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The GRETA project: the contribution of near-surface geothermal energy for the energetic self-sufficiency of Alpine regions

Progetto GRETA: il contributo del geoscambio per l'autosufficienza energetica dell'area alpina

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Parole chiave: cooperazione europea, pompe di calore geotermiche, impianti geotermici a circuito aperto, potenziale geotermico a bassa profondità

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Abstract: *The Alpine regions are deeply involved in the challenge set by climate change, which is a threat for their environment and for important economic activities such as tourism. The heating and cooling of buildings account for a major share of the total primary energy consumption in Europe, and hence the energy policies should focus on this sector to achieve the greenhouse gas reduction targets set by international agreements. Geothermal heat pump is one of the least carbon-intensive technologies for the heating and cooling of buildings. It exploits the heat stored within the ground, a local renewable energy source which is widely available across the Alpine territory. Nevertheless, it has been little considered by European policies and cooperation projects. GRETA (near-surface Geothermal REsources in the Territory of the Alpine space) is a cooperation project funded by the EU INTERREG-Alpine Space program, aiming at demonstrating the potential of shallow geothermal energy and to foster its integration into energy planning instruments. It started in December 2015 and will last three years, involving 12 partners from Italy, France, Switzerland, Germany, Austria, and Slovenia. In this paper, the project is presented, along with the results of the first year of work.*

Riassunto: Le regioni alpine sono fortemente interessate dal cambiamento climatico, che minaccia l'ambiente montano e attività economiche fondamentali come il turismo. Il riscaldamento e il raffrescamento degli edifici hanno una forte incidenza sul consumo totale di energia primaria in Europa e le politiche energetiche per la riduzione dei gas serra, per avere successo, devono quindi focalizzarsi su questo settore. La pompa di calore geotermica rappresenta una delle tecnologie meno carbon-intensive per il riscaldamento e il raffrescamento degli edifici, e utilizza una fonte energetica rinnovabile sfruttabile in gran parte dell'area alpina. Ciononostante, la geotermia a bassa entalpia è sempre stata poco considerata dalle politiche europee e dai progetti di cooperazione. GRETA (near-surface Geothermal REsources in the Territory of the Alpine space) è un progetto di cooperazione finanziato dal programma INTERREG – Alpine Space che ha l'obbiettivo di dimostrare il potenziale della geotermia a bassa entalpia e di stimolarne l'integrazione negli strumenti di pianificazione energetica. Il progetto è iniziato a dicembre 2015 e durerà tre anni, coinvolgendo 12 partner da Italia, Francia, Svizzera, Germania, Austria e Slovenia. In questo articolo viene presentato il progetto insieme ai risultati del primo anno di lavoro.

Introduction

The threat of climate change is known and widely accepted by scientists and decision-makers, who set ambitious international policies in recent years for the reduction of greenhouse gas emissions, such as the Kyoto Protocol (1997) and the recent agreement of COP21 in Paris (2015). In the meantime, the European Union set the "20-20-20 strategy" to cut 20% of energy consumption and greenhouse gas emissions and to cover 20% of the total demand with renewable energy sources (RES) (Eurostat 2016). Different targets were set for each Member State and sector (electricity, heat and transport), and a further burden sharing was set by each country among its regions. Italy set targets of renewable energy coverage at 26.4% for electricity, 17.1% for heat production and 10% for transport to cope with the global target of 17% set by the EU, which was achieved in 2014 (GSE 2015).

Buildings account for about 40% of the total primary energy consumption in the world (Nejat et al. 2015), and hence the efforts should concentrate in this field. Renewable heat sources for buildings are, ranked by heat production: woody biomass, heat pumps and solar thermal panels. Woody biomasses are the most economically convenient heat source in most EU countries, they have very low CO2 emissions (ideally, growing and burning trees is a close CO2 loop) but, on the other hand, they have high emissions of air pollutants such as particulate matter (both PM10 and PM2.5), volatile organic compounds, polycyclic aromatic carbons, CO, and NOx (ARPA Lombardia et al. 2010). Biomass heating poses a serious air quality issue in Alpine regions (Bari et al. 2010; Favez et al. 2010; Piazzalunga et al. 2013), and hence a further expansion of the use of this energy source is not desirable. In the European roadmap for a 100% renewable heat production in 2050, heat pumps play the most important role both as individual and district heating plants (Connolly et al. 2016; Connolly et al. 2014). They are considered as one of the least carbon-intensive heating solutions, unless coal and oil cover a large share of the electricity production (Kennedy et al. 2014; Saner et al. 2010). Heat pumps can be classified according to the functioning principle (electric/endothermic-engine compression, and absorption HP) and to the heat source (air-source, surface water and geothermal). Electric air-source heat pumps (ASHPs) are, by far, the most diffused type (EUROBSERV'ER 2016). Geothermal heat pumps (GHPs) use the ground and/or groundwater as a heat source and/or sink. Since the subsurface temperature is stable through the year, i.e. warmer than the air during winter and cooler during summer, a higher energy efficiency (COP, coefficient of performance) is generally achieved compared to ASHPs (Safa et al. 2015). In addition, GHPs are not affected by frosting, which is a strong issue in cold climates (Zhu et al. 2015). GHPs are divided into closed-loop systems, in which a heat carrier fluid is circulated into a pipe loop buried into the ground, and open-loop systems, performing the heat exchange on groundwater (Casasso and Sethi 2013; Omer 2008; Sarbu and Sebarchievici 2014). Closed-loop systems are further divided into vertical exchangers installed in foundation piles (energy piles) or in a borehole drilled on purpose (BHE, borehole heat exchanger), and horizontal heat exchangers (earth coils, geothermal baskets etc.). Open-loop systems, also known as ground water heat pump (GWHP), usually reinject water into the same aquifer by means of one or more water well; more rarely, groundwater is rejected on the surface (river, channel, lake) or in an upper portion of the same well (standing column well). Borehole heat exchangers are, by far, the most diffused type of geothermal heat exchangers, followed by GWHP with reinjection performed by wells.

