Greenhouse Gas Reduction Potential for South Korea[1]

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I. Trends and Future Projections in Energy and the Greenhouse Gas

South Korea's energy policies over the past 40 years have focused on securing stable energy supplies from fossil fuels and nuclear power. In 2000, imported energy, mainly coal, oil, natural gas and uranium, accounted for 97.2% of national energy supply. The country's energy intensity has been much above the world average and is still increasing. The energy consumption per capita grew from 2.17 tons of oil equivalent(TOE) in 1990 to 4.10 tons of oil equivalent(TOE) in 2000, higher than in Japan and Germany. South Korea was the tenth largest source of carbon dioxide (CO_2) emissions in the world as of 1999(World Bank, 1999).

South Korea has suffered environmental problems because of its heavy reliance on energy-intensive economy. South Korea's anthropogenic emissions of greenhouse gases in 1997 are shown in Table 1. Net CO_2 emissions in 1997 were 439.2 MT, and energy-related CO_2 emissions were 428.7, 98% of the total. South Korea's annual carbon dioxide emissions per capita are estimated to be 8.3 metric tons versus 20.8 metric tons in the United States (World Bank, 1999: 208-209).

The CO_2 emissions from fossil fuel combustion in the industrial sector contributed the largest share,

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Table 1. Greenhouse Gas Emissions and Sinks by Sector in South Korea (1997)

(Unit: 1,000 Tons)

Emissions Source	CO_2	CH_4	N_2O	NOx	CO	NMVOC
Net Emissions	439,206	3,041	24	1,837	4,316	2,088
Energy-Related Emissions	428,700	226	4	1,829	4,269	991
Industrial Process	33,981	19	11	9	46	1,096
Agriculture	-	603	9	-	-	-
Land Use and Forestry	-26,503	-	-	-	-	-
Waste Management	3,027	2,192	-	-	-	-

Source: MOCIE and KEEI. 1998. *The Second-Year Study of Planning National Actions for the United Nations Framework Convention on Climate Change*. December: 69.

Table 2. Projections of Trends in Major Economic and Environmental Indicators by MOCIE/KEEI

Major Indicator	1995	2000	2010	2020	Annual Growth (%)		
					96-00	01-10	11-20
GDP (In 1995 Won, Trillion)	377	461	784	1,163	4.1	5.4	4.0
Population (Million)	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 TC)	101.8	120.6	173.2	204.4	3.6	3.7	1.7
Energy/GDP (TOE/'95 Million Won)	0.40	0.41	0.35	0.29	0.8	-1.8	-1.9
CO_2/GDP (TC/'95 Million Won)	0.27	0.26	0.22	0.18	-0.5	-1.7	-2.2
Final Energy Consumption(MillionTOE)	122.0	152.4	213.9	257.9	4.6	3.4	1.9

Source: MOCIE/KEEI. 1999.

accounting for 35% of total CO_2 emissions in 1997. The electricity generation sector was the second largest source of CO_2 emissions, with a share of 25%. The shares for the transportation and the residential/commercial sectors were 22% and 17%, respectively. Even though the 1997-98 financial crisis dampened energy consumption and consequently reduced CO_2 emissions, South Korea resumed earlier trends, with the average annual growth rate of total CO_2 emissions being 0.8% during 1997-2000. The electricity and industrial sectors posted faster growth in 2000, surpassing 1997 levels. It is notable that despite South Korea's substantial investment in nuclear power, CO_2 emissions from electricity generation have grown faster recently than in any other.

The South Korean government's official forecast for energy and CO_2 is shown in Table 2. The CO_2 emissions from the energy sector are projected to more than double, growing at an annual rate of 2.8% during the period of 1996-2020, 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 TC in 1995 to 3.7 TC in 2020.

II. Greenhouse Gas Reduction Potential from Energy Efficiency Upgrading

An Energy Efficiency Database based on *Energy Innovations* (ASE et al., 1997) published by the U.S. Department of Energy (DOE) and its five national laboratories, a consortium of independent, non-governmental researchers in the U.S. and *Recommended Strategies for the Mitigation of* CO_2 *Emissions: Phase I* (CASA, 1997) was used to assess the potentials of energy savings and greenhouse gas reduction.

Industrial Sector

From 8,388 efficiency measures identified in the U.S. DOE's industrial assessment database for efficiency gains in all types of manufacturing, 2,832 measures were selected for the assessment. Each measure had to meet two criteria: energy savings greater than 10% for the particular manufacturing process involved; and payback periods of less than 5 years. The average payback period for all measures used in the analysis of this sector turned out to be 1.23 years. Full implementation of the efficiency upgrading is projected to realize a 25% reduction in industrial energy use (32.1 MTOE) and a 25% reduction in CO_2 emissions (23.4 MTC) in 2020 (see Table 3).

