Shallow Geothermal Potential Impact on the Energy Transition. A Case Study Region of Murcia, Spain

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***Abstract*—Nowadays, it can be assured that climate change represents an environmental danger for the planet with irreparable and unpredictable consequences in case both gas emissions as well as fossil fuel dependency does not go down. Population growth and its increasingly concentration in the cities turn these areas into a major consumer of energy, mainly due to the residential and service sector in order to meet the heating and cooling demand. In this scenario of taking advanced of renewable local resources shallow geothermal energy is presented as a renewable resource that can contribute to meet this demand with high energy and gas emissions savings. In this context, this work shows the art-of-state of the energy transition to a renewable energy society in Spain by means of the use of shallow geothermal energy. It proposes a procedure to transform the current fossil fuel consumption into renewable heating and cooling by the use of Ground Source Heat Pumps (GSHP). The methodology used is based on Geographical Information Systems (GIS) and is applied in Murcia Region, Spain. Positive results concerning gas savings emissions are expected converting shallow geothermal energy as an energy transition ally.**

Keywords— Renewable heating and cooling, GIS, Shallow geothermal energy, Energy transition

I. INTRODUCTION

The weather emergency timeline was consolidated with the Paris agreement [1], signed in 2015 set the goal of keeping the global temperature rise well below 2ºC above pre-industrial levels during this century. By the end of 2019, the European Parliament declared the climate emergency. The Commission goal was to ensure to reach to the 1.5ºC target by 2050, which implies cut emissions by 55% by 2030 and becomes climate neutral by 2050. International policy is then marked by the climate change mitigation: governments, energy and environmental protection organizations work in ambitious short-term and long-term plans combining energy, environmental and economic aspects [2,3] In addition, the world population has been increased and concentrated in cities. In parallel the heating/cooling demand has also increased considerably, turning cities into critical icons to facilitate climate action, energy transition and sustainability [4,5].

The residential sector is responsible for the emission of 1,931 and 454 Mt CO_2 in the world and Europe respectively [6]. Amon the different renewable energy sources, geothermal energy for heating/cooling represents a relevant resource with high energy savings and pollution reduction. Global geothermal gives a total of 25 GW in 2017, adding 1.4 GW power capacity. One of the fastest growing and largest volume sectors for the direct use of geothermal heat is focused on heating purposes. Unites States was the country with the largest amounts of geothermal power generating capacity at the end of 2018 (2,600 MW) followed by the Indonesia and Philippines (1,900 MW) [7].

In response to the imperative need for the change of the energy model, the main objective of this work is to describe the geothermal energy as a solution for energy transition purposes. The rest of the paper is structured as follows: Section II analyzes the state of the art of renewables at global and European level, as well as population growth statistics; Section III examines surface geothermal energy in Europe and the Region of Murcia (Spain), describing the current barriers and constraints; Section IV shows a case study of the city of Murcia and finally, Section V gives the conclusions.

II. STATE OF THE ART

A. Renewable energies for electricity production

The generation of electricity from renewables plays a fundamental role in the energy transition. The increase in the electrification of energy services with renewable sources and energy efficiency can provide more than 90% of the required CO_2 emission reductions [8]. The installed-accumulated capacity in the last decade maintains an annual growth rate globally. The renewable energy sector has reached a high degree of technological maturity highlighting the wind and solar sector. At the end of 2017 the total capacity was 2,302 GW, representing an increase of 74% with respect to the year 2010. For the year 2050, an increasing capacity of 681% is expected to be achieved with respect to 2017 (17,973 GW), see Fig. 1(A). The integration of renewables in power systems has presented an upward growth, mainly based on wind and solar resources. In 2010 the energy generated from renewable sources was 4,293 TWh, 7 years later this data was increased by 47% (6,312 TWh) and by 2050 an increase of 400% is expected, see Fig. 1(B).

