Climate Change and GHGs from Urban Transport

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Abstract

This paper aims at presenting information about urban transportation impact on climate change. The greenhouse gases (GHGs) and their global warming potential values are briefly described. Emissions from various transportation fuels and vehicles are demonstrated. The paper also tells two successful stories on climate change and transportation, one about integrated transportation planning in Xiamen China, and the other on compressed natural gas vehicle promotion in Beijing. Then, this paper briefly introduces ADB's Promotion of Renewable Energy, Energy Efficiency, and GHG Abatement (PREGA) program, and the Clean Development Mechanism (CDM) of the United Nations Framework for Climate Change Convention (UNFCCC). This paper concludes that governments in developing countries have various opportunities to mitigate climate change, and that integrated transportation planning combined with clean development mechanism will assist government decision makers of the developing countries to better develop their transportation systems.

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Key words

Climate Change, GHG emissions from urban transportation, Clean Development Mechanism

Introduction

Of all human activities, driving motor vehicles produces the most intensive CO2 emissions and other toxic gases per capita. A single tank of gasoline releases 140 ~180 kilograms of CO2. Over 25% of transportation-related GHG emissions originate from urban passenger travel (Yang M. 1998)

Throughout major cities in Asian developing countries, unsustainable trends in urban transportation have already manifested in frequent congestions, periodic gridlock, a lack of funds for desired road rehabilitation and maintenance, and evidence linking respiratory illnesses and deaths to poor air quality.

Many city governments in Asian development countries still have opportunities to make things better. In Hanoi and Ho Chi Minh City for example, urban passenger transportation is dominated by motorbikes. The city governments are just about to develop buses. With the development of Vietnamese economy, people would shift from motorbikes to cars. Two options, i.e. private or mass public transportation modes are facing the city governments.

Urban passenger travel presents unique challenges and opportunities if it is to contribute to achieving GHG emission reductions. Private cars and motorbikes, often with only a single occupant, dominate personal travel. However, compressed natural gas (CNG) releases about one quarter less CO2 than gasoline. Some of the noxious emissions are even less than this.

This paper presents basic concepts on the climate change, greenhouse gases and their global warming potential values, emissions from various transportation fuels and vehicles. The paper shows the city governments on how to initiate economically sustainable and environmental friendly transportation modes by two case studies in China: 1) Integrated transportation planning in Xiamen city; 2) CNG vehicle development in Beijing. In addition, the paper demonstrates how to access additional capital from the developed countries (CDM funds) to support sustainable development in developing countries.

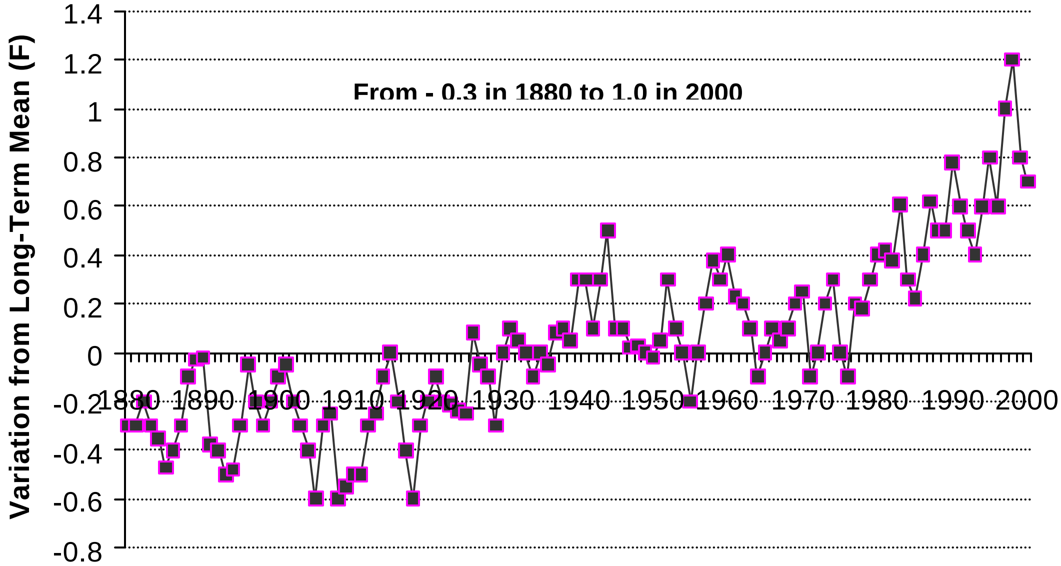
This paper is descriptive and experimental rather than academic research. The paper may interest policy makers in developing countries, who are less aware of climate change. This paper will help them better understand how to reduce GHG emissions in developing their urban transportation systems.