Transportation Sector

The principal targets for efficiency improvement in transportation sector are passenger cars, light-duty trucks and buses, and other transportation modes such as rail, marine and air transport. Passenger cars and light-duty trucks will account for 57% of energy use in the transportation sector and 56% of the sector's CO_2 emissions in 2020 in South Korea unless policy action is taken. The selected fuel economy improvement technologies for the target vehicles have payback periods of less than 5 years. The average payback period for all measures is less than 1.5 years. In addition, alternative fuel vehicles are projected to be introduced in 2020 in corporate and government fleets at modest rates (less than 3.5%). This is

Table 3. Greenhouse Gas Reduction from Efficiency Improvements in Industrial Sector

(Unit: MTOE/MTC)

Scenarios	Energy Use	Energy Savings	CO_2 Emissions	CO_2 Reduction
Business-As-Usual				
Industrial Sector	128.3	-	92.9	-
Targeted Industries	110.2	25.0%	83.0	25.2%
· Energy-Intensive Industries	76.9	24.4%	50.0	24.4%
· Non-Energy Intensive Industries	33.2	26.4%	33.1	26.4%
Efficiency Scenario	96.2	32.1(25.0%)	69.5	23.4(25.2%)

Table 4. Greenhouse Gas Reduction from Improvements in Transportation Sector

(Unit: MTOE/MTC)

Scenarios	Energy Use	Energy Savings	CO_2 Emissions	CO_2 Reduction
Business-As-Usual				
Transportation Sector	58.8	-	48.0	-
Targeted Technologies	58.8	28.1%	48.0	28.0%
· Passenger Cars	25.4	34.6%	19.7	35.7%
· Light-duty Trucks	8.3	24.2%	7.0	24.3%
· Heavy Trucks	4.2	23.6%	3.5	23.6%
· Buses	5.7	29.0%	4.8	28.4%
· Rail, Marine and Air	15.1	20.0%	13.0	19.3%
Efficiency Scenario	42.3	16.5(28.1%)	34.5	13.5(28.0%)

Table 5. Greenhouse Gas Reduction from Efficiency Improvements in Residential Sector

(Unit: MTOE/MTC)

Scenarios	Energy Use	Energy Savings	CO_2 Emissions	CO_2 Reduction
Business-As-Usual				
Residential Sector	43.4	-	35.4	-
Targeted Technologies	35.0	33.8%	27.4	34.5%
· Space Heating	32.0	26.9%	23.3	26.8%
· Air Conditioning	0.8	17.3%	1.0	17.3%
· Refrigeration	0.9	38.0%	1.2	38.0%
· Lighting	1.4	61.9%	1.9	61.9%
· Shell Technology Improvements	(1.9)	5.5%	(1.4)	5.1%
Efficiency Scenario	28.7	14.7(33.8%)	23.2	12.2(34.5%)

projected to realize a 28% reduction in energy use (16.5 MTOE) and a 28% reduction in CO_2 emissions (13.5 MTC) in 2020 (see Table 4).

Residential Sector

Target end uses considered in the residential sector are water heating, air conditioning, lighting, refrigeration and shell technology improvements. Energy used by these technologies will account for 81% of the sector's consumption and 77% of CO_2 emissions in 2020. For the analysis of this sector, high-efficiency technologies with a cost of conserved energy of less than 60 won/kWh (5¢/kWh) were selected. It is projected to realize a 34% decrease in energy use (14.7 MTOE) and a 35% reduction in CO_2 emissions (12.2 MTC) in 2020 (see Table 5).

Commercial Sector

In the commercial sector, HVAC (heating, ventilation and air conditioning) upgrades, shell improvements and the rapid diffusion of high-efficiency motors and high-efficiency lighting were the major target. HVAC systems, motors and lighting will be responsible for 83% of energy use in the commercial sector and 88% of CO_2 emissions in 2020 unless action is taken. Technology improvements were selected with a cost of conserved energy of less than 60 won/kWh (5¢/kWh). It is projected to realize a 36% savings in energy use (9.8 MTOE) and a 35% reduction in CO_2 emissions (9.9 MTC) in 2020 (see Table 6).

Summarizing the results, the primary energy can be saved by 95.4 MTOE, a 28.7% down from the BAU(business-as-usual) forecast and CO_2 emission can be reduced by 58.9 MTC, a 28.8% down from the BAU. The electricity savings amounts to 149.5 TWh which alleviate the need for constructing 17 nuclear power plants which can supply only 121.1 TWh as shown in Table 7. This shows that cost-effective options for energy efficiency improvements enable South Korea to meet national economic objectives without the construction of additional nuclear power plants, justifying a nuclear power moratorium. A key advantage of a moratorium policy would be the release of 30 trillion won (US$25 billion) for market-based development of energy efficiency (and other) strategies to meet South Korea's energy needs in an ecologically responsible way.

Figure 1 contrasts South Korea's projected primary energy consumption and CO_2 emissions in 2020 under the government's official forecast (MOCIE/KEEI, 1999) with the effects of full implementation of the energy efficiency improvement scenario.

Table 6. Greenhouse Gas Reduction from Efficiency Improvements in Commercial Sector

(Unit: MTOE/MTC)

Scenarios	Energy Use	Energy Savings	CO_2 Emissions	CO_2 Reduction
Business-As-Usual				
Commercial Sector	27.4	-	28.1	-
Targeted Technologies	22.8	35.8	24.8	35.3
· Space Heating	10.1	29.2	7.6	27.1
· Air Conditioning	2.4	39.0	3.3	39.0
· Lighting & Other	7.2	33.1	9.6	33.0
· Motor	3.2	42.0	4.3	42.0
· Shell Technology Improvements	(1.8)	7.8	(1.4)	5.5
Efficiency Scenario	17.6	9.8(35.8%)	18.3	9.9(35.3%)

Table 7. Summary of Primary Energy Savings and CO_2 Emission Reductions from Efficiency Improvement in 2020

