

Less Energy, a Better Economy, and a Sustainable South Korea: An Energy Efficiency Scenario Analysis

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An energy efficiency scenario (Joint Institute for a Sustainable Energy and Environmental Future) demonstrates that an energy future built on the use of cost-effective, high-efficiency technologies is clearly within the grasp of South Korea and would justify a nuclear power moratorium with significantly lower carbon dioxide emissions. This is a promising result, especially because applications of other sustainable energy options, such as renewables, decentralized technologies, material recycling/reuse, ecologically based land use planning, forest conservation, sustainable agriculture, and redirection of economic development toward an environment-friendly industrial base, are not included in the analysis. Here lies one of the most fundamental policy choices of the new century: Will we build a sustainable energy and environmental future, or will we send forward the burdens and risks of a policy regime that is unwilling to value the future beyond the satisfaction of short-term interests and convenience? It is a critical time for South Korean policy making.

Key Words: *energy efficiency, sustainable development, scenario analysis, nuclear moratorium*

Future global development will depend on energy resources that are safe, reliable, and environmentally sound. Yet most countries continue to use fuels that are

nonrenewable and technologies that pose significant hazards to the environment and human health. There is a pressing need in the new century to adopt sustainable energy options, especially in the face of mounting evidence of global warming linked to fossil fuel use and the persisting threat of nuclear accidents, unresolved problems of radioactive waste disposal, and the specter of nuclear weapons proliferation associated with continued use of nuclear power. Recent progress in the fields of energy efficiency, energy conservation, alternative energy, and materials recycling and reuse make possible an energy transition built on a decentralized, renewable, and low-emission technology platform.

South Korea can be an active participant in building such a future. To do so, it will need to change its energy strategy. The country's energy policies over the past 30 years have mainly sought to assure stable energy supplies from fossil fuels and nuclear power. In 1999, imported coal, oil, natural gas, and uranium accounted for 98% of national energy supply, whereas nuclear power represented 29% of electrical generation capacity (13.7 GW), provided 43% of electricity supplied (103.1 TWh), and accounted for 14% of total national energy supply (Ministry of Commerce, Industry and Energy and Korea Energy Economics Institute [MOCIE/KEEI], 2000). The country's energy intensity rate has been and remains above the world average

and is actually increasing. Energy consumption in South Korea has grown so dramatically that it is now the 10th largest source of carbon dioxide (CO₂) emissions in the world (World Bank, 1999).²

Recognition that environmental problems associated with energy use must be addressed by the entire global community is beginning to be reflected in national policies. This includes South Korea, which is a signatory to the UN Framework Convention on Climate Change. In 1998, the national government announced a plan to voluntarily reduce greenhouse gas (GHG) emissions from the year 2018. As shown in this article, there are practical and economical energy strategies available to South Korea that can reduce GHG emissions at a much faster rate than was anticipated in the government's 1998 pronouncement. Pursuing these strategies would allow the country to secure an environmentally sustainable future and a more competitive economy.

The first step in creating a sustainable future is for South Korea to take advantage of the significant energy efficiency and conservation opportunities available to the country. Called the *Joint Institute for a Sustainable Energy and Environmental Future* (JISEEF), this strategy offers the society a future that reduces energy-related pollution, enables it to be a leader in addressing the problem of climate change, saves a significant amount of capital for consumers and businesses (compared to the existing unsustainable energy path), and restores balance between human life and nature that has been a key reason for Korea's long and successful history. More than 1,000 years ago, Korea was described as "silk-embroidered rivers and mountains." It is possible for the country to recapture this legacy even as the society pursues its contemporary ambitions.

JISEEF

JISEEF, created by the sponsorship of the W. Alton Jones Foundation, is designed to play an innovative and creative role in identifying and promoting opportunities for a sustainable future for the Korean peninsula. It serves as a catalyst for reform and a comprehensive response to interlocking energy, environmental, economic, and policy issues. A central part of its activities is to present new ideas for an ecologically responsible future, to encourage the two Koreas to advocate energy and environmental policies that can bring about such a future, and to offer practical models for pursuing a sustainable future for the peninsula.

