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A Study on the Reduction Measures of Energy Demand and Environmental Pollutants on the Transport Sector in Korea

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교통부분에 있어서 에너지 소비 및 환경오염물질 저감방안에 관한 연구

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요 약

본 연구에서는 한국에서 도로 승용차로부터 배출되는 CO_2, 대기오염물질 및 에너지 소비에 대한 분석, 전망을 하였다. 도로 승용차 교통부분에서의 에너지 소비 및 CO_2와 환경오염물질의 추세는 자동차수와 년간주행거리, 평균 탑승자수, 연료 효율을 바탕으로 구하였다.

장래 에너지 소비와 배출, 시나리오 분석은 스톡홀름 환경연구소(SEI-B(Stockholm Environment Institute-Boston))에서 개발한 LEAP(Long Range Energy Alternative Planning System)을 이용하였다. 시나리오는 2005년부터 BaU(Business-as-Usual), CNG(Compressed Natural Gas) 버스의 도입, 경차 이용의 증가, 30＄/TC와 300＄/TC 탄소세 도입으로 정하였다. 1998년을 기준년도로 하고 2020년을 목표년도로 하여 시뮬레이션하였다.

분석결과 2020년까지의 전망 및 시나리오 분석을 통하여 도로자가용교통부분에서 에너지를 절감하고 CO_2 및 대기오염물질을 저감하기 위하여 도입한 개별정책들을 통합하고 정책간 상승효과를 볼 수 있도록 팩키지화시키는 것이 효과적이라고 분석되었다.

주요어 : 에너지 소비, 도로승용차 교통, 환경정책, LEAP

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I. Introduction

The transport sector is responsible for over 25% of world primary energy use and 22% of Carbon Dioxide(CO_2) emissions from fossil fuel use. It is the most rapidly growing sector with energy use in 1996 of about 70 Exajoule(EJ). Without appropriate counter actions, this figure will double to 140EJ in 2025(Banister, 1998).

In Korea, the energy used by transport amounted to 20.6% of total energy demand in 2000 and 13% in 1980 and it has increased by 7.6% during the last 20 years (Ministry of Commerce Industry, Republic of Korea & Energy &Korea Energy Economic Institute (MOCIE, ROK, KEEI, 2001). Because the transport energy demand has been growing faster than that in other sectors, this proportion will be rapidly increased.

Due to the rapid increase of the number of vehicles, the consumption of petroleum is 30,770,000 tonne of oil equivalent(TOE) in 2000. It is 6.3 times more than in 1980 and 2.2 times more than in 1990.

Transport is an important contributor of greenhouse gas emissions, particularly Nitrogen Oxides(NOx) and Carbon Monoxide(CO) (Acutt and Dodgson, 1998).

The CO_2 emissions from industrial and residential/commercial sectors have decreased during the last 10 years. On the other hand, the emissions from transport sector has increased CO_2 emissions from 17.7% in 1990 to 20.9% in 2000 (MOCIE and KEEI, 2001).

The factors which influence the energy consumption and air pollutants in transportation can be classified into three parts as follows: technology, operation, and demand of transportation vehicles (Korea Energy Economics Institute, 1998).

Korea is a densely populated country with a small land area. The country needs to promote a public transportation system more actively than other countries. Public transportation system in Korea is losing competitiveness over private transportation. This is due to a poor institutional system, poor quality of service and inefficient routing and operation. The share of public transportation in the nation's total transportation volume is declining (Ministry of Environment, ROK, 2001).

The objective of this paper is to provide useful information for establishing the desirable energy policy in road passenger transportation sector. It also aims to analyze and project the energy demand and emissions, based on different sets of policy scenarios that would be implemented now or in the future.

II. Methodology

In this study, we estimate the trends of energy demand, Greenhouse Gas(GHG), and air pollutants emission from road passenger transportation based on the vehicle population, annual vehicle travel, average number of occupants (load factor) and fuel economy. The method is:

$$EDi(t) = \sum_i Vi(t) \times PKi(t) \times EIi(t) \quad (1)$$

Where, EDi(t) is the total energy demand of vehicle type i in year t by passenger transportation in toe, PKi(t) is the average annual passenger kilometer by vehicle type i in year t, and EIi(t) is the energy intensity of vehicle type i in year t in

Table 1. Vehicle type of this study

Service	Use Type	Vehicle Type		Fuel Type
Road	Private	Passenger cars	Compact car (less than 800cc)	Gasoline and (LPG)
			Small car (less than 1500cc)	
			Medium car (less than 2000cc)	
			Large car (more than 2000cc)	
		Buses		Diesel and (LPG)
	Public	Buses		Diesel
		Taxi		LPG

liters/passenger-km[1]. Passenger-kilometer(p-km) demand for public cars is derived from a regression model. The model is:

$$InTDp(t) = 0.40096 \ln FDP(t) + 0.00868 TD_{t-1} + 6.633 \quad (2)$$

Where, InTDp(t) is the passenger-Kilometer(p-km) demand for public passenger car, GDP(t) is gross domestic product in year *t*, and TDt-1 is transport demand(pass-km) of previous year. using the GDP and transport demand(p-km) of previous year.

Table 1 shows the vehicle type used in this study. We focus on the passenger cars because in the transport energy demand in 1999, roads transportation contributed about 74% and the railroads - 1.7%, air transportation - 7.4%, marine transportation - 16.9%(KEEI, 1999). We, therefore, see that roads transportation contributed overwhelming portion. The demand for vehicles, especially passenger cars, will increase with the per capita income. Road passenger cars can be divided into the private and public types. Private vehicles can be further divided into passenger cars and buses.

