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GEOTHERMAL ENERGY: CURRENT STATUS AND FUTURE DEVELOPMENT IN EUROPEAN UNION

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Abstract

Geothermal energy represents an important renewable energy sources in the European continent which could successfully replace conventional energy. In this regard, this article provides an insight into the geothermal resource potential as well as its market and industry in the European Union. The study brings also into focus a comparative analyse between the NREAP predicted values for 2012 and reported data from the Member States. The final part of the paper reviews the support schemes and programmes on geothermal energy.

Keywords: geothermal energy, renewable energy, European Union

1. INTRODUCTION

Geothermal energy represents the thermal energy contained in the earth's inorganic material as sensitive heat. It occurs due to the slow decomposition of radioactive substances in all kinds of rock (MagnumTherm, 2014). Geothermal energy is a renewable energy source which can be used in various purposes: domestic, industrial or for electricity generation. Along with wind, solar or tidal energy, geothermal energy regenerates over time without producing radioactive waste or pollution (Cranganu, 2014). The production of this type of energy does not require fossil fuels and emissions from geothermal power plants are much lower than those of coal-fired power plants or natural gas-fired power plants. However, one of the main problems generated by geothermal energy production is induced seismicity during reservoir stimulation. That is why stimulation programs should be well conceived and presented to the citizens before starting any operation. Top of Form

2. OVERVIEW OF GEOTHERMAL RESOURCE POTENTIAL

Geothermal energy does not depend on weather conditions and could be exploited each day of the year. The potential of this energy source in Europe and worldwide is high (Sigfusson and Uihlein, 2015). However, only a small portion can be used for power production. Although its exploitation is limited to a

ISSN

2067- 2462

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Management Research and Practice
Volume 8 Issue 3 / 2016

few areas of Europe and other continents, it could successfully replace nonrenewable energy sources or supplement renewables that are only available intermittently and have significant and frequent variations in power supply.

Geothermal resources can be grouped into four categories: hydrothermal, geopressured, hot dry rock, and magma. Only one of these categories, namely hydrothermal resources, enjoys widespread use.

The most commonly used criteria for classifying hydrothermal energy is the enthalpy of the geothermal fluid (Abu - Hamatteh et al, 2011). Depending on their temperature (Sigfusson and Uihlein, 2015), these resources are divided into low (below 100ºC), medium (100ºC to 180ºC maximum) and high enthalpy (above 180°C). The first type could only be used for heating and cooling, making it impossible to convert it into electricity.

Geothermal resources of low enthalpy are used for heating and preparing domestic hot water (Feliks et al, 2015) as well as in residential buildings (housing), in industrial annexes, in the service sector (office buildings, schools and education, commercial spaces, hospitals etc), agrozootechnical construction (greenhouses, livestock farms etc). Geothermal resources of medium and high enthalpy are used especially for electricity generation (Mburu and Kinyanjui, 2012).