Sector	Effect of Energy Efficiency Improvement
TOTAL SAVINGS	
· Primary Energy	95.4 MTOE(28.7% down)
· CO_2	58.9 MTC(28.8% down)
New Nuclear Plant Capacity	30.3 MTOE(121.2 TWh)
Energy Efficiency Improvements(Electricity)	33.6 MTOE(149.5 TWh)

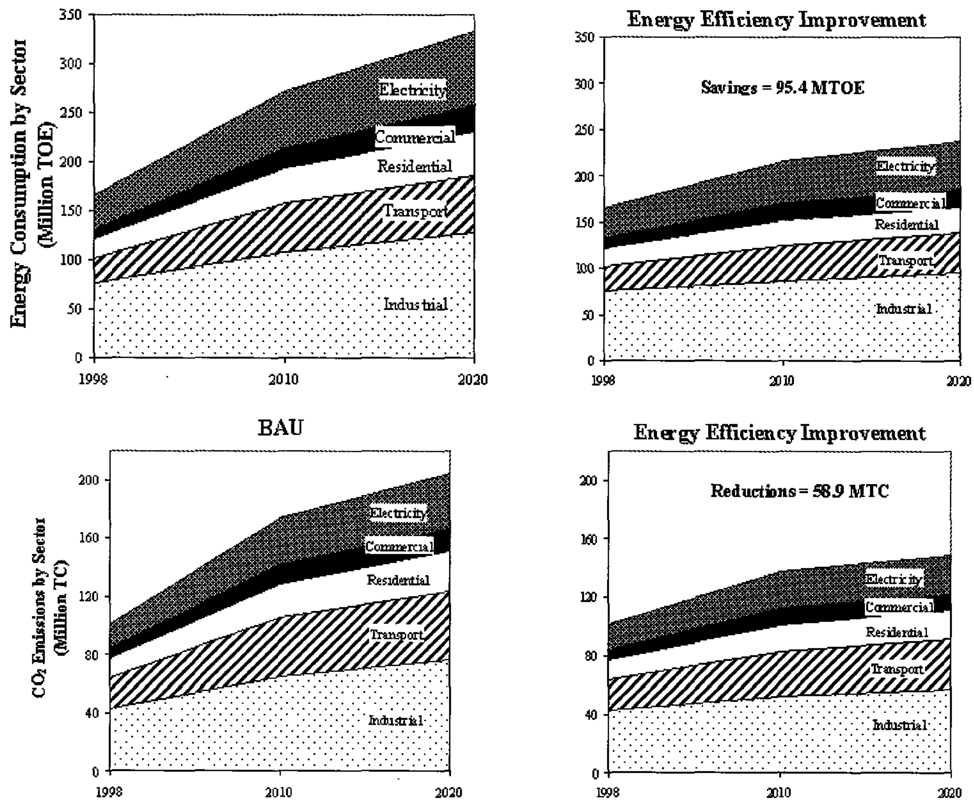

Figure 1. Energy Consumption and CO2 Emissions in 2020: BAU and the Energy Efficiency Improvement Scenario

III. Greenhouse Gas Reduction Potential in Land Use and Transportation

Transportation is the primary cause for the urban air pollution in Korea: it accounts for 87% of nitrogen oxides and 96% of hydrocarbons in Seoul(Jeon and Kim 1997), which are the main air pollutants causing the smog in the city. The air qualities in Korean metropolitan cities are much worse than other metropolitan cities in developed countries, even though the Korea's emission standards of automobiles are one of the tightest in the world. This means that the current transportation system in Korea is in great need of improvement to reduce the automobile trips. The energy use, especially that in transportation, varies markedly depending on the land use planning. The demand for transportation and energy can be reduced by improving the land use and the transportation system in such a way as to reduce the demand for automobile trip and the travel distance and to increase the share of mass transport and bicycle trip. Land use in national scale as well as urban scale affects the demands for energy and transportation. But it is not easy to assess the cause-effect analysis of land use and transportation system in national scale. So this study focuses on the urban land use and transportation system. Since the transportation accounts for about 20% of the total energy use in Korea(JISEEF, 1999), saving energy in this sector will have a significant effect on reducing GHGs.

The automobiles are the most important means of transportation in Korea: the share of automobiles in the passengers transportation was 81.7%, that of subway 10.7% and that of railroad 6.3% in 1997(JISEEF, 1999). Among the three, the number of automobiles is increasing the fastest. The number of automobiles is expected to grow two fold by 2020 according to the BAU scenario: the total number of vehicles is projected at over 22 million, nearly one car for every two persons.

The serious problem with the Korean transportation system is in that the distances automobiles travel are far longer than those in any other developed countries of the world. The sedan's mean distance traveled(MDT) in Korea is 25,696 km/year, which is far greater than the reported value of United States of America, 19,051 km/year, and 2.5 times that of Japan, 9,990 km/year(W.S. Kim, 1999).

The government is constructing local trunk roads to link between cities and surrounding regions to facilitate local transportation and national highways all over the country to link between every corners of the nation within 6 hours. Judging from the current transportation policies and trend, the automobile travel distances are by no means likely to decrease. The MDTs are projected to stay at almost the same level as the current level in spite of the increased number of cars as shown in Table 8 (SDI, 1998).

