STSM – Short Term Scientific Missions within the Action TU1405 – "European Network for Shallow Geothermal Energy Applications in Buildings and Infrastructures".

STSM FINAL REPORT

March 2017

Topic (correlation with the existing working groups within the Action):
Sustainability and urban planning – WG 3

Research Title: Development of geothermal potential maps at the urban scale

Home Institution: Politecnico di Torino (Italy)

Host Intitution:PGI-NRI (Poland)

Torino, 30/03/2017
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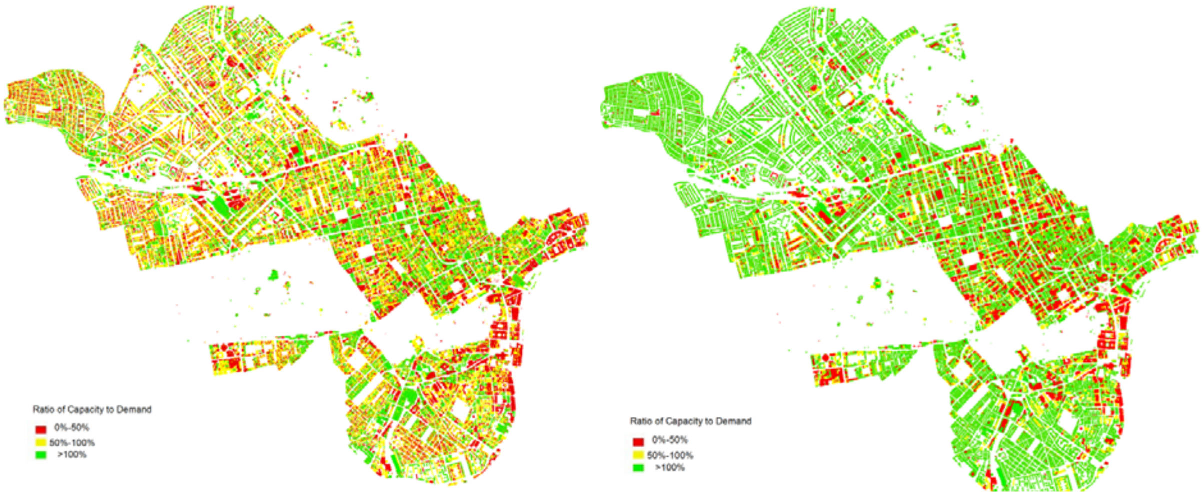
1 Purpose & aim of the STSM

1.1 Background

The maps of geothermal potential serve as a tool for identification of geoenergy sources for land development and spatial planning in both regional and urban scales. The main goal of this STSM was to develop a procedure similar to the one already developed by a team of the University of Cambridge for city and district scale geothermal mapping [1,2]. In that study, the city of Westminster (London) was used as a case study to identify areas where GSHPs can serve as a viable option renewable heating and/or cooling. Two scenarios were considered in the study, ‘Boreholes under Buildings’ as Scenario 1 and ‘Boreholes around Buildings’ as Scenario 2. A parametric study was conducted to investigate the influence of how space heating and cooling demand is quantified on the ratio of capacity to demand (C/D ratio) distribution map of Westminster as shown in Figure 1.



(a) Scenario 1 (b) Scenario 2

Figure 1 - The spatial distribution of the ratio of capacity to demand for the two scenarios. The buildings in green are those in which GSHP alone can provide both the heating and cooling supply. The buildings with GSHP can provide between 50-100% and 0-50% of the heating/cooling supply are shown in yellow and red, respectively [1,2].

The results show that many buildings (51% for scenario 1 and 67% for scenario 2) can install enough boreholes to support their own annual heating and cooling demands. For the rest of the buildings that have demand greater than their capacity, neighboring buildings with surplus capacity could share boreholes, leading to a district scale GSHP system. The analysis considered the influence of annual, monthly and hourly variation in heating/cooling demand estimation on the ratio of capacity to demand (C/D ratio) distribution map, and the influence of COP difference between design and operation on the electricity consumption. It was found that the influence of the variation in building load estimation is more significant under Scenario 1 than under Scenario 2.The hourly calculation of heating and cooling demand leads to a lower C/D ratio and the operational variation of COP influences the electricity consumption of the GSHP systems. The study showed that a comprehensive analysis including the capital cost, C/D ratio distribution, energy demand, and financial risk is highly recommended for district-level planning of GSHP systems and that a district scale GSHP is feasible. Although drilling many holes such as considered in the study are possible, they can be costly. The potential development of energy geostructures which combine GSHP with underground structures provides opportunity to realise a district scale GSHP.

1.2 Motivation and objectives

Geothermal geostructures are rapidly spreading all around Europe and are increasingly employed for heating and cooling of building in urban environment. Their diffusion is destined to continue in the next future. In this scenario, the interactions between close geothermal plants have to be carefully considered and specific urban planning is definitely needed. A first rough numerical model was developed for the central urban area of Torino in order to evaluate thermal anomalies induced by existing geothermal plants. Thus, the first objective of this mission is to share the methodology and knowledge about that experience in order to evaluate the applicability in other cities. The evaluation will be based on data availability and on the relevance of possible thermal alteration for the specific case of Warsaw. In fact the model output is intended as a layer of an advanced geothermal map. Geothermal maps are an easy to use planning tool intended for the local and regional authorities, inhabitants, engineering and drilling companies, etc. On one hand the maps provide information and data, which are important for urban planning and development of geothermal installations, and on the other hand they are needed to compose and dimension a geothermal plant. GIS-based simulation models are an effective tool in order to examine how many vertical closed loop GSHPs can be feasibly installed at city scale without overusing the geothermal energy underground. The objective of this mission was to share knowledge, information and work methods for the development of joined design procedures for a proper and efficient urban planning of geothermal systems. In particular this mission aimed at sharing detailed geological and thermal data referred to the construction site of Warsaw subway extensions. This data are definitively needed in order to develop a FE numerical simulation of thermo-hydraulic effects consequent to thermal activation of the tunnel lining. The mission was essential as detailed data (as borehole drilling records) were accessible only via intranet in the host institution (PGI-NRI) and with the interpretation of geologist expert for the above-mentioned site.

2 Work carried out

2.1 Agenda of the STSM

The STSM was conducted at the PGI offices in Warsaw (with the team involved in the COST action, led by Grzegorz Ryzynski) and in ITB (working group meeting attendance and discussion with Witold Bogusz).

