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

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and is actually increasing. Energy consumption in South Korea has grown so dramatically that it is now the 10th largest source of carbon dioxide (CO_2) 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 CO_2 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 CO_2 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 competitiveness[6] 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 CO_2

The JISSEF team has adopted the 1999 results of the KEEI/MOCIE model (MOCIE/KEEI, 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 CO_2 to the target year 2020.[9] Major energy and economic assumptions used in the KEEI/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). CO_2 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 CO_2 emissions are projected to increase from 2.3 tons of carbon (TC) in 1995 to 3.7 TC in 2020, but CO_2 per unit of GDP and per unit of energy consumed are projected to decline through 2020. The trends in energy consumption and CO_2 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 CO_2 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

					Annual Growth (%)		
Major Indicator	**1995**	**2000**	**2010**	**2020**	**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 CO_2 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
	Operation and maintenance upgrades
Transport sector:	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 CO_2 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; KEEI, 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 database 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 CO_2 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 CO_2 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 CO_2 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 CO_2 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 CO_2 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 CO_2 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 (CO_2) 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 CO_2 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).

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.

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 commitment 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]

On the other hand, the government calls for 30.3 MTOE (121.2 TWh) of new nuclear power capacity by 2020, which amounts to a doubling of electricity supply from this source (from 25.3 MTOE in 2000 to 55.6 MTOE in 2020). JISEEF has identified sufficient cost-effective energy efficiency improvements to enable South Korea to adopt a moratorium of all planned nuclear plant construction while meeting the same national economic objectives.

Although it can be shown that energy-efficiency opportunities exist to justify a nuclear power moratorium policy in South Korea, it may be difficult to realize all of the country's efficiency potential by 2020. A more realistic approach might consider the feasibility of capturing 65% of the country's efficiency potential through a major policy commitment strategy. To realize a nuclear power moratorium when only 65% of energy efficiency improvements are expected to be implemented, it is necessary to rethink the use of the country's existing and planned liquefied natural gas (LNG)–fired power plants.

In 2000, South Korean LNG combined cycle power plants ran at a 25% capacity factor (MOCIE, 2000), but that is projected to increase to 28% in 2020. Because this fuel is currently expensive, these plants are largely relegated to peak-load services. To meet the nuclear moratorium goal, additional generation of 24.0 TWh could be provided by increasing the capacity factor from 28% to 39% for existing and new LNG plants.[20] Such a step would increase fuel costs paid by South Korea's consumers and businesses. An initial estimate of the added fuel cost for more extensive use of LNG plants is 0.7 trillion won (or U.S.$0.6 billion).[21]

For this calculation, we assume an improvement in the heat rate of LNG plants from the 48.8% rate projected in the MOCIE/KEEI BAU forecast to a 60% rate anticipated by the United States and others (Pew Center, 1999).[22] Under these circumstances, the modest fuel cost increase occurred by increasing the LNG capacity factor could readily be offset by the net capital cost savings of 24.8 trillion won (U.S.$20.6 billion)[23] associated with the shift from nuclear power to energy efficiency to meet projected energy demand in 2020. Thus, by increased use of South Korea's LNG plants, it is possible to economically fulfill the objective of a nuclear moratorium even when only 65% of the country's identified efficiency gains are realized. At the same time, an increase in CO_2 emissions from LNG plants of only 0.21 MTC would result.[24]

Toward a Climate-Sensitive Energy Future

The JISEEF team estimates that full implementation of the JISEEF Scenario will yield energy savings of nearly 29% (i.e., a decrease of 95.4 MTOE) over official forecasts for 2020 and will cut CO_2 emissions by a similar rate (reducing national emissions by 58.9 MTC). Full implementation anticipates a national effort to capture all cost-effective energy efficiency measures identified by the JISEEF team. The major policy commitment strategy identifies energy and CO_2 savings of nearly 19% (corresponding to a decrease in energy use of 62.1 MTOE and emissions of 38.2 MTC) (see Table 5).

The aim of the JISEEF project is to create for South Korea a sustainable energy future. One standard of sustainability under investigation by the JISEEF team is to encourage South Korea to voluntarily seek to cap its emissions by 2020 at year 2000 levels. Measured by this yardstick, the JISEEF Scenario would help the country to make substantial progress toward meeting a year 2000 CO_2 cap. The official BAU forecast anticipates a near doubling of CO_2 emissions (from 120.6 MTC to 204.4 MTC). The JISEEF Scenario eliminates 70% of the MOCIE/KEEI projected growth in CO_2 emissions—a significant and positive step by any policy standard. This leaves only 24.9 MTC to be removed to achieve the stabilization cap of year 2020 emissions returning to year 2000 levels.

