OR/17/007 Shallow geothermal energy in urban areas - (Peter Dahlqvist, Jannis Epting and Peter Huggenberger)

From Earthwise
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Key words: geothermal urban environments; installation practice; monitoring practice; geothermal regulation

Introduction

This section provides a review of examples of good practice concerning sustainable city-scale geothermal use, as well as an overview of the drivers and barriers to Shallow Geothermal Energy (SGE) use in urban areas in Europe. The section discusses both open and closed SGE schemes in different geological, hydrological, hydrogeological and urban settings. Regulation of SGEs in different countries is reviewed to provide an insight into some of the key requirements of SGE monitoring and modelling so that these are able to support effective management and regulation. Needs for cities with different characteristics is illustrated with examples from cities with high versus low data availability.

Range of city drivers and planning needs for urban areas

The use of SGE provides a large opportunity for urban areas to meet increasing energy needs in the future, and to increase the resilience of cities, with lower reliance on finite hydrocarbon energy resources. The use of SGE to supplement increasing energy demands of cities (in terms of both heating and cooling) can, however, place significant pressure on urban aquifers if exploitation of the resource is not effectively planned, particularly if there are competing uses of the groundwater resource. SGE use can lead to changes in: groundwater levels and groundwater quality. Elevating the temperature of the urban groundwater resource can also have wider environmental implications which impact city planning. For example in the Netherlands, rises in groundwater temperature and subsequent increased microbial populations in groundwater in some cities have led to significant decay of wooden building piles in heritage areas, leading to building subsidence. Considering the geological, hydrological, hydrogeological and operational boundary conditions and their interaction in urban areas, the situation is very complex. In view of the increasing demand for sustainable energy it is likely that SGEs will become even more frequent in the future. Urban planning in three dimensions is one of the keys to a sustainable use of sub-urban ground and groundwater resources (link to WG4).

Key planning needs in relation to SGE are:
What is the ‘present thermal state’ of different urban areas?
What are the relevant ‘natural’ and anthropogenic boundary conditions which lead to the ‘present thermal state’?
What is the energy potential for ‘cooling’ and ‘heating demands’ in different urban areas, also in context of the spatiotemporal availability of thermal resources (seasonal availability, storage schemes)?
Can this energy be used to supplement district heating plans (i.e. is it economically and technically feasible to utilise the energy)?
Would SGE use negatively impact existing uses of the subsurface and groundwater resource (interference with contaminated sites, subsurface structures as buildings and tunnels, ecosystems)?
How many, and what density of SGE heat schemes can be sustainable in an area?

Range of SGE technologies

This report focuses on SGE, where ‘shallow’ in this context is <400 m depth. Depending on the geology, energy needs and city planning there are several different types of SGE that will be best adapted for the specific environment. SGEs can be classified into Ground Source Heat Pumps (GSHP) and Borehole Thermal Energy Storage (BTES) and open systems Aquifer Thermal Energy Storage (ATES).

Focusing for a moment on GSHP systems — there are two main types. The ground-coupled heat pump (GCHP) systems consist of a heat pump connected to a closed-loop network of thermally fused plastic piping that is buried in the ground. A water antifreeze solution is circulated through the inside of the pipe network transferring heat from the ground to the heat exchanger. No groundwater enters the pipe network; only heat is transferred by conduction to the refrigerant. Groundwater heat pumps (GWHPs), the second subset of GSHP systems, directly exploit the significant heat capacity of groundwater. Using an extraction (or production) well, the water is conducted directly to the heat pump, where heat is added or removed from the water. The heated or cooled water is then returned to the ground through an injection well.

Ground Source Heat Pumps (GSHP) and Borehole Thermal Energy Storage (BTES)

In the closed systems, a heat transfer liquid, often a glycol-water mixture is circulating in a closed loop, and the heat energy is gained using a heat pump. The simplest and most common system are composed by a single or double u-shaped loop containing a heat transfer liquid which is installed in a vertical borehole, approximately 50 to 250 m deep (Figure 3.1). GSHPs are mainly used for heating and cooling of small unit buildings (1 to 2 family houses). The BTES is a larger unit of GSHPs which is commonly used in apartment and public buildings with borehole fields with tens to hundreds of boreholes, often to a depth of 200–400 m. In these systems the temperature in the underground is changed and can be used as a seasonal storage. BTES may be charged by e.g. solar energy during the summer period and used for heating during the colder part of the year (Huggenberger and Epting 2011).
Aquifer Thermal Energy Storage (ATES)

