enerdrape

RESULTS SUMMARY OF THE PILOT PROJECT IN 2022

Performance of an enerdrape system

Underground car park of Sébeillon

2022

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CONTEXT

The purpose of this report is to present the results of the first pilot installation of an enerdrape system in a relevant field environment.

The objectives of this pilot were to realise a sub-system scale installation and analyse the performance of such installation.

The questions that are addressed in this report are the following:

- What is the typical performance of enerdrape systems?
- Is the harvestable power from enerdrape systems stable over time?
- Does the underground air temperature significantly influence the operation of enerdrape systems?
- Does the coefficient of performance associated with the operation of enerdrape systems significantly vary over time?
- What are the long-term impacts of the operation of enerdrape systems on the thermal conditions of the underground?

EXECUTIVE SUMMARY

This report presents the results of the world-first pilot installation of an enerdrape system in an underground car park located in Lausanne, Switzerland. The results refer to a 1-year long operation of the considered system.

This pilot project allowed to:

- prove the technical feasibility of enerdrape installations.
- quantify the exploitable thermal power.
- analyse the influence of the environmental conditions on the thermal behaviour and energy performance of the system.
- analyse the influence of the operation of the system itself on the environment.

In particular, the results support the following:

01 **Thermal power up to 170 W/m²**

Thermal powers of up to 170 W/m² are harnessed from the considered enerdrape system.

02 **Thermal power stability over time**

The harvested thermal power from enerdrape systems is significantly stable over time and approaches a steady state after a few hours of operation (5 hours, in this pilot installation).

03 **Air temperature influences up to 15% the performance**

The underground air temperature markedly influences the performance of enerdrape systems if significant airflows are present in the subsurface. For situations such as those charactering this pilot project, the air temperature only influences the output of the system by 15% during the year.

04 **Stable efficency over time**

The coefficient of performance of enerdrape systems is markedly stable over time.

05 **Long-term operation is ensured**

Enerdrape systems provide optimal performance even beyond 50 years of operation when resorting to an appropriate design and installation.

CASE STUDY

The pilot installation was installed in the Sébeillon neighbourhood, located on Avenue de Sevelin in Lausanne.

This residential asset consist of a lot of several buildings served by a private underground car park hosting the enerdrape system. This underground car park has a completely buried basement level and a total of 200 parking spaces serving 5 buildings on the surface. The car park is for the use of the residents of the buildings and is not characterised by heavy vehicle traffic. The car park has several bays, a smoke extraction system, and a standard mechanical ventilation system that regulates CO levels on the basis of real time thresholds.

Figure 1: Photo of the Sébeillon neighbourhood © marcello mariana

In order to demonstrate the performance of an enerdrape installation at scale, a representative subsystem of ten panels connected in series is tested in the Sébeillon car park. Each panel is spaced 20 cm apart to evaluate its effect on the wall.

Figure 2 illustrates the enerdrape panel subsystem installed at the pilot site.

Figure 2: Photo of the panels’ arrangement

PILOT INSTALLATION

The pilot installation is installed in the Sébeillon neighbourhood in collaboration with Realstone SA.

A continuous temperature measurement is made at the inlet and outlet of each panel to measure the temperature variations of the heat transfer fluid at each stage of the subsystem. The total flow rate and pressure are also measured at the heat pump outlet. The pilot plant consists of the following components, shown in Figure 3:

- A test device corresponding to an air-to-water heat pump. This device allows the temperature and flow rate of the medium in the enerdrape system to be determined independently and the pressure in the hydraulic network to be measured.
- A hydraulic distribution network for the return flow, i.e., 6 mm diameter plastic pipes with 25 mm insulation (armaflex type).
- 10 enerdrape panels connected in series.
- 13 temperature sensors.
- A data acquisition system collecting all site measurements.