Some cities in the world have successfully improved their traffic conditions by reducing the traffic. In this sense, Korea needs to improve land use and transportation system in such a way to minimize the travel demand and subsequently the energy use. This will help improve the air qualities as well as reduce the GHGs emissions.

Policy Approach

Land use policies to reduce traffic and energy demand can be approached in diverse ways both in national and regional scale. The policies frequently discussed include expansion of bicycle road, building pedestrian-friendly environment, suppressing automobile trips by reducing parking space and

Table 8. Projected Mean Distance Traveled by Types of Cars

(unit: km/day)

			1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
sedan	gasoline		50.6	49.3	47.9	49.8	49.8	50.3	50.3	50.5	50.5	50.5
	taxi(LPG)		224.2	222.9	231.8	231.8	231.8	234.1	234.1	235.2	235.2	235.2
bus	small	gasoline	65.3	62.8	60.4	62.8	62.8	63.4	63.4	63.7	63.7	63.7
		Diesel	65.3	62.8	60.4	62.8	62.8	63.4	63.4	63.7	63.7	63.7
	medium		49.5	46.8	44.2	46.0	46.0	46.4	46.4	46.6	46.6	46.6
	large		182.5	187.2	179.2	186.4	186.4	188.2	188.2	189.1	189.1	189.1
truck	small		65.6	63.1	60.8	63.2	63.2	63.8	63.8	64.1	64.1	64.1
	medium		127.6	121.8	116.3	121.0	121.0	122.2	122.2	122.7	122.7	122.7
	large		89.8	89.9	83.8	87.2	87.2	88.0	88.0	88.5	88.5	88.5

reducing commutation distance.

(1) Expansion of bicycle road and building pedestrian-friendly roads

The share of bicycle transportation is very low in Korean cities: it was 0.5% in Seoul in 1997 compared with 48% in Beijing, 25% in Tokyo, 20% in Copenhagen, 8% in Manhattan, 3% in Toronto, and 2% in London. The main problem is with the extremely poor bicycle road system. Seoul City has 160.2 km of bicycle road in 1997 compared with 7,843 km of automobile road(Seoul Development Institute, 1998). Recently a plan called '5-Year Bicycle Plan' under a catch phrase of 'Green Transportation Policy' was announced by Seoul City government. It was to raise the share of bicycle to 3% by 2002. According to the proposal, the goal could be achieved by expanding the bicycle road to 862.2 km, which is equivalent to 11% of the total road length. It is expected that the number of bicycles would rise to 2 million from 1.46 million in 1997 with the expansion of the bicycle road. In this study it is proposed that by 2020, the bicycle share of transportation be increased to 9%, which would require expansion of bicycle roads up to 33% of the total vehicle roads.

(2) Reducing the commuting distance

Newman and Kenworthy(1989) pointed out that citizens depended more on automobile and less on bicycle and walking as the urban density got lower, from the study of 10 metropolitan cities of the world. In Tokyo and Hong Kong, whose population densities are 171 and 403, respectively, less than 16 % of the population use car for commuting, while in Phoenix whose population density is 13, 93% of the population depended upon car for commuting. They especially noticed that when the population density got below 30 - 40 persons per hectare, the automobile dependency showed sharp rise.

The commuting distance can be reduced by mixed land use planning such as constructing residential buildings in office areas. In Portland, Oregon which has a population of 2 million commuters, relocation

Table 9. Population Distribution by Commuting Time in Capital Area

VTT between office and home	Population, %
<10 mins.	8.87%
10~20 mins.	17.01%
20~30 mins.	20.88%
> 30mins.	46.76%

source: , Seoul metropolitan data '97
※ VTT: Vehicle Time Travelled

of 20,000(1% of the total commuters) resulted in reducing the city's average vehicle mileage by 0.5 mile a day.

In the Capital Area which includes Seoul City, Incheon City and Kyung-gi Do, 46.76% of the population live within 30 minutes of vehicle commuting distance(see Table 9). In Portland, Oregon, increase of population by 1% within 30 minutes of commuting time resulted in reducing the MDT by 1.8%. It is assumed that the MDT would decrease by 1.8% by relocating 0.3 million people out of 30 million in the Capital Area within 30 minutes commuting time zone. It is proposed to increase the population of the 30 minutes commuting time zone by 7% by 2020. Then, 12.6% decrease in MDT may be achieved.

(3) Reducing parking space

Newman and Kenworthy(1989) reported that the size of parking spaces showed a close relationship with the automobile dependency, after surveying 32 metropolitan cities. They found that each office building in metropolitan cities of the world have parking spaces for 150-200 automobiles in average, but some cities with high automobile dependency had parking spaces for over 500 autos per building. It is very clear that parking space can be an important constraint for driving car to the office building. So they suggested that metropolitan cities reduce the parking spaces not to exceed spaces for 200 cars per building in average. Other researches also showed that reducing parking space was effective for reducing traffic volume and CO_2 emissions. According to Dasgupta et al.(1994), halving parking spaces could reduce the traffic volume by 3-5% and CO_2 emissions by 3.5-5.5% in cities in the United Kingdom.

Seoul City had parking spaces for 1,566,473 cars in total, and the number of registered sedan cars in Seoul was 1,653,149 as of 1997. Accordingly, 94.7% of the cars have parking space within the city. Kyung-gi Province had parking spaces for 1,477,652 cars for 1,498,138 cars registered. This policy has been frequently blamed for causing the traffic congestion by inviting cars to the city. The case study in the United Kingdom showed that reducing parking spaces could be a useful tool to reduce the traffic.

