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Abstract

In 2008, South Korea adopted ambitious targets for reducing its dependence on energy imports and its carbon emissions simultaneously. The first National Energy Plan called for cutting energy intensity by nearly half and reducing the country's dependence on imported fossil fuels by more than one quarter by 2030. Fossil fuels would be replaced by nuclear power and renewable sources of energy, which together would meet nearly 40 percent of South Korea's energy needs. The achievement of these targets has been impeded by a number of obstacles, however. In response, the government has adjusted its goals, most recently with the adoption of a second national energy plan in January 2014. But especially in the critical area of nuclear power, the targets remain highly ambitious, and there are still reasons to question their feasibility. As a result, South Korea may have to moderate further its energy ambitions or redouble its efforts to achieve them.

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South Korea's National Energy Plan Six Years On

I. Introduction[1]

When it comes to energy, few countries outrank South Korea in importance. Because of its steady and often rapid economic growth over the last four decades, South Korea now consumes more energy than all but eight other countries, and it is poised to pass Brazil, Germany, and Canada in terms of primary energy consumption (PEC) in the next few years. At the same time, and in almost direct proportion to its rising energy consumption, South Korea has also rapidly moved up the ranks of CO2 emitters and now stands in seventh place world-wide (BP, 2013).

Among the largest energy consumers, South Korea, along with Japan, stands out in terms of the precariousness of its energy situation. In contrast to the United States, China, Russia, Canada, and Brazil, it possesses almost no indigenous fossil fuel resources. And unlike Germany and India, it is isolated from the Eurasian landmass. As a result, South Korea must obtain virtually all of its energy supplies by sea, making it the world's fourth largest energy importer (MKE, 2012, p. 5).

In response to these circumstances, South Korea adopted ambitious targets for reducing its dependence on energy imports and its carbon emissions simultaneously in its 2008 National Energy Plan. In particular, the plan called for cutting South Korea's energy intensity by nearly half by 2030. It also called for reducing South Korea's dependence on imported fossil fuels by more than one quarter, from 82 percent to just 61 percent of PEC, over the same time period. The fossil fuel component in South Korea's energy mix would be replaced primarily by nuclear power and, secondarily, by new and renewable sources of energy. Nuclear power's share of PEC would rise from 15 to 28 percent of PEC, and nearly 60 percent of the country's electricity would be generated at nuclear power plants, making South Korea's electric power system the second most dependent on nuclear energy in the world, after France. Meanwhile, the share of renewables would rise from just 2.5 percent of PEC, the lowest level among all the advanced economics of the Organization for Economic Cooperation and Development (OECD), to 11 percent.

Since the plan was announced nearly six years ago, however, the achievement of these targets has been complicated, if not yet fully impeded, by a number of obstacles. Some of the challenges could have been anticipated while others, like the 2011 disaster at Fukushima Daiichi in Japan, could not. In response, the government has adjusted its goals, most recently with the adoption of a second national energy plan in January 2014. But especially in the critical area of nuclear power, the goals remain highly ambitious, and there are still reasons to question their feasibility. As a result, South Korea may have to moderate further its energy ambitions or redouble its efforts to achieve them.

This paper analyzes why South Korea adopted the particular targets of the 2008 energy plan, how it has planned to achieve them, the obstacles encountered so far, and subsequent adjustments in South Korean energy policy, especially in the wake of the events at Fukushima Daiichi. It begins with an overview of South Korea's energy situation, including the evolution of the energy mix, the structure of the energy industry, and the energy policy making process. The following section summarizes the 2008 National Energy Plan, which provided the first comprehensive statement of South Korean energy policy, and the specific measures adopted by the government to implement the plan. A third section analyzes the challenges that South Korea has faced in achieving the targets laid out in the national energy plan for the key areas of energy efficiency, nuclear power, and renewable energy. The penultimate section examines the adjustments that South Korea has made in response to these challenges, through the recent adoption of the second national energy plan, and the final section concludes.

II. <u>**Background**</u>

A. **South Korea's Energy Consumption and Mix**

Except for a brief dip during the Asian financial crisis, South Korea's energy consumption has grown steadily and often quite rapidly over the past five decades (see Figure 1). Between 1965 and 1997, PEC increased by an average of more than 10 percent per year. And although its growth was markedly slower during the decade following the 1997 Asian financial crisis, PEC continued to rise by nearly four percent per year (BP, 2013; see also Jones & Yoo, 2010, p. 7; ABB, 2011, p. 2).

Figure 1: Primary Energy Consumption, 1965-2012

Likewise, consumption of each of the four main energy sources – oil, coal, gas, and nuclear power – has grown substantially, but significant shifts have occurred in the energy mix (see Figure 2). In 1973, South Korea relied almost entirely on oil (60 percent) and coal (40 percent). Since then, a substantial reduction has occurred in oil's share of PEC and a smaller one in coal's, to around 40 percent and 30 percent, respectively, in 2012.[2]

Figure 2: Shares of Primary Energy Consumption, 1965-2012

Oil and coal have been replaced mainly by nuclear power and natural gas. The first nuclear reactor entered service in 1978, but the biggest buildup on nuclear generating capacity occurred in the 1980s and 1990s. Eight more reactors came on line between 1983 and 1989, followed by seven more between 1995 and 1999. By 2008, South Korea had 20 reactors with 17.7 gigawatts (GW) of capacity in operation, making it the fifth largest producer of nuclear power in world, and six more reactors were under construction (BP, 2013; WNA, 2013; Leem, 2010, p. 10). In the late 1980s, nuclear power accounted for nearly half of all electricity, but that figure now stands at around 30 percent because of increased reliance on natural gas. Natural gas was introduced relatively late, in 1986, in the form of imports of liquefied natural gas (LNG). But South Korea's gas consumption has grown quickly since then, and it recently passed nuclear power as a percentage of PEC (BP, 2013).