At PGI offices the attention was posed to the PGI database of engineering-boreholes (see pgf. 2.4 and http://atlasy.pgi.gov.pl), analyzing the available data and identifying the steps for the preliminary assessment of the potential application of energy tunnels for the Warsaw metro (see pgf. 2.2). Once identified the data available, they were selected and analyzed in order to proceed to the modelling phase. Two days were also devoted to the active attendance at working group meeting (see pgf. 2.3). As a complementary activity also the visit to PGI-NRI laboratories and geological museum was carried out.

The agenda was as follows:

•Monday 20/3: Participation to the Working Group meeting

•Tuesday 21/3: Participation to the Working Group meeting

•Wednesday 22/3: visit to the laboratories and the geological museum in PGI headquarters + discussion in PGI at Jagiellonska 76 street (Engineering-geological database)

•Thursday 23/3: Discussion in PGI at Jagiellonska 76 street+ creation of simplified profiles for Warsaw Metro 2nd line for numerical modelling of potential geothermal activation of metro structural elements (tunnel linings and station foundation elements – slab and diaphragm walls)

•Friday 24/3: Attribution of modelling parameters + Discussion including POLITO – PGI-NRI and Research Building Institute specialists.

•Monday 27/3: Analysis of geometrical data for 2nd Line of Warsaw Metro (stations C16, C17 and C18) + discussion about the use of GIS in advanced geothermal mapping

•Tuesday 28/3: Summary of STSM activities and future plans.

2.2 Modeling for Warsaw metro extension

The modeling activity performed for the Turin metro [3,4] and for a preliminary evaluation for the Warsaw metro was illustrated to the PGI partners. The participants agreed that the first results were interesting and that further and more detailed studies were worthy to be performed. The legislative framework in Torino and Warsaw were then compared in order to evaluate whether an analogue approach can be used in Warsaw case study. The city of Warsaw, in fact, is currently undergoing extensive renovation of its infrastructures. In particular the M2 line of the underground will be extended in the direction NE, SE and W as shown in Figure 2. The NE extension will be constructed in an area of the city (Praga) were renovation and modernization of the buildings and surface facilities is expected to take place and will be enhanced by the underground works and the consequent increase in land value. These are all favorable circumstances for proposing the use of the tunnel lining for exchanging heat in the ground and making district heating and cooling systems available for the new constructions on the surface.

In particular, the main points that were discussed about the improvement for the modelling were:

- creation of a number of sections both of metro tunnels and of the stations;
- improvement of the detail of the hydrogeological setting of the cross sections accounting for vertical stratification;
- assignment of realistic boundary conditions in terms of temperature.

Thus, the study that has been started with this STSM and the consequent planned publication are intended to persuade both public authorities and constructors that from thermally activating tunnel linings and diaphragm walls benefits are definitely expectable. The aim is to bring this technology in the design stage of other metro extensions that are already planned.

During the STSM the workflow that was agreed during the previous visit of Marco Barla and Alice Di Donna was refined. A first part of the related activity was performed. This allowed to exchange same data and knowledge about the site-specific setting and issues related to Warsaw. The work performed and planned is briefly described in the following paragraphs.

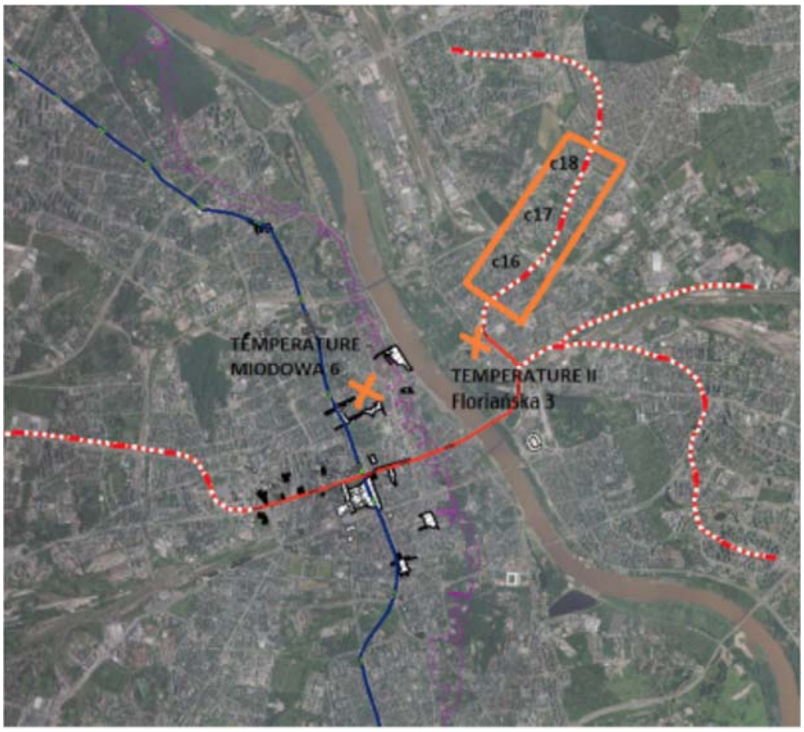


Figure 2 – Map of current Warsaw metro lines and future extensions of line M2 (red dotted lines). The area of interest of the study is highlighted within the orange box.

2.2.1 Definition of the areas of interest

The area of interest is included between the stations that are being constructed (C16, C17 and C18) in the NE extension of M2 metro line.

At first, the borehole dataset in the area was selected, both analyzing the Engineering-Geological Database of Warsaw and the documentation of the project. The identification of representative cross sections followed and the representative length was estimated on the basis of the longitudinal sections. The geological layers were then identified with the necessary properties and parameters.

Based on the data available, characteristic cross sections for numerical modeling were chosen and analysed in order to simplify them for modelling purposes.

2.2.2 Definition of the set of data needed for modeling

To prepare reliable numerical models the first step is to identify the key parameter that need to be assessed. This work was performed during the STSM. The parameters needed were identified in:

- Ground water flow conditions;
- ground geotechnical, thermal and hydrological parameters (thermal conductivity, specific heat capacity, permeability);
- initial temperature of the ground;
- geometry of stations and tunnels and depth of tunnels;
- geological model of the subsurface to a depth of 35 to 50 m.

