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Modeling of Diffusion of Geothermal Energy Technologies in Iran: System Dynamics Approach

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Keywords

Geothermal energy,
Renewable energy,
System dynamics.

Abstract

Utilization of renewable energy is one of the most important factors which can have strategic role for the energy import dependence countries. Among all types of renewable energy sources, geothermal energy is one of the sources with high potential of utilization in our case study, Iran. However, utilization output of this source is not noticeable that makes the role of adaptation policies important. This research is focused on the conceptualize modeling of geothermal utilization in the case study based on the system dynamics approach. The model shows the adaptation of geothermal energy to show the effects of important adoption variables on the system.

1. Introduction

Energy demand has increased dramatically in the recent decades. Fossil fuels and nuclear power have dominate role in the world energy system. This bring challenges of energy supply, environmental effects, security issues, etc. [1]. For the both developing and developed societies. To response the challenges governments have provided different strategies. Diffusion of renewable energy resources (RER) is an important strategy, in particular after the first energy crisis in the world [2]. Free, renewable, eco-friendly, and clean are the important advantages of RERs compared with other fuels. However, the diffusion and adoption of RE utilization has faced with challenges, in particular for fossil fuels exporters. While the oil, gas and coal exporters have limit fossil sources, the economy of some of them like Iran has high dependency on the exports of these fuels [3]. However, the energy domestic consumption growth in Iran has caused that the government starts to think about the utilization of renewables. Due to the researches Iran has great potentials in geothermal energy so this renewable energy is a great supply for being a substitution of fossil fuels in Iran.

In this paper, first the importance of geothermal energy and its utilizations are discussed. After that, it sources in Iran is reviewed and then its adaptation in Iran is modelled by system dynamic approach.

2. Literature Review

2.1. Energy Importance in Communities

Technology development and expansion of industries lead communities to be dependent to the energy more and more. On the other hand, due to the growing population in the world, the important role of energy in the world today and in the future has been increased [4]. By increasing population growth (especially in developing countries) to reach the required amount of energy resources is getting more difficult. The rate of growth in energy demand is very fast. It is expected that demand will continue to increase.

Today, the growth of industrial energy consumption in modern societies, in addition to the risk of rapid completion of fossil fuels, has faced the world with irreversible and threatening environmental changes. Therefore, plans and policies assigned a special role to renewable energy sources in line with international global sustainable development [5].

2.2. Important of Geothermal Energy Definition

Renewable energy sources at the economic scale are categorized in five sources: solar energy, wind, hydropower, geothermal energy, and biomass. One of the main renewables is geothermal energy. Geothermal energy means the energy within the Earth's origin. This energy originates from the inner Earth in the form of sensible heat water in the rocks and in holes in rocks in the Earth's crust. During centuries, the internal produced heat was reserved in the

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ground and held there [6]. This has provided an important energy source and is now considered as an unlimited energy.

Areas with hot springs are the first areas where geothermal energy is utilized and developed. Currently, almost all electricity from geothermal energy comes from such places. In some areas, temperatures of rocks may reach 300 degrees Celsius and provide enormous quantities of geothermal energy. Therefore, geothermal energy can be formed in places where geological processes have allowed the magma raise near the surface of lava flow. Magma could be close to the surface in the region:

1) Junction of the continental and oceanic plates (subduction), such as fire ring around the Pacific ocean
2) Development centers, where the continental plates away from each other, such as Iceland and the rift valley in Africa
3) The hot spots, where magma is sent up from the mantle to the Earth's surface and constantly forma row of volcanoes.

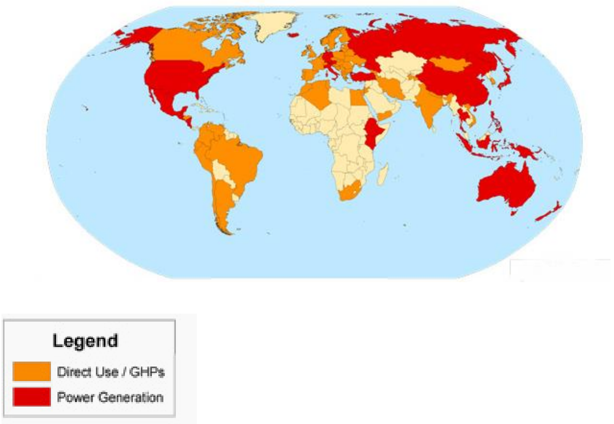

Figure 1. Potential of geothermal [7]

The potential of geothermal around the globe is shown in Figure 1. Table 1 shows the installed capacity of geothermal in the world from 1955 to 2020 and produced energy from 1995 to 2015. According to the table, the installed capacity of geothermal energy is increasing rapidly in the world. By the end of 2010, installed geothermal capacity in the world was about 10/8 Gigawatts while it is expected to reach 21 Gigawatts by the end of 2020 [7]. The most active and increase in power generation geothermal power plant is in Iceland [8].