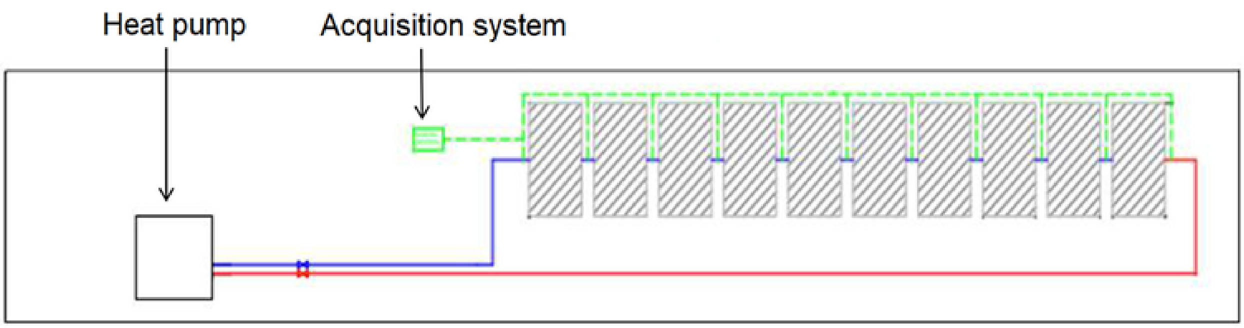

Figure 3: Schematic of the system

TESTS PERFORMED

Several types of exploitations were tested to gather all the information needed to define the properties of the system and characterise a *'business-as-usual'* operation.

The different tests carried out are the following:

- Heat extraction at fixed temperature in different seasons to quantify the influence of the ambient air temperature and seasonal variations.
- Heat extraction at different injection temperatures to define a power curve according to the operating temperature of the system.
- Heat injection to study the behaviour of the system in free-cooling mode at different heat transfer fluid temperatures.
- Different operating cycles (ON/OFF) to define the behaviour of the system for peak productions and to study the thermal inertia of the wall and the system.

Ambient air temperature readings in the car park were taken throughout the year to establish the temperature profile of the ambient air in the car park in relation to the outside air. Such data were also used as the basis for a numerical model detailed in Chapter 5, which was used to study the long-term effects.

The test protocol for the various tests conducted at the Sébeillon site follows the following steps:

- Temperature and fixed flow rate injected into the enerdrape system.
- Continuous measurement of the flow and return fluid temperatures at each panel inlet and outlet and environmental temperatures (wall and ambient).
- Calculation of the thermal performance of the system and the nominal extracted/injected thermal power.

THERMAL PERFORMANCE AND POWER

The system has been in operation for more than a year, and data collection for one heating and one cooling period has been carried out. During the year 2022, the system was operated at different setpoint temperatures to test different operating profiles.

Figure 4 below shows the relationship between the system operating temperature and the power extracted for the Sébeillon test installation.

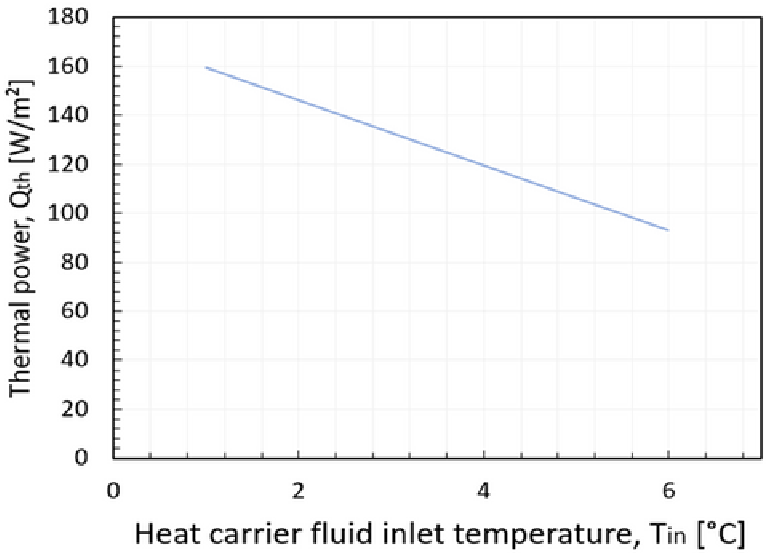

Figure 4: Thermal extracted power

170 W/m²

Maximal extracted thermal perfromance

Relationship between the system operating temperature and the power extracted can only be established for a specific location. Each site has its own local temperature and terrain conditions, giving it a unique power function.

