MUSE- Managing Urban Shallow geothermal Energy. A GeoERA geo-energy project

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ABSTRACT

The MUSE project (http://geoera.eu/projects/muse/) is one of 15 awarded project proposals under the H2020 GeoERA program that will be implemented from July 2018 to June 2021. GeoERA (Establishing the European Geological Surveys Research Area to deliver a Geological Service for Europe) is the largest European research programme in the field of geoscience, co-funded by the European Commission via ERA-NET Cofund action in the scope of Horizon 2020. The MUSE project itself focuses on shallow geothermal energy (SGE) in European urban areas. A group of 16 geological survey organisations from the EU member states and associated countries are involved in the project. MUSE addresses the investigation of resources and possible conflicts of use and will deliver key geoscientific subsurface data to stakeholders via a user-friendly web based GeoERA Information Platform Project (GIP-P).

The assessment of geothermal resources and conflicts of use will lead to the development of management strategies considering both efficient planning and monitoring of environmental impacts to feed into the general framework strategies of cities such as Sustainable Energy Action Plans (SEAPs). The developed methods and approaches will be tested and evaluated together with input from local stakeholders in 14 urban pilot areas. The pilot city regions are geologically and climatologically diverse and have a varying range of heating and cooling degree-day characteristics, making the project outputs and shared learnings relevant across Europe and elsewhere.

MUSE will adapt workflows to focus on local scale investigations suitable for densely-populated urban areas, where national heating and cooling demand is generally highest, and which might represent the most important SGE market in the future. The outcomes of the project will represent a comprehensive collection of methods, approaches and tools that could be transferred to other urban regions in Europe and adapted by other organisations.

1. INTRODUCTION

Managing shallow geothermal energy is multidisciplinary topic and draws on many geoscientific sub-disciplines such as geology, hydrogeology, geothermics, hydraulics, hydrochemistry, borehole and well design and completion, geoengineering and geohazards (e.g. karstic regions and shrink-swell-prone rocks). However, it also covers wider issues related to energy economics, environmental law and regulation, district heating and cooling systems, and energy-decarbonisation and land-use planning.

A significant body of geoscientific knowledge is already available from numerous national and international projects. However, these projects often address only a few specific issues within the above-mentioned topics or cover only single regions or a few European countries. This leads to various and partly contradictory methods and concepts to address resources and conflicts of use, and to fragmented strategies for managing efficient and sustainable SGE use. In this context, it should be mentioned that even a uniform definition of shallow geothermal energy is not yet available for Europe as a whole.

At the moment, there is a challenge in efficiently conveying geoscientific datasets on resources and possible conflicts to the decision-makers (managing authorities, planners, city administrations and investors). In particular, the overall cumulative effect of competing SGE uses can be difficult to assess from static geoscientific datasets like thermal conductivities or expected maximum thermal capacities of SGE installations. Therefore, MUSE is aiming to provide valid solutions for identification of issues and opportunities to enable interactive decision support tools, methods and workflows.

The ambition of MUSE is to develop a comprehensive and integrated set of methods, concepts and strategies allowing for local-scale management of shallow geothermal energy in European urban areas, which can later be applied by other Geological Survey Organisations (GSOs) or comparable entities in other European cities.

2. AIMS AND OBJECTIVES

The overall aim of the MUSE project is to support methodologies and concepts for an efficient and sustainable use of SGE in the urban areas for heating, cooling and seasonal heat storage that can be implemented across Europe. To reach this goal, the following objectives have been set:

1) Identifying, summarising and developing state-of-the-art methods including harmonised standards for: quantifying the potential of SGE use in urban areas, evaluating the cost-efficient geophysical exploration and monitoring tools, assessing conflicts of use associated with the open and closed-loop systems and evaluating the efficiency and impacts of shallow geothermal installations.

2) Develop strategies for efficient and sustainable use of SGE in European urban areas by means of: evaluating current regulation, identifying and promoting prospective technical concepts and summarising criteria, strategies and actions for planning, managing and monitoring of SGE use in cities.

3) Transfer of methods and integration into strategies in the specific urban pilot areas across Europe in order to estimate the resources for SGE use, monitor the thermal state of the subsurface and assess and map the resources and conflicts of use associated with SGE utilisation.

4) Disseminate shared knowledge by displaying spatial output datasets via web-hosted services integrated in the GeoERA Information Platform and other dissemination actions.