Open geothermal systems use the geothermal energy of the groundwater. In contrast to closed systems, the groundwater itself is the heat transfer liquid and the aquifer is used as energy storage. Such systems involve a pumping well to withdraw groundwater and a reinjection well where the used groundwater is reinjected into the aquifer after its thermal energy has been gained using a heat pump (Figure 3.1). ATES systems are mainly operated by larger energy users (airports, department stores, hotels) for heating and cooling purposes. The direct use of groundwater as the heat transfer liquid represents a direct large-scale interference with the aquifer and the thermal groundwater regimes (Huggenberger and Epting 2011[1]).

Geological environments of urban SGE use

Europe is a wide area with large differences in geology and the groundwater and SGE resources contained within these geological environments. Whereas ‘natural’ groundwater temperatures should follow the regime of mean annual air temperatures in urban areas the Urban Heat Island (UHI) can be observed (e.g. Epting et al. 2013[3]). Whereas, the groundwater mean temperature on a few tens of meter can vary between 2 to 20°C between northern and southern Europe, and within cities where there are influences of subsurface buildings heat loss and multiple uses of the groundwater resource, groundwater temperatures can vary by 7 to 10°C on a kilometre scale. Different geological environments present different opportunities and potential for SGE use in cities.

Consolidated sedimentary bedrock geology

Areas with sedimentary rocks are of great value for the SGE use. The porous media often holds sufficient groundwater resources that can be used. ATES solutions may be the best adapted SGE in these areas. In sedimentary rock environments there might be special conditions and formations that makes it difficult and sometimes dangerous to use SGE, like karstic areas and areas with salt and evaporates (Huggenberger and Epting 2011[1]). These areas are very important to be mapped in three dimensions. Karstic areas with an underground conduit network and sinkhole development need careful attention. Evaporites may expand (swell) resulting in a considerable rock volume increase, and salt bearing formations may leach, which can lead to terrain uplift, respectively, or land-subsidence. Areas with sandstones and quartzite sedimentary rock make a good example where GSHP may be a well-adapted scheme, the high quartz content making it a very good heat
transporter.

**Crystalline basement geological environments**

In the crystalline basement the most common and applicable SGE is the BTES solution, but GSHP solutions are also applicable depending on the urban setting and needs. The reason is that these rocks are less porous and the water is primarily transported in fractures. Fracture zones can be very important and graded drillings to use these zones are quite common.

These graded drillings makes mapping even more difficult if not carefully reported to the authorities. Otherwise much of the heat transfer ability in these rocks depends on the mineral composition. Having a robust map of the heat transfer ability within a city or region, developing geothermal energy in these geological environments is therefore good practice.

**Unconsolidated Quaternary deposits and buried valleys**

In unconsolidated sedimentary environments the porosity and the water content (heat capacity and conductivity of the solid matrix and the fluid) governs the heat transfer ability. High water content is necessary and thereby the thickness of the deposits and the saturated zone is of high importance. ATES is the most common SGE solution in these environments. Information of sediment thickness, water table, flow direction, saturated zone, etc, therefore are important datasets from geological surveys or research organisations to help inform decisions of city planners. Good examples can be retrieved from Garcia-Gil et al. (2014)\(^4\) and Epting et al. (2013)\(^3\) which discuss the geothermal management of alluvial urban aquifers by examples from Zaragoza and Basel, respectively.

**Multi-layered groundwater aquifers — layered opportunities**

When two superimposed aquifers are present they are often separated by an aquitard that makes them two different systems. This means one aquifer can potentially support water supply, and another geothermal energy use, without the two competing demands on groundwater resources coming into conflict. However, it is important the separating aquitard should not be penetrated more than necessary with drilling to ensure the two aquifers remain isolated. Any wells drilled to the lower aquifer should always be packed so that there will be no short-circuit, either of heat or pollutants, between the aquifers. The lower aquifer is often the one with higher quality groundwater and less endangered from urban risks. Therefore the lower aquifer should preferably be used for drinking water purposes and the upper for SGEs. It is important to know the depth of the boundaries of the different aquifers and aquitards, and their respective geometries. It is of great value if high quality data from well drillings can be arranged into a geological model to show these boundaries.