At a fixed location, the thermal conditions (temperature and thermal conductivity) of the terrain are stable, which allows the power of the subsystem to be described as a function of the difference between the inlet temperature of the heat transfer fluid in the enerdrape system and the average temperature of the wall, for a constant flow rate.

At the pilot site, characterised by a ground temperature of about 13°C, the power extracted from the system at a constant flow rate of 2.1 l/min can be described as follows:

$$Q_{th} = -13{,}3\ T_{in} + 172{,}9$$

THERMAL POWER EXTRACTED

It can be observed that a thermal power greater than 150 W/m² can be extracted from the system in any season considering an inlet temperature of 2°C, which corresponds to a standard operating condition of a brine (geothermal) heat pump.

Figure 5 shows the measured extracted powers at different inlet temperatures of the heat transfer fluid throughout the year.

- Inlet temperature 2°C
- Inlet temperature 6°C
- Inlet temperature 7°C

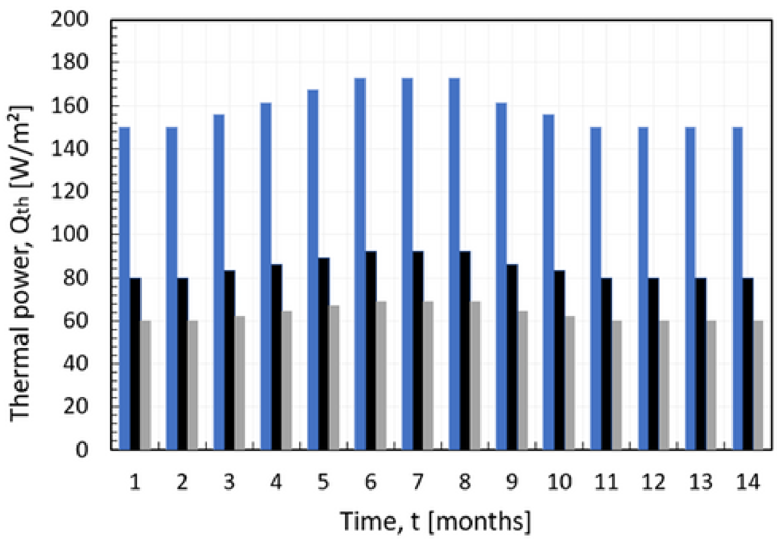

Figure 5: Seasonal influence on thermal power

The extracted power achieved by the enerdrape system is therefore 2 to 3 times higher than those of conventional geothermal exchangers (e.g., 20 to 40 W/m² for energy walls).

Under the conditions of the pilot site, the installation allows an annual production of 350 kWh/m² for a heating period of 2300 hours.

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INFLUENCE OF WALL TEMPERATURE

A continuous measurement of the wall temperature with a thermocouple inserted in a 50 mm deep hole in the concrete allowed to evaluate the influence of the enerdrape panels operation on the thermal gradient of the wall.

Figure 6 shows the evolution of the wall temperature during the operation of the enerdrape panel system.

Inlet temperature of heat carrier fluid
Outlet temperature of heat carrier fluid
Wall temperature
Parking Ambient air temperature