JISEEF accomplishes its goals by linking a highly respected international research team organized by the Center for Energy and Environmental Policy with South Korea's foremost experts in the energy and environmental fields led by the Environmental Planning Institute of Seoul National University; the Research Institute for Energy, Environment and Economy of Kyungpook National University; and the Citizens' Institute for Environmental Studies of the Korea Federation of Environmental Movements. This unique organization is undertaking a series of studies and planning initiatives to identify and promote sustainable energy and environmental paths for South Korea. This represents an unprecedented nongovernmental arrangement to tackle major issues for the country's 21st century.

This article intends to introduce the results of the JISEEF initiatives prepared by an international team of 38 independent researchers using objective engineering and economic methods to evaluate more than 3,000 technology options for improving energy efficiency in South Korea. The JISEEF team identified a detailed, practical, and economical strategy to reduce South Korea's energy consumption while improving environmental quality and strengthening the national economy. These technologies already exist—no research and development breakthroughs are needed to implement the initiatives.

JISEEF provides South Korea's citizens with a clearly defined policy choice: one based on market development of energy services versus one based on monopoly investment planning. Because the latter option precludes vigorous pursuit of a more energy-efficient future, the JISEEF team has painstakingly examined the country's options, using objective methods and the best available engineering and economic databases, to determine if an efficiency-led future is viable. Its researchers have documented in detail an alternative path that is safer, environmentally sustainable, and economically more practical. Through a comprehensive study of energy efficiency opportunities addressing nearly all of the society's energy-using activities—from lighting to automobile and truck transportation, refrigeration, heating, air conditioning, and electricity service—JISEEF provides an action agenda for South Korea's public and private sectors to build a better future.

What follows is first a brief description of JISEEF's modeling approach, followed by an introduction of the Korean government's official "business-as-usual" (BAU) scenario devised by the KEEI in collaboration

with the Korean MOCIE. The BAU forecast includes information on energy consumption and CO₂ emissions by energy sector for the years of 2010 and 2020. To prepare our sustainable scenario analysis (JISEEF Scenario), a sectoral energy efficiency database for South Korea was built. Policy scenario methodology was reviewed, and energy efficiency potentials by energy sector were derived. Next, the JISEEF Scenario compared energy efficiency opportunities with nuclear power investment. In the final section, the energy and CO₂ impacts of a nuclear power moratorium are evaluated.

“Bottom-Up” Model

The JISEEF team adopted a bottom-up modeling approach that employs engineering and economic estimates of energy savings, emissions, and costs of different technologies to create a database for analysis of efficiency technology potentials. Often, these estimates can derive from actual results of the deployment of new technology in various applications. But impact estimates for technology that has not reached the market, even in the form of pilot or demonstration projects, requires estimations based on engineering design information and calculations.

The data needed to build a database that will adequately and credibly represent the technology choices available at the macrosocial scale can be daunting. Indeed, the large data requirements of a bottom-up analysis have led researchers, in certain instances, to prefer the less data-intensive “top-down” approach.³ South Korea’s data systems are quite extensive in their coverage of energy use by fuel type and sector. Data on a variety of energy supply technologies and existing equipment stocks are also readily available. However, limited information exists on high-efficiency technologies in South Korea’s markets.⁴

To address this data gap, the JISEEF team turned to databases prepared by U.S. and Japanese research organizations. Although one must be careful in the use of such data to ensure its applicability to South Korean circumstances (e.g., it was essential to recognize differences in U.S., Japanese, and South Korean building stocks),⁵ this strategy to address the detailed informational requirements for a bottom-up analysis can be analytically sound. Two important factors, in this regard, that can justify the use of international data sets are market competitiveness⁶ and international policy trends.⁷

The JISEEF team sought a method for its scenario analysis that could capture the benefits of both bottom-up and top-down approaches while pursuing a decision strategy to address the unavoidable problems associated with any model that avoided overly optimistic decisions of the potential for change in South Korea’s economy-environment-energy relationships. Toward that end, top-down modeling was embraced to establish the BAU forecast.⁸ The JISEEF team then employed a bottom-up analytical strategy to assess the potential for energy efficiency.

BAU Projections of Energy and CO₂

The JISEEF team has adopted the 1999 results of the KEEL/MOCIE model (MOCIE/KEEL, 1999) as the benchmark for its analyses. This choice was dictated by our desire to evaluate sustainable energy options against the South Korean government’s official BAU forecast for energy and CO₂ to the target year 2020.⁹ Major energy and economic assumptions used in the KEEL/MOCIE model and the forecasted results are presented in Table 1.