**Interference of SGE use in urban areas with subsurface infrastructure and contaminated sites**

SGE systems can interfere with existing subsurface structures as e.g. tunnels or sewage networks, which can be associated with considerable risks for urban subsurface resources as for the infrastructures itself. In areas with ongoing or abandoned underground mining there are a lot of special issues to be elucidated. First, there is a need of three dimensional mapping of mining infrastructure before any SGE-planning can take place in the area. The caverns may be a huge risk during drilling and different pressure levels of the groundwater may lead to problems with flooding of infrastructure or drawdown, sometimes leading to subsidence. Mining galleries act as fast transport route which may lead to pollution of the aquifers. If carefully examined, there are however opportunities too, the occurrence of underground waterways may be used for specially designed
An important foundation for SGE planning in urban areas is a three dimensional mapping of contaminated sites. Drillings, withdrawal, heating, etc from SGE systems may lead to a quicker and more extensive pollution in the subsurface. In Utrecht high-performance ATES is believed to remediate polluted groundwater resources and to account for a major contribution to an energy-neutral city by 2030 (see Case studies).

**Drivers and barriers to SGE use in urban areas**

Whilst SGE offers a significant potential to cities to meet increasing energy demands and decrease reliance on carbon economy, there has been a very disparate uptake of SGE in urban areas in Europe, due to different financial, political, and physical barriers and drivers to exploitation of the resource.

A report from the RE-GEOCITIES project (RE-GEOCITIES 2012) provides a review of the main drivers and barriers to SGE use in urban areas in Europe. Common drivers for SGE use are:

- government subsidies and financial profit incentives
- national renewable energy targets to which construction industry must meet
- private sector growth and investment in SGE technology

The most common barriers to SGE use are:

- high installation costs of GSHP
- strict regulation of SGE use — time and cost, and high level of site investigation required
- crowded subsurface with competing uses, combined with a lack of information on the subsurface

The RE-GEOCITIES project highlights clearly that having a clear and appropriate level of SGE regulation and legislation is critical to: the amount of uptake of SGE in a country and the degree of private sector investment in SGE; and, to achieving sustainable use of SGE, particularly in urban areas where there is the greatest opportunity and demand for SGE schemes.

Having too little legislation and regulation of SGE, leads to uncertainty and poor uptake and investment in SGE by the private sector. Countries in Europe which have the lowest use of SGE all cite the lack of clear regulatory and legatorial framework as being a key barrier to SGE exploitation, alongside:

- Low private sector investment in SGE technology
- Low level of knowledge of subsurface and existing subsurface infrastructure
- Different regional competencies within the country to understanding use of SGE
- Poor borehole data availability
- Lack of legislative drivers

Conversely, having too much legislation and regulation of SGE use, can also act as a barrier to SGE investment if the legislation and regulation incurs too much time (and therefore cost) to investors. A careful balance in legislation, regulation and planning permissions/licensing is, therefore, required to be struck to strengthen private sector investment in SGE and to ensure sustainable management of SGE, particularly in urban areas. Furthermore, legislations should be based on decisions which also consider long-term use of urban subsurface resources and a holistic view of the interference of different subsurface usages in urban areas, including e.g. those of quantitative and thermal
groundwater use with subsurface structures.

**Need for good practice**

A wide range of approaches exists across Europe to harness and manage SGE in urban areas, in response to local opportunities, issues and subsurface conditions. Comparing these individual approaches enables general rules of key points of good practice to be identified for SGE use in urban areas.

There is a clear need for good practice in the use and management of SGE to ensure the SGE resource is managed sustainably alongside the many other competing uses (e.g. different quantitative and thermal groundwater uses and subsurface structures) of the subsurface in urban areas. In the future, a higher density of geothermal use will lead to unavoidable conflicts between neighbouring sites and other utilizations of subsurface resources (Huggenberger and Epting 2011), and the subsurface potential for different heating and cooling systems may be exceeded and affect groundwater quality (e.g. Possemiers et al. 2014). Moreover, in most urban areas, regulations for water resource management and geothermal energy use are currently sparse and often limited to the rule ‘first come, first served’. As a consequence, groundwater temperatures have increased significantly in some cities (e.g. north-western Basel, where groundwater temperatures reach seasonally up to 17°C (approx. 10°C long-term average annual air temperature)) (Epting et al. 2013). Indeed, the impacts of regional and local SGE use and groundwater exploitation are often orders of magnitude larger, particularly in urban areas, than any impacts of climate change (Epting and Huggenberger 2013).