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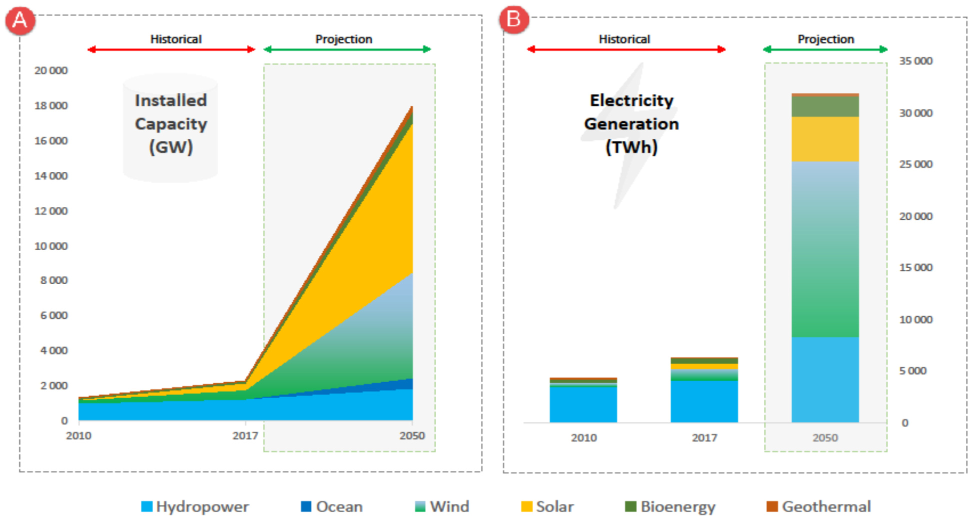

Fig. 1. Evolution of installed capacity with renewable sources (A) and electricity generation with renewable origin (B). Source:[8]

However, the presence of renewables in final energy consumption is globally quite low. In 2015, heating/cooling demand accounted for 48% of total final energy consumption, followed by transport (32%) and electricity consumption (20%), only 27 % was given by renewables with 16.40% of traditional biomass, see Fig. 2. Government initiatives applied to renewable heating/cooling necessities are far from achieving significant results, compared to the generation of renewable energies. However, the renewable energy potential for this sector paralyzed due to different aspects [7].

B. *Share of Renewable Energy evolution in Europe*

According to European Environment Agency (EEA), renewables represented 43% in 2017 of gross final renewable energy consumption in the EU, 50% for Heating and Cooling (H&C) and 7% in transport, see Fig. 3. The dominant market sector in renewables in Europe remains the H&C, reaching up to almost 20% by 2020.

Renewables in the electricity field represent the second largest market sector with a 0.9 % average growth rate from 2005. According to the EEA estimations, 32.1% of total energy consumption is provided by renewable energy sources (RES), and a growth of at least 7% must be maintained to reach the NREAP objectives. However, only five countries (Germany, Ireland, Portugal, Spain and United Kingdom) had a share of 50% of all gross final consumption of renewables in 2017.

In the transport sector, renewables have reached up to 8.1% on average, being the third market sector in the RES. Their small role in the total RES consumption is due to the use of biofuels and their fast growth (30% per year from 2005-2017). Likewise, additional efforts are needed in line with the growth rate requirements of 32% to reach NREAP in 2020. The share of RES in the transport sector among the different EU countries ranging from 45% in Luxembourg to less than 1% in Croatia.

C. *Growth of the urban world population*

During the last decades, a progressive increasing in the population has been experiencing with a clear tendency towards the concentration of urban areas. The world population has had an increase of 27.5% in the period 1998-2018, but the urban population in the same period has increased by 53%. For example, Spain, in the same line of such growth has increased its population from 1998 to 2018 by 16.2%, and the concentration in urban areas has increased by 22.6% during the same period. It should be noted that the urban population in 2018 represented 80.3% of the total population, see Fig. 4. These figures turn the residential sector into large energy sinks, mainly used in conditioning of buildings. These systems currently use fossil fuels, increasing negative effects on climate change.