The growth in South Korea's electricity consumption has been equally dramatic, especially since the 1970s (see Figure 3). According to various estimates, it rose 12-fold between 1981 and 2010, or by some nine percent per year, and between 1990 and 2009, it grew almost twice as fast as final energy consumption. In 2009, the largest share of electricity (47 percent) was generated from coal, followed by nuclear power (33 percent) and gas (15 percent) (Leem, 2010, p. 7; Sheen, 2011, pp. 274-5; ABB, 2011, pp. 3-4; BP, 2013).

Figure 3: Electric Power Generation, 1981-2012

Renewable sources of energy have made only a very small contribution to meeting South Korea's energy needs. In 2007, they accounted for just 2.37 percent of PEC, the lowest in the OECD area, and three-quarters of that was heat generated from waste. Only about one percent of electricity was generated by renewables, despite the introduction of a feed-in tariff (FIT) system in 2002, and most of that was from hydropower (Lee, 2010, p. 6; Hunton & Williams, 2010; IEA, 2012a, p. 10).

Over the years, South Korea has relied increasingly on energy imports. Until the early 1970s, the country was self-sufficient in coal and imported only oil. Now, South Korea must import virtually all of the fossil fuels it consumes, accounting for some 85 percent of PEC, and if imports of uranium are included, the level of import dependence rises to 97 percent. South Korea is now the second largest importer of LNG (after Japan), the third largest importer of coal (after Japan and China), and the fifth largest net importer of oil (MKE, 2012, p. 5; Lee, 2012, p. 5; OECD, 2012, p. 240).

Among the OECD countries, South Korea has been a relative laggard when it comes to reducing energy intensity (see Figure 4). Indeed, energy intensity may be higher than it was at the time of the oil shocks. Owing in part to South Korea's relatively belated industrialization and its heavy investment in energy-intensive industries, such as steel, shipbuilding, petrochemicals, and automobiles, energy intensity trended upward until the late 1990s. From 1997 to 2010, it declined by more than one percent per year on average. But at the end of that period, it still stood at about the same level as it had in 1990 and about 25 percent above the OECD average (IEA, 2012a, pp. 39, 41, and 45; ABB, 2011, p. 3; UNEP, 2010, p. 9).

Figure 4: Energy Intensity, 1965-2010

B. **Structure of the Energy Industry**

The South Korean government has been deeply involved in the energy sector, although its role has diminished somewhat in recent years. Traditionally, Korean energy policy has been "mainly aimed at providing stable, reliable supplies at low prices to enhance industrial competitiveness, fuel economic growth, and control inflation" (Kim, Shin & Chung, 2011, p. 6887). And for many years, it was widely believed that the achievement of this goal was best served by public ownership and control (Vine, Rhee & Lee, 2006, p. 1108).

The government's role has been smallest in the petroleum industry, which was deregulated in the 1990s. Today, a handful of large private companies dominate oil imports, refining, distribution, and the sale of petroleum products. Likewise, coal is freely imported by consumers in the electric power, steel, cement, and other industries. In contrast, the gas sector remains primarily under public ownership. The state-owned and operated Korean Gas Corporation (KOGAS) owns three of South Korea's four LNG terminals – a major iron and steel company operates a small fourth terminal -- the national transmission system, and almost all storage capacity, and KOGAS is the sole wholesaler of gas (IEA, 2002; IEA, 2012a; OECD, 2012, p. 240).

Meanwhile, the electric power industry remains stuck in the middle of a transition from state control to a market-based structure. Until the late 1990s, the industry was synonymous with the state-owned and vertically integrated Korean Electric Power Corporation (KEPCO), which had monopolized generation, transmission, and distribution since 1961. In 1998, however, the government adopted a plan to restructure the industry by introducing market competition and privatization, in three stages. First, KEPCO's power generation assets would be divested and privatized. Second, the transmission system would be opened up and wholesale competition introduced. Finally, individual customers would be allowed to choose their power providers.

In 2001, according to plan, KEPCO's power generation sector was duly split into six subsidiaries: Korea Hydro and Nuclear Power (KHNP) and five others with fossil fuel-fired thermal power plants. With the exception of nuclear power, power generation was to be opened to private companies and most of the subsidiaries sold off. Following the presidential election in late 2002, however, the new administration ordered a reexamination of the restructuring plan and, in 2004, the government suspended the plan's implementation before any of KEPCO's assets were privatized. Today, independent power producers own approximately 20 percent of Korea's generation capacity, but KEPCO remains the only wholesale buyer of power and still controls transmission and distribution (Lee & Ahn, 2006; IEA, 2002, pp. 56 and 63; Vine, Rhee & Lee, 2006, p. 1110; OECD, 2012, p. 240).

Paralleling the mixed industry structure, energy prices are determined in part by the state and in part by market forces. Traditionally, a goal of South Korean energy policy was to provide low-cost energy supplies in order to encourage and sustain economic development. In the late 1990s, however, all petroleum price controls were lifted, while the government has continued to regulate the wholesale price of natural gas (IEA, 2002, 90; Vine, Rhee & Lee, 2006, p. 1108; OECD, 2012, p. 240; IEA, 2012a, p. 55).

Likewise, the government continues to set the price of electricity, which has tended to be lower than in other OECD countries. Indeed, between 1982 and 2008, the price increased just 12 percent, even as overall consumer prices rose by nearly 250 percent. In addition, the government has imposed lower electricity tariffs on industrial and agricultural users than on residential and commercial consumers (IEA, 2012b, p. 53; IEA, 2002, p. 26; Lee & Ahn, 2006; Lee, 2012, p. 10).

C. **Energy Policy-Making**

As in many countries, energy policy has been the responsibility of a frequently changing cast of ministries: the Ministry of Trade and Industry (until 1978), the Ministry of Energy and Resources (1978-1993), the Ministry of Trade, Industry and Energy (1993-1998), the Ministry of Commerce, Industry and Energy (1998-2008), the Ministry of Knowledge Economy (MKE, 2008-2013), and once again the Ministry of Trade, Industry and Energy (MOTIE, 2013-present). Beneath this seeming pattern of flux, however, has been a high degree of continuity.