The negative effects of SGE use can be minimised by effective management. This is only possible if there are sufficient hydraulic and temperature data that allow the urban thermal and groundwater regimes to the characterised at an appropriate resolution for city scale planning and regulation and risk evaluation. This enables the relation between groundwater flow and temperature regimes to be understood, and an appropriate level of SGE use planned or permitted within a city. A good practice of SGE planning is to provide suitability maps that enable a transparent approval practice for geothermal facilities, such as that developed in the city of Basel by Epting et al. (2013), who developed a thermal use concept for a pilot area in the Basel region on the basis of calibrated high-resolution heat-transport models. This makes the SGE potential and risk in different areas of the city understandable and accessible for city planning. It also provides guidelines on how risks associated with SGEs drillings can be minimized, and what monitoring methods and data are required to be collated to assist long-term sustainable management. Similarly the groundwater temperature maps developed for Berlin highlight regions suitable for SGE use and over-exploited areas, based on temperature data from 350 monitoring points across the city from 0 to 100 m depth. ([www.senstadt.3pc.de/umwelt/umweltatlas/eda214_07.html](http://www.senstadt.3pc.de/umwelt/umweltatlas/eda214_07.html)).

**Good practices**

**Key points of good practices for planning SGE use in urban areas**

Before a permit for SGE use are granted every operator and permit authorities need a decision basis including:

- geological characteristics (sediment thickness, rock type, fracture frequency, porosity, permeability, heat transfer ability)
- hydrogeological conditions (groundwater levels, temperature, chemistry, flow direction)
- planned borehole depth, grading and distance to SGE points close by
- planned pumping rates and abstraction and re-injection temperatures
Several of these facts can often be collected by data mining, e.g. a lot of this data are available in company reports, at geological surveys, and unfortunately not systematically arranged in the same database. Although it will take time to produce an accurate database, it is convenient that such a work is compiled by the municipality or region. One example on an extensive compilation is the 3D spatial planning tool for the Basel region (Dresmann et al. 2013).

A good example on a thematic map that is possible to do with good material is suitability maps for geothermal use. In the Netherlands TNO has developed a public web-based information system called ThermoGIS that provides potential maps and also depth, thickness, porosity and permeability maps of potential aquifers in the Netherlands.

An example of SGE resources can be found in the Metropolitan Area of Barcelona (Spain) (García-Gil et al., 2015a). The automated calculation in the setting of a GIS platform has allowed the development of a multilayered 3D mapping of the low-temperature geothermal potential for GSHP exploitation systems, taking into account heat advection by groundwater flow.

A correct borehole construction and completion is crucial when the actual drilling and borehole is the highest risk in SGE systems. Guidelines for construction of SGE installations are necessary (e.g. Butscher et al. 2010). To increase the probability of a correct drilling it is important to use a certified operator. In nearly all European countries, drillers and contractors installing SGE schemes must be certified. In most countries, certification is at company-level, rather than individual drillers and certification is not legislated (RE-GEOCITIES).

Finally it is important to have comprehensive and established decision criteria for approval of SGE in the city. For the Swiss canton Basel-Landschaft a criteria based system was developed as a decision basis (Butscher et al. 2010; Huggenberger and Epting 2011):

**Areas where SGE systems are not allowed**

- Groundwater protection zone
- Contaminated sites
- Sites with competing subsurface usage (e.g. tunnels)
- Outside settlements
- Unit susceptible for heavy karstification
- Geological unit with the risk of rock swelling and sub-erosion

**Areas where SGE are allowed with specific requirements (geological, hydrogeological and geotechnical clarifications)**

- Groundwater protections area AU
- Area with the risk of karstification
- Area with multiple aquifer levels, confined artesian aquifers, saline aquifers
- Area with geogenic risks (landslides, oil shale, natural gas, rock swelling, subrosion)
- Area with insufficient geological information
- Capture zone of mineral or thermal springs

**Areas where SGEs are allowed with standard requirements**

- Other areas
**Key points of good practice for monitoring and operation of SGE**

