Managing Urban Shallow Geothermal Energy

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731166

Establishing the European Geological Surveys Research Area to deliver a Geological Service for Europe

GeoERA MUSE
Fact sheets on the pilot areas

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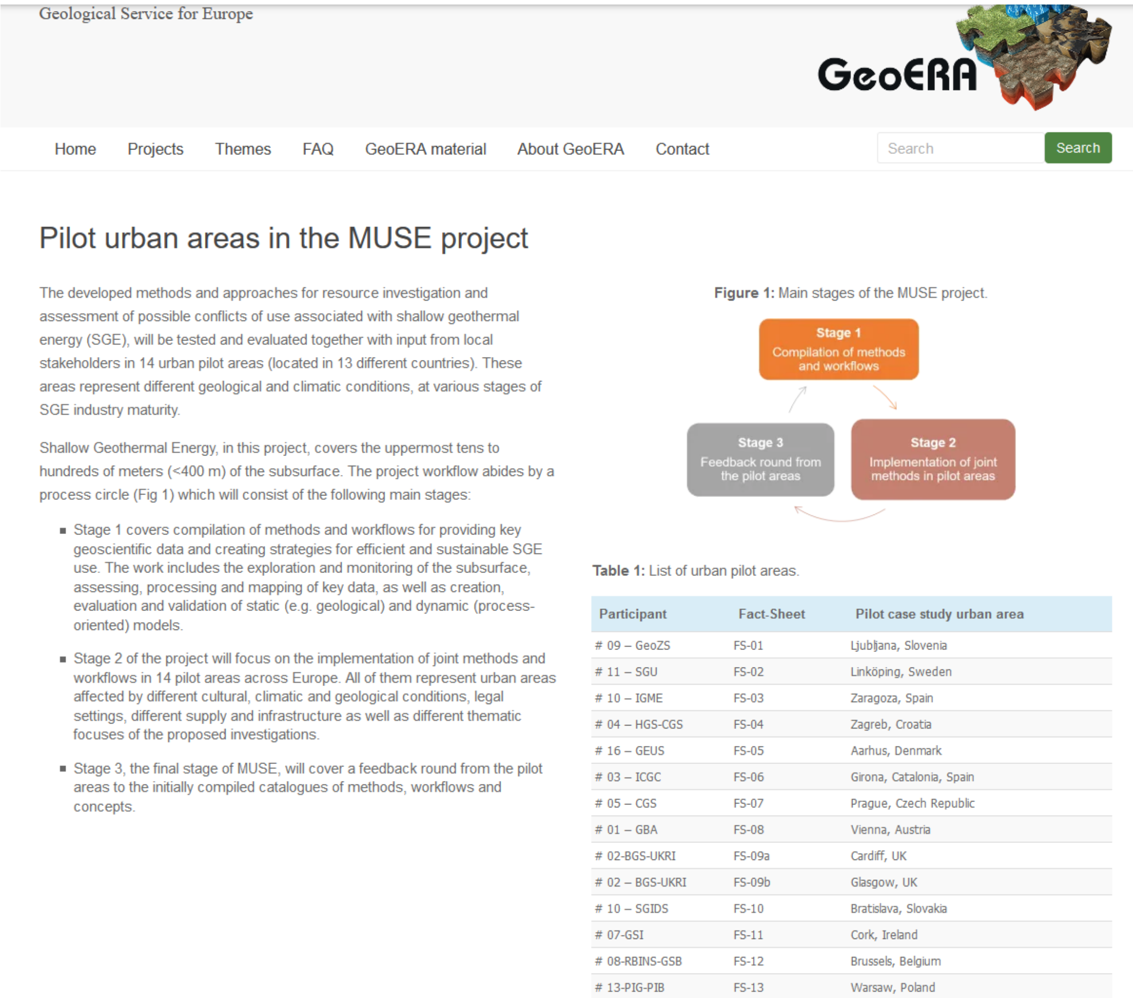
Description of the deliverable and version

The fact sheets are intended to give an overview of (1) the current situation on SGE use, (2) the outline of relevant constraints and impacts of SGE use and (3) a summary of the activities and results achieved. The fact sheets represent living documents updated during the project implementation and will be published on the project website.

Apart of a general introduction to the pilot areas with regard to hydrogeological, climatic and geographical settings, the initial version of the fact sheets included the current situation on shallow geothermal energy use as well as the ambition of MUSE inside the pilot areas. The initial version of the pilot areas fact sheets were finalized in 2019 and published at the MUSE website: https://geoera.eu/projects/muse3/pilot-urban-areas-in-the-muse-project/.



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Pilot urban areas in the MUSE project

The developed methods and approaches for resource investigation and assessment of possible conflicts of use associated with shallow geothermal energy (SGE), will be tested and evaluated together with input from local stakeholders in 14 urban pilot areas (located in 13 different countries). These areas represent different geological and climatic conditions, at various stages of SGE industry maturity.

Shallow Geothermal Energy, in this project, covers the uppermost tens to hundreds of meters (<400 m) of the subsurface. The project workflow abides by a process circle (Fig 1) which will consist of the following main stages:

- Stage 1 covers compilation of methods and workflows for providing key geoscientific data and creating strategies for efficient and sustainable SGE use. The work includes the exploration and monitoring of the subsurface, assessing, processing and mapping of key data, as well as creation, evaluation and validation of static (e.g. geological) and dynamic (process-oriented) models.
- Stage 2 of the project will focus on the implementation of joint methods and workflows in 14 pilot areas across Europe. All of them represent urban areas affected by different cultural, climatic and geological conditions, legal settings, different supply and infrastructure as well as different thematic focuses of the proposed investigations.
- Stage 3, the final stage of MUSE, will cover a feedback round from the pilot areas to the initially compiled catalogues of methods, workflows and concepts.

Figure 1: Main stages of the MUSE project.

Table 1: List of urban pilot areas.

Participant	Fact-Sheet	Pilot case study urban area
# 09 – GeoZS	FS-01	Ljubljana, Slovenia
# 11 – SGU	FS-02	Linköping, Sweden
# 10 – IGME	FS-03	Zaragoza, Spain
# 04 – HGS-CGS	FS-04	Zagreb, Croatia
# 16 – GEUS	FS-05	Aarhus, Denmark
# 03 – ICGC	FS-06	Girona, Catalonia, Spain
# 05 – CGS	FS-07	Prague, Czech Republic
# 01 – GBA	FS-08	Vienna, Austria
# 02-BGS-UKRI	FS-09a	Cardiff, UK
# 02 – BGS-UKRI	FS-09b	Glasgow, UK
# 10 – SGIDS	FS-10	Bratislava, Slovakia
# 07-GSI	FS-11	Cork, Ireland
# 08-RBINS-GSB	FS-12	Brussels, Belgium
# 13-PIG-PIB	FS-13	Warsaw, Poland

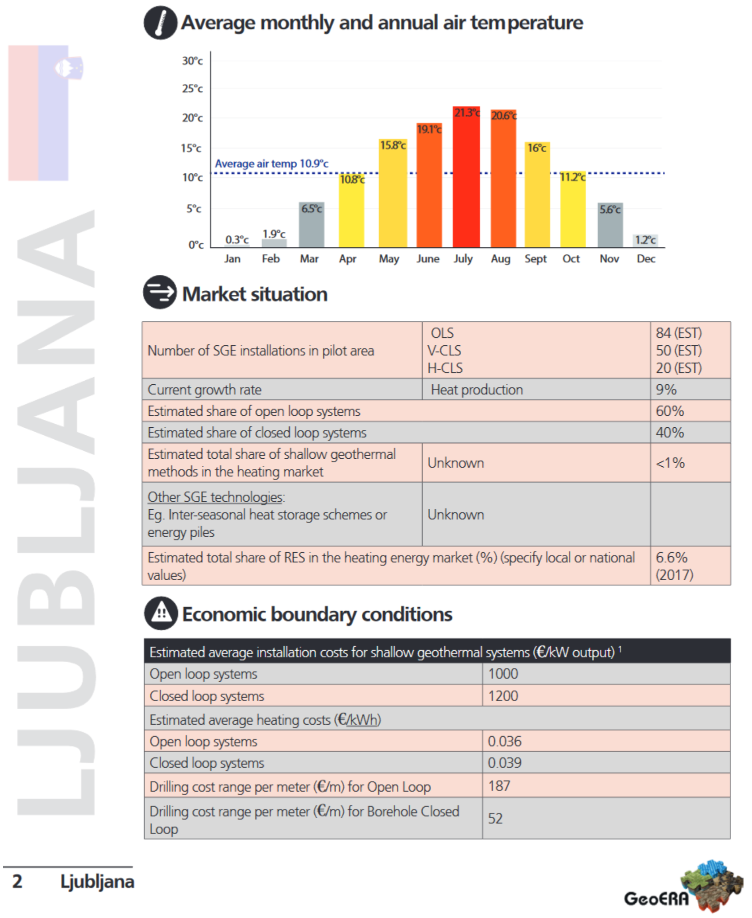
Figure 1: Overview of the MUSE fact sheets on at the MUSE website.

Content and structure of the initial fact sheets

All fact sheets followed the same layout and structure including the following sections:

- Geographical overview of the pilot area and key facts
- Climatological sections including annual temperature profiles

- Market situation regarding shallow geothermal including key market figures with reference to the year 2017
- Economic boundary conditions for the use of shallow geothermal energy (e.g. leveled energy costs, drilling costs etc.)
- Regional hydrogeological and geothermal (thermogeological) characteristics
- Scheduled work plan (will be replaced in the final version)
- References and contact details



Market situation

Number of SGE installations in pilot area	OLS V-CLS H-CLS	84 (EST) 50 (EST) 20 (EST)
Current growth rate	Heat production	9%
Estimated share of open loop systems		60%
Estimated share of closed loop systems		40%
Estimated total share of shallow geothermal methods in the heating market	Unknown	<1%
Other SGE technologies: Eg. Inter-seasonal heat storage schemes or energy piles	Unknown	
Estimated total share of RES in the heating energy market (%) (specify local or national values)		6.6% (2017)

Economic boundary conditions

Estimated average installation costs for shallow geothermal systems (€/kW output) [1]	
Open loop systems	1000
Closed loop systems	1200
Estimated average heating costs (€/kWh)	
Open loop systems	0.036
Closed loop systems	0.039
Drilling cost range per meter (€/m) for Open Loop	187
Drilling cost range per meter (€/m) for Borehole Closed Loop	52

2 Ljubljana

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Figure 2: Screenshot from the standardized fact sheets for the pilot area Ljubljana.

Outlook

In the remaining period of MUSE an updated version of the fact sheets will be published, which include the following additional information:

- Highlights of the activities in the MUSE pilot areas
- Impact of the work achieved.

The updated fact sheets will be published before September 2021.

Annexes

Link to digital MUSE fact sheets: https://geoera.eu/projects/muse3/pilot-urban-areas-in-the-muse-project/

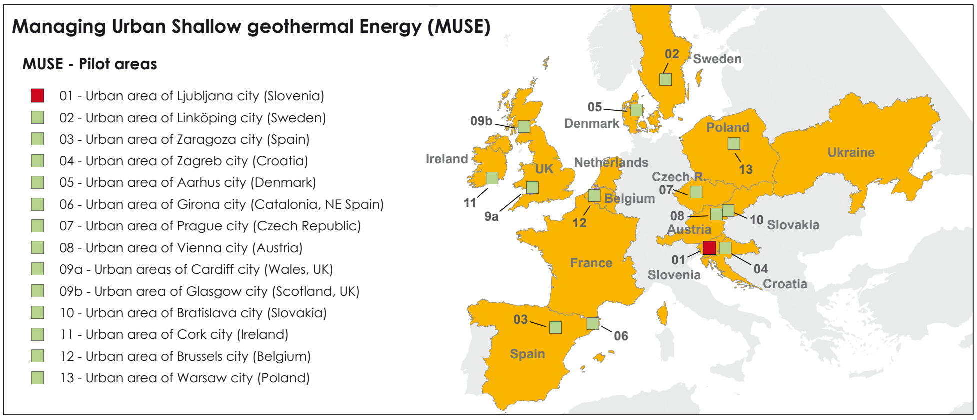
PDF version of fact sheets attached to this document.

LJUBLJANA FACTSHEET

SI/WP4/D4.1/FS01/2018

MUSE

Pilot area information



Ljubljana pilot area is one of the most urbanised and developed areas in Slovenia. At the moment coal and biomass powered district heating system covers most of densely populated area and distributes heat to 74 % of all households. Natural gas is the complementary source of heating. The share of geothermal energy use for heating and cooling is very low. Rough estimate of total amount of installed capacity for geothermal heating is 2,554 kW, and for geothermal cooling 670 kW, respectively, while approximate produced energies from ground source heat pumps are 2.9955 GWh for heating and 0.3534 GWh for cooling, respectively.

The central flat landscape of the area (altitude 295 m a.s.l.) is composed of permeable gravel and sand beds with significant quantities of groundwater which is the main resource exploited for the public water supply of the city of Ljubljana. The basement of Quaternary aquifer consists of Carboniferous and Permian rocks of which hills and hilly hinterland are mainly composed.

Pilot Area	Ljubljana
Task (MUSE)	T-4.2
Country	Slovenia
Area (km²)	Pilot Area - 65 km² Municipality - 275 km²
Total number of inhabitants (date)	289 500 (2018) (Municipality)
Inhabitants per km²	1053 (Municipality)
Level of urbanization	Unknown
Elevation range (m a.s.l.)	265 -320m

Climatological settings

HDD/CDD data according to EUROSTAT method	
Heating degree days (HDD); [baseline reference values]; (period for data calculations)	2551 [15/18] (2017)
Cooling degree days (CDD); [baseline reference values]; (period for data calculations)	218 [21/24] (2017)
Length of the heating season (days)	218 (3 successive days at 9 p.m. T<12 oC, ARSO)
Length of the cooling season (days)	Unknown

Source of data: Eurostat. https://ec.europa.eu/eurostat/data/database

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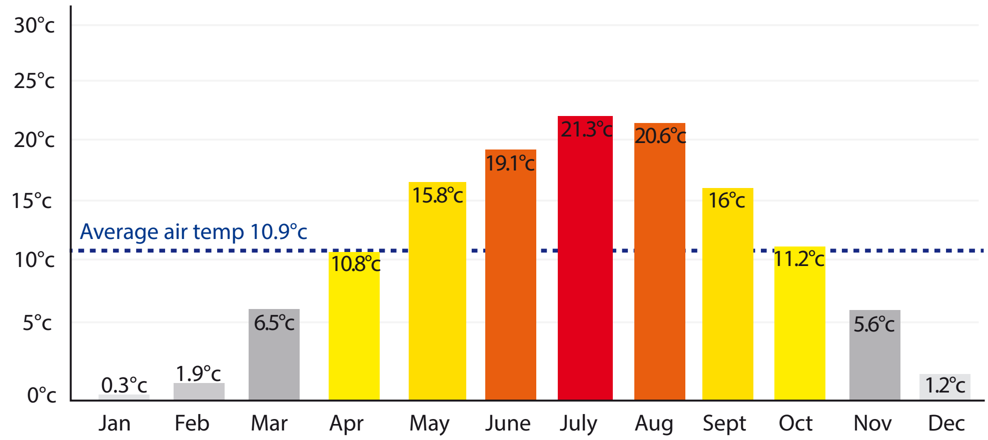
Average monthly and annual air temperature



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LJUBLJANA FACTSHEET

Regional geological and hydrogeological characteristics

General Geology

Bedrock Age: Carboniferous and Permian

Bedrock lithology: schistose mudstone, quartz sandstone, and conglomerate

Quaternary: Pleistocene and Holocene fluvial sediments consist of coarse channel deposits (gravel and sand, 45%), silt and clay with gravel (36%), and fine sediments (silt and clay, 5%), the remaining material (14%) is composed of conglomerate—gravel cemented by calcium carbonate.

The Ljubljana Basin is located in the transition zone between three active fault systems 1) Dinaric Fault System on SW, consistent of NW-SE-striking dextral faults, 2) Periadriatic Fault System on N, consistent of E-W- to NW-SE-striking dextral faults and 3) belt of Sava Folds on E, consistent of E-W-striking reverse faults and folds.

Hydrogeology

Target aquifer: Quaternary fluvial deposits (highly permeable).

Groundwater flow is in general directed from the north western toward the eastern part of Ljubljansko polje alluvial plain. Groundwater flow velocity is high, estimated to be up to 20 m/day. Coefficient of hydraulic conductivity is in general in the order of magnitude of 10–2 to 10–3 m/s.

Depth to water table: increases with distance from the river, from a few meters (near the river on the lower terrace) up to 25 to 30 m.

Aquifer thickness: (0-100m)

Thermogeology

Groundwater temperature: (Ave, Min Max range) 12.5 oC, (9-14.5 oC)

Zone of Seasonal Fluctuations (typically upper 15-20m below surface)

Summary of works and timeline

Main Objectives	
	Evaluation and characterization of geology/ hydrogeology / thermal conditions
	SGE assessment resources (for OCS and/or CLS) / and evaluation of UTES-BTES)
✓	Study of conflicts of use (OLS / GWL - OLS/CLS). Hazards/interferences, effects on sub-surface
✓	Strategies and actions for management and local energy plans
Relation of foreseen tasks	
	Data collection (TRT, DTRT, rock samples, GWL, T-profile's etc)
	New field works (TRT/geophysics /new samples and lab etc)
✓	Monitoring existing SGE/GWL/T etc)
	Mapping (in general terms)
✓	2D/3D Modelling (in general terms)

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LJUBLJANA FACTSHEET

LJUBLJANA

Detailed summary of works at the Pilot Areas and brief timeline

March 2019 – March 2020 MUSE monitoring period.

Monitoring (March 2019 – October 2020)

Testing and implementing developed joint methods for assessing conflicts of use associated with SGE (September 2019 – September 2020)

Evaluation of existing regulation measures and application of the developed methods and management concepts for SGE (September 2019 – September 2020)

Analysis of potential hazards and interferences od SGE use and integration these aspects into strategies and actions for integrated groundwater management (March 2020 – March 2021)

Reference

Janža M. 2017. Management of the groundwater resource beneath the city of Ljubljana. Procedia Engineering 209: 100–103.

Janža M, Lapanje A, Šram D, Rajver D. 2017. Challenges of sustainable use of groundwater resources in an urban area (Ljubljana case study). In: Posavec K and Markovi T (eds) Groundwater Heritage and Sustainability: 44th Annual Congress of the IAH. Dubrovnik.

Janža M, Lapanje A, Šram D, Rajver D, Šram D. 2017b. Research of the geological and geothermal conditions for the assessment of the shallow geothermal potential in the area of Ljubljana, Slovenia. Geologija 60/2: 309-327.

Janža M. 2015. A decision support system for emergency response to groundwater resource pollution in an urban area (Ljubljana, Slovenia). Environmental Earth 61 Sciences 73: 3763–3774.

Jamnik B, Janža M, Prestor J. 2012. Project INCOME: developing a comprehensive approach for Slovenian aquifer management. Water21

Description of Ljubljana pilot area

https://www.interreg-central.eu/Content.Node/GeoPLASMA-CE/D.T3.1.1-report-partC-Ljubljana-fin.pdf

Contact

Managing Urban Shallow geothermal Energy
Project number GeoE.171.006

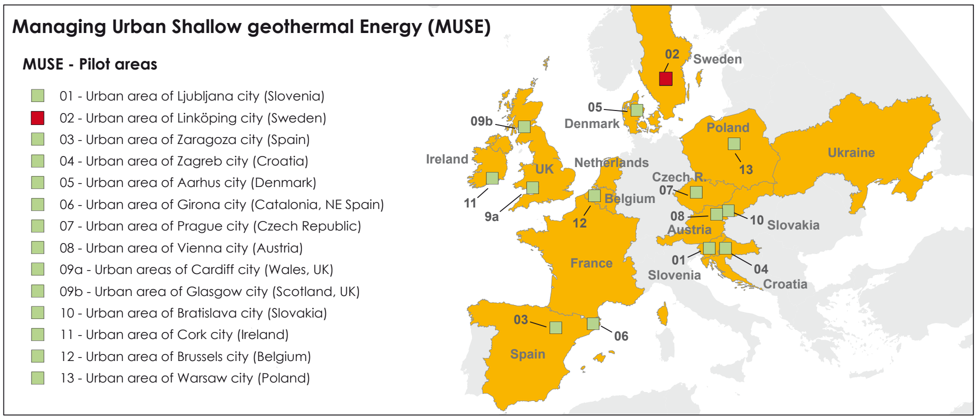
Website - www.geoera.eu/projects/muse
MUSE Project office: MUSE@geologie.ac.at
Pilot area contact person: Mitja Janza

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731166

LINKÖPING FACTSHEET

SE/WP4/D4.1/FS02/2018

Pilot area information



Linköping is the fifth largest urban area in Sweden with c. 160 000 inhabitants. The heating demand is mainly supplied by the district heating system. The heat resource is primarily a waste to energy plant with a heat capacity of 510 GWh corresponding to the heating of 25 000 houses. The scope of the pilot is to investigate the possibility to build a large H-BTES to switch 100 GWh heat from summer to winter. Preliminary design involves 1300–1400 wells to 300 m depth with an individual distance of c. 5 meters. A number of potential locations are now investigated and assessed regarding their geological, hydrogeological and thermal prerequisites as well the potential risks and environmental impacts.
Besides the large-scale H-BTES c. 4000 private closed loop systems exists in the Linköping area of which 62 are located in the pilot area.
The site lies at 35–45 m a.s.l. and the yearly mean temperatures vary between -2.7 and 16.8 °C.