GHP is an emerging technology, with over 1.4 million plants installed in Europe up to 2015 and a yearly growth rate of 5.9% (EUROBSERV'ER 2016). This growth is still limited by factors such as i) the high installation costs ii) the high cost of electricity compared to methane iii) the scarce knowledge of this technology, both of customers and technical staff (also HVAC designers) iv) a complicated and fragmented legislation and v) the scarce consideration of GHP in energy planning. The EU-funded projects GROUNDMED (Montagud et al. 2013), GROUNDHIT (Sanner et al. 2007) and the ongoing H2020 projects Cheap GSHPs (Bernardi et al. 2015) and G€OTECH (Solintel et al. 2015) have been implemented to reduce the installation costs of shallow geothermal systems. Electricity is highly taxed in Europe, i.e. 33% of average in EU28 and over 50% in Germany (Eurostat 2017), and hence a tax reduction would be highly desirable. Knowledge exchange on GHP has been addressed by projects such as REGEOCITIES (European Geothermal Energy Council-EGEC et al. 2015), LEGEND (Tinti et al. 2016) and GEOPOWER (Giambastiani et al. 2014).

This paper presents the GRETA project, funded by the EU program INTERREG-Alpine Space. The objective is to sustain the use of shallow geothermal energy in the Alpine regions and it is pursued by improving the knowledge of general public and decision makers on this renewable energy source, exchanging best technical and administrative practices and developing decision support tools for individual installations (maps of the near-surface geothermal potential) and energy planning at local and regional scale (e.g. sustainable energy action plans, SEAPs). The planned project activities are described in next chapter, along with the first results of the project reported in detail in the deliverables published on December 2016 (Bottig et al. 2016; Capodaglio et al. 2016; Prestor et al. 2016; Zambelli et al. 2016).

Description of the project

The INTERREG – Alpine Space program

The European Union is committed to the collaboration between territories to address common challenges through the INTERREG programs. The cooperation area of Alpine Space covers Switzerland, Austria, Liechtenstein, Slovenia and the Alpine regions of Italy (Liguria, Piemonte, Valle d'Aosta, Lombardia, Veneto, Trento, Bolzano, Friuli-Venezia Giulia), France (PACA, Rhone-Alpes, Alsace, France-Comté), and Germany (Freiburg, Tubingen, Schwaben and Oberbayern). It is a large territory (388,000 km2) with a population exceeding 66 million, including some of the richest European regions. The Alpine Space program has four main priority axes, namely 1) Innovative 2) Low Carbon 3) Liveable and 4) Well-Governed Alpine Space. The GRETA project is carried out under the priority axis 2, for the specific objective of establishing transnationally integrated low carbon policy instruments.

Project activities, work packages and partners

GRETA is the acronym of "near-surface Geothermal REsources in the territory of the Alpine space".

The project aims at removing the non-technical barriers to the diffusion of shallow geothermal systems, through a number of interlinked actions organised by different Work Packages (WPs):

- development of a proposal for the harmonisation of legislation and authorization procedures for near-surface geothermal systems (WP2);
- knowledge exchange on near-surface geothermal systems and on their possible applications (WP3);
- assessment and mapping of qualitative and quantitative near-surface geothermal potentials in the Alpine territory (WP4);
- development of tools for the implementation of NSGE in local energy plans (WP5);
- interaction and feedback loop with stakeholders (WP6);
- innovative communication tools to reach the large public, such as the development of a geo-caching app for GHP and the construction of a 'geothermal trail' (WP7).

Some of the interactions between WPs are shown in Fig. 1 and are further described in next paragraphs. Guidance for the assessment and mapping of shallow geothermal potentials (WP4) is provided by legal (WP2) and technical (WP3) criteria and constraints, and a feedback loop is established with stakeholders (WP6) to assess their needs and preferences for the tools to be developed. The resulting maps of geothermal potentials are an essential input for the integration of near-surface geothermal energy (NSGE) into energy plans (WP5) and will be implemented in a mobile-friendly Web-GIS.

The project consortium is led by the Technical University of Munich (TUM) and is composed of 11 other partners (Fig. 2): Politecnico di Torino (POLITO, leader of WP4) and University of Basel (UniBasel), the research centre EURAC Bolzano (leader of WP5), the geological surveys of Slovenia (GEOZS, leader of WP2), Austria (GBA, leader of WP3) and France (BRGM, leader of WP7), the environmental agency

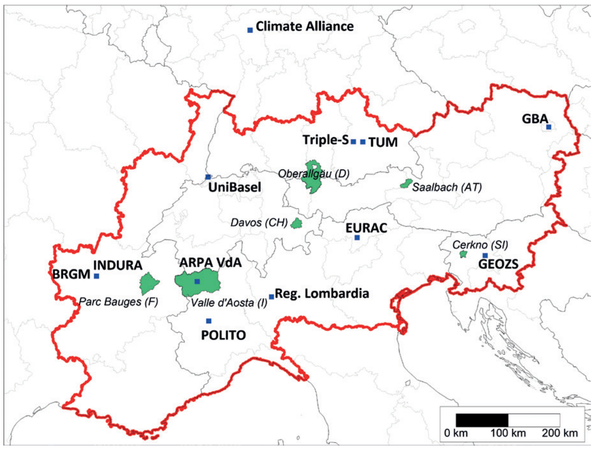

Fig. 2 - Cooperation area of the EU program INTERREG – Alpine Space, with the positions of the project partners and of the six case-study areas: Region Valle d'Aosta (Italy), Parc des Bauges (France), Davos (Switzerland), Oberallgau (Germany), Saalbach (Austria), and Cerkno (Slovenia. Scale: 1:10000000 (1 cm=100 km).