Table 10. Summary of Policies and Their Effects

policies	effects	net effect in 2020
1. expand 2,586 km bicycle road → increase in TSR of bicycle by 9% 2. reduce parking space by 50% → decrease in MDT by 3.7% 3. increase population within 30 mins. commuting time zone by 7% → decrease in MDT by 12.6%	· decrease in TSR by 9% · decrease in MDT by 16.3%	Traffic: 23% ↓ (= 100 - 91 × 0.837) Energy: 9.7 MTOE ↓ CO_2: 7.9MTC ↓

※ TSR(Transportation share ratio)
MDT(Mean distance travelled)

Reducing the parking spaces by 50% by 2020 was set as a possible scenario following the British example.

Reduction Potential

These three policies proposed above and their effects are summarized in Table 10.

We can reduce the traffic demand considerably just by expanding bicycle roads, reducing parking spaces and relocating commuters closer to their work places. If the policies suggested in this study, which has been proved effective in other countries, are fully implemented, the traffic demand could be reduced by 23%. This can further reduce the energy use by 9.7 MTOE and CO_2 emission by 7.9 MTC in 2020.

IV. Greenhouse Gas Reduction Potential in Agricultural Sector

The GHGs emissions arise from a variety of sources including methane(CH_4) from rice paddies and livestock, nitrous oxide (N_2O) from the use of nitrogenous fertilizer, cultivated soils and feedlots, and carbon dioxide(CO_2) from the consumption of energy used in farming machines and heating of green house.

The beneficial role of agriculture in sequestering GHGs used not to be counted in assessing the GHGs emissions in Korea(Office for Government Policy Coordination, 1999).[3] The agriculture can reduce the

3) According to the documents on climate change issued by the government, the agricultural sector was simply considered as an emitter of GHGs while the forestry was regarded as a creditor of GHGs. And in projecting the future emission of GHGs, the increase in energy and GHGs emission from mechanization and greenhouse farming was not considered. Thus, according to the Comprehensive Plan for Climate Change Strategies made by the government, it is predicted that the GHGs emissions from the agricultural sector would reach 2.56 million TC in 2020, which is 1.0% of the total down from 2.2% in 1995.

amount of atmospheric CO_2 through biomass production, especially through integrated ecological farming systems including rotation of crops, crop mixing, improved irrigation system, management of nutrient budgets, livestock waste management, and conserved tillage.

There have been conflicting opinions regarding the contribution of paddy land in GHGs. Some western countries see the paddy land as a main source of methane and insist that the GHGs emission tax should be imposed on the rice-producing countries in the East and Southeast Asia(Ministry of Environment, 1997). In 1992, the rice paddies in South Korea was estimated to produce 399,000 metric tons of methane. But the carbon dioxide absorbed in the same year by the paddies was estimated at 18,975,000 metric tons(JISEEF, 1999). Since the methane gas is considered to be 11 times more effective in warming up the globe than carbon dioxide, the net effect of the rice paddies will be absorption of 14,586,000 tons of carbon dioxide, which is more than 4 times the global warming effect of methane gas produced by the paddies(see Table 11). Therefore, rice paddies should be considered as GHGs creditor, not an emitter.

The rice paddies in South Korea have been rapidly converted into other land uses such as urban, industrial and resort development because farming is not economically attractive at all, thus lowering the self-reliance rate of food in South Korea down below 30%. Therefore it was regarded as very important to suppress the reckless conversion of rice paddies to other land uses to a minimum to secure a certain acreage of land for rice production.

The Emission of GHGs and Sequestration

(1) Emission

The main emission sources of GHGs are methane(CH_4) from paddy land, nitrous oxide(N_2O) from the use of chemical fertilizer, methane(CH_4) from the livestock raising, and carbon dioxide(CO_2) from the energy consumption for machine and greenhouse farming.

The projected emissions of GHGs in agriculture in whole are summarized in table 12(J.W. Kim et al., 2002). Some important messages of the results can be pointed out as follows.

-The emission of GHGs from rice paddies is expected to decrease and its contribution to the total GHGs in agricultural sector also: from 47% in 1985 to 23% in 2020. It will not be the major emission source of GHGs in agricultural sector anymore in the future.

Table 11. The Carbon Dioxide Absorbed and Methane Produced by the Rice Paddies In South Korea(as of 1992)

CO_2 absorbed	CH_4 produced	equivalent CO_2 produced(11 times CH_4)	net CO_2 absorbed
18,975,000t	399,000t	4,389,000	14,586,000

Table 12. The Projected Emission of GHGs in Agricultural Sector(BAU)

		1985	1990	1995	2000	2005	2010	2020
CH_4 from Paddy	emission(1000 TC)	2,322	2,407	1,992	1,920	1,820	1,820	1,820
	percent to the total	47%	42%	32%	27%	24%	24%	23%
N_2O	1000 TC	696	934	776	749	708	667	667
	percent to the total	14%	17%	12%	11%	10%	9%	8%
CH_4 from Livestock	1000 TC	1,195	1,043	1,470	1,510	1,575	1,640	1,770
	percent to the total	24%	18%	23%	21%	21%	22%	22%
CO_2 from Energy Use	1000 TC	726	1,251	2,090	2,925	3,343	3,510	3,677
	percent to the total	15%	22%	33%	41%	45%	46%	46%
total	1000 TC	4,939	5,635	6,328	7,104	7,446	7,637	7,934
	growth rate	basis	14%▲	28%▲	43%▲	50%▲	54%▲	60%▲

-The emission of N_2O from nitrogenous fertilizer is expected to remain steady, but its contribution to the total GHGs will decrease in the future: from 14% in 1985 to 8% in 2020.