5) Contributing to the overall GeoERA objectives by knowledge exchange and interacting with other projects of GeoERA covering overlapping and cross-cutting aspects of SGE use in urban areas. Also providing technical concepts and datasets for implementing geoscientific knowledge related to SGE use in the EGDI information platform.

MUSE will cooperate with active international projects dealing with SGE use, and will build on outcomes from accomplished projects such as GRETA (Interreg Alpine Space), GeoPLASMA-CE (Interreg Central Europe), ThermoMap (ICT PSP), REGEOCITIES (Intelligent Energy Europe), SUB-URBAN (COST), ESTMAP (H2020), and Geothermal4PL (EEA Grants) among others.

3. PARTNERS

In total, 16 GSOs from across 15 European countries (Table 1 and Fig.1) are partipating.

The different members of the consortium present complementary levels of knowledge and experience, important aspects to have a broad vision of the different issues in the scope of the SGE and thus achieve the objectives of the project:

- 14 out of 16 partners have already performed national studies on relevant topics including exploration, geoscientific modelling, resource and conflict mapping;
- some GSO also represent managing authorities or perform consulting on behalf of their local governmental authorities.

Table 1: List of participants.

PARTICIPANTS		COUNTRY
GBA	Geologische Bundesanstalt	Austria
BGS-UKRI	British Geological Survey (BGS-UKRI)	United Kingdom
ICGC	Institut Cartogràfic i Geològic de Catalunya	Catalonia (Spain)
HGI-CGS	Hrvatski Geološki Institut	Croatia
CGS	Ceska Geologicka Sluzba – Czech Geological Survey	Czech Republic
BRGM	Bureau de Recherches Géologiques et Minières	France
GSI	Geological Survey Ireland	Ireland
RBINS-GSB	Royal Belgian Institute of Natural Sciences – Geological Survey of Belgium	Belgium
GeoZS	Geološki zavod Slovenije	Slovenia
IGME	Instituto Geológico y Minero de España	Spain
SGU	Sveriges Geologiska Undersökning	Sweden
TNO	Nederlandse Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek	Netherlands
PIG-PIB	Państwowy Instytut Geologiczny – Państwowy Instytut Badawczy	Poland
SGIDS	State Geological Institute of Dionýz Štúr	Slovakia
GEOINFORM	State Research and Development Enterprise State Information Geological Fund of Ukraine	Ukraine
GEUS	Geological Survey of Denmark and Greenland	Denmark