Fig. 2 - Area di cooperazione del programma INTERREG – Alpine Space, con le posizioni dei partner di progetto e delle 6 aree di studio: Regione Valle d'Aosta (Italia), Parc des Bauges (Francia), Davos (Svizzera), Oberallgau (Germania), Saalbach (Austria) e Cerkno (Slovenia). Scala 1:10000000 (1 cm=100 km).

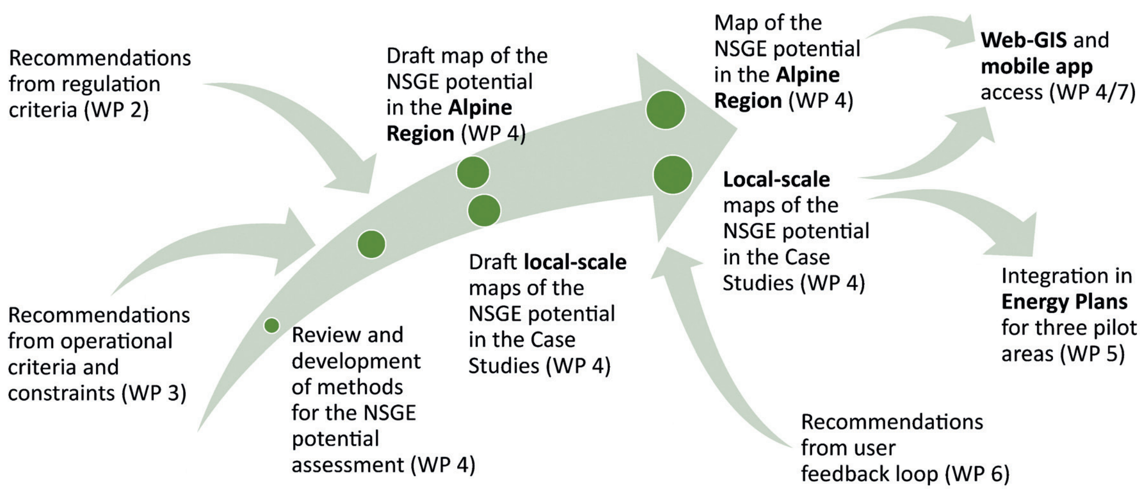

Fig. 1 - Interactions of NSGE assessment and mapping (WP4) with the other project activities: regulation (WP2) and technical (WP3) criteria, feedback from users (WP6), and integration into energy plans (WP5).

Fig. 1 - Interazioni dell'attività di studio e mappatura del potenziale geotermico (WP4) con le altre attività progettuali: criteri di regolamentazione (WP2) e tecnici (WP3), feedback dagli utenti (WP6) e integrazione nella pianificazione energetica (WP5).

ARPA Valle d'Aosta (leader of WP6), the industrial cluster INDURA (Infrastructures Durables Rhone-Alpes), the administration of Regione Lombardia, the German enterprise Triple-S (developing innovative GHP solutions for transport infrastructures) and Climate Alliance, a European association of municipalities committed to the sustainable development of their territories.

WP2 – Legislation

As explained before, legislation is one of the main barriers to the diffusion of GHPs. Fragmentation, under-regulation and over-regulation are the most serious issues in this field. The activity of this WP started with the collection and review of existing regulations and authorisation procedures in Alpine countries and regions, identifying a common set of criteria. This phase is already concluded and results are presented in next chapter. The authorisation processes are then compared analysing case studies of GHP installations collected by WP3 as best-practice examples and covering different countries, regions and technologies (e.g., closed vs open-loop systems). A specific deliverable will be published on June 2017 and, together with the analysis of regulations, it will be the base for a wide debate with stakeholders conducted through focus groups and questionnaires organised with WP6. A guideline for the regulation of NSGE will be published in September 2018, gathering the good practices of different Alpine regions and countries identified by partners and stakeholders along with their proposals, and will serve as a basis for public bodies to implement or reform the regulation on NSGE.

WP3 – Knowledge exchange on technical criteria

The climate of Alpine Space area ranges from warm Mediterranean with less than 1500 heating degree-days (HDD) in Liguria and Cote d'Azur to cold Continental up to about 5000 HDD in high mountain towns (e.g. Sestriere, Sankt Moritz). The analysis of how the different GHP technologies can be implemented in such varying contexts is key to provide a guidance useful for both technically and non-technically skilled stakeholders. Two main activities are carried out in this WP:

- Studies on GHP are conducted by the partners, focusing on different techniques and related design issues. POLITO is studying thermal recycling in GWHP (Casasso and Sethi 2015) and, together with TUM, the propagation of thermal alterations in groundwater (Böttcher 2014). The GBA is studying how the elevation and the slope orientation affect the ground temperature in Alpine valleys, since this is a key input for the design of GHP in this particular environment. BRGM is studying the viability on the French Alps of borehole thermal energy storage (BTES);
- Case studies of existing shallow geothermal installations are reviewed by partners in different parts of the Alpine Space, covering a wide range of utilizations (residential, commercial, touristic and industrial sector, road and platform de-icing, ice rinks, swimming pools etc.) and techniques (mostly BHE and GWHP, but also horizontal collectors). Data collected from these plants serve both as a guidance and as an example of how widely can GHP be applied. As reported above, the authorisation process of these installations is analysed by WP2 to assess the effectiveness of different regulation schemes in different countries and regions.

