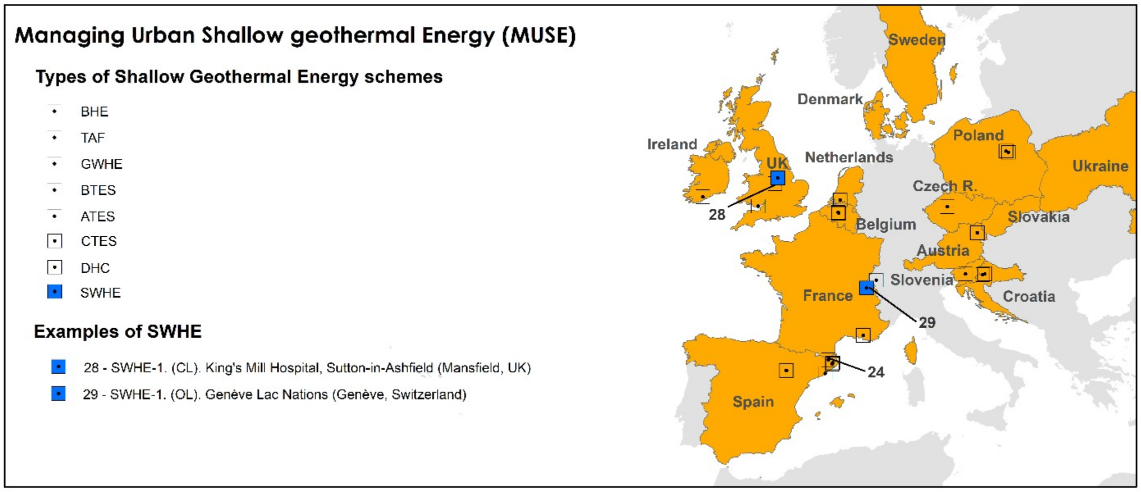
CL-SWHEs SHOULD BE THE CHOICE, BUT…

CL-SWHEs have a clear edge over OL-SWHEs. **The heat pump loop is isolated from the heat source/sink** (like in BHEs), so:

- Water chemistry becomes a minor concern.
- A lower temperature of operation under heating mode is permitted (even 0 °C).

Nevertheless, CL-SWHE systems should be discarded in rivers, mainly due to complex installation and maintenance (water inherent thrust and dragging of multiple objects). Only plate heat exchangers instead of coiled pipes could be a feasible option. **In seawater, CL-SWHEs are not recommended in locations with a high human activity**, like seaports or bays, since installation and maintenance would be tricky again due to the continuous operation of boats, ships and ferries.

5 EXAMPLES



SWHE-1 (CL). King's Mill Hospital in Sutton-in-Ashfield (Mansfield, United Kindom)

MANSFIELD

Location (WGS84 coordinates): N 53.135924 W -1.234571

	heating (15/18)	cooling (21/24)
Degree-days$_{2017-18}$ [ºC·days/year]	2539	2

Minimum T_{brine} [ºC]: unknown
Maximum T_{brine} [ºC]: unknown
Max./Min. $T_{reservoir}$ [ºC]: 21 / 3*

Depth of exchangers [m]: 4
Surface of exchangers [m^2]: 1560
Volume of the reservoir [Hm^3]: 8.3

	Heating	Cooling
Capacity installed [kW]	5000	5400
Demand [MWh]	unknown	unknown
Seasonal performance (SPF_{H2})	unknown	unknown

This is the largest closed-loop surface water heat exchanger system in Europe. The heat source is the old King's Mill reservoir, which is an artificial lake close to the Hospital. 42 heat pumps are operated for space heating (45 ºC) and cooling (6 ºC). The brine exchanges heat with the water reservoir by means of plate heat exchangers (Slim Jim^{TM} type) located at the bottom of the water reservoir.

** Surface temperature (2013)*

SWHE-2 (OL). Genève Lac Nations in Genève (Switzerland)

GENÈVE

Location (WGS84 coordinates): N 46.2277 E 6.1388

	heating (15/18)	cooling (21/24)
Degree-days$_{2017\text{-}18}$ [ºC·days/year]	3000	156

Maximum flow [m^3/h]: 2700	Depth of intake [m]: 37
Minimum $T_{lake\ water}$ [ºC]: 6	Depth of outtake [m^2]: 4.5
Maximum $T_{lake\ water}$ [ºC]: 10	Volume of the reservoir [km^3]: 89

	Heating	Cooling
Capacity installed [kW]	2900	16200
Demand [MWh]	5000	20000
Seasonal performance (SPF_{H2})	2.5	8.8

The bottom water of the lake Léman is pumped (open loop) to provide heating and cooling to a district heating and cooling network, with emblematic buildings like those of United Nations or the Red Cross. The pipes are made of stainless steel. Cooling is "free cooling" (no heat pumps involved). Compared to other shallow geothermal energy typologies, power consumed by circulating pumps is remarkable (the water is pumped through 6 km of stainless pipes from the lake to the different buildings). However, the low seasonal performance factor under heating mode is compensated by the high value obtained under cooling mode. The overall coefficient of performance is approximately 6.5 (considering heat produced + heat rejected divided by electricity consumed).