Private passenger cars use gasoline or LPG. However, the share of gasoline in private passenger cars was 99% in 1998. Private buses also use ether diesel or LPG. However, the share of using the diesel in private buses was 82% in 1998. Public buses use only diesel and taxis use the LPG. In this study, a small portion of fuel used by vehicle type is ignored.

The projection of economic growth was derived from data in the 'Long-term Energy Outlook and Strategy Development Report for the 21st Century in Korea'(KEEI, 2001). Passenger-Kilometer(p-km) demand for private cars is derived from the estimated number of vehicles, average mileage and road factor (average number of occupants).

$$PKi(t) = VPi(t) \times VM(t) \times RFi(t) \quad (3)$$

Where, PKi(t) is the total average annual passenger kilometer traveled by vehicle type *i* in year *t*, VPi(t) is the registered number of vehicle by vehicle type *i* in year *t*, VM(t) is the annual average mileage of vehicle type i in year *t*, and RFi(t) is average number of occupants by vehicle

1) According to the result of interviews with people who are in charge of the transportation data which is recorded at statistics year book based on the survey data, we can get relatively correct data on the transport demand of the public vehicle. However, we cannot be convinced of the precision of the data on the private passenger car because the elements needed to investigate private passenger-kilometer demand are diverse.

type i in year t in pass-km/veh-km.

It is important to project the number of vehicles hereafter since the rapid increase of energy demand is caused by an increase in the number of vehicles. The fact that the number of vehicles, VPi(t) will not increase continuously in the future is well known due to various constraints (Transportation Development Institute, 2000). It was forecasted that the rate of vehicles growth would slow down as it approaches the saturation level. Therefore, we chose a Gompertz function to analyze this trend.

The saturation level of the number of vehicles was determined by referring to the research results of Transportation Development Institute and also by comparing and verifying with the number of vehicles of Japan. The geographical and traffic conditions of Korea are similar to those of Japan. The saturation level of private passenger cars is estimated as about 3.0 persons per car in 2020 and private passenger buses is about 43 buses per 1000 people.

VMi(t) and LF(t) are obtained from the report on Energy Census made by the Korea Energy Economics Institute(KEEI) (MOCIE, 1999) and projected based on the changing rate of the yearly mean (KEEI, 2001). Energy intensities are the average energy consumption of some device or end-use per unit of activity. The formula for calculating the energy intensity (Stockholm Environment Institute, 2000) is given as:

$$EIi(t) = 1/FEi(t) \times RFi(t) \quad (4)$$

Where, EIi(t) is the energy intensities by vehicle type i in year t, FEi(t) is fuel economy of vehicle type i in year t, and RFi(t) is average number of occupants by vehicle type i in year t in pass-km/veh-km.

Table 2 shows the major indicators used in this study. Total emissions by emission type are estimated by multiplying the emission factor in equation 1. Emission factors are obtained from the report of the National Institute Environmental Research(2000) and the Intergovernmental Panel on Climate Change(IPCC) for CO_2 emission factor.

The methodology of this study is described in Figure 1. With the in-put data, the projected energy demand, CO_2 emission, and other air pollutants are estimated between the 1998 and 2020.

Table 2. Major indicators for energy demand and environmental analyses in road passenger transportation sector in Korea.

Vehicle type		Fuel type	Annual Driving Distance (km)	Fuel Economy (km/l)	Occupancy Rate (Passenger/vehicle)
Private Car	less than 1500cc	Gasoline	13,825.5	12.24	1.67
	less than 2000cc	Gasoline	15,651.5	9.24	1.72
	more than 2000cc	Gasoline	19,097.5	6.64	1.64
	total		16,191.5	10.52	1.68
Taxi		LPG	82,035.0	7.20	4.00
Private Bus		Gasoline	17,340.0	4.27	15.08
Company Bus		Diesel	104,728.0	2.76	46.00

Source : Korea Energy Economics Institute (KEEI), 1999, Energy Consumption Survey, Ministry of Commerce, Industry and Energy MOCIE), Korea

