



A review on energy systems and GHG emissions reduction plan and policy of the Republic of Korea: Past, present, and future



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ABSTRACT

The primary objectives of this study were to understand the energy plans and policies of the Republic of Korea (ROK) and outline its development in the energy sector. Both qualitative and quantitative information were gathered and evaluated in the context of the defined objectives. The study has outlined that the primary motivational factor for achieving the current improved energy status of the ROK was to support the rapid industrial growth and socio-economic development of the country. The major steps taken were to manage the country's escalating energy demand and to minimize the greenhouse emissions in energy sector along its progressive economic development. The economic growth of the country had good correlation with the escalating fossil fuel consumption. This is however among the great concerns in the country in today's global agenda of sustainable energy managements. The country has been primarily relying on the imported energy sources, which averaged to 84% (including nuclear generation) of the total primary energy supply (TPES) during the period of 2000–2014. Oil has been the main source of energy supply in the country, followed by coal and natural gas. Penetration of renewable energy technologies was primarily motivated to meet the country's strategic goals, including the downscaling of GHG emission by 37% by 2030 compared to the business-as-usual (BAU) situation. Despite the different initiations in the energy management, renewable energy sources covered only 4.5% of the TPES in 2014. In addition, the country's urgent need now is also towards the management of the available natural resources to support the growing demand of bio-economy. At this particular interest, the country needs to identify the sustainable availability of resources to balance the multi-fold sectors. This demands comprehensive energy-system analysis along with identifying the avenues of the utilization of biomass resources.

1. Background

Population growth, industrial and socio-economic developments are the key drivers for ever-increasing energy demand in any developing economies [1–3]. After the first and second oil crisis, there have been increased attentions on the sustainable energy conversions and the consumption across the world [4]. The concerns on sustainability of energy system also have substantially encouraged to upscale renewable energy (RE) technologies in the total energy mix of different countries [5]. The major concerns that are still prevailing in the energy sector are related to the over-exploitation of limited fossil resources, greenhouse gas (GHG) emissions and increasing energy insecurity [6]. In addition, the surges in the oil prices is also making the energy and economic

sectors vulnerable, as they are most likely affecting the strategy set by different countries for increasing the penetration of renewable fuels to support the green growth economy [7]. This, in general are affecting the energy pricing policies, especially based on renewable energy systems, whenever they have to compete with fossil fuel based systems [8]. The decade-long debates on energy and the environment management options, however, have shown directions for securing a reliable and affordable supply of energy carriers [9].

Most often, in developing countries, energy demand is coupled with the economic development, generally with Gross Domestic Product (GDP) [7]. The nexus between the per capita GDP and energy consumption also clearly showed a good correlation in the case of Republic of Korea (ROK). For instance, the GDP of the ROK in 1990

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was 8610 USD (United States Dollar)/capita and increased to 34,356 USD/capita in 2014. This connectivity of the GDP with the Total Primary Energy Supply (TPES) shows that it was increased by more than two-fold in 2014 (2.34×10^{-4} PJ (petajoule)/capita) compared to 1990 (9.01×10^{-5} PJ/capita) [10,11].

Cho et al. [12] analyzed the feasibility and impact of the ROK energy policy and presented that the country has to cover 20% of the TPES for electricity generation by renewable energy in 2040. Cho (2015) [12] stressed that utilization of wind energy is the immediate action to be initiated for meeting the purpose. The importance of increasing the productivity of wind power is very significant for addressing and implementing some of the most urgent needs such as: (i) to steadily decrease the operations of the thermal power plants (ii) to increase the share of the RE sources in the TPES and (iii) to reduce the national GHG inventory in the future. Kim et al. [13] argued that the contribution of CO₂ emissions from the energy sector was partly because of a higher dependency on imported fossil fuels and relatively low electricity price triggering the consumption.

There are limited studies to capture the historical energy trend of the ROK and have had discussed the importance of energy policy of ROK to meet its long-term development plans. In the context of understanding the future energy outlook of the country, thus it is relevant to understand the past energy development trends which can assist delineating opportunities of sustainable energy development of the ROK. This paper made a review on the energy development system of the ROK, with a special focus on the progress in the past, formulation of policies and plans to fulfil the growing energy demand and the targets to reduce the emissions from the energy sector.

The study is organized in five sections. Section 1 presents the overview of the study; Section 2 explains the methodology of the study; and Section 3 gives an overview on the reviews of the past energy interventions, emission reduction outcomes, identification of potential energy resources and constraints for their development. In Section 4, the study discusses the energy and emission plans and policies, also making illustrations on the evolution of ROK's economy and energy status. It also outlines the strategies of the government to reduce energy dependency, e.g. by increasing the domestic generation capacity, particularly from renewable resources. Finally, in Section 5, the key achievements and strategies are discussed along with some research perspectives.