-The emission of CH_4 from the livestock farming will increase, but the contribution to the total is expected to remain almost the same: from 24% in 1985 to 22% in 2020.

-The contribution of energy use for farming machines and greenhouse is growing rapidly and is becoming the major source of GHGs in agriculture. In 1985, it accounted for only 15% of the total GHGs emission. But it is expected to reach more than 46% of the total in 2020.

(2) Sequestration

Well-managed agricultural resources can increase both the environmental benefits and the efficiency of agricultural production. But the role of agriculture in reducing CO_2 has been almost neglected. The sequestration effect of agriculture for GHGs has decreased continually, mainly because the farming area has decreased..

The GHGs sequestration effect of agriculture depends on the kind of crops. The sequestration of GHGs is estimated from each crop's capacity of carbon assimilation and its farming area as in Table 13.

The Staple food crops such as grains, beans and potato are better than non-staple crops such as vegetables and fruits in terms of both sequestration and food security(see Table 14). The government has tried to preserve especially the rice paddies for food security by banning conversion of rice paddies to other land uses but unsuccessfully. Other grain crops, without the government's supportive policy, have fallen down much more rapidly. The BAU analysis shows that the farming area for staple crops other than rice in 2020 would fall to 34% of that in 1985.

Table 13. The CO_2 Absorption Capacities of Crops

(unit: 1000 tons/year, as of 1993)

grains	rice	16,351
	other 9 major grains	2,624
	sub-total	18,975
vegetables	fruits	67
	leaves	146
	roots	212
	sub-total	425

Table 14. Sequestration of GHGs in Agricultural Sector

(unit: 1000 TC)

	1985	1990	1995	2000	2005	2010
Staple Crops	8,108	7,603	6,136	5,835	5,560	5,414
Rice	5,635	5,669	4,811	4,691	4,560	4,560
Other Staple Crops (barley, miscellaneous grains, pulse and potato)	2,473	1,933	1,325	1,144	1,000	854
Non-Staple Crop (vegetables, fruits and so on)	133	160	232	210	195	170
Total	8,241	7,763	6,368	5,938	5,755	5,646

Strategies

(1) Strategy1: Reduction of Emission

-CH_4 from Paddy

Since paddy land is very beneficial for sequestrating GHGs through photosynthesis, the reduction of paddy lands is not recommended. Rather paddy lands should be preserved as much as possible. The effective ways for solving the CH_4 emission from rice paddies are not in reducing the paddy lands, but should be found in improving the farming methods such as irrigation and seeding. For example, direct seeding is better than transplantation and methane production can be reduced by improving irrigation method.

-N_2O from Fertilizers

Nitrous oxide is 270 times more effective in absorbing heat than carbon dioxide. The best way to reduce the emission of N_2O is in reducing the use of nitrogenous fertilizers. Recently the government announced that it was planning to reduce the fertilizer use by 30% in Saemangum watershed to improve the water quality of the freshwater lake to be constructed in the reclamation site. It declared that such reduction would have no impact on the agricultural output(Joint Investigation Committee for

Saemangum Project, 2000).

The following strategies are considered as effective in reducing the N_2O emission.

· The organic wastes such as manure and food wastes are composted for fertilizer.

· Growing ducks, snails and loaches in rice paddies as practiced by some farmers in order to remove weeds and pests can reduce significant amount of chemical fertilizers.

· The use of nitrogen-fixing plants commonly found in Korea such as azola can help reduce the use of nitrogenous fertilizers. These grasses are also very effective in suppressing the growth of other weeds.

-CH_4 from the Livestock

Reduction of the livestock farming is the best way to reduce the CH_4 emission from livestock farming. Anaerobic digestion is à good method to dispose of the livestock manure. Methane is produced in the process, but it can be used as fuel instead of being released into the atmosphere. It reduces the water pollution as well as the methane emission. The digested sludge is an excellent organic fertilizer which would reduce the use of nitrogenous fertilizer. This in turn will reduce the emission of nitrous oxide.

-CO_2 from Energy Consumption

Until now Korea has emphasized on raising the crop production per unit area neglecting all the energy input to produce it. But in fact it should be realized that the net production is more important after all because most types of energy are exchangeable through market. Emphasis should be given to raising the energy efficiency of farming machines and developing ecological farming practices like no-tillage and direct seeding which require less energy and manpower. The greenhouse is a very energy-intensive farming. It is mainly to supply out-of-season fruits and vegetables. The government used to give subsidy for establishing large-scale greenhouses. But it is time to reconsider the policy and give subsidy to de-greenhousing for environmental reasons.

(2) Strategy2: Raising of Sequestration

-The Most important point is that the scale of agriculture must not be reduced. The reduction of agricultural activity is the root of all wrongs in the GHGs management policy.