The growth rate for primary energy consumption in South Korea is projected to increase, but at a slower rate than that of the gross domestic product, throughout the forecast period. As a result, the official forecast anticipates a lower energy intensity rate for the national economy, declining from 0.40 in 1995 to 0.29 in 2020 (see Table 1). CO₂ emissions from the energy sector are projected to more than double, growing at an annual rate of 2.8% during the period from 1996 to 2020, from 101.8 million tons of carbon (MTC) in 1995 to 204.4 MTC in 2020. Per capita CO₂ emissions are projected to increase from 2.3 tons of carbon (TC) in 1995 to 3.7 TC in 2020, but CO₂ per unit of GDP and per unit of energy consumed are projected to decline through 2020. The trends in energy consumption and CO₂ emissions are associated with economic growth rates that project continued rapid development of South Korea, although at a slower pace than in the 1990s. Full recovery from the financial difficulties affecting the region since the end of 1997 is expected to occur by the end of 2001.¹⁰

Energy Efficiency Database

With the South Korean government’s BAU forecast for energy consumption and CO₂ emissions in 2020 as the benchmark, the JISEEF team has developed alter-

Table 1. Business-as-Usual Projections of Trends in Major Economic and Environmental Indicators

Major Indicator	1995	2000	2010	2020	Annual Growth (%)		
					96-00	01-10	11-20
Gross domestic product (GDP) (in billions of 1995 won)	377	461	784	1,163	4.1	5.4	4.0
Population (millions)	45.1	47.3	50.6	52.4	0.9	0.7	0.4
Primary energy consumption (MTOE)	150.4	191.1	271.2	332.2	4.9	3.6	2.1
CO ₂ emissions (million tons of carbon)	101.8	120.6	173.2	204.4	3.6	3.7	1.7
Energy/gross domestic product (TOE/in millions of 1995 won)	0.40	0.41	0.35	0.29	0.8	-1.8	-1.9
CO ₂ /GDP (tons of carbon/in millions of 1995 won)	0.27	0.26	0.22	0.18	-0.5	-1.7	-2.2
Final energy consumption (MTOE)	122.0	152.4	213.9	257.9	4.6	3.4	1.9

Source: Ministry of Commerce, Industry and Energy and Korea Energy Economics Institute (1999).

Note: MTOE = million tons of oil equivalent; TOE = tons of oil equivalent.

native scenarios for a sustainable energy and environmental future for South Korea. The first scenario developed (JISEEF) is focused on energy efficiency improvements only and is aimed at evaluating potential energy savings and CO₂ emission reductions.¹¹

The JISEEF team focused on specific technologies in each end-use sector as part of its construction of the JISEEF Scenario analysis. These technology categories were selected for two reasons: (a) They represent significant sources of energy consumption in South Korea, and (b) detailed data on current technology stocks in South Korea were available. In some instances, data limitations prevented the team from exploring energy efficiency improvements that have been found in studies of other countries to be significant (e.g., high-efficiency windows and doors, wall and roofing materials, and efficient building design strategies). The technology categories targeted in JISEEF for efficiency improvements in each sector are listed below:

Industrial sector:	Heat recovery upgrades
	Space conditioning upgrades
	Boiler and steam efficiency upgrades
	Motor drive efficiency upgrades
	Fuel switching
	Enhanced cogeneration
	Lighting upgrades
Transport sector:	Operation and maintenance upgrades
	Passenger car fuel efficiency upgrades
	Light and heavy truck fuel efficiency upgrades
	Bus fuel efficiency upgrades
	Rail, air, and marine transport efficiency upgrades
	Introduction of alternative fuel

	vehicles
Commercial sector:	Commercial space conditioning efficiency upgrades
	High-efficiency commercial lighting
	High-efficiency motor
	Building shell upgrades
Residential sector:	Residential space conditioning efficiency upgrades
	High-efficiency residential lighting
	High-efficiency residential refrigeration
	Fuel switching for water heating
	Housing shell upgrades