2. Methods

The study systematically searched the relevant existing literature, using the keywords, such as 'energy demand', 'energy supply', 'energy policy', 'energy plan', 'greenhouse gas emissions', 'New and Renewable energy', and 'Republic of Korea'. Literatures relevant to the scope of this study were collected by using the document review techniques and were categorized into following: (i) regulatory framework documents, (ii) academic articles and (iii) technical/other documents. The new and renewable energy promotional acts [14], energy and GHG emission plans and policies [15–23] were categorized as the regulatory framework documents. The peer-reviewed articles that describe the energy structures and the energy systems of the ROK were categorized as academic articles [12,13,24–27], and technical/other documents included national and international energy and GHG emission reports and statistics of the ROK, e.g. as published in the Refs. [10,11,28–42] along with other popular writings in the sector of energy management and technological advancement, e.g. as published in news articles [43–46]. The study used mixed research method, as syntheses of both qualitative and quantitative information were made for understanding the energy system of the ROK. Microsoft Excel 2007 was used to analyze the data. The literature review aimed at answering the following key research questions: (i) what is the present status of the ROK? (ii) did the past energy policies achieved their objectives?, and (iii) what was the goal of 'low carbon, green growth' plan of the ROK and the strategy to meet the goal?

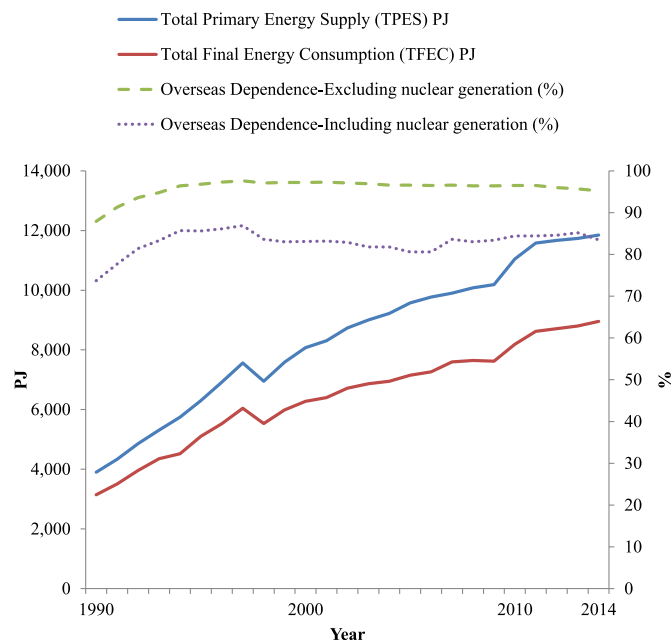


Fig. 1. Total primary energy supply, final energy consumption and import dependency in the ROK (1990–2014), prepared after Korea Energy Statistics [11].

3. Past energy interventions

3.1. Energy supply and consumption

Due to the rapid economic development of the ROK and the connected energy demand, the TPES of the country increased more than 300% between the period of 1990 and 2014 (i.e. 3905 PJ in 1990 to 11,846 PJ in 2014). The challenge was a lower domestic energy production, which triggered the dependency to imported energy sources. For instance, it rose from 88% to 95% (excluding nuclear power) between that 1990–2014 (Fig. 1) [11,47]. The overuse of imported sources of fossil fuel (e.g. 82% of the TPES in 2006) was partly responsible for doubling the GHG emission in 2006, as compared to 1990 level [11,28]. In 2014, about 37% of the TPES was covered by petroleum sources, and the industrial sector was the main consumer. The sector covered about 64% of the total final energy consumption (TFEC), which amounted to 8954.5 PJ [11]. The ROK was ranked 5th in the world in terms of per capita coal consumption in 2014. The inclination on the per capita coal consumption was from 0.85 t of coal equivalent (TCE) to 2.29 TCE during the period of 1990–2014 [43].

In 2014, out of the TPES (i.e. 11,855 PJ) about 37% was from petroleum sources, followed by coal (30%), LNG (17%), nuclear (12%) and renewable sources (4%) (Fig. 2) [11].

The rapid industrialization of the country increased the consumption of energy in the industrial section. For instance, in 1990 industrial consumption was 48% of the TFEC (i.e. 3145 PJ), which increased to 63% in 2014 (i.e. of 8955 PJ). There was also reduction in the shares of energy consumption in the sectors, such as residential and commercial (dropped from 29% to 18%); transportation (from 19% to 17%); and in the public sectors dropped from 4% to 2% (Fig. 3) [11]. The reduction in the stated sectors was also partly due to development in the energy management initiatives and improvement in the energy efficiency [48–52]. The coal consumption during 1990–2000 was increased by about 107%. However, it was increased only by about 47% between 2000 and 2014 (Table 1) [11].

The annual growth rate of the TPES in the ROK is projected to stabilize at around 2% in the coming decade; which in the 1990s was about 14% and decreased to 5% between 2000 to 2010 [53].

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