D. *Renewable Heating and cooling production*

According to the specific literature, around 50% of the European countries' annual energy consumption is used for heating and cooling. Residential sector presents a Greenhouse Gas (GHG) savings potential up to 80%.

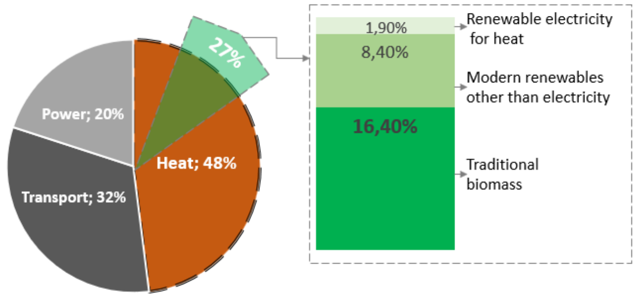

Fig. 2. RES in total final consumption: heat end-use sector [7]

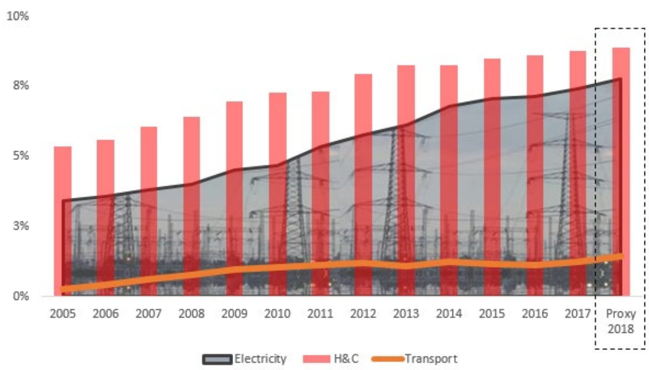

Fig. 3. Share of RES in gross final energy consumption in the EU [9].

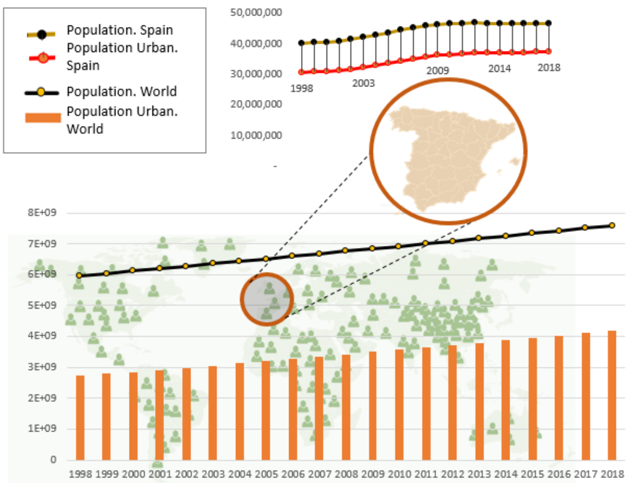

Fig. 4. Evolution of the world population and Spain. Source: [10]

Nowadays, heating and cooling is mainly produced by natural gas and only a residual share of 5% comes from renewable sources (wind, PV and hydro), see Figure 5. Solar thermal coupled with geothermal energy accounts for 1.5% [1]. Therefore, only 18% of the energy demanded by the H&C was produced by renewables in 2017 and subsequently, H&C currently presents a huge emissions reduction potential. In this way, increasing the share of renewables in H&C is then necessary to fulfill the climate goals by the EU. Moreover, it is expected that, by end of 2020, 25% of the thermal demand could be supported by renewables. This objective can be achieved by the electrification of the sector from low-carbon renewable resources, where heat pumps play a key role to achieve these objectives. Indeed, heat pumps not only account for a high efficiency technology, but also their use will progressively decrease the primary energy needs. In fact, as less energy is required, and will increase the renewable energy penetration as long as the electricity is produced by high share of renewable energies.