An Energy Efficiency Database by end-use sector has been constructed by the JISEEF team that is based on South Korea's energy end-use characteristics. It relies on comprehensive technology assessments conducted by the U.S. Department of Energy (DOE) and its five national laboratories, a consortium of independent, nongovernmental researchers in the United States that published *Energy Innovations* (Energy Innovations, 1997), and an independent, nongovernmental research team in Japan that published *Recommended Strategies for the Mitigation of CO₂ Emissions: Phase I* (Citizens' Alliance to Save the Atmosphere and Earth, 1997). These studies are used to complement data gathered from a full range of South Korea sources (including Korea Electric Power Corporation [KEPCO], 1997a, 1997b, 1997c, 1999; KEEL, 1997, 1998a, 1998b, 1999a, 1999b, 2000; Korea Energy Management Corporation, 1997a, 1997b, 1997c; Korea Institute of Construction Technology, 1999; Korea Institute for Industrial Economics and Trade [KIET], 1998; and MOCIE, 1998). This data-

base is in a spreadsheet format, in which row entries have energy-efficiency technologies and column entries contain energy and economic savings information, including percentage energy savings, incremental costs (to install and operate the improved technology), cost of conserved energy, and payback period.

For the industrial sector, two criteria were used to select efficiency technologies: energy savings from individual technology changes that are greater than 10%.¹² and a payback period of less than 5 years, with an average of 1.23 years. For the residential and commercial buildings sectors, technologies were selected that have a cost of conserved energy of less than 5¢/kWh.¹³ In the case of the transportation sector, efficiency measures with a payback period of less than 5 years were selected.

The database was subjected to validation checks by energy experts in South Korea, including members of KEEI. The JISEEF team has adjusted the technology matrix in the database to reflect existing South Korean data, and it has compared the matrix entries with comparable ones developed in bottom-up studies for Japan.¹⁴ Using the refined database, the team has conducted an alternative scenario analysis for each end-use sector to evaluate the potential energy savings from energy-efficiency improvements. From its estimated energy savings by fuel source, potential CO₂ emission reductions specific to each sector are then determined.

Policy Scenario Methodology and Results

The JISEEF team prepared three policy strategies for capturing the efficiency benefits identified in each end-use sector: a full-implementation scenario in which all identified cost-effective, technically feasible savings are realized; a major policy commitment strategy that would seek to realize 65% of the identified energy and CO₂ savings under the full-implementation scenario; and a modest policy commitment strategy that would capture 35% of identified savings of the full implementation scenario. These policy strategies are modeled after the recently published U.S. national study by the Interlaboratory Working Group (IWG, 1998, 2000).

Based on the efficiency technologies and measures identified by the U.S. IWG and other U.S., South Korean, and Japanese databases, the JISEEF team was able to develop a detailed, sector-by-sector forecast of

energy demand through 2010. It then extrapolated technological improvements from 2010 to the target year of 2020 by means of autonomous energy efficiency improvement indices estimated by the KIET.

A summary of energy and CO₂ savings from energy-efficiency improvements is shown below by energy sector. Most significant savings are from the industrial sector, followed by the electricity sector (see Table 2). Total savings in primary energy use and in CO₂ emissions from full implementation are 95.4 million tons of oil equivalent (MTOE) and 58.9 MTC, respectively. A major policy commitment strategy is expected to achieve a 19% savings in primary energy use and a 19% reduction in CO₂ emissions.

A Nuclear Power Moratorium for South Korea

To prepare an analytically sound strategy that can be used to accomplish a sustainable future for South Korea, the JISEEF team has defined an alternative energy scenario benchmarked against the South Korean government's BAU energy forecast for the year 2020. In particular, JISEEF contrasts a sustainable energy policy-based energy service strategy focused on efficiency improvements with the monopoly planning approach of the Long-Term Power Development Plan of MOCIE/KEPCO. The JISEEF Scenario describes a future for South Korea that could sustain economic development with significantly lower CO₂ emissions. The magnitude of the identified cost-effective efficiency opportunities in electricity use is compared below to the increase in electricity generation from new nuclear power plants that is forecasted by MOCIE/KEEI. The official estimate is that approximately 17 new nuclear power plants will be needed to generate 121.2 TWh (equivalent to 17.3 GW)¹⁵ by 2020 (MOCIE/KEEI, 1999).