Global warming

The latest data confirm what a growing number of scientists have been saying for several years - that the Earth's climate is rapidly changing. According to the US National Climate Data Center (2001), global temperatures increased by over 1 degree Fahrenheit over the course of the last 120 years, and will likely rise even more during this century. See Figure 1. Some US scientists predict that unless GHG emissions are reduced substantially, temperatures in the United States will rise by about 5 to 10 degrees Fahrenheit on average in the next 100 years, an increase even larger than what's predicted globally.

Such abrupt temperature changes will cause a broad range of impacts. Sea levels will rise, flooding coastal areas. Glaciers and polar ice packs will melt. Heat waves will be more frequent and more intense. Droughts and wildfires will occur more often. In addition, as habitat changes or is destroyed, species will be pushed to extinction.

Figure 1 Global Warming over the past 120 Years



Source: US National Climate Data Center 2001

GHGs affect climate change

The term "greenhouse effect" was coined by Jean Fourier, a scientist in the 19th century. The greenhouse effect occurs when GHGs allow sunlight to reach the Earth's surface but absorb or scatter most of the heat emanating from the Earth's surface, thus retaining heat in the atmosphere. Without the natural greenhouse effect, the average temperature would be about -18^{o}C, or -0.4^{o}F (IPCC, 1990)

During the past decade or so, people have become concerned with how human activities may be affecting the world's climate. This concern has focused largely on anthropogenic GHGs, that is GHGs generated by human activity such as the combustion of fuel for transportation. Anthropogenic GHGs intensify the natural greenhouse effect, increasing the heat trapped inside the atmosphere. See Figure 2. GHGs occur naturally in the atmosphere, and they are essential to life on Earth in its present form. The concern is that human activity may be increasing the concentration of atmospheric GHGs enough to alter the climate worldwide.

Figure 2 GHG Effect (Simplified Diagram)