To date, a catalogue of existing NSGE techniques and practices has already been published (Bottig et al. 2016) and it is presented in next chapter, while another deliverable dealing with the analysis of best practice examples is foreseen in June 2017. Finally, a multi-language guideline based on the WP research activities for the implementation of GHP in the typical Alpine conditions will be delivered in September 2018.

WP4 – Mapping

The viability and the economic convenience of GHPs are strongly influenced on the site-specific subsurface properties. In this light, it is important to study the geological features and the ground thermal properties to deliver effective tools to support the planning of NSGE installations. The WP4 is collecting, comparing and processing this information to develop a web GIS at two scales:

- Large-scale maps covering the Alpine area will deal with geological features which can cause installations issues and hazards, such as swelling anhydrites (Sass and Burbaum 2010) and karst aquifers (Bonacci et al. 2009). The web GIS will highlight the areas where shallow geothermal systems can be installed without relevant technical and environmental issues, other zones where special measures are required to avoid adverse impacts, and where borehole heat exchangers or wells cannot be installed due to local geological conditions;
- Local-scale maps will be delivered for six case-study areas, shown in Fig. 2: Region Valle d'Aosta (Italy), Parc des Bauges (France), Davos (Switzerland), Oberallgau (Germany), Saalbach (Austria), and Cerkno (Slovenia). In these areas, the G.POT method developed by Casasso and Sethi (2016) will be adopted to assess the amount of heat that can be efficiently extracted by a BHE with a typical depth (100m) for building heating. G.POT is based on a simplified model of heat transport in the ground and inside the BHE, which is used to simulate the operation of a heating-only or cooling-only GHP. The thermal properties of the ground are derived based on measures and on empirical correlations with geological data (Casasso and Sethi 2017). A flowchart of the process is shown in Fig.3.

WP5 – Planning

SEAPs are plans of actions set by municipalities (single or grouped) to reduce energy consumption and the impact of human activities on the environment. These plans include measures on public buildings, lightning, plantation of trees, incentives for energy saving by privates, and awareness raising