The first major energy legislation in South Korea was the Rational Energy Utilization Act, which was adopted in late 1979 following the second oil shock. The act was followed by the establishment of the Korean Energy Management Corporation (KEMCO), a non-profit government agency that was initially responsible for the implementation of conservation measures (IEA, 2002, p. 35).

During the following two and a half decades, however, the government took a generally piecemeal approach to energy policy. In the 1990s, it started developing separate plans for every part of the energy sector that were updated every two to five years. These included a

Basic Rational Energy Utilization Plan (every 5 years, since 1993), a Basic Plan for Long-Term Electricity Supply and Demand, which set targets for the number of nuclear and other power plants (every 2 years), a Long-Term Natural Gas Supply and Demand Plan (every 2 years), a Comprehensive Nuclear Energy Promotion Plan (every 5 years, since 1997), and a Basic Plan for New and Renewable Energy Technology Deployment and Development.

In 2006, however, the government decided to take a more comprehensive approach. It adopted the Basic Energy Law, which established a National Energy Committee that would develop a National Energy Plan every five years. The Plan would provide a long-term vision, looking out at least 20 years, and it would have priority over and provide direction for the more specific existing plans in each energy sector. The development of the plan would be subject to intensive consultation, with the government soliciting input from all stakeholders with the aim of achieving a broad social consensus (IEA, 2012a, pp. 20-21; interviews).

III. **The 2008 National Energy Plan**

In September 2008, the government adopted the first National Energy Plan under the new policy framework. The plan set targets for energy production and consumption out to 2030 (OPM, 2008; Ko & Kwon, 2009, p. 3484).[3]

A. **Motivations**

The plan was motivated by three main sets of concerns. The first was to reduce South Korea's dependence on energy imports, especially of fossil fuels. As noted above, imports meet nearly all of South Korea's energy needs, and spending on imports has consumed a large share of

South Korea's export earnings – as much as one-third in 2008. Thus reducing dependence on energy imports would both enhance South Korea's energy security and improve its global economic position (Choi, 2009; MKE, 2012, p. 5; Lee, 2012, p. 5).

A second important motivation was to reduce South Korea's greenhouse gas emissions. Between 1990 and 2004 alone, these had increased by 90 percent, and by one estimate, South Korea had the world's second highest growth rate in carbon emissions (Lee, 2012, p. 7; Park, 2009). Thus as the National Energy Committee finalized the new plan in 2008, South Korea had gained the unenviable position of being the tenth largest emitter of carbon dioxide and was poised to move even higher in the global rankings. At the same time, at least one analysis found that South Korea was more vulnerable than average to the effects of climate change (UNEP, 2010, p. 6).

Thus in August 2008, the government announced a "low carbon, green growth strategy" that led, the following year, to the adoption of a formal goal of reducing GHG emissions by four percent below the 2005 level, or 30 percent below business-as-usual (BAU) projections, by 2020 (Hunton & Williams, 2010; Jones & Yoo, 2011; IEA, 2012a, p. 22). Most of the reductions would have to be found in the energy sector, which was responsible for nearly 90 percent of all GHG emissions. Indeed, energy-related emissions of CO2 had more than doubled between 1990 and 2004 and were forecast to grow by another 85 percent from their 2000 levels by 2030 (IEA, 2006, pp. 47-49; IEA, 2012a, p. 29).

A third motivation was to promote the further development of South Korean industry. On the one hand, the government sought to lay the foundation for "green" growth by recasting the export-driven economic base to compete in the emerging green-tech field. To this end, the government also adopted a "National Strategy for Green Growth" in July 2009 that sought to create new engines of economic growth while dealing with climate change and increasing South Korea's energy independence (Hunton & Williams, 2010; IEA, 2012a, p. 22). According to one estimate, the green energy industry alone would create nearly a million jobs (Kim, Shin & Chung, 2011, p. 6889).

On the other hand, the government was eager to promote the domestic nuclear power industry. The 1990s had seen the development of the Korean Standard Nuclear Power Plant (KSNP), which was based almost entirely on indigenous technology and was used in all new reactors built in South Korea starting in the late 1990s. The following decade saw the development of a successor to the KSNP, the Advanced Power Reactor (APR 1400), which was to be marketed for export. Indeed, the government hoped to capture 20 percent of the world market for new commercial reactors, a market that was expected to generate some $400 billion in revenues by 2030 (Leem, 2010; WNA, 2013; Sheen, 2011, p. 277). These hopes were bolstered in December 2009, when a Korean–led consortium won the contract to build four reactors in the United Arab Emirates over more seasoned competitors from France and Japan (O'Donnell, 2013, p. 3).

B. **Demand Side Measures**

The 2008 energy plan contained targets for both energy consumption and production. On the demand side, it – and the updated Basic Rational Energy Utilization Plan – set a goal of reducing energy intensity by 46 percent by 2030, or an average of 2.6 percent per year, and cutting overall energy consumption by 42 million tons of oil equivalent (mtoe), or 12 percent, below

BAU projections (Kim, Shin & Chung, 2011, p. 6888; IEA, 2012a, p. 41; MOTIE, 2014, p. 6). To do so, the plan called for a paradigm shift in energy demand policy. Henceforth, the government would engage in the active management of energy demand, establishing energy savings targets for each sector, letting energy prices properly reflect costs, and using a mix of regulations and incentives to promote conservation (Choi, 2009, p. 9).

