Technological Forecasting & Social Change 80 (2013) 148–160

Contents lists available at SciVerse ScienceDirect

Technological Forecasting & Social Change

Telescopic drilling view for future: A geothermal foresight study in Turkey

Melih Soner Celiktas *, Gunnur Kocar

Solar Energy Institute, Ege University, 35100 Bornova-Izmir, Turkey

ARTICLE INFO

Article history:
Received 20 February 2012
Received in revised form 9 July 2012
Accepted 11 July 2012
Available online 29 July 2012

Keywords:
Geothermal energy
Delphi
Technology foresight
Hot dry rock
Technology
R&D

ABSTRACT

This paper analyzes Turkey's geothermal energy future perspective and power generation strategy with a view to explaining Delphi approach to geothermal energy development. In this study, the two round Delphi survey was conducted to experts to determine and measure the expectations of the sector representatives through online surveys where a total of 32 experts responded from 14 different locations. The majority of the Delphi survey respondents were from different universities (59.4%), industries (25%) and governmental organizations (15.6%). The article discusses expert sights on geothermal energy technologies and also includes bibliometrical approaches in order to assess the potentials of emerging and existing technologies. The results indicated that Turkey's geothermal power installed capacity is expected to reach 500 MW by around 2021 subsequent to the implementation of "Renovation of Standards and Regulations" and "Fiscal Approaches".

1. Introduction

For centuries geothermal springs have been used for bathing, healing and cooking. Only in the early 20th century did people start to consider the heat from inside the Earth as a practical source of energy with huge potential. Geothermal energy is used to produce electricity on a significant scale, as well as for direct use applications like space heating, greenhouses and aquaculture. The exploitable geothermal resources are found throughout the world and are being utilized in at least 78 countries. Electricity is produced from geothermal in 24 countries spread over all continents. Six countries obtain 10–30% of their electricity from geothermal [1].

Although geothermal energy is well positioned within the renewables current growth is only steady but rather slow. While wind and solar PV show exponential growth, geothermal power develops rather linearly, so far provided by hydrothermal resources, located in special geological settings [2].

The thermal energy used is 121,696 GW h/year, about a 60% increase over 2005, growing at a compound rate of 9.9% annually. The distribution of thermal energy used by category is approximately 49% for ground-source heat pumps, 24.9% for bathing and swimming, 14.4% for space heating, 5.3% for greenhouses and open ground heating, 2.7% for industrial process heating, 2.6% for aquaculture pond and raceway heating, 0.4% for agricultural drying, 0.5% for snow melting and cooling, and 0.2% for other uses. Energy savings amounted to 46.2 million tonnes of equivalent oil annually, preventing 46.6 million tonnes of carbon and 148.2 million tonnes of CO_2 being release to the atmosphere which includes savings in geothermal heat pump cooling [3].

According to International Geothermal Association [1], the growth of geothermal utilization for power generation has averaged roughly 5.5% per year over the last 30 years, and the geothermal installed capacity in the world has been increased by about 1000 MWe every 5 years. The geothermal power plant installed capacity in the world is expected to reach 10,715 MW at the end of year 2010. Another expectation is the total installed capacity of geothermal power plants to increase from the value of 10.7 GW in 2010 to about 160 GW by 2050.

* Corresponding author. Tel.: +90 232 311 12 29; fax: +90 232 388 60 27.
E-mail addresses: soner.celiktas@ege.edu.tr (M.S. Celiktas), gunnur.kocar@ege.edu.tr (G. Kocar).

0040-1625/$ – see front matter
doi:10.1016/j.techfore.2012.07.004

Geothermal energy can play a significant role in developing countries [4]. The El Salvador 25% of electricity comes from geothermal steam [5] in the Philippines 17% [6], 14% in Costa Rica, 11% in Nicaragua [7], and 8% in Kenya [8].

Turkey is located on the Alpine–Himalayan orogenic belt, which has high geothermal potential. The first geothermal research and investigations in Turkey were started by The Mineral Research & Exploration Institute of Turkey (MTA) in the 1960s.

From this time, 186 geothermal fields have been discovered by MTA, where 95% of them are low-medium enthalpy fields, which are suitable mostly for direct-use applications. With the existing geothermal wells and spring discharge water, the proven geothermal capacity calculated by MTA is approximately 4000 MWt. Geothermal resources of the country are wide spread but the favorable reserve for heating and generating electricity is limited and even this limited reserve has not yet been used [9]. The geothermal potential is estimated at 31,500 MWt (5,000,000 residences equivalence). This figure means also that 30% of the total residences in Turkey could be heated by geothermal energy. Turkey is the 7th richest country in the world in geothermal potential [10].