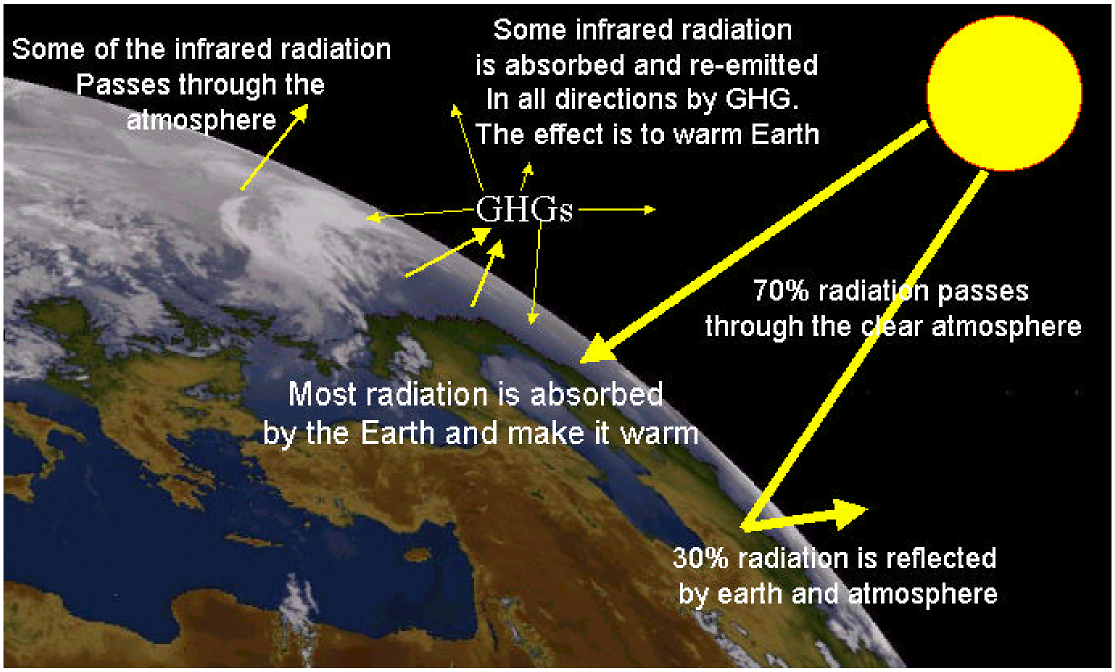


Figure 2 briefly shows the GHG effect. Most of the radiation reaching the Earth's surface and atmosphere is visible and infrared light. About 70 percent of the radiation reaching the Earth's atmosphere and surface is absorbed. The Earth's atmosphere and surface reflect the remainder. Molecules always emit lower energy than they absorb. Therefore, when the visible light of solar radiation is absorbed, it is emitted as long wavelength infrared heat waves. Part of the total heat emitted as a result of visible and infrared light absorption is absorbed by GHG molecules and clouds and re-emitted in all directions. Some of the re-emitted radiation is absorbed by the surface. The remainder of the total heat escapes through the atmosphere and into space.

The major GHGs are water vapor (H_2O), carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), fluorocarbons[1], and ozone (O_3). Of these, carbon dioxide is the most commonly discussed. However, water vapor is the most important GHG due to its abundance (it represents about 3 percent of the gases in the Earth's atmosphere). Carbon dioxide and water vapor are the two major products of all hydrocarbon fuel combustion.

Methane (CH_4) is a product of organic decay. The largest natural source of methane is the world's wetlands, and it is also the major constituent of natural gas and a potent GHG. Although methane occurs in the atmosphere in one two-hundredth of the quantity of carbon dioxide, it has 5-10 times the heat-trapping potential per molecule (US Climate Change Report, 1994). Methane is increasing in the atmosphere at an annual rate of 1

[1] Chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs), hydrofluorocarbons (HFCs), and perfluorocarbons (PFCs)

percent, double the rate of increase for carbon dioxide. Activities that release methane are rice-paddy agriculture, waste treatment, biomass burning, livestock production, and venting during natural gas and coal exploration and production activities. Methane is also released during the transport of natural gas.

Nitrous oxide (N_2O) is also a powerful GHG. It stays in the atmosphere for 150-180 years, eventually floating up into the stratosphere where it helps destroy the ozone layer. Its concentration is increasing by 0.2 percent to 0.3 percent per year. Its main source is the tropics, but roughly 20 percent of nitrous oxide emissions result from manufacturing and using chemical fertilizers and from burning fossil fuels. The use of fertilizers in growing corn for ethanol is the major component of the ethanol fuel cycle's high nitrous oxide emission.

Although chlorofluorocarbons (CFCs) are not products of engine combustion, these chemicals are associated with vehicle activity because they result from the production and use of air cooling devices. Automotive CFCs are being phased out of new models. Concentrations of CFCs are rising approximately 0.5 percent per year, and these chemicals typically persist in the atmosphere from 75 to 180 years. CFCs are 20,000 times more potent than carbon dioxide in trapping Earth's thermal radiation. However, some scientists believe that CFCs might have countervailing effects that cause cooling, so on balance, the effect of CFCs is not clear.

Ozone is not produced directly from the combustion of transportation fuels; however, combustion products like NO_x, hydrocarbons, and water vapor play a major role in its formation. Ozone is a beneficial GHG in the stratosphere and a harmful pollutant in the troposphere. Ozone survives anywhere from a few hours to a few days in the upper troposphere and for only an hour in the stratosphere Thinning the stratospheric ozone layer increases the amount of harmful UV-C radiation reaching the Earth's surface. This will not only increase UV-induced diseases, but also aid the production of ozone in the troposphere. It is beneficial when ozone stays in the stratosphere because ozone shields the Earth's surface from harmful ultraviolet rays of the Sun. Because of its oxidizing power, ozone is hazardous to health. Therefore, ozone is classified as a criteria pollutant in the troposphere. Throughout the atmosphere, however, ozone acts as a greenhouse gas.

Greenhouse gases have the ability to absorb infrared radiation (radiation with a wavelength of 1 micrometer or more) and also have, in general, longer residence times in the atmosphere than criteria pollutants. Although some compounds (e.g., carbon monoxide, oxides of nitrogen [except nitrous oxide], and non methane volatile organic compounds) have properties of greenhouse gases in terms of absorption of infrared radiation, they are also called criteria pollutants because they are hazardous to health.