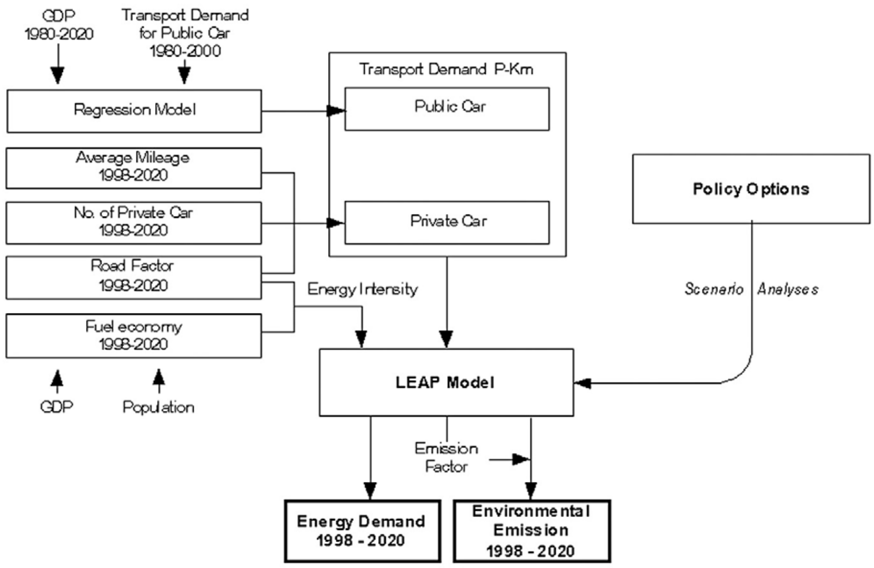

Fig. 1. The structure of methodology

The LEAP(Long Range Energy Alternative Planning System) model(version 2000), developed by SEI-B(Stockholm Environment Institute-Boston) was used to project future energy demand, CO_2 and air pollutants and scenario analyses for the transportation sector in Korea. The LEAP model does not only serve as a database but also projects the energy demand and environmental emissions. It also simulates and assesses the physical, economic impacts of alternative energy policy. LEAP model is a bottom-up model and scenario-based energy environment modeling tool and has the advantage to produce the analysis results by each device, energy level, sub-sector and travel demand.

Travel demand was selected as a fundamental base unit for aggregation in the LEAP model. In this study, future travel demand is exogenously estimated and supplied to LEAP. The National Institute of Environmental Research(NIER), Korea publishes each fuel emission factor of the transportation sector. The emission factors for CO_2, CO, NOx, SO_2, TSP are specified for each device in Technology and Environmental Database(TED) of LEAP.

III. Basic Profiles of Energy Demand and Environment Emissions

In the world, Korea ranks the 25th in population, the 11th on total production(GDP), the 12th in export amount, and the 12th in import amount. Korea ranks the 10th in primary energy consumption, the sixth in oil consumption, the fifth in energy importation and the third in oil importation in 1999(Kim *et al.*, 2001)

The population has increased by 1.1% from 1980 to 2000, and this means that it has reached stability. Also it was estimated to have a low

Table 3. Stock of major index

Index	Unit	1980	1985	1990	1995	1998	1999	2000	Growth rate		
									’80~’90	’90~’00	’80~’00
GDP[1)]	Billion	75,466	111,330	263,430	377,350	394,710	436,799	4761,109	13.3	6.1	9.6
Population	1000P.	38,124	40,806	42,869	45,093	46,430	46,858	47,275	1.2	1.0	1.1
Total	No.	291,565	684,968	2,458,660	6,618,874	8,330,246	8,830,375	9,155,990	23.8	14.1	18.8
Private Passenger car[2)]	No.	186,286	457,541	1,915,591	5,791,730	7,338,736	7,581,856	7,813,836	26.2	15.1	20.5
Taxi	No.	62,816	99,118	159,331	214,560	242,190	255,350	270,090	9.8	5.4	7.6
Private Bus[3)]	No.	14,249	91,179	338,418	553,283	683,245	921,544	994,395	37.3	11.4	23.6
Public Bus	No.	28,214	37,130	45,320	59,301	66,075	71,625	77,669	4.9	5.5	5.2
Bus Total	No.	42,463	128,309	383,738	612,584	749,320	993,169	1,072,064	24.6	10.8	17.5

Source : Yearly published data from Korean statistical information system, Korea National Statistical Office http://kosis.nso.go.kr/
[1)] Series at 1995 constant prices, [2), 3)] government use+private use

growth rate of 0.5% after two decades. The average GDP growth rate was 9.6% from 1980 to 2000. However, the growth rate of passenger cars has been 20.5% from 1980 to 2000. This is over 2 times more as compared with the GDP growth rate. When based on 1980, the number of private car has increased by 42 times in 2000 (Table 3).

Figure 2 shows the estimated energy consumption trends by fuel type(gasoline, diesel and LPG) for passenger transportation. Diesel is found to decrease from 60% in 1983 to 22% in 1998. Gasoline has dramatically increased from 9% in 1983 to 64% in 1998. The use of gasoline has increased greatly with the increase of the number of private passenger cars.

Total energy consumption is estimated to have increased by about three times from 4.21 Mtoe in 1983 to 13.4 Mtoe in 1998. The LPG for transportation is mostly used by taxis. Therefore, the portion of LPG in total energy consumption of the passenger transportation is smallest.

Table 4 shows the emissions of various air pol-

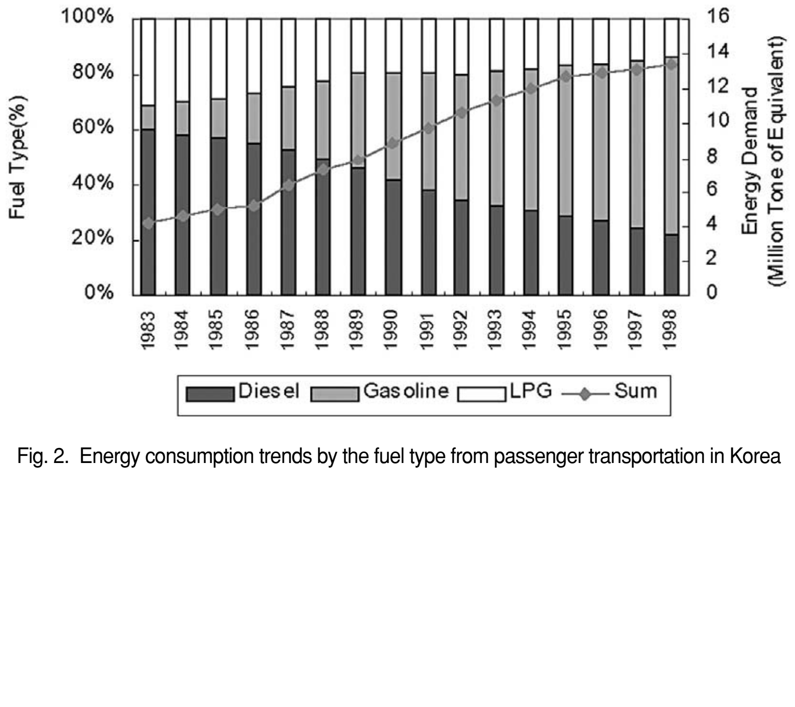

Fig. 2. Energy consumption trends by the fuel type from passenger transportation in Korea