The JISEEF major policy commitment strategy will significantly cut expected CO_2 emissions while removing the need to build any nuclear power plants. To realize an additional 47.6 MTC of CO_2 reduction necessary to meet a year 2000 CO_2 gap, the JISEEF team is investigating scenarios that promote renewable energy use, take advantage of materials recycling and reuse, invest in new technologies (notably, fuel cells), and embrace sustainable development planning strategies to cut CO_2 emissions still further. Through these scenarios, JISEEF's partners are confident that they can offer practical pathways for creating sustainable energy choices for South Korea that also enable the society to meet a climate-sensitive goal of CO_2 emission stabilization.

Conclusion

In one future projected by MOCIE/KEEI, energy use and CO_2 emissions continue to rise rapidly. Indeed, the BAU forecast anticipates a 74% increase in

Table 5. Summary of Primary Energy Savings and Carbon Dioxide (CO_2) Emission Reductions in 2020 for the Joint Institute for a Sustainable Energy and Environmental Future Scenario by End Use Sector (unit: MTOE, MTC)

Sector	Full Implementation		Major Policy Commitment	
Total savings				
Primary energy	95.4	(28.7% ↓)	62.1	(18.7% ↓)
CO_2	58.9	(28.8% ↓)	38.2	(18.7% ↓)
MTOE in 1998	165.9	165.9		
MTOE in 2000: BAU	191.1	191.1		
MTOE in 2020: BAU[a]	332.2	332.2		
CO_2 emissions in 1998	101.0	101.0		
CO_2 emissions in 2000: BAU	120.6	120.6		
CO_2 emissions in 2020: BAU[a]	204.4	204.4		
Energy reduction with nuclear moratorium	30.3	27.7[b]		
CO_2 reduction with nuclear moratorium	58.9	38.0[c]		
CO_2 emissions in 2020 for JISEEF Scenario	145.5	166.4		
Additional CO_2 reduction needed to meet a Year 2000 emissions cap	24.9	45.8		

Note: MTOE = million tons of oil equivalent; MTC = million tons of carbon; BAU = business as usual; JISEEF = Joint Institute for a Sustainable Energy and Environmental Future.
a. The BAU forecast is provided in Ministry of Commerce, Industry and Energy and Korea Energy Economics Institute (1999).
b. Electricity savings of 21.8 MTOE derived from the 65% policy commitment are not enough to meet the 30.3 MTOE required for a nuclear moratorium. Liquefied natural gas (LNG) power plants are operated at a higher capacity factor with a higher heat rate, which increases energy consumption by 5.9 MTOE.
c. This figure is adjusted for increased emissions from LNG plants (38.2 – 0.2 million tons of carbon).

energy consumption and a 70% increase in CO_2 emissions. The latter projection is especially sobering because the BAU forecast assumes a major increase in nuclear power capacity; still, national CO_2 emissions grow substantially. Such a future also expands the country's social and environmental vulnerabilities through a dramatic escalation in the use of nuclear power. This is the future that South Korea's current energy managers offer. In the JISEEF alternative, the country can choose a sustainable future in which energy consumption and CO_2 emissions reach plateaus by 2015 at levels that are nearly one third less than conventional policy now expects. This sustainable future dramatically reduces energy-based pollution, frees up economic capital to serve important social needs, protects national and global ecological resources, and offers an opportunity for expanding public participation in the process of energy decision making.

Assuming that the year 1999 oil price of $27 per barrel and electricity price of 71 won (5.9¢) per kWh would be maintained through 2020, the JISEEF team estimates that the full implementation strategy of the JISEEF Scenario would yield economic savings of 43.5 trillion won (U.S.$36.3 billion) for South Korea in 2020.[25] Environmental benefits[26] in the form of CO_2 emission reductions from the JISEEF Scenario are also significant. According to Edmonds, Scott, Roop, and MacCracken (1999), reducing CO_2 emissions to 1990 levels will cost Japan approximately U.S.$324 (1992 dollars) per avoided TC in 2020 (assuming no emissions trading). The United States will have relatively lower marginal abatement costs (U.S.$170/TC avoided) but will bear the largest total costs because of the large amount of carbon reduction to be avoided (Edmonds et al., 1999).

