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Relative efficiency of energy technologies in the Korean mid-term strategic energy technology development plan

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ABSTRACT

Korea is vulnerable to oil price volatility due to its significant energy import dependence, which accounts for almost 97% of the primary energy consumption. Korea ranked eighth worldwide in terms of the volume of oil consumption in 2014 according to the BP statistical review 2015. Consequently, the best way to address the energy problem in Korea and enhance its national energy security is to implement a mid-term strategic energy technology development plan supported by the Korean Research Council for Public Science and Technology, along with well-focused research and development (R&D). We thus established a mid-term strategic energy technology development plan for the five years from 2007 to 2011, which serves as a guide for producing focused R&D outputs and outcomes, and provides a continuous energy technology development policy for coping with the significant government scientific and technology policy shift toward a world class research institute. This paper applies data envelopment analysis (DEA), a multi-criteria decision-making approach, to measure the relative efficiency of nine selected energy technologies included in the mid-term strategic energy technology development plan, from an economic viewpoint, from 2007 to 2008. As policymakers, we need to analyze and determine whether nine energy technologies have to be carried out continuously or not by considering the R&D performance of the nine selected energy technologies is competitive under limited R&D investment and resources. Using the DEA approach, energy technology R&D programs can be thus effectively assessed in relation to the relative efficiency of the nine selected energy technologies. Two core technologies, namely redox flow battery (RFB) and combined heat and power plant (CHP), need to enhance their R&D outputs and outcomes to become relatively efficient technologies from an economic viewpoint. The government and energy policymakers can re-evaluate their status and enhance any weak points towards strategically shifting to a world-class research institute within five years.

1. Introduction

Korea is one of the largest oil consumers worldwide, ranking eighth in oil utilization in 2014, when it consumed 273.2 million tons [1]. Fig. 1 shows the world primary energy consumption in 2014: China is the world's largest primary energy consuming nation, as a result of its rapid economic growth and expansion, followed by the U.S., Russia, and India in this order. The BRICs (Brazil, Russia, India, and China) are included in the top seven primary energy consuming countries, as their economic development required the heavy consumption of their energy resources. Japan, the fifth largest energy consuming nation, consumed 456.1 million Tonnes of Oil Equivalent (TOE) in 2014. Regarding Korea's primary oil consumption, its primary energy consumption is slightly larger than that of France. Additionally, 98% of the energy resources consumed by Korea are imported, making it vulnerable to oil price volatility. As a result, interest in the strategic and well-focused development of energy technologies has increased in Korea due to its large dependence on imported energy resources and limited research and development (R&D) budget. Korea is also facing the challenge of reducing greenhouse gas (GHG) emissions in observance of the United Nations Framework Convention on Climate Change (UNFCCC). The importance of this task is underscored not only by the fact that Korea is the ninth largest emitter of carbon dioxide worldwide, but also by that it registers the fastest rate of carbon dioxide emission increase.

Over the past decades, the Korean economy has demonstrated rapid growth, along with high-tech industrialization. The Korean government has faced the challenge of moving from catch-up to lead-up strategies in the R&D sector. The government has also attempted to solidify the

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Nomenclature

AHP	Analytic hierarchy process
B	R&D budget
CHP	Combined heat and power plant
D	Domestic
DEA	Data envelopment analysis
DMU	Decision making unit
DOE	Department of Energy
DSSC	Dye-sensitized solar cell
ETRM	Energy technology roadmap
F	Technology dissemination fee
HERC	Hydrogen energy R&D center
HR	Human resources
J	DMU reference set
KORP	Korean Research Council for Public Science and Technology
KRW	Korean won
N	Number
O	Overseas
PEMFC	Polymer electrolyte membrane fuel cell
RFB	Redox flow battery
SWOT	Strengths, weaknesses, opportunities, and threats
TD	Technology dissemination
TOE	Ton of Oil Equivalent