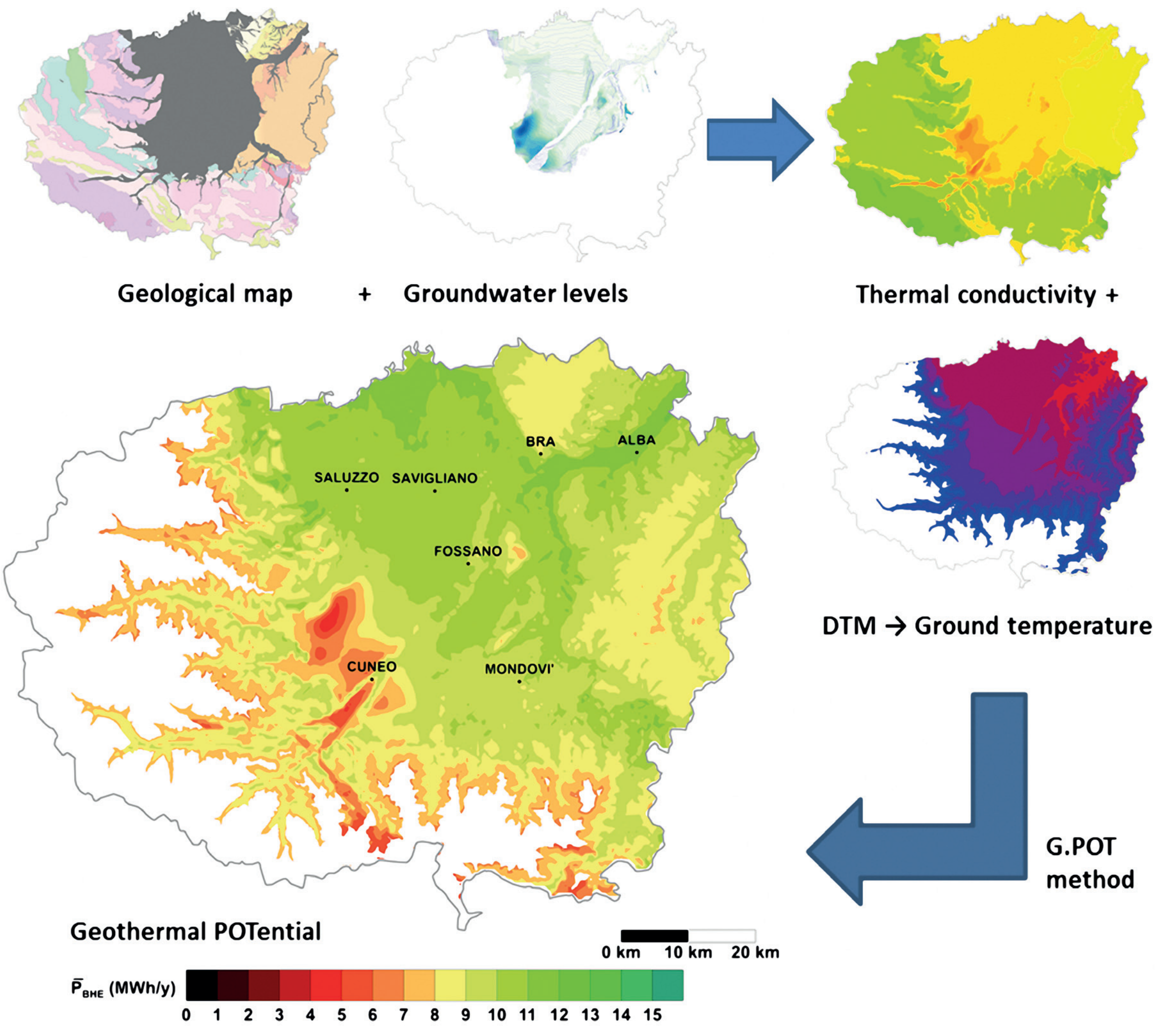

Fig. 3 - Process of shallow geothermal potential mapping with the method G.POT. Modified from Casasso and Sethi (2017).

Fig. 3 - Processo seguito nella mappatura del potenziale geotermico a bassa entalpia con il metodo G.POT. Modificata da Casasso and Sethi (2017).

campaigns. Shallow geothermal energy is usually little considered in these plans, also due to the difficulty of assessing its economic viability and its potential heat demand coverage share. Methodologies and tools will therefore be developed to fill this gap, and will be tested on three selected pilot areas. The tools address different aspects of energy planning, such as the matching between demand and resources, the economic feasibility compared to other energy sources (with different prices from country to country), and the perception of NSGE profitability among different stakeholders. Scenarios that can boost the replacement of fossil-fuel heating with GHP will be analysed, identifying targets based on different factors such as the current building stock, the foreseen refurbishment and the geothermal potentials.

WP6 – Interaction

GRETA is delivering tools and guidelines which should be useful for citizens, practitioners and public administrations. Getting feedback from them, avoiding a top-down approach, is key to succeed in this purpose. For this reason, stakeholders have been identified and contacted by partners and will be involved through questionnaires and focus groups on specific topics, i.e. regulations, technical criteria, and tools to be developed by WP4 (mapping) and WP5 (energy planning).

A synergy was found with another Alpine Space project, CESBA (Regione Piemonte et al. 2014), which developed a 'Wiki' hypertext to gather, summarize and conserve the results of European projects on sustainable building. WP6 will therefore organise the contribution of the other WPs to create a hypertext of the results of GRETA.

WP7 - Communication

GHP are still a niche application, and hence providing visibility to existing installations is pivotal for boosting their growth. The REPOWERMAP project led to the creation of a European Web GIS of renewable energy plants, which are mapped based on a voluntary data submission by plant owners (Repowermap EU et al. 2014). GHP are also included, but a few installations are present. A mobile geo-caching app will be developed to add further plants, and a contest will be held in 2018 to reward the most innovative geothermal installation presented. The winner will take part to the final conference to present the installation. A "geothermal educative trail" in Cerkno, explaining geothermal energy by examples and showing geological features of the territory, will moreover be set up. The geo-caching app, the contest and the geothermal trail will be delivered in 2017-2018, and hence no update is reported in next chapter.

First results and upcoming activities

The GRETA consortium has been working for one year and the first deliverables have been published in December 2016. Hereby we give an overview of the main findings, with a short summary of the documents available at http://www.alpine-space.eu/projects/greta

WP2 – analysis of legislative framework and authorization procedures

The collection and analysis of existing regulations focused on the competence (national, regional, local) and on the identification of regulation elements of different laws, decrees and rules (Prestor et al. 2016). The 55 elements identified and described in Tab. 1 are divided into 5 main categories, namely i) implementation of NSGE application, ii) installation in special geological conditions and iii) protected or endangered areas, iv) public services for NSGE applications, v) permitting and charging procedures for NSGE applications (Prestor et al. 2016). Large differences of criteria adopted for the authorisation of NSGE systems have been found among countries and regions, thus confirming the conclusions of previous studies (European Geothermal Energy Council-EGEC et al. 2015; Giambastiani et al. 2014; Haehnlein et al. 2010). For example, reinjection into the same aquifer is compulsory for GWHP in almost all regions, except Valle d'Aosta where this practice is forbidden. Operating temperatures of NSGE systems are regulated in different ways: for open-loop, thresholds are imposed for the reinjection temperature (Germany, France, Lombardia), the temperature difference between abstraction and injection (Italy, Slovenia, France) or the temperature alteration at a certain distance (France). Specific prescriptions are imposed in regions where particular geological conditions occur, e.g. drilling is not allowed in Austria for artesian aquifers with hydraulic heads over 3 m above ground surface. The criteria reported in Tab. 1 are the starting point for the ongoing discussion with stakeholders through questionnaires and focus groups (in collaboration with WP6) and the analysis of the authorisation process of a number of NSGE installations (the best-practice examples collected by WP3), which will highlight the criticalities of existing rules. Scientific literature and research activities conducted by partners (see WP3) are also considered in the assessment of regulation criteria. The objective of these activities is to derive a set of suggested prescriptions for lean, simple, safe and scientifically sound regulations. These guidelines will be implemented in a multi-language hypertext (see WP6).

Tab. 1 – Technical, environmental and legal elements considered in the comparison of existing laws, regulation and authorisation procedures on Near-Surface Geothermal Energy (NSGE). Each regulation element can be found in laws, standards and rules at European (E), national (N), regional (R),and/ or local (L) level in Italy (IT), France (FR), Germany (DE), Austria (AT), and Slovenia (SI).Adapted from Prestor et al. (2016).