During the operational stage it is important that data are collated, shared and used for optimizing and securing the operation. Monitoring of groundwater levels and temperature enables evaluation of the thermal groundwater facilities, making it possible to optimise operation schedules as well as extraction and injection locations. Monitoring data can also be used to develop, or incorporated into heat-transport models (hyperlink to WG 2.1 and WG 2.3) used by planners or city authorities and regulators to estimate the environmental impact and potential hazards on the groundwater resource (Butscher et al. 2010[9], Huggenberger and Epting 2011[1]). A good practice can be observed where there are several operators (water companies, city regulators and planners) who use combined monitoring programmes and models, such as in the city of Hamburg (Bonsor et al. 2013). Data that should be collated are:

- groundwater levels
- groundwater temperature (from top to bottom to get temperature profiles — and also upstream and downstream of the GHSP point)
- abstraction and re-injection temperatures
- pumping rates and volumes (extraction and reinjection sites)

A daily frequency might be proposed as good practice, but dependent on automatic recorders and monitoring equipment. Data should not only be retrieved from the production wells. It is necessary to have a representative amount and location for the monitoring wells both upstream and downstream which allow capturing the induced thermal impact of the individual SGE system. To get sufficient data for planning and management needs, a city may need to collate data from different sources, municipalities, geological surveys, operators, etc. and hence it is important, and a key point of good practice, that different operators collect the same monitoring data from different SGE schemes across a city, so the data can be combined within national or city databases (e.g. the national well database Jupiter in Denmark; [www.geus.dk/departments/geol-info-data-centre/jupiter-uk.htm](http://www.geus.dk/departments/geol-info-data-centre/jupiter-uk.htm)).

**Key points of good practice relating to regulation of SGE in urban areas**

New installations should be placed at an appropriate distance from surrounding SGE systems to ensure there is no interference between the systems, and the efficiency of individual schemes is maintained, and no long-term change to the groundwater temperatures have to be expected.

To minimise the impact of individual SGE schemes it is important to regulate:

- correct separation distances between SGE points
- temperature thresholds and acceptable thermal effect
- water abstraction quantities (for ATES)
- depth (may be site specific or where the Deep Geothermal Energy starts)
- the use of the same aquifer for abstraction and re-injection
- a registration system (to database, see RE-GEOCITIES, Database Handbook, 3.2)
- a monitoring reporting system (gives feedback to the permitting authority)
- areas where SGE is restricted ([see Knowledge gaps](#))

Hähnlein et al. (2010[10]) compiled the international status of the use of shallow geothermal energy. Regulation of these may be done in different scale, national, regional, or local levels; whereas requirements of detail depend on the geological and urban settings, conflicting interests and the SGE opportunity in the area. There is large disparity in legislation and regulation of SGE use in Europe (RE-GEOCITIES 2012). In almost all countries, legislation only extends to open SGE, and closed SGE are regulated to varying amounts non-legislatively. The Netherlands are one of the few countries, to regulate closed SGE using both separation distance and by temperature thresholds.
Moreover, the permitted temperature change regulated by Dutch Law is one of the strictest in Europe — a change of +/- 1°C being permissible. Abstraction and re-injection temperatures, both at the SGE point and in adjacent observation boreholes must be submitted to the regulatory authority. Most other countries regulate only on separation distances, and permissible temperature changes if regulated are much wider — +/- 5 to 7°C being permissible generally, as long as the net balance per year is zero (i.e. SGE are used for heating and cooling over a year). In Finland you need a planning permission, since 2012, even for single loop closed systems in urban areas. The operator pays the municipality ca.200 Euro to do a mapping and description of the area. The municipality collects all data in a database, in the city of Helsingfors there are now data from over 2000 SGE since 2012.

**Good practices for thermal waste management**

Thermal waste (Epting et al. 2013[3]) occurs when there are excess or un-used high or low temperature groundwaters. Poor thermal waste management can lead to degradation not only of the groundwater resource, but also surface waters and ecosystems. To achieve a zero thermal gain/loss annually in the groundwater resource, excess energy can be injected into separate aquifers where there is a layered aquifer stratigraphy, or often it is more convenient to re-inject to the same aquifer, but ensuring equal annual heat addition and decrease — i.e. the aquifer is being used for both heating and cooling. To achieve this it is important to know groundwater and heat transport direction. The characteristics and distance to the downstream recipient is also important; a river may be influenced into a poor state if high or low temperature groundwater is entering and changing the local area. Different cities regulate different acceptable thermal annual changes, depending of other uses of the groundwater resource.