Pilot Area	Linköping
Task (MUSE)	T-4.3
Country	Sweden
Area (km²)	1568.57 km² Linköping community 11.1 km² site area
Total number of inhabitants (date)	158 841 (2018) Linköping community 106 502 (2015) Linköping city
Inhabitants per km²	111
Level of urbanization	90% (live in urban areas)
Elevation range (m a.s.l.)	35-45

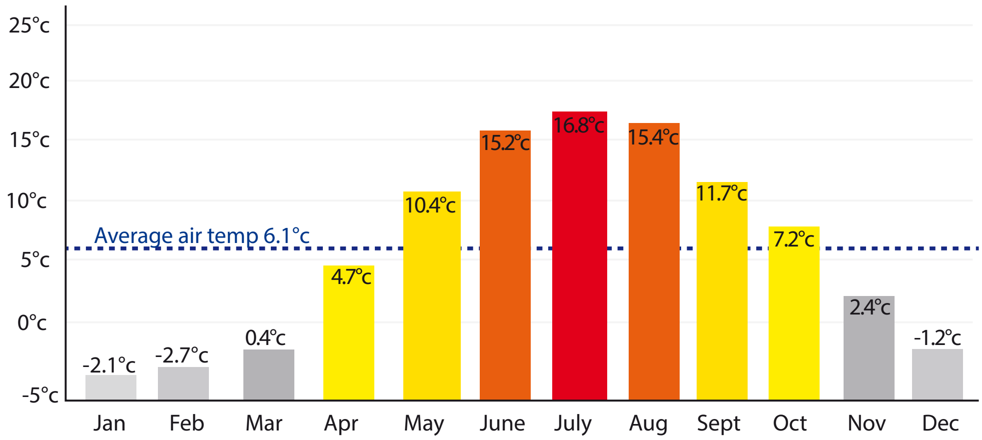
Climatological settings

HDD/CDD data accordingly to the local methodologies at the Pilot areas	
Heating degree days (HDD) / a/baseline reference values / period of data for calculations (note unit is hours)	4682; (15°C/15°C) (period 2011 – 2016)
Cooling degree days (CDD) / a/b values / period of data for calculations	(21°C/21°C) (period 2011 – 2016)
Length of the heating season (days)	Unknown
Length of the cooling season (days)	Unknown

Source of data: Eurostat. https://ec.europa.eu/eurostat/data/database

LINKÖPING FACTSHEET

Average monthly and annual air temperature



Market situation

Number of SGE installations in pilot area	V-CLS	0 (OD) 62 (OD) 10 (EST)
Current growth rate	No. of Installations	10 (EST)
Estimated share of open loop systems		0
Estimated share of closed loop systems		100
Estimated total share of shallow geothermal methods in the heating market	V-CLS	100
Other SGE technologies: Eg. Inter-seasonal heat storage schemes or energy piles	Unknown	
Estimated total share of RES in the heating energy market (%) (specify local or national values)		Unknown

Economic boundary conditions

Estimated average installation costs for shallow geothermal systems (€/kW output) [1]	
Open loop systems	Unknown
Closed loop systems	1 500 - 2000 €/kW
Estimated average heating costs (€/kWh)	
Open loop systems	Unknown
Closed loop systems	0.06 €/kWh
Drilling cost range per meter (€/m) for Open Loop	100 €/m
Drilling cost range per meter (€/m) for Borehole Closed Loop	100 €/m

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Regional geological and hydrogeological characteristics

Bedrock Age: Precambrian (1700-2000 Ma)

Bedrock lithologies: Svecofennian granite and gneissic granitoids, and metabasite

Quaternary: 5-10 m thick glacial sandy-silty till and postglacial clay

Faults and deformation zones: the pilot area is transected by several brittle deformations zones resulting in increased fracturing

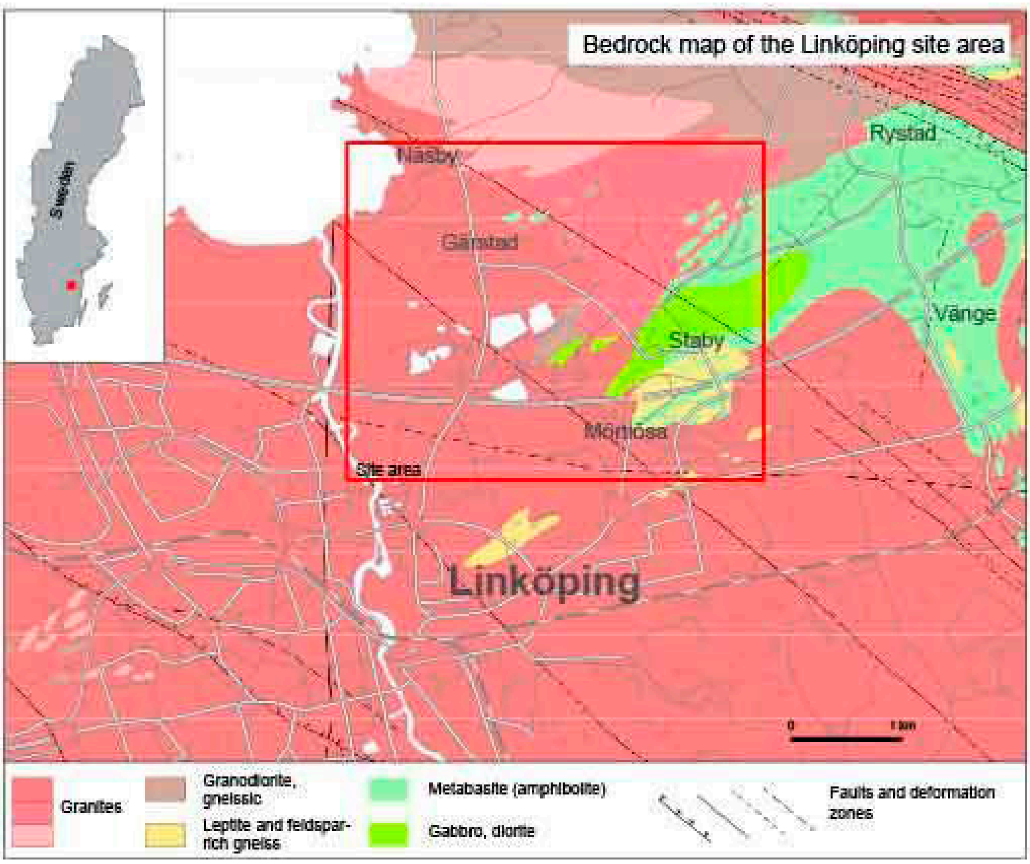
Target aquifer unit(s): minor local aquifers in the Quaternary deposits. Main aqiufer consists of the fractured bedrock domain down to c. 150 m depth where the salinity of the groundwater disqualifies its use as freshwater resource.

TRT data indicate a Lambda values between 2.73 and 3.28 W/mK

Depth to water table(s): 2-3 m below surface

Average groundwater temperature: 9.5°C

Temperature at 300 m: 11.6°C



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Description of the works

The geological survey of Sweden has been involved in the design of the pre-investigations intended to define the most suitable location of a multi- well High temprature-BTES plant in Linköping. The ongoing thermal evaluations are performed by consulting agencies specialized in design and monitoring of borehole heat exchangers using distributed temperature measurements (DTRT). These investigations are to be complemented by geological and hydrogeological characterizations of the site area. The intention is to evaluate the pre-investigations with respect to the composition of the bedrock mass and groundwater conditions. The thermal data will be available for the GeoERA project as well as the possibility to perform additional measurements and tests in the existing wells. The geological survey is today working with compiling maps of the thermal properties of the bedrock, based on models of modal composition of rocks and TCS measurements as well as collecting TRT and DTRT data from SGE systems. The Linköping pilot will give an opportunity to further evaluate this data as well as testing the relevance and relation between different types of data sets in the selection process as well in the assessment of risks and environmental impact. The stakeholder "Linköpings Tekniska Verk" has committed to let us use the data involving the properties necessary for the modelling and to be a stakeholder contact. The planned activities include geophysical ground measurements and wire-line logging as well as thermal measurements on rock samples and thermal modelling using petrological modal data.

Summary of works and timeline

Main Objectives	
✓	Evaluation and characterization of geology/ hydrogeology / thermal conditions
✓	SGE assessment resources (for OCS and/or CLS) / and evaluation of UTES-BTES)
✓	Study of conflicts of use (OLS / GWL - OLS/CLS). Hazards/interferences, effects on sub-surface
✓	Strategies and actions for management and local energy plans
Relation of foreseen tasks	
✓	Data collection (TRT, DTRT, rock samples, GWL, T-profile's etc)
✓	New field works (TRT/geophysics /new samples and lab etc)
	Monitoring existing SGE/GWL/T etc)
✓	Mapping (in general terms)
✓	2D/3D Modelling (in general terms)

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Detailed summary of works at the Pilot Areas and brief timeline

March 2019 – March 2020 MUSE monitoring period.

Measurement of thermal properties on rock types occurring in the site area

Construction of bedrock geothermal prognosis map

Characterization of groundwater conditions

Geophysical Investigations for location of hydraulically significant fracture zones

Wire-line logging of test wells

Geological correlation of DTRT data

Communication with stakeholder

Contact

Managing Urban Shallow geothermal Energy
Project number GeoE.171.006

Website - www.geoera.eu/projects/muse
MUSE Project office: MUSE@geologie.ac.at
Pilot area contact person: Mikael Erlstrom

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ES/WP4/D4.1/FS03/2018

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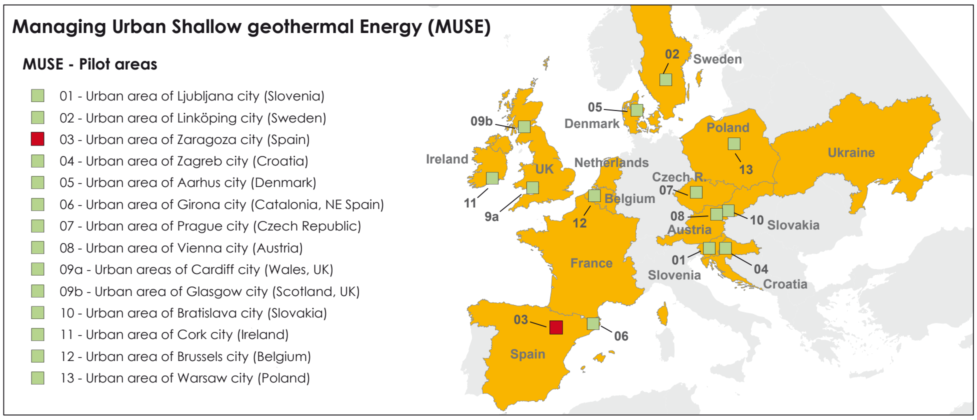
Pilot area information



The pilot area is located In the central sector of the Ebro River basin (Spain), where the confluence of the Gállego and Huerva River tributaries occurs. In this area there is an important alluvial aquifer that is overlain in part by the Metropolitan Area of Zaragoza. The main uses of groundwater are watering public parks and gardens (14%), processing water supplies (8%), recreational use (10%) and geothermal use (68%). The urban alluvial aquifer has experienced an intensive geothermal exploitation since the early 2000s. A total of approximately 250 wells are currently in use in the urban area of Zaragoza, where a total of 71 GWHPs involve 176 geothermal wells (105 are production or pumping wells, and 71 are for injection) that reach depths ranging from 20 to 60 m. The first estimates of the total heat power installed can add up to 110 MWt for cooling purposes (of which only 67 MWt is actually supplied for cooling purposes), where 21 installations are equipped with reverse-cycle heat pumps with 34 MWt of heat power that is actually supplied for heating demand.

Pilot Area	Zaragoza
Task (MUSE)	T-4.4
Country	Spain
Area (km²)	106.03 km²
Total number of inhabitants (date)	697,895 (2018)
Inhabitants per km²	721.66
Level of urbanization	Unknown
Elevation range (m a.s.l.)	184-265

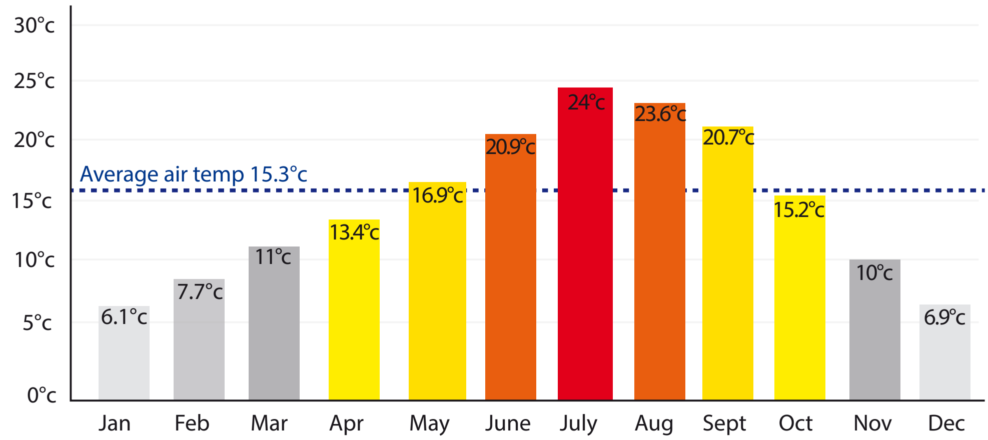
Climatological settings

HDD/CDD data according to EUROSTAT method	
Heating degree days (HDD); [baseline reference values]; (period for data calculations)	1749 [15/18] (2017)
Cooling degree days (CDD); [baseline reference values]; (period for data calculations)	283 [21/24] (2017)
Length of the heating season (days)	155
Length of the cooling season (days)	124

Source of data: Eurostat. https://ec.europa.eu/eurostat/data/database

ZARAGOZA FACTSHEET

Average monthly and annual air temperature



Market situation

Number of SGE installations in pilot area	OLS	71 (OD)
Current growth rate	No. of Installations	2.8% (EST)
Estimated share of open loop systems		Unknown
Estimated share of closed loop systems		Unknown
Estimated total share of shallow geothermal methods in the heating market	Unknown	Unknown
Other SGE technologies: Are there inter-seasonal heat storage schemes or energy piles in your pilot area?	Unknown	Unknown
Estimated total share of RES in the heating energy market (%) (specify local or national values)		Unknown

Economic boundary conditions

Estimated average installation costs for shallow geothermal systems (€/kW output) [1]	
Open loop systems	Unknown
Closed loop systems	Unknown
Estimated average heating costs (€/kWh)	
Open loop systems	Unknown
Closed loop systems	Unknown
Drilling cost range per meter (€/m) for Open Loop	Unknown
Drilling cost range per meter (€/m) for Borehole Closed Loop	Unknown

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Regional geological and hydrogeological characteristics

Geological Situation in Pilot area

Bedrock Age: Oligo-Miocene

Bedrock Depositional Environment: Extensive high-salinity playa-lake Bedrock lithologies: Anhydrite/gypsum, halite and glauberite, with interlayered marls and mudrocks including calcite, dolomite and quartz grains

Quaternary: alluvial deposits formed by gravels dominated by carbonate and siliciclastic materials with a sand-silt matrix, frequently cemented by carbonates.

Hydrogeology

The city of Zaragoza overlays the alluvial aquifer of the Ebro River [1]. The portion of this alluvial aquifer under the city of Zaragoza is called the "Urban alluvial Aquifer of Zaragoza". The aquifer is composed of two primary sedimentary domains corresponding to Quaternary alluvial terraces related to the Ebro River and tributaries and to a Quaternary alluvial fan area in genetic relation with the Huerva tributary. The terrace deposits are formed by channel facies with siliceous and carbonate gravels, generally grain supported, which are presented in high lateral extension with several meters thickness. Generally, these deposits are tabular bodies with cross-bedding; however, channel bodies with trough cross-bedding are dominant locally. A general W–E flow pattern in the northwest sector of the pilot area can be identified that changes to a NW–SE flow pattern in the southeast. At the south, the hydraulic connection of the Huerva alluvial aquifer with the Ebro River alluvial aquifer in the central sector generates a groundwater flow toward the Ebro River through the alluvial fans and discharges into the terraces, where the groundwater acquires a W–E flow direction nearly parallel to the Ebro River. Transmissivities vary from 3·102 up to 4·103 m2day-1[2].

Pumping tests are available but TRT test data is not

Depth to water table(s): 5 to 34 m below surface

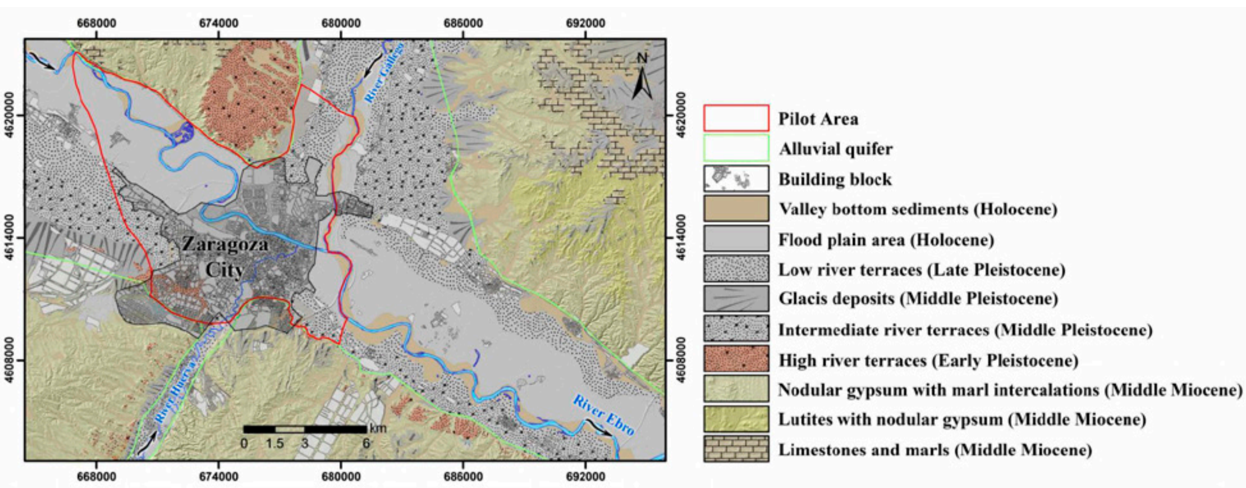
Aquifer unit thickness: (5-60 m)

Thermogeology

Groundwater temperature: (Ave, Min Max range)= 17.0 oC, 16.9 17.2 0.3 oC)

Zone of Seasonal Fluctuations: 9-12 m

42 groundwater monitoring points.