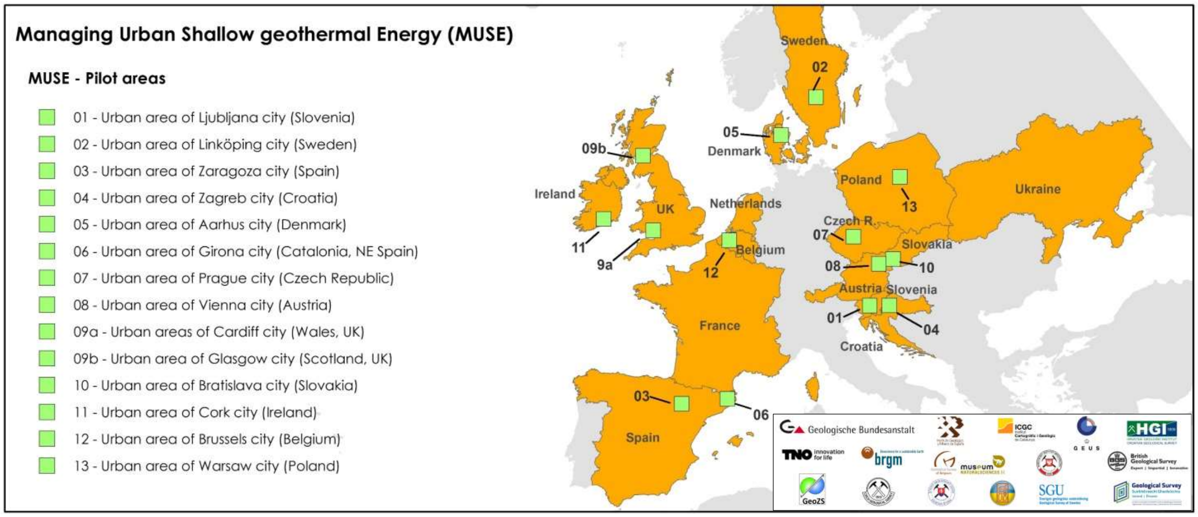

Figure 1: Participating countries and the project pilot areas of MUSE

4. METHODOLOGY AND WORK PACKAGES

MUSE will pool knowledge on managing the efficient and sustainable use of shallow geothermal energy in European cities. This covers the uppermost tens to hundreds of meters of the subsurface, and shallow aquifers accessed by the geothermal schemes within the 0 to 400 m depth range. The project flow abides by a process circle (Fig.2), which consists 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 and dynamic models. A catalogue of joint methods appropriate for the wider range of thermogeological characteristics of the pilot regions will be created using literature reviews, partner questioners and special technical working group meetings.

The management circle also includes the legal framework and regulatory dimensions, administrative procedures, social dimensions and policies, as well as aspects of land-use and subsurface spatial planning, often using 3D visualisations of geospatial data.

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 climatic and geological conditions, legal settings, different supply and infrastructure as well as different thematic focuses of the proposed investigations. Using the compiled concepts and standards will lead to interoperable and comparable project outputs.

The project pilot areas, which are evenly distributed throughout Europe (Fig.1), will act as the test and demonstration sites for applying modern management approaches strongly based on geoscientific data and expert knowledge.

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. Based on the outcomes and lessons learned in the pilots, the project team will gather at a joint feedback workshop, and will modify the preliminary collection of methods and concepts into a final version for general dissemination among other regions and institutions in Europe and beyond.

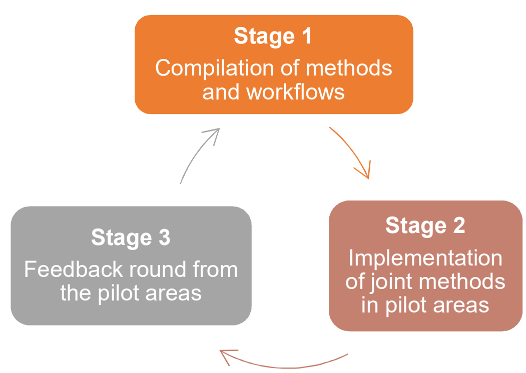

Figure 2: Main stages of the MUSE project.

The development of the overall project is structured in six work packages (WP) (Fig. 3) as follows:

WP1: Project management, internal communication and general dissemination. This WP concerns project implementation and reporting to the programme management. It also will establish efficient decision-making and implement quality control measures. Additionally, this WP is responsible for disseminating the project and its outcomes to scientific and professional experts, local and national government, as well as the general public.

WP2: Technical aspects of shallow geothermal energy use in urban areas. This WP focuses on assessing resources for SGE use in urban areas and possible conflicts of use associated with open and closed-loop systems. Best adapted methodologies for operational monitoring of the performance and the environmental impact will be identified. This will allow defining risks and possible hazards due to inappropriate technical concepts and operation.

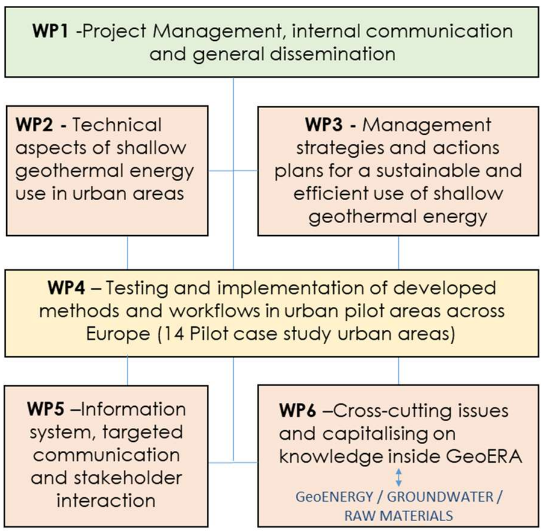

Figure 3: Work packages scheme of MUSE project.

WP3: Management strategies and action plans for a sustainable and efficient use of shallow geothermal energy. This will focus on analysing the existing regulation measures for SGE in Europe dealing with technical guidelines for managing and with environmental protection action plans.