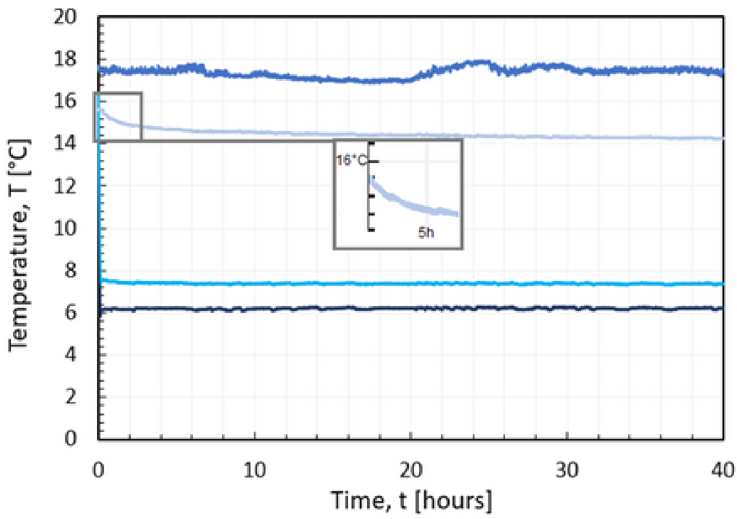


Figure 6: Stabilisation behaviour of the system

It can be observed that the wall temperature is affected by the heat conduction phenomenon induced by the panels. The wall temperature stabilises after 5 hours of operation of the system. Indeed, after 5 hours the temperature variation in the wall as a function of time is less than 5%.

5 hours

The wall temperature stabilises after 5 hours of operation

After 40 hours of continuous use, no further temperature variation is observed.

After 5 hours of operation, the enerdrape system has a constant temperature source.

INFLUENCE OF AIR AND ENVIRONMENTAL CONDITIONS

It can be observed that the ambient temperature in the car park is more stable in the face of seasonal and punctual temperature changes, which is quite typical of underground environments.

Figure 7 describes the annual measurements of the ambient air temperature in the car park over the year and the outdoor temperature in Lausanne.

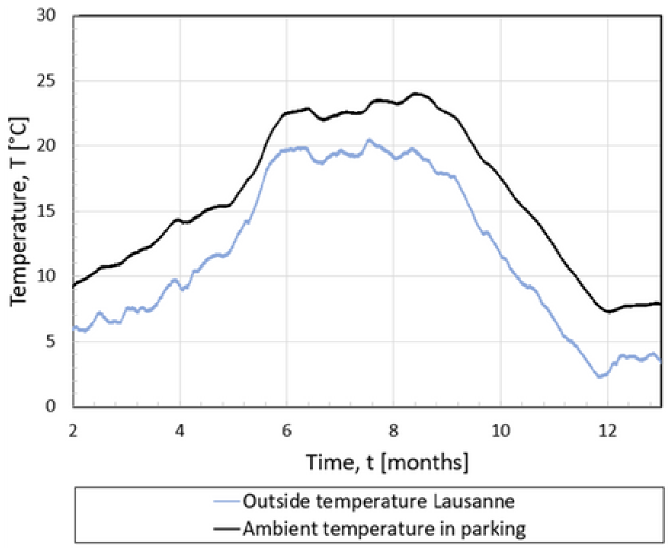


Figure 7: Evolution of air temperature for one year

The thermal inertia of the surrounding soil is the main reason for this evidence. The waste heat released by the vehicles can also influence the ambient temperature of the car park, however this heat is quickly dissipated and results in daily temperature variations of +/- 0.5 to +/- 1.0 °C on average.

The air temperature in the car park is not influenced by the operation of the system. No difference in the air temperature of the car park was measured because of the operation of the system. Heat conduction between the panels, the wall, and the ground dominates the heat exchange of the enerdrape system.

In the context of an underground car park, where air circulation is limited around the panel, convective exchange between the air and the panel (natural and forced convection) is limited. A relationship between the air temperature in the car park and the thermal output of the panel can be observed but remains marginal. On the pilot site, a maximum power difference of 15% due to a natural variation of the air temperature in the car park was observed throughout the year.

Figure 8 shows the power variation for a fixed injection temperature of 7 degrees tested at different ambient air temperatures in the car park.

15%

Maximal power difference observed due to a natural variation of the air temperature in the car park.

