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Thermal Uses of Geothermal Energy, Country Update for Italy

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ABSTRACT

This paper presents an overview on the development of thermal applications of geothermal energy in Italy since the last WGC2015. The Italian situation is described till the end of 2017, being this the most recent year for which data are available at the writing date of this report. The total installed capacity amounts to 1424 MWt, with a corresponding heat energy use of about 10915 TJ/yr. The main share is held by the space heating sector (42% of the total energy, 52% of the overall installed capacity), followed by thermal balneology (32% in both values) and fish farming (18% and 9% namely). Agricultural applications, industrial processes and other minor uses together account for around 8% of the total geo-heat use. Additionally, the paper presents a brief overview on the national geothermal potential, the current regulatory framework, and the main international research activities with Italian participation. The data show an overall stagnant situation for direct uses in Italy with respect to what described in WGC2015. The main drawbacks of the slow increase of geothermal thermal applications, to be overcome to ensure a new development phase for the geothermal energy in Italy, are presented and discussed.

1. INTRODUCTION

The energy consumption of Italy is among the highest in Europe, after Germany, France and UK (EUROSTAT). In the year 2017, the most recent year for which official data are available at the date of this report, the final energy consumption in Italy amounted to 120.4 Mtoe ($5.04 \cdot 10^6$ TJ), with a share of Renewable Energy Sources (RES) in gross final energy consumption of 18.3% (GSE, 2018). In the thermal sector the share of RES is 20%, with a contribution of 11.2 Mtoe ($4.69 \cdot 10^5$ TJ). The vast majority is provided by solid biomass for residential use (68%), followed by heat pumps (25.9%). The amount of geothermal heat production in the total thermal production by RES is 2.1%, 0.8 being related to ground source heat pumps (GSHPs) and 1.3% to other thermal uses. Most of the heat consumption from RES in Italy is for residential heat (38.2%) and services (36.4%), with only 3% dedicated to industrial uses, and 22% lost in the transmission.

Although the contribution of geothermal energy appears small if compared to the high country energy demand, Italy is one of the most renowned country worldwide in the geothermal sector. Thanks to a favorable geology, its wealth of geothermal resources makes it be ranked among the top 10 countries for electricity generation (Bertani, 2016) and among the first 20 for thermal applications (Lund and Boyd, 2016). Electricity from geothermal resources nowadays is produced in the Tuscany region, central Italy. Many direct applications of geothermal heat are also located in Tuscany, however thermal uses are widespread in the national territory, with district heating systems (DHs) mostly localized in the north, while other direct uses and ground source heat pumps (GSHPs) distributed on a much larger territory.

This paper presents the actual status of geothermal production by thermal applications in Italy and discusses the evolution of thermal uses of geothermal energy in Italy since the last WGC2015. Data regarding thermal applications are mainly derived from the Italian Energy Services Manager (GSE) publications, enriched by datasets and information of the two geothermal Associations (UGI and ANIGHP). The main issue reported in previous WGC proceedings related to the lack of official and robust statistics relevant to thermal application of geothermal energy in Italy has been partially solved by the regulators, and nowadays geothermal plants are periodically monitored by GSE. However, small systems, in particular Ground Source Heat Pumps (GSHP), still lack of an official and complete register and data are the result of educated guess, based on indirect information (e.g. market information).

After a brief introduction dealing with the country geology background and geothermal potential (section 2), the report illustrates the current status of thermal applications in Italy (section 3), and discusses their evolution in a 3-year period (2014-2017), being 2017 the most recent year for which data are available at the writing date of this report (section 4). The costs and legislation are also described in section 4, before concluding in section 5.

2. GEOLOGY BACKGROUND AND GEOTHERMAL RESOURCES AND POTENTIAL

Italy is a tectonically active country, being located along the African-Eurasian plates convergent margin (Manzella et al. 2017 and ref. therein). The complex tectonic regime produced the two mountain chains characterizing the country, the Alps and Apennines, and an oceanic basin in the western margin, below the Tyrrhenian Sea (Fig. 1, left). The tectonic complexity of the Italian territory results in a pronounced lateral variability of the surface Heat Flow (HF), which mimics the main structural features and magmatic domains (Fig. 1, right). The western sector of the Apennine and the Tyrrhenian margin shows the most favorable conditions for hosting geothermal resources. This area is characterized by a reduced crustal and lithosphere thickness, a widespread magmatic activity and a high geothermal heat flow. The presence of geothermal systems at relatively shallow depth has been verified in several areas from north to south of the Italian territory and in offshore zones, thanks to the numerous deep wells drilled for oil and gas or for geothermal exploration. High temperatures at relatively shallow depth, suitable for electricity production and district heating, have been recorded in numerous areas. Hydrothermal circulation has been recognized in volcanic, sedimentary and crystalline rocks, and local rise of warm waters from deep formations through faults or lateral discontinuities produces numerous natural hot springs.

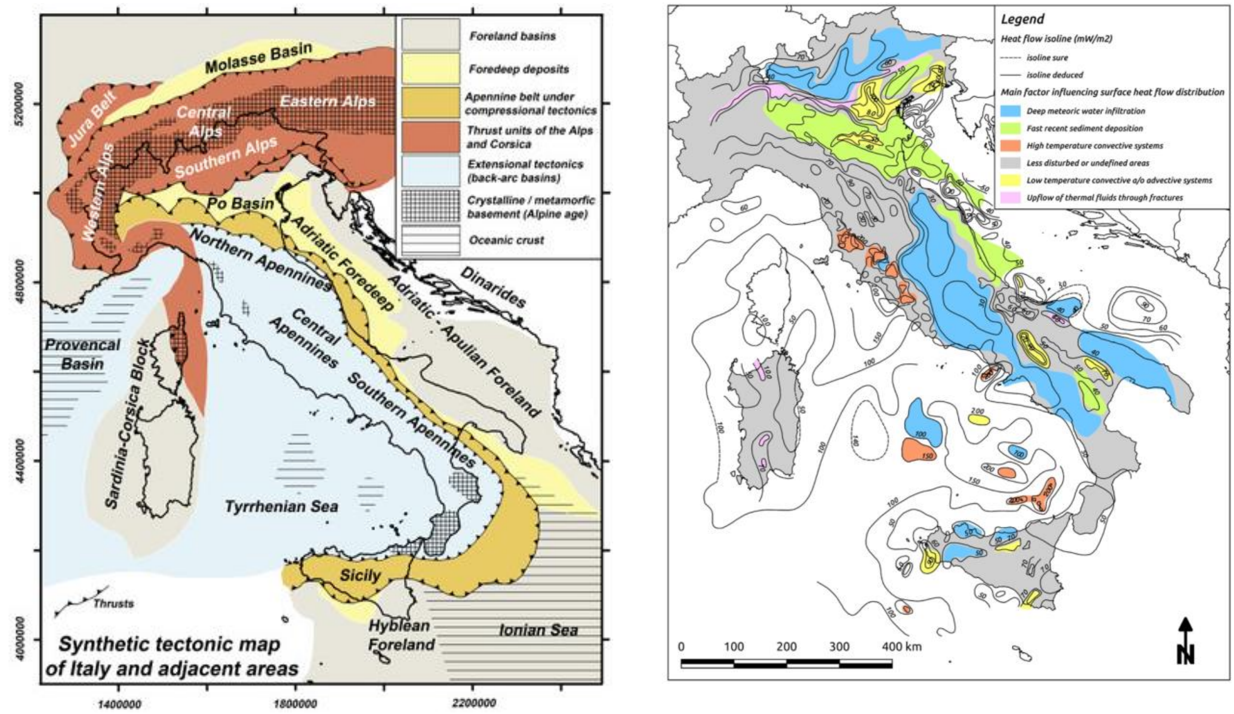

Figure 1. Left: tectonic and geothermal provinces, and temperature distribution at 3 km depth in Italy (modified from Carminati et al. 2004). Right: Heat flow distribution and its relation to hydrogeological conditions (modified from Della Vedova et al., 2001).