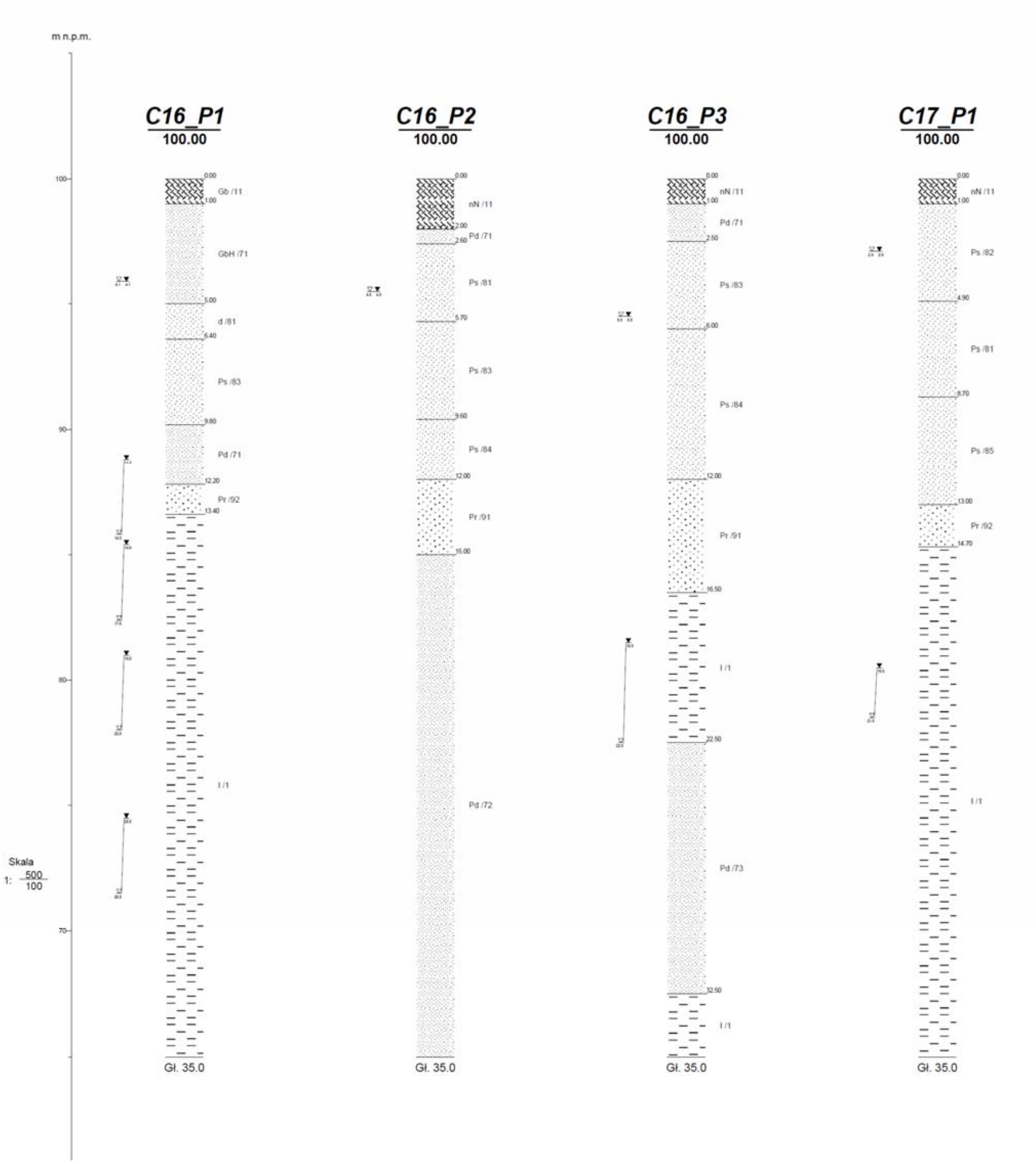


Figure 3 - Synthetic geotechnical profiles for analyzed stations and tunnels of 2nd line of Warsaw Metro (stations C16, C17 and C18). Each station was attributed with 3 simplified, representative geotechnical profiles.

The Metro Line M2 is expected to be excavated at an average depth between 13 to 23 m with a twin circular tunnel geometry. Stations will be constructed with the cut and cover method. Designed alignment, tunnel and station dimensions have been provided by the Office of Architecture and Spatial Planning of Warsaw Municipality. Furthermore, during the STSM it was possible to discuss with experts from ITB about the construction methods planned for the construction of both the tunnels and the stations. This represents also an example of active collaboration with other Working Group within the COST Action TU1405. In particular with WG4 member Witold Bogusz from ITB.

At this stage some simplification has to be done both from the geological and the construction point of view.

The geological model used for analyses has been prepared on the basis of GIS data from Engineering-Geological Database of Warsaw, maintained by Polish Geological Institute – National Research Institute, as one of the tasks of Polish Geological Survey (detailed explanation in pgf. 2.4 and at atlasy.pgi.gov.pl). Geo-engineering atlases of urban agglomerations are the largest unique collection of digital data of this type in Poland. They include detailed information obtained from geo-engineering, geotechnical, hydrogeological reports as well as borehole profiles. Thematic maps of the atlases are a visual synthesis of the geo-engineering information from the Central Geological Database (Centralna Baza Danych Geologicznych – CBDG). They allow the assessment of geo-engineering conditions of the agglomeration areas, for instance in spatial planning. Also, they help to take decisions related to planning detailed substratum surveys and minimizing the environmental damage as well as preparing prognoses and economic aspects of investments. Layers with data on geological and economic threats can be analyzed to prepare maps of risk.

The above mentioned data were obtained and analysed directly from documentation available in the PGI geotechnical database. Based on the design documentation, expecially referring to the geological investigations carried out, typical geological cross sections were identified and interpreted in order to be used in the modelling phase.

