Renewable Energy 79 (2015) 140–149

Contents lists available at ScienceDirect

Renewable Energy

journal homepage: www.elsevier.com/locate/renene

Evaluation of potential fossil fuel conservation by the renewable heat obligation in Korea

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A R T I C L E I N F O

Article history:
Received 19 March 2014
Accepted 4 October 2014
Available online 23 October 2014

Keywords:
Renewable heat obligation
Fossil fuel conservation
Ground-source heat pump
Unit cost
Energy efficiency obligation

A B S T R A C T

The developers of new buildings in South Korea are going to have a renewable heat obligation to meet some proportion of heating & cooling demand with renewable heat sources such as ground-source heat pumps, biomass wood pellet boilers and solar water heating panels from 2016. This study evaluated the potential fossil fuel conservation by implementation of the renewable heat obligation in Korea, based energy demand patterns of the target buildings and cost and performance of the renewable heat sources. Results show that most of the developers of new buildings will adopt a ground-source heat pump because of long lifespan and low variable cost under the current electricity tariff. Ground-source heat pumps consume electric power generated from fossil fuel as the major source for operation while solar and biomass do not. This implies that under the current plan the percentage of potential decrease of fossil fuel use will be much lower than the percentage of heating & cooling demand met by renewable heat sources. Reclassifying ground-source heat pumps as highly energy efficient conventional heat sources rather than renewable heat sources, as the International Energy Agency does, would correct this undesired outcome and is suggested as a policy correction.

1. Introduction

It has been about two centuries since fossil fuel was used as the major energy source of the world. Fossil fuel such as oil, coal, and natural gas are about 80% of total primary energy source in the world of today [1]. This enormous and accumulated fossil fuel use is now causing both emission problem like global warming and international conflicts related to energy security. So many countries have made efforts to make proper policies for promotion of renewable energy use for fossil fuel conservation. For the power sector, there are many kinds of useful policy instruments such as feed-in-tariff (FIT), renewable portfolio standard (RPS), and capital subsidies in many countries already. But for the heat sector, many countries are still in the planning stage although the estimated portion of heat in the final energy consumption is higher than that of electricity and transportation [2]. Two representative policy instruments which are currently in action for promotion of renewable heat use are renewable heat incentive (RHI) in England and renewable heat obligation (RHO) in Germany.

Korea has also discussed policy instruments for renewable heat use. Such policy instruments are very beneficial to Korea because Korea has enormous heating & cooling energy demand caused by existence of clear four seasons, and because about 96% of primary energy use in Korea depends on import. Currently, Korea is going to implement RHO from 2016. Since there are few previous studies about policy instruments for renewable heat in Korea, it is worth doing an analysis of the upcoming RHO in Korea to evaluate its fossil fuel conservation effectiveness and potential problems. There are some previous studies about proper policy instruments for promotion of renewable heat done by European researchers [3–5]. These studies explained various kinds of policy instruments and their mechanism, pros and cons, and selection criteria. But most of the previous studies about renewable energy policy instruments are based on the macroscopic analysis, which uses qualitative instrument comparison tables and national-level statistical data such as market trend, governmental budget, annual emission, and others. There are not many analysis based on the microscopic analysis, which uses technical & economic data of the individual energy supply & demand system. Like macroscopic analysis, microscopic analysis also can greatly contribute to making energy policy instruments. For example, an analysis based on estimated hourly solar insolation, efficiency curve of photovoltaic panel and

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http://dx.doi.org/10.1016/j.renene.2014.10.014
0960-1481/

tariff system for each household revealed a problem of the capital subsidy program for solar photovoltaic power system in Korea [6]. In this study, the potential fossil fuel conservation by implementation of RHO in Korea was evaluated with the microscopic analysis, which uses heat demand pattern in buildings, heat production performance and cost data of renewable heat sources.

The specific plans of the RHO in Germany and Korea are introduced in Section 2. Methodology of the microscopic analysis is also described in Section 2. Calculation results and a policy suggestion based on the results are described in Section 3. Finally, conclusions are drawn in Section 4.

2. Background and methodology

2.1. Renewable heat obligation in Germany and Korea

The RHO in Germany started in 2009. The target buildings of the RHO are new buildings including both residential and non-residential buildings. Developers of new buildings of the new buildings can choose what renewable heat source to adopt. Then, the developers of new buildings should meet a certain proportion of heating & cooling energy demand in buildings with the chosen renewable heat source. The standard proportion is 15% for solar thermal energy, 30% for gasified biomass energy, 50% for liquefied or solid biomass energy and geothermal energy. District heating and waste heat from cogeneration plant can substitute the renewable heat sources for the RHO [7,8].