The industrial sector, which accounted for approximately half of all energy consumption, was expected to reduce energy use by 16.7 mtoe, or 12.5 percent below the BAU scenario. Here a principal tool would be "negotiated agreements" between the government and large energy consuming companies to reduce the latters' energy use. The policy would initially apply to only the largest consumers, those using more than 550 thousand tons of oil equivalent (ktoe) per year, but it would quickly be broadened to include those with annual consumption as low as 20 ktoe. As an incentive, businesses that invested in energy-saving technology would be entitled to subsidies covering up to 20 percent of the cost (IEEJ, 2010; ABB, 2011, p. 5; UNEP, 2010, p. 24).

The transportation sector was expected to cut energy consumption by 7.0 mtoe, or 15.1 percent below the BAU projections. The principal measure to be used here was a significant tightening of the fuel economy standards for automobiles. In 2009, the government announced that all cars would have to achieve 17 kilometers per liter (km/l) or produce no more than 140 grams of CO_2 emissions per kilometer by 2015. This goal represented a significant increase over the existing standards of 12.4 km/l for vehicles with an engine displacement of 1500cc or less and 9.6 km/l for larger cars (IEEJ, 2010; IEA, 2006, p. 65; UNEP, 2010, p. 30; IEA, 2012a, p. 9). In 2010, the government also introduced a Green-Car Promotion

Strategy to encourage the deployment of 1.3 million low emission cars, including electric and hydrogen-powered vehicles (IEA, 2012a, p. 35).

In the residential and commercial sectors, the target was a reduction of 12.0 mtoe, or 20.3 percent below the BAU projection (IEEJ, 2010). Here a number of measures were relied upon. One was a complete ban on inefficient incandescent light bulbs by 2013. Energy efficiency requirements were expanded to cover all buildings. A new building code required all new residential complexes of more than 20 units to improve energy efficiency by at least 20 percent over the existing structures. And a 2009 economic stimulus package included $6.2 billion to improve the energy efficiency in buildings (UNEP, 2010, pp. 24 and 32; MKE, 2012, p. 13; IEA, 2012a, p. 42).

B. **Supply Side Measures**

On the supply side, the 2008 National Energy Plan called for replacing a substantial share of the energy provided by fossil fuels with nuclear power and renewable sources of energy. South Korea's reliance on fossil fuels would drop from 83 to 61 percent of PEC, and that of oil from 43 to 33 percent, by 2030. At the same time, the amount of oil and gas produced with the involvement of South Korean companies would rise from just four percent to 40 percent, thereby resulting in an increase in "energy self-reliance" from 27.5 percent to 65 percent (OPM, 2014, p. 62; MOTIE, 2014, p. 4).

1. Nuclear Power

Given the overall goals of the plan with regard to reducing energy import dependence and greenhouse gas emissions, South Korea had no choice but to increase its reliance on nuclear power. The plan called for raising nuclear power's share of PEC from 15 to 28 percent and of all electricity to an astounding 59 percent. Achieving these targets would require increasing the number of reactors from 21 to 38 or 39 and the total nuclear generating capacity from 17.7 to 43 GW at a cost of some $32 to $40 billion (Sheen, 2011, p. 275).

Table 1: Projected Growth of Nuclear Power

As impressive as these numbers may seem, the plan did little more than ratify targets that had been set in previous years. In the 2000 Basic Plan for Long-Term Electricity Supply and Demand, the government planned to build eight more reactors by 2014, for a total of 28, and expected to construct an additional eight by 2030, for a total of 36. Likewise, the earlier Third Comprehensive Nuclear Energy Development Plan, covering the years 2007-2011, anticipated that nuclear power would account for 60 percent of electricity generation in the future (Leem, 2006, p. 447). Nevertheless, given the current size of the nuclear power sector, the achievement of these targets would still require a major effort.

2. New and Renewable Sources of Energy

The targets for increases in new and renewable sources of energy contained in the 2008 energy plan were nearly as ambitious, although some of the details were only spelled out in the Third

Basic Plan for New and Renewable Energy, which was issued in December 2008. The plans called for a rough doubling of the amount of renewable energy expected to be available under BAU assumptions by 2030, from a previously forecast 5.7 percent to the now projected 11 percent (Hunton & Williams, 2010; KEMCO, n.d.). According to one estimate, achieving the new target would require a total investment of 111.4 trillion South Korean Won by 2030, of which the government would provide just over one quarter (32 trillion Won) (Jones & Woo, 2010, p. 22).

Much of the increase would come in the electric power sector, where the contribution from renewables would rise from less than one percent to around 12 percent (39.5 TWh) by 2030. Overall, renewable generating capacity would grow from just 657 MW in 2008 to some 10.8 GW in 2030 (Lee, 2010, p. 21). Of this, wind power would account for some two-thirds, or 7.3 GW of capacity, and it would make the largest single contribution to renewable power generation, 16.6 TWh or 42 percent (IEA Wind, 2012, p. 189).

To help achieve these ambitious targets, South Korea planned to introduce a Renewable Portfolio Standard (RPS) in 2012. The RPS would replace the 2002 FIT, which had been found to be relatively ineffective. By 2013, the government had already spent some 1.4 trillion Won with limited results, and the annual cost was rising. In addition, the FIT provided little or no incentive to improve technology (interviews). Under the RPS, the 13 largest power producers (those generating more than 500 MWh per year) would have to generate or purchase a rising share of their power from renewable sources. The requirement would start at 2 percent in 2012 and gradually rise to 10 percent by 2022 (UNEP, 2010, p. 28; IEA, 2012a, p. 96).

The RPS would be supplemented by several other programs intended to foster increased use of renewable energy. A pre-existing program to promote the deployment of photovoltaic (PV) systems on 100,000 roofs was broadened and expanded as the One Million Green Homes program, which would embrace the installation of wind power and solar thermal as well as PV systems (ABB, 2011, p. 3; IEA, 2012a, pp. 35 and 95). In 2011, the government required that new buildings of over 1000 square meters obtain an increased share of their energy, starting at 10 percent and rising to 20 percent in 2020, from renewable sources. And the government planned to adopt a renewable fuel standard (RFS) that would require wholesalers to include a growing share of biodiesel in the transportation fuel supply (Lee, 2010, p. 17; UNEP, 2010). In fact, the bulk of South Korea's renewable energy – nearly two-thirds -- would come from the use of waste and biomass (UNEP, 2010, p. 27; Lee, 2010, p. 19).