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ZARAGOZA

Summary of works and timeline

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Relation of foreseen tasks	
	Data collection (TRT, DTRT, rock samples, GWL, T-profile's etc)
	New field works (TRT/geophysics /new samples and lab etc)
✓	Monitoring existing SGE/GWL/T etc)
	Mapping (in general terms)
✓	2D/3D Modelling (in general terms)

Detailed summary of works at the Pilot Areas and brief timeline

The aim of MUSE in the pilot area of Zaragoza is to exchange problems, experiences, solutions and research results with other pilot areas in order to develop management indicators to be applied. This will allow us to provide a scientifically-based procedure to assess the state of the shallow geothermal resources and identify possible existing conflicts of use in the resource exploitation at a city scale.

March 2019 – March 2020 MUSE monitoring period.
Baseline temperature monitoring
OLS monitoring
Mapping installed systems and potential conflicts of use
Heat flow or Hydrogeological models (FEFLOW)
3D Geological Models (ESRI)

Reference

García-Gil, E. Vázquez-Suñe, E. Garrido, J.A. Sánchez-Navarro, J. Mateo-Lázaro, The thermal consequences of river-level variations in an urban groundwater body highly affected by groundwater heat pumps, Science of the Total Environment (2014).

García-Gil, E. Vázquez-Suñé, J.A. Sánchez-Navarro, J. Lázaro, Recovery of energetically overexploited urban aquifers using surface water, Journal of Hydrology 1(1) (2015) 111.

Contact

Managing Urban Shallow geothermal Energy
Project number GeoE.171.006

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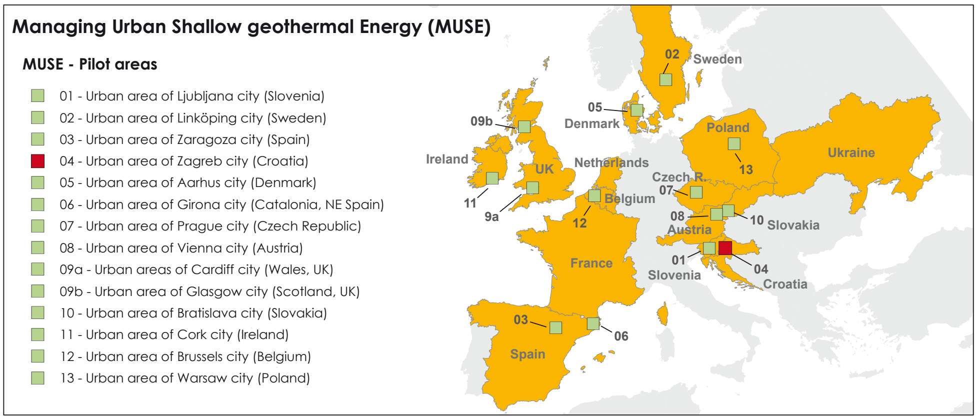
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731166

GeoERA

ZAGREB FACTSHEET

HR/WP4/D4.1/FS04/2018

Pilot area information



Pilot actions in the City of Zagreb urban area will concentrate on the influence of open-loop groundwater heat pump systems at two locations. The systems are abstracting water from, and reinjecting it into, the shallow aquifer which is also used for public water supply of the City of Zagreb. A continuous monitoring scheme will be established using their wells and the nearby observation boreholes to determine groundwater level draw-downs and temperature changes in the investigated shallow aquifer.

Heat pump utilization in Zagreb (as well as in Croatia in general) is regulated only for open-loop systems since they need to obtain water permits and concession for economic utilization of water. However, closed-loop systems are unregulated in the whole country, so their existence and number are only a matter of speculation and educated guesses, since no permitting is required.

Pilot Area	Zagreb
Task (MUSE)	T-4.7
Country	Croatia
Area (km²)	641 km²
Total number of inhabitants (date)	802,338 (2018)
Inhabitants per km²	1,232
Level of urbanization	Unknown
Elevation range (m a.s.l.)	120 - 1,033 (majority 120 - 300)

Climatological settings

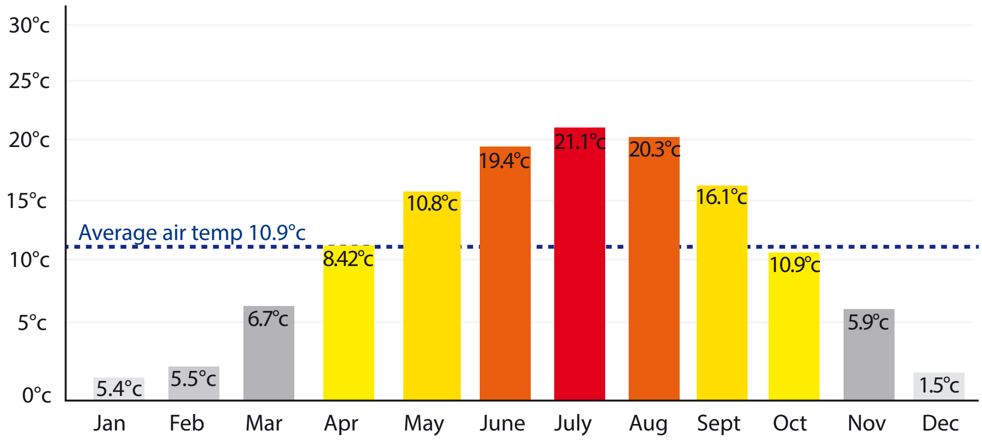
HDD/CDD data according to EUROSTAT method	
Heating degree days (HDD); [baseline reference values]; (period for data calculations)	2396 [15/18] (2017)
Cooling degree days (CDD); [baseline reference values]; (period for data calculations)	196 [21/24] (2017)
Length of the heating season (days)	220
Length of the cooling season (days)	Unknown

Source of data: Eurostat. https://ec.europa.eu/eurostat/data/database

ZAGREB

ZAGREB FACTSHEET

Average monthly and annual air temperature



Market situation

Number of SGE installations in pilot area	Unknown	0 (OD) 20 (OD) 10 (EST)
Current growth rate	Unknown	
Estimated share of open loop systems		
Estimated share of closed loop systems		
Estimated total share of shallow geothermal methods in the heating market	Unknown	
Other SGE technologies: Eg. Inter-seasonal heat storage schemes or energy piles	Unknown	
Estimated total share of RES in the heating energy market (%) (specify local or national values)		

Economic boundary conditions

Estimated average installation costs for shallow geothermal systems (€/kW output) [1]	
Open loop systems	800 (based on 500 kW system)
Closed loop systems	1333 (based on 12 kW system)
Estimated average heating costs (€/kWh)	
Open loop systems	0.05 - 0.07
Closed loop systems	0.07 - 0.08
Drilling cost range per meter (€/m) for Open Loop	120
Drilling cost range per meter (€/m) for Borehole Closed Loop	60

ZAGREB
FACTSHEET

Regional geological and hydrogeological characteristics

Geological Situation in Pilot area
Bedrock Age: Triassic
Bedrock Depositional Environment: marine - intertidal
Bedrock lithologies: limestone and dolomite
Tertiary: thick layers of marls, fine-grained sandstones, siltstones and claystones
Quaternary - Holocene: alluvial sediments, anthropogenic deposits.

Hydrogeology
The aquifer system comprises two Quaternary aquifers. Quaternary deposits are divided into three basic units: the overburden of clay and silt; a shallow Holocene aquifer of medium-grain gravel mixed with sands; and deeper aquifers from the Middle and Upper Pleistocene, with frequent lateral and vertical alternations of gravel, sand and clay.
Major Faults/ Hazards: major fault at the foothills of Medvednica Mt., active, epicenters usually W from Zagreb; landslide hazard
Target aquifer unit: Zagreb aquifer - a thick, mostly gravelly aquifer, also utilized for water supply of the urban area
Pumping test data and TRT data are available.
Depth to water table(s): 1 to 11 m below surface
Aquifer unit thickness:

Thermogeology
Groundwater temperature: 11.4 - 17 °C; average 13.5 [06]
Zone of Seasonal Fluctuations: 12 m below surface [07]

Summary of works and timeline

Main Objectives	
✓	Evaluation and characterization of geology/ hydrogeology / thermal conditions
✓	SGE assessment resources (for OCS and/or CLS) / and evaluation of UTES-BTES)
✓	Study of conflicts of use (OLS / GWL - OLS/CLS). Hazards/interferences, effects on sub-surface
	Strategies and actions for management and local energy plans
Relation of foreseen tasks	
✓	Data collection (TRT, DTRT, rock samples, GWL, T-profile's etc)
	New field works (TRT/geophysics /new samples and lab etc)
✓	Monitoring existing SGE/GWL/T etc)
✓	Mapping (in general terms)
✓	2D/3D Modelling (in general terms)

ZAGREB FACTSHEET

Detailed summary of works at the Pilot Areas and brief timeline

March 2019 – March 2020 MUSE monitoring period.

Planned activities for March 2019 – March 2020 MUSE monitoring period.
(Dec 2018 - as long as possible, probably also after project closure)
Investigation of aquifer properties
Baseline temperature monitoring
GSHP pilot monitoring
Mapping installed systems and potential conflicts of use
Heat flow or Hydrogeological models.
3D Geological Models (software used)

Reference

City of Zagreb official web-site (https://www.zagreb.hr/)

Croatian bureau of statistics (https://www.dzs.hr/default_e.htm)

Official Gazette (https://narodne-ovine.nn.hr/clanci/sluzbeni/2015_11_128_2428.html; https://narodne-novine.nn.hr/clanci/sluzbeni/2010_03_36_930.html; https://narodne-novine.nn.hr/clanci/sluzbeni/dodatni/408177.pdf

Croatian meteorological and Hydrological Service (http://meteo.hr/klima.php?section=klima_podaci&param=k1&Grad=zagreb_maksimir)

Naki , Z., Ruži i , S., Posavec, K., Mileusni , M., Parlov, J., Ba ani, A., and Durn, G., 2013, Conceptual model for groundwater status and risk assessment - case study of the Zagreb aquifer system: Geologia Croatica, v. 66, no. 1, p. 55-76.

Kova , Z., Naki , Z., and Pavli , K., 2017, Influence of groundwater quality indicators on nitrate concentrations in the Zagreb aquifer system: Geologia Croatica, v. 70, no. 2, p. 93-103.

[07] - Kurevija, T., 2010, Energetic evaluation of the shallow geothermal potential in the Republic of Croatia [PhD: University of Zagreb, 183 p.

Contact

Managing Urban Shallow geothermal Energy
Project number GeoE.171.006

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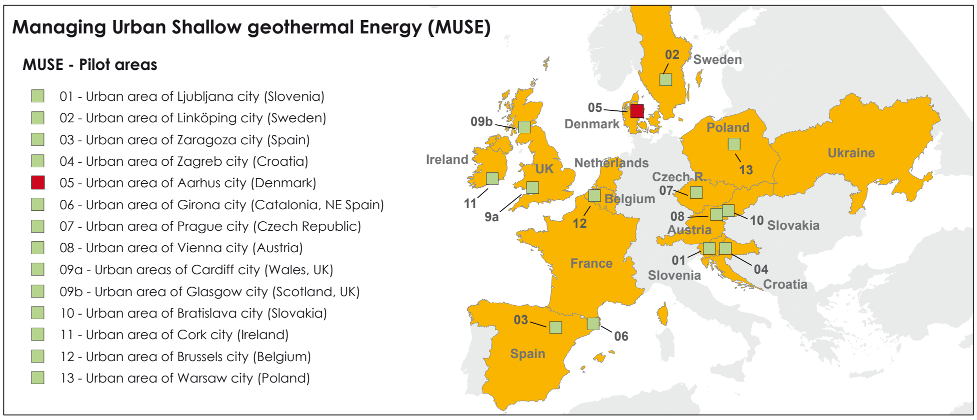
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731166

AARHUS FACTSHEET

DK/WP4/D4.1/FS05/2018

Pilot area information



This pilot area comprises the municipal area of Aarhus, and the aim of the desktop case study is to investigate the possibilities of integrating SGE and energy storage in a mature central heating system. Potential geothermal resources will be mapped using a wide arrange of existing geological and geophysical data. A catalogue of relevant SGE technologies prepared in WP2 will feed into a current update of the heating plans for Aarhus. Furthermore, the work will focus on the local possibilities of geological energy storage, mapping of potential sites for storage and extraction of heat; mapping potential conflicts; prioritising possible sites in relation to expected yield and proximity to the existing grid; and the integration of the results into the local energy plans.

Pilot Area	Aarhus
Task (MUSE)	T-4.6
Country	Denmark
Area (km²)	469 km²
Total number of inhabitants (date)	336,411 (2017)
Inhabitants per km²	717
Level of urbanization	Unknown
Elevation range (m a.s.l.)	0 -128 (1-100 populated)

Climatological settings

HDD/CDD data accordingly to the local methodologies at the Pilot areas	
Heating degree days (HDD) / a/baseline reference values / period of data for calculations (note unit is hours)	2722; (17°C/17°C) (period 2011-2017)
Cooling degree days (CDD) / a/b values / period of data for calculations	Unknown
Length of the heating season (days)	Unknown
Length of the cooling season (days)	Unknown

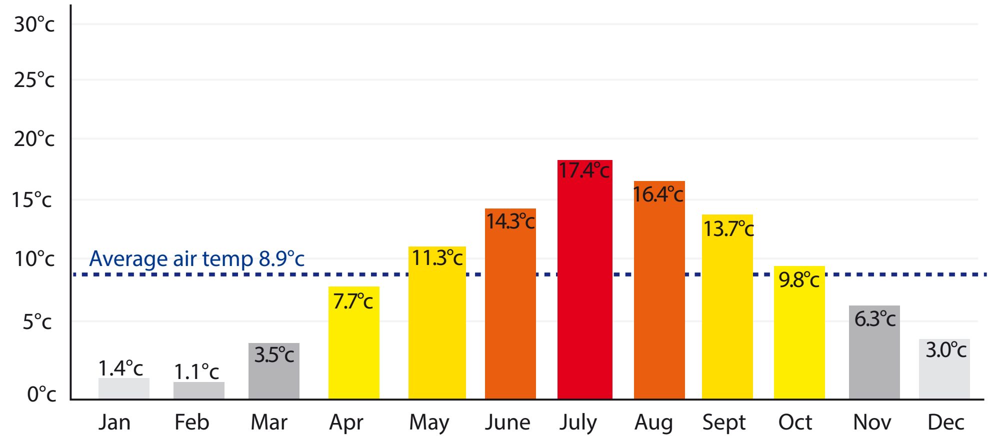
Source of data: Eurostat. https://ec.europa.eu/eurostat/data/database

AARHUS

GeoERA

AARHUS FACTSHEET

Average monthly and annual air temperature



Market situation

Number of SGE installations in pilot area	OLS V-CLS H-CLS	4 plants (36 boreholes) (EST)
Current growth rate	Heat production	
Estimated share of open loop systems		
Estimated share of closed loop systems		
Estimated total share of shallow geothermal methods in the heating market	Unknown	
Other SGE technologies: Eg. Inter-seasonal heat storage schemes or energy piles	Unknown	
Estimated total share of RES in the heating energy market (%) (specify local or national values)		

Economic boundary conditions

Estimated average installation costs for shallow geothermal systems (€/kW output) [1]	
Open loop systems	Unknown
Closed loop systems	Unknown
Estimated average heating costs (€/kWh)	
Open loop systems	Unknown
Closed loop systems	Unknown
Drilling cost range per meter (€/m) for Open Loop	Unknown
Drilling cost range per meter (€/m) for Borehole Closed Loop	Unknown

GeoERA

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FACTSHEET

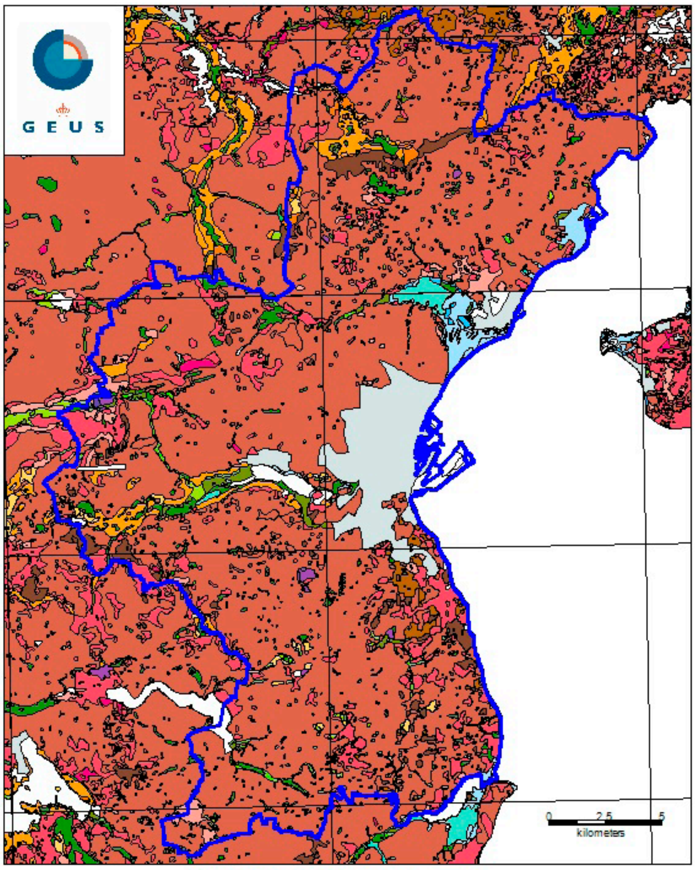
Regional geological and hydrogeological characteristics

Geological Situation in Pilot area
Bedrock Age: Danien to Miocæne
Bedrock Depositional Environment: Marine, shallow marine and fluvio-deltaic
Bedrock lithologies: (Danien Limestone. Paleocene –Oligocene smectitic marine clays. Miocene marine silty muds and deltaic quartz rich sands

Quaternary: Glacial (Devension and older) including deep buried valleys .
Shallow marine, (Holocene),
Anthropogenic 800 AD and younger in city center up to 5 m approx.

Hydrogeology
Target aquifer unit(s): Glacio- fluvial sand and gravel in buried valleys. Groundwater flow direction (general). Towards the coast (eastwards). Locally following buried valleys.
Is pump tests data available Yes
Is TRT test data available Probably not
Depth to water table(s): 1 to 30 m below surface
Aquifer unit thickness: (0-50m)

Thermogeology
Groundwater temperature: (Ave, Min Max range) 8,5 oC, (7-11 oC)



Surface geological map
Pilot Area Aarhus

Main lithologies:
Clay Till
Diluvial Sand
Postglacial fresh-water dep.
City center (not mapped)
Extramarginal glacio-fluvial sand
Postglacial marine dep.

AARHUS FACTSHEET

Summary of works and timeline

Main Objectives	
✓	Evaluation and characterization of geology/ hydrogeology / thermal conditions
✓	SGE assessment resources (for OCS and/or CLS) / and evaluation of UTES-BTES)
	Study of conflicts of use (OLS / GWL - OLS/CLS). Hazards/interferences, effects on sub-surface
	Strategies and actions for management and local energy plans
Relation of foreseen tasks	
✓	Data collection (TRT, DTRT, rock samples, GWL, T-profile's etc)
	New field works (TRT/geophysics /new samples and lab etc)
	Monitoring existing SGE/GWL/T etc)
✓	Mapping (in general terms)
	2D/3D Modelling (in general terms)

Detailed summary of works at the Pilot Areas and brief timeline

March 2019 – March 2020 MUSE monitoring period.

Planned activities for March 2019 – March 2020 MUSE monitoring period.

Screening existing geological and geophysical data for

1) Aquifers with limited drinking water interests. Seeking pumping test from these areas

2) Deposits with limited groundwater flow suited for BTES installations

Mapping the amount, temperature and location of excessive heat in the district heating system as well as the seasonal variations.