Assuming a cost of U.S.$200 per avoided ton of carbon for South Korea,[27] the full implementation strategy, with its currently cost-effective efficiency opportunities, would save 14.2 trillion won (U.S.$11.8 billion) for the South Korean economy by 2020. Combining the economic and environmental savings (43.5 trillion won plus 14.2 trillion won under JISEEF's full implementation strategy), societal savings of 57.7 trillion won (U.S.$48.1 billion) can be expected in 2020.

Figure 1 depicts the supply curve of avoided CO_2 emissions under the full implementation strategy of the JISEEF Scenario. In this graph, the *y* axis denotes the cost per avoided ton of carbon, and the *x* axis denotes avoided carbon emissions. To calculate the unit cost of the avoided carbon emissions, the annual investment in each efficiency measure (for materials and labor) is divided by the annual carbon emissions avoided. Among the 28 aggregate measures displayed in Figure 1, commercial lighting is the least expensive measure to avoid CO_2 emissions in South Korea,

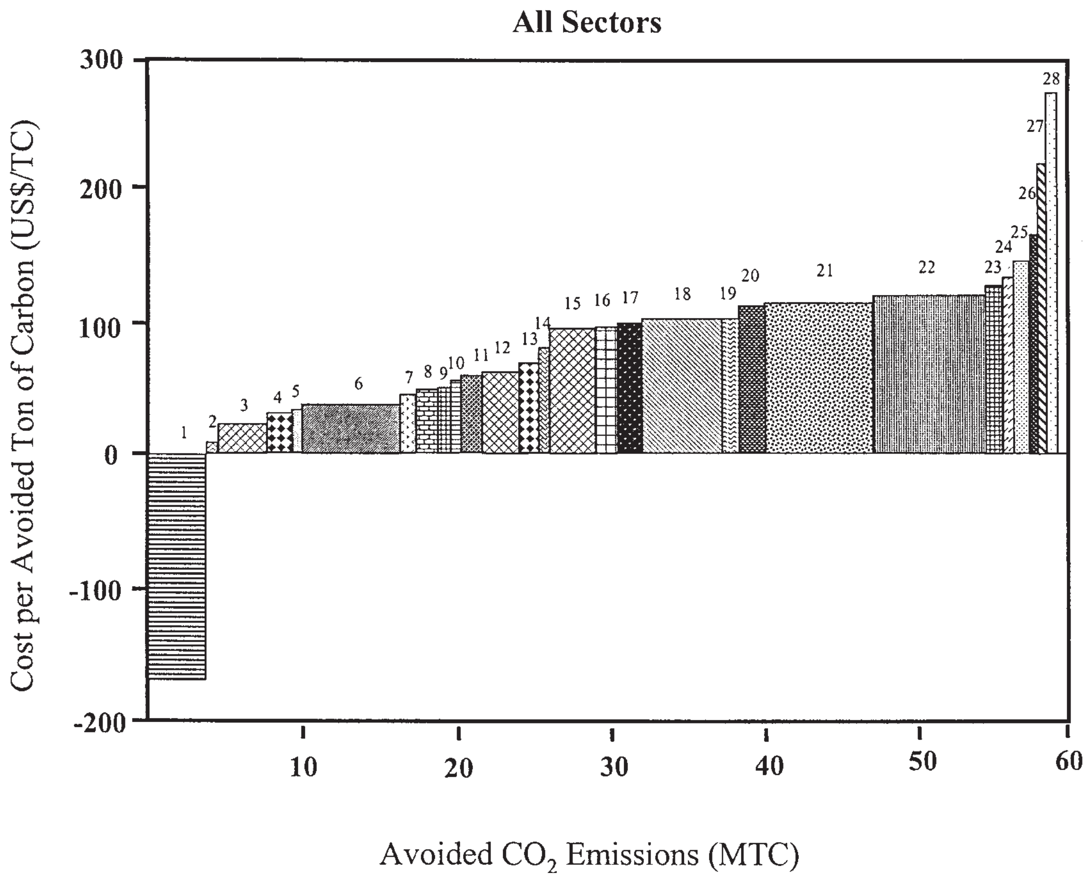

Figure 1. A Supply Curve of Avoided Carbon Dioxide Emissions in South Korea: Full Implementation Strategy
Note: MTC = million tons of carbon; TC = tons of carbon.