Table 1 GHG and Global Warming Potential

Greenhouse Gas	Relative Effectiveness	Decay Time (years)	Relative Effectiveness in 100 Years
Carbon Dioxide (CO_2)	1	120-500	1
Methane (CH_4)	70	7-14.5	15-30
Nitrous Oxide (N_2O)	210	120	320
Ozone (O_3)	1800	0.01	3
CFC	4000	50	4000

Source: Rhode H. (1988)

The greenhouse effectiveness of a gas in the atmosphere depends, in part, on its concentration. As the atmospheric concentration of a gas increases, the effectiveness of additional gas decreases. The relative effectiveness means the effectiveness of a greenhouse gas relative to carbon dioxide. The relative effectiveness refers to global warming potential (GWP) of a gas relative to carbon dioxide GWP. See Table 1.

The decay time is a rough measure of how long the greenhouse gas remains in the atmosphere. If the decay time is 150 years, one-half of the initial amount remains in the atmosphere after 150 years. The relative contribution is the accumulated greenhouse effect as the integral of the greenhouse effect over time, when each gas is undergoing an exponential decrease, while at the same time being added to by continuing industrial emissions.

Vehicle efficiency factors

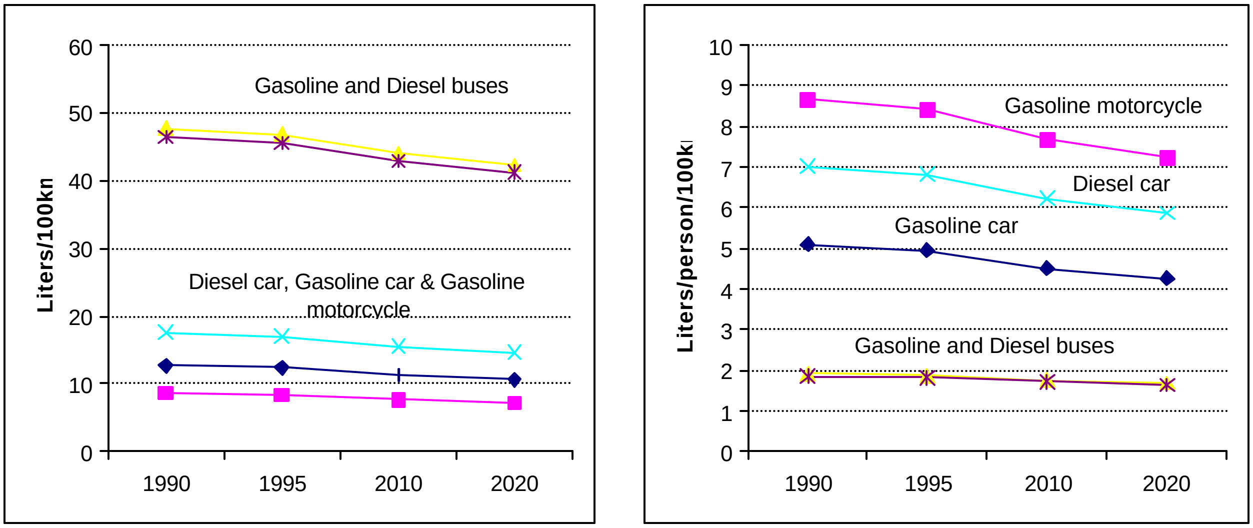
Vehicles efficiency factors varies on the basis of different assumptions and methodologies. Generally speaking, buses are most energy and GHG-emission intensive in per vehicle –100 km travel; however, cars and motorbikes are the most intensive in per-person per 100 km travel. See Figure 3.

The left chart in Figure 3 shows energy intensity of buses, cars and motorbikes in Canada in 1999. Gasoline and diesel buses rank the highest at the range of 40 to 50 liters per 100 km traveled. The least energy intensive vehicle is motorbikes, consuming less than 10 litters per 100 km. Diesel and gasoline cars burn about 10 to 20 liters per 100 km.

The right hand chart of Figure 3 shows energy intensity in liters per person per 100 km. We assume that all the vehicles are half loaded, i.e., 25 people for a bus, 2.5 for a car and one person for a motorbike. Then, energy intensity range order will be inversed when compared with the case in the left chart. Gasoline motorbike requires 7-9 liters per person-100 km travel, but a bus rider consumes no more than 2 liters. Diesel and gasoline cars are in the range between 4 to 7 litters per person-100km.