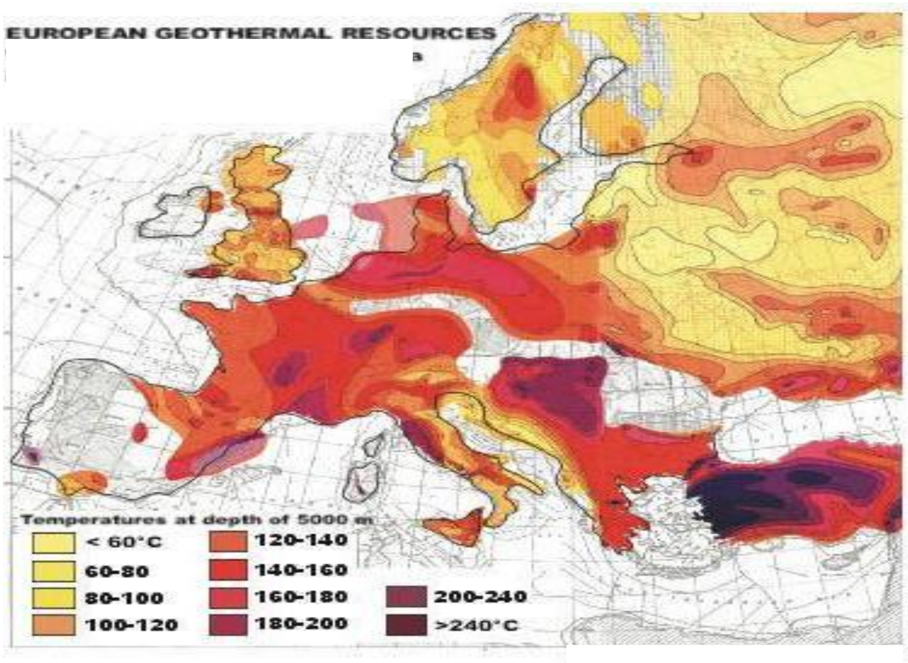


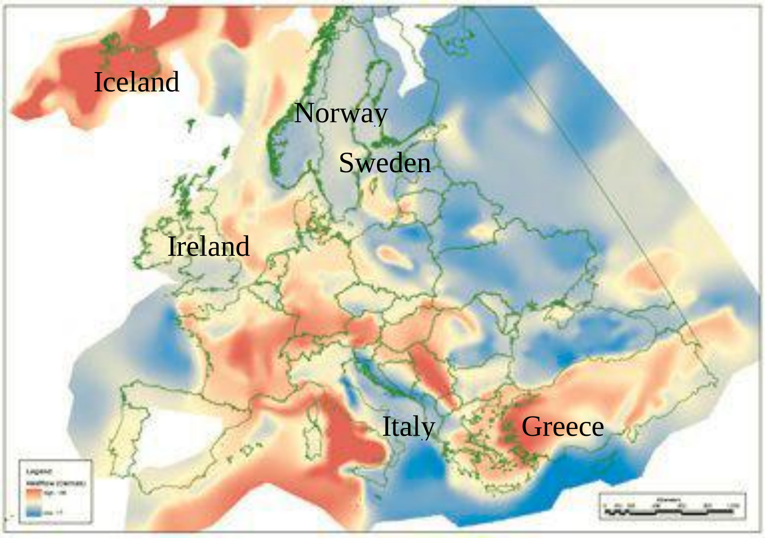
FIGURE 1 - EUROPEAN GEOTHERMAL RESOURCES.
Source: Baumgärtner 2002

Due to thermal and geological conditions, low enthalpy resources prevail in Europe (Kepinska, 2008). They are found in sedimentary formations and located in the Pannonian Basin in Eastern Europe at

ISSN
2067- 2462

mrp.ase.ro
Management Research and Practice
Volume 8 Issue 3 / 2016

temperature of 20-100°C (Hungary, Slovakia, Slovenia, Romania) and the Paris Basin (France). High enthalpy resources, suitable for geothermal power production and related to tectonic and active volcanic areas are located in Italy (Larderello), Greece, Portugal (Azores), Spain (the Canary Islands) and in France (Guadeloupe island in the Eastern Caribbean) (World Energy Council, 2004).



High enthalpy:
Iceland, Italy, Greece, parts of France, Germany and Austria

Low enthalpy:
Ireland, Norway, Sweden, UK, Poland

FIGURE 2 - HEATFLOW MAP OF EUROPE.
Source: European Federation of Geologists, 2008

Another classification of geothermal resources is based on the reservoir equilibrium state (Nicholson, 1993). This category of resources referring to low-temperature and geopressured systems has been discovered in very deep oil wells (Gulf of Mexico, USA) and it is not considered an economically attractive investment (Dickson and Fanelli, 2004).

Currently, a significant geothermal resource (also called petrothermal energy) is represented by hot dry rocks (150-200°C) where cold water transported from the surfaces could be heated (Enhanced Geothermal Systems). Such systems are in operation in Alsace, Soultz-sous-Forets (France) since 1987 and Landau Germany since 2007 (EurOBserv'ER, 2006). Outside the EU, Iceland has also the intention of using unconventional geothermal resources by developing an international Iceland Deep Drilling Project. A similar project located near Basel, Switzerland, was closed in 2006 after causing a 3.4 magnitude earthquake. According to Holm et al. (2010), the Czech Republic, Latvia, Norway, the Netherlands and the United Kingdom also carry out researches funded by government policies in this area.

ISSN
2067- 2462

mrp.ase.ro
Management Research and Practice
Volume 8 Issue 3 / 2016

3. GEOTHERMAL ENERGY MARKET AND INDUSTRY

3.1. Direct use

The different direct-use applications of geothermal energy involve a wide variety of purposes depending on location and temperature (Lund et al, 2011): space heating and cooling, recreation (bathing/swimming), medical treatment (balneotherapy), horticulture (greenhouses and soil heating), industry (zinc extraction, heap leaching for gold recovery, milk pasteurization, etc.) and aquaculture (fish farming).