1. Commercial lighting upgrades
2. Improved industrial operation and maintenance improvments
3. Improved industrial combustion systems
4. Residential lighting upgrades
5. Improved industrial building and grounds
6. Improved industrial thermal systems
7. Commercial cooling upgrades
8. Commercial motor upgrades
9. Improved industrial motor drives
10. Commercial shell technology upgrades
11. Residential shell technology upgrades
12. Industrial others
13. Commercial others
14. Higher efficiency heavy-duty trucks
15. Residential others
16. Higher efficiency light-duty trucks
17. Commercial heating upgrades
18. Residential heating upgrades
19. Higher efficiency buses
20. Transportation others
21. Higher efficiency passenger cars
22. Cogeneration
23. Compressed natural gas buses
24. Residential air conditioning upgrades
25. Residential refrigeration upgrades
26. Compressed natural gas passenger cars
27. Electric vehicle passenger cars
28. Electric vehicle buses

whereas electric cars and buses are more expensive. The largest avoided CO_2 emissions in the JISEEF Scenario derive from industrial cogeneration (7.6 MTC), followed by efficiency upgrades for industrial thermal systems (6.9 MTC), fuel efficiency gains for passenger cars (6.8 MTC), residential heating upgrades (5.1 MTC), and commercial lighting improvements (3.9 MTC).

The total investment cost for JISEEF efficiency upgrades under the full implementation strategy amounts to 5.1 trillion won (U.S.$4.3 billion), and the avoided CO_2 emissions are 58.9 MTC, yielding a marginal cost of approximately 86 thousand won (U.S.$72) per avoided ton of carbon. Thus, the net benefits to the South Korean economy would be 52.6 trillion won (U.S.$43.8 billion) in 2020 (economic and environmental benefits of 57.7 trillion won minus a marginal investment cost of 5.1 trillion won). This is probably a conservative estimate because the uncertainties associated with petroleum prices, CO_2 abatement costs, and multiplier effects are likely to favor higher benefit values.

Can South Korea sustain its economic development without further construction of nuclear power plants? The JISEEF Scenario demonstrates that it is possible to meet forecasted national energy needs without additional nuclear power plants and with significantly lower CO_2 emissions. Moreover, JISEEF is likely to provide at least 19.6 trillion won (U.S.$16.3 billion) in net societal benefits. This is a promising result, especially because applications of other sustainable energy options, such as renewables, decentralized technologies, material recycling and 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.

The choice outlined here for South Korea is not for this country alone. All industrial countries must make equivalent decisions. Our planet can sustainably recycle approximately 3.3 tons of CO_2 per person per year, but all industrial countries are well above this rate (the U.S. rate is more than 20 tons of CO_2 per person per year; see Byrne, Wang, Lee, & Kim, 1998). An industrial BAU response to our global energy problem will risk climate change, environmental degradation (especially loss of biodiversity), and continued social inequality to serve the luxury appetites of the wealthy countries. The responsible alternative is to direct international efforts toward a climate-sensitive, sustainable energy future that replaces social, economic, and environmental risk with a livable world for future generations to appreciate.

Notes

1. The Joint Institute for a Sustainable Energy and Environmental Future (JISEEF) is an umbrella organization that relies on researchers from several institutions. The authors of this article have their primary appointments in the following institutions: Young-Doo Wang, John Byrne, Kyung-Jin Boo, Sun-Jin Yun, Yu Mi Mun, Chung-Kyung Kim, Yongkyeong Soh, and Takuo Yamaguchi, University of Delaware; Jung wk Kim, Seoul National University; and Jong dall Kim, Kyungbuk National University.

2. Carbon dioxide is the principal gas released by human activity that has been linked to the prospect of climate change (Intergovernmental Panel on Climate Change, 1990, 1996, 2001).

3. Top-down models rely on econometric methods to build multiequation descriptions of macroscale energy-environment-economy (E^3) interactions based on historical data. If existing conditions prevail in to the future, these models furnish a reliable picture of the interactive character of E^3 relations in a society, but they have limitations in this case because significant changes are poised to occur in the energy sector.

4. For example, information on annual purchases of existing lighting technologies can be found; and audit data exist from which reasonable estimates of the share of energy use for lighting needs in different buildings can be derived. But the performance of high-efficiency lighting in South Korean buildings compared to existing equipment could not be found in sufficient detail to calculate energy savings and costs.