In Asia, mass transportation will be more efficient than the scenario described in the right chart, because buses in Asia are usually more than half-loaded and cars are less than half-loaded.

Figure 3 **Average Fuel Efficiency Factors for Urban Travel (Canada)**



Source: Adopted and revised from Hagler Bailly (1999)

Emission from fuels

Table 2 shows the weighted GHG emissions in moles of CO_2 equivalent per vehicle-mile traveled (VMT) which is equal to the un-weighted quantity multiplied by the global warming potential per mole of each gas, relative to carbon dioxide. One can see that compressed natural gas (CNG) and liquefied petroleum gas (LPG) vehicles emit least GHGs among all the transportation fuels and alternatives.

Table 2 Weighted missions From Gasoline and Alternative Fuels (Unit: Moles of CO2 eq per VMT (Weighted)

Greenhouse Gas	Gasoline	Methanol From Natural Gas	Ethanol From Corn	Compressed Natural Gas	Liquefied Petroleum Gas
Carbon Dioxide (CO_2)	7.9	8.7	7.4	5.64	6
Methane (CH_4)	0.22	0.35	0.39	0.91	0.17
Nitrous Oxide (N_2O)	0.54	0.54	2.98	0.54	0.54
Nitrogen Oxides (NO_x)	1.06	1.45	2.33	0.97	0.92

Carbon Monoxide (CO)	0.99	0.98	0.78	0.97	0.98
Total	**10.71**	**12.02**	**13.88**	**9.03**	**8.61**

Source: Michael Q. Wang (1995)
Note: one Mole contains 6.023 ´ 10^{23} molecules or atoms

Case studies

In the following, we present two case studies in transportation and environment planning: Integrated transportation planning in Xiamen China and CNG vehicle development in Beijing.

Integrated transportation planning in Xiamen

The project was funded by the USEPA in 1997 to promote a model of clean city in China via integrated transportation and environment planning. The project team studied the traffic congestion and air pollution problems in Xiamen, analyzed policies adopted by the Xiamen municipal government to improve the transportation conditions and air quality, presented a methodological framework for integrated transportation planning in Xiamen, provided on-site training to Xiamen municipal government officers and professionals on emission tests, vehicle regulation and standard development, and recommended additional policies and rules to improve Xiamen's transportation and environment. A detailed description of the project is available in Yang M. (1998). In the following, we present the key results of the study.

There are eight main components in the Xiamen's integrated transportation planning. They are:

- Deciding system boundary;
- Forecasting transportation demand;
- Integrating all possible elements related to transportation system
- Focusing on access not just mobility;
- Designing alternative scenarios;
- Using linear programming models to carry out system optimization;
- Evaluating planning results; and
- Implementing the plan.