Introducing technologies from WP2 to the local stakeholder

References

http://data.geus.dk/geusmap/?mapname=varmelagring&lang=en
https://aarhus.dk/english/collaborate-with-the-city/urban-development/the-environment/#1

Contact

Managing Urban Shallow geothermal Energy
Project number GeoE.171.006

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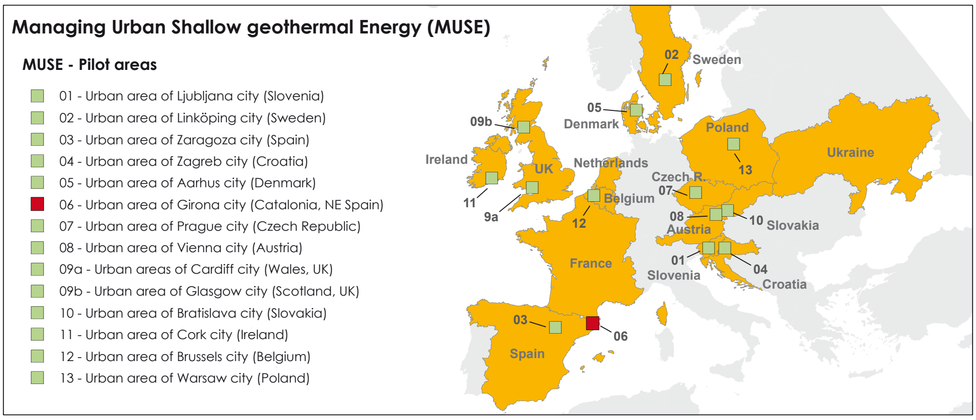
GeoERA

GIRONA FACTSHEET

ES/WP4/D4.1/FS06/2018

Pilot area information



The metropolitan urban area of Girona city (Girona and Salt cities, and surroundings) is a model for urban areas with a poorly-developed shallow geothermal energy (SGA) market. Until recently, only a few closed-loop systems existed in the whole area. Utilization of shallow geothermal energy for heating and cooling is increasing in Catalonia, from 2016 to 2018 the overall installed thermal power has increased more than 140%. Despite this increase, geothermal energy still covers just a minor part of the heating market. The topographical level of the study area varies from 65 to 186 m a.s.l., temperature ranges from 8.2ºC to 22.3ºC, with a mean value of 14.7ºC, maximum of 37.5ºC and minimum values of -6.8ºC. Urban area of Girona stands on Cambro-Ordovician, Carboniferous-Permian and Paleogene bedrock, configuring a basin filled with Neogene continental alluvial deposits and quaternary fluvial sediments, which aquifers will be utilized for geothermal development. Groundwater is rather shallow, i.e. 3 – 26 m below surface [1], and water temperature varies between 16oC and 17oC. Hydraulic conductivity of surface deposits varies between 0,1 to 1 m/d for the Neogene aquifer and from 4 to 80 m/d for the alluvium quaternary deposits (Ter and Onyar rivers).

Pilot Area	Girona
Task (MUSE)	T-4.7
Country	(Catalonia); Spain
Area (km²)	48 km2 (39,1 km2 from Girona city)
Total number of inhabitants (date)	138.702 inhabitants (2016) (98.255 from Girona city)
Inhabitants per km²	2.889 hab./km² (2016) (2512 hab./km² from Girona city)
Level of urbanization	16 km² /48 km² = 33% (2016) (12 km² /39 km² = 30% from consolidated urban area of Girona city)
Elevation range (m a.s.l.)	65 – 186

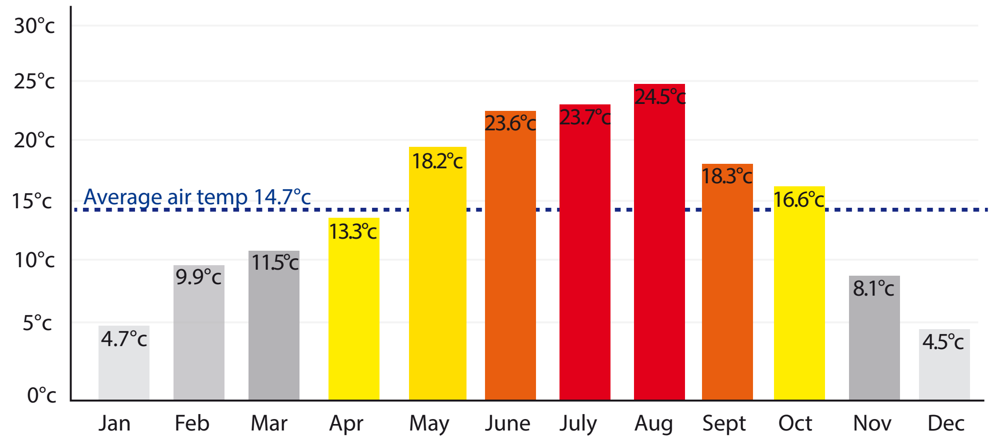
GIRONA FACTSHEET

Climatological settings

HDD/CDD data according to EUROSTAT method	
Heating degree days (HDD); [baseline reference values]; (period for data calculations)	1733 [15/18] (2017)
Cooling degree days (CDD); [baseline reference values]; (period for data calculations)	228 [21/24] (2017)
Length of the heating season (days)	106; (18°C/18°C) 79; (15°C/15°C)
Length of the cooling season (days)	74; (20°C/20°C) 61; (23°C/23°C)

Source of data: Eurostat. https://ec.europa.eu/eurostat/data/database

Average monthly and annual air temperature



Market situation

Number of SGE installations in pilot area	V-CLS	16 (OD)
Current growth rate	No. of Installations	140% from 2016 in Cat
Estimated share of open loop systems		
Estimated share of closed loop systems		
Estimated total share of shallow geothermal methods in the heating market	V-CLS	5%
Other SGE technologies: Are there inter-seasonal heat storage schemes or energy piles in your pilot area?	Unknown	No UTES exists Unknown foundation piles
Estimated total share of RES in the heating energy market (%) (specify local or national values)		8.5%

GIRONA

GeoERA

GIRONA FACTSHEET

Economic boundary conditions

Estimated average installation costs for shallow geothermal systems (€/kW output) [1]	
Open loop systems	Unknown
Closed loop systems	1700 - 2200€/ kWt
Estimated average heating costs (€/kWh)	
Open loop systems	Unknown
Closed loop systems	0.025 – 0.05 €/kWh (data: 2012)
Drilling cost range per meter (€/m) for Open Loop	50-600 €/m.l. (percussion drilling rig – Ø 250/500mm)
Drilling cost range per meter (€/m) for Borehole Closed Loop	50 -60 €/m.l. (rotary air percussion drilling rig - Ø 115/150mm)

Regional geological and hydrogeological characteristics

Bedrock:
Paleozoic (schists, slates and quartzites intruded with quartz and aplite dykes and veins; post-Variscian granodiorites and granites) and Paleogene (lower and middle Eocene: Nummulite limestones and marls). Geological structure: highly controlled by major normal faults in NW-SE direction.

Plio-Quaternary:
Continental alluvial fans and fluvial sediments. Shales and coarse sands with gravel and conglomerate intercalations from Pliocene and alluvial and fluvial coarse sediments in the Quaternary related to the Ter and Onyar rivers. Anthropogenic deposits are observed as well.

Hydrogeology:
Target aquifers: The alluvial Quaternary aquifers associated to Ter and Onyar rivers, and the semi-confined Pliocene aquifer. Other aquifers are located in the highest parts of the city (karstic limestone aquifer - Eocene) In general, groundwater flows eastwards.

- Alluvial aquifers: show medium-high permeability (gravels) to lower permeability (clays). Intergranular porosity. GWL situated from 3 to 8 m deep [01]. Permeability ranges from 4 to 80 m/d.
- Pliocene aquifer: low permeability (gravel and conglomerate) to very low permeability (silt and clays). Intergranular porosity. GWL situated from 10 to 26 m deep [01]. Permeability ranges from 0,1 to 1 m/d.
- Limestone aquifer: Fractured and karstic dual porosity, unconfined/confined. GWL: from artesian conditions to 70 m deep. Highly variable permeability.

Thermogeology:
Measured groundwater temperature: 16 - 17oC (from 50 to 100m deep) (nov18).

GIRONA

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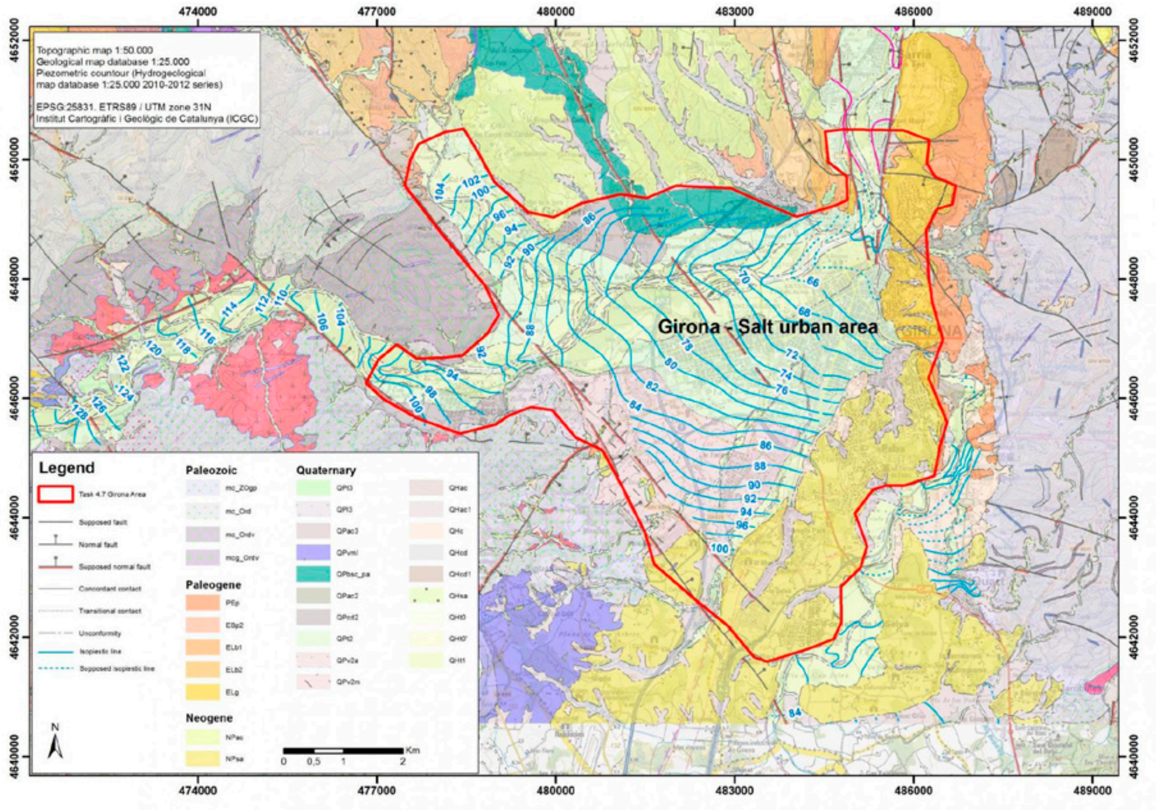
GIRONA



Summary of works and timeline

Main Objectives	
✓	Evaluation and characterization of geology/ hydrogeology / thermal conditions
✓	SGE assessment resources (for OCS and/or CLS) / and evaluation of UTES-BTES)
	Study of conflicts of use (OLS / GWL - OLS/CLS). Hazards/interferences, effects on sub-surface
✓	Strategies and actions for management and local energy plans
Relation of foreseen tasks	
✓	Data collection (TRT, DTRT, rock samples, GWL, T-profile's etc)
✓	New field works (TRT/geophysics /new samples and lab etc)
✓	Monitoring existing SGE/GWL/T etc)
✓	Mapping (in general terms)
✓	2D/3D Modelling (in general terms)

GIRONA FACTSHEET

Detailed summary of works at the Pilot Areas and brief timeline

March 2019 – March 2020 MUSE monitoring period.

Field works - Data collection
Borehole construction (foreseen 3 to 10 wells) (Nov 2018 – March 2019)
Geophysical well logging: Gamma ray and temperature profiles
Environmental baseline monitoring: GWL and T° (data sensors)

TRT (expected 3 to 4 new TRT)
Characterization, analyses and assessment:
Characterization of geology/ hydrogeology / thermal conditions
Baseline temperature monitoring - mapping
3D Geological, hydrogeological and thermal modelling (LeapFrog3D and Feflow)
Assessment and mapping of shallow geothermal potential of open and closed loop systems
Development of guides for deployment and integration SGE in energy plans

Reference

Arnó G., Colomer M., Camps V., Carbonell J., Riberta F., Núñez J. A., Rivas Pozo M., Nogués A. and Vega J. L. (2015). Geotreball V. Mapa hidrogeològic. Salt 333-2-1 (76-25). Institut Cartogràfic i Geològic de Catalunya (ICGC).

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Margarit i Roset, Jaume, Vilalta i Juvanteny, Lluís, Escobar i Mariné, Miquel A. (2003): Els graus-dia de calefacció i refrigeració de Catalunya: resultats a nivell municipal. Estudis monogràfics: 14, Institut Català d'Energia, Departament de Treball, Indústria, Comerç i Turisme, Generalitat de Catalunya

Meteorological Service of Catalonia (2018). meteo.cat

Contact

Managing Urban Shallow geothermal Energy
Project number GeoE.171.006

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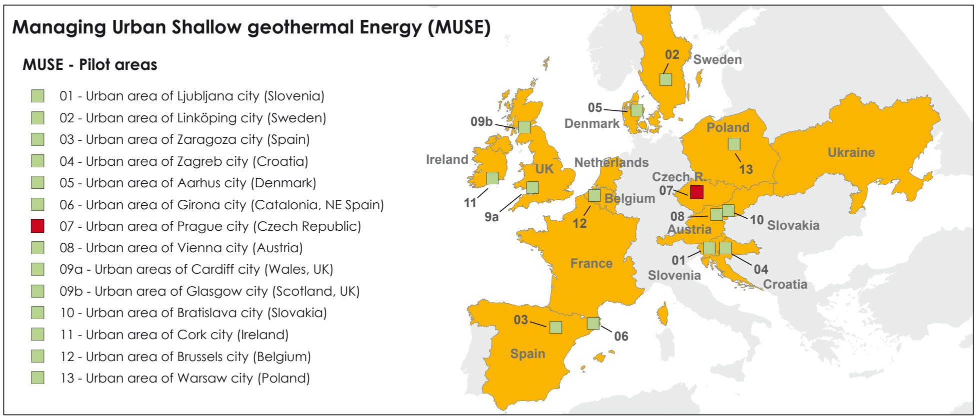
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731166

G I R O N A

PRAGUE FACTSHEET

CZ/WP4/D4.1/FS07/2018

Pilot area information



The urban area of Prague acts as a model for urban areas of medium-developed SGE market. The topographical level varies from 177 to 399 m a.s.l. Temperature ranges from 1 °C (-3 °C at night) in winter to 24 °C (13 °C at night) in summer, with a mean value of 8.5 °C. Relative humidity is 65 to 90%.

Shallow geothermal for heating and market is slightly increasing in Czech Republic, although the exact data are not freely available. In the specific case of Prague city, the number of SGE installations and projects have increased largely recently due to higher interest of public and business sector. Several projects of multi-borehole heat exchanger arrays are under construction currently.

Pilot Area	Prague
Task (MUSE)	T-4.8
Country	Czech Republic
Area (km²)	496km²
Total number of inhabitants (date)	1,294,513 (2018)
Inhabitants per km²2	610
Level of urbanization	100%
Elevation range (m a.s.l.)	177 - 399

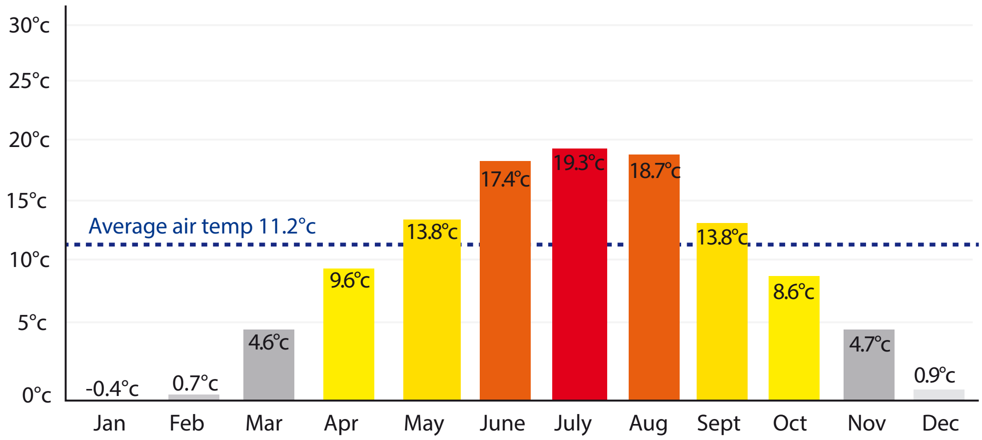
Climatological settings

HDD/CDD data according to EUROSTAT method	
Heating degree days (HDD); [baseline reference values]; (period for data calculations)	2985 [15/18] (2017)
Cooling degree days (CDD); [baseline reference values]; (period for data calculations)	53 [21/24] (2017)
Length of the heating season (days)	232 (period 2007-2017)
Length of the cooling season (days)	Unknown

Source of data: Eurostat. https://ec.europa.eu/eurostat/data/database

PRAGUE FACTSHEET

Average monthly and annual air temperature



Market situation

Number of SGE installations in pilot area	OLS V-CLS H-CLS	Unknown 40 (EST) 0 (EST)
Current growth rate	No. of Installations	10
Estimated share of open loop systems		10%
Estimated share of closed loop systems		90%
Estimated total share of shallow geothermal methods in the heating market	V-CLS	1%
Other SGE technologies: Eg. Inter-seasonal heat storage schemes or energy piles	Unknown	
Estimated total share of RES in the heating energy market (%) (specify local or national values)		10.5% (national)

Economic boundary conditions

Estimated average installation costs for shallow geothermal systems (€/kW output) [1]	
Open loop systems	Unknown
Closed loop systems	1700
Estimated average heating costs (€/kWh)	
Open loop systems	Unknown
Closed loop systems	0.06
Drilling cost range per meter (€/m) for Open Loop	Unknown
Drilling cost range per meter (€/m) for Borehole Closed Loop	35 - 40

PRAGUE

GeoERA

PRAGUE FACTSHEET

Regional geological and hydrogeological characteristics

Pilot area: Prague
Bedrock Age: Neoproterozoic-Paleozoic (folded)
Bedrock Depositional Environment: Marine
Bedrock lithologies: Greywacke, sandstone, interlayered shales and sandstones, limestones
Platform sediments: Cretaceous marlstones to sandstones
Quaternary: River terrace sands and gravels, loesses, anthropogenic deposits. Include typical thickness of superficial overburden.
Karst is developed in Silurian and Devonian limestones, possibly also in cretaceous marlstones.

Hydrogeology
Target aquifer unit(s):
A) Proterozoic to Ordovician fractured sedimentary rock aquifer
B) Highly permeable lowest river terrace (sand and gravel, average aquifer thickness 3-5 m, Kf = 1.10-1 m.s-1), water level connected with river.

Hydrochemistry:
A) Fractured rock aquifer - 400 – 1500 mg/l, Ca-SO4 type
B) River terrace aquifer – lower mineralization due to mixing with river water

Pump tests data are available, TRT test data can be acquired from geothermal exploration companies.

PRAGUE

PRAGUE FACTSHEET

Summary of works and timeline

Main Objectives	
	Evaluation and characterization of geology/ hydrogeology / thermal conditions
	SGE assessment resources (for OCS and/or CLS) / and evaluation of UTES-BTES)
✓	Study of conflicts of use (OLS / GWL - OLS/CLS). Hazards/interferences, effects on sub-surface
✓	Strategies and actions for management and local energy plans
Relation of foreseen tasks	
	Data collection (TRT, DTRT, rock samples, GWL, T-profile's etc)
	New field works (TRT/geophysics /new samples and lab etc)
✓	Monitoring existing SGE/GWL/T etc)
	Mapping (in general terms)
	2D/3D Modelling (in general terms)

Detailed summary of works at the Pilot Areas and brief timeline

March 2019 – March 2020 MUSE monitoring period.

Communication with stakeholders (Czech heat pump association etc.) and mapping installed systems and potential conflicts of use.

Analysis of local legal framework. Evaluating currently existing regulation measures for SGE in Europe with focus on the addressed pilot areas. Cooperation with municipality organs in order to identify challenging issues and propose scientific-based solutions. Development of plans and measures for integrating SGE use in urban energy supply strategies and action plans (WP3).