5. It is important to note that the JISEEF Scenario has been subjected to peer review. In fact, reviews by South Korea's experts have occurred through extensive meetings and workshops held since July 1999 with organizations such as the Korea Energy Economics Institute; the Korea Environment Institute; the Korea Energy Management Corporation; the Korea Electric Power Corporation; the Ministry of Environment; the Ministry of Commerce, Industry and Energy; the President's Commission for Sustainable Development; and the Environmental Forum of the Korea National Assembly.

6. Adoption of technologies that improve efficiency and services are an important factor in maintaining competitiveness. South Korea's recent success in the international cell phone market is due to innovations introduced by a number of its companies. Just as South Korea industries can gain market share by technology innovation, it is also possible that its companies need to consider the adoption of high-efficiency technologies to maintain or expand their performance in competitive markets.

7. International policy trends in the environmental and energy areas suggest that competition for higher energy efficiency will become an increasingly important goal for industrialized and newly industrialized countries alike. International action to address climate change will place increased emphasis on energy efficiency and other sustainable energy options.

8. The Korea Energy Economics Institute and Ministry of Commerce, Industry and Energy forecast of a business-as-usual future for South Korea is based on a top-down model that modifies LEAP software developed at the Stockholm Environment Institute.

9. *Business as usual* (BAU) is a term used by energy researchers to refer to the likely demand for energy at a future date (in this study, that date is the year 2020) if there are no significant changes in the society, its economy, and its policies. The so-called BAU forecast offers Ministry of Commerce, Industry and Energy and Korea Energy Economics Institute's (MOCIE/KEEI's) best estimate of demand based on current knowledge and trends, and assumptions about future technology and economic changes. For our JISEEF analysis, we have used the BAU forecast of MOCIE/KEEI because these organizations have official responsibility for preparing national energy demand estimates (which are used in national

and international policy discussions). Our use of their forecast does not mean that we agree with its contents. Indeed, the JISEEF research team doubts the assumption of continued, rapid economic growth used to make the official BAU forecast. The team believes that slower growth is likely; however, this belief was not pursued in JISEEF in order to evaluate the government plan on its own terms.

10. The Asia-Pacific Energy Research Centre (1998), an arm of the Asia-Pacific Economic Cooperation, anticipated a somewhat slower recovery process than the MOCIE/KEEI projection. However, economic growth in 1999 and the first quarter of 2000 would suggest a rapid return to precrisis patterns.

11. Additional scenarios are being developed to incorporate such sustainable energy options as renewables, other decentralized generation technologies, materials recycling, and industrial restructuring (beyond that already anticipated in the official business as usual).

12. Discussions with industrial facility managers in the United States and South Korea indicated that small energy savings—even when cost-effective—can be ignored because staff planning time may be better used on projects with more significant impacts.

13. In the commercial lighting case, certain efficiency technologies have negative costs of conserved energy. This is due to the labor savings associated with a reduced need to replace longer lived halogen and compact fluorescent lamps.

14. See Citizens' Alliance to Save the Atmosphere and Earth (1997).

15. The calculation is based on an 80% capacity factor projected for nuclear plants by MOCIE (2000).

16. This study did not set out to prove the validity of a nuclear power moratorium. Rather, the finding that a moratorium is economically justified is an outcome of the detailed analysis conducted by the JISEEF team. One economic reservation to this finding might be that the marginal cost of nuclear power is lower than that of natural gas and, therefore, that gains in energy efficiency should be directed at reducing the use of liquified natural gas (LNG) power plants. In terms of marginal generation cost, nuclear power in South Korea may be a less expensive supply option, but such a conclusion ignores social and environmental costs, which may be much higher for nuclear power. In any case, LNG is used in the South Korean electricity system to serve intermediate and peak loads. However, the energy efficiency technologies analyzed by the JISEEF team address long-term, base-load electricity demand. Nuclear power is a base-load supply technology. Thus, energy efficiency is properly conceived as a competitor to nuclear power (and coal) to serve South Korea's base-load electricity markets. Because the cost of electric end-use efficiency improvements is much cheaper than nuclear power as a base-load option, a nuclear power moratorium is a logical conclusion of the JISEEF study of efficiency potential.