Table 1. The installed capacity from 1950 to 2015 and forecasts to the end of 2020 [7]

Year	Installed Capacity (MWe)	Produced Energy (GWh)
1980	2110	-
1985	4764	-
1990	5834	-
1995	6832	38035
2000	7972	49261
2005	8933	55709
2010	10897	67246
2015	12635	73549
2020	21443	-

In Figure 2, the installed capacity of geothermal energy within leading countries is shown.

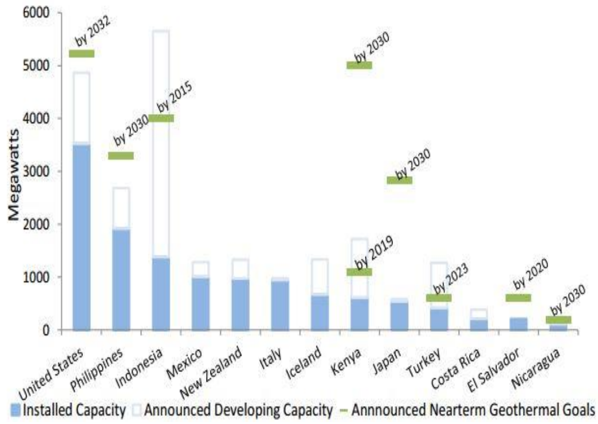

Figure 2. Installed capacity and plans in the top countries [9]

Iceland has a high potential for geothermal energy utilization in which has a share of 26% of total electricity generation in Iceland in 2015. Indeed, around 87% of water heating production is from geothermal energy in 2015. This country has aimed of using 0% of fossil fuels in future and for this goal they are trying to develop their facilities in order to advance this progress. Now in Iceland geothermal energies are used for (54%) heating urban and apartments, (28%) electricity, (4%) pools and tourist based centers (4%) ice melting projects, (2%) industrial uses, (5%) fish tanks, (3%) agricultural uses. Based on statistics Iceland has the power of electricity generation of 2421 Mwatt in four major powerhouses [9].

2.3. Evaluation of Geothermal Energy Potential Geothermal the Case Study

Iran has economics potential of geothermal utilization (Figure 3). Despite the high potential og geothermal energy, the utilization achievements are not noticeable [10].

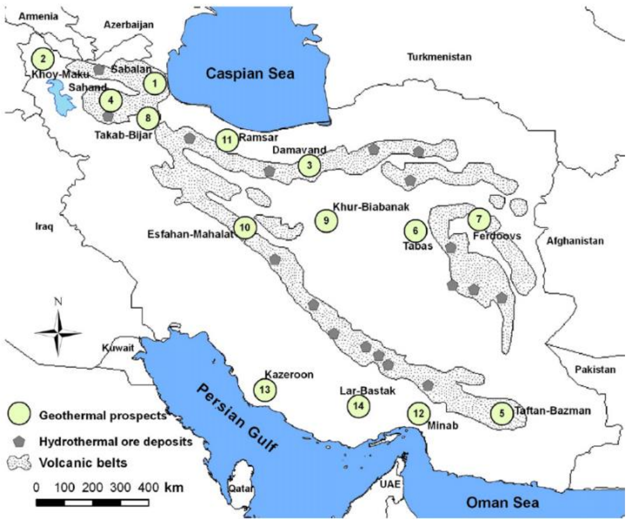

Figure 3. Geothermal potential in Iran [10]

3. Research Method and Analysis

This paper is an applied research from research purpose and is a descriptive-causal one from the method. Adaptation for using renewable energy instead of fossil fuels is one of the dilemmas that policy makers should consider, according to the long history of using such fuels there are several parameters and even barriers that can affect this adaptation. This paper tries to recognize these parameters and understand how these parameters can affect this adaptation. The present modelling has been done bye system dynamic (SD) approach [11].

SD is a quantitative modeling tool that uses systems thinking to analyze the impact of feedback loops in complex, dynamic systems [12]. This paper uses SD to model and then simulate the dynamics of geothermal diffusion. The system dynamic model develop a simulation by which the decision makers can analyze better and have a better view for the future of policies they are supposed to take, since these systems are complex system dynamic helps making them easier for understanding . Therefore, this approach differs from those that focus on short period therefore considers factors that can affect on the adopters' ideas in a long term.

We tried to model the adaptation of geothermal energy according to high potential of this source in Iran. First, we identify the elements that can effect this energy and by identifying the boundary of this system, the model has been articulated this model is designed by the means of system dynamics and further studies could be needed in this category.