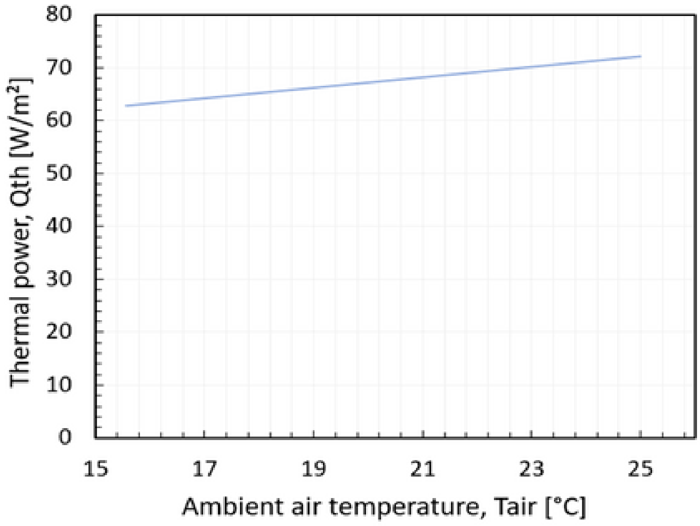


Figure 8: Thermal power function of air temperature

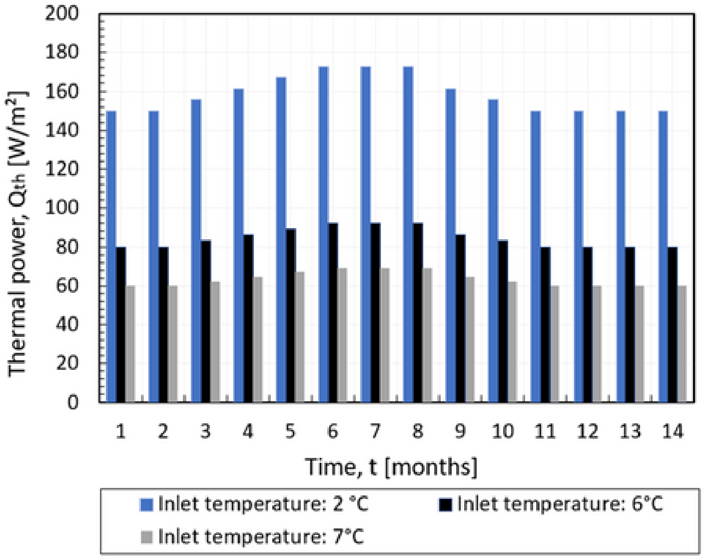
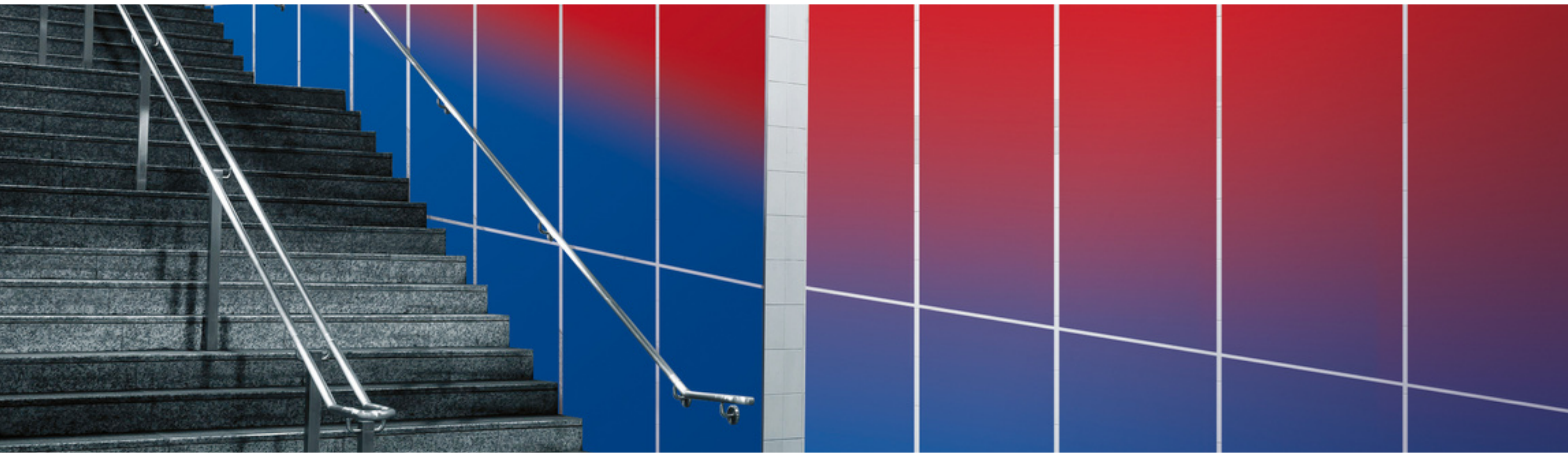


Figure 9: Seasonal influence on thermal power

On an annual scale, Figure 9 also illustrates this phenomenon with reference to the extracted power per month. A slight seasonal increase is observed but is limited to 15% of annual variation on the system performance. The influence of the air temperature on the thermal power extracted from the enerdrape geothermal panel is therefore limited.