Tab. 1 - Elementi tecnici, ambientali e legali considerati nel confronto delle leggi, regolamenti e procedure autorizzative esistenti in materia di geotermia a bassa profondità. Tali elementi possono trovarsi in leggi, norme e regolamenti a livello europeo (E), nazionale (N), regionale (R) e locale (L) in Italia (IT), Francia (FR), Germania (DE), Austria (AT) e Slovenia (SI). Adattato da Prestor et al. (2016).

n°	Regulation element	Description	IT	FR	DE	AT	SI
		Implementation of NSGE applications					
1	Drillling/excavating below water table	Minimum depth for a drilling to be declared	N	N	N		N
2	Reinjection	Compulsory, facultative or forbidden reinjection for GWHPs	NR		N	NR	N
3	Minimum distance	From buildings, drinking water wells, infrastructures	NL			R	
4	Minimum distance	From neighbouring BHE or well	R		N	R	
5	Minimum distance	From property line	NL			R	
6	Minimum distance	Between pumping and reinjection wells			N		N
7	Temperature difference	Between pumping and reinjection wells	L	N		R	
8	Temperature drop	Min/max fluid temperature, maximum thermal alteration	L	N	N	R	
9	Heat carrier fluid	Allowed fluids and anti-freeze additives	RL	N		N	
10	Refrigerant type	Allowed heat pump refrigerants	E	E	E	E	E
11	Tightness	Prescribed tightness tests for BHE circuits	R			NR	
12	Backfilling of BHE	Prescriptions on the sealing of boreholes	R	N	N	NR	
13	Decommissioning	Compulsory notifications	R		N	N	N
14	Monitoring	Requested monitoring activities depending on type and size	RL	N	N	R	N
15	Safety devices	Prescribed safety device for closed pipe loops	L				

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n°	Regulation element	Description	IT	FR	DE	AT	SI
		Installation of NSGE systems in special geological conditions					
16	Artesian aquifers	Drilling forbidden (or allowed with prescriptions) over a certain pressure threshold	L	N	R	NR	
17	Very shallow water table	Minimum water table depth for reinjection in GWHP			N		
18	Perched groundwater	Prescribed expert advice			N		
19	Multiple aquifer layers	Prescriptions/ban if different aquifers are crossed	L	N	R	NR	
20	Mineral water resources	Ban/limits for installation close to springs	R	N		N	
21	Thermal water resources	Ban/limits for installation close to thermal springs	R	N		N	
22	Gas occurrences	Ban in the presence of shallow gas/hydrocarbon layers			N	NR	N
23	Unstable ground	Landslides, evaporates, risk of settlements		N	R	R	
24	Contaminated soil	Ban/prescriptions in contaminated sites	L	N	N	R	
25	Karst area	Ban/zoning required in karst areas	L	N	NR	R	
		Installation of NSGE systems in protected/endangered areas					
26	Water Protection Area (WPA)	Ban/limits/prescriptions	L	N	L	NR	N
27	Natura 2000 area	Installation of GHP could be conditionally allowed	R	N			N
28	Nature protected ecosystem area	Installation of GHP could be conditionally allowed	R				N
29	Flood and erosion areas	Installation of GHP could be conditionally allowed	R				N
30	Landslide area	Installation of GHP could be banned or conditionally allowed	RL				N
31	Riparian/coastal areas	Installation of GHP could be conditionally allowed	R				N
32	Other areas	Installation of GHP could be conditionally allowed					
		Public services for NSGE applications					
33	Prescriptions for GHP	Minimum Seasonal Performance Factor of the heat pump	NRL	NR	NR	NR	NR
34	Subsidies	Minimum SPF values to get subsidies	N		N	R	N
35	Insurance	Insurance for a GHP may be requested by public authorities	R	N	R		
36	Certification	Certification may be required for drillers, installers and engineers	N	N	N	NR	N
37	Borehole drilling report	A borehole stratigraphy may be requested	N	N	N	NR	N
38	Pumping test report	May be requested for the authorisation of a GWHP	N	N	N	R	N
39	Proof of well drilling	May be requested by the investor	N	N	N	N	EN
40	Thermal response test	May be requested, along with an evaluation of thermal impact	RL	N	N	NR	
41	Water pumping data report	Periodic report on abstracted groundwater volumes	R	N	N	R	N
42	Heat production report	Periodic report on the heat produced by the GHP			N	R	
43	Register of heat pumps	Heat pumps (also air-source) could be registered in a database	RL		N		N
44	Register of heat exchangers	BHE and collectors could be registered in a database	RL				
45	Register of NSGE production	Data on GHP required by national authorities for 20-20-20 objective	EN		N		N
46	Register of drilling data	Data on GWHP wells could be registered in a database	RL			N	
47	Register of geothermal data	GWHP wells could be registered in a database on geothermal resources	RL				
48	Register of groundwater abstraction	In addition to point 41, continuous well flow rate recording could be requested	NR		N	N	N
		Permitting and charging procedures for NSGE applications					
49	Research/drilling permit	Permission to drill BHE and/or exploratory wells	RL	N	N	R	N
50	Declaration/Recorded special use of water	A special authorisation or declaration may be requested for thermal use of groundwater (GWHP)	NR			N	N
51	Water consent	Consent to drill wells or to drill in Water Protection Areas				R	N
52	Water permit	Permission to drill below aquifer water table			N	R	N
53	Water fee	Fees requested to abstract groundwater for thermal use	R				N
54	Concession	Temporary authorisation to exploit geothermal resources	NR	N			N
55	Royalty/concession fee	Variable or fixed fee to use GWHP	NR				N
56	Energy fee	Possible fees on heating/cooling systems					

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WP3 – assessment of existing practices

During the first year of the project, data on the diffusion of GHP in different countries have been collected. Germany, Austria and Switzerland are the most mature market, while GHP are emerging in Italy, France and Slovenia. Closed-loop systems and, in particular, borehole heat exchangers are predominating, although open-loop well doublets are quite diffused, especially for larger installation in alluvial plains. Design and operational data on 30 best-practice examples have also been collected, thanks to the collaboration with stakeholders (Bottig et al. 2016). They cover a wide range of technologies and applications, thus giving a comprehensive view of the potential of GHP.