This electrification brings about significant environmental benefits, by reducing air pollution (NO_x, SO_x and ozone) and then being considered a paramount in urban areas where population is highly concentrated. By considering the previous aspects, Shallow Geothermal Energy (SGE) can be presented as a key candidate for meeting these goals, being able to play a significant role in the H&C low carbon energy transition. This solution would increase cities 'resilience by taking advantage of their local natural resources, reducing significantly air pollution. The implementation can be carried out through both individual buildings as well as with combined systems in urban areas, industries, and services.

III. Shallow Geothermal Energy

A. Status in Europe

Geothermal energy is classified into deep and shallow geothermal or low enthalpy. Deep geothermal is used for both producing electricity and H&C, basically through district heating. In 2018, geothermal power reached to 3,091 MWeq of capacity in Europe, with 127 geothermal plants in operation. Shallow Geothermal Energy (SGE) is an unlimited energy present everywhere, and it is mainly used for H&C.

There are different ways to integrate this resource, such as Ground Source Heat Pumps (GSHP) and Underground Thermal Energy Storage (UTES), being the latter the most worldwide spread. In 2018, an installed capacity of 23.000 MWth [12] distributed in over more than 1.9 million GSHP installations along the EU. However, its deployment lay far below its potential, and the EU countries should promote the uptake of this renewable local energy to reach to 2030 and 2050 energy and climate goals.

B. Barriers and constraints

In accordance to the enormous potential and support given by the authorities to the geothermal resource for renewable H&C, there are significant barriers that are preventing SGE for a better deployment and a more relevant inclusion in the market along the EU. Nevertheless, specific situations and policies vary greatly from one country to another, though there are specific issues that can be found everywhere along the UE, see Fig. 6.

With regard to non-technological barriers along with the high upfront costs, they are responsible for most of the issues. Among the non-technological barriers, a lack of awareness in stakeholders and decisions and policy makers, and a lack of legal clearness or high-level bureaucracy are present in all of them. In order to deal with this situation, all kind of authorities, ranging from European to regional ones, must promote a variety of campaigns with the aim of raising awareness among all of the actors implied.

C. Projection and targets for 2020

In 2012, the heat production provided by geothermal in the EU-28 target exceeded EU targets set in the National Renewable Action Plan (NREAP). By then, reported shallow geothermal heat raised up to 27,080 GWhth while the target was 18,946 GWhth, thus it was produced an additional 143% more than expected. Among the EU members, 19 of the 28-EU Member States has adopted one or more categories of geothermal into their NREAP [13]; and a stable growth is expected to be achieved with stable units' sales. According to recent contributions, there is no an official report. However, from the 2018 data, countries such as Sweden and Austria with historically high rates of GSHP, sales are expected not to reach the objectives, see Fig. 7.

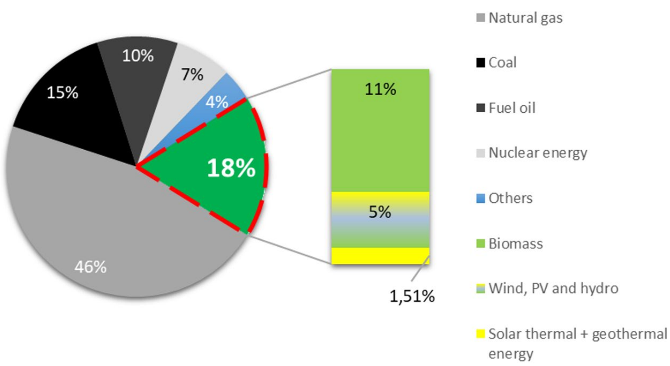

Fig. 5. Share of primary energy source for the production of heating and cooling in Europe (2016).