The hottest geothermal resources of Italy are located in what is called the “traditional” geothermal area of Italy, in the tectonically active regions of Southern Tuscany (Fig. 2). These areas host all the national geothermal plants for electricity production and most of the geothermal district heating networks.

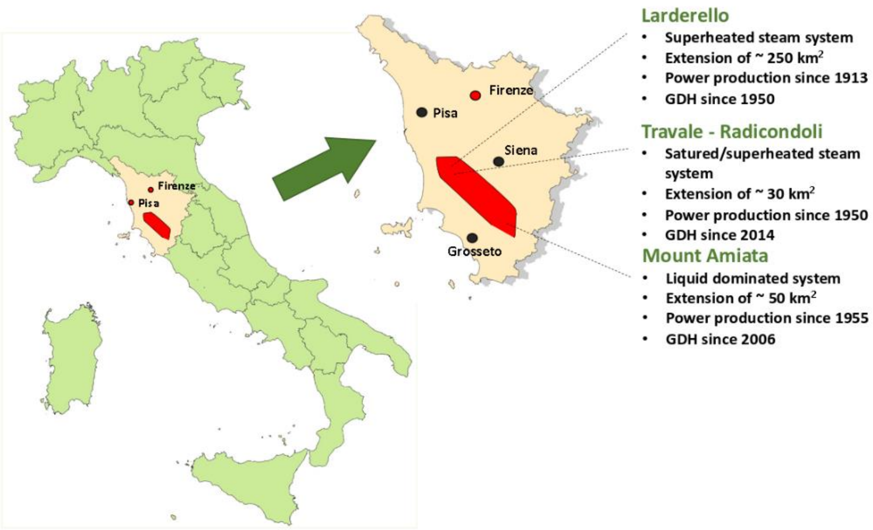

Figure 2. “Traditional” geothermal areas in Italy, where electricity is produced from geothermal high temperature resources, and the most productive geothermal district heating (GDH) networks are located.

The last national assessment of deep, hydrothermal resources in Italy was carried out at the end of the 1980s with the completion of the Inventory of the Italian Geothermal Resources (Cataldi et al., 1995). In the assessment, Italy was divided and ranked in seven categories on the basis of the presence of a regional aquifer of up to 3 km depth and on the fluid temperature range. More recently, geothermal potential was computed at local scale, especially for mining lease requests of power production projects, but the potential at a national scale has been only roughly estimated. On the basis of the temperature distribution, the Italian Geothermal Association (UGI) esteems a potential total production from geothermal resources within 5 km depth of 21 Exajoule (Buonasorte et al., 2011).

Two third of them have temperature below 150°C. Resources at temperature >80-90°C at relatively shallow depth can be found in many areas, i.e. those showing a high surface heat flow. In particular, low temperature resources can be found almost everywhere in Italy, and they could be efficiently used for thermal applications, also in combination with by GHSP technologies.

Waiting for modern resource assessment at national level, various assessments have been carried out at regional level, using diversified methodologies. The most comprehensive assessment of geothermal resources has been carried out by the National Research Council in four regions of southern Italy. The provided maps show the location of geothermal resources that can be developed with the current technologies, including district heating, both in heating and heating/cooling (H&C) mode, and open- and closed-loop GSHP systems (Manzella et al., 2017 and ref. therein).

UGI (2017) forecasts a step increase of the aggregate installed capacity and production of the direct use of geothermal heat by 2050, passing from about 10500 TJ/yr in 2015 to values ranging between 53400 TJ/yr and 75350 TJ/yr, depending on the market and national support condition (Fig. 3).

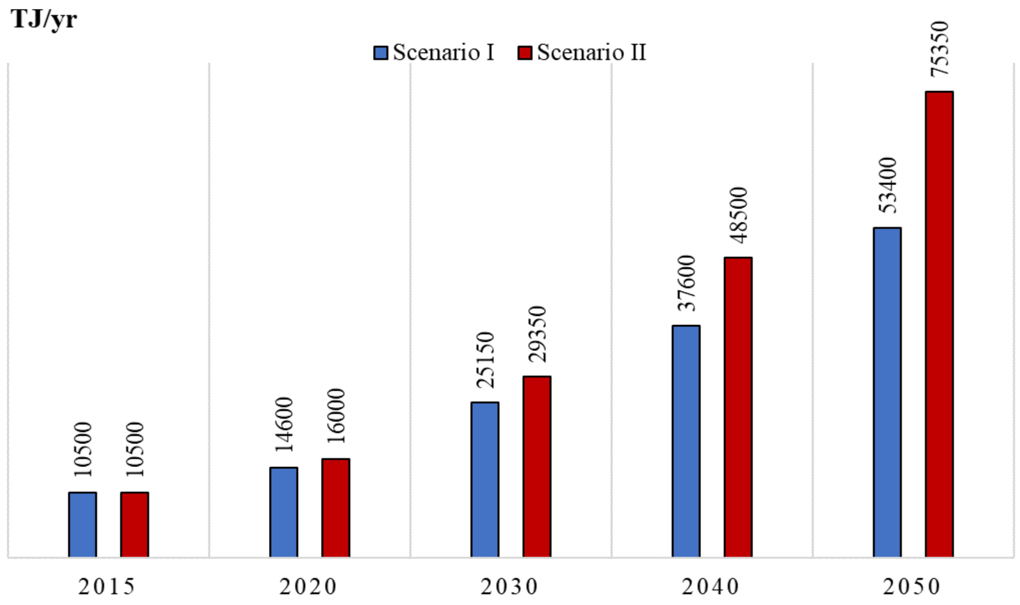

Figure 3. Development of direct uses, including heat pumps, 2015-2050, as forecasted by UGI (2017).

3. GEOTHERMAL ENERGY UTILIZATION FOR THERMAL USES

3.1 Terminology, evaluation, methodology and data accuracy

The data presented in this part have been produced using the same methodology presented and applied in previous Italian Country Updates, as established by UGI, the Italian Geothermal Union (Conti et al., 2015, Conti et al., 2016, Manzella et al., 2019). The following definitions hold:

- "Geothermal capacity" is the maximum instantaneous geothermal energy deliverable by the system under well-defined and declared operational conditions;
- "Energy" or "Production" refer to the amount of geothermal energy delivered to the end-user systems (losses included) over a declared period;
- "Capacity factor" (CF) is the ratio between the actual energy delivered by a system and the maximum theoretical output if operation at full capacity load were indefinitely possible.

The evaluation of the figures is based on the energy balance of each considered system, according to the three reference layouts for direct use of geothermal heat described in Cataldi et. al. (2013), Conti et al. (2015), Conti et al. (2016).

The statistics on the geothermal energy employed in the agriculture, aquaculture, balneology, and industrial sectors are based on the data reported in GSE (2018). For district heating systems (DHs), we refer to the data declared by systems owners and collected by AIRU (2019) and UGI. Finally, statistics on ground-source heat pumps (GSHPs) are based on the data reported in GSE (2018) and EurObserv'ER (2018), according to the methodology proposed in the European Decision 2013/114/EU that considers both electrically and thermal driven heat pumps. Only the heating service is considered. When it was not possible to obtain the actual data, the statistics have been estimated according to available information, some rational considerations, suitable capacity factors (CF), and/or equivalent full load hours of operation (EOHs). For instance, there is no data on the capacity installed in the agriculture, aquaculture, balneology, and industrial sectors. Therefore, we used the same CF values of previous country reports and the global average values suggested by Lund and Boyd (2016).

3.2 Thermal production by geothermal energy

For this section the most recent official data referring to December 2017 (GSE, 2018) have been used. Data elaboration has been performed according to the methodology described in Section 3.1 and mentioned references. The situation of direct uses in Italy is presented in Tables 3 and 5, at the end of this report, following the scheme required for WGC. In Tables A-B and Fig. 4-5 we show data according to the established UGI methodology.