NUMERICAL SIMULATION RESULTS

In order to determine the influence of the system's operation on the behaviour of the surrounding soil, dynamic numerical simulations were carried out over 50 years of operation.

Figure 10 describes the load profile used for the dynamic thermal simulations.

The data collected during the entire operation of the Sébeillon system were used to calibrate a numerical model. The design criteria defined by the SIA 384/6 standard for geothermal probes are used.

An 8-month heating season in which 100 W/m² is extracted by the system for 9 hours per day followed by a 4-month seasonal recharge is simulated for 50 years.

Figure 11 describes the temperature evolution in the soil at 10 cm from the equipped wall and at 10 m from the equipped wall.

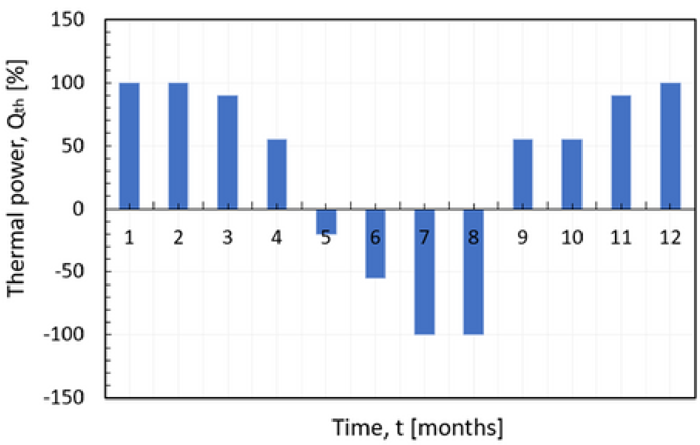


Figure 10: Power charge profile for the simulation on 50 years.

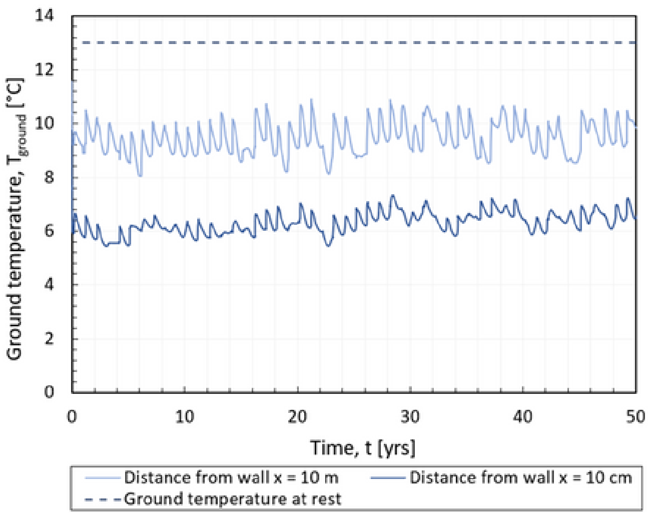


Figure 11: Evolution of ground temperature over 50 years

The initial temperature of the soil and the wall is 13°C. It can be observed that close to the wall (x = 10 cm) the soil temperature is disturbed by about 6°C, while far from the wall (x = 10 m) the disturbance of the soil temperature is limited to a variation of 3°C. It is interesting to note here that the ground temperature disturbances are relatively constant over the years for this load profile and stabilise in the first years of operation of the system. Oscillations result from the seasons and changes in the type of operation (heating/free cooling).

The criterion for the design of a geothermal system after 50 years according to SIA 384/6 (art. 3.1.2), i.e., a minimum average exchanger temperature of -1.5°C, is met here. It can therefore be concluded that the operation of the enerdrape system at 100 W/m² and for the load profile simulated here meets the design criteria over 50 years and ensures the sustainability of the source over time.