Table 4. Emissions from passenger transportation in Korea

(unit: thousand tons)

			CO_2	Nox	SO_2	CO	TSP
Vehicle type	Passenger car	Total	6,583.3	60.3			1.3
		Compact	174.7	1.6	-	-	0.0
		Small	2,474.7	22.7	-	-	0.5
		Medium	2,833.1	26.0	-	-	0.5
		Large	1,100.8	10.1	-	-	0.2
	Taxi		1,304.1	23.2	-	-	-
	Bus	Total	2,871.6	101.7	2.4	55.3	17.2
		Private	1,238.7	43.9	1.1	23.8	7.4
		Company	1,632.9	57.9	1.4	31.4	9.8
	Total emissions		10,759.0	185.3	2.4	55.3	18.5
Fuel type	Diesel vehicles		2,871.6	101.7	2.4	55.3	17.2
			(26.7)	(54.9)	(100.0)	(100.0)	(93.1)
	Gasoline vehicles		6,583.3	60.3	-	-	1.3
			(61.2)	(32.6)	-		(6.9)
	LPG vehicles		1,304.1	23.2	-	-	-
			(12.1)	(12.5)	-	-	-
Use type	Private transportation		7,822.0	104.2	1.1	23.8	8.7
			(72.7)	(56.2)	(43.0)	(43.1)	(47.1)
	Public Transportation		2,937.0	81.1	1.4	31.4	9.8
			(27.3)	(43.8)	(57.0)	(56.9)	(52.9)

lutants from passenger transportation in Korea in 1998. Diesel cars from passenger transportation are responsible for emitting 54.9% of total emissions of NOx, 100% of SO_2 and CO, 93.1% of total emissions of TSP and 26.7% of total emissions of CO_2. In 1998, gasoline and LPG passenger vehicles accounted for 90% of the nation's total passenger vehicles, and diesel passenger vehicles accounted for the remaining 10%. In case of TSP emission, diesel consumption is responsible for most part of the emissions. Emission control technology for diesel vehicles is not yet as advanced as that for gasoline vehicles.

In 1998, private passenger cars, which have the largest share in vehicle population(87%), were responsible for 72.7% of CO_2, 56.2% of NOx, 43% of SO_2, 43.1% of CO and 47.1% of TSP, respectively. Public transportation consumption, with 3.7% share in vehicle population, is responsible for emitting 27.3% of CO_2, 43.8% of NOx, 57.0% of SO_2, 56.9% of CO and 52.9% of TSP.

IV. Scenario Analysis

1. Scenario Setting

Based on the year of 1998, the simulations are set up to the year 2020. The reasons for setting the year 1998 as the base year are the data availability and possibility of introducing related policy.

The year of 2020 is selected because the Korean government announced in 1998 that it would comply with the reduction of GHGs from the third compliance period (2018-2022). It is very important to develop concrete plans for reducing emissions of CO_2 and to predict the energy demand and other environmental emissions as well as CO_2 emissions by 2020.

Various scenarios are developed to predict the outcome of possible policy introduction now or in the future. The case scenarios for the present analysis are as follows:

1) BaU : Business-as-usual(BaU) scenario

This is the current trend of energy consumption patterns that will continue without any attempt to mitigate emission of CO_2 and air pollutants.

2) SC 1: Compressed Natural Gas(CNG) bus scenario

In Korea, CNG(Compressed Natural Gas) buses were introduced in 2000. When CNG buses are operated, the emissions of HC and NOx to be chemically transformed to ozone induction material as well as smoke are reduced by 70% as compared with diesel buses.

Therefore, the introduction of CNG buses is necessary for the improvement of air quality over the city area. The Korean government is very actively propelling the introduction of CNG buses. It aims to supply 5,000 CNG buses in the year 2002 and 20,000 by the year 2007, respectively. However, it is estimated that real supply of CNG buses will not be over half of the government target. In this scenario, an introduction target of the 40% of CNG bus is analyzed.

The government goal up to the year 2010 is to increase the CNG buses by 1,000 units per year. Passenger-km of CNG bus is obtained from the share of vehicle population of CNG buses. The annual average mileage and occupants number would be same as the existing public passengers. The economics of fuel for CNG buses is based on their operations in Seoul.