At the end of 2017, the geothermal energy thermal use installed capacity exceeds 1400 MWt, for a corresponding total energy use of 10915 TJ/yr (Fig. 4-5, Tables A, B, 3 and 5). The main sector of utilization is the space heating - DH networks and individual systems - which holds 42% and 52% of the total energy use and installed capacity (namely, 4566 TJ/yr and 739 MWt). Thermal balneology is the second sector, representing 32% of both energy use and installed capacity (3501 TJ/yr and 456 MWt, respectively); fish farming is the third main sector, holding 18% of the total geo-heat utilization with 2019 TJ/yr, and only 9% of the overall installed capacity (130 MWt). Heat utilization for agricultural applications, industrial processes and minor uses amounts to less than 8% of the total, with a capacity of 100 MWt employing roughly 830 TJ/yr.

Table A: Summary table of geothermal thermal uses as of 31 December 2017 in Italy

Sector of application	Capacity (MWt)			Energy (TJ/yr)			Capacity Factor		
	Total	**GSHPs**	**DHs**	**Total**	**GSHPs**	**DHs**	**Total**	**GSHPs**	**DHs**
Space heating	739	515	149	4566	3165	853	0.20	0.19	0.19
Thermal balneology	456	-	-	3501	-	-	0.24	-	-
Agriculture uses	80	13	-	656	75	-	0.26	0.18	-
Fish farming	130	-	-	2019	-	-	0.49	-	-
Industrial process heat + minor uses	20	4	1	174	25	10	0.28	0.20	0.32
TOTAL	**1424**	**532**	**150**	**10915**	**3265**	**863**	**0.24**	**0.19**	**0.19**

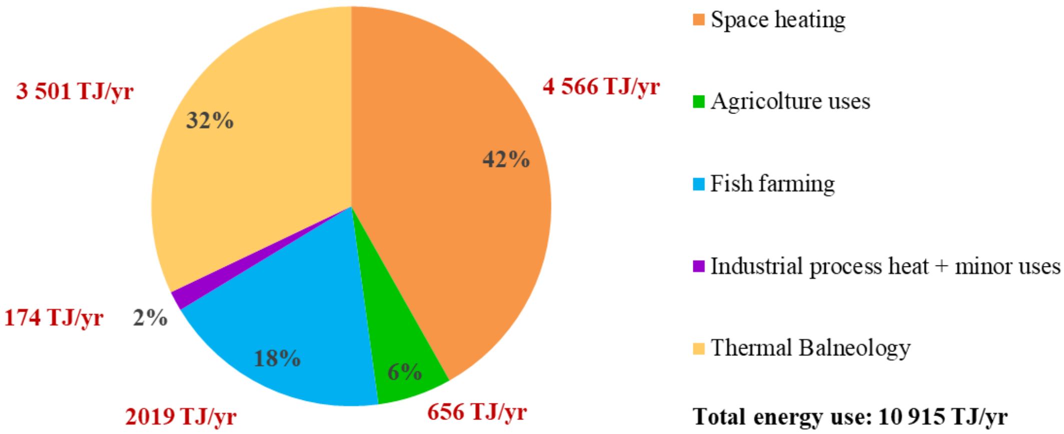

Figure 4. Share of geothermal energy utilization of direct uses of geothermal heat in 2017 in Italy

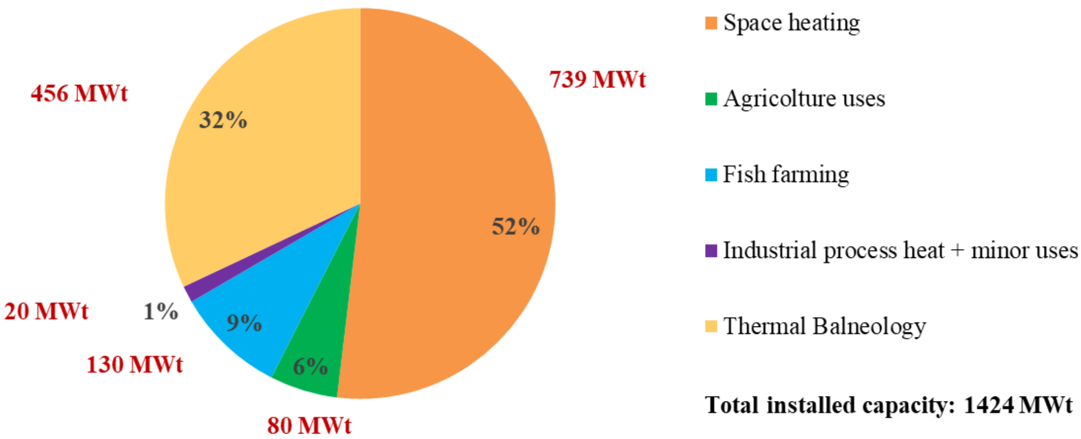

Figure 5. Share of geothermal installed capacity of direct uses of geothermal heat in 2017 in Italy

Regarding ground-source heat pumps, they account for 38% of the total installed capacity and some 30% in terms of energy. It is a common practice to consider the heating power available for the end-user system (i.e. the condenser output) as the nominal thermal capacity of the system. However, to the aim of this report, we are interested in the power/energy provided by the ground source. Thus, it is worth to recall that all the presented statistics concerning GSHP applications refer to the energy exchange at the evaporation section, namely where geothermal energy enters the energy system (see Conti et al., 2015 and Conti et al., 2016 for further details on statistics processing methodology). The total nominal capacity in Italy for ground-source heat pump systems is almost 780 MWt (GSE, 2018; EurObserver, 2018). The latter value corresponds to about 530 MWt in terms of geothermal installed capacity (i.e., nominal thermal power at the evaporator). The geothermal energy exploitation exceeds 3200 TJ/yr (see Table 3). Cooling operation is not accounted.

District heating systems represent about 8% of the total geothermal heat utilization (863 TJ/yr) with a total installed capacity of about 150 MWt. The main systems are in Tuscany Region within the geothermal electrical power production area. The fluid used to feed the DH networks is indeed produced by the same deep wells feeding the power plants and is delivered as waste or valuable steam (see Section 4.2 for details). The other main Italian geothermal DH application is in Ferrara, where a 14 MWt-capacity system with 2 production wells of about 2 km depth produces pressurized hot water at almost 100 °C, which is then totally reinjected in a third well. The other two systems worth to be mentioned are in Milano, where ground-source heat pumps are used to deliver heat to the network, and Bagno di Romagna (FC). The statistics on Milano system are accounted in the DH category in Table 3.

The average CFs of both GSHPs and DHs range around 0.19, while the total geothermal annual CF is equal to 0.24 by reason of the high equivalent working hours of fish farming (CF=0.49), industrial processes (CF=0.28) and agricultural uses (CF=0.28), as detailed in Table A.

4. DISCUSSION

4.1 Data discussion and comparison with WGC2015

In this section we present a short summary of the evolution of thermal applications in Italy since last WGC2015, as summarized in Table B.

- Installed capacity has increased from ~ 1300 MWt to more than 1400 MWt, with an average annual growth rate of about 1.7%/yr. The increase is mainly due to new DH networks that have almost doubled their capacity: from ~ 78 MWt to 149 MWt. The corresponding average annual growth rate is ~ 30%/yr.
- Total geothermal energy use has been stable around 11000 TJ/yr. The increase in the DH sectors (+8%/yr) has been balanced by the decrease of agricultural uses and balneology;
- The overall annual CF has decreased from 0.26 to 0.24 (-1.9%/yr). The sectors with the highest decrease of equivalent full hours have been agriculture and balneology;
- Space heating, again the first utilization sector, had a constant energy use of about 4600 TJ/yr. Thermal balneology and geothermal greenhouses have been reducing their relevance. GSHPs have practically constant figures, around 550 MWt of installed capacity and 3300 TJ/yr of geothermal energy utilization.

The data analysis shows an overall static situation for direct uses in Italy. After the notable increase occurred between 2010 and 2014 (Fig. 6, see Manzella et al., 2019), the last three-year period shows that DHs is the only sector with a significant increasing trend, followed by industrial applications which are still a limited fraction of the overall capacity and energy used. The current status of geo-district heating networks is briefly presented in the following section.