Are cost-effective options for energy efficiency improvements in South Korea's future sufficient to enable the society to meet national economic objectives without the construction of additional nuclear power plants? JISEEF answers this question in the affirmative, based on careful, detailed analyses of the country's efficiency opportunities. The answer provided by the JISEEF Scenario is that an energy future built on the use of cost-effective, high-efficiency technologies is clearly within the grasp of South Korea and would justify a nuclear power moratorium.¹⁶ A key advantage of a moratorium policy would be the release of 30 trillion won (U.S.\$25 billion) for market-based

Table 2. Summary of Primary Energy Savings and Carbon Dioxide (CO₂) Emission Reductions in 2020 for the Joint Institute for a Sustainable Energy and Environmental Future Scenario by End-Use Sector (unit: million tons of oil equivalent, million tons of carbon)

Sector	Full Implementation		Major Policy Commitment	
Industrial savings				
Final energy	32.1	(25.0 ↓)	20.8	(16.3 ↓)
CO ₂	19.1	(25.2 ↓)	12.4	(16.4 ↓)
Transportation savings				
Final energy	16.5	(28.1 ↓)	10.7	(18.2 ↓)
CO ₂	13.3	(28.0 ↓)	8.6	(18.2 ↓)
Residential savings				
Final energy	14.7	(33.8 ↓)	9.6	(22.0 ↓)
CO ₂	9.6	(34.5 ↓)	6.2	(22.5 ↓)
Commercial savings				
Final energy	9.8	(35.8 ↓)	6.4	(23.3 ↓)
CO ₂	5.7	(35.3 ↓)	3.7	(22.9 ↓)
Reduced electricity losses^a				
Energy conversion	22.3	(28.7 ↓)	14.6	(18.7 ↓)
CO ₂	11.2	(28.7 ↓)	7.3	(18.7 ↓)
Total Savings				
Primary energy	95.4	(28.7 ↓)	62.1	(18.7 ↓)
CO ₂	58.9	(28.8 ↓)	38.2	(18.7 ↓)

Note: Percentages are in parentheses.

a. Denotes avoided energy losses and CO₂ emissions from conversion due to end-use energy savings.

Table 3. Electricity Savings in 2020 From the Joint Institute for a Sustainable Energy and Environmental Future Scenario (unit: million tons of oil equivalent)

End-Use Sector	Full Implementation	Major Commitment (65%)
End-use electricity savings		
Industrial	4.37	2.84
Transportation	0.13	0.08
Residential	1.01	0.66
Commercial	4.56	2.96
Total end-use electricity savings		
	10.07	6.54
Primary energy savings ^a	29.22	18.98

a. Primary energy savings are obtained by multiplying end-use electricity savings by a factor of 2.902, which is derived from Ministry of Commerce, Industry and Energy and Korea Energy Economics Institute (1999).

development of energy efficiency (and other) strategies to meet South Korea's energy needs in an ecologically responsible manner.

Electricity savings estimated by sector for the JISEEF Scenario are shown in Table 3. Electricity savings from full implementation for end uses targeted in the JISEEF Scenario amount to 10.1 MTOE, which is equivalent to 29.2 MTOE of primary energy savings.¹⁷ If the country champions JISEEF's major policy com-

Table 4. Nuclear Moratorium Through Energy Efficiency Improvements

Energy Options	Full Implementation
New nuclear plant capacity	30.3 MTOE (121.2 TWh)
Energy efficiency improvements (electricity)	33.6 MTOE (149.5 TWh)

Note: MTOE = million tons of oil equivalent; MTC = million tons of carbon.

mitment strategy to capture 65% of the electricity savings identified in JISEEF, it is possible to reduce electricity demand by 19.0 MTOE. The industrial and commercial sectors are projected to be major contributors to electricity savings from efficiency improvements identified in the JISEEF Scenario.

The estimated primary electricity savings of 29.2 MTOE in 2020 is derived from efficiency improvements in targeted energy uses, which account for 87% of the total electricity consumed by the society.¹⁸ Assuming that equivalent opportunities for efficiency improvements exist for uses of electricity that are included in the 13% of national electricity consumption not analyzed by JISEEF, the savings of 29.2 MTOE is equivalent to 33.6 MTOE (149.5 TWh) in the event of full implementation (see Table 4).¹⁹

