Energy Policy 52 (2013) 288–296

Contents lists available at SciVerse ScienceDirect

Energy Policy

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

An analysis of long-term scenarios for the transition to renewable energy in the Korean electricity sector

Nyun-Bae Park [a], Sun-Jin Yun [b], Eui-Chan Jeon [a,*]

[a] Sejong University, Graduate School of Climate Change, 98 Gunja-Dong, Gwangjin-Gu, Room 1119 Gwanggaeto Building, Seoul 143-747, Republic of Korea
[b] Graduate School of Environmental Studies, Seoul National University, 599 Gwanagno, Gwanak-gu, Seoul 151-747, Republic of Korea

HIGHLIGHTS

- This paper analyzed three kinds of electricity scenarios in Korea by 2050 using LEAP model. Baseline and governmental policy scenarios focus on the electricity supply through nuclear expansion.
- Sustainable Society scenario focuses on demand management and renewable electricity.
- The latter improves energy security and reduces more GHG with the affordable cost.

ARTICLE INFO

Article history:
Received 29 September 2011
Accepted 8 September 2012
Available online 29 October 2012

Keywords:
Renewable energy
Electricity scenarios
LEAP model

ABSTRACT

This paper analyzes the energy, environmental and economic influences of three electricity scenarios in Korea by 2050 using the "Long-range Energy Alternatives Planning system" (LEAP) model. The reference year was 2008. Scenarios include the baseline (BL), new governmental policy (GP) and sustainable society (SS) scenarios. The growth rate of electricity demand in the GP scenario was higher than that of the BL scenario while the growth rate in the SS scenario was lower than that of the BL scenario.

Greenhouse gas emissions from electricity generation in 2050 in the BL and GP scenarios were similar with current emissions. However, emissions in 2050 in the SS scenario were about 80% lower than emissions in 2008, because of the expansion of renewable electricity in spite of the phase-out of nuclear energy.

While nuclear and coal-fired power plants accounted for most of the electricity generated in the BL and GP scenarios in 2050, the SS scenario projected that renewable energy would generate the most electricity in 2050. It was found that the discounted cumulative costs from 2009 to 2050 in the SS scenario would be 20 and 10% higher than that of the BL and GP scenarios, respectively.

1. Introduction

As the per capita electricity consumption and the greenhouse gas (GHG) emissions from electricity generation continually increase in Korea, it has become more important to introduce measures to reduce electricity generation-induced GHG emissions. While national GHG emissions have doubled from 1990 to 2008, there has been a fourfold increase in emissions from the energy transformation sector. Most emissions in the energy transformation sector come from electricity generation, accounting for about 34% of the total net emissions in the country in 2008 (estimated from GIR, 2011).

In spite of the increasing threat of high oil prices, fossil fuel and uranium depletion, and climate change, the Korean government has developed energy scenarios in which per capita electricity consumption is continuously increasing and consequently electricity supply needs to be increased to keep up with the demand. Thus, nuclear power is considered as an effective power option in light of its huge potential for large-scale power supply with far less GHG emissions. Even though this approach taken by the government has been challenged in Korea, there has been no attempt yet to introduce alternative energy scenarios.

There are many different opinions on how much nuclear energy, Carbon Capture and Storage (CCS), and renewable energy can contribute to low-carbon power generation. While some studies suggest that nuclear power and CCS technology will play a considerable role in providing the required energy and reducing GHG emissions (ECF, 2010; ECN, 2007; EPRI, 2009; Eurelectric, 2010;

* Corresponding author. Tel.: +82 234 084 353; fax: +82 234 084 354.
E-mail address: ecjeon@sejong.ac.kr (E.-C. Jeon).

0301-4215/$ - see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.enpol.2012.09.021

IEA, 2010c, 2010d; IEP, 2009; IPCC, 2007; Mckinsey, 2009; METI, 2010; Pacala and Socolow, 2004), others say that it is possible only through the improvement of efficiency, cogeneration and renewable energy without the construction of additional nuclear power plants (Friends of the Earth, 2006; Greenpeace and EREC, 2009; Heaps et al., 2009; Sawin and Moomaw, 2009; WWF, 2009). According to the Korean government's current plan for long-term electricity supply and demand, it is expected that demand for electricity will increase and nuclear power will become the most important source of electricity generation. This is mainly due to the consideration placed on the reduction of GHG emissions and costs. But some demerits of nuclear power generation include the risk of nuclear accidents from man-made or natural factors, long-term management of radioactive wastes, and the need to import uranium to fuel the plants. For those reasons, there is a limit on sustainability.

Therefore, this study will construct an electricity transition scenario (which provides electricity using demand side management, renewable energy and the natural gas combined cycle) that shows the reduction of GHG emissions until 2050 without adding new nuclear power plants except those already under construction. This study will further analyze the effects on energy systems (electricity generation and capacity by each energy source), the environment (greenhouse gas, air pollution, thermal effluent, land use, etc.) and the economy (costs). This study will be the first attempt to construct an alternative electricity transition scenario in Korea in order to analyze the feasibility of substituting nuclear power with renewable electricity at a reasonable cost.