3) SC 2 : Increasing share of using compact car scenario

1500 cc - 2000 cc, medium size private passenger cars occupy over half of the total private passenger cars. In the year 2000, the holding rate of compact cars in Korea was 8% and, this is low as compared with the rate of compact cars in Japan or Europe countries (about 30%). The number of people who want to use compact cars has increased due to the financial crisis that was accompanied by a high oil price and a large exchange rate since the mid-1997. However, people return to medium-large size passenger cars as soon as the financial crisis was over and the government abolished the tax imposition on households having two cars or more. Four plus wheels per km of road in Korea is 135.8 vehicles, which means that it is the highest among the OECD countries compared with 32.7 of USA, 57.9 of Netherlands and 62.3 of England and Korea imports all the fuel which these cars are utilizing (Korea National Statistical Office, 2001). For this reason, the use of compact cars should be encouraged. Therefore, this study examines the importance of using compact cars and estimates how much they can reduce energy demand and air pollutants emissions. In this scenario, the number of compact cars that will be attained in 2020 will be 30%, the level in Japan in 1998 is analyzed.

For annual average mileages and occupant number of compact cars, the data for the small passenger cars was used because the data on the compact car did not exist. Fuel economy of compact cars was obtained from the Korea NGO's Energy Network (KNET)(http://enet.or.kr/data/thrift/thrift_a_05.htm)

4) SC 3 : Carbon tax $30/TC scenario

This is one of several incentive-based instruments for reducing greenhouse gas emissions (Kamat *et al*., 1999). It has been already implemented in Sweden, Finland, Norway, Denmark and Holland in the range of $200/TC (Nakata *et al*., 2001). Cost-benefit analysis for the introduction of carbon tax has been variously processed in Korea. Economic effect of carbon tax is altered according to the magnitude, time and target of imposing the carbon tax and substitution elasticity of production function. This study calculates the quantity of CO_2 to be reduced and economic effect by the introduction of carbon tax $30/TC based on the energy demand and CO_2 emissions in BaU scenario from 2005.

5) SC 4 : Carbon tax $300/TC(ton of carbon) scenario

This study calculates the quantity of CO_2 to be reduced and economic effect by the introduction of carbon tax $300/TC based on the energy demand and CO_2 emissions in BaU scenario from 2005. An energy price was calculated based on prices in 1998 (KEEI, 2001) and energy price elasticity obtained from the report by Korea Energy Economics Institute (KEEI, 2000). Table 5 shows the summary of the scenarios.

2. Scenario Results

1) Business-as-Usual Scenario(BaU) :

Figure 3 shows the estimated travel demand in billion passenger-kilometers and modal split. Travel demands of private passengers and private buses, in particular, are dominant. Their shares have gradually increased from 7.2% in 1983 to 43% in 1998 and 18.3% in 1983 to 41.5% in 1998, respectively. However the structure of travel demand by vehicle types is projected to have little change from 1998 to 2020. The reason is that the growth rate of private passenger cars will be reduced as its supply rate reaches saturation level and also driving distance is predicted to be shorter than now.

Figure 4 presents the projection of the energy demand and share by service in passenger cars in BaU scenario. Total energy demand of passenger transportation in 2020, with the BaU scenario, would be 30,810 Thousand toe, and this is more than 2.3 times larger than that in 1998. Estimated

Table 5. Summary of scenarios

Scenario	Period	Description
BaU	1998-2020	Business as Usual : No policy intervention
Scenario 1(SC 1)	2000-2020	Compressed Natural Gas(CNG) bus : 40% Introduction of the government's target of CNG bus
Scenario 2(SC 2)	1998-2020	Increasing share of using compact car : The rate of compact car : 30% in 2020
Scenario 3(SC 3)	2005-2020	Carbon tax 30$: Based on BaU scenario
Scenario 4(SC 4)	2005-2020	Carbon tax 300$: Based on BaU scenario

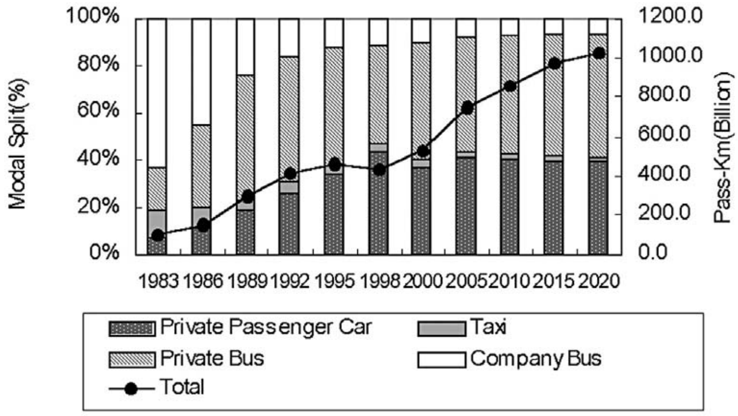

Fig. 3. Trend of travel demand and modal split

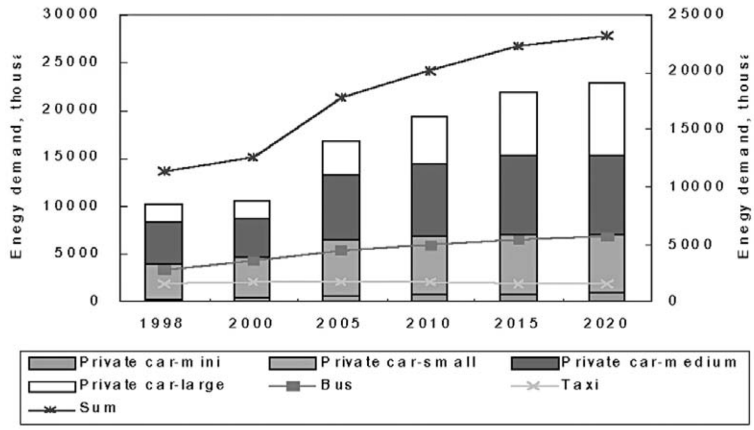

Fig. 4. Estimated energy demand of passenger transportation in Korea in BaU, 1998-2020

energy demand of private passenger cars, buses and taxis in 2020 is 19156 thousand toe, 6784 thousand toe and 1850 thousand toe, respectively.