Cathegory number	Description	Symbol	-	Complete ID	Geostar code	Plasticity I_p/I_l [-]	bulk density ρ [kg/dm³]	Shear strenght parameter – Drained conditions – angolo di resistenza a taglio φ' [°]	Drained conditions – coesione c' [kPa]	Undrained conditions – angolo di resistenza al taglio non drenata Φ_u [°]	Undrained conditions – coesione non drenata c_u [kPa]	Shear stiffness G_0 [-]	Elastic stiffness – Strain level 0.10% E [Mpa]	Elastic stiffness – Strain level 0.50% E [Mpa]	Elastic stiffness – Strain level 1% E [Mpa]	Compressivity M [Mpa]	Thermal conductivity – Suggested λ [W/mK]	Thermal conductivity – Minimum λ [W/mK]	Thermal conductivity – Maximum λ [W/mK]	Void index e [-]	Permeability K_lit [m/s]	Thermal capacity cp [10^-3 J/kg/K]
I	Pliocen clays	pl	c	Iplc	1	0-0.25	2	12-25 / 22	3-18 / 8	13-19 / 17	9-18/ 9	80-200 / 90	35-105 / 50-85	15-50 / 20-40	10-18 / 15-18	30-50 / 30-40	1.6	2.2	0.9	0.6 / 0.4-0.7	10^-8	
II	Glacial tilts (sandy silty clay - OC)	Qr3	c	IIQr3c	21	0-0.25	2.1	17-22 / 19	8-11 / 8	18-24 / 18	3-8 / 8	-	58 / 58	31 / 31	22 / 22	20-30 / 20-25	2	0.9	2.2	0.25/0.2-.35	10^-5 - 10^-7	
		Ql2	c	IIQl2c	22	0-0.25	2.07	27-28 / 28	4-6 / 4	28 / 28	2/2	-	47-80 / 66	22-38 / 29	18-27 / 21	30-50 / 40	2	0.9	2.2	0.25/0.2-.35	10^-5 - 10^-7	
		Pl	c	IIPlc	23	0-0.25	2.1	11-22 / 21	8-11 / 8	18-24 / 18	3-8 / 3	-	58 / 58	31 / 31	22 / 22	20-60 / 20	2	0.9	2.2	0.25/0.2-.35	10^-5 - 10^-7	
IV (weak 2)	Glacial tilts (sandy clay/sandy silts NC)				4	0-0.25	2.1	10-15/15	8-11/8	18-24 / 18	3-8 / 8	-	58 / 58	31 / 31	22 / 22	20	2	0.9	2.2	0.25/0.2-.35	10^-5	
V	Pliocene clay / silts / sand	Pl	c	VPlc	5	0-0.25	2.15	18-25 / 24	2-8 / 5	20-25 / 22	4-10 / 8	-	35 / 35	22 / 22	12 / 12	40-70 / 40	2	0.9	2.2	0.8 / 0.7-0.9	10^-6 - 10^-7	
VI	Silt (wet)	Pl	c	VIPlc	6	0-0.2	2.05	18-23 / 23	2-8 / 6	17-24 / 20	2-10 / 8	-	42 / 42	23 / 23	13 / 13	65-100 / 55	1.8	1	2.3	0.7	10^-5 - 10^-6	
VII	Sandy silt (wet silt)	Qr4	b1	VIIQr4b1	71	0.3-0.4	1.7	31-35/ 31-33	-	31-34 / 31.5-32	-	100	80 / 80	45 / 45	28 / 28	50-90 / 50	2	0.9	2.2	0.7	10^-4 - 10^-6	
		Ql2	c	ViiQl2c	72	0.6-0.8	2	34-36 / 34	-	34-36 / 34	-	120	-	-	-	80-100 / 80	2	0.9	2.2	0.5	10^-4 - 10^-6	
		Pl	b1	VIIPlb1	73	0.4-0.5	1.9-2.0	31-34 / 32	-	32-34 / 33	-	110	100 / 100	45 / 45	22 / 22	70-100 / 80-85	2	0.9	2.2	0.6	10^-4 - 10^-6	
VIII	Fluvioglacial Sand	Qr4	b1	VIIIQr4b1	81	0.3-0.4	1.9	31-34 / 31	-	31 -36 / 31.5-35	-	150 / 150	80-110 / 80-110	45-70 /45-70	28-35 / 28-35	30-60 / 50-60	2.4	1.73	5	0.65	10^-3 - 10^-4	
		Qr4	b2	VIIIQr4b2	82	0.4-0.6	2	34-35 / 35	-	34-38 / 34	-	200-300 / 150	120 / 120	65 / 65	40 / 40	60-80 / 60	2.4	1.73	5	0.5	10^-3 - 10^-4	
		Qr3	b1	VIIIQr3b1	83	0.3-0.4	1.95	32-36 / 32	-	32-35 / 32.5	-	110	65 / 65	33 / 33	25 /25	60-110 / 60	2.4	1.73	5	0.65	10^-3 - 10^-4	
		Qr3	b2	VIIIQr3b2	84	0.5-0.6	2.05	38 / 38	-	35-39 / 39	-	120	110 / 110	55 /55	40 / 40	110-160 / 110	2.4	1.73	5	0.5	10^-3 - 10^-4	
		Qr3	c	VIIIQr3c	85	0.6-0.8	2.05-2.15	35-40 / 35-40	-	36-40 / 37.5-40.5	-	>300 / 180-200	135-150 / 140	75-110 / 100	48-85 / 75	>120 / 140-150	2.4	1.73	5	0.4	10^-3 - 10^-4	
		Qr1	c	VIIIQr1c	86	0.5-0.8	2.05	34 - 37 / 35	-	35-39 / 37	-	180	100-150 / 120	50-70 / 60	30-50 / 40	120-160 / 140	2.4	1.73	5	0.45	10^-3 - 10^-4	
IX	Gravel	Qr3	b	IXQr3b	91	0.4-0.6	2.05	33-35/ 34-35	-	34-36 / 35-36	-	140	130 / 130	65 / 65	38 /38	90-130 / 130	1.8	-	-	0.3	10^-3	
		Qr3	c	IXQr3c	92	0.6-0.8	2.1	41 / 41	-	40-42 / 42	-	150-200/200	160 / 160	75 / 75	45 / 45	>120 / 150	1.8	-	-	0.25	10^-3	
XI	Antropogenic grounds	Qh	-	XIQh	11	-	1.7	22-28 / 22	-	-	-	-	-	-	-	-	-	-	-	-	10^-3 - 10^-6	

Figure 4 – Table of the thermal, mechanical and hydrological parameters adopted for the representative cross sections

2.2.3 Definition of the modeling approach

The numerical analysis will be conducted with the aim to quantify the efficiency of the energy tunnel system with reference to the specific case study of the Warsaw metro extension. The performances of diaphragm walls in the stations will be also assessed with the numerical analysis.

A thermo-hydro mathematical formulation is required to simulate the thermal exchange between the fluid circulating through the pipes, installed in the tunnel concrete lining, and the surrounding soil, submerged under the ground water table.