According to Eurobserv'er (2013), the highest share in the direct use of geothermal energy in 2012 is recorded by Italy (400 MW for balneology, 298 MW for agricultural and industrial purposes and 80.7 MW for heating networks), Hungary (with 60 MW more than in 2011) and France (295 MW for heating networks, 50 MW for balneology and 20 MW for industry and agriculture) followed by Romania, Germany, Slovakia, Poland, Greece and Austria. Latvia ranks last with 0 MW. Figure 3 presents a situation for all types of geothermal energy direct utilisation.

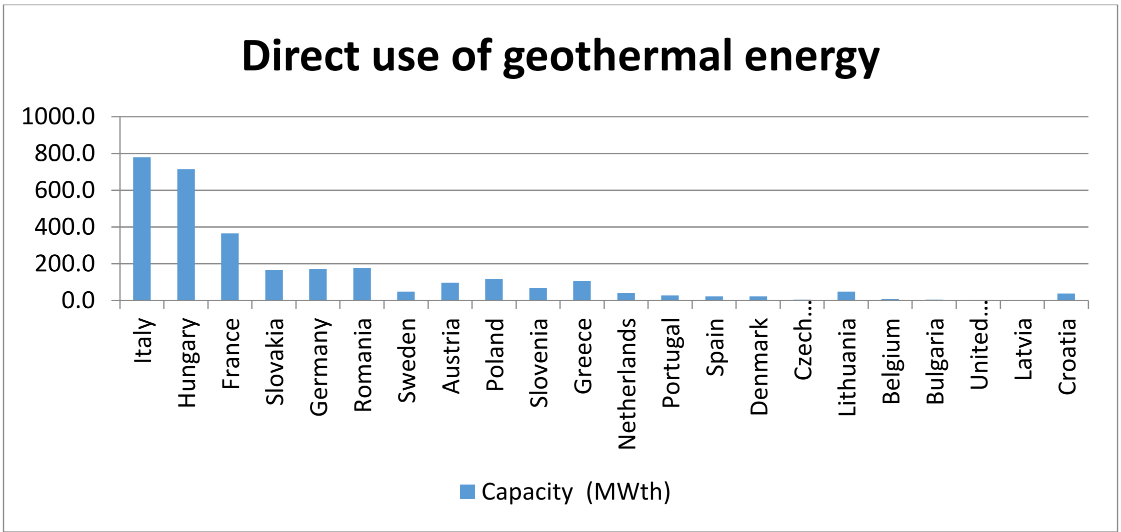


FIGURE 3 - DIRECT USES OF GEOTHERMAL ENERGY (EXCEPT GEOTHERMAL HEAT PUMPS) IN 2012 IN THE EUROPEAN UNION COUNTRIES
Source: processed from Eurobserv'er 2013

In general, direct application of geothermal energy in the European Union countries refers to heating networks (about 50%) and balneology (about 20%). The direct use of geothermal energy has enjoyed significant growth (almost 25%) in 2012 compared to 2011. As regards geothermal district heating, it represents about 0,5% of the total district heating market (Euroheat and Power, 2014).

ISSN
2067- 2462

Management Research and Practice Volume 8 Issue 3 / 2016

In 2011 Sweden was among the world leaders as regards the direct use of geothermal energy (see Table 1). In the same year, Norway and Denmark were among the world leaders in terms of direct geothermal energy use per person (REN21, 2012).

TABLE 1. BEST COUNTRIES IN THE WORLD IN USING GEOTHERMAL ENERGY IN 2011.

Rank	Geothermal direct use	
	Country	Twh
1.	China	21
2.	USA	18.4
3.	Sweden	13.8
4.	Turkey	10.2
5.	Japan	7.1
6.	Iceland	7

Source: REN21, 2012

3.2. Electricity generation

Two categories of geothermal resources can be used for generating electricity: hydrothermal and petrothermal. However, 99,99% geothermal power plants are running on hydrothermal resources (Rybach, 2014).

The geothermal electricity market continues to expand both at European level and the global one, although the net geothermal electricity capacity in EU has recorded a slight growth in 2012 (by 0.5% to 783MW). Italy ranks first (see Table 2), its geothermal capacity being concentrated in the following places: Larderello, Travale-Radicondoli and Monte Amiata.