Cooperation with real-estate developers using geothermal energy resources, mapping of SGE use in Prague focused on the good and bad practices. (WP4)

Contact

Managing Urban Shallow geothermal Energy
Project number GeoE.171.006

Website - www.geoera.eu/projects/muse
MUSE Project office: MUSE@geologie.ac.at
Pilot area contact person: Jaroslav Rihošek

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731166

PRAGUE

GeoERA

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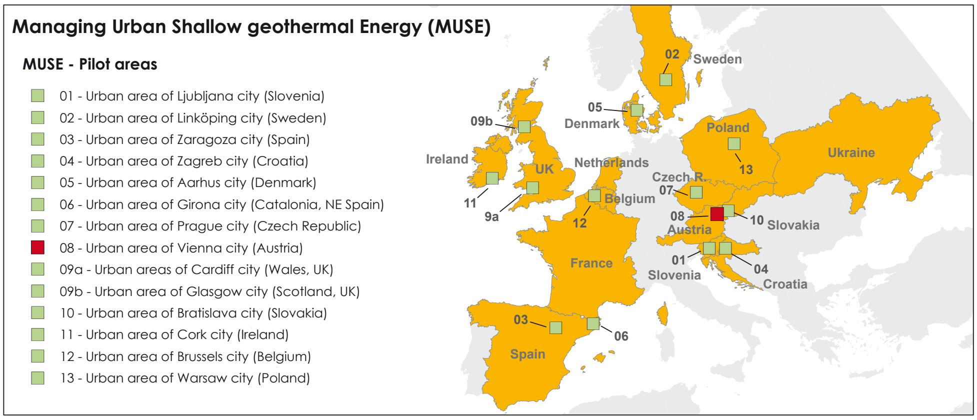
MUSE

Pilot area information



The pilot area is dominated by the Vienna districts 2 and 20. The main aquifer is located in Quaternary gravels, below there are marly to sandy sediments of the Neogene Vienna basin. The Quaternary aquifer adjacent to both sides of the river Danube plays an important role for shallow geothermal applications. Due to the availability of groundwater in shallow depths, the dominating system of shallow geothermal applications are OLS in the pilot area.
The market of SGE is already well developed in the city of Vienna. It faces strong pressure due to increasing numbers of OLS, which may lead to negative impact on the aquifer. The licensing authorities of Vienna demand monitoring of larger OLS, but instead of applying a harmonized monitoring system, the plants are monitored individually.
Therefore the pilot area is well qualified to develop and test tools to overcome challenges of user conflicts and a harmonized monitoring system for OLS.

Pilot Area	Vienna
Task (MUSE)	T-4.9
Country	Austria
Area (km²)	43.5 km²
Total number of inhabitants (date)	242,000 (2017)
Inhabitants per km²	5563
Level of urbanization	90 % (est.)
Elevation range (m a.s.l.)	150-170

Climatological settings

HDD/CDD data according to EUROSTAT method	
Heating degree days (HDD); [baseline reference values]; (period for data calculations)	2468 [15/18] (2017)
Cooling degree days (CDD); [baseline reference values]; (period for data calculations)	213 [21/24] (2017)
Length of the heating season (days)	Unknown
Length of the cooling season (days)	Unknown

Source of data: Eurostat. https://ec.europa.eu/eurostat/data/database

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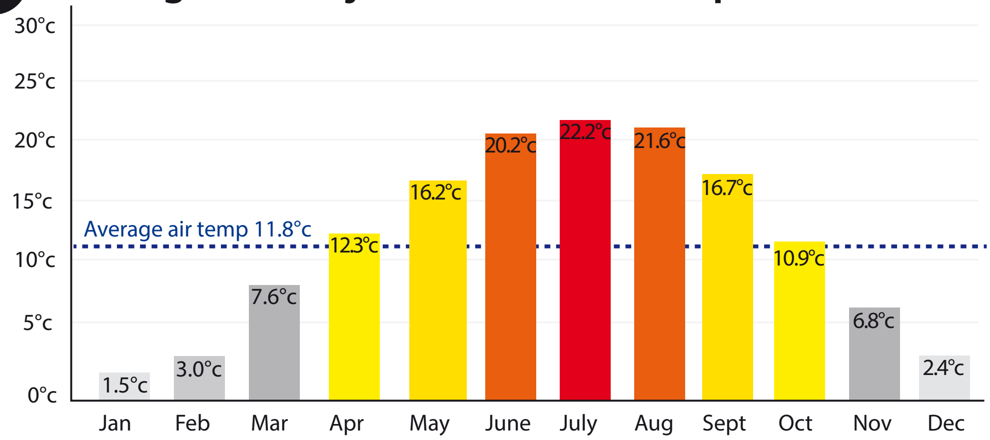
Average monthly and annual air temperature



Market situation

Number of SGE installations in pilot area	OLS V-CLS	83 (OD 2016) 20 (EST 2016)
Current growth rate	No. of Installations	CLS: 3.3% p.a. (period 2013 – 2016) OLS: +0.4% p.a. (period 2013 – 2016) All systems: 1.7% p.a. (period 2013 – 2016)
Estimated share of open loop systems		80%
Estimated share of closed loop systems		20%
Estimated total share of shallow geothermal methods in the heating market	OLS V-CLS	OLS + CLS: 0.53% (referring to produced heat in the year 2015)
Other SGE technologies: Eg. Inter-seasonal heat storage schemes or energy piles	Foundation Piles (energy piles)	
Estimated total share of RES in the heating energy market (%) (specify local or national values)		11.5 % (est. for Vienna)

GeoERA

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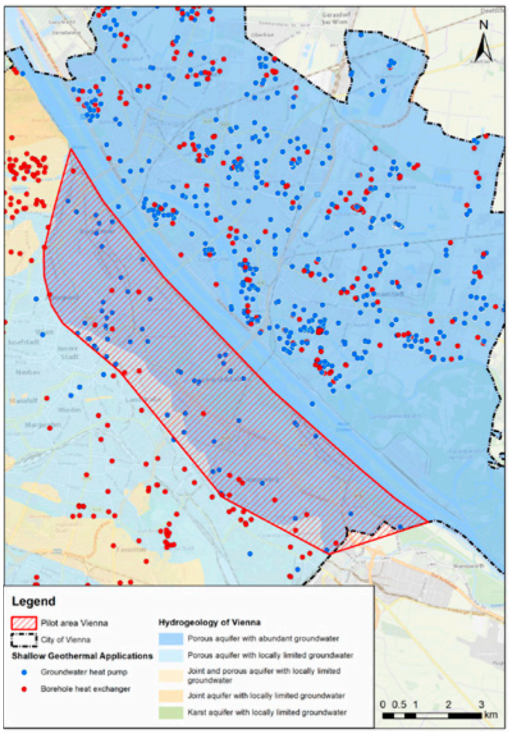
Economic boundary conditions

Estimated average installation costs for shallow geothermal systems (€/kW output) [1]	
Open loop systems	Small scale (10 kW gross capacity): 2000 €/kW Large scale (50 kW gross capacity): 600 €/kW
Closed loop systems	Small scale (10 kW gross capacity): 2400 €/kW Large scale (50 kW gross capacity): 1500 €/kW
Estimated average heating costs (€/kWh)	
Open loop systems	0.084 €/KWh (est.)
Closed loop systems	0.097 €/kWh (est.)
Drilling cost range per meter (€/m) for Open Loop	125 €/m (2500 EUR/well)
Drilling cost range per meter (€/m) for Borehole Closed Loop	50 €/m

Regional geological and hydrogeological characteristics

Pilot area is located in the Vienna Basin
Miocene fault systems formed the pull-apart basin, which remains slightly seismically active until today. However tectonics are no limitations to shallow geothermal energy.



Basin fillings:
Neogene sediments – Mostly marine, fine grained silts and sands, thickness up to 5000 m.
Quaternary sediments – Fluvial gravel and sands, deposited from river Danube.

Hydrogeology **-** Target aquifer: Southern Vienna Basin – porous aquifer, which is strongly related to the Marchfeld groundwater body in the pilot area.

Quaternary gravel and sands covered by anthropogenic deposits and alluvial sands and silts.
Confining layers cannot be excluded, but mainly free aquifer.
Average Aquifer thickness around 8 m
Hydraulic conductivity: 7*10-3 m/s
Depth to water table around 5 m below surface
General groundwater flow direction NW-SE
One TRT test available
No pumping test available now in the pilot area, but in comparable adjacent areas.

Thermogeology **-** Groundwater temperature: Annual average 12.5 °C

VIENNA

VIENNA FACTSHEET

VIENNA

Summary of works and timeline

Main Objectives	
✓	Evaluation and characterization of geology/ hydrogeology / thermal conditions
✓	SGE assessment resources (for OCS and/or CLS) / and evaluation of UTES-BTES)
✓	Study of conflicts of use (OLS / GWL - OLS/CLS). Hazards/interferences, effects on sub-surface
✓	Strategies and actions for management and local energy plans
Relation of foreseen tasks	
✓	Data collection (TRT, DTRT, rock samples, GWL, T-profile's etc)
✓	New field works (TRT/geophysics /new samples and lab etc)
✓	Monitoring existing SGE/GWL/T etc)
✓	Mapping (in general terms)
	2D/3D Modelling (in general terms)

Detailed summary of works at the Pilot Areas and brief timeline

Data collection of pumping tests, TRTs, groundwater temperatures, groundwater level, existing SGE. Existing conflict maps and resource maps covering entire Vienna.
Data collection: 01/2019 – 04/2019

Groundwater temperature measurements with temperature loggers developed at GBA. Thermal conductivity measurements in the field. Optional: TRT measurements, if BHEs are accessible.
Field measurements: 03/2019 – 03/2020

Resource mapping focusing on open loop systems and closed loop systems including urban heat island effects, using all data collected and generated under objective A1: 03/2020 – 08/2020
Optional: Groundwater temperature monitoring of selected open loop systems, if OLS are accessible.
Measurements: 03/2019 – 03/2020

Mapping conflicts of use for open loop and closed loop systems, based on data from A1. Important possible conflicts: existing SGE, natural reserves, contaminated sites, water protection areas.
Mapping: 05/2019 – 10/2019

Elaboration of strategies to foster integrative management of open loop systems and closed loop systems based on outcomes of resources and conflicts including urban heat island effects.: 03/2020 – 11/2020

Evaluation of licensing and management procedures (guidelines for applicants and authorities).

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VIENNA FACTSHEET

Reference

[Nowy, W.; 2001; Schutz von Tiefengrundwässern in Wien – Grundlagen für eine wasserwirtschaftliche Rahmenverfügung – Endbericht; Vienna.

Pfleiderer, S. & Hofmann, T.; 2004; Digitaler angewandter Geo-Atlas der Stadt Wien – Projekt WC 21 – HYDRO-Modul (Pilotphase) Endbericht; GBA; Vienna.

Geological 3D-Model Vienna - https://gisgba.geologie.ac.at/3dviewer/

Contact

Managing Urban Shallow geothermal Energy
Project number GeoE.171.006

Website - www.geoera.eu/projects/muse
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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731166

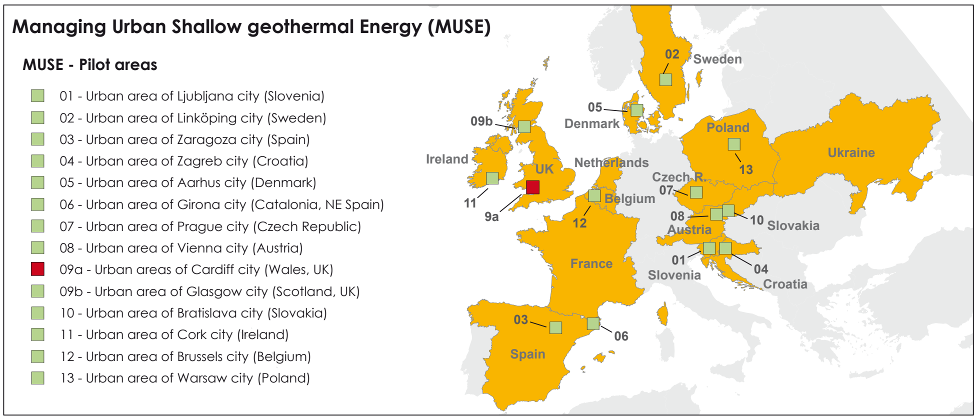
VIENNA

CARDIFF FACTSHEET

UK/WP4/D4.1/FS9A/2018

MUSE

Pilot area information



Cardiff is the Capital city of Wales and an important administrative, business and residential center. The urban area of Cardiff, UK is a medium-sized low-lying coastal city with an area of 140 km^2.

Topographically Cardiff is fairly flat ground and rises from sea level to low hills in the north, east and west to around +30 m asl. It has an average annual air temperature of 10.8 °C and is affected by Urban heat island effect. It is intersected by two rivers that drain into an impounded man made freshwater lake called 'Cardiff Bay'.

Much of the city is underlain by thin deposits of glacial sand and gravel and alluvium which offer a shallow aquifer for open loop geothermal use, in addition to conventional vertical and horizontal closed loop systems in the bedrock and till. There are several deep (>100m) closed loop systems into the underlying Triassic, mainly mudstone, bedrock. There is one known operational shallow (<20m) open loop heat pump system in the south of the city, which abstracts from the shallow aquifer.

The groundwater level in the superficial gravels is shallow, typically no more than 5 m below ground level. Seasonal temperatures in the shallow sand and gravel aquifer (0-20m depth) range between 9.1 and 16.1°C (Farr et al 2017). The shallow aquifer makes shallow open loop systems technically feasible, making Cardiff an idea place to investigate shallow urban heat recovery. For use in low carbon district heat networks.

Pilot Area	Cardiff
Task (MUSE)	4.10a
Country	Wales, United Kingdom
Area (km²)	140 km²
Total number of inhabitants (date)	346,000 (2012)
Inhabitants per km²	2,471
Level of urbanization	Approx. 70%
Elevation range (m a.s.l.)	0-30 masl average 10masl

GeoERA

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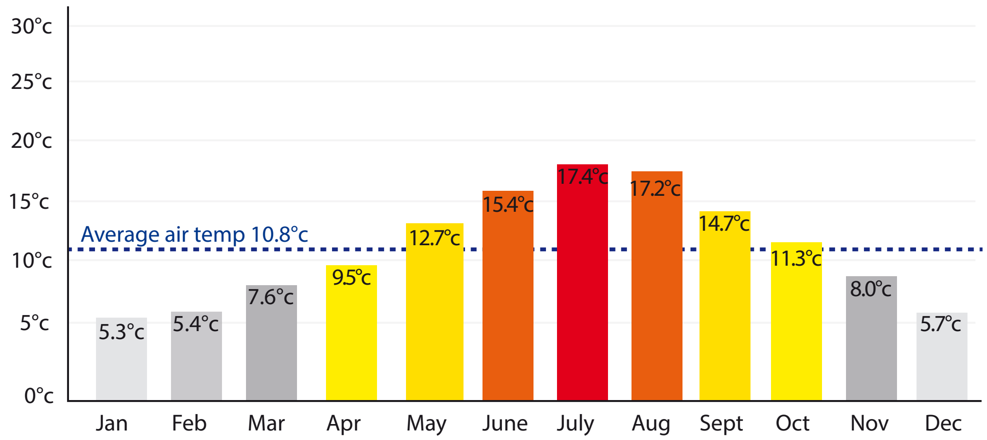
Climatological settings

HDD/CDD data according to EUROSTAT method	
Heating degree days (HDD); [baseline reference values]; (period for data calculations)	2275 [15/18] (2017)
Cooling degree days (CDD); [baseline reference values]; (period for data calculations)	5 [21/24] (2017)
Length of the heating season (days)	October – May (8 months, 240 days)
Length of the cooling season (days)	July – August (2 months, 60 days)

Source of data: Eurostat. https://ec.europa.eu/eurostat/data/database

Average monthly and annual air temperature



Economic boundary conditions

Estimated average installation costs for shallow geothermal systems (€/kW output) [1]	
Open loop systems	800
Closed loop systems	1600 (ground source install cost ~10,000 – ~22,000, depending on size (excluding RHI)
Estimated average heating costs (€/kWh)	
Open loop systems	25?
Closed loop systems	25?
Drilling cost range per meter (€/m) for Open Loop	50 - 100
Drilling cost range per meter (€/m) for Borehole Closed Loop	50 -100

CARDIFF

GeoERA

CARDIFF FACTSHEET

Market situation

Number of SGE installations in pilot area	OLS V-CLS H-CLS	1 (OD) 2 (EST) 0 (EST)
OLS = 1 - 'Grangetown Nursery School' installed by BGS 20kw installed in 2015 VCLS = 1 - 'Senedd Building, Cardiff Bay' 100kW installed in 1999 2 - 'Unknown location, Cardiff' 120 kW installed 2016? HCLS = no known systems		
Current growth rate	No. of Installations - UK saw an 18% increase in heat pump installations in 2017 compared with 2016 (BSRIA, May 2018) - Around 22,000 heat pumps (air and ground source) were installed in UK in 2017 (BSRIA, May 2018) - Only 1 in 10 of the UK's ~20,000 installed heat pumps in 2016 were GSHP (BSRIA, 2016) - UK Governments' Renewable Heat Incentive (RHI) scheme has been extended to 2021 for domestic and non-domestic and have to be installed by Microgeneration Certification Scheme (MCS) certified installers. - The UK's 4th Carbon budget is calling for 4 Million domestic and 600 000 commercial heat pumps to be installed by 2030. 8000 heat pumps installations per week from 2025 are required to meet 2050 CO2 targets.	
Estimated share of open loop systems		10%
Estimated share of closed loop systems		90%
Estimated total share of shallow geothermal methods in the heating market	V-CLS	<1%
Other SGE technologies: Eg. inter-seasonal heat storage schemes or energy piles	It's unknown (there are probably some energy piles)	Unknown
Estimated total share of RES in the heating energy market (%) (specify local or national values)		National

Regional geological and hydrogeological characteristics

Quaternary Sand and Gravel Aquifer: 'Target Aquifer'

The Glacial Sand and Gravel is the target aquifer for shallow open loop geothermal development in the city. In the north of the city it is unconfined and towards the south becomes confined under Tidal, Alluvial sediments (Devensian and Holocene). Groundwater in the sand and gravel aquifer, which can be up to 30m thick, is frequently < 5 m below ground level. Groundwater flows towards the rivers and the coast. Pumping tests and dewatering operations show that the sand and gravel aquifer can sustain yields of up to 10 l/s however further testing may prove higher yields are achievable, though re-injection rates may be lower.

Groundwater chemistry can range from 'fresh' groundwater to brackish and even saline, a reflection of the proximity of the city to the coast but perhaps also due to the legacy of heavy industrial pollution. Groundwater is naturally elevated in iron and manganese – both of which pose challenges for heat pump infrastructure.

There is a 3D Geological Model (built in GSI3D software) of the superficial deposits recently developed using data from 3000 boreholes.

Geological: Bedrock

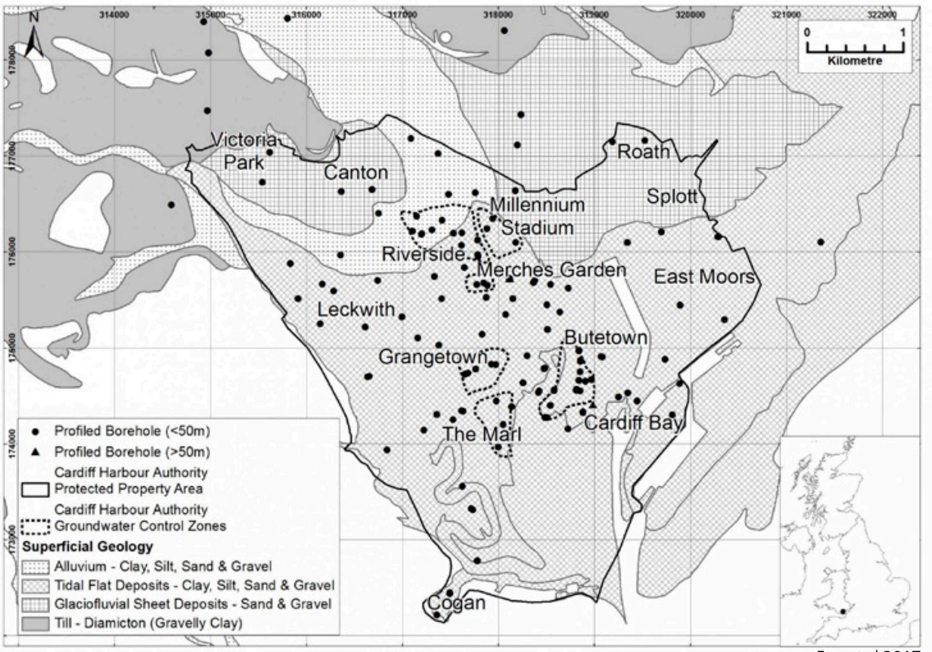
The bedrock is mostly of Triassic Age and was deposited in desert environment associated with player lakes. Lithologies include; Interlayered Mudstone, Sandstone and Limestone with minor Gypsum seams. The bedrock aquifer is considered to be low productivity although some horizons can yield useable quantities of water. At least two deep (100 m) closed loop systems are known to be installed into the bedrock, and one experimental open loop in the shallow aquifer.