The basis for such a modelling is the geometry of the thermoactive geostructure and the hydrogeological setting (see par. 2.2.2).

To this end, the finite element software FEFLOW© (Diersch 2009), license available at the Politecnico di Torino, is selected. For the simulation of the absorber pipes installed in the tunnel lining, 1D discrete features elements provided in FEFLOW© will be adopted. The use of these elements to simulate pipes in geothermal systems has been validated and showed good agreement when compared to analytical solutions (Diersch 2009). The mass and energy conservation equations are satisfied also for these elements, while the fluid flow inside them is described by the Hagen-Poiseuille law.

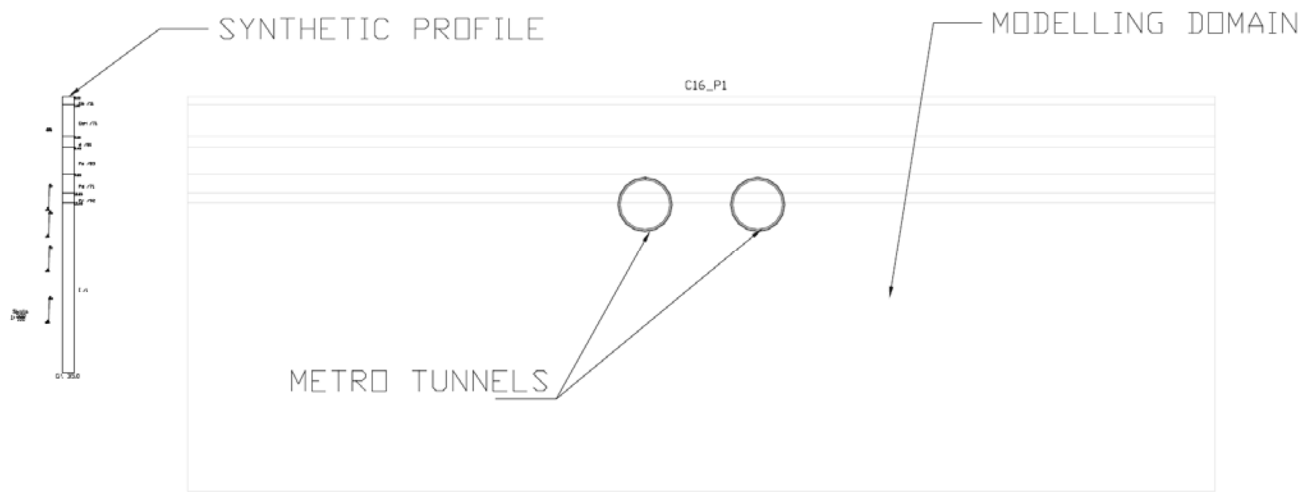


Figure 5 – Example of CAD import of simplified geological profiles to be included in FEFLOW© 3D Finite Element analysis software

3D finite element models will be built in order to reproduce the typical cross sections of the Warsaw metro tunnel and stations that have been selected (see par. 2.2.1), instrumented with heat absorber pipes.

In order to allow possible comparisons with Torino case study, which has been deeply investigated in Politecnico di Torino, the same kind of segmental thermo-active lining will be simulated as tunnel sections.

This assumption is also intended to provide a background to further collaboration and studies, both from the theoretical and from the practical point of view. In fact on one hand numerical analysis are intended as a detailed study of potential use of the metro infrastructure as an energy source. The results of these simulations are planned to be the basis for a publication as a contribution to the dissemination strategy of GABI Cost Action TU1405.

On the other hand, these theoretical studies are intended to provide a solid background for the proposal of joint projects which may involve PoliTO, PGI-NRI and ITB. During the STSM the project carried out in Torino about an experimental site for Energy tunnels has been presented. One of the possible follow-up of the discussion and collaboration between the involved institutions is therefore the proposal of building a similar experimental site along Warsaw M2 extension.

2.2.4 Interpretation of the results and dissemination strategies

The results of modeling will allow quantifying the amount of heat in terms of W/m^2 that can be exchanged in winter and summer, for the specific conditions of the Praga district in Warsaw. The results will be extrapolated to the appropriate length of the tunnel and of the station (based on the longitudinal sections) to compute total heat exchange for the whole tunnel length that will be activated.

A scientific paper will be prepared at the end of the work to be presented preliminarily at a national conference in Poland (and possibly also in Italy) and to be submitted to a scientific journal, eventually within the special issue organized by the GABI COST Action.

The paper title will be "The perspectives for geothermal activation of North-Eastern 2nd metro line extension in Warsaw". The paper preliminary outline will comprise the following sections:

- Introduction
- Geological settings
- Constructional aspects of North-Eastern extension of 2nd metro line
- Geotechnical and geothermal parametrisation
- Methodology for numerical modelling of geothermal activation of tunnels and stations
- Results
- Conclusions

2.2.5 Planned further studies and collaboration

As a further step for numerical modelling, the assessment of environmental impact of thermal activation of stations and tunnel will be carried out.

The study will move from the evaluations and the specific outcomes of the above-mentioned modelling phase. The aim is to study the development of a Thermally Altered Zone (TAZ) at district scale in case of thermal activation of metro extensions. This study might "complete" the theoretical framework to support the installation of heat exchangers in the metro line future extensions. The whole activity, focusing both on the capabilities of such a thermo-active infrastructure and on the impact on the city, will allow to take into account both public authorities and stakeholders interests. Thus it can be used as a decision support tool.

The latter part of the study regarding the evaluation of thermal impacts at district level are intended to lead to a second scientific paper publication that will be prepared at the end of the work. The work will be presented at a national conference in Poland and/or in Italy and will be submitted to a scientific journal, eventually within the special issue organized by the GABI COST Action.

2.3 Working Group meeting

As the STSM took place in the same period of the Working Group meeting held in Warsaw, two days were devoted to the participation to this meeting.

The agenda of the WG meeting was as follows:

Monday 20th March:

- Plenary session: 13:00-13.30
- WG meeting session#1: 13.30-15.00
- WG meeting session#2: 15.30-17.00

Tuesday 21st March:

- WG meeting session#3: 9.00-11.00
- Plenary session: 11.30-12.30

In particular during WG meeting sessions the content of the guidelines that will be one of the main deliverables of the COST Action TU1405 have been discussed.