Table B. Development of geothermal thermal uses in Italy during the 3-year period 2014-2017

Sector of application	Capacity (MWt)			Energy (TJ/yr)			Capacity Factor		
	Total	**GSHPs**	**DHs**	**Total**	**GSHPs**	**DHs**	**Total**	**GSHPs**	**DHs**
Space heating	1.9%	-6.4%	90.8%	-0.9%	-1.4%	24.9%	-2.3%	5.3%	-33.0%
Thermal balneology	8.2%			-5.3%			-12.5%		
Agriculture uses	15.9%	-7.1%		-9.6%	-8.5%		-22.0%	-1.5%	
Fish farming	6.2%			4.8%			-1.3%		
Industrial process heat + minor uses	9.0%	-		61.4%	-		48.0%	-	
TOTAL	**5.1%**	**-6.4%**	**92.1%**	**-1.4%**	**-1.6%**	**26.3%**	**-5.8%**	**5.2%**	**-33.1%**

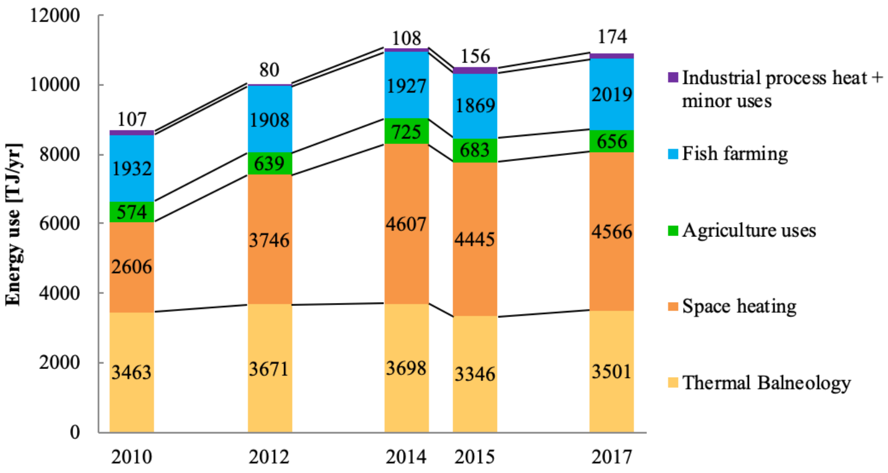

Figure 6. Development of the different sectors of direct uses in Italy (2010-2017).

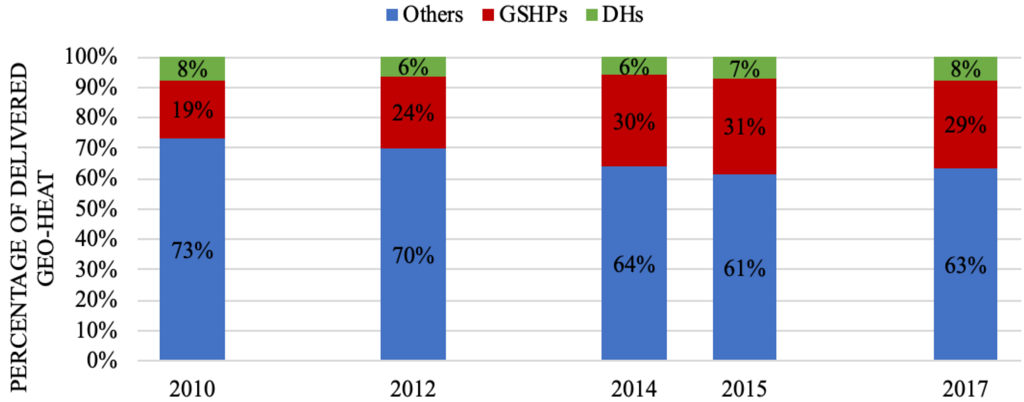

Figure 7. Development of geothermal DHs and GSHPs for space heating&cooling with respect to the total geo-heat delivered in Italy (2010-2017)

4.2 Recent developments in the geo-district heating sectors and market analysis

Four new DH networks in the historical geothermal areas of Tuscany have been operating (AIRU, 2018): two in the Travale-Radicondoli area, in Radicondoli and Chiusdino, and two in the Mount Amiata area, in Piancastagnaio. La Rota, in the Mount Amiata area, was completed in 2017 and provides heating to 19 enterprises, two farming facilities and a religious center, with a capacity of 4.4 MWt. The network in Radicondoli started operation in the winter 2018-2019, with a capacity of 5.8 MWt. The Piancastagnaio village network development is planned to start by 2019 and to supply 1100 buildings; the Chiusdino network already started its production in October 2019 (it is not included in Table 3); an overall installed capacity of 9 MWt is foreseen by 2020. The Chiusdino network is composed of two districts (one working and one still under construction), with a capacity of 13.68 TJ/yr and 32.40 TJ/yr respectively. Other DH networks are planned in Tuscany, outside the historical geothermal territories: in Castelfiorentino the planned networks will serve 1500 buildings, and in Montecatini the planning has recently started.

DH operators operate on the free market as all energy utility companies in Italy, thus there is not a homogeneous tariff among Regions and consumers; the actual heat selling price depends on specific market conditions. However, we hereby report the tariffs applied by the two main Italian geo-DH operators as representative case-studies (i.e.: Ferrara and Tuscany region) to show the current economy benefits for geo-DH customers with respect to traditional heating boilers.

In Ferrara, where the DH network is operated by HERA Group, the tariff varies in dependence of the tariff scheme (monomial\binomial), end-user type (domestic/non domestic or industrial) and consumption bands. In addition to the variable costs depending on the actual consumption, the end-users have to pay some fixed costs (meter rental cost and eventually an extra cost depending on the installed power). Depending on the consumption band, the variable cost for the geo-heat is between 48-72 €/MWh, 45-67 €/MWh and 46-44 €/MWh namely for domestic, non-domestic and industrial end-users, with respect to natural gas cost for domestic end-users of 87-110 €/MWh.

In Tuscany, GES S.p.a. is the main geo-DH operator. Here the accounting tariffs are set as constant at 63 €/MWh, including 22€/MWh that can be deducted in the form of investment supplements, as fiscal support measure envisaged by the current legislation for renewable energy source use (L448/98 and L354/00), for a total tariff of around 1/3 of the tariff for natural gas users. The cost is particularly low thanks to the increasing use of geothermal fluids that the power plant operator considers not useful for electricity production. These “waste steam” fluids are purchased at 3 €/MWh, whereas the “valuable” steam, i.e. the one subtracted to the power production is purchased at 16 €/MWh.

4.3 Focus on Ground Source Heat Pumps, status and data

Official national-scale data are provided by GSE (2018) and EurObserv'ER (2018): both datasets are estimates, as of today no official register has been established at national or regional level. Following the official national reporting (GSE, 2018), the share of heat pumps in the total thermal production by RES is 25.9%, of which a very minor part is represented by GSHPs (0.8% in heat production). If we refer to the heating power available for the end-user system (i.e. the condenser output), the nominal thermal power of GSHP systems is about 780 MWt (GSE, 2018, EurObserver, 2018). It is worth recalling that GSHP statistics refer to the evaporator of the HP units as it is considered as the reference point to evaluate the actual geothermal contribution for heating operation. Therefore, the above-mentioned value of 780 MWt corresponds to about 530 MWt in terms of geothermal installed capacity (i.e., nominal thermal power at the evaporator). The geothermal energy use exceeds 3200 TJ/yr. The values at the condenser (i.e. the useful power/heat delivered to the end-user system) are reported in Table C. As already-mentioned, cooling operation is not accounted.