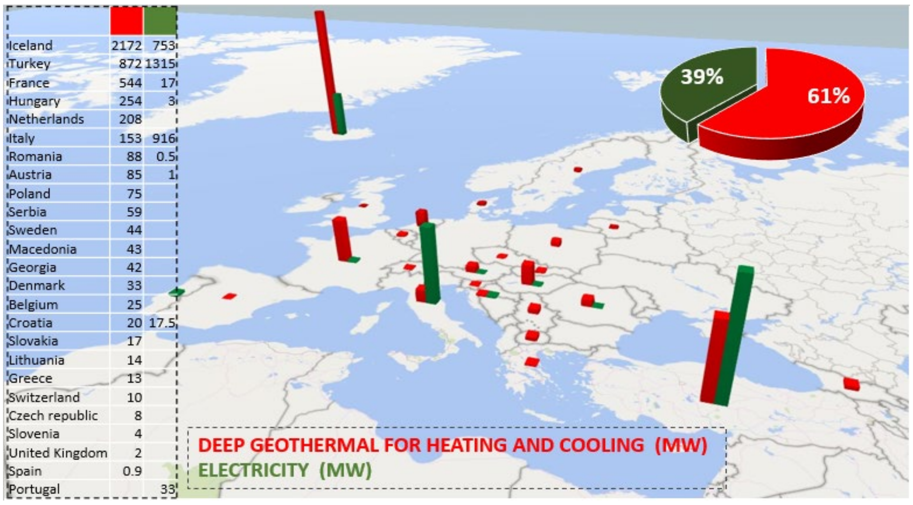

Fig. 6. Installed capacity for geothermal electricity and district heating by country in 2018 (MW). Source: [12]

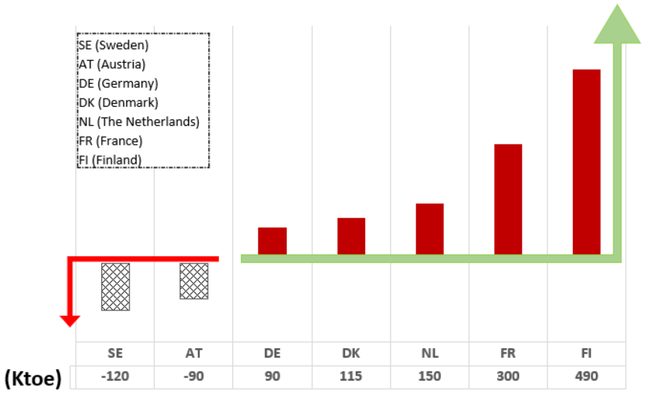

Fig. 7. Progress towards GSHP NREAP´s objective in selected Member states (Ktoe).

Other countries, such as Finland or France, have promoted great efforts to increase their renewable H&C share, see Fig. 8. It's then expected to double the heat produced with shallow geothermal energy in 2012, and to reach almost 50,000 GWth for 2020.

D. Shallow geothermal energy in the EU Energy agendas and in Murcia region

Renewable Energy Directive 2009/28/EC [14] is set as the most important directive regarding the geothermal sector. It is required by the EU Members that 20% of their final energy consumption to be produced from RES. The 2010/31/EU Energy Performance of Buildings Directive [15] set the nearly zero-energy buildings concept. Moreover, 2020 was set as the year for public buildings become energetically self-sufficient. However, SGE can be very rarely found as a reliable way to achieve this target. In fact, it is usually included under other renewable options, such as solar thermal solutions. An example is the case of the new Spanish Building Technique Code [16], issued in 2019 and focused on cutting 40% GHG emission in buildings. However, shallow geothermal energy is not even mentioned as a reliable alternative to reach those goals. Likewise, a minor relevance is thus given in Murcia Region (located in the south-east of Spain) to the exploitation of this renewable and local resource.

