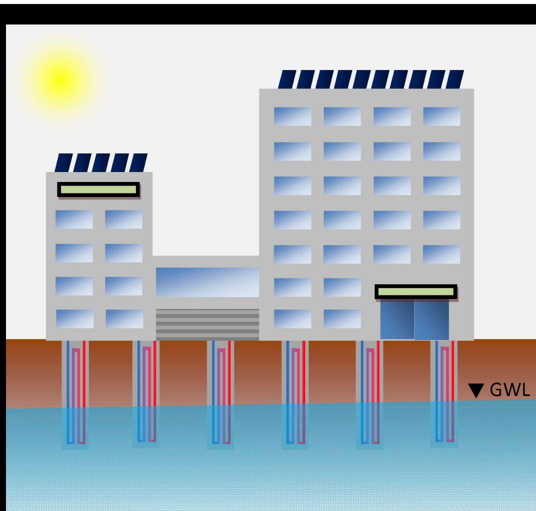
FACTSHEET2 **Managing Urban Shallow Geothermal Energy**

THERMO-ACTIVE FOUNDATION SYSTEMS



Thermo-active foundations (TAFs) embed heat exchanging probes into the subsurface concrete structures, which act as the foundations of a building, like piles and/or diaphragm walls. They are also known as thermally activated building structures/systems (TABSs), although the latter refers not only to foundations. Some commercial solutions exist like the Building-Integrated GEOexchangers (BiGEOs).

1 PROVEN CONCEPTS

LITTLE INVESTMENT, GREAT SAVINGS

As an energy solution, TAFs represent the attribution of **a new functionality to the structural elements of a building without incurring a proportional increase in costs** (no additional drilling works and no further land use). In fact, using TAF solutions allows up to 40% in investment cost savings compared to vertical borehole heat exchangers (BHEs). Additionally, the payback period can be as low as 4 years.

NOT SUITABLE FOR THE SMALLEST ONES

TAFs are rarely found in small residential buildings. Conversely, **large buildings (office, commercial and arena buildings, hospitals) are the main beneficiaries of this option**. District heating and cooling networks are neither among the main targets, by now.

Austria is a pioneer in this field, although other regions are following in its footsteps. A recent and remarkable example is the renovation of the *Sant Antoni* market in Barcelona (Spain). The installed capacity corresponding to TAFs is 600 kW_{th}, which fully covers the heating demand, and > 65% of the cooling. PE-X probes are embedded in 40 m deep diaphragm walls (Figure 1), with a total area of 16500 m^2, and a specific heat extraction rate of 40 W/m^2.

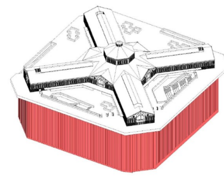


Figure 1. Thermally activated diaphragm walls in red at Sant Antoni market in Barcelona (Spain).

2 FUTURE CONCEPTS

TAFs IN METRO INFRASTRUCTURE

Austria is also the first country where TAFs have been applied in new metro stations. Within the scope of the extension works in the metro line U2 (Wien, 2008 - 2013), the metro stations were constructed by the “cut and cover” method. Diaphragm walls and bottom slabs were used to install the geothermal probes. The new and massive project “Grand Paris” (Paris, France) is taking over with more than 200 km of new metro tunnels and 68 new stations planned. The first feasibility studies have been undertaken for the application of TAFs in the stations.

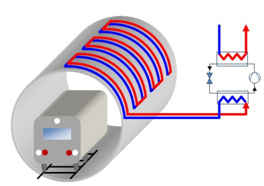


Figure 2. Illustrative scheme of an energy tunnel.

However, **the true big potential remains in excavated metro tunnels** (as for urban scenarios), which are usually too deep to be made by the “cut and cover” method, and therefore different types of heat exchangers (Figure 2) are installed during tunnel construction. Specific energy tubbing segments can be implemented in tunnels excavated by tunnel drilling machines. Nevertheless, depth is an advantage in terms of the specific heat extraction rate.