IV. <u>**Obstacles to Implementation**</u>

The 2008 National Energy Plan contained ambitious targets, especially in the key areas of energy efficiency, nuclear power, and new and renewable energy sources. Thus it was clear from the outset that their achievement would not be easy. To the contrary, the implementation of each set of targets would face numerous and often substantial challenges.

A. **Obstacles to Reducing Energy Intensity**

Of the three major focal points of the plan, the targets for improvements in energy efficiency appeared to be the most feasible. One reason was simply that South Korea's energy intensity was relatively high to begin with, on the order of 50 percent higher than in Japan, and the government had made relatively little effort to try to reduce it over the years (IEA, 2012b, p. 53). Nevertheless, reducing energy intensity by a significant amount would be challenging, for at least several reasons.

One was the fact that a large percentage of South Korea's energy consumption was concentrated in a small number of energy-intensive industries, especially steel and petrochemicals. Both industry as a whole and energy-intensive industry in particular accounted for shares of South Korea's GDP, about 28 percent and 12 percent, respectively, that were well above the OECD averages. As a result, industry's share of final energy consumption was large and rising, going from 42 percent in 1990 to 55 percent in 2009, and some 62 percent of this went to energy-intensive industries. Within the industrial sector that year, petrochemicals accounted for the largest share, roughly 50 percent, of energy use and steel for another third. Since most of the former consisted of feed stocks, however, there was little room for reducing consumption without making equivalent cuts in output. Meanwhile, the steel industry was becoming less energy efficient, with energy used per ton of steel produced growing by more than one percent per year between 1990 and 2008 (UNEP, 2010, p. 9; ABB, 2011, pp. 2 and 5-6; IEA, 2012a, p. 18; Jones & Yoo, 2010, p. 24; Kim, Shin & Chung, 2011, p. 6885). Thus it would be difficult to reduce South Korea's overall energy intensity by a substantial amount without significantly modifying the country's industrial structure.

A second challenge concerned electricity pricing. As noted above, South Korea's retail electricity rates as a whole have been relatively low by OECD standards, and those for industrial customers have been even lower, at less than 90 percent of the average rate. Indeed, in recent years, tariffs have reflected neither the actual cost of producing power nor its market value. As a result, KEPCO has run a substantial deficit, amounting to $2.75 billion in 2011 alone. And as long as rates remained low, customers had little incentive to reduce consumption. Yet the government has long been reluctant to raise electricity rates for political reasons. Many have feared that higher rates could cost jobs or cause inflation, and pricing decisions have required negotiations among multiple ministries because of their potentially broad impact on national life. And when the government did announce plans to introduce a pricing system that would allow KEPCO to pass fuel costs on to customers, in June 2009, the plan was suspended before being put into operation. It was only after South Korea suffered power shortages in September 2011 that KEPCO was able to raise rates repeatedly, but even then by less than needed to cover its increased outlays (IEEJ, 2010, p. 95; IEA, 2012a, pp. 86-90; Kim & Chance, 2012; Han, 2013; Patel, 2013; interviews).

Finally, some observers anticipated resistance, or at least a lack of support, by the state-run energy companies. As Vine, Rhee, and Lee wrote in 2006, KEPCO, KOGAS, and the Korea District Heating Corporation (KDHC) have been hesitant to promote energy efficiency for fear of reducing their sales (Vine, Rhee & Lee, 2006, p. 1109).

B. **Problems with Nuclear Power**

In the 2008 energy plan, South Korea staked much of its energy future on nuclear power. This decision may have been justified in view of the South Korea nuclear program's record of low operating costs, high average capacity factors, and no nuclear accidents. But there were reasons to doubt whether the target of obtaining nearly 60 percent of South Korea's electricity from nuclear power was feasible, or even wise.

One was heightened concern about the safety and reliability of South Korea's nuclear reactors, especially as the oldest ones approached and passed the end of their original operating lives. Public approval for nuclear power dropped to its lowest level in 15 years following the accident at Fukushima Daiichi in March 2011 (IEA, 2012a, p. 109). Indeed, 80 percent of the respondents to a February 2012 poll opposed extending the lifetimes of older reactors (Han & Humber, 2012). Then a series of incidents at Korean power plants put the issue of nuclear safety of Korea's own power plants squarely in the spotlight, further eroding public trust in the program. As a result, a March 2013 survey found that 63 percent of respondents considered Korea's nuclear reactors to be unsafe (Bloomberg, 2013; see also O'Donnell, 2013).

The problems started in early 2012, with a temporary power failure at the Kori power plant that went unreported for a month (Han & Humber, 2012). Then in June 2012, an unexplained alert signal at the Yeonggwang power plant triggered an automatic shutdown (Herman, 2012). In October 2012, microscopic cracks were found in control rod tunnels at another Yeonggwang unit undergoing inspection (Kwon, 2012). That same year, two reactors were shut down in the wake of the revelation that they contained thousands of parts that had been supplied with fake warranties over a period of 10 years. And in May 2013, two additional reactors were shut down and the start of two more was delayed when it was discovered that the safety certificates of key components had been fabricated after control cables failed to pass a safety test (Choe, 2013). Eventually, more than 100 government and industry officials, including a former KHNP CEO and a vice president at KEPCO, were indicted for corruption in the scandal. In response to these shutdowns and delays, the government ordered heavy electricity users to reduce their consumption by as much as 15 percent during the period of peak use in August 2013 (H. Lee, 2013a).