**Remediation measures for the over-heated urban groundwater bodies**

Robust remediation measures for the over-heated urban groundwater bodies of both cities include: (1) the use of groundwater for heating purposes and reinjection of comparably ‘cold’ water to the aquifer; (2) artificial recharge of comparably ‘cold’ surface water to the aquifer; as well as (3) seasonal storage of heat within the unconsolidated rock and underlying bedrock. Each of these measures and appropriate application of the measures are discussed in more detail by work within the cities of Basel (Epting et al. 2013[3]) and Zaragoza (García-Gil et al. 2015[11]).

These regeneration strategies would actively also reduce the temperature of groundwater exfiltrating into rivers, accommodating temperature thresholds formulated in some legal frameworks that also limit the use of shallow geothermal energy. For the investigated urban groundwater bodies of Basel and Zaragoza the use of groundwater for heating purposes would offer an economically auspicious alternative of resource exploitation. Thereby, shallow systems could be used for cooling and deeper systems (up to 400 m) for heat storage (i.e. seasonal storage of heat in deeper geological formations).

**Workflows of good practice**

Good practice to assess the influence of SGE systems on urban groundwater flow and thermal regimes GWBs should include each of the following worksteps. This builds on work to develop good practice of shallow geothermal assessment in cities of Basel and Zaragoza (Epting et al. 2013[3]; Epting and Huggenberger 2013[6], Garcia Gil et al. 2014[12]). The same worksteps are also true for the optimisation of existing assessments, and can be directly applied:
This stepwise procedure allows to approach new SGE systems in dependence of the complexity of the individual settings in different urban settings. Whereas practices range from simple mapping to applications of analytical solutions to simulate SGE impact in combination with mapping to high-resolution heat-transport modelling where numerous different subsurface usages come together.

**Case studies**

**Defining a ‘current’ and ‘potential natural’ state of urban groundwater bodies**

**Basel (Switzerland)** — The city of Basel and the work done by the University of Basel (Epting et al. 2013[3], Epting and Huggenberger 2013[6]) provides a key example of good practice in establishing a robust understanding of how the anthropogenic influence of urban buildings, and shallow geothermal groundwater use has been affected the aquifer and groundwater resource. The work has specific emphasis to examining the effects of increasing building density and the urban heat island effect in the city, combined with increasing thermal groundwater use for cooling purposes and river-groundwater interaction affecting temperature patterns.

Existing and new monitoring network data were modelled to identify and characterize the seasonal and anthropogenic influences on the temperature regime of a study area within the urban groundwater body in Basel. The results derived from the investigated groundwater body allowed providing guidelines and a suitability map for geothermal subsurface use to the authorities across the city. Research work by Basel University (Epting and Huggenberger 2013[6]) has enabled the potential natural state under undisturbed (pre-exploitation) conditions to be developed, from which different scenarios of groundwater use, urban development, and climate change can be modelled and understood, to help develop understanding of: the potential influence of climate change for the groundwater body in the urban area of Basel; and how the thermal groundwater regime developed before major urbanization of the region, and without thermal groundwater use.
Zaragoza (Spain) — Groundwater monitoring data, from a high resolution monitoring network in the city of Zaragoza has enabled highly effective management of the urban groundwater resource, and heat pump use, with natural river flood events which effectively cool the aquifer. There is a high level of shallow geothermal energy use in the city, and increasing concerns over the collective impact to raising groundwater resource temperature in the urban area, and the need to regulate and manage the thermal resource.

Modelling work, using the high resolution monitoring data, has enabled to strength of the hydraulic connectivity between the river and the groundwater resource, and the thermal impact seasonal flood events have to the groundwater resource. As a result of the understanding gained from this work, ‘cold’ winter floods and the interaction with geothermal installations can be utilised by the regulators to enable enhanced thermal management of the aquifer.

This management of the resource is essential to enable increasing use of geothermal energy in the city, without negative impact. The work also highlights that such management of the resource, and utilizing natural flood events to mitigate anthropogenic impacts, requires a detailed and robust understanding of both the ‘natural conditions’ of the groundwater resource, but also the current impact of anthropogenic use. Understanding of the variable influences of hydraulic and thermal boundary conditions within an urban area specific geological and hydrogeological setting is crucial, for this level of management, and requires high resolution observational data and modelling capacity.

The high resolution monitoring network in Zaragoza has been developed from collaboration between the Spanish geological survey (Instituto Geológico y Minero de España, IGME) and the water local administration (Confederación Hidrográfica del Ebro, CHE). The modelling work has been led by the University of Zaragoza and the Institute of Environmental Assessment and Water Research (IDÆA-CSIC).