According to [12], Murcia Region lays in an area with high expectations for a wider development of combined H&C production, mainly due to climatic reasons. Nevertheless, and in accordance to the Regional Energy Plan [17] promoted by 2009/28/EC Directive, only one of the 105 proposed measures against climate change included the use and promotion of shallow geothermal energy. This roadmap, along with the complexity in the procedures and bureaucracy when legalizing an SGE systems, is preventing the Murcia Region from a better deployment.

IV. Study Case in Murcia City (Spain)

In order to create awareness concerning the potential of using and integrating the shallow geothermal potential into the Mediterranean countries in general (and in the Murcia Region in particular), an assessment of the ground capacity to meet the space heating demand in Murcia city (Spain) is developed by the authors and following discussed.

A. Shallow Geothermal potential

An evaluation of the shallow geothermal potential was firstly carried out with Geographic Information System (GIS) tools based on lithological information and water saturation grade. With this aim, the 1:200.000 Murcia Region Lithological map [18] was used to estimate the specific heat extraction values. The Murcia city underground is mainly formed by Quaternary gravels, conglomerates, sands and silts. The close presence of the Segura river, which splits the city into two parts, addresses the water saturation of the ground, enhancing dramatically the thermal properties. The German rule VDI 4640 [19] provides specific heat extraction rates. A GSHP can extract from the underground based on the rock type, water saturation and the operation time of the GSHP. According to the Murcia underground characteristics, an average of 70 W/m^2 is expected to be extracted. The shallow geothermal potential for the whole city area was estimated supposing an exploitation of the geothermal resource with vertical close loop GSHP system as can be found in [20]. For this purpose, the number of maximum Borehole Heat Exchangers (BHE) was calculated considering the minimum safety distance required for BHE, and avoiding any thermal interference among them. The spatial analysis has been performed by means of GIS tools. Parameter values used for these estimations and results of the potential in Murcia city are summarized in Table 1.

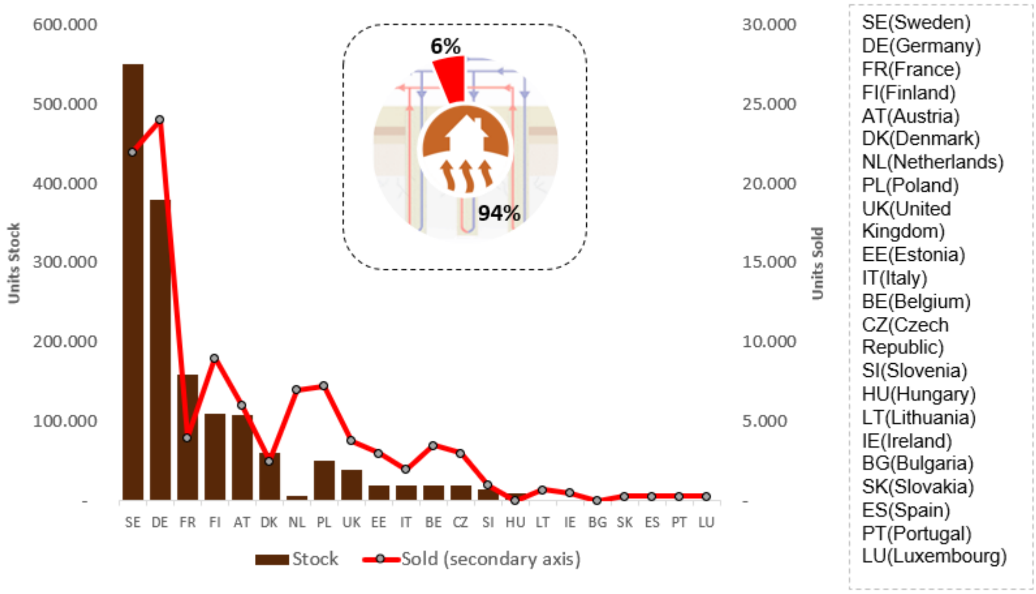

Fig. 8. Stock of GSHP per country, highlighting sold in 2018. Source: [11]