Anthropogenic

There are extensive and highly heterogeneous made ground deposits, some of which contain perched water tables. They are not considered as potential sources of water in this study area.

Thermogeology

Groundwater temperature: 9.1 to 16.1°C average of 12.4°C (within a depth range of 0-20m). The average depth of the 'Zone of Seasonal Fluctuation' is 9.5 mbgl and extends to a maximum of 15.5 mbgl.



Farr et al 2017

CARDIFF FACTSHEET

Summary of works and timeline

Main Objectives	
✓	Evaluation and characterization of geology/ hydrogeology / thermal conditions
✓	SGE assessment resources (for OCS and/or CLS) / and evaluation of UTES-BTES)
	Study of conflicts of use (OLS / GWL - OLS/CLS). Hazards/interferences, effects on sub-surface
✓	Strategies and actions for management and local energy plans
Relation of foreseen tasks	
✓	Data collection (TRT, DTRT, rock samples, GWL, T-profile's etc)
✓	New field works (TRT/geophysics /new samples and lab etc)
✓	Monitoring existing SGE/GWL/T etc)
✓	Mapping (in general terms)
✓	2D/3D Modelling (in general terms)

Detailed summary of works at the Pilot Areas and brief timeline

March 2019 – March 2020 MUSE monitoring period.
Investigation of aquifer properties
Baseline temperature monitoring
GSHP pilot monitoring
Mapping installed systems and potential conflicts of use
Geophysical Investigations (BGS-TNO collaborations?)
TRT(BGS-GBA collaborations?)
Pumping test
Thermal conductivity measurements (field and lab/core)
Heat flow or Hydrogeological models
Governance: Review of regulation (WP2 & 3)
Social Science: Stakeholder questionnaires & Public engagement, Installer questionnaires (WP2, 3 and 5)

Reference

Farr et al. 2017 Mapping shallow urban groundwater temperatures, a case study from Cardiff, UK. Quarterly Journal of Engineering Geology and Hydrogeology, 50 (2). 187-198. https://doi.org/10.1144/qjegh2016-058

Kendall, R.S. 2015 Conceptual cross-sections of superficial deposits in Cardiff. British Geological Survey, pp10. (OR/15/045) http://nora.nerc.ac.uk/id/eprint/511584/

Kendall et al., 2018. Model metadata report for Cardiff Superficial Deposits. British Geological Survey Open Report, OR/16/031. 19pp.

www.ukgeos.ac.uk/Cardiff

CARDIFF FACTSHEET

CARDIFF

Contact

Managing Urban Shallow geothermal Energy
Project number GeoE.171.006

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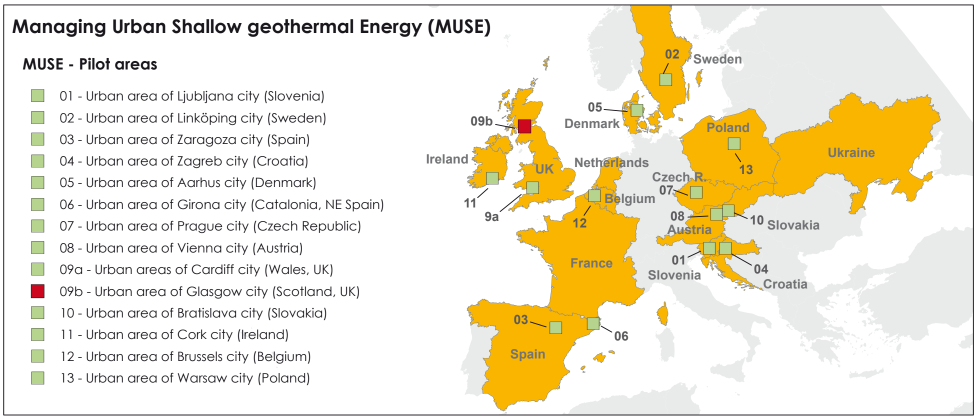
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731166

GLASGOW FACTSHEET

UK/WP4/D4.1/FS9B/2018

MUSE

Pilot area information



The east end of Glasgow, Scotlands largest city, is the location for the UK Geoenergy Observatories 'Glasgow Geothermal Energy Research Field Site'. Permissions for this research facility into low temperature mine water geothermal energy have been granted and borehole drilling starts in Autumn 2018. The challenges are similar to other towns and cities across Europe where coal mines closed and became flooded, and there is a legacy of industrial land use. There is interest in integrated district heating/ storage networks plus a small mine water geothermal scheme has been operating successfully at nearby Shettleston. The mine waters are expected to be around 12°C and this will be confirmed when the 6 mine water, 5 environmental baseline and 1 seismic monitoring boreholes are drilled. The Observatory will provide openly accessible data on ground motion, soil/ground gas, surface and groundwater and soil chemistry environmental baseline monitoring.

Pilot Area	Glasgow
Task (MUSE)	T-4.10
Country	UK
Area (km²)	Pilot Area - 45.7 km² Glasgow City area - 176 km²
Total number of inhabitants (date)	621020 (total for whole of Glasgow City, 2017, National Records of Scotland)
Inhabitants per km²	3500 per km² for Glasgow City area (not the pilot area)
Level of urbanization	Uknown
Elevation range (m a.s.l.)	0-196m

Climatological settings

HDD/CDD data according to EUROSTAT method	
Heating degree days (HDD); [baseline reference values]; (period for data calculations)	3054 [15/18] (2017)
Cooling degree days (CDD); [baseline reference values]; (period for data calculations)	0 [21/24] (2017)
Length of the heating season (days)	Unknown
Length of the cooling season (days)	Unknown

Source of data: Eurostat. https://ec.europa.eu/eurostat/data/database

GLASGOW

GeoERA

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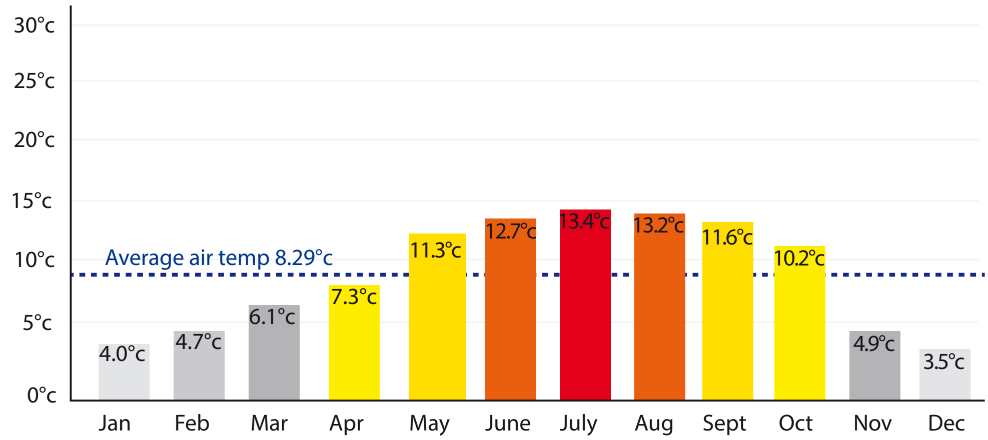
Average monthly and annual air temperature



Market situation

Number of SGE installations in pilot area	Unknown	0 (OD) 20 (OD) 10 (EST)
Current growth rate	Heat production	
Estimated share of open loop systems		
Estimated share of closed loop systems		
Estimated total share of shallow geothermal methods in the heating market	Unknown	
Other SGE technologies: Eg. Inter-seasonal heat storage schemes or energy piles	A operating mine water scheme (Shettleston), plus the UK Geoenergy Observatory	
Estimated total share of RES in the heating energy market (%) (specify local or national values)		

Economic boundary conditions

Estimated average installation costs for shallow geothermal systems (€/kW output) [1]	
Open loop systems	Unknown
Closed loop systems	Unknown
Estimated average heating costs (€/kWh)	
Open loop systems	Unknown
Closed loop systems	Unknown
Drilling cost range per meter (€/m) for Open Loop	Unknown
Drilling cost range per meter (€/m) for Borehole Closed Loop	Unknown

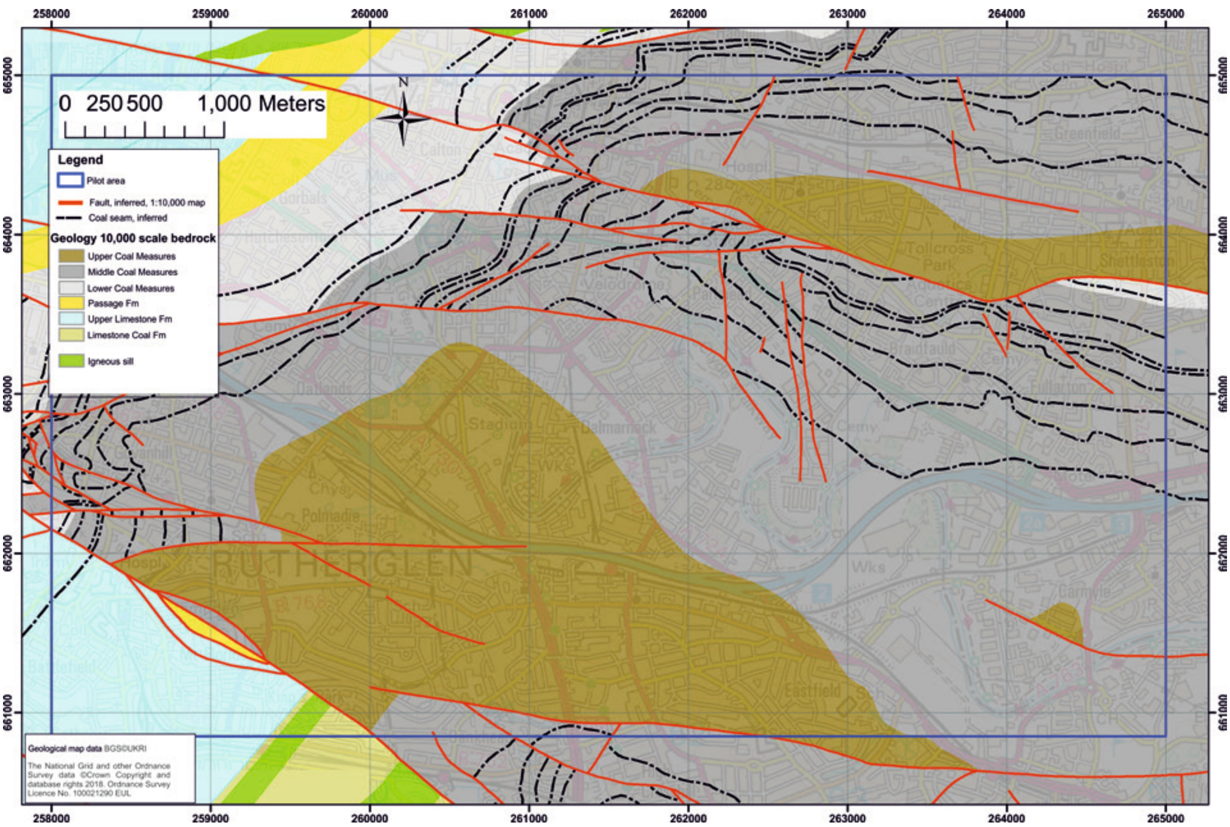
GLASGOW
FACTSHEET

Regional geological and hydrogeological characteristics

Bedrock
Faulted Carboniferous, extensively mined for coal and ironstone
Bedrock Depositional Environment: fluvio-deltaic coal swamps with marine incursions
Bedrock lithologies: mudstone, siltstone, paleosol, coal, sandstone
Quaternary
Glacial and post-glacial marine, fluvial, lacustrine, extensive artificial ground some with land contamination.
Thickness superficial deposits 0-30 metres.

Hydrogeology Heterogeneous Quaternary aquifer system
Three units form a linear aquifer approximately 2 to 3km wide and typically between 10 and 30m thick beneath central Glasgow.
Bedrock - Unmined Carboniferous sedimentary rocks typically form multi-layered and vertically segmented aquifers. Groundwater flow paths thought to be complex. Mining has significantly changed natural hydrogeological conditions and increased aquifer transmissivity.
Variable depth to water table. Limited data in bedrock.

Thermogeology Bedrock groundwater temperature
Likely 12-15 °C at depths to a few hundred metres



GLASGOW FACTSHEET

GLASGOW

Summary of works and timeline

Main Objectives	
✓	Evaluation and characterization of geology/ hydrogeology / thermal conditions
✓	SGE assessment resources (for OCS and/or CLS) / and evaluation of UTES-BTES)
	Study of conflicts of use (OLS / GWL - OLS/CLS). Hazards/interferences, effects on sub-surface
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Relation of foreseen tasks	
✓	Data collection (TRT, DTRT, rock samples, GWL, T-profile's etc)
✓	New field works (TRT/geophysics /new samples and lab etc)
✓	Monitoring existing SGE/GWL/T etc)
✓	Mapping (in general terms)
✓	2D/3D Modelling (in general terms)

Detailed summary of works at the Pilot Areas and brief timeline

March 2019 – March 2020 MUSE monitoring period.
Borehole construction and environmental baseline monitoring
Baseline temperature, level, conductivity monitoring
Baseline groundwater chemistry monitoring
Pumping tests
Investigation of aquifer properties
Geophysical downhole monitoring – resistivity and temperature
3D Geological Models (GOCAD-SKUA)
Heat flow and Hydrogeological models

Reference

Monaghan et al. 2018 http://nora.nerc.ac.uk/id/eprint/521444/
Monaghan et al. 2017, http://nora.nerc.ac.uk/id/eprint/518636/
www.bgs.ac.uk/research/energy/esios/glasgow/home.html

Contact

Managing Urban Shallow geothermal Energy
Project number GeoE.171.006
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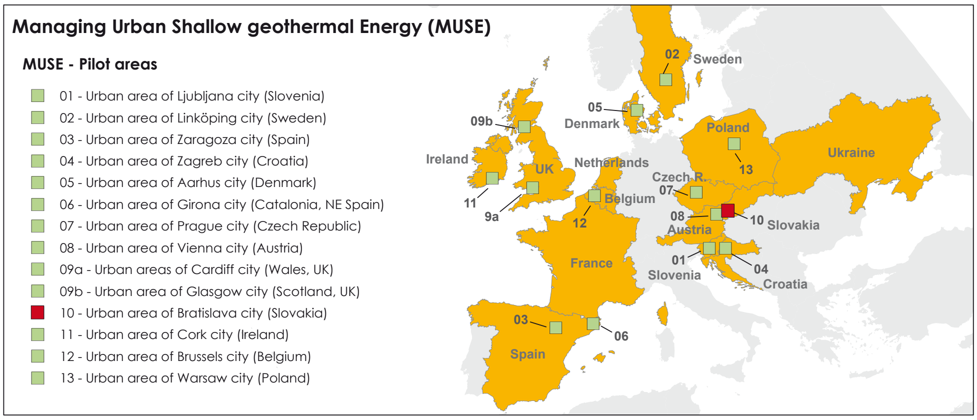
GeoERA

BRATISLAVA FACTSHEET

SK/WP4/D4.1/FS10/2018

Pilot area information



The chosen pilot area for Slovak Republic is capital city Bratislava. The market with shallow geothermal energy is growing. Due to the current regulation (within Water Act., Geological Act.) there is still gap in management and monitoring of the shallow geothermal energy sources (its influence to the groundwater warming and the urban heat island).

With a population of about 450,000, it is one of the smaller capitals of Europe but still the country's largest city.[1] The area of the city is 367 km2. The greater metropolitan area is home to more than 650,000 people. Bratislava is in southwestern Slovakia, occupying both banks of the River Danube and the left bank of the River Morava. Bordering Austria and Hungary, it is the only national capital that borders two sovereign states.[2] Elevation varies from 126 m a. s. l. (m above the see level) to 514 m a. s. l. with average value of 134 m a. s. l. Part of the city area is covered by Male Karpaty Mts.

The forest in city administration covers cca 30 km2, but in total forest covers more than 50 km2.

Bratislava has a moderately continental climate [3] with mean annual temperature (1990–2009) of around 10.5 °C, average temperature of 21 °C in the warmest month and –1 °C in the coldest month and precipitation spread rather evenly throughout the year [4].

Recently, the transitions from winter to summer and summer to winter have been rapid, with short autumn and spring periods. Snow occurs less frequently than previously [3]. Extreme temperatures (1981–2013) – record high: 39.4 °C,[5] record low: –24.6 °C. Average annual precipitation is 565 mm.

The geothermal energy is the defined in connection to the deep geothermal sources, the definition is established in legal regulation, though regulation is via permission of water withdrawal (geothermal water is by definition groundwater with temperature over 20°C). In Slovakia shallow geothermal energy market is growing both for purpose of heating and cooling. Though relevant data are still missing.

Pilot Area	Bratislava
Task (MUSE)	T-4.11
Country	Slovakia
Area (km²)	367 km²
Total number of inhabitants (date)	429,564 (2017)
Inhabitants per km²	1169
Level of urbanization	55%
Elevation range (m a.s.l.)	126 - 514

BRATISLAVA

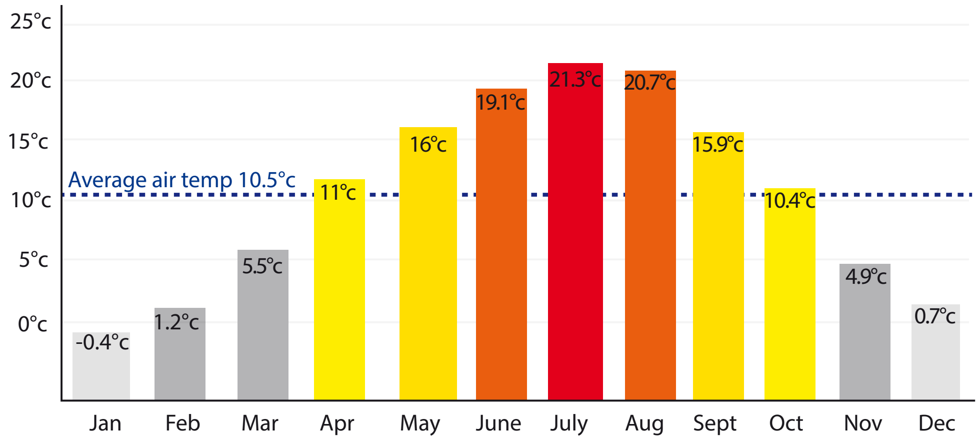
BRATISLAVA FACTSHEET

Climatological settings

HDD/CDD data according to EUROSTAT method	
Heating degree days (HDD); [baseline reference values]; (period for data calculations)	3152 [15/18]
Cooling degree days (CDD); [baseline reference values]; (period for data calculations)	
Length of the heating season (days)	
Length of the cooling season (days)	

Source of data: Eurostat. https://ec.europa.eu/eurostat/data/database

Average monthly and annual air temperature



BRATISLAVA

GeoERA

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MUSE

BRATISLAVA

Market situation

Number of SGE installations in pilot area	OLS V-CLS	300 (EST) Total Estimation on OLS and VCLS
Current growth rate	No. of Installations	5% p.a. (2017-2018) (EST)
Estimated share of open loop systems		>60% (EST), OLS are obliged to apply for permission/file the report to the Ministry of Environment for the pumping over 0,5 l/s
Estimated share of closed loop systems		< 40% (EST) (CLS are not accounted by government)
Estimated total share of shallow geothermal methods in the heating market	OLS V-CLS H-CLS	≤1 % (EST)
Other SGE technologies: Eg. Inter-seasonal heat storage schemes or energy piles	Unknown	
Estimated total share of RES in the heating energy market (%) (specify local or national values)		11,7% (2016) [10] Other information source 9,9 % (2016)

Economic boundary conditions

Estimated average installation costs for shallow geothermal systems (€/kW output) [1]	
Open loop systems	800 - 1500 €/kW
Closed loop systems	1500 – 2000 €/kW
Estimated average heating costs (€/kWh)	
Open loop systems	0.05 – 0,08 €/KWh (EST)
Closed loop systems	0.05 – 0,08 €/KWh (EST)
Drilling cost range per meter (€/m) for Open Loop	50 – 150 €/m + casing and backfill ca. 10 – 30 €/m
Drilling cost range per meter (€/m) for Borehole Closed Loop	50 – 150 €/m

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BRATISLAVA

Regional geological and hydrogeological characteristics

From the geological point of view, the area is created by core mountains (with crystalline core and sedimentary envelope) Malé Karpaty Mts. Lowland belongs to the Vienna basin and the Danube basin with sedimentary fill of Neogene and Quaternary sediments. From the lithological point of view, the area has great variety in rock types and sediments that creates different condition for water recharge and ground water circulation, as well as geothermic conditions important for shallow geothermal heat pumps installation.