17. Primary energy savings include electricity savings by end users and the reduction in fuel consumption at power plants as a result of lower electricity use in industry, homes, and commercial buildings (currently, little electricity is consumed by South Korea's transportation sector). The conversion factor for primary energy savings is 2.902, which is derived from primary energy used in electric power generation divided by electric end-use consumption as reported by the MOCIE/KEEI in its 1999 report titled *The Third-Year Study of Planning National Actions for the United Nations Framework Convention on Climate Change* (December, but released for public use in autumn 2000).

18. In other words, end-use electricity consumed in South Korea amounts to 38.7 million tons of oil equivalent (MTOE), but the target end uses analyzed in the Joint Institute for a Sustainable Energy and Environmental Future Scenario account for only 33.7 MTOE of total end-use electricity consumption.

19. The conversion from MTOE to TWh in the case of nuclear power is based on the 1999 MOCIE/KEEI report, which uses the following factor: 1.0 MTOE $\ni$ 4.0 Twh.

20. According to the 1999 MOCIE/KEEI report, South Korea is expected to have LNG plants with a combined capacity of 25 GW (62.4 TWh) and operating at a 28% capacity factor in 2020. To increase electricity generation by 24 TWh, the capacity factor needs to increase by 11%.

21. We arrive at this figure by using the assumption made in the MOCIE/KEEI (1999) BAU that LNG prices would increase annually by 0.7% between 1999 and 2020.

22. Also see *Estimated Costs: Combined Cycle vs. Nuclear Plants* at http://www.ieer.org/ensec/no-5/table.html and *Greenhouse Gas Emissions from Power Station* at http://www.ieagreen.org.uk/emis5.htm.

23. The South Korean government estimate of the capital cost for nuclear power plants implies a 30 trillion won (U.S.$25 billion) payment for new nuclear generation by 2020. Our estimate of the capital cost of electricity efficiency upgrades in the major policy commitment strategy for the JISEEF is 3.4 trillion won (U.S.$2.8 billion—for a savings of 21.8 MTOE). This means that JISEEF offers capital savings of 26.6 trillion won (U.S.$22.2 billion) over the government long-term power development plan (with the added fuel cost of 0.7 trillion won—U.S.$0.6 billion) for extensive use of LNG plants).

24. Our calculation uses a conversion factor of 0.637 million tons of carbon (MTC) per 1 MTOE in the process of producing electricity from an LNG combined cycle power plant (MOCIE/KEEI, 1999). Assuming a higher capacity factor of 38.8% as projected here and the higher heat rate of 60%, LNG combined cycle plants would burn an additional 3.1 MTOE (4.2 * 44.8 / 60) of fuel instead of 4.2 MTOE to generate the 24 TWh needed to meet electricity demand under the major policy commitment scenario. This would lead to the release of an additional 1.97 MTC. But after applying the 60% heat rate to all LNG generation by 2020, the BAU-projected generation of 62.4 TWh needs only 8.15 MTOE instead of 10.92 MTOE fuel, reducing CO_2 emissions by 1.76 MTC, compared to the BAU forecast. Consequently, the net increase in CO_2 emissions would be only 0.21 MTC.

25. The MOCIE/KEEI forecast adopts the 1999 oil price for its forecast. The JISEEF team did not alter this assumption. Recent increases in world oil prices underscore the conservative character of this assumption. The assumed constant price of electricity through 2020 is mainly due to the effect of expected competition to be introduced by restructuring of the electricity sector. Of the primary energy savings of 95.4 MTOE, 33.6 MTOE that will be annually realized with full implementation of the JISEEF Scenario are electricity savings. The economic benefit of these savings is estimated to yield a value of 29.1 trillion won (U.S.$24.3 billion). The remaining savings of 61.8 MTOE are mostly in the form of oil imports that will be annually avoided with full implementation of JISEEF. The economic value of these avoided imports is 14.4 trillion won (U.S.$12 billion) based on an oil price of $27 per barrel in 2020 and a conversion factor of 7.21 barrels per 1.0 TOE.

26. Only CO_2 savings were considered here, but efficiency improvements offer many environmental benefits. For instance, increased energy efficiency reduces the release of not only CO_2 but SO_2, NOx, creosote, radon, TSP, and so forth. These pollutants adversely affect air and water quality and can elevate acid levels in soils that harm tree growth and threaten a variety of vegetation. Thus, it is likely that the JISEEF team's estimate of the JISEEF Scenario's benefits is conservative.

27. The $200 figure is based on the assumption that an international market for carbon emissions credits is established by 2020.

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