TABLE 2 - CAPACITY INSTALLED AND NET CAPACITY USABLE OF GEOTHERMAL ELECTRICITY PLANTS IN THE EU IN 2011 AND 2012 (MWE).

Country	2011		2012	
	Capacity installed	Net capacity	Capacity installed	Net capacity
Italy	882.5	728.1	875.5	728.1
Portugal	29.0	25.0	29.0	25.0
France	17.2	17.2	17.2	17.2
Germany	8.0	8.0	12.0	12.0
Austria	1.4	0.7	1.4	0.7
Total EU	938.1	779.0	935.1	783.0

Source: EurOBserv'ER, 2015

In 2013 new power plants began their activity in EU countries: Germany (16 MWe), Romania (0.05 MWe), and Italy (1 MWe). As regards technology, the European market is dominated by dry steam and single flash technology (Sigfusson and Uihlein, 2015).

In 2012, the share of geothermal energy in total electricity generation in European Union was about 0.2% while the share of renewable energy in total electricity generation was about 0.9 (European Geothermal Energy Council, 2014). The EU leader in generating electricity with geothermal resources was Italy, followed by Portugal and France (see Figure 4).

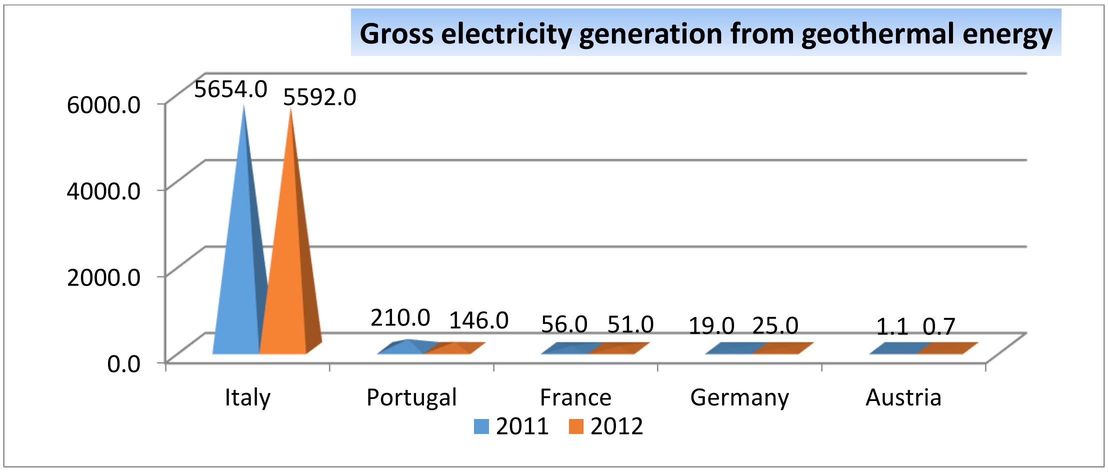


FIGURE 4 - GROSS ELECTRICITY GENERATION FROM GEOTHERMAL ENERGY IN THE EUROPEAN UNION COUNTRIES IN 2011 AND 2012 (GWH).
Source: processed from EurOBserv'ER, 2013

3.3. Geothermal heat pumps

The geothermal heat pump markets (Germany, France, and Austria) recorded decline in 2008 and 2009 due to the economic crisis, but this situation did not affect all European countries. According to EurOBserv'ER (2011), the countries of Northern Europe have experienced significant growth: Sweden 31954 GSHPs installed in 2010 and Finland 8091 GSHPs. Therefore, the EU installed capacity and renewable energy captured by heat pump grew in 2010, the first position being ranked by Sweden, Germany, Finland, France, Austria.

The market continued to decline in the coming years due to dependence on the construction sector which was also decreasing. Germany, Sweden, France and Austria remained the most important markets for ground source heat pumps in 2011 and 2012 (see Table 3). However, according to the experts in the field, the market will grow in the future.

As regards the sales of geothermal heat pumps, the sales volume has decreased in most EU countries in 2014 compared to 2013 (see figure 5):

- Sweden: from 24897 to 23356 units sold.
- Germany: from 21100 to 18500 units sold.
- Finland: from 12341 to 11125 units sold.
- Austria: from 6073 to 5127 units sold.
- France: from 4003 to 3249 units sold.

ISSN
2067- 2462

mrp.ase.ro
Management Research and Practice
Volume 8 Issue 3 / 2016

- Netherlands: from 3052 to 2510 units sold, etc.