The viability of the application of shallow geothermal systems for different climates and building types was analysed, focusing on the balance between the annual heating and cooling need of the building (Fig. 4) and on the cumulative distributions of heating and cooling thermal loads (Fig. 5, Fig. 6). These aspects are key for the sizing of the heat pump and the efficient exploitation of the ability of the ground to conduct heat. An estimation of the thermal load and the energy need of the building was performed through transient numerical simulations of residential, hotel and office buildings, setting an indoor design temperature of 20°C for winter operation and 26°C for summer operation. Both existing constructions (with the typical techniques adopted in the Sixties) and recent or brand new ones (far more well-insulated) were simulated. As shown in Fig. 4, the results highlight that well-insulated buildings have high cooling need even in cool climates such as the climate zones B and D (1500÷3000 HDD) defined by Tsikaloudaki et al. (2012). In addition, the integration of GHP with a gas, LPG or biomass boiler could be considered to cover high heating peak loads without oversizing the heat pump and the BHE field. Indeed, as shown in Fig. 5, the highest heating loads of a building occur for a few hours per year, and for most of the time a thermal power much lower than the annual peak value is required to heat the building. As reported in Fig. 6, a heat pump sized for 60÷70% of the peak heating load could cover up to 90% of the total annual heating need, but with a significantly smaller initial investment compared to a GHP sized to cover the peak load. In addition, the increase of the heat pump load factor leads to a higher efficiency both for inverter and on-off heat pumps.

WP4 – data collection

The first year of activity of this WP was dedicated to the definition of mapping criteria and to the collection of data to build the web GIS accordingly. For the large-scale mapping, a number of criteria, shown in Tab. 2, was derived based on peculiar geological features, such as the presence of anhydrites, artesian wells, landslides etc., and a questionnaire has been distributed to practitioners and public bodies to get their feedback on the validity of these criteria to identify suitable and unsuitable areas for the installation of GHPs. Large-scale (e.g., 1:1M) and medium-scale (e.g. 1:250k, 1:100k) geological maps will be used for this purpose.

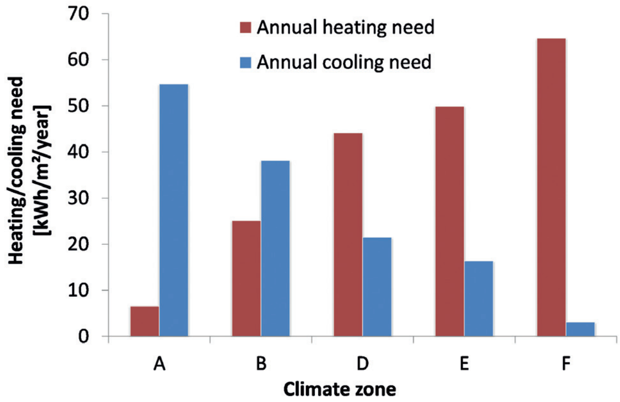

Fig. 4 - Annual energy need for heating and cooling of a typical office building, well insulated, in different climate zones.

Fig. 4 - Fabbisogno di energia termica per riscaldamento e raffrescamento per un ufficio ben isolato, in diverse zone climatiche.

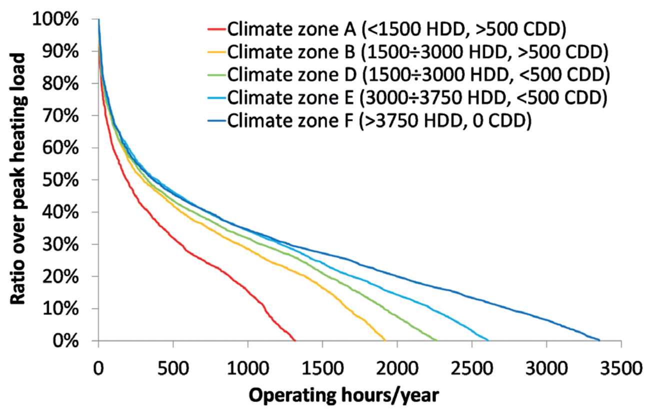

Fig. 5 - Cumulative distribution of the building heating load (ratio over peak value) for a well-insulated residential building, in different climate zones identified by heating (HDD) and cooling (CDD) degree-days.

Fig. 5 - Curva cumulata del carico termico di riscaldamento, espresso in percentuale sul valore di picco, per un edificio residenziale con buon isolamento termico, in diverse zone climatiche caratterizzate per numero di gradi-giorno di riscaldamento (HDD) e raffrescamento (CDD).