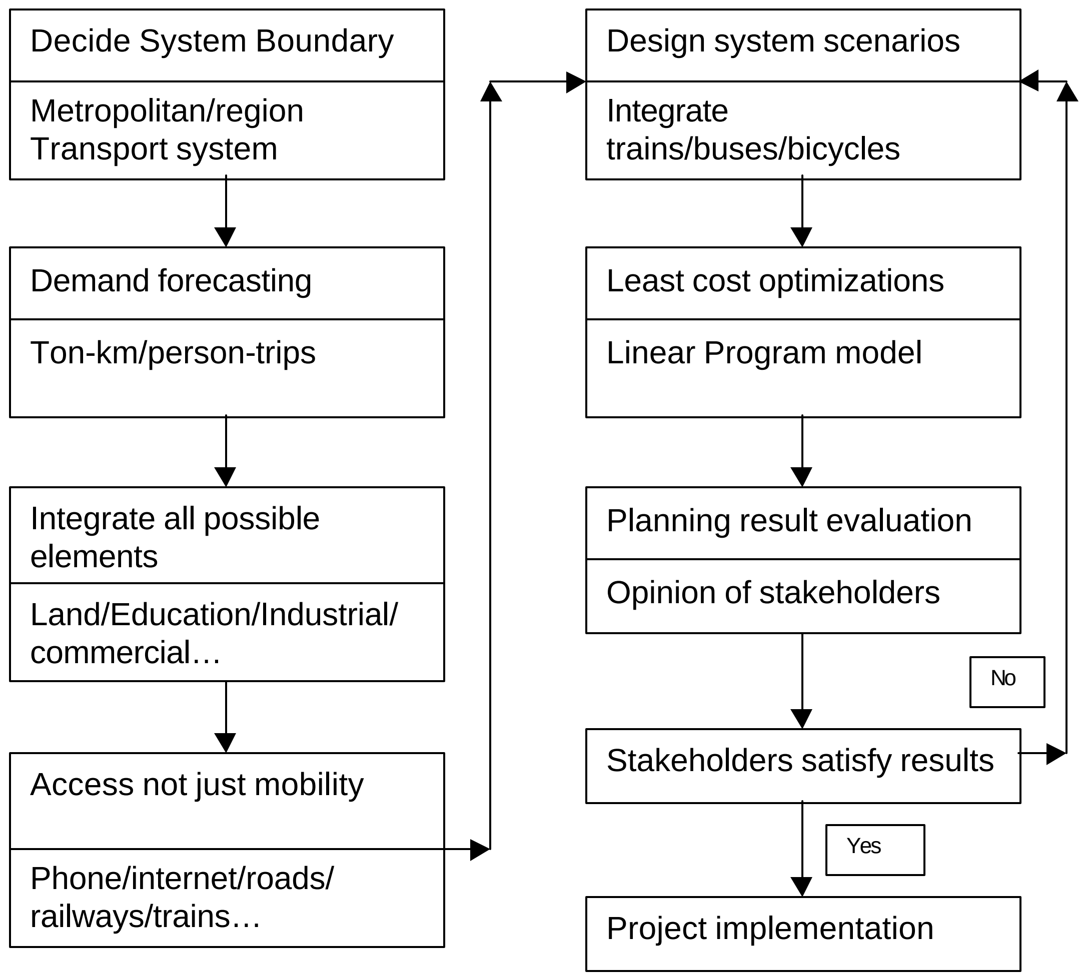
Figure 4 shows the relationships among the steps.

The following results are derived and adopted by the Xiamen municipal government to reduce vehicle transportation demand:

1. Improve the city outline plan for new city development zones. Tourism industrial facilities, commercial and entertainment facilities, schools and hospitals will be developed in each zone.
2. Design special transportation means for residential areas, where large trucks are not allowed to enter.

3. Focus on public transport development and establish alternative modes of transport. These include: pavement; bicycle lanes; bus lanes; high-occupancy vehicle lanes; integrate system with trains, bus and bicycles; pricing measures; and market based parking measures.
4. Leave leeways in road planning.

Figure 4 Methodological framework for Integrated Transportation Planning



Source: Yang M. (1998)

5. Build express roads across the city and high way around the city.
6. Reduce the number of one-way streets and roads.
7. Towing system should be pout into operation in the main roads of the city.
8. Adopt special policies to attract investment in transportation infrastructure, levy fuel consumption taxes and inspect vehicles regularly.
9. Levy high penalty on those whose vehicle tail gas does not meet the standards.

Construct parking lots with the development of new roads and buildings.

Compressed natural gas vehicles in Beijing

In 1997, a group of engineers and economists (project team), funded by the USDOE and USEPA reviewed the state-of-the-art of compressed natural gas (CNG) technologies and evaluated the market prospects for CNG vehicles in Beijing. The team undertook a feasibility study of the natural gas resource supply for fleet vehicles. The costs and benefits of establishing natural gas filling stations and promoting CNG vehicle were estimated. The quantity of GHG reduction is calculated. Standard economic and financial analyses were carried. For detailed information regarding the project, see Yang M. (1997). In the following, we present the basic scenarios and project results.

Basic scenarios and project barriers:

In 1995 in Beijing, 800,000 vehicles daily produced an estimated 24,000 tons of CO2, 320 tons of hydrocarbons, 12 tons of oxides of nitrogen (NOx), 67 tons of non-methanol carbide, 24 kilograms of benzene and lead Guo X. Y. (1996).

The Beijing Municipal government manages about 70,000 fleet vehicles, 10% of total vehicles in Beijing in 1996. These fleet vehicles include buses, taxies, post trucks, and the trucks used by environmental and sanitary sectors and by Beijing transportation companies.