More information can be found on this work from the research publication by Garcia-Gil et al. (2014).

Approval process for new shallow geothermal exploitations in urban GWBs

Zaragoza (Spain) — In the city of Zaragoza (Spain), forms a key example of a first approach to standardize the concession process of new geothermal exploitation installations has been proposed (García-Gil et al. 2015b). The use of a groundwater and heat transport model and a specifically designed high resolution monitoring network for geothermal exploitation has favourably reproduced the evolution of heat plumes and thermal interferences in urban environments. This has allowed the development of a concession process protocol considering the evolution of heat plumes and thermal interferences in urban environments as a numerical water policy assessment initiative. The concession process protocol proposed takes into account: (1) sustainability which guarantees an energetically balanced system and therefore a renewable utilization of the resources, (2) legal certainty which guarantees the stakeholders investments and (3) equal opportunity which guarantees a fair exploitation of the resources.

High resolution monitoring for remediation, can enable optimization of thermal urban groundwater resource

Utrecht (Netherlands) — The urban groundwater resource beneath the city of Utrecht is polluted from different sources. Estimation is that 180 million m3 groundwater is polluted with VOC’s in an area of 700 ha. This groundwater is remediated by a combination of ATES and biological natural attenuation. Observation wells with filters at different depth to measure the impact of ATES on the
contamination and a 3D glass-fibre network (www.fomebes.nl/het-project/partners/deltares/) for measuring the thermal spread of heat and cold is installed in the area. The fibre glass monitoring system generates a 3D picture of the energy balance in the subsurface which makes it possible to optimise the use of SGE in different areas. Similar projects are installed in Delft and Eindhoven. The results of the project will be available in early 2017.

**Knowledge gaps**

Some of the key missing knowledge gaps with respect to sustainable SGE use, and the planning of SGE use in cities are:

- How can a series of local water supply and thermal groundwater use systems be integrated into a network based on local and regional scale risk minimization, considering long- and medium-term development (development of groundwater and heat use concepts, suitability maps)?

And, how can these complexities be communicated and included into city planning?

- To what degree can water-supply and thermal groundwater use systems be optimized?
- What thermal, chemical and microbiological effects occur downstream of thermal groundwater use and how can they influence future groundwater use?

<table>
<thead>
<tr>
<th>ID</th>
<th>Current State</th>
<th>Desired State</th>
<th>Gap Description</th>
<th>Gap Reason</th>
<th>Remedies</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>The subsurface is used by several needs but in many cities too scarce monitoring and cooperation makes the use insufficient and unsustainable.</td>
<td>Use of the subsurface is coordinated and based on risk minimisation. Complexities are communicated and included into city planning, e.g. suitability maps and 3D-models.</td>
<td>Absence of integration of water supply and thermal groundwater use systems into a network considering long- and medium-term development.</td>
<td>Lack of monitoring and networks and regulation. The overall responsible for arranging is not clear.</td>
<td>Monitoring, research, case studies, legislation.</td>
</tr>
<tr>
<td>2</td>
<td>Water supply and SGE are using the same resource, but not necessary in the optimal way.</td>
<td>The subsurface including heat, cold and water supply is managed in an effective way.</td>
<td>It is not clarified how and to what degree the water supply and thermal groundwater use systems can be optimised.</td>
<td>Lack of monitoring data and research.</td>
<td>Monitoring, scientific work, case studies.</td>
</tr>
<tr>
<td>3</td>
<td>In most cities there is a lack of monitoring data. The research results are not communicated or used in the cities.</td>
<td>Thermal groundwater use does not restrict ongoing and future drinking water supply.</td>
<td>The thermal, chemical and microbiological effects occurring downstream of thermal groundwater use and how they influence future groundwater use.</td>
<td>Lack of monitoring data and research on effects.</td>
<td>Monitoring, scientific work, case studies.</td>
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The correct data is collected and research programmes are developed.
References


Retrieved from ‘http://earthwise.bgs.ac.uk/index.php?title=OR/17/007_Shallow_geothermal_energy_in_urban_areas_-_(Peter_Dahlqvist,_Jannis_Epting_and_Peter_Huggenberger)&oldid=33146’

Category:
- OR/17/007 Groundwater, Geothermal modelling and monitoring at city-scale: reviewing European practice and knowledge exchange