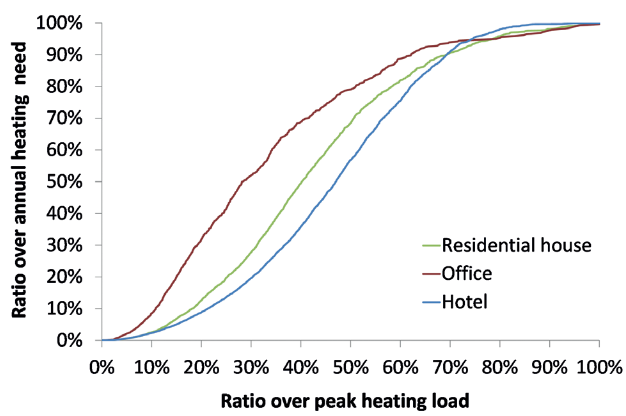

Fig. 5 - – Cumulative distribution of the annual heating need vs the building heating load (ratio over peak value) for a well-insulated residential, office and hotel building in different climate zones.

Fig. 5 - Curva cumulata del carico termico di riscaldamento, per edifici ad uso residenziale, per uffici e alberghiero, in diverse zone climatiche

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Tab. 2 – Technical, environmental and legal criteria used for the large-scale mapping of areas suitable for geothermal application in the territory of Alpine Space.

Tab. 2 - Criteri tecnici, legali ed ambientali utilizzati per la mappatura su larga scala della fattibilità degli impianti geotermici nel territorio dello Spazio Alpino.

Constraint type	Installation possible	Issue details	Technology involved
Technical constraints	No	Anhydrite: outcropping area + buffer of 2 km	closed loop
	No	Salt: outcropping area + buffer of 2 km	closed loop
	Yes	Karstic rocks (artesian waters, groundwater level changes, caverns, loss of drilling mud while drilling)	closed loop
	Yes	Artesian / confined aquifer	closed loop
	Yes	Aquifer communication (multi-aquifer formation)	closed loop
	No	Ground movement / landslides (active and potential)	open & closed loop
	No	Mining areas / artificial caverns	open & closed loop
Environmental constraints	Yes	Groundwater or well-head protection area	open & closed loop
	Yes	Water sanctuary area	open & closed loop
	Yes	Nature protection area (Natura2000 etc.)	open & closed loop
Legal constraints	Yes	Imposed instances from (drinking water) wells imposed by local regulations, if any	open & closed loop
	Yes	Imposed depth limits to avoid the crossing of aquitards/ aquicludes	closed loop
	No	Open loop systems forbidden (e.g. in some parts of Veneto)	open loop
	No	Reinjection is forbidden into the aquifer (e.g. in Valle D'Aosta)	open loop

Regarding the mapping of shallow geothermal potentials in the six case-study areas, partners collected input data about detailed stratigraphy, hydrogeology and ground thermal properties. When available, detailed geological maps (e.g. 1:50k, 1:25k) will be used to achieve the highest accuracy in the characterization of the subsurface. In addition, information was collected on existing GHP installations in the three pilot areas identified by WP5 (Oberallgau, Cerkno and Valle d'Aosta). This dataset is key for the implementation of shallow geothermal systems in local energy plans, since it provides a practical demonstration of the viability of this technology, an indication of how this technology is diffused in a certain territory and where interferences between neighbouring plants may occur. Among the three pilot areas, data on existing GHPs Valle D'Aosta were missing. A census of GHPs in this region was therefore conducted by POLITO and ARPA Valle d'Aosta and a total number of 67 plants was found, with a cumulative power of 3.9 MW. These data pose the Region Valle d'Aosta (128,000 inhabitants) above the average diffusion of GHP in Italy, where a total of 13,200 installations is estimated by the Italian Geothermal Union (Conti et al. 2016).

WP5 – selection of pilot areas

The collection of data conducted by WP4 is also key for the implementation of NSGE in energy planning instruments. For the six case study areas (Fig. 2), data have been collected to characterise the local geology, climate, building stock, energy sources adopted for building heating and cooling, existing policies etc. Three pilot areas - Region Valle d'Aosta (Italy), Oberallgau (Germany) and Cerkno (Slovenia) - were eventually chosen among the six case studies to test the tools for the integration of shallow geothermal energy in energy plans (Zambelli et al. 2016).

WP6 – stakeholders' assessment

The first year of activity was mainly focused on the identification of relevant stakeholders in the field of NSGE. A total of 421 people and institutions was contacted for a short questionnaire, and 79 stakeholders were identified from the answers. More than 50% of stakeholders come from Italy (43 on 79), which is also the most populated part of the Alpine Space area (35% of the population) (Capodaglio et al. 2016). Most of the institutions work on research and technical studies (38%), policy and regulation (26%), while the rest of the institutions is involved in public/social development (17%), environmental advocacy (11%) and investments (8%).

The second questionnaire, which is still open, deals with barriers and opportunities for NSGE and was addressed to the participants of the first one. The ongoing analysis of the results is highlighting common issues among stakeholders from the Alpine countries, such as the uncertainty on the time for the approval of the installation, the difficulty to access to geological and environmental data, the request for expensive monitoring activities, the lack of knowledge on the economic and environmental advantages of NSGE, and the lack of low-interest loans.

Conclusions

Geothermal Heat Pumps can have a noticeable contribution in the reduction of the environmental impact of the heating and cooling of buildings, which accounts for a large part of the total energy consumption in Europe. The GRETA project addresses the non-technical barriers to the growth of shallow geothermal installations and aims at raising the awareness of the potential of this technology in Alpine regions. The main aspects addressed by GRETA are the fragmentation and the complexity of regulations on shallow geothermal energy, the scarce knowledge about the potential applications of GHP and the suitability of different territories to their installation, and the scarce consideration of this widely available RES in local energy plans. The feedback from relevant stakeholders in this field is key for the successful implementation of the measures proposed by the project. For this reason, the authors warmly invite people interested in this project to get in contact through the website or the project partners.

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