Passenger travel by road in Korea was 56.5% in 2000 (Transport Paper, 2001) and share of private passenger travel in road travel was almost 80% in 1998, this means that transportation of structure in Korea is more dependent on the road transport and private transport. Accordingly, energy demand share of buses would decrease from 36.5% in 1998 to 31% in 2020.

Energy demand share of small vehicles in private cars decreased from 37.6% to 26.3% in 2020. In the same year, energy demand share of large passenger vehicles in private car increased from 16.7% in 1998 to 33% in 2020. Increasing of energy demand of large passenger cars with the fuel economy is twice as big as small private cars. This is a major factor in increasing total energy demand of passenger transportation.

Figure 5 shows estimated emissions from passenger transportation in Korea using BaU

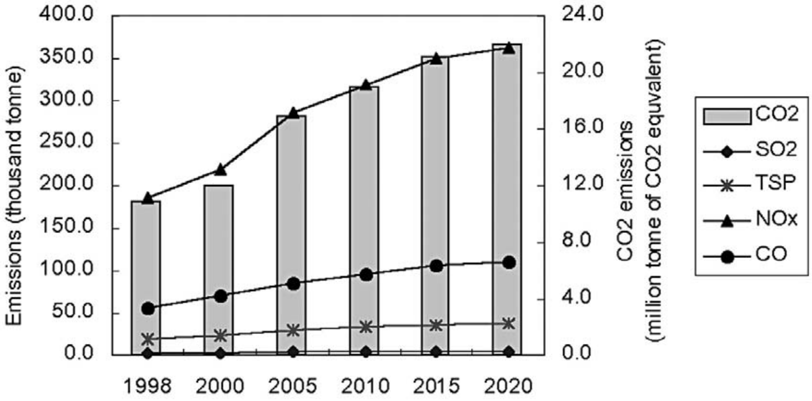

Fig. 5. Estimated emissions from passenger transportation in Korea in BaU, 1998-2020

between 1998 and 2020. Environmental emissions for 2020 at BAU scenario are estimated at 2.0 times of SO_2, 2.0 times of TSP, 2.0 times of NOx, 2.0 times of CO and 2.1 times of CO_2 as compared to the based year 1998. It is estimated that the amount of increase of CO_2 would be highest by 2020. Private cars are responsible for the majority of CO_2 emission in 2020. Buses are primarily responsible for the majority of SO_2 and CO emissions.

2) Implication of alternate scenarios

Figure 6 shows future energy demand in passenger transportation sector with BaU scenario and others. By imposing increasing share of using compact cars, it is possible to reduce energy demand by 0.2 million toe, 0.5 million toe and 1.2 million toe in year 2005, 2010 and 2020 respectively. According to the carbon tax of 300$, it might be possible to reduce energy demand by 2.5 million toe, 2.8 million toe and 3.4 million toe in year 2005, 2010 and 2020 respectively.

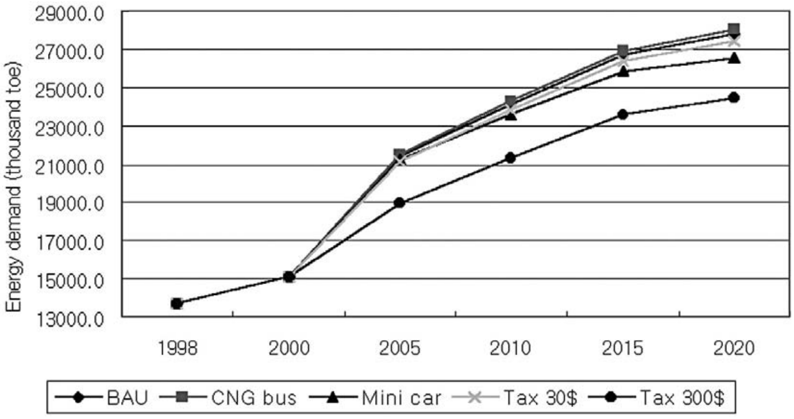

Fig. 6. Energy demand projection under the various scenarios

Table 6. Reductions of pollutant emissions from BAU under various scenarios

(unit : 1,000 tons)

	SO_2				TSP				CO				NOx				Total			
	2000	2010	2015	2020	2000	2010	2015	2020	2000	2010	2015	2020	2000	2010	2015	2020	2000	2010	2015	2020
Mini car	0.00	0.00	0.00	0.00	0.00	0.04	0.08	0.13	0.00	0.00	0.00	0.00	0.00	1.70	3.83	6.32	0.00	1.73	3.91	6.45
CNG bus	0.00	0.12	0.28	0.45	0.00	0.85	1.90	3.11	0.01	2.83	6.28	10.29	0.02	4.10	9.11	14.93	0.04	7.91	17.56	28.79

However, by introducing CNG bus, it is estimated to increase the energy demand by 0.04 million toe, 0.1 million toe and 0.25 million toe in year 2005, 2010 and 2020, respectively. The economics of fuel for CNG buses has an annual mean of 2.2km/m^3. This is not yet as advanced as that of the other fuel vehicle. Therefore, the policy measures in this sector should focus on how to achieve fuel substitution, promote the use of public transportation system, and make the energy efficient vehicles available in the market.