From hydrogeological point of view all kinds of aquifers according to the type of permeability are present. There are fissured crystalline hard rocks, karstified Mesozoic aquifers and porous aquifers of different stratigraphy and permeability value.

The Quaternary sediments have sufficient thickness and effective porosity and create background for water sources with high yield and good quality of the water. The Danube river deposits (gravels and sands – alluvium in the area between Devín and Bratislava) show thicknesses between 2 and 18 meter. The direction of groundwater flows, as well as of groundwater levels are connected to the Danube river and its deviation channel. The Petržalka area (right side of the Danube river) is characterized by a smaller thickness of fluvial gravels and sands (around 10 - 20 m) with good permeability. The fluvial sediments in Cunovo area have the highest mean values of the transmissivity coefficient in Slovakia, with values of hydraulic conductivity of up to 4. 10-2 m.s-1. The average thickness of groundwater body is 100 m and the mean permeability coefficient of 4. 10-3 m.s-1 (Malík et al., 2000).

Summary of works and timeline

Main Objectives	
✓	Evaluation and characterization of geology/ hydrogeology / thermal conditions
✓	SGE assessment resources (for OCS and/or CLS) / and evaluation of UTES-BTES)
✓	Study of conflicts of use (OLS / GWL - OLS/CLS). Hazards/interferences, effects on sub-surface
	Strategies and actions for management and local energy plans
Relation of foreseen tasks	
✓	Data collection (TRT, DTRT, rock samples, GWL, T-profile's etc)
✓	New field works (TRT/geophysics /new samples and lab etc)
✓	Monitoring existing SGE/GWL/T etc)
	Mapping (in general terms)
✓	2D/3D Modelling (in general terms)

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Detailed summary of works at the Pilot Areas and brief timeline

The pilot case study is situated in the urban area of Bratislava, in the southwest of the Slovak Republic. The activities will focus on the monitoring of thermal, hydraulic and chemical regime of shallow aquifers. The results will be used to evaluate possible conflicts of use between drinking water supply and SGE use, installed systems and potential conflicts of use.

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https://ec.europa.eu/eurostat/statistics-explained/index.php?title=File:Table_4-Share_of_renewable_energy_sources_in_heating_and_cooling_2004-2016.png

https://www.vrtanie-studni.sk/sk/cennik-cena, www.solar-eshop.sk/c/tepelna-cerpadla/zeme-voda

http://www.domy-kosice.sk/tepelne-cerpadlo

Contact

Managing Urban Shallow geothermal Energy
Project number GeoE.171.006

Website - www.geoera.eu/projects/muse
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Pilot area contact person: Radovan Cernak

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731166

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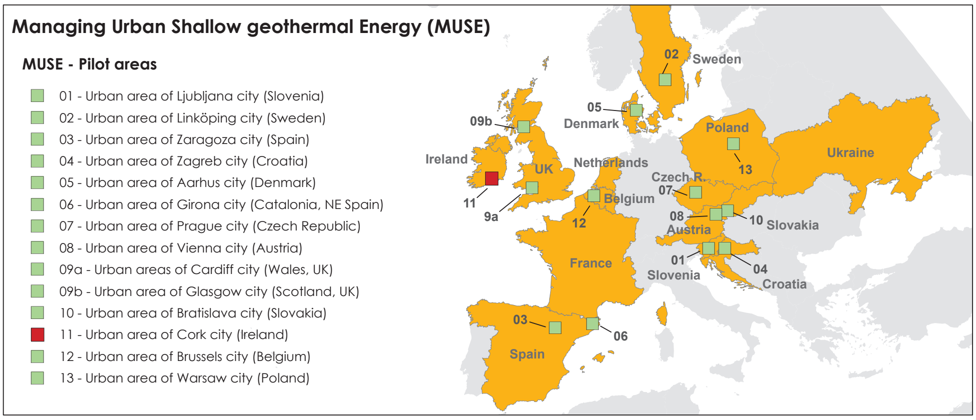
CORK FACTSHEET

IRE/WP4/D4.1/FS11/2018

Pilot area information



The Pilot Area encompasses central Cork City and some of its environs. Cork was chosen as it has a long history of ground source heat use, and more readily available data than other parts of Ireland. There are three hydrogeological units within the study area: a glacio-fluvial sand and gravel unit; karstified limestone underlying the river valley; and sandstone and conglomerate underlying the topographic ridges (GSI, 2004). The main target for this study is the glacio-fluvial sand and gravel unit. Groundwater in these sands and gravels are known to have temperatures between 9 and 13 °C (Connor, 1998), and groundwater temperatures of 19 – 20 °C have been recorded in the centre of the Pilot Area at a depth of 20 m in the karstified limestone unit beneath the sands and gravels (Allen and Burgess, 2010).

There is a lack of data in Ireland with regard to ground source heat exchangers, and it is difficult to find statistics on the use of shallow geothermal energy. In 2017, RES-H was 6.9 %, and 13 % of the renewable heat energy expenditure was attributed to heat pumps (mostly air source) (SEAI, 2019). The number of SGE installations in Ireland is unknown, and information on domestic installations is particularly hard to obtain (Pasquali et al., 2015).

During the MUSE project, additional data on GSHP heating and cooling installations will be collected, and databases on groundwater temperatures, hydrochemistry and water levels will be developed and populated. This information will be used to develop a better understanding of the hydrogeothermology of the study area.

Pilot Area	Cork City
Task (MUSE)	T-4.12
Country	Ireland
Area (km²)	40.7 km²
Total number of inhabitants (date)	125,622 (2016 total for Cork City)
Inhabitants per km²	3367.9 (in Cork City)
Level of urbanization	100%
Elevation range (m a.s.l.)	0-115

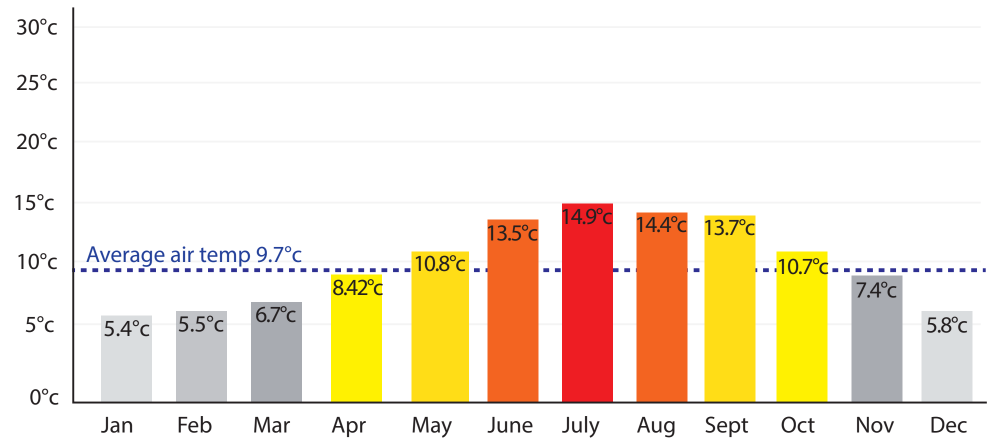
CORK FACTSHEET

Climatological settings

HDD/CDD data accordingly to the local methodologies at the Pilot areas	
Heating degree days (HDD) / a/baseline reference values / period of data for calculations (note unit is hours)	1906; (15°C) (period 2014-2018)
Cooling degree days (CDD) / a/b values / period of data for calculations	0 (24 °C) (period 2014-2018)
Length of the heating season (days)	220 (period 2014-2018) at (15°C)
Length of the cooling season (days)	0 (24 °C) (period 2014-2018)

Source of data: Geological Survey of Ireland

Average monthly and annual air temperature



Market situation

Number of SGE installations in pilot area	Mixture of open loop and closed loop (mainly open loop in sands and gravels, closed loop in bedrock)	27 (currently unknown)
Current growth rate		Unknown
Estimated share of open loop systems		Unknown
Estimated share of closed loop systems		Unknown
Estimated total share of shallow geothermal methods in the heating market		Unknown
Other SGE technologies: Eg. Inter-seasonal heat storage schemes or energy piles		Unknown
Estimated total share of RES in the heating energy market (%) (specify local or national values)		Total market share - 6.9 % (2017) (SEAI, 2019)

CORK FACTSHEET

Economic boundary conditions

Estimated average installation costs for shallow geothermal systems (€/kW output) [1]	
Open loop systems	1,600 (based on figures for 10 kW domestic systems from GSI (2015)
Closed loop systems	V-CLS: 2000 €/kW H-CLS: 1300 €/kW
Estimated average heating costs (€/kWh)	
Open loop systems	0.16 €/kWh (Ground source heat pump) Annual maintenance cost: €250 (GSI, 2015)
Closed loop systems	0.16 €/kWh (Ground source heat pump) Annual maintenance cost: €150
Drilling cost range per metre (€/m) for Open Loop	€35 per metre (GSI 2015)
Drilling cost range per metre (€/m) for Borehole Closed Loop	€25 per metre (GSI 2015)

Regional geological and hydrogeological characteristics

General Setting

Cork city occupies an elongate E-W to ENE-WSW river valleybounded by E-W ridges to the North and South of the City. The valley floor is partially occupied by the River Lee flood plain that runs through Cork City (GSI, 2004).

Geology

Geological ages: Devonian, Carboniferous and Quaternary at or close to the surface within the study area.
Depositional Environment: In the Devonian, terrestrial dunes and occasional rivers deposited large pebbles and cobbles, and sand beds. This was followed by a transgressive marine environment in the Carboniferous. There are no younger rocks in the pilot area so at least one episode of erosion must have occurred, followed by successive glaciations in the Quaternary.
Bedrock lithologies: Devonian Old Red Sandstone Formation consisting of sandstones and conglomerates; these are overlain by Carboniferous (Dinantian) mudstones and sandstones with bands of grey-black, slatey mudstone; followed by pure unbedded Dinantian Waulsortian Limestone Formation. These bedrock units are cross-cut by N-S faults.
Quaternary lithologies: Alluvium, glacio-fluvial sands and gravels, and glacial tills (diamicton). These units tend to be around 10 m in thick and sit above the limestone bedrock.

Hydrogeology

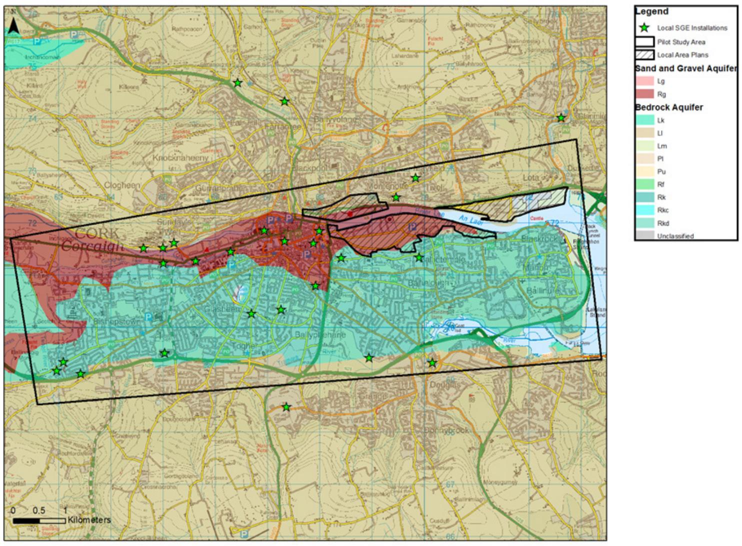
There are three types of aquifer in the study area: the Old Red Sandstone (LI – locally important fractured bedrock), karstified limestone (Rkd – regionally important karstified limestone), and the sands and gravels (Rg – regionally important sand and gravel aquifer).

Thermogeology

At shallow depths within the gravels beneath Cork City temperatures range between 9 and 13 ºC (Connor, 1998); temperatures up to 20 ºC have been observed locally in the underlying karst limestone (Allen and Burgess, 2010). The depth to the water table can vary from a few metres up to more than 10 m below ground level, depending upon topography. Seasonal variation in groundwater level is minimal next to the river, although it is tidally influenced. Under elevated ground, groundwater levels can vary by 5 – 10 m seasonally (GSI, 2004).

CORK

CORK FACTSHEET



CORK

Summary of works and timeline

Main Objectives	
✓	Evaluation and characterization of geology/ hydrogeology / thermal conditions
✓	SGE assessment resources (for OCS and/or CLS) / and evaluation of UTES-BTES)
	Study of conflicts of use (OLS / GWL - OLS/CLS). Hazards/interferences, effects on sub-surface
✓	Strategies and actions for management and local energy plans
Relation of foreseen tasks	
✓	Data collation (TRT, DTRT, rock samples, GWL, T-profile's etc)
✓	New field works (TRT/geophysics /new samples and lab etc)
✓	Monitoring existing SGE/GWL/T etc)
✓	Mapping (in general terms)
✓	2D/3D Modelling (in general terms)

Detailed summary of works at the Pilot Areas and brief timeline

Planned activities for March 2019 – March 2020 MUSE monitoring period (may extend further)

WP3: Review of current regulations
WP3, 4 and 5: Stakeholder questionnaires & Public engagement, Installer questionnaires

WP4: Study area – Cork City

- Collation of existing data and previous studies – geology, hydrogeology, hydrochemistry, thermogeology, GSHP installations, engineering studies.
- Baseline temperature, water level and hydrochemistry monitoring at different locations in pilot area.
- Mapping installed systems and potential conflicts of use. Assessing, where possible, current status of GSHP system (in use/abandoned/problems).

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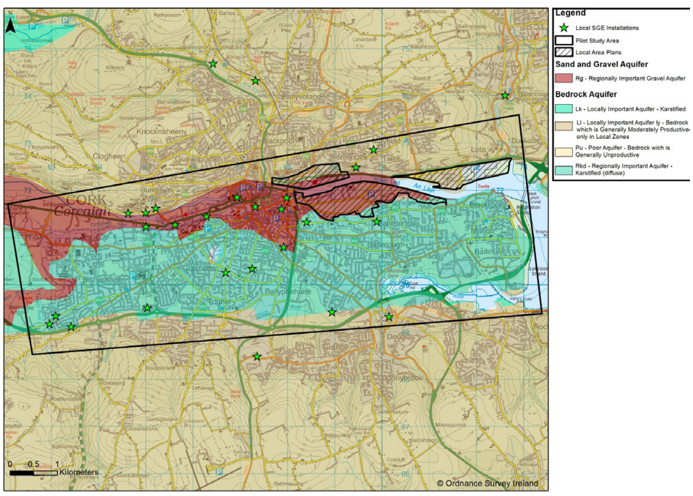
Appendix

1. Map



CORK

2. Regional geological and hydrogeological characteristics extended

Bedrock

Compression of these rocks occurred during the Variscan Orogeny forming a series of folds on E-W axes. Over time the more soluble limestone was eroded away on the anticlines, exposing the more resistant sandstone, however these limestones were preserved within the synclines of the folds. These anticlines and synclines now represent the E-W trending mountains and valleys seen today. The orogenic event caused extensive fracturing and faulting, causing the ridges and valleys to be cut by shear faults in a N-S direction and thrust faults in a E-W. A drop in sea level of ca.-130 mOD Pleistocene rivers cut down to a new base level forming the valley which Cory City sits in.

Quaternary

The valley created during glaciation became infilled with sand and gravels. Scourse et al (1992) suggested that the deeper sediments are of glaciofluvio outwash whereas shallower represents reworked glaciofluvial sediment caused by the rising sea level towards the end of glaciation (Hemmingway et al; 2011). Overtime the Lee River deposited alluvium in the form of estuarine clays, silts and peats with a typical thickness of 3-4 m. The upper estuary became marshland surrounded by the braided which became embanked and reclaimed by the river (Hemmingway et al; 2011).

The thickness of the sand and gravel deposits varies significantly, although they tend to be greater than 10 m. The River Lee flows along the northern side of this GWB with a 10-30 m depth to bed rock within the flood plain of this river. The undulating nature of the subsoil depth is linked to the highly karstified pure unbedded limestone beneath. Areas to the Southern and Western portions of the River Lee flood plain, subsoil thickness lessens with the underlying limestone unit becoming exposed in areas. Moving away from these outcrops in the Southern section the subsoil tends to be up to 10 m thick however areas of deeper subsoil can exist.

Hydrogeology

The area is composed of three aquifer bodies, these being the ORSS (LI), karstified limestone (RKd), and the sand and gravels (Rg).

The limestone has no primary intergranular permeability, groundwater exploits secondary permeability of faults and joints that have undergone karstification, the water table tends to be within 10 m from the surface. This is a regional scale aquifer defined as RKd under GSI's classification system. The limestones being overlain by sand and gravels are in hydraulic continuity with one another. The sand and gravels provide recharge to the karstified limestone and additional storage under saturated conditions.

The Alluvium is thought to be of 'moderate' permeability with the sand and gravel deposits being 'high' permeability and glacial tills considered to be 'moderate' (GSI, 2004).

Contact

Managing Urban Shallow geothermal Energy
Project number GeoE.171.006

Website - www.geoera.eu/projects/muse
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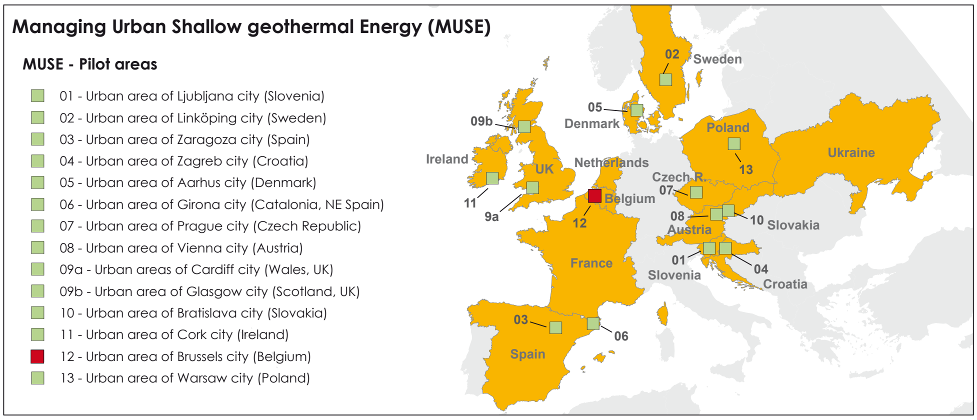
BRUSSELS FACTSHEET

BE/WP4/D4.1/FS12/2018

Pilot area information



The MUSE Brussels Pilot Area is represented by the entire Brussels Region (RBC) (161.4km²). Most of the shallow geothermal systems installed are closed vertical loops (85%). Unfortunately, collecting information on exiting small geothermal installations (below 10kW) is complex because no legal authorization/ declaration is currently legally required in RBC.
The shallow geological setting in RBC is highly diverse and therefore widely suitable to different GSHP applications. The variability of underground conditions (from soft Tertiary sediments to Cambrian quartzite, from 1 aquifer to 5 aquifers available) in an urban context implies different technics and variable costs related. The importance to well characterize the SGE potential and interaction with other resources in this area appears essential for the development of the SGE market.
Despite several incentives/grants by regional governments, market of shallow geothermal development hasn't grown in the way it was expected over the past few years, but a new positive trend last months is observed in RBC.