There were several barriers to the development of CNG vehicles in Beijing. These include the lack of public awareness of CNG vehicles, capital shortages, high prices of natural gas, and shortage of advanced technologies. The Chinese normally thought that a CNG container with pressurized natural gas in a car is like a big bomb which is likely explode anytime. Drivers are reluctant to have their vehicles installed with the container, and passengers do not like to take the “risky” vehicles. Developing CNG vehicles requires capital investment in establishing filling stations and retrofitting vehicles. In addition, the price of natural gas was expensive, since the gas was transmitted from Northwest China, thousands of kilometres away, and costs were very high.

Project activities to overcome the barriers:

The project team undertook several workshops in Beijing, distributed flyers, and wrote articles for newspapers and magazines on safety of CNG vehicles. The project team worked with North China Vehicle Research Institute, which would be willing to invest in gas filling station development and importing retrofitting technology from New Zealand. The team also worked hard to convince the government of Beijing to reduce the prices of natural gas from 0.16 Yuan/m^3 to 0.13 Yuan/m^3 for fleet vehicle use and increase the tax of gasoline consumption for subsidising CNG vehicles. With new price the CNG vehicles would be financially viable under the economic, technological and social conditions.

Data collected and results of the feasibility study:

- Needs 350 Stations, Each feeds 200 at 500 M^3/hr
- Using New Zealand (NZ) CNG Vehicle technologies to reduce conversion investment
- Comparing the NZ CNG vehicles with gasoline trucks:
    - CO reduced by 97%
    - Hydro-carbon reduced by 72%
    - NOx reduced by 39%
    - CO2 reduced by 25%
- GHG saving calculation for one station 200 vehicles:
    - Baseline: Petrol 42 kg/day, 300 days/yr => 50,400 tonnes of petrol => 156,240 tonnes CO2.
    - Additionality: 200 CNG vehicles save 39,000 tons CO2 per year

CNG vehicles are developing very quickly in Beijing. About one third of the bus fleet were run by CNG engines in Beijing by the beginning of October 2001[2].

PREGA, CDM and funds

PREGA is short for "Promotion of Renewable Energy, Energy Efficiency, and Greenhouse Gas Abatement." The PREGA project which was approved by the ADB Board on 04 January 2001, will further develop the developing member countries' (DMCs) capacities across a wide range of disciplines, enabling them to access financial resources and technology transfers for their sustainable development, while contributing to the global imperative of mitigating climate change. PREGA, which is a 3-year project, is co-financed by the Royal Government of The Netherlands and the ADB on a grant basis.

PREGA's main objective is to promote investments in REGA technologies that will increase access to energy services by the poor, realize other strategic development objectives, and help reduce GHG emissions.

PREGA will develop capabilities of national policymakers, technical experts, and staff of financing institutions for promoting technologies for REGA technologies; and support policy, regulatory, and institutional reforms, including removal of energy pricing distortions, and facilitating access to commercial institutional finance.

[2] Source: Author's on-site survey in Beijing in September 2001.

Clean Development Mechanism (CDM) is a modified version of Joint Implementation that was included in the Kyoto Protocol for project-based activities in developing countries. In Article 12.2 of the Protocol, the parties established the CDM for the purposes of assisting developing countries in achieving sustainable development and helping Annex I parties meet their emissions limitation and reduction obligations. Under the supervision of an executive board, private and public funds may be channeled through this mechanism to finance projects in developing countries. As in the case of JI, but with slightly different language, any party "may involve private and/or public entities" in the regime. One innovative aspect is that a share of the proceeds from project activities is to be used to cover the administrative expenses of the clean development mechanism. Another part of those proceeds will be used to help particularly vulnerable developing countries meet the costs of adapting to a changing climate. As the Protocol stands now, developing country commitments are restricted to voluntary participation in CDM and the undertaking of general obligations such as the formulation of national programs and political as well as scientific cooperation among each other.

With CDM, countries co-operate in an emissions mitigation project in a developing country with the donor country acquiring the Certified Emission Reduction Units generated by the project while the host country benefits from the contribution of the project to sustainable economic development through investment in environmentally sound technologies.

It is estimated that US$ 1.2 billion will be transferred as CDM funds from Annex B countries to the developing countries each year during the next decade. In the following, we present the willingness to pay of the government of Netherlands as a simple example of the funding source.

Funding transfer - Dutch government example

Under the Kyoto Protocol, the government of Netherlands has committed itself to reduce the emissions of GHG by 6% during 2008-2012 relative to the 1990 emission level. It is the intention of the Netherlands to realize about 50% of the GHG emission reduction by means of Kyoto mechanisms including CDM.