Beyond these incidents have been a set of deeper structural issues that critics have pointed to. Although all the nuclear power plants are located far from the main population center around Seoul, the oldest and most incident prone plant at Kori lies within 25 kilometers of two smaller cities with a combined population of 4.6 million. Another plant, at Wolsong, was allegedly built on an active fault line, yet with only a low level of seismic fortification in order to reduce construction costs. And all of South Korea's nuclear reactors are concentrated at just four locations, potentially raising the level of risk, as suggested by the cascading problems that occurred at Fukushima Daiichi (Leem, 2006, p. 448; Leem, 2010). Lying underneath all this has been a concern that over the years, the nuclear industry and associated government and regulatory bodies have grown too close to one another, resulting in a dangerous lack of objectivity, scrutiny, or accountability (H. Lee, 2013a; Choe, 2013b).

Reinforcing these general safety concerns has been a long history of local opposition to the construction of facilities associated with the nuclear power program. Under the Local Autonomy Act, local authorities have the power to block the construction of power plants, and since the 1990s, the development of new nuclear sites has met with intense local resistance. As a result, the government has elected to build all new reactors in and around the four power plants established in the 1970s and early 1980s. Thus, the IEA concluded as early as 2002, the need for local approval of power plants might eventually become a barrier to the long-term development of nuclear power (IEA, 2002, pp. 67-68; Leem, 2006, pp. 448 and 454).

In recent years, this local opposition has extended to ancillary facilities, such as high voltage transmission lines. Since 2008, protestors have been preventing the completion of a power line intended to connect two new reactors to industries in southeastern Korea (Choi, 2013; Cho & Chung, 2013).

Anti-nuclear nimbyism was likely to pose a particularly acute challenge to South Korea's efforts to build a long-term storage facility for nuclear waste. As Sung-Jin Leem has noted, the issue of storing nuclear waste has been one of the most controversial issues in South Korean politics. Government attempts to build nuclear waste disposal facilities have provoked violent resistance from local citizens. Indeed, anti-nuclear waste campaigns have played a central role in the history of South Korea's anti-nuclear movements (Leem, 2006, p. 448).[4]

South Korea recently opened an underground storage facility for low- and intermediate-level waste that covers two square kilometers. But the government has yet to establish a permanent repository for high-level waste. Thus all spent fuel continues to be stored at interim facilities at each reactor site (Leem, 2006, p. 459; Park, 2009).

Yet as South Korea ramped up its nuclear power program, the need for a long-term solution to the waste disposal problem would become only more pressing. At the end of 2009, KEPCO had accumulated more than 10 thousand tons of spent fuel. According to several estimates, the existing fuel storage is expected to reach capacity before 2020, and by sometime in the 2020s at the very latest. And estimates for the amount of spent fuel generated by 2100 exceed 100 thousand tons (Park, 2009; Ko & Kwon, 2009, p. 3484; IEA, 2012a, p. 106; Sheen, 2011, p. 276; Kang, 2012; Dalnoki-Veress et al., 2013, pp. 17-18).

To store this much waste, South Korea would need an underground disposal area of at least 20 square kilometers, or 10 times the size of the low/intermediate-level waste facility for which the government paid at least $2 billion. So finding sufficient storage space is likely to be enormously difficult and costly, and this problem will create an additional challenge to the sustainability of the nuclear power program (Park, 2009; Ko & Kwon, 2009, p. 3484; Sheen, 2011, p. 276; Dalnoki-Veress et al., 2013, p. 20).

One way to reduce South Korea's high-level waste storage requirements would be to reprocess and recycle used nuclear fuel. Reprocessing would enable South Korea to separate out uranium and plutonium, which could be reused in nuclear reactors. Using conventional reprocessing technology, South Korea could cut the amount of high-level nuclear waste by up to 50 percent, and a promising new technology, known as pyroprocessing, could raise that figure to as high as 95 percent. Reprocessing would also enable South Korea to reduce its uranium imports by a significant amount (Sheen, 2011, pp. 276-277; Y. Lee, 2013).

In fact, the South Korean government has been keen to acquire a complete nuclear fuel-cycle capability involving enrichment, the reprocessing of spent fuel, and the construction of fast reactors that can use large amounts of plutonium. Not only would doing so help to solve South Korea's spend fuel problem, but it would make the country a more competitive nuclear exporter. Having the complete fuel cycle would enable South Korea to provide purchasers of its reactors the full range of services for fueling the reactors and disposing of spent fuel (Dalnoki-Veress et al., 2013, p. 23).

But this hope has run up against U.S. concerns about nuclear proliferation. A 1973 agreement on nuclear cooperation between South Korea and the United States requires U.S.

consent for any reprocessing or enrichment activities related to U.S.-supplied materials and technology. The United States has thus far refused to grant such consent, however, for two main reasons. First, U.S. officials have believed that allowing South Korea to acquire a complete nuclear fuel cycle would undermine U.S. efforts to establish an effective global nuclear non-proliferation regime. To give a green light to South Korea would set a precedent that could be invoked by other countries that seek to acquire similar capabilities. Second, U.S officials have feared that South Korean engagement in enrichment and reprocessing would greatly complicate efforts to limit North Korea's own nuclear program (Sheen, 2011; Holt, 2013).

The two countries planned to reach a new agreement by 2014 that South Korea hoped would relax these restrictions, but negotiations reached an impasses in early 2013 and the parties simply agreed to extend the existing agreement for two years (Sheen, 2011, p. 278; WNA, 2013; Holt, 2013). And even if South Korea were able to overcome American proliferation concerns, pyroprocessing and the associated fast reactors would not be available on a scale sufficient to deal with the country's spent fuel for several decades even under the most optimistic assumptions (Dalnoki-Veress et al., 2013, p. 10).