TABLE 3 - TOTAL NUMBER OF HEAT PUMPS IN OPERATION IN 2011 AND 2012 IN THE EUROPEAN UNION AND ASSOCIATED RENEWABLE ENERGY PRODUCTION (KTOE).

Country	2011		Country	2012	
	Geothermal heat pumps	Renewable energy captured (ktoe)		Geothermal heat pumps	Renewable energy captured (ktoe)
Italy	9300	53	Italy	10300	61
France	114815	150	France	123045	161
Sweden	218538	598	Sweden	243058	442
Finland	60631	104	Finland	72420	140
Germany	244000	319	Germany	264800	344
Denmark	34216	45	Denmark	36335	48
Netherlands	36048	87	Spain	6011	20
Spain	5500	18	Netherlands	41253	98
Bulgaria	3146	1	Bulgaria	3749	2
Austria	101058	104	Austria	113633	114
Portugal	652	1	Portugal	691	1
United Kingdom	15366	20	United Kingdom	17760	23
Estonia	4755	9	Estonia	5955	11
Czech Republic	15711	21	Czech Republic	18240	24
Poland	15500	31	Poland	20621	41
Belgium	2628	3	Belgium	4046	5
Slovenia	4194	23	Slovenia	4669	25
Slovakia	1974	4	Slovakia	2221	6
Ireland	1824	2	Ireland	2303	3
Hungary	756	1	Hungary	1049	1
Lithuania	1173	2	Lithuania	1623	2
Romania	970	1	Romania	1250	1
Luxembourg	106	0	Luxembourg	106	0
Total EU	892861	1398	Total EU	995138	1574

Source: EurOBserv'er, 2013

Currently, there are many geothermal heat pump manufacturers operating in the European countries: Sweden, Germany, Austria, France and Italy (see Table 4). The different types of manufacturing actors have made significant investments in recent years in order to improve their productivity: general heating companies (Bosch Thermotechnik - Sweden, Viessmann and Vaillant - Germany, etc.), electric heating companies (Nibe Energy Systems - Sweden, Stiebel Eltron - Germany, Ansaldo/Tosi - Italy etc). When talking about total capacity, Ansaldo/Tosi is the world's fourth-ranking producer of turbines after three companies from Japan. The third market player refers to manufacturing companies of heat pump systems (Alpha-InnoTec and Waterkotte - Germany, Ochsner - Austria) (EurOBserv'ER, 2011; REN21, 2012).

ISSN
2067- 2462

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Management Research and Practice
Volume 8 Issue 3 / 2016

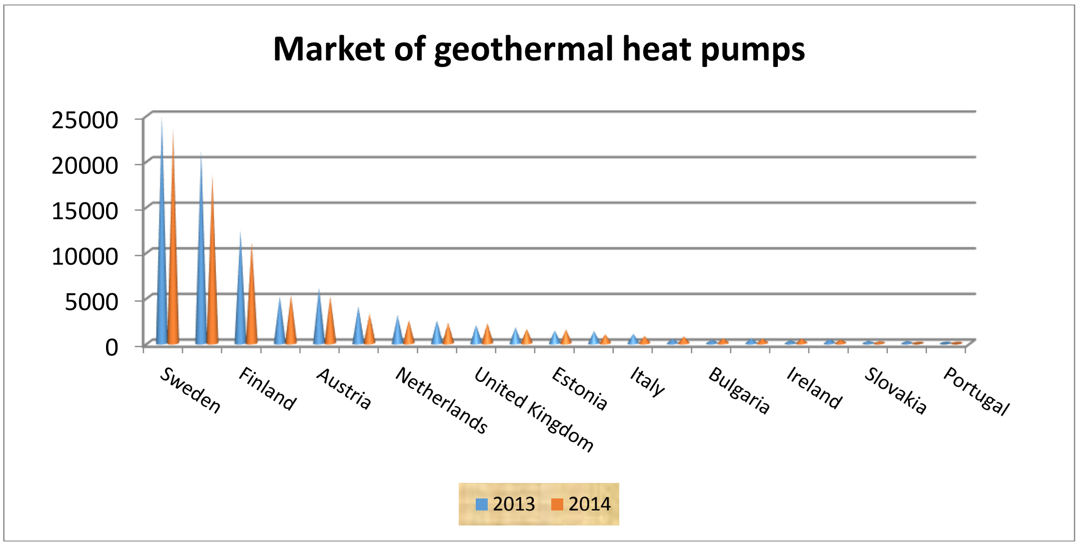

FIGURE 5 - MARKET OF GEOTHERMAL HEAT PUMPS IN 2013 AND 2014 (NUMBER OF UNITS SOLD);
Source: processed from EurOBserv'ER, 2015

TABLE 4 - MAJOR GEOTHERMAL HEAT PUMP MANUFACTURERS IN THE EUROPEAN UNION IN 2010 (N.A. - NOT AVAILABLE).