The RHO in Korea is going to start in 2016. Korean government decided to obligate developers of new buildings to adopt renewable heat sources because an RHI is an economic burden for the government, and because to obligate community energy system (CES) business owners to adopt renewable heat sources may strongly depress the CES market. By the master plan of the RHO shown in a press release published by the Ministry of Trade, Industry & Energy, the target buildings of the RHO are new industrial, business, and commercial buildings. The standard proportion of heating & cooling energy demand in buildings to meet is 10% for 2016–2019, and from 2020 it increases by 1% per year until 2030. So from 2030, 20% of the total heating & cooling demand of the buildings should be met by renewable heat sources. Developers of new buildings can choose a mix of solar thermal energy, biomass energy, geothermal energy, and heat energy from fuel cell. Applying correction factor for each renewable heat source to consider the cost difference between renewable heat sources is under discussion, but no exact value of the correction factor is decided yet.

2.2. Heating & cooling energy demand of the buildings

It is well known that timely energy demand patterns are necessary for accurate energy planning and management for buildings. But in Korea, there is no official open-database of energy demand patterns of various kinds of buildings. Fortunately, Distributed Energy Resources Customer Adoption Model (DER-CAM), an economic model developed by the Lawrence Berkeley National Laboratory (LBNL) for finding optimal distributed generation configuration [9], has an open-database of representative energy demand patterns of various types of buildings and various cities in the United States of America. In this study, energy demand patterns of Baltimore, Maryland will be used because the climate of Maryland is expected to be similar to the climate of Korea. Both Korea and Maryland have four clear seasons. The latitude of Korea (37° for Seoul) and Baltimore (39°) is similar. And both Korea and Maryland contacts sea. Also, a quantitative parameter named degree day supports the similarity of climate and heat energy demand of buildings of Korea and Baltimore. Degree day is defined as a summation of the differences between a reference temperature and the outdoor air temperature over a period of time. So degree day reflects the demand for energy needed to heat a building. Table 1 shows the value of annual heating degree day (HDD) and cooling degree day (CDD) in Korea and Baltimore. Data of Korea is from an investigation of HDD and CDD of major cities in Korea [10], and data of Baltimore is from an open-access record made by Southeast Regional Climate Center [11]. Data based on both Celsius scale and Fahrenheit scale is shown because published data of Korea was based on Celsius scale while published data of Baltimore was based on Fahrenheit scale. Actually, CDD of Maryland with base temperature of 78.8 °F is not in the record, so 3rd order polynomial curve fitting method with published data with other base temperatures was used to obtain the value of CDD of Baltimore with base temperature of 78.8 °F, as shown in Fig. 1. As shown in Table 1, HDD and CDD of Korea and Baltimore are similar. In short, it is acceptable to use the heating & cooling energy demand pattern of Baltimore, Maryland.

In this study, large office building, department store, hospital, and hotel are selected for the analysis because these are the most common types of industrial, business, and commercial buildings. Fig. 2 shows the normalized annual space heating, space cooling and water heating demand patterns of the selected type of buildings with one representative day per month in Baltimore, Maryland. In this study, all the results are shown as normalized data because the demand patterns in DER-CAM do not correspond to a specific size of building but any size of buildings by adjusting the electricity consumption and natural gas consumption per year, which are the input for generating the demand patterns in DER-CAM. Also, this means that the calculation results of this study are independent of the size of the building, provided that the shape of heat energy demand pattern of the actual building is similar to the shape of the demand pattern data in DER-CAM. The ratio between the electricity consumption and the natural gas consumption per year was set as 0.65 for the large office building data, 0.35 for the department store data, 2.75 for the hospital data, and 2.0 for the hotel data considering some field studies. For simplicity, space heating demand of May to September and space cooling demand of October to April are neglected.

2.3. Renewable heat sources for the RHO and their energy production performance

As mentioned in the Section 2.1, solar thermal energy, geothermal energy, biomass energy, and heat from fuel cell are discussed as the possible renewable heat energy sources for RHO in Korea. In this study, heat energy from fuel cell is excluded because usually fuel cells lack economic feasibility, and because fuel cells will follow power load profile mainly. Also, only ground-source heat pump is regarded as the renewable heat source using geothermal energy because there are not many developed deep spots of high-temperature geothermal energy in Korea [12]. And since wood pellet is the most commonly traded biomass fuel, only wood pellet is considered as biomass energy. As a summary, Fig. 3 shows the general schematic of the heating & cooling energy systems in the target buildings for the RHO. EHP means the electric heat pump, a commonly used heat source which consumes electric power and meets space heating and space cooling demand. GSHP

Table 1
Annual HDD and CDD of Korea and Baltimore.

	HDD		CDD	
	°C scale (18 °C)	°F scale (65 °F)	°C scale (26 °C)	°F scale (78.8 °F)
Korea	2000–2500	3600–4860	30–80	54–144
Baltimore	2377	4278	55.4	99.8