As in Torino meeting the structure of the contribution of WG3 were discussed, the responsible people for each paragraph were already been identified. Thus in Warsaw meeting the content prepared by each of the responsible (in form of bullet points) was carefully shared with all the group members and discussed. As a result, a more coherent structure of the content has been developed within WG3. Furthermore, a similar activity has been performed at WG leader level in order to harmonize the whole content of the deliverable.

One of the main results of the WG meeting session was to change the case studies that will be included as examples of district/city scale management of geothermal shallow energy. Participants were addressed as responsible for each of them, on the bases of individual experience.

In addition, in the part regarding the sustainability has been decided to be structured like the Guide To Cost-benefit analysis of investment projects. Proper adaptation will be performed for the shallow geothermal energy case based on the content of the previous sections.

2.4 Engineering-geological data base historical background

2.4.1 The local authority's maps in the scale 1:10000

The very first attempt to create engineering-geological data base has been done in late 1990`s when the digital background for engineering-geological and environmental mapping on local level was introduced for spatial planning (Bażyński et al., 1999). The main idea was to deliver guidelines for visualisation of geological data in the unified and customer friendly manner.

2.4.2 Engineering-geological databases

Engineering-geological atlases of biggest Polish urban agglomerations are the largest unique collection of digital data of this type in Poland. They include detailed information obtained from geo-engineering, geotechnical, hydrogeological reports as well as borehole profiles. The cities which have the atlases prepared are Warszawa, Katowice, Kraków, Poznań, Wrocłąw, Trójmiasto, Wałbrzych, Rybnik, Łódź. Also, they help to take decisions related to planning detailed substratum surveys and minimizing the environmental damage as well as preparing prognoses and economic aspects of investments. Layers with data on geological and economic threats can be analysed to prepare maps of risk.

Engineering-geological atlases in the scale of 1:10 000 and borehole databases were prepared on request of the Ministry of the Environment. Contractors were selected in a public tender procedure. From 1998 till 2012 such situation resulted in heterogenic methodologies of data gathering and visualisation, giving in effect the 9 separate (desktop - interbase) file databases. The need for integration of these databases emerged. Since 2013 Polish Geological Survey was given the task by Ministry of Environment to unify the existing 9 databases and prepare 6 new areas including: Bydgosz, Koszalin, Płock county, Piaseczno county and selected sections of Baltic cliff coast shoreline.

While investments in urban areas are prepared and planned, it is necessary to have a considerable amount of varied information about natural geo-engineering conditions, infrastructure, and ways of land use, ownership relations etc. Equally important is the possibility of processing the obtained data in various ways. This is the main purpose of gathering of the engineering-geological data in PSG in form of Engineering Geological Database (EGDB).

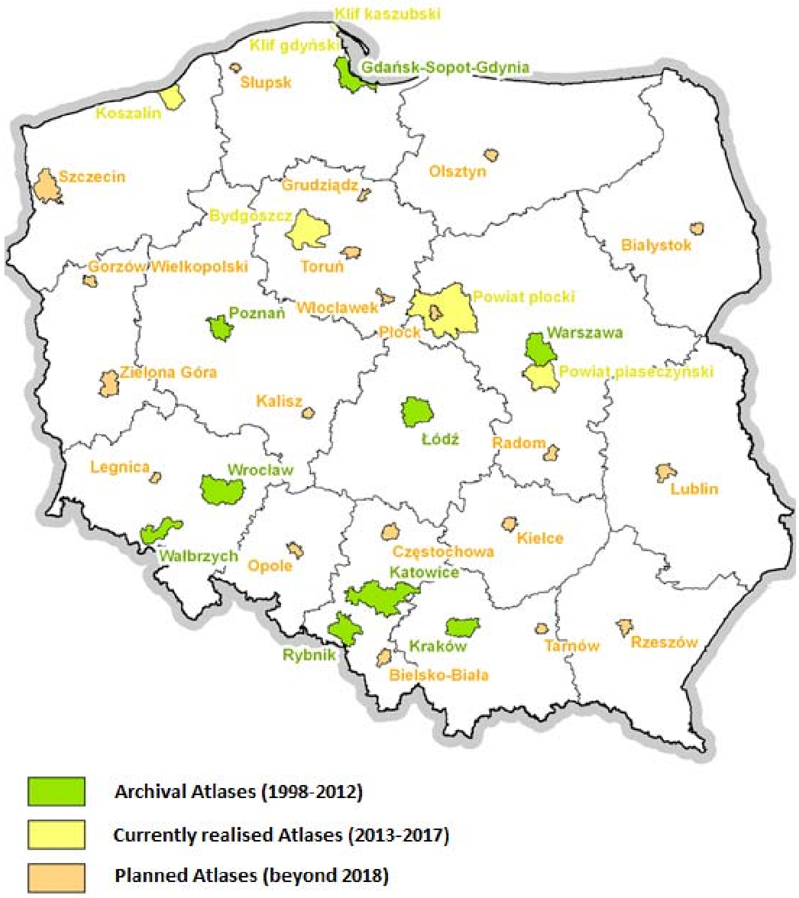


Figure 6 - Location of Cities covered by PGI-NRI Engineering Geological Database Project (acronym EGD) (see http://atlasy.pgi.gov.pl)