Table 6 shows the reduction of SO_2, TSP, CO, NOx and total reduction of the amount of pollutant emissions under compact cars and CNG buses scenarios from BaU. Results shows that CNG bus scenario reduces the largest amount of environment emissions in all future years as compared to other scenarios. Especially, for the reduction of CO and NOx emissions, CNG buses scenario established the most effective scenario.

Figure 7 shows future CO_2 emissions in passenger transportation sector with BaU scenario and others. By imposing carbon tax of 300$, it is possible to reduce CO_2 emissions by 1952 thousand tones of CO_2 equivalent, 2245 thousand tones of CO_2 equivalent and 2650 thousand tones of CO_2 equivalent in year 2005, 2010 and 2020, respectively. According to the increasing share of using compact cars, it might be possible to reduce CO_2 emissions by 185 thousand tones of CO_2 equivalent, 418 thousand tones of CO_2 equivalent and 953 thousand tones of CO_2 equivalent in year 2005, 2010 and 2020, respectively. Also, by introducing CNG bus it is estimated to reduce the CO_2 emission by 4 thousand tones of

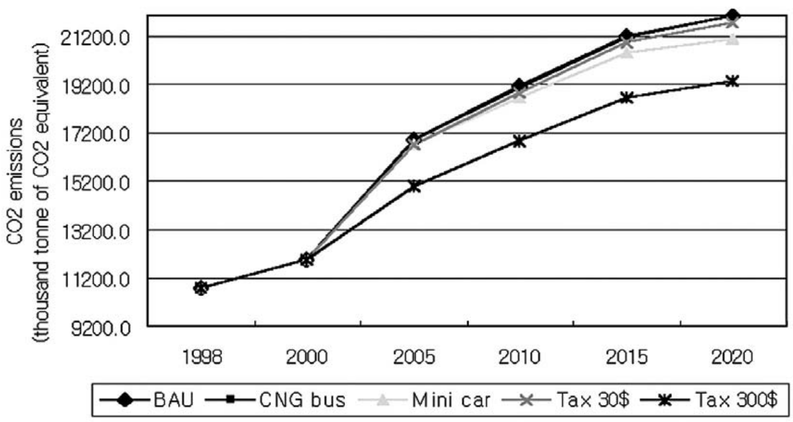

Fig. 7. CO_2 emission projection potentials in passenger transportation sector.

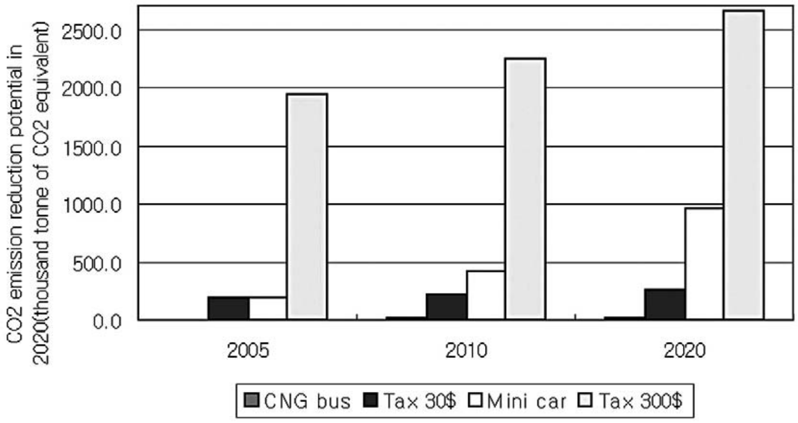

Fig. 8. CO_2 emission reduction potentials in passenger transportation sector.

CO_2 equivalent, 8 thousand tones of CO_2 equivalent and 20 thousand tones of CO_2 equivalent in year 2005, 2010 and 2020, respectively. However, in 2020, Carbon 300$ scenario is estimated to decrease by the largest amount, i.e. 2650 thousand tones of CO_2 equivalent as compared with CO_2 emissions from BaU(Fig. 8).

V. Conclusion

In this study, the energy demand, the air pollutants and CO_2 emissions for road passenger transportation sector in Korea are projected up to the year 2020. Also, policies that could be possibly introduced now and in the future are assessed under the various scenarios. Regarding the CNG buses, the increasing share of using compact cars and imposition of carbon tax 30$/TC and 300$/TC were also evaluated.

The major results of this study could be summarized as follows:

As shown in the BAU scenario analysis, the energy demand, air pollutants and CO_2 emission will continuously increase in the future if appropriate policy interventions are not made. Introducing CNG bus scenario is found to reduce air pollutants by 6.6%, and CO_2 by 0.1% from BAU in 2020. However, this does not save the energy because the annual mean fuel economy of CNG bus of 2.2km/m^3 is not yet as advance as that of the other fuel vehicles. It is expected that large amount of air pollutants emitted from transportation sector can be reduced if the government continuously enhances a fuel economy of CNG buses and replaces the current 20,000 diesel bus with CNG bus by 2007.

In addition to the CNG buses, the Korean government has already taken some efforts to develop and supply low pollution vehicle such as electric and hybrid automobile, electric and hybrid prototypes in the natural environment conservation areas and special tourist zones for a specific period from the year of 2000. Although, the Korean government has already taken some effort to develop policies, it has encountered problems such as constraints on power performances, driving ranges, high cost recharging facilities and other technical problems. Therefore, government has to provide subsidies, tax breaks and other assistance for improving technologies that are commonly used. By increasing the share of compact cars, it is possible to save energy demand by 4.4% and to reduce air pollutants by 1.4% and CO_2 4.4 % from BAU in 2020.