Table C: Status of ground source heat pumps (GSHP), official estimates

	Geothermal Heat Pumps (GSHP), total			**New (additional) GSHP in 2018**		
	Number	Capacity (MW_{th})	Production (TJ/yr)	Number	Capacity (MW_{th})	**Share in new constr. (%)**
In operation end of 2017	**15000 (1)** **12800 (2)**	**745/532 (1)** **800 (2)**	**4572/3262** **3266(3)**	**800 (1)**	-	-

(1) From EurObserv’ER (2018)

(2) From GSE, personal communication, include only closed loop

(3) From GSE (2018), include only closed loop

The evolution of thermal applications in Italy since 2014 summarised in Table B shows that during the last three years GSHP systems decreased their installed capacity (-6.4%) and the annual energy use (-1.4%). With respect to 2010 data, however, GSHP installations have experienced a significant increase in terms of both installed capacity and energy use, passing from ~ 250 MW_t to 530 MW_t and from 1500 to 3265 TJ/yr respectively (Manzella et al. 2019). At the end of 2010 they accounted for only 17% and 25% of the total geothermal energy use and installed capacity, namely, whereas in 2017 they ranged around 30% and 38%, respectively, with an average annual growth rate of 12% and 11%.

Thermal use of the ground through geothermal heat pumps is difficult to quantify in Italy, a country where the diffusion of air conditioning systems with heat pumps is widespread, thanks to the high number of cooling units installed, working mainly during the summer. To date there is no national census of geothermal systems with heat pumps, and only a very few local authorities have a plant register. Moreover, the absence of a univocal regulatory framework results in a high fragmentation of the few available data, which are then difficult to compare because they refer to different systems (in some cases the data refer to water-based heat pumps, in other cases to vertical closed-loop systems, in others to any closed-loop geothermal system). The only Italian region where a register of closed-loop systems with vertical geothermal probes has been established and recorded data since 2010 is Lombardy. Lombardy Region is also one of the regions where the GSHP market has reached interesting levels, hence the analysis of these data and related considerations could be tentatively extended nationwide, although only on a qualitative level.

The Register indicates that in Lombardy an average of 100-150 new GSHP geothermal plants are installed each year. A total of 1000 plants are recorded, for an overall installed capacity of approximately 26.5 MWt in heating and 18.5 MWt in cooling. The average power of individual systems is about 25 kW in heating and 17.5 kW in cooling.

Fig. 8 (right) shows the yearly distribution of vertical geothermal probes surveyed by the Register. There is a relative negative trend in general, although most probably the high values of the first 3 years are partly due to the registration of plants built in the years preceding 2010. A total of 4580 vertical geothermal probes with an average depth of 115 meters are recorded. It is interesting to observe the distribution of GSHP plants in the area (Figs. 8-9). The Milan Metropolitan Area and neighboring provinces show the highest concentration. In general, there is a large diffusion of GSHP plants in the northernmost provinces and coldest areas, with a higher heating requirement compared to cooling. In the southernmost part of the Region GSHP plants are less common and are used at the same extent for heating and cooling requirements.

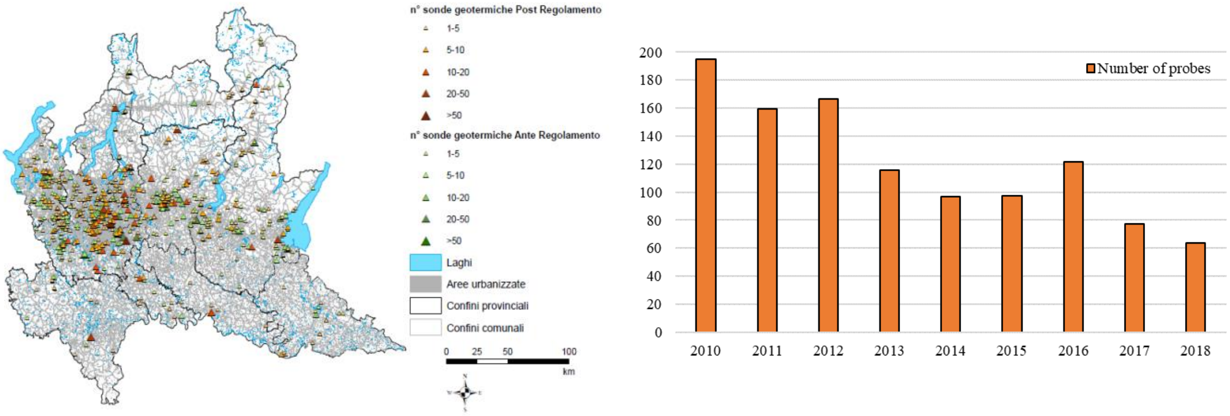

Figure 8. Left: Map of plants in Lombardy (Manzella et al., 2019); Right: Number of probes recorded per year in the Lombardy Region Register (adapted from Manzella et al. 2019).

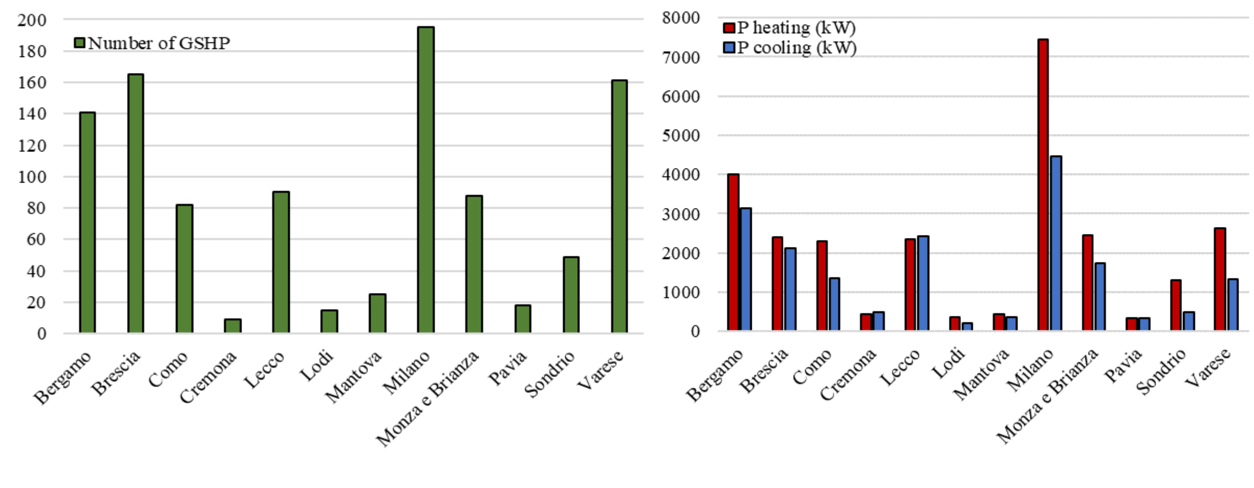

Figure 9. Left: Distribution of GSHP plants in the 12 provinces of Lombardy (adapted from Manzella et al. 2019); Right: Lombardy, total thermal power installed (heating and cooling), divided by province (adapted from Manzella et al. 2019).

The document recently published by EurObserv'ER (2018) reports the number of geothermal heat pump units sold per year in each country. The figure indicated for Italy is 860 GSHP units sold in 2017, practically the same as in 2016, and includes open-loop systems. The total number of units in Italy appears very low when compared to the volumes for other countries that have a developed and consolidated market (Sweden, Germany, Finland, Austria, France, Denmark, etc.) or where GSHP plants are spreading rapidly (Poland, The Netherlands, United Kingdom, Belgium, etc.).

GSE (2018) reports the total amount of heat pumps data, most of which are in aggregated figures, including air-air, water-air and geothermal (closed-loop) systems. Only the energy production is subdivided, and the report shows that geothermal closed-loop systems provides 907.14 GWh, representing 2.94% of the total production from heat pumps in Italy. Water based systems, including geothermal open-loop systems, produced on 2017 104.67 GWh, i.e. 0.34% of the total energy production from heat pumps in Italy.