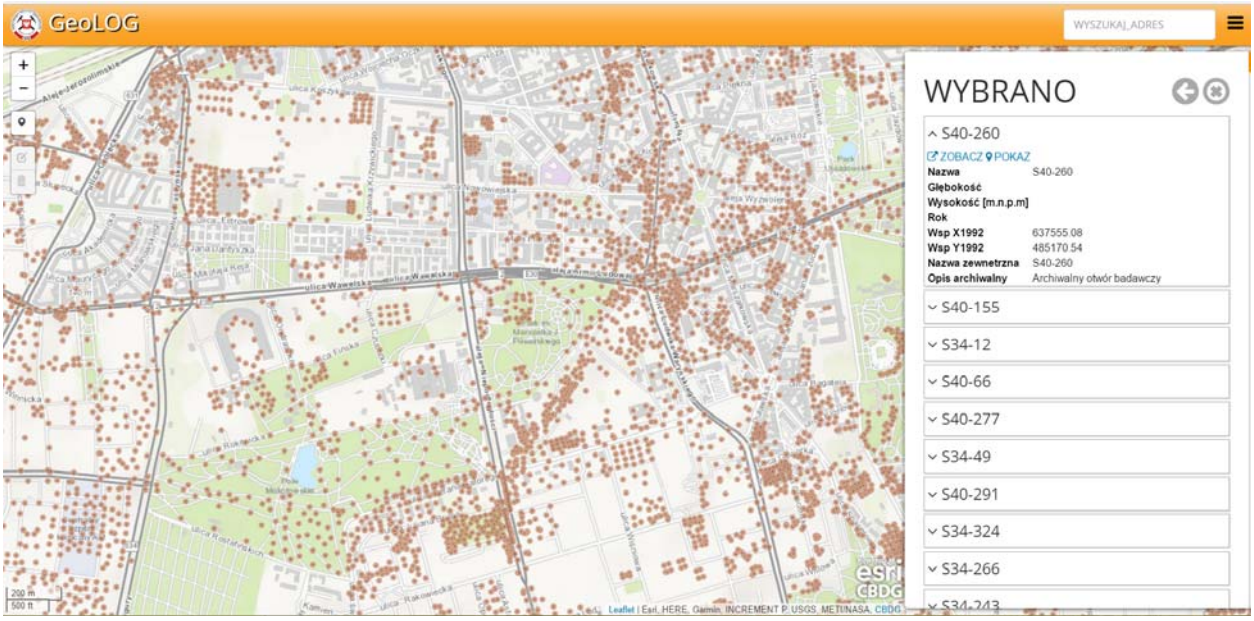


Figure 7 - GeoLOG – an online GIS browser of PGI-NRI spatial data. EGD project boreholes and spatial layers are available for download directly from the website.

Main problems with separate 9 desktop Interbase engineering-geological databases were at first: the lack of unified dictionaries of lithology, genesis and stratigraphy, accordant to Polish Standards and European ISO/Eurocode classification standards. Second problem was with the coordinates of boreholes, as each of archival 9 databases was in different projections. Lastly the big barrier towards integration and reprocessing of borehole database was the high amount of transcription errors in table fields containing the soil/rock symbol, stratigraphy and genesis ("the human factor"). This situation also blocked any advanced and quick reclassification and geo-processing of archival interbase datasets. The quality of data is now constantly improved by implementation of abovementioned dictionaries and the use of "data input wizard", which significantly improves data quality by not allowing the data input "by hand". The performed engineering-geological data unification allowed merging all 9 archival datasets and 6 newly gathered datasets into one unified professional geodatabase in Oracle 12 standard. This is a milestone for an advanced GIS geo-processing implementation in the domain of engineering geology in Polish Geological Survey.

This unified dataset has a very practical application. Appropriately prepared geological information allows the assessment of geo-engineering conditions of the subsoil in urban areas for the purposes of spatial planning, for instance when selecting the location of housing estates or mapping out a number of possible routes of linear construction features and underground infrastructure (highways, railways, pipelines, high voltage lines, etc.) Also, the use of GIS-processable engineering-geological data helps to take decisions related to planning detailed geotechnical site investigations and to minimize the environmental damage as well as preparation of prognoses and economic aspects of investments.

2.4.2.1 GEOSTAR – the first step towards local standards

All borehole data in Engineering Geological Database (EGDB) is gathered in the database format of Geostar software. The Geostar is one of the most popular geological software package in Poland. It is used over 400 private and public parties, including universities, mining plants, geotechnical consultants, research institutes and small and medium geological companies.

The GeoStar package enables the creation of documentation cards for borehole profiles, dynamic and hydrogeological soundings, as well as the generation of geological sections of selected boreholes or their straight-line projections. The package has a modular structure, enabling the user to select just the modules needed, including creation of cross section, borehole and sounding logs, documentation maps.

Borehole database which is used by Geostar software has become an informal standard for geotechnical and engineering geological boreholes gathering and management. The database is in interbase format (*.gdb). It is a desktop file geodatabase. Its structure is presented in form simplified schema on figure 1. Throughout the years of Geostar software development since 1995 the database structure evolved and constantly grown, however the main tables and fields remained the same (tables GS_Boreholes and GS_Profile log). This allows the Geostar databases to be fully backwards compatible. This approach also allows to fully use all archival databases from archives of private and public companies and geological authorities (which is often stored on CD/pendrives/hard disks in interbase files). The database structure (see fig. 1) is a set of related tables, containing only one spatial component – the x,y and z coordinates of the borehole. Two main tables are GS_Borehole (it contains the information about localisation, depth, contractor, date of drilling, drilling method, etc.) and GS_Profile Log (includes litho-stratigraphic profile with information about genesis of strata and the reclassification of borehole profile into engineering geological, parameterized units. Dictionaries used for Geostar software for Engineering Geological Database were developed in accordance with Polish Standards for soil and rock classification and ISO/Eurocode EU standards. Other tables, such as GS_Soundings and GS_Samples contain optional information about geotechnical soundings profiles accompanying the boreholes and information about the depth, location and amount of samples collected for certain strata and the laboratory testing results.

Interbase databases (*.gdb desktop standard) are widespread among geological companies, geotechnical consultants and contractors. Large part of engineering-geological data collected from these parties by Polish Geological Survey for National Geological Archive (obligation by the Mining and Geology Law) has the same *.gdb desktop format and Geostar database structure.

As in Poland there is no official standard for engineering-geological borehole data, due to this situation the Geostar data structure was considered by PGS as a “engineering geological borehole data standard”. A good example of borehole data standardisation can be the AGS format for borehole data developed by British Geological Survey (see http://ags.org.uk/data-format/).