WP4: Testing and implementation of developed methods and workflows in urban pilot areas across Europe. That means testing and implementing developed joint methods of assessment and mapping SGE resources (derived from WP2) in specific urban pilot areas and case studies for open and closed-loop systems. It will assess scientific methodologies and workflows in order to allow comparison of different kinds of parameters as a function of data availability.

This WP also includes the assessment and evaluation of existing regulation measures and application of the developed methods and management concepts (derived from WP3). Outputs will include documented spatial output datasets in the pilot areas delivered via the web-based GeoERA Information Platform (cooperation with WP5 and the project website).

WP5: Information systems, targeted communication and stakeholder interaction. This WP deals with dissemination of acquired knowledge. First designing and testing an end-user-oriented display interface for local authorities and other stakeholders for presenting the thematic outcomes from pilot areas, and second deploying publically-accessible web-tools for displaying on the GIP-P the spatial datasets from the pilot areas.

WP6: Cross-cutting issues and capitalising on knowledge inside GeoERA, i.e. identifying existing or possible conflicts in the shallow subsurface between water supply, heat supply and mineral resources extraction in urban areas with different geological settings with other GeoERA projects, including the Groundwater and Mineral Resources research areas. Under WP6 the knowledge exchange workshops, web conferences, and stakeholder communication will be co-organized.

4. PILOT AREAS

MUSE has 14 pilot areas (Fig.1) located in 12 EU countries. This coverage will presents to have a very wide variety of case studies in different geologies, geographies and cultures .

The geological and hydrogeological settings are different in each pilot area: from sediments of the Cretaceous, Paleogene, Neogene and Quaternary periods (case of Warsaw agglomeration), Miocene fault systems (pull-apart Vienna basin) or Proterozoic to Ordovician fractured sedimentary rock aquifers covered by highly permeable river terrace (as in Prague), but there are some common similarities (e.g. shallow urban aquifers).

Climatic conditions are also quite different between the 14 pilot areas, so they present a diverse range of energy demands. Table 2 shows the values of Heating and Cooling Degree Days (HDD and CDD) as a proxy for the heating and cooling energy demand and loads for buildings. As expected, pilot areas located in northern Europe have a double value of the HDD compared to locations in southern Europe and vice versa for the CDD values.

Table 2: Preliminary Heating and Cooling Degree Days estimation (HDD and CDD) for each pilot area for 2017 (source: Eurostat)

Pilot area	HDD	CDD
Linköping, Sweden	4682	-
Bratislava, Slovakia	3152	-
Glasgow, Scotland	3054	-
Warsaw, Poland	3054	-
Prague, Czech Rep.	2985	53
Aarhus, Denmark	2722	-
Ljubljana, Slovenia	2551	218
Vienna, Austria	2468	213
Brussels, Belgium	2440	17
Zagreb, Croatia	2396	196
Cardiff, Wales	2275	5
Cork, Ireland	2083	2
Zaragoza, Spain	1749	283
Girona, Catalonia	1733	228

The degree of SGE use is also at different levels of deployment or maturity across pilot areas considered. Some pilot areas are in a very preliminary stage of development with no knowledge about the number, power and characteristics of the installed open and closed-loop systems while other countries are already well developed and concerned and working on thermal interferences and the environmental impacts of SGE use. Therefore, these is scope for all European countries to optimise their developments with the benefit of shared learnings from more experienced countries.

5. EXPECTED RESULTS

The outcomes of the project will be a comprehensive collection of methods, approaches and tools, which can be transferred to other urban regions in Europe and adapted by other organisations.

Two catalogues will be elaborated: one of the evaluated methods and guidelines on exploration, assessment and technical monitoring of SGE use in urban regions, and other of factsheets of evaluated and characterised SGE concepts of use in urban areas.

From the **WP3** analyses a report on the current legal frameworks, procedures and policies on SGE use in selected European cities will be produced. Guideline for integrating and managing the use of SGE in urban areas will also be generated.

From **WP4** activities, it has been planned to obtain documented thematic output datasets for web presentation of selected pilot areas. The thematic output datasets represent spatial datasets (GIS based vector- and raster datasets as well as 3D datasets), which will be compiled and transferred to **WP5** for web hosting. All datasets produced will be accompanied by annotation reports, which will also be published on the GIP-P related web platform.

Figure 4: Factsheets of the Pilot areas.