Both ANIGHP and the IAH (International Association of Hydrogeologists) Italian Chapter (Idrogeoter Working Group – Cerutti et. al., 2013, 2014, 2015a, 2015b) carried out separate inventories and analyses of Geothermal Systems. ANIGHP estimates a total annual market of 1000/1200 plants (including open loop systems) with an average power of about 30 kW and a turnover of about 80-90 million Euros. This is clearly still a niche market, currently destined for a range of medium-high customers, both in financial and environmental-awareness terms.

4.4 Legislative framework and support measures

In descending order of size, Italy is made up of the State, Regions, Provinces, Metropolitan Cities and at the lowest level Municipalities. Each of these has specific administrative functions related to geothermal exploration and development as regulated by Italian law. Following a Royal Decree of 1927, the geothermal resource, ascribed to the class of "mines", does not belong to the owner of the land, but it is an asset of the State and its development is subject to a license. A series of decrees regulated the obligations, the authorization procedures and the classification of geothermal resources. The classification is based on two main parameters: temperature and installation size. The resources are ranked as *high enthalpy* for temperatures higher than 150°C; *medium enthalpy* for temperatures ranging from 90° to 150° C; *low enthalpy* for temperatures lower than 90°C. Based on the installable thermal capacity, the legislation classifies the resources as those of *national interest* (high enthalpy resources economically viable for running a geothermal project ensuring an overall thermal capacity of at least 20 MWt), of *local interest* (medium-low enthalpy resources and thermal capacity up to 20 MWt) and *small local utilizations* (for geothermal installations of up to 2 MWt using a well of up to 400 meters deep closed loop GSHPs are also included in this class).

Italian law provides two kinds of titles for the exploration, use and development of geothermal resources of national and local interest: an exploration permit and a "mining" lease. The competent authorities for the release of mining titles for onshore geothermal resources are the regional administrations (or delegated bodies) in whose territory the projects are located. In the case of the offshore discovery of geothermal resources, the authorization is granted by the Ministry of Economic Development (MiSE) in agreement with the Ministry of Environment and Protection of Land and Sea (MATTM). In spite of well-defined procedures for authorizing exploration permits and mining leases, the continuous request for further data during the authorization of exploration activities often results in prolonged procedures. DH projects developing geothermal resources of local interest often face this issue.

Small local utilizations, which includes GSHPs, are not regulated by the mineral legislation of 1927, and their authorization procedures are simplified. However, these simplified prescriptions have not been yet promulgated. This regulation gap has been partially filled with voluntary schemes by some regional and provincial administrations but still represents a significant barrier to the diffusion of GSHP technologies. Moreover, an official and complete registry of GSHP installations at national level has not been implemented, and at the moment it is not possible to perform a quantitative analysis of the installed capacity of GSHPs for the various regions. The lack of official registries for small local utilizations is also hindering the sustainable development of shallow geothermal resources, as the fluid withdrawal or the underground temperature perturbation requires regulations based on reliable data.

The promotion of the use of RES in heating and cooling is achieved in Italy by tax relief of 55% on RES technologies installation costs (the so-called *Conto Termico*), and as part of a wider measure to promote energy savings in the building sector. The latter consists of: 1) for new buildings which are not yet fully operational, the obligation to cover a quota (50%) of their energy needs for domestic hot water with renewable sources; 2) for existing buildings, the possibility of deducting 55% of the costs incurred for energy retrofit operations from personal income tax (IRPEF) or corporate income tax (IRES) obligations (so-called *Ecobonus*).

The Italian Energy Strategy released in 2017 (MiSE, 2017) did not forecast any specific increase or promotion of heat production from geothermal sources, and vaguely refers to the will of expanding heat pump uses and district heating infrastructure. A new Energy and Climate Planning has been drafted by MiSE and will be enforced in 2020. The position of the government in the preliminary text that circulated for consultation appears in favor of supporting DH and heat pumps, although without any specific mention to geothermal technologies.

4.5 R&D activity in geothermal energy topics

Italian entities have been recently involved in numerous European projects dealing with resource mapping, development of new materials, innovative technologies and tools, investigation of common methodologies and collection of open science-based reliable data to ensure geothermal energy exploitation a key role in the future energy system. The overall investments on these projects consists of 183 M€, mainly from EU contribution, and involves academia and research institutions, enterprises, companies, associations from 21 EU and non-EU countries (i.e.: Switzerland and Israel). Italian partners have been funded for about 25 M€ during the 2013 - 2022 period. Projects name, subject, overall funding and Italian share are summarized in Table D.

Table D. European projects concerning geothermal energy in which Italy is involved as a partner. Funding scheme: IA (Innovation Action), RIA (Research and Innovation action), CSA (Coordination and Support Action), SME-1 (SME instrument phase).

PROJECT NAME WEBPAGE PERIOD OF ACTIVITY	PROJECT DESCRIPTION AND MAIN GOALS	BUDGET (K€) PROJECT COORDINATION
Cheap-GSHPs (IA) 01/06//2015-31/05/2019 https://cheap-gshp.eu/	The Cheap-GSHPs project improved drilling/installation technologies and designs of Ground Source Heat Exchangers (GSHE's) by developing more efficient and safer shallow geothermal systems to reduce the overall cost. Secondly, a decision support (DSS) and other design tools covering the geological aspects, feasibility and economic evaluations based on different plant set-up options, selection, design, installation, commissioning and operation were implemented. The designed solutions were built and proved in various sites with different undergrounds in different climates.	5717 total, 4844 EU contribution,1874 contribution to Italy Italian coordination
DEEPEGS (IA) 01/12/2015-30/11/2019 https://deepegs.eu/	The aim is to demonstrate the feasibility of enhanced geothermal systems (EGS) for the supply of energy from renewable resources in Europe. Testing EGS stimulation technologies that will be applied in deep wells under different geological conditions will provide innovative solutions and models for larger deployments of EGS tanks with sufficient permeability to provide significant amounts of geothermal energy across Europe.	42173 total ,18983 EU contribution , 220 contribution to Italy Icelandic coordination
DESCRAMBLE (RIA) 01/05/2015-30/04/2018 http://www.descramble-h2020.eu/	DESCRAMBLE project aims to develop novel drilling technologies for a proof-of-concept test of reaching deep geothermal resources, to explore the possibility of reaching extremely high specific productivity per well with a closed loop, zero emissions, and minor land occupation. The first drilling in the world in an intra-continental site at a middle-crustal level was carried out. The main outcomes were: improved drilling concepts in deep crustal conditions, new drilling materials, equipment and tools, physical and chemical characterization of deep crustal fluids and rocks.	15687 total, 6754 EU contribution , 4561 contribution to Italy Italian coordination
ETIP-DG (CSA) 01/07/2017-30/06/2019 https://www.etip-dg.eu/	The project DG-ETIP was meant to support the Secretariat activities of the European Technology and Innovation Platform for Deep Geothermal technologies. The primary objectives have been the drafting of the Vision, Strategic Research and Innovation Agenda and Implementation Roadmap of ETIP-DG, and to establish a sound and large stakeholder group.	597 total, 597 EU contribution, 162 contribution to Italy Belgian coordination
EoCoE (RIA) 01/10//2015-30/09/2018 https://www.eocoe.eu/	It explores how to make the computing potential of the increasingly powerful High Performance Computing HPC available to accelerate Europe's energy transition. The project has a section dedicated to geothermal energy.	5689 total, 5403 EU contribution, 571 contribution to Italy French coordination
GECO (IA) 01/10/2018-30/09/2022 https://www.carbfix.com/geco	GECO project aims at proceeding in reducing carbon and sulphur emissions from geothermal energy use by applying an innovative technology, already proven at pilot scale in Iceland, to limit the discharge of emissions from geothermal power plants by condensing and re-injecting gases or turning the emissions into commercial products. The technology will be applied in four distinct geothermal systems in four different European countries, including Italy	18220 total, 15599 EU contribution, 2402 contribution to Italy Icelandic coordination
GEMEX (RIA) 01/10/2016-31/05/2020 http://www.gemex-h2020.eu/index.php?lang=en	The GEMex project is carried out by a European consortium and a corresponding consortium from Mexico. The project goals are: 1- to assess and quantify the resource potential at two unconventional geothermal sites, 2- to characterize the reservoir using techniques developed at conventional geothermal sites, and test and refine novel geophysical and geological methods for their application at the two project sites; 3- to draft concepts for site development, with the purpose of defining drill paths, recommending a design for well completion, and investigating optimum stimulation and operation procedures.	10000 total, 10000 EU contribution, 2367 contribution to Italy German coordination
GEOCOND (RIA) 01/05/2017-31/10/2020 https://geocond-project.eu/	GEOCOND will develop solutions to increase the thermal performance of the different subsystems configuring a Shallow Geothermal Energy Systems (SGES) and Underground Thermal Energy Storage (UTES). The main objective is to reduce costs of about 25%, leading to a substantial gain in competitiveness. GEOCOND will be articulated on four key development areas: development of new pipe materials, advanced additives and concepts, advanced Phase Change Materials and system-wide simulation and optimization.	3956 total, 3956 EU contribution, 254 contribution to Italy Spanish coordination
Geo-Drill (RIA) 01/04/2019-30/09/2022 https://www.geodrillproject.eu/project	Geo-Drill aims to reduce drilling cost with increased ROP and reduced tripping with improved tools lives. Geo-Drill is proposing drilling technology incorporating bi-stable fluidic amplifier driven mud hammer, low cost 3D printed sensors & cables, drill monitoring system, Graphene based materials and coatings.	4996 total, 4996 EU contribution, 409 contribution to Italy English coordination
GEOENVI (CSA) 01/11/2018-30/04/2021 https://www.geoenvi.eu	GEOENVI project aims at investigating deep geothermal in order to make this technology application and development sustainable. The main objectives are to assess the environmental impacts and risks of geothermal projects in Europe, to prove a robust framework to propose recommendations on environmental regulations to the decision-makers, an adapted methodology for assessing environment impact to the project developers, and, finally, to communicate properly on environmental concerns with the general public. Secondly, GEOENVI aims at engaging with both decision-makers and	2496 total, 2496 EU contribution, 677 contribution to Italy Belgian coordination