Company	Country	Capacity (in kW)	Turnover 2010 (in M€)	Employees 2010
Nibe Energy Systems (Groupe Nibe)	Sweden	5 to 60 kW	700	1 974
Buderus (Bosch Thermotechnik)	Germany	6 – 91,2 kW	n.a.	n.a.
IVT Industrier (Bosch Thermotechnik)	Sweden	6 – 70 kW	n.a.	n.a.
Thermia Värme AB (Groupe Danfoss)	Sweden	4 – 45 kW	n.a.	245
Ochsner Wärmepumpen	Austria	2 – 1 000 kW	n.a.	n.a.
Viessmann	Germany	1,5 – 2 000 kW	1 700	9 400
Alpha-InnoTec (Groupe Schulthess)	Germany	6 – 160 kW	n.a.	380
Stiebel Eltron	Germany	4 – 67 kW	450	3 000
Waterkotte	Germany	5 – 1 000 kW	n.a.	n.a.
Thermaties Technologies, marque Sofath (Groupe BDR Thermea)	France	2,3 – 31 kW	n.a.	n.a.
Vaillant	Germany	1,5 to 64 kW	2 300	12 400

Source: Source: EurOBserv'ER, 2011

3.4. Current and future trends

Compared to other renewable energy sources, geothermal projects do not receive substantial financial support from the European Union. Only 29.4 million euros of 1.7 billion euros allocated for renewable energy projects had been granted to geothermal projects until 2012. Although the activities of the sector are diverse (exploration, drilling, engineering, to construction and plant operation), the geothermal industry is quite low, with few companies operating in Europe (Sigfusson and Uihlein, 2015).

National Renewable Energy Action Plans (NREAP) explains how each EU country will reach the mandatory targets of 20 % share of energy from renewable sources in overall consumption until 2020. In

ISSN
2067- 2462

this regard, EU member states made considerable progress. Table 5 displays that in 2012 shallow geothermal and geothermal power capacity exceeded the NREAP target.

TABLE 5: GEOTHERMAL POWER CAPACITY AND HEAT PRODUCTION IN THE EU-28 IN 2012 AND NREAP TARGETS IN 2012 AND 2020.

Type	Reported Values 2012	NREAP target 2012	NREAP target 2020
Shallow geothermal (mainly GSHP) GWhth	27080	18946	49340
Deep geothermal resources (direct heat) GWhth	9404	10440	30589
Geothermal power capacity MWe	876	787	1612

Source: Antics et al, 2013

In Figures 6, 7, and 8 a comparative analysis between reported data from EU countries and the NREAP predicted values for 2012 and 2020 is presented.

As regards geothermal heat production with ground source heat pumps, the EU countries exceeding the NREAP mandatory targets for 2012 were Austria (1440 GWhth compared to 128 GWhth NREAP target), Romania (32 GWhth compared to 2 GWhth NREAP target) and Sweden (15200 GWhth compared to 4431 GWhth NREAP target).

On the opposite pole, Denmark (695 GWhth compared to 1570 GWhth NREAP target), France (2775 GWhth compared to 3954 GWhth NREAP target), Italy (472 GWhth compared to 779 GWhth NREAP target), Netherlands (880 GWhth compared to 1372 GWhth NREAP target), Slovenia (96 GWhth compared to 151 GWhth NREAP target) and UK (500 GWhth compared to 2024 GWhth NREAP target) has placed at a considerable distance from the target.