TABLE I. INPUT VALUES AND RESULTS OF THE CALCULATION OF THE SHALLOW GEOTHERMAL POTENTIAL IN MURCIA CITY (SPAIN)

Parameters	***Values***
Safety BHE distance (meters)	10
Lenght BHE (meters)	100
COP	4
SHe (W/m)	70
Annual operation time (hours)	2160
BHE number	57109
SGE Potential (GWh)	1151.31
SGE Potential (TJ)	4156.38
Murcia area (Km^2)	8.84
SGE Potential density (TJ/Km^2)	470.179

B. Shallow geothermal capacity

Annual H&C demand density in Murcia city range from 0 to >300 TJ/ km^2 [21] and from 0 to 10 *TJ/km^2* respectively. Since heating demand density can become 30 times higher than the cooling demand, we focus our work only on the heating demand.

Murcia SGE potential is approximately 470 *TJ/km^2* and annual heat demand density range from 0 to 300 *TJ/km^2*, see Fig. 9, depending on the city area. Therefore, Murcia city underground accounts for capacity space heating ranging from 1.6 to 47 (Table 2) depending on the heating demand range. It can be concluded than from 160 to 4700% of the heating demand can be potentially covered by the shallow geothermal resources in the city of Murcia.

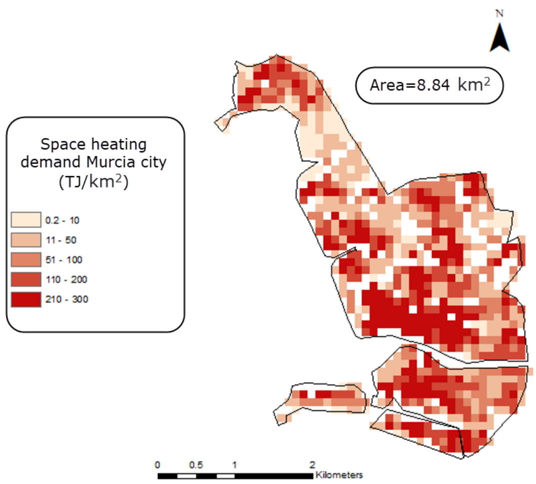

Fig. 9. Heating and cooling demand density in the city of Murcia (Spain) [21]

TABLE II. INPUT VALUES AND RESULTS OF THE CALCULATION OF THE SHALLOW GEOTHERMAL POTENTIAL IN MURCIA CITY (SPAIN)

Annual Heating demand (TJ/km^2)	***Heat demand capacity for 100 meters depth BHE***
300	1.6
200	2.4
100	4.7
50	9.4
10	47.0

V. CONCLUSIONS

The European Union is currently promoting different directives and economic efforts to achieve the goals for moving toward a competitive low-carbon economy, keeping global warming below 2ºC, mostly in electricity and heating production. Nevertheless, cutting greenhouses emissions is being a tedious task, as population and cities maintain a relevant growing and, in parallel, the energy demand is increased more and more.

The promotion of local renewable resources is considered greatly needed; for example, through the integration of shallow geothermal potential, located under our feet everywhere. The Mediterranean countries account for significant characteristics for its exploitation, mainly due to climatic reasons. However, and due to the lack of information and awareness, this renewable resource is still quite untapped.

An assessment of the potential use of the shallow geothermal resource in the city of Murcia (located in the south-east of Spain) is described and discussed in this work. It is based on hydrogeological conditions of the underground and the expected space heating demand of this are. This analysis concludes that that the city, with a population of approximately 350000 inhabitants, has a capacity of fulfilling the required energy demand from 1.6 to 47 times. Due to the rapid rate of urbanization of the city, extracting the heat content stored in the ground will not only fulfil the energy demand requirements, but also will be able to play a positive role in slowing down the urban warming and pollution.

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