It is very important that the reforms of consumption in excess trends which prefers large-medium size passenger cars as well as consciousness level of drivers not to excessively use passenger cars. This includes active and continuous policies for supplying compact cars. There is a need to promote a shift to fuel-efficient vehicles like compact cars. For improving fuel efficiency of vehicles, it is necessary to strengthen fuel efficiency regulations and standards. Although the technical efficiency of vehicles has improved steadily over the last 20 years, consumer preferences for larger, heavier and more powerful models have offset most of the efficiency gains, yielding little change in fuel economy.

Since Korea is a densely populated country with little land area, the country needs to promote a public transportation system more actively than other countries. Nevertheless, Korea's public transportation system is losing competitiveness over private means of transportation.

If the government will make an effort to improve the poor institutional system, the poor quality of service and inefficient routing and operations, citizens will try to reduce using the private passenger cars. The country can reap remarkable benefits from energy conservation and exhaust pollution reduction. This is because the energy consumption efficiency of public transportation is much higher than that of private transportation

Carbon tax is the most effective reduction of CO_2 emissions and energy saving in the transportation sector. The imposition of carbon tax in this sector, it would increase large amount of government revenue.

However, the key factor is how to use this revenue. Firstly, reducing income and corporate tax to boost the economy by increasing the competition and investment. Secondly, transferring this tax revenue to energy saving programs and environmental improvement. Thirdly, supporting energy R and D in energy and environment technology area. Finally, a more comprehensive examination of the whole tax reform is needed.

A key aspect in developing fuel savings and CO_2 emissions reduction transport policies is to integrate individual policies and measures into packages that befit the synergistic interaction among the components (IEA/OECD, 2001). Also we need to integrate local and global environment policy, which in general, is applicable to many Asian developing countries having the same situations.

References

Banister, D., 1998, Introduction: Transport Policy and the Environment, E&FN Spon, London and new York, 1.

European Conference of Ministers of Transport (ECMT), 1993, Transport Policy and Global Warming, ECMC.

IEA/OECD, 2001, Saving Oil and Reducing CO_2 Emissions in Transport, OECD, Paris.

Korea Energy Economics Institute(KEEI), 1998, The second-year study of planning national actions for the United Nations Framework Convention on Climate Change, KEEI, Korea. (in Korean)

Korea Energy Economics Institute(KEEI), 1999, Energy Consumption Survey, Ministry of Commerce, Industry and Energy(MOCIE), Korea. (in Korean)

Korea Energy Economics Institute(KEEI), 2000, Analysis and Outlook of Energy Demand, KEEI, Korea.

Korea Energy Economics Institute(KEEI), 2001, Application Plan of Energy&Carbon tax for Sustainable Development, KEEI. (In Korean)

Korea Energy Economics Institute(KEEI), 2001, Long-term Energy Outlook and Strategy Development for the 21st Century in Korea, KEEI, Korea.

Korea National Statistical Office(KNSO), 2001, Main Statistical Indicator for OECD member countries, KNSO, Korea.

Korea Transport Institute(KTI), 2001, Transport in the 21st century : Prospects, Vision and Strategy, KTI, Korea.

Ministry of Commerce, Industry and Energy, Korea Energy Economics Institute(MOCIE&KEEI), 2001, Energy Info Korea, MOCIE&KEEI, Korea, 24-43.

Ministry of Commerce, Industry and Energy, republic of Korea(MOCIE, ROK), 2000, Korea's Efforts to Harmonize Energy, Economy and Environment, MOCIE&KEEI, Korea.

Ministry of environment, Republic of Korea(MOE, ROK), 1997, Environmental Protection in Korea, MOE, Korea.

Ministry of Environment, Republic of Korea(MOE, ROK), 2001, Preservation of Air Quality, MOE, Korea.

Ministry of Finance and Economy, republic of Korea (MOFE, ROK), 2000, First-Half Economic Achievements of Kim Dae-jung Administration, August 2000.

Ministry of Public Management, Home affairs, Posts and Telecommunication, 2002, Japan Statistical Year book, Japan.

National Institute of Environmental Research(NIER), 1999, Cars and CO_2, NIER, Korea.

National Statistical office, 2001, 1996, 1991, 1986, 1981, 1976, Korea Statistical Yearbook, Korea.

Kamat, R., Rose, A. and D. Abler, 1999, The impact of a carbon tax on the Susquehanna River Basin Economy, Energy Economics, 21, 262-284.

Kim, S. H., Kim, T. H., Kim, Y. D. and I. G. Na, 2001, Korean energy demand in the new millennium: outlook and policy implication 2000-2005, Energy Policy, 29, 899-910.

Nakata, T. and A. Lamont, 2001, Analysis of the impacts of carbon taxes on energy systems in Japan, Energy Policy, 29, 159-166.

Transport Paper, 1999, Transportation year book, Korea.

Transportation Development Institute(TDI), 2000, Estimating Automobile Ownership Levels in Korea 2000, TDI, Korea. (in Korean)

World Energy Council, 1995, Global Transport Sector Energy Demand 2020, WEC.

http://enet.or.kr/data/thrift/thrift_a_05.htm.

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