Based on these data regarding the potential of geothermal energy in Turkey, a necessity has arisen for systematical evaluation of the field and Delphi approach was the most appropriate tool due to not just its benefits to aggregate group opinion of selected experts [11–14] but also a structural procedure for anonymous group discussion [15–17] in order to deal with various aspects of the geothermal energy and technology demand.

Therefore, the aim of this study was to identify the most important geothermal technologies and research priorities likely to be demanded by the Turkish energy industry and contribute to the achievement of strategic goals in the geothermal energy sub sectors vital for the national wealth creation, environmental effect and improvement of the quality and security of life. The specific geothermal energy technology statements and the features of societal expectations are synthesized by respondents. Furthermore, the intention of the study was to describe trends in the development of geothermal energy technologies and to bring out research and development needs in order to reach the priorities identified in the geothermal energy technologies. The ultimate objective was to provide advice on geothermal energy R&D priorities, based on sound expert knowledge with a time horizon of 2050.

In the scope of this study, bibliometric study was conducted in order to investigate the literature, one-to-one meetings were organized with the experts yielding the data for SWOT (Strengths, Weaknesses, Opportunities and Threats) analysis and finally the two-rounded Delphi questionnaire was designed for eliciting the geothermal energy technologies in Turkey projected for the year 2050.

2. Methodology

Qualitative (e.g. expert interviews, literature reviews, expert workshops) and quantitative methods (e.g. standardized surveys, patent analysis) are nowadays to be regarded as complementary rather than competing methods for gaining insights after years of debate [18]. Integrating research methods has proven to be useful in other studies as well [19–22].

In this study, a bibliometric analysis [23] was conducted to find out the development trends of the scientific studies in the field of geothermal energies in Turkey. Additionally, a constructive SWOT analysis [24] has been carried out with the data gathered via face to face interviews by eliciting the opinions of previously identified academicians, policy makers and politicians, industrialists and representatives of civil society organizations, operating on renewable energies. The core of this study was a Turkey-wide Delphi geothermal energy technology survey with two rounds of expert consultations. The rationale of the Delphi method is based on expert judgment, reflection and iteration in order to produce consensus and accurate forecast when direct information for trend analysis and prediction is not available. The Delphi method is an appropriate approach not only to gain a consensual-based technological foresight, but also to integrate technological, social and economic perspectives of sustainable development [25–28]. The method is used for gathering data from respondents within their domain of expertise (Fig. 1). The technique is designed as a group communication process which aims to achieve a convergence of opinion on a specific real-world issue [29]. The Delphi methodology belongs to the subjective and intuitive methods of foresight. Issues are assessed, on which only uncertain and incomplete knowledge exists. It is based on a structured survey of expert groups and makes use of the implicit knowledge of participants. Hence, the Delphi method has both quantitative and qualitative dimensions. There is not a single method, but all agree [30–32] that a Delphi study requires an expert survey in at least two or more rounds. Starting from the second round, a feedback is given about the results of previous rounds: the same experts assess the same matters once more, influenced by the opinions of the other experts. The methodology facilitates a relatively strongly structured group communication process, revealing conflicting as well as consensus areas. Delphi-based foresight exercises, therefore, were used repeatedly and increasingly in the context of policymaking, building on their capacity to facilitate an alignment of actors' expectations through interactions [33].

In this study, Delphi statements were developed by using the results obtained from the bibliometric and SWOT analyses. The survey was thus able to give a comprehensive view of the future of geothermal energy from basic research to social impact and from subjective and normative points of view to objective and extrapolative perspectives. The results of the impacts were subsequently weighted using the weights attributed to a particular level. The particular expertise categories and corresponding weight are calculated as (High (expert) responses $*(2)+$ Knowledgeable responses $*(1)+$ Familiar responses $*(0)+$ Unfamiliar responses $*(-1))$ / total responses on impacts (non-responses not included). Finally, overall impact was calculated as overall impact index $1/4[(\text{index of wealth creation impacts})^2+(\text{index of environmental impacts})^2+(\text{index of life quality impacts})^2+(\text{index of energy supply safety impacts})^2]^{0.5}$.

This work is a part of a holistic foresight analysis of renewable energies in Turkey and Delphi studies. In bibliometric study [23], a total of 12,197 publications were processed article by article and as a result 1555 papers were found to focus on renewable energies between the years 1980 and 2008. For each paper, the distributions of publications over years, the authors, the authors'