Figures 12 and 13 show the soil temperature after a period of 50 years in January and July respectively, at a maximum extraction power of 100 W/m².

The soil after 6 metres depth maintains a stable temperature of about 13 °C. Further down, the temperature fluctuates by a few degrees with the seasons. This is because the surface layers of the soil are more subject to temperature variations due to external weather conditions (sunshine, weather, air temperature).

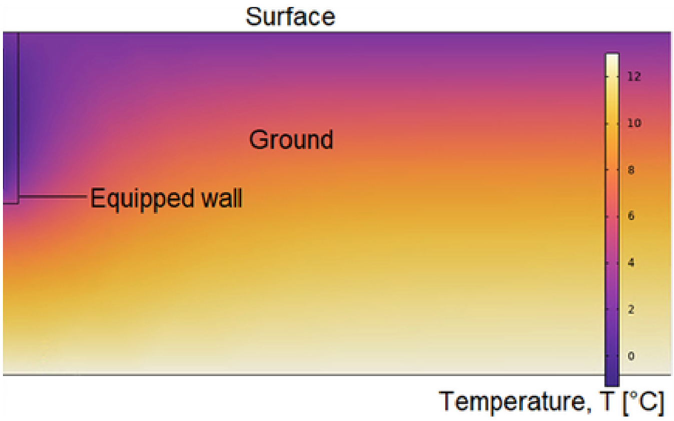


Figure 12: Ground temperature in January after 50 years of operation

However, this phenomenon is less observed in urban and dense areas where human constructions protect the surface layers.

It can be observed that in the direct vicinity of the surface activated by the enerdrape system the thermal behaviour cycle of the soil remains reasonably impacted after 50 years.

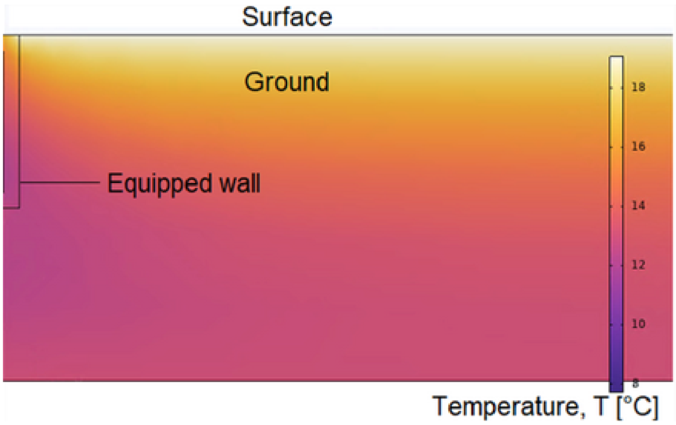


Figure 13: Ground temperature in July after 50 years of operation

CONCLUSIONS

This report summarises the results obtained in the first pilot installation of an enerdrape system. The results confirm the outstanding energy performance of enerdrape installations and demonstrate the wide applicability of this technology in underground built environments. The main conclusions that can be drawn from this study are the following:

1	The extraction and injection capacity of the system depends on the inlet temperature of the heat transfer fluid and the average wall temperature. For the operating conditions tested in this pilot, a maximum thermal output of more than 170 W/m² was achieved.
2	A stable thermal behaviour is observed after 5 hours of operation. After 5 hours of operation, the system draws a stable power; the nominal power is therefore reliable.
3	The system output is only slightly influenced (approx. 15%) by the ambient temperature of the air in the car park. As a result, the system's output remains stable in winter and does not suffer from a large drop in performance during the cold periods of the year.
4	The ambient air temperature in the car park is not influenced by the operation of the system. The temperature in the car park will not be influenced by the use of the panels, so no discomfort will be experienced by car park users.
5	The enerdrape system has a high seasonal stability, which guarantees a relatively constant coefficient of performance (COP). The enerdrape system can therefore be used at nominal power all year round.
6	At the recommended operating powers, the inertia of the floor is guaranteed for 50 years of operation. The enerdrape system can therefore be used for more than 50 years without any change in performance or freezing of the ground.

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