MUSE GeoERA GEO-ENERGY

Moreover, it is well known that **trains are an inherent source of heat** contributing to ground warming in the long run (like in the famous case of London). Hence, the application of TAFs or any other alternative heat exchanger technology could be welcome in existing and future underground infrastructure for cooling and of course heating, if necessary.

3 GOOD EXISTING PRACTICES

A good indicator of maturity in the construction industry is the level of integration of environmental and energy efficiency aspects into the draft projects. This applies to both the private and public sector. **Any new infrastructure or building should have TAFs in mind.**

SHALLOW... BUT THE DEEPER, THE BETTER

TAFs are a shallow geothermal energy solution between horizontal and vertical ground-source heat exchangers. Usually, seasonal ground temperature variations are low after the first 5 m and nearly suppressed from 15 m depth downwards. **Minimum depth of piles or diaphragm walls should be at least 10 m to be used as TAFs**. Two main aspects **impact feasibility and profitability**:

- **Ground thermal diffusivity (α)**. Concerning seasonal ground temperature (T_{gr}) variation, low α values and temperate climates are favourable for the implementation of TAFs (Figure 3).

  However, the relationship between α and the ground thermal conductivity λ_{gr} should not be forgotten:

  $$\alpha = \frac{\lambda_{gr}}{\rho \cdot c_p}$$

  A low α should not be at the expense of a low λ_{gr}. Conversely, high values of ground density (ρ) and specific heat capacity (c_p) are those that should minimise α.

- **Groundwater dynamics.** A comprehensive knowledge of groundwater occurrence before, during and after the execution of TAFs is required. **Monitoring of the water table variations along the year** is crucial not only for construction purposes, but also for the performance of the TAFs, since λ_{gr} will be largely affected by groundwater flows surrounding them.

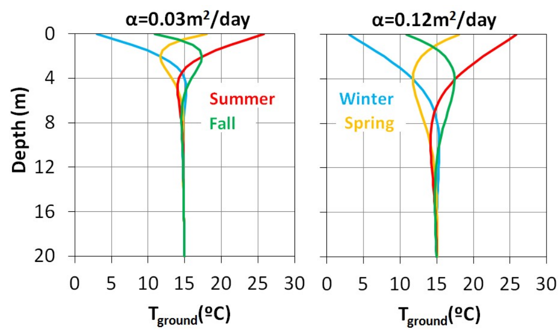


Figure 3. Typical ground temperature depth profile of a warm climate location for two different values of α.

4 LESSONS LEARNED

BEWARE OF THE UNDERGROUND

Given the shallow nature of TAFs, a local characterization of groundwater flows is needed because of the **multiple subsurface structures that can deviate or block the groundwater flow** with respect to its natural path.

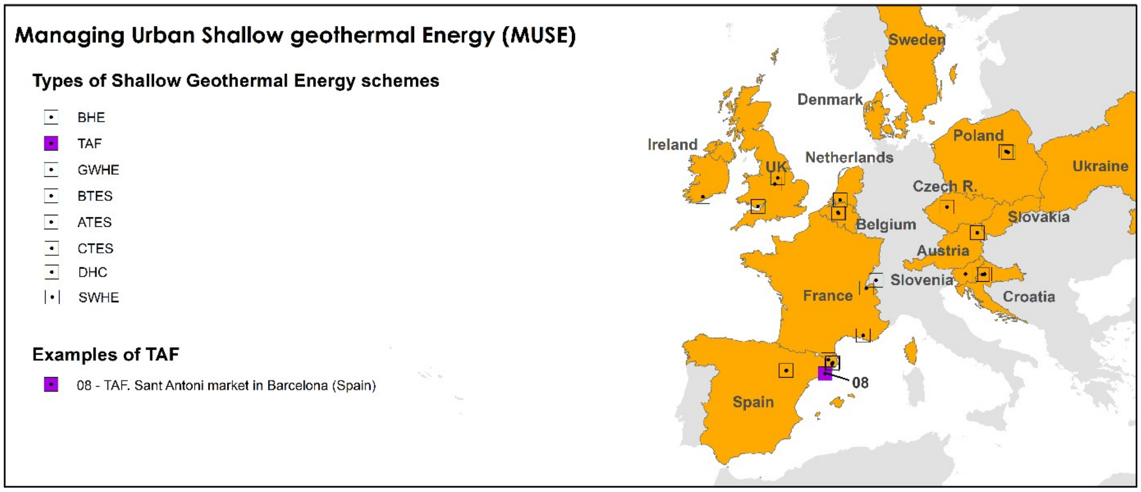
In this sense, operation managers should **keep an eye also on nearby construction works**, and general urban infrastructure management.