C. **Challenges for New and Renewable Sources of Energy**

We finally turn to the challenges that have faced the achievement of the targets set for new and renewable sources of energy in the 2008 plan. As the United Nations Environment Program noted, the targets were relatively modest in comparison with those adopted in many similar countries (UNEP, 2010, p. 10). Even then, however, some South Korean experts regarded the 11 percent goal as highly ambitious and perhaps even impossible to achieve (interviews).

The first problem was the country's relatively limited renewable potential. Some 70 percent of South Korea is covered with mountains, where it is much more costly to install solar facilities and onshore wind turbines (IEA, 2012a, pp. 17 and 98). Meanwhile, the development of offshore wind is complicated by deep-sea foundation issues, concerns over fishery rights, military radar issues, and environmental concerns. As a result of such considerations, the Korea Institute of Energy Research (KIER) put South Korea's total wind power potential at just 25.8 GW (IEA, 2008, p. 190).

Like nuclear power, moreover, the development of new and renewable energy sources has been impeded by a complex approval process and local opposition. Unlike nuclear power, however, wind farms and other renewable power plants may have difficulty obtaining permits for connecting to the grid (IEA, 2008, p. 190). Thus by the end of 2012, South Korea had less than 500 MW of installed wind capacity, or just 200 MW more than at the end of 2008, and the total for solar power was not much greater. Achievement of the 7.3 GW target in the 2008 plan would depend heavily on the success of a single 2.5 GW offshore wind farm planned for the western coast. And achievement of the goals of the RPS would be artificially facilitated by including weighting factors for offshore wind installations, which would count as 1.5-2 times as much as onshore wind, depending on the distance from shore (IEA Wind, 2012, p. 118).

V. **Subsequent Adjustments in South Korean Energy Policy**

In response to changing circumstances, the South Korean government has already made significant adjustments in its energy policy since 2008. The biggest changes have occurred in the area of nuclear policy, primarily in response to the disaster at Fukushima Daiichi. Immediately after the March 2011 incident, the Ministry of Education, Science and Technology (MEST) conducted safety reviews of all of the nuclear reactors. The inspections found that all reactors could withstand the maximum strength quake or tsunami so far predicted to occur in South Korea, but they also identified 50 measures that could be taken to improve safety. As a result, the MEST planned to spend one trillion Won by the end of 2015 to implement the measures (WNN, 2011; NEA, 2011).[5]

Then in July 2011, a team from the International Atomic Energy Agency (IAEA), reviewed South Korea's nuclear safety regulatory system, which had until then been the responsibility of the MEST. At about the same time, the South Korean National Assembly passed a long-debated bill that established a new Nuclear Safety and Security Commission (NSSC). The NSSC was placed under the Office of the President in order to enhance its independence and to increase the country's regulatory capacity (NEA, 2011; Lee, 2012, p. 14).

In the wake of the subsequent revelations about problems with South Korea's own reactors, the government took additional measures to restore public confidence in the safety of the nuclear program. In order to ensure the quality and authenticity of all materials and parts, it banned independent purchases by power plants and required the KHNP to establish its own procurement office. It also relaxed the goal of limiting the scheduled maintenance of reactors to 30 days, placing more emphasis on ensuring reactor safety than restarting reactors as quickly as possible (Yonhap News, 2013).

In the area of energy efficiency, the most important development has concerned fuel economy in the transportation sector. In 2013, the government introduced new regulations that would raise the minimum fuel efficiency requirement for all passenger cars to 20 km/l from 2020. This represented an increase of nearly 20 percent above the target for 2015 (Newton, 2013).

Meanwhile, the MKE/MOTIE was developing the first comprehensive revision of the 2008 energy plan. The new plan was shaped by a number of considerations. One was a continued desire to reduce South Korea's CO2 emissions and fossil fuel imports while meeting a growing demand for electricity. Another was changed views about the desirability of nuclear power, which might result in less emphasis on that component of energy policy but also reinforced the need to obtain societal acceptance of the nuclear program. Partly as a result, greater emphasis was placed on involving the public from the outset of the planning process (interviews). Nevertheless, the nuclear lobby remained an influential voice in South Korean policymaking circles, and the government still wielded powerful tools for winning the support of local communities for new nuclear facilities. For example, it was estimated that construction and operation of a new power plant at Samcheok on the eastern coast would pump some $5.7 billion into the local economy (O'Donnell, 2013, p. 5).

At the same time, the planning had to take into account the problems encountered so far with the deployment of new and renewable sources, which had reinforced pre-existing doubts about the feasibility of achieving the 2008 targets. Indeed, the ministry convened a task force of 60 experts to reanalyze the potential for renewables. On the positive side of the ledger was the revolution in shale gas production in the United States and potentially elsewhere, which some hoped would ease some of the tensions in South Korean energy policy (interviews).

Indeed, as the outlines of the new plan emerged in late 2013, they seemed to reflect all of these considerations. A 60 member advisory group made up of representatives from industry, academia, and civic bodies recommended in October 2013 that the government reduce Korea's reliance on nuclear generated electricity in view of the drop in public confidence in the safety of nuclear power and the increasing unpopularity of the nuclear industry in the wake of the various scandals (Cho, 2013a). Specifically, the advisory group recommended that nuclear generating capacity be limited to 22 -- 29 percent of South Korea's total electricity generating capacity in 2035. This recommendation was "based upon consensus to minimize social conflict over the proportion of nuclear power generation" (National, 2013).