-The production of other staple crops such as grains like barley and wheat, pulse and potato should be increased. Especially, wheat and barley grown in rice paddies can effectively reduce GHGs in winter without much additional energy input. If wheats are grown in 28% of the paddy land in winter, it can supply 30% of domestic wheat consumption. In 1965, 27% of wheat consumption was supplied from the domestic production. But, the import of wheat flour from the U.S.A from 1970 totally destroyed the base of domestic wheat production.

Table 15. Summary of Emission Reduction Strategies to Reduce GHGs in Agricultural Sector(The result of 2020 compared with 2000)

Sector		Emission in 2000 (1000 TC)	Reduction in Emission and Increase in Sequestration in 2020
Emission Reduction Strategy	CH_4 from Paddy	1920	5%
	N_2O	749	66% (fertilizer: 6% ↓ per year by 2010 3% ↓ per year by 2020)
	CH_4 from Livestock	1510	15% (livestock: 1% ↓ per year by 2010 0.5% ↓ per year by 2020)
	CO_2 from Energy Consumption	2925	20% (energy use: 1.4% ↓ per year by 2010 0.7% ↓ per year by 2020)
Sequestration Increase Strategy	Absorption from Rice	4691	same as BAU
	Absorption from Other Staple Crops (Barley, Mislleneous Grains, Pulse, Potato)	1144	50% (production: 6% ↓ per year by 2010 3% ↓ per year by 2020)
	Absorption from Non-Staple Crops (Vegetables, Specialty Crops, Fruits...)	210	same as BAU

Table 16. Summary of GHGs Emission Reduction Potential in Agricultural Sector (1000 TC)

		1985	1990	1995	2000	2005	2010	2020
BAU	emission	4,939	5,635	6,328	7,104	7,446	7,637	7,934
	sequestration	8,241	7,763	6,368	5,938	5,755	5,646	5,646
	net effect	-3,302	-2,128	-40	1,166	1,691	1,991	2,288
After Strategies	emission	4,236	4,839	5,546	7,104	6,408	5,989	5,633
	sequestration	8,241	7,763	6,368	6,045	6,243	6,663	7,245
	net effect	-4,005	-2,924	-822	1,059	165	-675	-1,611

Reduction Potential

The strategies are summarized in Table 15. In spite of all those policies proposed, the net effect of the agricultural sector as an absorber of GHGs in 2020 is not expected to be improved beyond the level in 1990, because mechanization of agriculture and the subsequent increase in energy use are expected to continue in a foreseeable future judging from the present trend. It is estimated that the CO_2 can be additionally reduced by 3.9 TMC in 2020 by reforming agricultural practice(see Table 16).

V. Sequestration from Forests

The Kyoto Protocol to the United Nations Framework Convention on Climate Change specifies the principle that carbon sequestration can be used by participating nations to help meet their respective net emission reduction targets for carbon dioxide and other green house gases. Several studies have found that growing trees to sequester carbon could provide relatively low-cost net emission reductions for a number of countries including Korea(Richard G. Newell, Robert N. Stavins, 1999).

However, the forest area has decreased steadily during the course of industrialization and urbanization, from 6,701,000 ha in 1960 to 6,436,000 ha in 1998(Statistical yearbook of forestry, 29, 1999). The main cause of decrease in forest area is conversion of forest into other land uses. As of 1995, forests occupied 65.8% of the total land in Korea, farm land 22.1%, public area 2.4%, building site 2.2%, manufacturing area 0.4% and others 7.1% as of 1995(Korea Research Institute for Human Settlement, www.kiris.re.kr). The sequestration capacity of the forests is projected to decrease as shown in Table 17.

Policy Approach

The forest policy in Korea should be focused first on preserving the forest lands, because they have been disappearing continually, and next on enhancing the carbon sequestration capacity of the existing forests by increasing the forest storage.

(1) Preservation of the forest area.

The forests in Korea have been disappearing mainly because of logging, conversion of forest lands for development into other land uses and pest infection.

Table 17. CO_2 Sink and Emission in Forest Sector (BAU)

(unit: MTC)

Year		1990	1995	2000	2010	2020
The Change of forestry or other ligneous biomass storage	Net absorption	-7.154	-6.866	-8.750	-7.910	-7.450
	Gross absorption	-7.957	-7.493	-10.020	-9.900	-10.310
	The emission of deforestation	0.803	0.627	1.270	1.990	2.860
The emission of CO_2 from forestry and grassland conversion		NA	.071	.050	.040	.030
The emission from the soil		NA	1.278	1.300	1.230	.770
Total		-6.212	-5.517	-7.400	-6.640	-6.660

Source: Office for Government Policy Coordination(1999), The Comprehensive Responsive Program about Climate Change Convention

Reducing logging

Currently, 8.7% of the forest storage is logged annually (Forestry Administration, The Fourth Forest General Planning ('99~2008)). If this trend continues further in the future, there is not much left to do about forest policies. Therefore, it is very important to control the logging at a certain manageable level.

Suppressing the conversion of forest lands into other land uses

The conversion of forest land into other uses should be controlled. According to the BAU scenario, the land use conversion of forest land is expected to decrease by 4.8% each year from 2000.

Pest management

Effective management of forest may be more effective than securing forest area and planting the trees. So the Korean government is gradually showing more interest in managing the forest. Especially, pest management is important. Every year, vermin does a great harm to pine forests. According to <The Fourth Basic Forest Plan>, the government is planning to work on 270,000 hectares each year for pest management.