It is of special relevance for the mid and long term to achieve **a close-to-null balance with the ground** (same heat extracted and rejected). Notice that for this to happen, the building heating load should be, as a rule of thumb, approximately 50% higher than the cooling load.

BEST THINGS ARE NEVER FREE OR EASY

It has been demonstrated in extreme cases that **seasonal temperature cycling of the fluid within TAFs can induce stresses** on the reinforced concrete structures (expansion and contraction). This will eventually affect the settlement process of the entire building, so thermal loads and structural loads should be correlated in the design phase. It is recommended also to monitor the phenomena by the installation of displacement gauges on the TAFs.

5 EXAMPLES FROM PILOT AREAS



TAF-1. Sant Antoni market in Barcelona (Spain)

BARCELONA

Location (WGS84 coordinates): N 41.3786048 E 2.1620784

	heating (15/18)	cooling (21/24)
Degree-days$_{2017-18}$ [ºC·days/year]	1754	187

Undisturbed T_{ground} [ºC]: 19.8
Minimum T_{brine} [ºC]: no data
Maximum T_{brine} [ºC]: no data
Depth of foundations [m]: 40
Area exposed to ground [m^2]: 16530
Total probe length [m]: 43970

	Heating	Cooling
Capacity installed [kW]	600	450
Demand [MWh]	2700	850
Seasonal performance (SPF_{H2})	> 4	>5

The old market of Sant Antoni was refurbished, and new floors were gained in the underground. During excavating work, old city walls were encountered and extra work was planned to preserve this valuable heritage. 40 m deep diaphragm walls were constructed following the perimeter of the block where the market is located. These walls were used as thermo-activated foundations (TAFs). The total surface of the resulting heat exchanger allowed the full coverage of heating demand by means of heat pumps (HPs), and more than 65 % of the cooling demand. Additionally, the HPs operate very efficiently during summer, since the heat rejected by the building is re-used for domestic hot water (DHW) production.

TAF-2. Austria Campus in Wien (Austria)

WIEN PILOT AREA

Location (WGS84 coordinates): N 48.212830 E 16.415016

	heating (15/18)	cooling (21/24)
Degree-days$_{2017-18}$ [ºC·days/year]	2377	229

Undisturbed T_{ground} [ºC]: 12.8

Minimum T_{brine} [ºC]: no data

Maximum T_{brine} [ºC]: no data

Depth of foundations [m]: 14

Area exposed to ground [m^2]: No data

Total probe length [m]: 250000

	Heating	Cooling
Capacity installed [kW]	3000	No data
Demand [MWh]	No data	No data
Seasonal performance (SPF_{H2})	No data	No data

The Austria Campus is a business district consisting of offices, underground parking, a hotel, health and conference centre, and areas for restaurants and retail (Rental space: 20 hectares). Apart from the borehole heat exchanger (BHE) field, thermo-active foundations (TAFs) were implemented (what this factsheet is about): slurry (diaphragm) walls, auger piles and parts of the base plate are geothermally activated through absorber pipes for the purpose of heating and cooling in the building complex. As an innovation, the installation of geothermal energy cycles into unreinforced piles was realized by means of a specially developed distribution system. Combined it is one of the largest geothermal projects in Austria.