From pilot areas, a compilation of fact sheets including the main findings of MUSE has been prepared (Fig.5) 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. They will be updated and complemented with a summary report describing the outcomes in the pilot areas.

The **WP5** will focus on the web platform related to MUSE (http://geoera.eu/projects/muse/) and a Data Management Plan for the specification of output data formats, data types, attributes, expected semantics and the description of required functionalities related to the display on the GIP-P.

The guidelines on the delivery of geodata and knowledge related to SGE to the GeoERA and the guidelines on the use of the SGE web platform tools at the GIP-P will be published to assist future SGE use in urban areas outside MUSE.

Finally, an activity report on capitalising activities with other project teams inside GeoERA will log and summarise all major activities in overlapping pilot areas.

6. DISSEMINATION OF RESULTS

A preliminary general Communication, Dissemination and Exploitation Plan has been devised. This includes:

- web services presenting output datasets at the pilot areas and all the related geographical information outcomes to be hosted at the GIP-P;
- all output datasets produced in the pilot areas to be hosted on the GIP-P, will also be accessible for downloads as GIS datasets in a standard format.

For the general public, scientific community, local stakeholders in the pilot areas, EU & national stakeholders and the GeoERA group, a website and a leaflet (Fig.5) will be made available. Also one catalogue of evaluated SGE concepts will be completed in order to raise the awareness on SGE for decarbonisation of European cities.

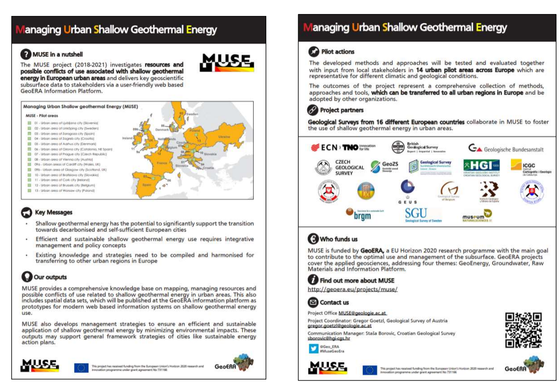

Figure 5: Leaflet available at MUSE website.

More specifically for the GeoERA group, EU & national stakeholders and scientific community, different seminars and workshops will be held during which the web conferences and knowledge transfer activities will play an important role.

The project Communication-Dissemination-Exploitation Plan includes dissemination actions to scientific and expert communities with a cumulative research paper and presentations at conferences and expert workshops. The guidelines referring to the SGE use, adapting the joint methods, workflows and concepts in Europe will comprise the list of tools necessary for the dissemination of MUSE results.

7. RESUME

The MUSE project (*Managing Urban Shallow geothermal Energy*) investigates resources and possible conflicts of use associated with SGE use in European urban areas and delivers key geoscientific subsurface data to stakeholders via a user-friendly web based GeoERA information platform.

MUSE will lead to the development of management strategies considering both efficient planning and monitoring of environmental impacts to feed into general framework strategies of cities like SEAP's.

The developed methods and approaches will be tested and evaluated together with input from local stakeholders in 14 urban pilot areas across Europe which are representative for different conditions.

The outcomes of the project will represent a comprehensive collection of methods, approaches and tools, which can be transferred to other urban regions in Europe and adopted by other organizations.

REFERENCES

ESTMAP: Energy Storage Mapping and Planning. EC funded Horizon 2020 project

GeoPLASMA-C: Shallow Geothermal Energy Planning, Assessment and Mapping Strategies in Central Europe. INTERREG VA Programme. Central Europe. European Union (www.geoplasma-ce.eu).

Geothermal4PL: Support for Sustainable Development and Use of Shallow Geothermal Energy within the Areas of the Mieszkanie Plus Programme in Poland. European Economic Area Grants. Norway Grants.

GRETA. Near-surface Geothermal Resources in the Territory of the Alpine Space. INTERREG VA Programme. Alpine Space. European Union (https://www.alpine-space.eu/projects/greta/en/home).

SUB-URBAN TU1206 (COST Action). EU Framework Programme Horizon 2020.

REGEOCITIES. Shallow Geothermal Energy. Intelligent Energy Europe Programme of the European Union.

ThermoMap: Mapping shallow geothermal potential across Europe. (2010-2013). Funded by the FP7 ICT-PSP.