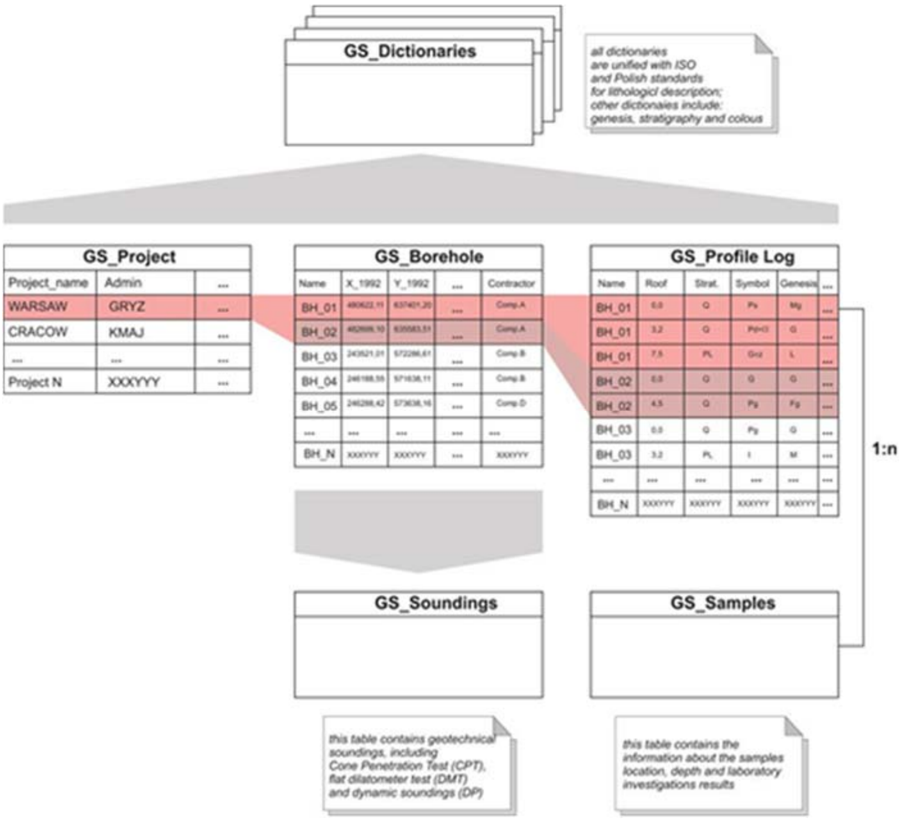


Figure 8 - The simplified scheme of GEOSTAR Borehole Data Base structure.

3 References

[1] Zhang Y, Soga K and Choudhary R. Shallow geothermal energy application with GSHPs at city scale: study on the City of Westminster. Géotechnique Letters. 2014;4(2):125–31.

[2] Zhang Y, Soga K, Choudhary R and Bains S. GSHP Application for Heating and Cooling at “City Scale” for the City of Westminster. Proceedings World Geothermal Congress. Melbourne, Australia; 2015.

[3] Barla, Marco; Di Donna, Alice; Perino, Andrea. Application of energy tunnels to an urban environment. Geothermics, 2016, vol. 61, pp. 104-113. ISSN 0375-6505

[4] Di Donna, Alice; Barla, Marco. The role of ground conditions on energy tunnels heat exchange. Environmental Geotechnics. 2016. ISSN 2051-803X

[5] Grzegorz Ryżyński, Tomasz Nałęcz. Engineering-geological data model, the first step to build national Polish standard for multilevel information management. IOP conference series: Earth and environmental science 44 (2016) 032025. World Multidisciplinary Earth Sciences Symposium, WMESS 2016

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Polish Geological Survey

Polish Hydrogeological Survey

Warsaw, 27 March 2017

To the attention of Short Term Scientific Mission (STSM) Committee

COST Action 1405:
"European Network for 1 Shallow Geothermal Energy Applications in Buildings and Infrastructure" – GABI

Subject: STSM "Development of geothermal potential maps at the urban scale - Held at PGI-NRI, Warsaw, Poland, 18th-28th March 2017

Dear STSM Evaluation Committee Members,

Within the framework of cost action TU1405 ""European Network for Shallow Geothermal Energy Applications in Buildings and Infrastructure" the PGI-NRI had a pleasure to welcome Matteo Baralis (Ph.D. candidate) from the DISEG-Politecnico di Torino for a ten-day STSM.

During the STSM activities were held in Warsaw at PGI-NRI. The main attention was posed to the PGI database of engineering-boreholes (see http://atlasy.pgi.gov.pl), analyzing the available data and performing the first steps for the preliminary assessment of the potential application of energy tunnels for the Warsaw metro. In fact, significant data have been analyzed, interpreted and exchanged. These activities will allow to perform proper numerical analysis for assessment of exchangeable heat from the thermal activation of underground structures related to the NE extension of metro line M2.

Two days were also devoted to participate to the Working Group meeting within the GABI COST Action. One day was also devoted to the modeling issues with 3D geological software (transfer of model data to ArcGIS software), as a part of the development of advanced geothermal maps that can constitute design tools for a proper and efficient urban planning of geothermal systems. Discussion were hold to evaluate options and ideas about geothermal advanced map development that can be performed by Matteo Baralis during his Ph.D. project.

The agenda was as follows:

- Monday 20/3: Participation to the Working Group meeting
- Tuesday 21/3: Participation to the Working Group meeting
- Wednesday 22/3: visit to the laboratories and the geological museum in PGI headquarters + discussion in PGI at Jagiellonska 76 street (Engineering-geological database)
- Thursday 23/3: Discussion in PGI at Jagiellonska 76 street+ creation of simplified profiles for Warsaw Metro 2nd line for numerical modelling of potential geothermal activation of metro structural elements (tunnel linings and station foundation elements – slab and diaphragm walls)

- Friday 24/3: Attribution of modelling parameters + Discussion including POLITO – PGI-NRI and Research Building Institute specialists.
- Monday 27/3: Analysis of geometrical data for 2nd Line of Warsaw Metro (stations C16, C17 and C18) + discussion about the use of GIS in advanced geothermal mapping
- Tuesday 28/3: Summary of STSM activities and future plans.

The STSM resulted in a useful exchange of the methodologies used by POLITO and PGI-NRI of database management, geothermal city-scale mapping and geothermal numerical modeling by FEFLOW. The main benefit from this STSM was the exchange of detailed geological data which will allow modelling of the thermal activation of Warsaw Metro line M2 extension in North-East direction. The plans for two peer reviewed papers were refined and discussed.

We are confident that our collaboration will continue beyond this STSM and we already have plans for future joint research activities.

The direct effect of performed STSM will be a peer reviewed paper (a contribution to COST GABI Action) on city scale potential of thermoactive structures in Warsaw according to results of numerical modelling in FEFLOW.

Reassuming we are very glad with our opportunity to cooperate with our guests from POLITO and we confirm the successful execution of the STSM project.

Best Regards.

ZASTĘPCA KIEROWNIKA PROGR.
Bezpieczna Infrastruktura i Środowisk
mgr inż. Grzegorz Ryżyńsk

Grzegorz Ryżyński
Deputy Head of Programme
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