The government eventually adopted the upper end of this range (29 percent), which was presented as representing a significant decline from the figure of 41 percent contained in the 2008 National Energy Plan, although it was slightly higher than the then current share of about 25 percent (Cho, 2013a; Business Korea, 2013). In fact, however, the new national energy plan anticipated little relaxation of the previous goals for nuclear energy. Like the 2008 plan, it still called for a buildup to 34 GW of nuclear capacity by 2024 and an ultimate goal of nearly 43 GW, although the target date was now postponed from 2030 to 2035, and nuclear power would constitute a growing percentage of South Korea's primary energy consumption (MOTIE, 2014, pp. 35 and 44). The difference in the figures for the nuclear share of South Korea's power generating capacity probably reflected a significant increase in the total projected generating capacity, rather than a decline in the amount of nuclear capacity. Thus

South Korea would need to complete the 11 reactors that were already either under construction or planned by 2024 and then at least another handful and possibly more by 2035, depending on whether reactors started in the 1980s and 1990s were granted extensions of their operating licenses. As many as 13 or 14 were expected to expire by 2035 (Cho, 2013b; Cheung, 2014). It perhaps came as no surprise, then, when the government approved the construction of two more reactors at the end of January 2014 (UPI, 2014).

Any reduced reliance on nuclear power, moreover, would not be compensated by any significant increase in renewable power. A draft of the new Basic Plan for Long-Term Electricity Supply and Demand earlier in the year projected that the goal of 12 percent of electricity generation from renewables would be achieved by 2027, rather than 2030 as envisions in the 2008 plan (Jee-yeon Seo, 2013). But in the new national energy plan, both the working group and the government decided to maintain the overall renewable target of 11 percent of the total supply, and the government would now have five more years, until 2035, to attain it (National, 2013; MOTIE, 2014, p. 103).

Instead, South Korea might have to rely even more heavily on imported fossil fuels for power generation. Of these, coal would be the least expensive, but it would also result in the highest greenhouse gas emissions. Thus although the government indicated that it would not issue its targets for other sources of power until the end of 2014, natural gas was expected to be the main substitute for any planned reductions in reliance on nuclear power. Gas was considered cleaner than coal, and new plants could be built more easily near the cities where their output would be needed. But it was also likely to be much more expensive, perhaps more than four times so, than nuclear power, according to the new national energy plan (Cho, 2013a: MOTIE, 2014, p. 40).

The cost problem was exacerbated by the fact that electricity demand was expected to grow by 60 percent by 2027 and as much as 80 percent, to 816 Twh, by 2035. Thus, according to one estimate, South Korea could need to import as many as 25 million more tons of LNG at a cost approaching $20 billion per year by 2035 (Patel, 2013; H. Lee, 2013b; Cho, 2013a; MOTIE, 2014, p. 36). The government hoped to ease the problem by reducing electricity demand by as much as 15 percent below the projections, to 696 TWh, through a combination of higher electricity prices and efficiency improvements over the long term (Park, 2013; H. Lee, 2013b; MOTIE, 2014, p. 39). But even 43 GW of nuclear power operating at 90 percent capacity would meet less than half of this demand.

Thus many hopes for relief were rooted in the spreading shale gas revolution, which was expected to result in growing supplies of LNG and lower prices. The U.S. government had just started to approve the export of a growing volume of LNG, which would provide an additional source of supply for East Asia and put pressure on traditional sellers in the region to delink their prices from that of oil. Indeed, two Korean companies were among the first to sign long-term contracts with the new American LNG terminals, with deliveries beginning late in the decade. According to one industry executive, the delivery price to Asia would eventually fall from roughly $16 dollars per million British thermal units to $10 to $11. And over time, fracking was expected to spread to Australia and China, which were thought to have among the largest recoverable shale gas reserves in the world, thereby further adding to the liquidity of the regional gas market (Cho, 2013a; Harlan, 2013; Patel, 2013).

V. **Conclusion**

Even after the adoption of the new national energy plan in early 2014, a number of questions still surrounded South Korean energy policy. Especially in the critical area of nuclear power, the targets remained ambitious, and those for coal and natural gas had yet to be spelled out. Meanwhile, renewable sources of energy were expected to grow only slowly, while demand for electricity surged by at least half and possibly more. Thus it remained to be seen how the government would square its desire to reduce significantly its fossil fuel imports and CO2 emissions while continuing to power a growing economy. Doing all this while maintaining the safety and support of the South Korean people would remain a major challenge.

This challenge was not unique to South Korea, however. Both Japan and Taiwan have in recent years faced similar sets of problems. All three countries have had few indigenous fossil fuel resources, forcing them to rely almost entirely on imports of coal, oil, and natural gas. And since the 1970s, all three have invested heavily in nuclear energy. In more recent years, all three have struggled to balance the often competing goals of energy security, affordable energy supplies, and environmental sustainability, especially in the form of reducing greenhouse gas emissions. And all three have been constrained in these efforts by growing concerns about the safety of nuclear power as well as numerous obstacles to the large-scale deployment of renewable sources of energy. Knowing that the challenges they face are shared may offer little solace to South Korean leaders. But it also means that these countries may have opportunities to learn from one another as they struggle to determine the best way forward.

Notes

[1] This paper draws on interviews conducted with officials in South Korea's Ministry of Trade, Industry, and Energy and the Korea Energy Economics Institute in May 2013.

[2] It may be worth noting that these changes were not linear. Oil's share of PEC dropped steadily between 1978 and 1986, to below 50 percent, but it then rose back above 60 percent after the price of oil collapsed in the mid-1980s and did not begin to decline again until the mid-1990s. Conversely, coal continued its previous decline until the late 1970s, when it hit just 30 percent of PEC, but then rose to more than 40 percent in the mid-1980s, before beginning a second slide. Its share of PEC bottomed out at under 20 percent in the mid-1990s and since then has been rising gradually.

[3] English language summaries are "National Basic Energy Plan, Korea (2008-2030)," Retrieved from http://www.energyplus.or.kr/pdf/11_ing/110207_t2.pdf (accessed September 20, 2013), and "National Basic Plan for Energy (2008-2030)," Retrieved from http://www.apec-vc.or.kr/?p_name=database&query=view&unique_num=ED2008060121 (accessed September 20, 2013).

[4] Leem (2006) provides a history of the government's unsuccessful efforts to create nuclear waste storage facilities, dating back to at least 1980.

[5] For additional details, see Jong-tae Seo (2013).

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