By use of the CDM-mechanism the Netherlands want to acquire CERs generated in host countries as part of the Dutch obligations under the terms of the Kyoto Protocol. To that end, the Dutch government intends to buy CERs from investors whom are initiating and operating CDM projects.

A CRE or Certified Emission Reduction unit is a unit pursuant to Article 12 of the Kyoto Protocol and the requirements there-under, and is equal to 1000 kg CO2-

equivalent, calculated by using global warming potentials defined by decision 2 of COP 3 in accordance with article 5 of the Kyoto Protocol (CERUPT, 2001).

The Dutch government intends to purchase at least 3 million CERs due to different CDM projects with different prices listed in Table 3.

Table 3 Willingness to pay CO2 Credit by the Netherlands Government

Projects	Prices	
Renewables energy (excluding biomass):	EUR 5.5	US$ 4.8
Energy production by using clean, sustainable grown biomass (excluding waste)	EUR: 4.4	US$ 3.8
Energy efficiency improvement	EUR: 4.4	US$ 3.8
Others, among which fossil fuel switch and methane recovery	EUR 3.3	US $ 2.9

Note: On Feb 15, 2002, 1 EUR = 0.873 US$, Source:
http://goeurope.about.com/gi/dynamic/offsite.htm?site=http%3A%2F%2Fwww.x-rates.com%2F

Assuming the average price to be US$ 4.0, the government of Netherlands alone is willing to pay US$ 12 million in CDM projects to buy CER units.

Possible CDM transportation projects under PREGA

PREGA covers 14 counties in Asia. At current stage, the PREGA core team has initially planned to take a few transportation projects into consideration. These projects include mass development in Vietnam and CNG vehicles in Bangladesh.

Substitution of passenger buses for motorbikes in main cities of Vietnam. In Hanoi and Ho Chi Minh City, motorbikes are currently dominant in passenger transportation. As indicated early in this article, motorbikes are one of the most energy and GHG intensive means of transportation. Mass transportation system does barely exist in the two cities. If the city governments would develop mass transportation, CNG buses for instance, it will definitely benefit global and local environment conservation.

Developing mass transportation needs to be well planned. Without a good plan, bus and train system may not be able to work due to traffic congestions. The development of bus lanes, regulations on the use and registration of motorbikes should go hand in hand. Consequently, an integrated transportation planning, followed by government policy and regulations on vehicle uses, and implementation of mass clean fuel vehicle development may be good steps for the municipal governments in Vietnam cities to adopt.

CNG vehicle promotion in Bangladesh. Bangladesh is rich in natural gas resources but short of petroleum supply. In 2000, Bangladesh imported about

58,400 barrels of oil per day (USDOE 2001). Developing CNG vehicles will not only benefit environment, but also reduce burden of foreign current expenditure. The government of Bangladesh has intention to convert about 100 thousand vehicles when the technology is financially viable. CDM will add extra benefit for the project. It may make the project financially and economically viable.

Conclusions

Over the past century, the world average temperature has risen by bout 1 F°. It is widely accepted that the global warming is related to anthropogenic GHGs.

GHGs include the common gases of carbon dioxide and water vapor, but also rarer gases such as nitrous oxide methane and chlorofluorocarbons (CFCs) whose properties relate to the transmission or reflection of different types of radiation. The increase in such gases in the atmosphere, which contributes to global warming, is a result of the burning of fossil fuels, the emission of pollutants into the atmosphere by power plants and vehicle engines, etc.

According to the US IEA (2001), CNG and LPG vehicles are the least emission technologies so far. Because of the maturity of technology, developing CNG is one of the options to promote environmental friendly transportation in urban areas for those countries where domestic natural gas resources are available.

Case studies show that good transportation modes can be achieved in Asia, as long as there are good plans, policies and regulations. These policies and regulations should encourage the use the mass transportation and discourage the use of private cars and motorbikes.

Governments in developing countries do not have obligations to abate GHGs so far, but they have many opportunities to contribute GHG reduction. They can make better plan in their transportation modes and guide people to use more energy efficiency transportation means.

CDM may change some financially distractive projects into attractive ones. Project examples include mass transportation in Vietnam and CNG vehicle development in Bangladesh. PREGA core team are willing to help the governments of the two counties develop the projects.

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