(2) Enhancement of sequestrating capacity of forest

Enhancing the carbon sequestrating capacity of forest land by accumulating forest storage is also very important. The methods to increase the biomass storage of forest can be listed as follows.

Planting trees in the forests

According to <The Fourth Basic Forest Plan>, afforestation area will be 21,000 hectares each year. It is known that the natural forest in Korea generally can fix 4.36kg of carbon/m^2-year (Jo, 1995). Then, 916 million tons of carbon can be fixed additionally if this plan is implemented.

Managing the urban forests

There are two methods of managing the urban forests. One is creating new urban forests and the other is planting the roadside trees. According to <The Fourth Basic Forest Plan>, urban forest afforestation area will be 58,000 hectares each year, and the number of roadside trees to be planted is 2 million each year. It is reported that the urban forest can fix 3.55kg of carbon/m^2-year (Jo, 1995). Then, 2 million tons of carbon can be fixed annually by urban forest. Ginkgo, widely planted in roadside, is known to be an excellent carbon absorber: each ginkgo tree is known to absorb 0.2kg of carbon a year in average (Jo, 1995). Then, 2 million trees can fix 0.4 million tons of carbon in a year.

Conversion of idle land into forestry

Many farm lands have been left idle as farmers leave the country. Those idle lands rarely are returned to farm lands again. They are usually located in remote areas or deep mountain areas. These lands can be changed into forest. According to <The Fourth Basic Forest Plan>, 400 hectares of idle lands will be made into forest each year. Since the Korean natural forest is known to absorb 4.36kg of carbon/m^2-

Table 18. Summary of Policy Scenarios

Scenario	Measure Explored
BAU (Business As Usual)	-the CO_2 emission due to logging increases by 4% annually. -the CO_2 emission from land use conversion decrease by 2.5% annually
Forest Sequestration Strategies	-policy1: no increase in CO_2 from logging. -policy2: the CO_2 emission from land use conversion decrease by 2.8% each year. -policy3: create 0.916 MTC with new forestry each year. -policy4: create 2.059 MTC with urban forest each year. -policy5: create 0.400 MTC with urban landscape trees each year. -policy6: create 0.017 MTC by converting idle land into forestry each year.

Table 19. Carbon Sequestration by Forest

(Unit: MTC)

	BAU	With Forest Policies
1990	-6.212	-6.212
1995	-5.517	-5.517
2000	-7.400	-7.400
2005	-7.020	-12.033
2010	-6.640	-11.975
2015	-6.650	-12.186
2020	-6.660	-12.387

year, this plan can absorb 17,000 tons of additional carbon annually.

Planting pollution-resistant trees and trees with better carbon-fixing ability

Planting the pollution-resistant trees and trees with better carbon-fixing capability is more effective in sequestrating carbon emission. It is known that broad-leaved trees can store 2.5 times more carbon than conifers because of rapid growth (Jo, 1995).

Sustainable forestry

Well-managed forests are known to be 1.3 times more effective in storing carbon than neglected forests (Korea Forest Research Institute, 1998). According to <The Fourth Basic Forest Plan>, 261,000 hectares of forest will be taken care of each year under the sustainable forestry program.

The policies are summarized in Table 18.

Table 19 shows the amount of CO_2 sequestered until 2020. As shown in the table, Korea's carbon sequestration capacity can be raised through proper management of forest. The full implementation scenario can raise the sequestration capacity by 12.387 MTC, the major sink development scenario by 10.916 MTC per year and the moderate scenario by 9.357 MTC per year in 2020.

The Sequestration of carbon by forest was estimated at 6.212 MC in 1990 and projected to stay at

Table 20. Summary of Energy Use and Greenhouse Gas Reduction Potential in 2020

(Unit: MTOE/MTC)

Scenarios	Energy Use	Energy Savings	CO_2 Emissions	CO_2 Reduction
Business-As-Usual	332.2		204.4	
Policies				
Energy Efficiency Improvement	95.4	58.9		
Land Use and Transportation Reform	9.7	7.9		
Environmental Agriculture	2.9	3.9		
Forest Management		5.7		
Total Effect	224.2	108.0(32.5% ↓)	128.0	76.4(37.4% ↓)

6.660 MC in 2020 under the BAU scenario. The sequestration is expected to reach to 12.387 MTC in 2020, a 86% increase from BAU, if all the available policies are fully implemented. Thus, an additional sequestration of 5.727 MTC is possible by forest management.

VI. Summary

The total effects of the greenhouse gas reduction policies are summarized in Table 20. With the policies, the energy can be saved by 108.0 MTOE, a 32.5% down from the BAU projection, and the greenhouse gas by 76.4 MTC, a 37.4% down from the BAU scenario. Mind that in this estimation, the energy efficiency is upgraded with the existing technologies already in market and the land use and the transportation system is improved not beyond the systems already practiced in developed countries. This tells us that the there are a lot more rooms to reduce the energy use and the greenhouse gases if we continue to develop new technologies and reform our land use and transportation system. Take note that the agriculture and forest can play a significant role in reducing the greenhouse gases. Denmark has an ambitious plan to reduce the energy use by half by 2020 and replace all the energy sources with renewable ones(Viegand. 2000). It may not be impossible for Korea to reduce the energy use by half by 2020 either. This will help Korea build stronger economy.

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