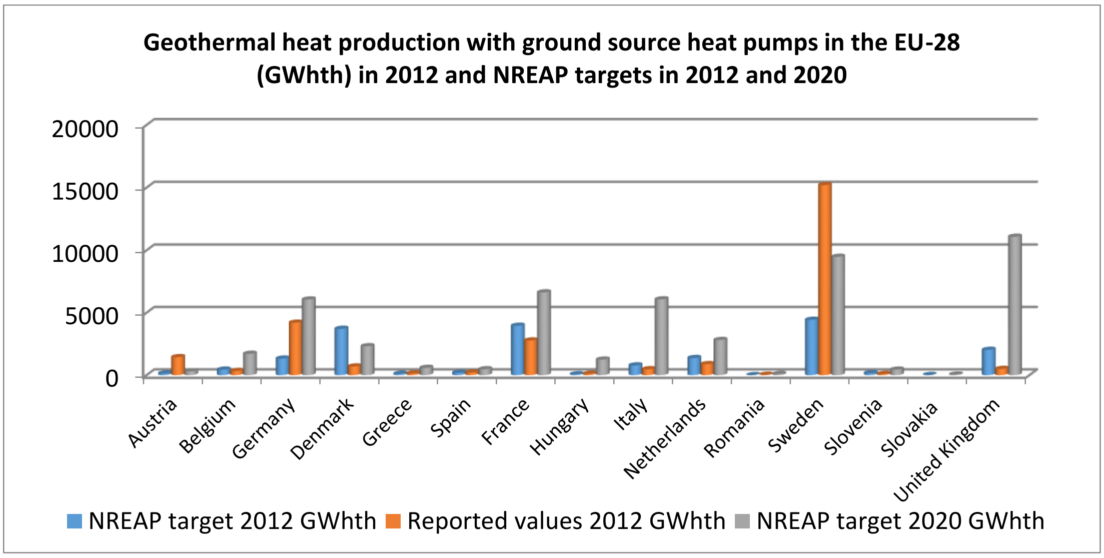

FIGURE 6 - GEOTHERMAL HEAT PRODUCTION WITH GROUND SOURCE HEAT PUMPS IN THE EU-28 (GWHTH) IN 2012 AND NREAP TARGETS IN 2012 AND 2020.
Source: processed from Antics et al, 2013

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For deep geothermal heat production, the difference between NREAP target for 2012 and reported values for EU-28 countries was 958 due to the reduced rate of new installations. The best results have been recorded by Greece (504 GWhth compared to 244 GWhth NREAP target), Hungary (2849 GWhth compared to 1396 GWhth NREAP target) and Lithuania (93 GWhth compared to 35 GWhth NREAP target) while Belgium (18 GWhth compared to 41 GWhth NREAP target) and Netherlands (202 GWhth compared to 872 GWhth NREAP target) are far away from their 2012 targets.

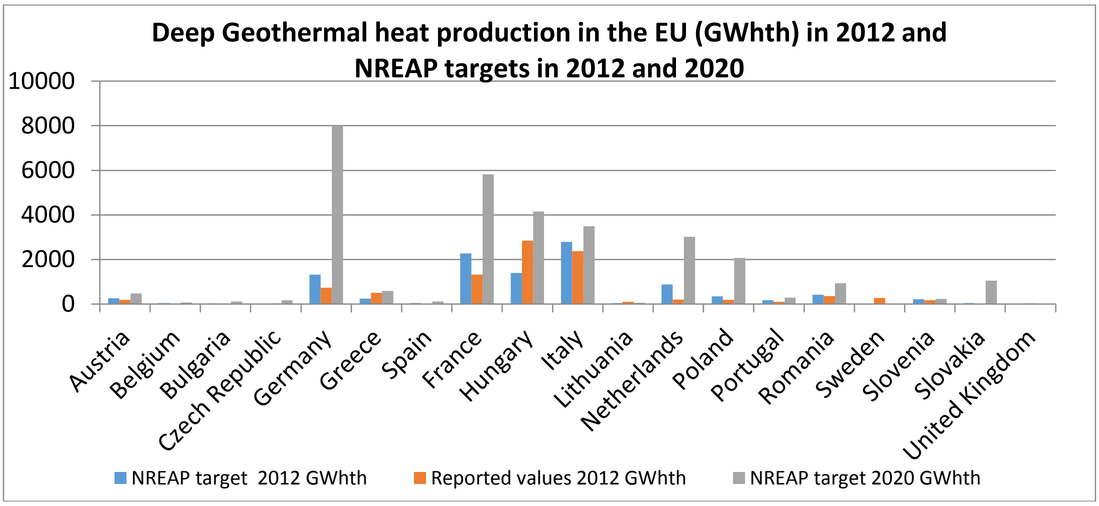

FIGURE 7 - DEEP GEOTHERMAL HEAT PRODUCTION IN THE EU (GWHTH) IN 2012 AND NREAP TARGETS IN 2012 AND 2020. INCLUDES DISTRICT HEATING, INDUSTRY AND AGRICULTURE, BALNEOLOGY AND OTHER.
Source: processed from Antics et al, 2013

In terms of installed geothermal power generation capacity, the NREAP targets of 881 MW has been exceeded in 2012 (934 MW) by the EU countries. Italy ranks first (875.5 MW compared to 787 MW NREAP target), while France (17 MW compared to 37 MW NREAP target) and Germany (11.9 MW compared to 27 MW NREAP target) are far from fulfilling the targets.