	geothermal market actors, to have the recommendations on regulations adopted and to see the LCA methodology implemented by geothermal stakeholders.	
GeoFit (IA) 01/05/2018-30/04/2022 https://geofit-project.eu	GeoFit aimed at the use of enhanced geothermal systems (EGS) and at the renovation of buildings seeking for a higher energy efficiency. This involves the technical development of novel EGS and its components, namely novel heat exchanger configurations, a new hybrid heat pump and electrically operated compression heat pump systems, and components for heating and cooling to be integrated with the new GSHP concepts, all designed to be applied in retrofitting projects.	9862 total, 7897 EU contribution, 2060 contribution to Italy Italian coordination
GeoSmart (IA) 01/06/2019-31/05/2023 https://cordis.europa.eu/project/rcn/223942/factsheet/en	GeoSmart combines thermal energy storages with flexible ORC solutions to provide a highly flexible operational capability of a geothermal installation. During periods with low demand, energy will be stored in the storage to be released at a later stage when the demand is higher. To improve efficiency, we also propose a hybrid cooling system for the ORC plant to prevent efficiency degradation due to seasonal variations.	19728 total, 17364 EU contribution, 533 contribution to Italy English coordination
GEOTeCH (IA) 01/05/2015-30/04/2019 http://www.geotech-project.eu/	GEOTeCH aimed at improving the drilling technology used for installation of vertical borehole heat exchangers. The main project pillars were: - employing a different drilling concept that requires cheaper equipment, enhances safety and avoids the environmental risks and costs of dealing with water supplies and contaminated waste; - a better integration between heat exchange elements during installation; - implementing cost-effective geothermal systems in large size buildings; - developing optimized hybrid solutions in small and large buildings market. The GEOTeCH's approach sought the maximum use of the foundation structures also for heat exchange purposes.	9025 total, 7137 EU contribution, 1129 contribution to Italy Spanish coordination
Geo4civhic (IA) https://geo4civhic.eu/ 01/04/2018-31/03/2022	The aim of Geo4civhic project is to find the best shallow geothermal energy solutions for each combination of building type/climate/geological conditions, and to reduce overall engineering costs, avoid design mistakes, eventually facilitating the building refurbishment under different constrains. The main objectives are: - identify or develop building blocks solutions in drilling, GSHE types, heat pumps and other renewable energy/storage technologies, heating and cooling terminals for every type of built environment; - generate and demonstrate the easiest way to install cost-effective solutions using and improving existing and new tools.	8143 total, 6842 EU contribution, 2048 contribution to Italy Italian coordination
MATChING (IA) http://www.matching-project.eu 01/03/2016-31/08/2019	The aim is to reduce the need for cooling water in production facilities with targeted technological solutions, to be demonstrated in geothermal plants for electricity and heat production.	11791 total, 9706 EU contribution, 3693 contribution to Italy Italian coordination
ThermoDrill (RIA) http://www.thermodrill-h2020.org/ 01/09/2015-31/08/2019	ThermoDrill addresses the development of integrated innovative drilling techniques. Drilling is achieved with high-pressure jets in combination with rotary technologies, thus varying stress in progress and improving performance. Enhanced drilling and other innovations in the circulation fluids front allow an estimated doubling of the drilling speed.	5825 total, 5381 EU contribution, 603 contribution to Italy Austrian coordination
IMAGE (RIA) http://www.imageh2020.eu/ 01/03/2016-29/02/2020	The IMAGE project aimed at developing a novel exploration and assessment method to image geothermal reservoirs by three steps: 1- understanding the processes and properties that control the spatial distribution of critical exploration parameters to predict temperatures, in-situ stresses, fracture permeability and hazards; 2- improving well-established exploration techniques for imaging, detection and testing of novel geological, geophysical and geochemical methods to provide information on critical subsurface exploration parameters; 3- proving the added value of an integrated and multidisciplinary approach for site characterization and well-siting.	9013 total, 7000 EU contribution, 1184 contribution to Italy French coordination
GRETA Interreg project (SME-1) https://www.alpine-space.eu/projects/greta/en/home 01/12/2016-31/05/2017	GRETA aimed to prove the potential of Near-Surface Geothermal Energy (NSGE) in the Alpine Space and to promote the integration of this technology into future energy plans in the area. The main results of the project were decision support tools, legal and technical guidelines for the utilization of NSGE. These results were meant to encourage the implementation of NSGE into policy instruments at different administrative levels. The final purpose was to reduce total CO_2 emissions in environmentally sensitive regions using renewable energy sources, thus establishing transnationally integrated low carbon policy instruments.	71 total, 50 EU contribution, 50 contribution to Italy Italian coordination

CONCLUSION

The review of the development of geothermal direct uses in Italy shows a stable situation during the three-year period 2014-2017. Both installed capacity and energy use data are close to those presented at the last WGC2015. At the end of 2017, the installed capacity is about 1450 MWt (+5% with respect to 2014) for a corresponding energy use of about 11000 TJ/yr. Space heating remains the main application sector in terms of both installed capacity (52%) and energy use (42%). A notable contribution comes from GSHPs and DH systems, which together account for about 88% of the geo-heat delivered for space heating and 38% of the total geothermal energy used in all Italian direct application. Balneology and fish farming are the second and the third application sectors, accounting for 32% and 18% of the total geo-heat utilization, respectively. Geothermal district heating is the only application that is currently expanding at a significant rate of about 30% and 8% per year in terms of capacity and energy used, respectively. Also, industrial applications are growing after a decrease period due to economic reasons, but their contribution is still limited to about 1% in terms of both installed capacity and energy use. In Tuscany a recently established "Geothermal Law" requires the operators of new power production plants to use at least 50% of the residual energy from electricity production for heat applications. This will probably result in an increasing number of applications and use of geothermal heat.