3.1. Analysis

In this model, geothermal utilization has been considered as the source and means the rate of utilizing the geothermal energy for heating pumps. There are two currents entering this source including the new users and current users and one current exiting this source which is quitters. The parameters considered in this model are innovation and invention, which means the new products which can be used in this industry or the new ones which can facilitate its use. Product attractiveness means the power this product have for attracting the customer to use this power instead of other sources. Word of mouth means what people says about this product and what they've said spread among others. Product features are the main features this energy source have that differs it from other sources. Product development capability means its capacity for development in means and features and structure. By the term attractiveness from availability of complimentary products means how these products can support geothermal energy for enhancing this industry. Cost means the money needed for installing the related instruments and its usage and it has been divided into two main parts installation cost and maintenance cost means budget needed keeping these installed instruments workable. Repairing units are the units or shop in which the related technical problems of these facilities can be solved and plentitude of the repairing units are the number of these units. First, the policy structure model is stated (Figure 3).

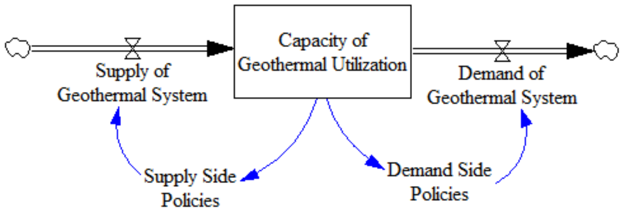

Figure 3. Policy structure of the model

System dynamics is designed to be a practical tool that policy makers can use to help them solve the pressing problems they confront in their organizations. (sterman) Throughout this rigorous tool we can show how mathematical concepts in the sciences or engineering can be applied to the messy world of the policy maker.

The way policies affect the system is shown by the policy structure model. This model, illustrates the dynamical effects of applied policies to the main particles of the system. The ultimate goal of a dynamic model is to understand the effects of different approaches toward a specific issue which can make some changes to the main.

In this system, "Capacity of Geothermal Utilization" is known as the main stock and we assume that two policies can affect the main stock. These policies are demand and supply policies. These two policies will apply to the system and will create the capacity of utilization. Clearly these policies will have some output results. These results will be analyzed and studied by detail, in the following sections specifically with stock and flow model. Based on policy structure model and the known micro policies which can affect the system the following causal model is developed (Figure 4).

After that, the stock flow diagram will be developd as depicted by Figure 5.

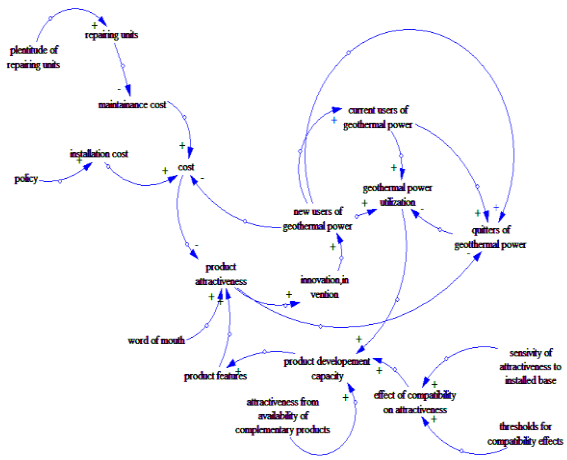

Figure 4. The causal loop diagram of the model

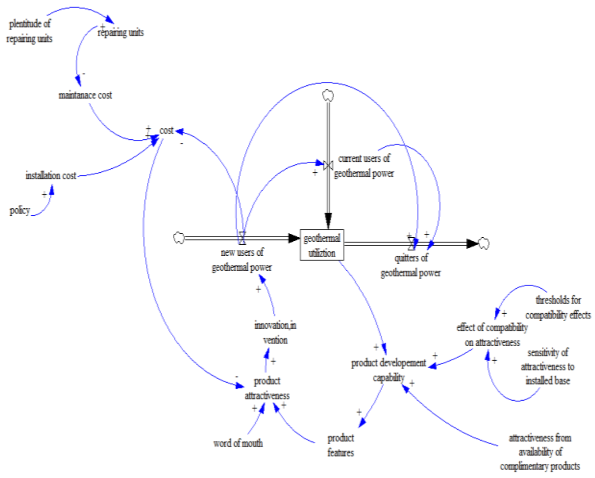

Figure 5. Casual loop diagram of the model

4. Conclusions

Based on the model as the policies for encouraging the renewable energy by the governments develop, the rate of the attractiveness of geothermal energy will increase. On the other hand, the results illustrate that as the frequency of the maintenance units increase and the total costs decrease, the utilization of such energy will increase.

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