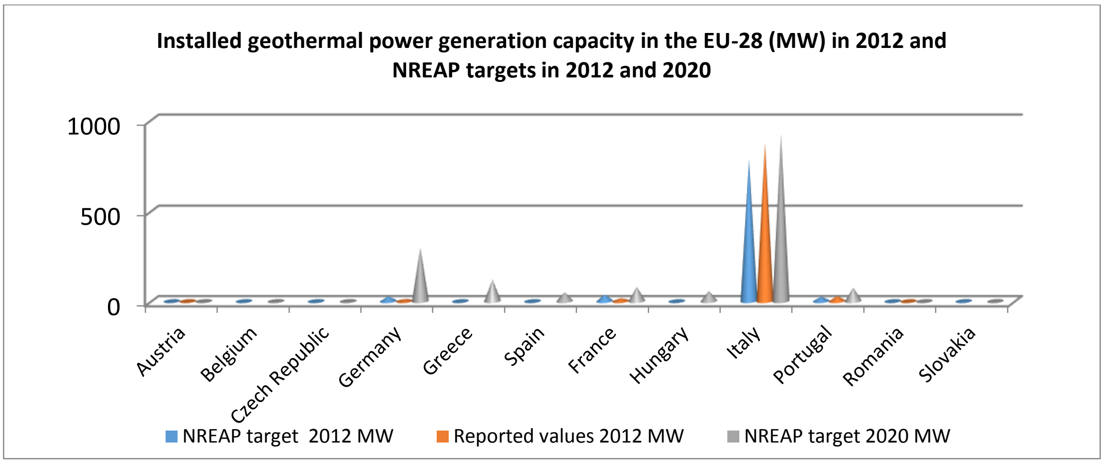

FIGURE 8 - INSTALLED GEOTHERMAL POWER GENERATION CAPACITY IN THE EU-28 (MW) IN 2012 AND NREAP TARGETS IN 2012 AND 2020.
Source: processed from Antics et al, 2013

Management Research and Practice
Volume 8 Issue 3 / 2016
ISSN 2067- 2462

4. POLICY SUPPORT SCHEMES AND PROGRAMS

Without a real support, the development of renewable energy sources could become a problem (Păceșilă, 2013; Păceșilă et al, 2016). That is why there are different instruments of supporting the development of renewable energies in modern societies (Zamfir, 2013; Zamfir, 2014). In this regard, many EU countries developed state programs providing support for geothermal energy investments (Holm et al, 2010; Sigfusson and Uihlein, 2015) in the form of:

- feed-in-tariffs (Austria, Denmark, France, Germany, Greece, Hungary, for small renewable plants in Italy, Portugal, Slovenia, Slovakia, Spain, Czech Republic, Portugal - only Azores). In 2011 these schemes have been considered the most important form of supporting renewable energies.
- feed in premiums (Estonia, the Netherlands, Slovenia, Italy), especially used for electricity generation (Angelone and Labini, 2014)
- tax exemption, (Czech Republic, Renewable Energy Tax Excise in Poland)
- tradable green certificates (Belgium (Flanders), Romania, Great Britain). According to Mir-Atrigues and del Rio (2014) only six countries from European Union have used this support scheme in 2014, but only three of them for geothermal sector.
- financial incentive schemes (market incentive Program in Germany, preferential Loans for Energy Saving Measures in France)
- government subsidies (combined heat and power law in Austria).

5. CONCLUSIONS

This paper gives an overview of geothermal resource potential and provides an analysis of its current trends in market and industry. Moreover, the study explains the purposes and benefits of this renewable source of energy and highlights the diversity of the geothermal resource nature.

Compared to conventional energy sources, geothermal energy provides benefits in terms of cost, reliability and environmental protection. Starting with the development of new technologies, it can contribute significantly to electricity generation in many countries having significant geothermal resources. Moreover, along with other renewable energy sources, geothermal energy could help eliminate conventional energy which presents risks for human health and environment.

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