Pilot Area	Brussels
Task (MUSE)	T-4.13
Country	Belgium
Area (km²)	161.38 km²
Total number of inhabitants (date)	1,205,309
Inhabitants per km²7	468.76
Level of urbanization	86%
Elevation range (m a.s.l.)	10-130

Climatological settings

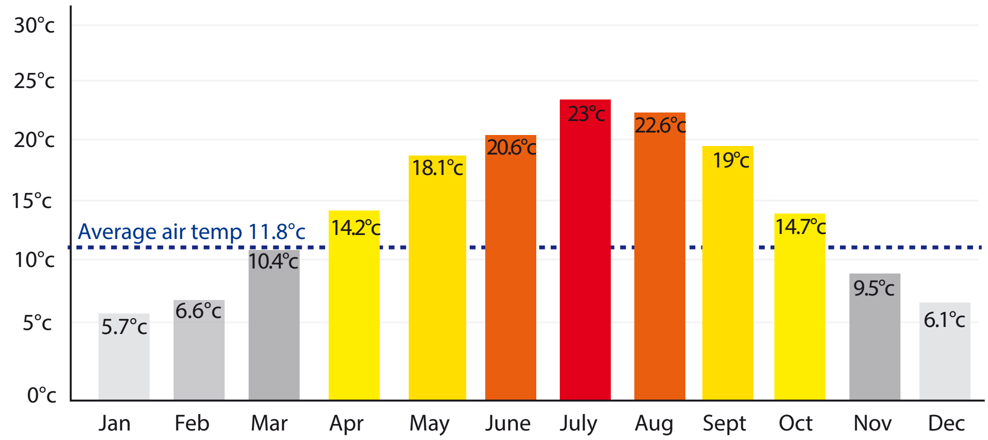
HDD/CDD data according to EUROSTAT method	
Heating degree days (HDD); [baseline reference values]; (period for data calculations)	2440 [15/18] (2017)
Cooling degree days (CDD); [baseline reference values]; (period for data calculations)	17 [21/24] (2017)
Length of the heating season (days)	Unknown
Length of the cooling season (days)	Unknown

Source of data: Eurostat. https://ec.europa.eu/eurostat/data/database

BRUSSELS FACTSHEET

BRUSSELS

Average monthly and annual air temperature



Market situation

Number of SGE installations in pilot area	OLS V-CLS	4 (OD) 40 (OD)
Current growth rate	No. of Installations	5% (est)
Estimated share of open loop systems		15% (est)
Estimated share of closed loop systems		85% (est)
Estimated total share of shallow geothermal methods in the heating market	V-CLS	No official figures yet for Brussels but <1%
Other SGE technologies: Eg. Inter-seasonal heat storage schemes or energy piles	UTES	
Estimated total share of RES in the heating energy market (%) (specify local or national values)		12%

Economic boundary conditions

Estimated average installation costs for shallow geothermal systems (€/kW output) [1]	
Open loop systems	1000-2000
Closed loop systems	1800
Estimated average heating costs (€/kWh)	
Open loop systems	Unknown
Closed loop systems	Unknown
Drilling cost range per meter (€/m) for Open Loop	110-225 €/m

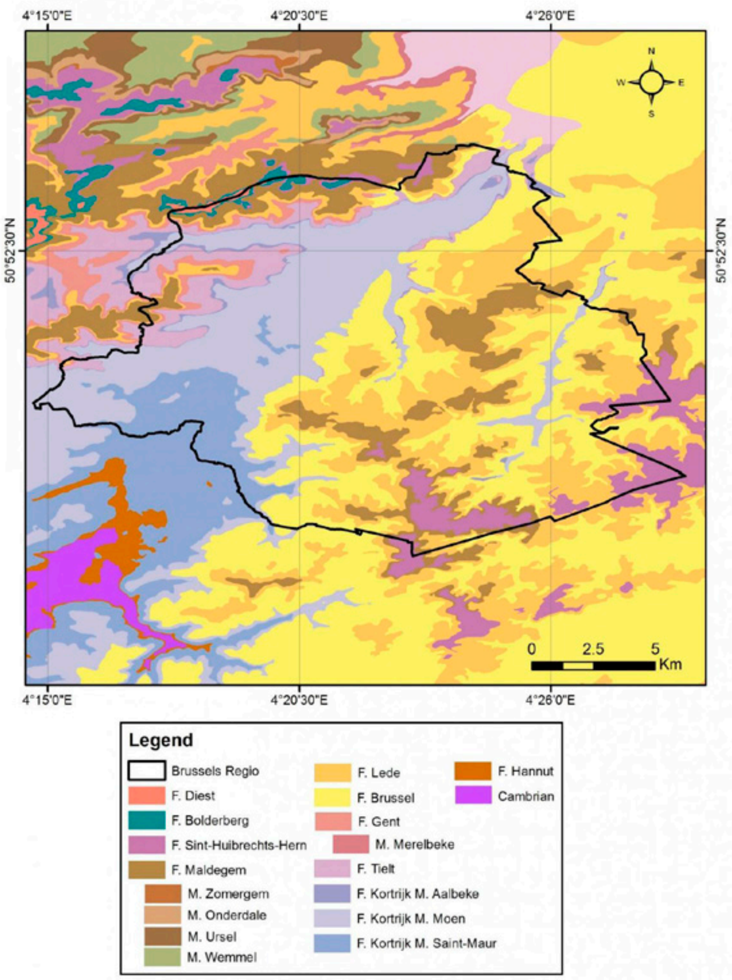
GeoERA

BRUSSELS FACTSHEET

Regional geological and hydrogeological characteristics

The Brussels test site has a Cenozoic soft cover (Quaternary and Tertiary) where aquiferous sandy formations and relatively more impermeable clayey layers alternate. The thickness varies from 10 to over120m.

This cover rests (unconformably) in the Eastern part of Brussels on the aquifer chalks of the Gulpen Formation (Cretaceous) and then on the faulted and folded Cambro-Silurian basement of the Brabant Massif composed of coherent rocks (shales, sandstones, quartzites). The basement top is usually weathered (argilized) for a few meters. The Cambrian basement is relatively close to the surface (30-40m of depth) in the SW of the pilot area (in the Senne Valley), whereas it can deepen to 200m in the North.



Hydrogeology

5 target aquifer units in Brussels: 3
Tertiary sandy layers, Cretaceous chalk, Cambrian fractured reservoir.
Pumping test data available, TRT and eTRT data available.
Depth to water table(s): 3-10m below surface
Aquifers unit thickness variable, hydraulic conductivities data available for some aquifers (3D hydrogeological models exist for 2 aquifers in Tertiary sands).

Thermogeology

Groundwater temperature: 11.8°C (to be validated)

BRUSSELS

FACTSHEET

Summary of works and timeline

Main Objectives	
✓	Evaluation and characterization of geology/ hydrogeology / thermal conditions
✓	SGE assessment resources (for OCS and/or CLS) / and evaluation of UTES-BTES)
	Study of conflicts of use (OLS / GWL - OLS/CLS). Hazards/interferences, effects on subsurface
	Strategies and actions for management and local energy plans
Relation of foreseen tasks	
✓	Data collection (TRT, DTRT, rock samples, GWL, T-profile's etc)
✓	New field works (TRT/geophysics /new samples and lab etc)
✓	Monitoring existing SGE/GWL/T etc)
✓	Mapping (in general terms)
✓	2D/3D Modelling (in general terms)

Detailed summary of works at the Pilot Areas and brief timeline

Planning in progress.

References

Royal Institute of Meteorology: https://www.meteo.be/meteo/view/fr/360955-Normales+mensuelles.html
Brussels Institute of Statistics and Analysis: http://ibsa.brussels/themes/population#.W_aGeuhKiUk
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Contact

Managing Urban Shallow geothermal Energy
Project number GeoE.171.006

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731166

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GeoERA

PL/WP4/D4.1/FS14/2018

WARSAW FACTSHEET

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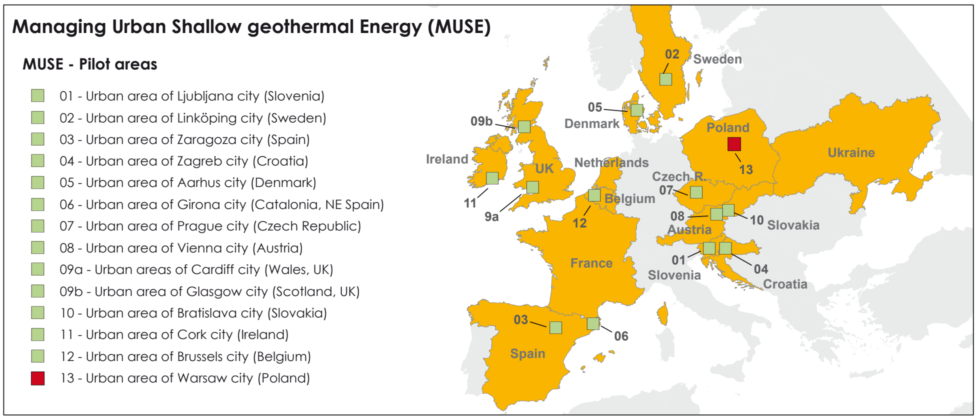
Pilot area information



Warsaw, the capital city of Poland, is the largest city in the country and its second largest urban agglomeration. It has a well-developed heating district system based on coal combustion. The SGE market is however poorly-developed - until present only a limited number of the closed-loop systems have been installed in both private and public buildings. The topographical level varies from 78 to 121 m a.s.l. Air temperature ranges from -2,2 to 18,9 °C, with a mean value of 8,3 °C, maximum of 37 °C and minimum point values of -30 °C. Relative humidity is 79%. The Vistula River divides Warsaw into two major parts, while its valley is the paramount geomorphological unit. The shallow geology is dominated by unconsolidated Quaternary and Neogene sediments – mainly sands, gravels, tills and clays. Hydrogeological conditions are rather complicated showing several unconfined and confined aquifers interbedded with aquitards and aquicludes.

Pilot Area	Warsaw
Task (MUSE)	T-4.10
Country	Poland
Area (km²)	Pilot Area 2847 km² Warsaw City area – 517 km²
Total number of inhabitants (date)	1 764 615 (1.01.2018) – city area ≈3 101 000 - metropolitan area
Inhabitants per km²	3412 (Warsaw City area)
Level of urbanization	57%
Elevation range (m a.s.l.)	78-121

WARSAW

GeoERA

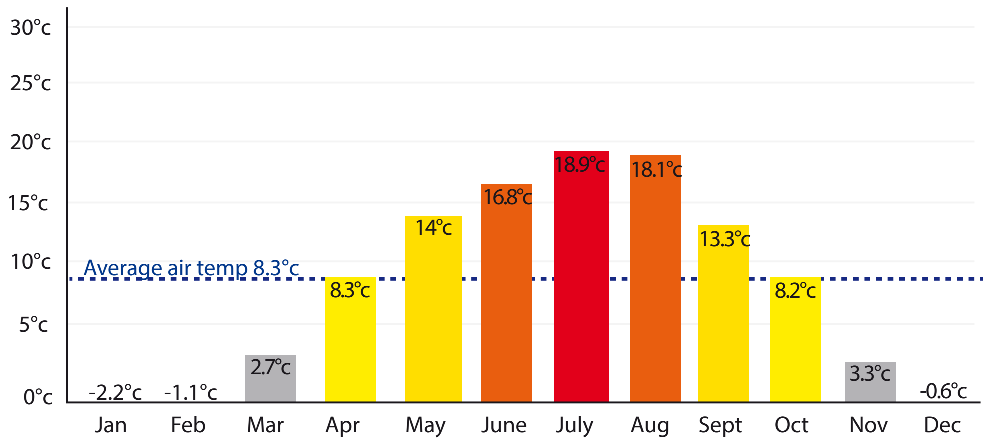
WARSAW FACTSHEET

Climatological settings

HDD/CDD data according to EUROSTAT method	
Heating degree days (HDD); [baseline reference values]; (period for data calculations)	3054 [15/18] (2017)
Cooling degree days (CDD); [baseline reference values]; (period for data calculations)	32 [21/24] (2017)
Length of the heating season (days)	182[1] 264[2]
Length of the cooling season (days)	Unknown

Source of data: Eurostat. https://ec.europa.eu/eurostat/data/database

Average monthly and annual air temperature



Market situation

Number of SGE installations in pilot area	Unknown	Unknown
Current growth rate	Heat production	Unknown
Estimated share of open loop systems		Unknown
Estimated share of closed loop systems		Unknown
Estimated total share of shallow geothermal methods in the heating market	Unknown	Unknown
Other SGE technologies: Eg. Inter-seasonal heat storage schemes or energy piles	Unknown	Unknown
Estimated total share of RES in the heating energy market (%) (specify local or national values)		Unknown

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Economic boundary conditions

Estimated average installation costs for shallow geothermal systems (€/kW output) [1]	
Open loop systems	Unknown
Closed loop systems	1300-1800 €/kW
Estimated average heating costs (€/kWh)	
Open loop systems	Unknown
Closed loop systems	0,04 €/kWh [3]
Drilling cost range per meter (€/m) for Open Loop	25-50 €/m
Drilling cost range per meter (€/m) for Borehole Closed Loop	25-50 €/m

Regional geological and hydrogeological characteristics

Warsaw is located in the central part of the geological unit called the Masovian Synclinorium. The unit is filled mainly with the sediments of the Cretaceous, Paleogene, Neogene and Quaternary periods. The oldest drilled bedrock of the Masovian unit is a Cretaceous chalk formation described mainly as white or gray marl (sometimes sandy), limestone and sandstone. Paleogene period comprises only the Oligocene deposits – predominantly fine and medium-grained sands with glauconite, sometimes lined with extensive clays. Neogene period is represented by Miocene deposits, mainly sands interbedded with lignite, as well as Pliocene deposits 95% of which are plastic clays. Quaternary period consist mainly of the Pleistocene clays, tills, fine and coarse grained sands, glaciolacoustrine deposits and Holocene anthropogenic deposits [4].

Hydrogeology:

Two main aquifers – Oligocene, Quaternary
Oligocene:

- Fine and medium-grained sands,
- Pumping efficiency: 30-50 m3/h,
- Aquifer unit thickness: 30-40 m,
- Depth to water table: 180-270 m

Quaternary:

- Fine and coarse grain sands,
- Pumping efficiency: 50-100 m3/h,
- Aquifer unit thickness: 5-60 m,
- Depth to water table: 5-100 m

Groundwater flow – Vistula river direction

Thermogeology
Groundwater temperature: to be measured
Zone of Seasonal Fluctuations (typically upper 20 m below surface)

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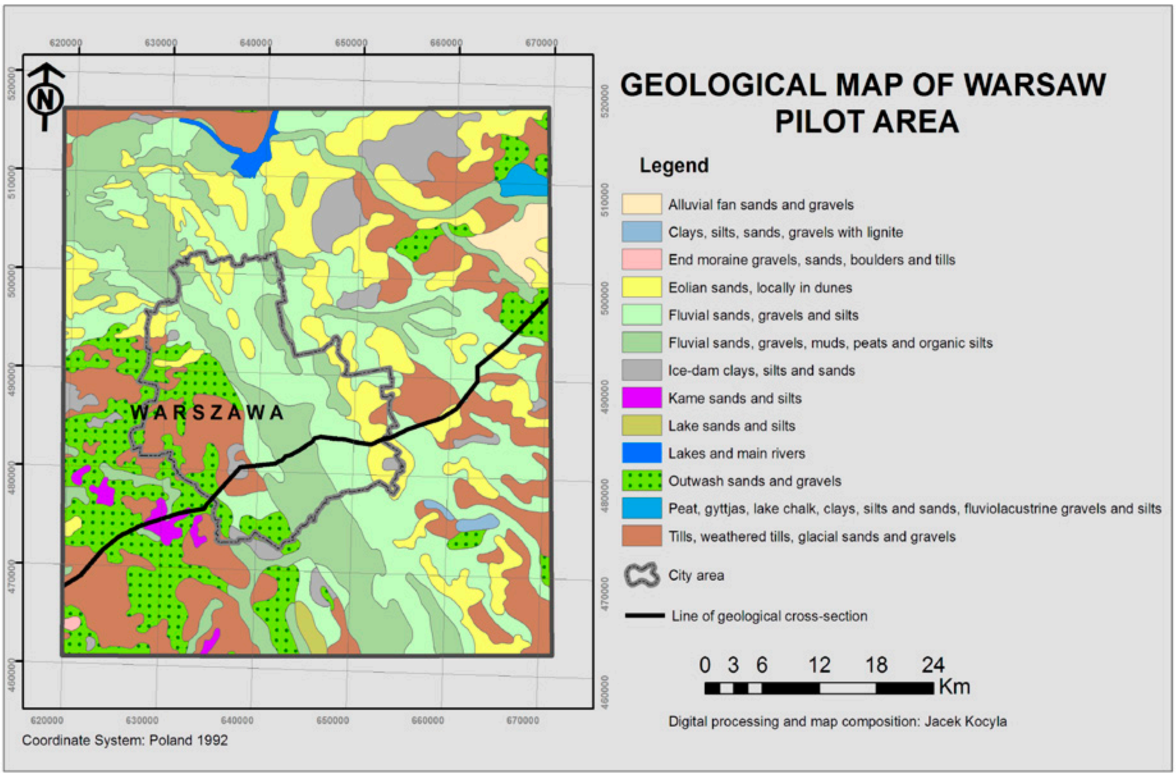

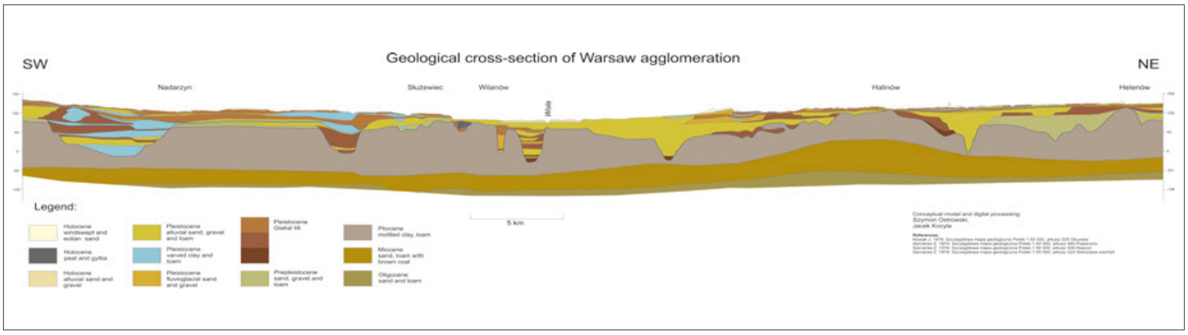

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Summary of works and timeline

Main Objectives	
✓	Evaluation and characterization of geology/ hydrogeology / thermal conditions
✓	SGE assessment resources (for OCS and/or CLS) / and evaluation of UTES-BTES)
✓	Study of conflicts of use (OLS / GWL - OLS/CLS). Hazards/interferences, effects on subsurface
✓	Strategies and actions for management and local energy plans
Relation of foreseen tasks	
✓	Data collection (TRT, DTRT, rock samples, GWL, T-profile's etc)
✓	New field works (TRT/geophysics /new samples and lab etc)
✓	Monitoring existing SGE/GWL/T etc)
✓	Mapping (in general terms)
✓	2D/3D Modelling (in general terms)

Detailed summary of works at the Pilot Areas and brief timeline

March 2019 – March 2020 MUSE monitoring period

- Design and construction of monitoring well (thermopiezometer): design, installation, tests (TRT) and monitoring
- Geophysical investigations: Vertical Electrical Sounding, Electrical Resistivity Tomography, Seismic Refraction Tomography
- Thermal conductivity lab and field testing
- Geological database including field verification of boreholes and verification of archive borehole data
- GIS layers: SGE potential, hydrogeology, environmental conflicts
- 2D – 3D geoscientific modelling

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Managing Urban Shallow geothermal Energy
Project number GeoE.171.006

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