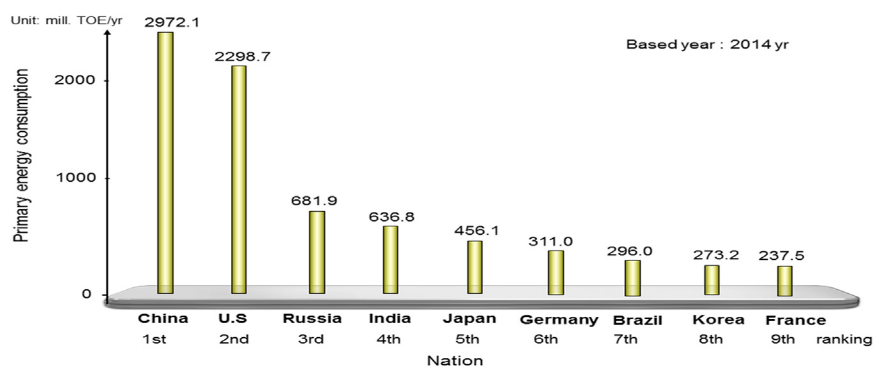

Fig. 1. World primary energy consumption according to BP 2015.

structure of sustainable development using strategic investment in the R&D sector. Specifically, the energy R&D sector is crucial to addressing national energy security, including global climate change issues and low-carbon green growth.

Moreover, Korea has been exerting significant efforts to ensure national energy security by diversifying its energy R&D programs and plans. As energy technology development is a crucial issue for energy security, Korea introduced various strategic national energy technology development plans for producing excellent outputs and outcomes through well-focused R&D.

In 1991, the Korean government established the five-year national energy conservation technology development plan for 1992–1996 with large energy saving potential [2,3]. It was included as part of the seventh five-year economic and social development plan.

In 1997, the 10-year energy technology development plan for 1997–2006 was launched with the scope of focusing on energy R&D projects of energy efficiency, alternative energy, and clean energy technology [4]. Specifically, 21 core energy programs were selected by their energy efficiency impact, improvement of energy supply and demand structure, technologies that lacked economic efficiency and were unlikely to expect voluntary participation by the private sector, and technologies that could minimize the environmental impact of energy use.

In 2005, the Korean government established the national energy technology development plan for 2006–2015 [5], which is significant because it is based on technological trees instead of R&D projects, giving rise to the establishment of the energy R&D technological trees with the consensus of experts in energy technology development and the policy sector. It is composed of five major sectors, namely energy efficiency, greenhouse gas, new and renewable energy, electrical power technology, and natural resource technology. This crucial plan also includes a technology roadmap for developing and acquiring core technologies in five major sectors until 2015.

In 2006, the Korea Institute of Energy Research (KIER), a government supported research institute for developing energy efficiency, greenhouse gas, new and renewable energies, and energy material technology, formulated an energy technology roadmap (ETRM) for the subsequent 10 years from the viewpoint of Korea's national energy technology and policy [6]. This program provides a direction for the national energy policy, beginning with the analysis of the world energy outlook. Moreover, the ETRM focuses on the development of energy technologies, while taking into account the aspects of the Korean energy environment, because the Korean government focused on producing excellent R&D outcomes and on government sponsored research institutes becoming world-class institutes within five years [7].

In 2008, President Lee's government introduced low-carbon and green growth as the national agenda within the transition towards becoming a global leader of green economic growth [8]. The Basic Energy Law was enacted for the implementation of the First National Basic Energy Plan, which is to provide future-oriented energy policy direction every five years until 2030 [9,10]. It mainly covers energy security, energy supply and management, supply and use of environmentally friendly energies, the reduction of greenhouse gas emissions, and safe management of energy.

Consequently, our study employs data envelopment analysis (DEA) to analyze the relative efficiency of nine strategic energy technologies for the mid-term strategic energy technology development plan because KIER, as a government sponsored research institute, requires to shift toward a world-class energy research institute in order to cope with the Korean government's science and technology policy direction through well-focused R&D programs. Additionally, energy policymakers need to recheck the portfolio of the mid-term strategic energy technology development plan by measuring the relative efficiency of R&D from an economic viewpoint. The plan comprises five major sectors, namely, energy efficiency, synfuel oil production, carbon capture and storage (CCS), renewable energy, and hydrogen infra-fuel cells.

In other words, the mid-term strategic energy technology development plan aims to produce world-class R&D outcomes within five years in terms of energy R&D technologies that manage the Korean energy environments flexibly and enhance national energy security. It focuses