2. Background to Korea's electricity sector

While the GDP of Korea has increased by 2.5 times from 1990 to 2008, the total primary energy supply and CO_2 emissions from fuel combustion have increased by 2.4 and 2.2 times, respectively (IEA, 2010a). Total electricity generation (produced and purchased by public utilities) has increased by 3.9 times from 107.7 TWh in 1990 to 421.6 TWh in 2008. The installed capacity of power facilities has increased by 3.4 times from 21.0 GW in 1990 to 72.5 GW in 2008 (KPX, 2010) (See Fig. 1).

There were major changes in the electricity generation structure between 1990 and 2008. In 1990, nuclear power accounted for 49.2%; coal, 20.9%; oil, 12.4%; LNG, 11.5%; pumped storage, 1.6%; hydropower, 4.4%; and renewable energy (non-hydro) and others, 0.0%. In 2008, nuclear power accounted for 35.8%; coal, 41.3%; oil, 2.0%; LNG, 18.0%; CHP, 1.3%; pumped storage, 0.6%; hydropower, 0.7%; and renewable energy (non-hydro) and others, 0.3%. It is evident that currently most electricity is provided by nuclear power and coal-fired power generation. Though the share of non-hydro renewable energy generation is currently increasing, it accounts for only 0.3% of the entire generation of electricity in 2008. The share of hydropower and renewable energy generation in Korea was 1% in 2008, the lowest amongst OECD countries (IEA, 2010b).

The emission intensity and GHG emissions for the power sector from 1990 to 2008 have increased by 1.4 and 5.5 times, respectively, while the total emissions of the country have increased by twofold during the same period (estimated by the KEEI, 2006; KPX, 2010; ROK, 2011). Also, the proportion of emissions from electricity generation against the total emissions of the country increased from 12% in 1990 to 32% in 2008. Given the fact that electricity demand in the future is expected to increase, more importance will soon be placed on the transition to low-carbon generation technology.

The average annual growth rate of electricity consumption in Korea from 1990 to 2008 is 8.5% (KEEI and MKE, 2010), and the average annual growth rate of electricity generation is 8.2% (KPX, 2010). The difference between these two numbers is due to transmission and distribution losses decreased and the effect of increase in non-utility generation. Per capita electricity consumption in Korea in 2008 was higher than that of Japan and developed countries in Europe, both areas that have a higher per capita income than Korea. Accordingly, it is necessary to strengthen the management of electricity demand in the future. At the end of 2010, the government established the fifth plan for long-term electricity supply and demand (MKE, 2010). According to this plan, electricity consumption is expected to increase an average of 1.9% annually from 2010 to 2024, and electricity generation will increase on average 1.6% annually. Furthermore, the electricity generation by each energy source in 2024 is projected to be as

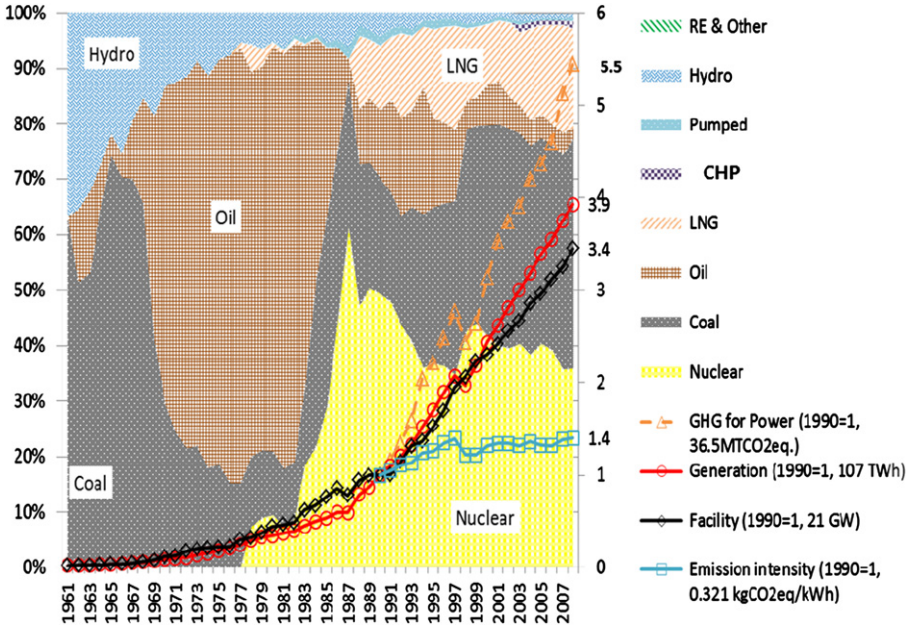

Fig. 1. Sources of electricity generation and generation indicators in Korea.