The slow increase of GSHP applications is due to the combination of different drawbacks that must be overcome to ensure a new development phase for the geothermal energy in Italy. While on one hand Legislative Decree 28/2011 finally recognized the positive role of GSHP systems, and the contribution of policies to combat climate change and to enhance energy efficiency, on the other hand the issuing of the so-called "*posa-sonde*" Ministerial Decree is necessary to define the guidelines on the simplified procedures for the authorization of closed-loop geothermal plants. Such decree, whose technical text has been defined in a coordinated effort among the main stakeholders and associations since 2016, still waits its final text and issue.

The second "non-technological barrier" for GSHP is cultural: the technology is still little known compared to other renewable energy sources and sometimes it is even hampered due to a general hostility towards all forms of underground activities that imply perforations and extraction of geothermal resources: in this regard it is considered necessary to make a decisive distinction between “deep geothermal” and “shallow, heat exchange" heat pump systems, highlighting the difference in terms of lower risks and potential environmental impacts.

Another obstacle is linked to the lack of incentive schemes that are reserved only for the replacement of existing plants (*Conto Termico* and *EcoBonus* - which are not always sufficiently attractive for this solution), while no incentives are envisaged for new plants, or tariff concessions for GSHP electricity consumption.

Eventually, there is an organizational barrier: the sector still lacks of a mature supply chain able to efficiently promote the necessary professionals (designers and installers); these latter also require a precise identification and training on GSHP systems, both in terms of design and work management, and in terms of drilling and systems installation..

At the same time, in the last few years some signs of new impulse for GSHP systems diffusion appeared. First of all, Legislative Decree 28/2011 requires to gradually increase the RES share to cover the thermal energy demand of new buildings (intended as the sum of heating, cooling and domestic hot water). This obligation currently sets at 50% the RES share, and it is destined to grow as a result of the recently issued renewable directive 2018/2001 which prospects a minimum annual increase of 1.3% in the RES share for the coverage of the thermal needs of buildings.

Furthermore, the development of innovative technologies and solutions in the field of geothermal systems with heat pumps allows a better diffusion of these systems: today there is a variety of solutions - including hybrid, both in the use of other exchange sources combined with heat pumps, and integration with other energy sources – which makes it possible to evaluate the use of geothermal systems in situations and contexts that precluded their use until a few years ago.

Eventually, an important driver for the use of GSHP systems is the growing interest in the protection of air quality, given the degraded air conditions in many cities in Central and Northern Italy. The conversion or replacement of fossil fueled systems with low-enthalpy geothermal systems (both single and combined with urban district heating networks) can be a straightforward solution to guarantee an air quality improvement in the short-medium term. Finally, the combination of geothermal systems with other RES is perceived as a promising solution to achieve Near Zero Emission Buildings (NZEBs).

In conclusion, although the heating&cooling geothermal technologies did not penetrate the Italian market as in other European countries, the conditions are nowadays favorable for an appropriate development, especially for geothermal heat pump technologies, well known and established in numerous other countries and expected to grow at a much higher pace than before, and for district heating systems.

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TABLE 3. **UTILIZATION OF GEOTHERMAL ENERGY FOR DIRECT HEAT AS OF 31 DECEMBER 2017 (other than heat pumps)**

I = Industrial process heat

C = Air conditioning (cooling)

A = Agricultural drying (grain, fruit, vegetables)

F = Fish farming

K = Animal farming

S = Snow melting

H = Individual space heating (other than heat pumps)

D = District heating (other than heat pumps)

B = Bathing and swimming (including balneology)

G = Greenhouse and soil heating

O = Other

Enthalpy information is given only if there is steam or two-phase flow

Capacity (MWt) = Max. flow rate (kg/s)[inlet temp. (ºC) - outlet temp. (ºC)] x 0.004184

or = Max. flow rate (kg/s)[inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.001

Energy use (TJ/yr) = Ave. flow rate (kg/s) x [inlet temp. (ºC) - outlet temp. (ºC)] x 0.1319

or = Ave. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.03154

Capacity factor = [Annual Energy Use (TJ/yr)/Capacity (MWt)] x 0.03171

Note: the capacity factor must be less than or equal to 1.00 and is usually less, since projects do not operate at 100% of capacity all year.

Locality		Type[1)]	Maximum Utilization					Capacity[3)]	Annual Utilization		
			Flow Rate (kg/s)	Temperature (ºC) Inlet	Outlet	Enthalpy[2)] (kJ/kg) Inlet	Outlet	(MWt)	Ave. Flow (kg/s)	Energy[4)] (TJ/yr)	Capacity Factor[5)]
Emilia Romagna		D						15.4		237.6	0.49
Friuli-Venezia Giulia		D						2.3		0.0	0.00
Tuscany		D						100.1		536.8	0.17
Veneto		D						1.0		20.9	0.66
Lombardy		D						30.0		57.2	0.06
Tuscany		H						5.7		18.0	0.10
Veneto		H						52.3		472.2	0.29
Campania		H						12.0		56.2	0.15
Friuli-Venezia Giulia		H						4.9		0.0	0.00
Lombardy		H						0.2		1.7	0.29
Tuscany		I						16.0		149.0	0.30
Tuscany		F						61.0		963.0	0.50
Apulia		F						23.5		372.3	0.50
Lombardy		F						2.8		20.4	0.24
Friuli-Venezia Giulia		F						1.0		0.0	0.00
Veneto		F						0.3		5.0	0.51
Estimated other fish farming uses		F						41.5		658.4	0.50
Latium		G						9.3		44.0	0.15
Tuscany		G						56.6		534.5	0.30
Veneto		G						0.4		2.6	0.24
Friuli-Venezia Giulia		G						0.8		0.0	0.00

Basilicata		B						0.1		0.6	0.24
Calabria		B						0.7		15.9	0.77
Campania		B						73.3		517.3	0.22
Emilia Romagna		B						4.4		51.2	0.37
Lazio		B						41.0		410.1	0.32
Liguria		B						0.6		3.2	0.17
Lombardy		B						9.8		91.3	0.29
Marche		B						0.4		5.5	0.46
Piedmont		B						10.1		72.6	0.23
Puglia		B						0.2		1.3	0.22
Sardinia		B						5.5		41.7	0.24
Sicily		B						7.2		90.8	0.40
Tuscany		B						96.3		747.4	0.25
Trentino-South Tyrol		B						1.5		10.5	0.22
Umbria		B						0.0		0.1	0.23
Veneto		B						205.0		1441.4	0.22
TOTAL								893		7651	0.27

TABLE 5. SUMMARY TABLE OF GEOTHERMAL DIRECT HEAT USES AS OF 31 DECEMBER 2019

[1] Installed Capacity (thermal power) (MWt) = Max. flow rate (kg/s) x [inlet temp. (ºC) - outlet temp. (ºC)] x 0.004184

or = Max. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.001

[2] Annual Energy Use (TJ/yr) = Ave. flow rate (kg/s) x [inlet temp. (ºC) - outlet temp. (ºC)] x 0.1319

or = Ave. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg) x 0.03154

[3] Capacity Factor = [Annual Energy Use (TJ/yr)/Capacity (MWt)] x 0.03171
Note: the capacity factor must be less than or equal to 1.00 and is usually less, since projects do not operate at 100% capacity all year

[4] Other than heat pumps

[5] Includes drying or dehydration of grains, fruits and vegetables

[6] Excludes agricultural drying and dehydration

[7] Includes balneology

Use	Installed Capacity[1] (MWt)	Annual Energy Use[2] ($TJ/yr = 10^{12}$ J/yr)	Capacity Factor[3]
Individual Space Heating[4]	75	548	0.23
District Heating [4]	150	863	0.18
Air Conditioning (Cooling)			
Greenhouse Heating	67	581	0.27
Fish Farming	130	2019	0.49
Animal Farming			
Agricultural Drying[5]			
Industrial Process Heat[6]	15	139	0.29
Snow Melting			
Bathing and Swimming[7]	456	3501	0.24
Other Uses (specify)			
Subtotal	893	7651	0.27
Geothermal Heat Pumps	532	3265	0.19
TOTAL	1425	10916	0.24