REVIEW

ESTIMATION OF CO_2 EMISSIONS REDUCTION USING ALTERNATIVE ENERGY

– Potential Application of Clean Developed Mechanism (CDM) in the Transport Sector to Developing Countries –

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1. INTRODUCTION

The transport sector seems to be the main target of CO_2 emission reduction for mitigating global warming as the sector causes 20–30 % of total CO_2 emissions worldwide[1]. Particularly, the CO_2 emission from the transport sector in developing countries is increasing significantly, which is attributed to rampant motorization associated with rapid economic growth. It is estimated that CO_2 emission from the transport sector in developing countries will more than double in the next twenty years increasing by a rate of 3.5% per year[2].

In reaction to the rapid increase of CO_2 emission, the Kyoto Protocol has come up with an agreement made under the United Nations Framework Convention on Climate Change (UNFCC) in order to stabilize CO_2 emission for mitigating global warming. It is apparent that the Kyoto Protocol has not committed CO_2 abatement to developing countries, but only developed countries. Instead, it provides a market mechanism – CDM, the only mechanism that involves with developing countries. It has been realized that the transport sector in developing countries is most likely to be a subject of growing global concern. It is known that combining the transportation projects with the CDM can promote economic and environmental efficiency of the projects. However, at present, there have been few CDM projects in the transport sector comparing other sectors such as power and energy.

This paper discusses CO_2 reduction opportunities and briefly reviews CDM projects in the transport sector which derives the key questions on how a range of transportation projects fit within the current CDM development including project baseline certification, boundary verifying and monitoring. The paper raises an assumed case study of potential use of bio-fuel applicable for a CDM project in Beijing, China in order to derive both technological and financial solutions for reducing emissions from the perspective of developing countries. Finally, conclusions are developed regarding how transportation projects currently fit into the CDM framework and potential changes for post Kyoto Protocol.

2. CO_2 EMISSION REDUCTION OPPORTUNITIES IN THE TRANSPORT SECTOR

There are four key components to drive transportation CO_2 emissions which are travel activity (i.e., vehicle kilometers traveled, or VKT), mode share, fuel intensity, and fuel carbon content[3]. The efforts to reduce CO_2 emission in the transport sector must aim to effect at least one of the components mentioned above. Any effort to influence travel activity patterns or mode choices is essentially behavioral change in nature, while other efforts influencing fuel intensity and carbon content are a technological change. There have been three main potential approaches for essentially mitigating CO_2 emissions. These are:

1) Vehicle Technology Improvements
Vehicle technology improvements imply changing the fuel efficiency of vehicles through technological improvement of individual vehicles. Regulation of vehicle fuel economy has been a very successful policy in the developed world such as U.S., Europe and Japan, and will likely be an important tool in the future. New greenhouse gas standards in California are anticipated to achieve a 30% reduction in new passenger vehicle CO_2 emission rates by 2016[4]. In a developing country, like China, the efforts are expected to improve the fuel economy of new vehicles by 23–33% by 2010. Unfortunately, rapid growth in driving motor vehicles is projected to continue to outweigh even these progressive efforts.
2) Lowering Carbon Intensity of Fuels
It is the way of promoting the fuel content to lower carbon contents such as biofuels (ethanol and biodiesel), compressed natural gas (CNG), and hydrogen fuel cells and so on. Biofuels can reduce GHG emissions as the carbon contained in the fuel is absorbed in the atmosphere by crops.
For instance, E10 (gasoline with 10 per cent ethanol) can be used in most cars and B20 (diesel with 20 per cent biodiesel) can be used in most trucks and reduce the lifecycle of GHG emissions which are depending upon the crops used. It is estimated that GHG emission reductions for Biofuel feedstock include a 70–110% reduction for fibers such as switchgrass and poplar, 65–100% for wastes like waste oil, harvest residues and sewage, 40–90% for sugars such as sugar cane and sugar beet, 45–75% for vegetable oils including rapeseed, sunflower seed and soybeans, 15–40% for starches such as corn and wheat[5].
Also, hydrogen fuel cell vehicles have attracted much attention in recent years as a promising solution to petroleum dependence and greenhouse gas emissions. At present, hydrogen fuel cell vehicles face significant technical and economic barriers. Industry and government analysts predict that it will take from 25 to 40 years until these vehicles become commercially available, affordable and achieve significant market penetration[6].
3) Cutting Travel Demand Growth
Cutting travel demand growth is an alternative to reducing VKT through various measures and policies ranging from efficient transport provision, comprehensive land use pattern that accommodate walking and transit, and complementary incentives. Current infrastructure investment, development decisions and transportation policies will have a major impact on future emissions. Rapid growth in car ownership and use appears inevitable, but the availability of efficient options such as bicycle infrastructure will require deliberate planning and investment. A review of regional sustainable transportation plans in the U.S. that emphasizes public transit and "smart growth" land use policies indicates that such initiatives can reduce CO_2 emissions by 3–25% below business-as-usual forecasts[7].

3. CDM AND CDM IN TRANSPORT SECTOR

3.1 Brief description of CDM

The CDM is a project based framework that allows public or private entities in developed countries to invest in GHG mitigating activities in developing countries and earn abatement credits, which can then be applied against their own GHG emissions or sold on the open market. A CDM project must comply with several requirements, agreed upon by the signatories to the UNFCCC and must follow a series of stages from project identification, project description with details of the baseline, and a monitoring plan. After the project gets a letter of approval from the CDM Designated National Authority (DNA) in the host country, the project proposal goes to the CDM Executive Board (CDM-EB) who either rejects or accepts the project. If the project is accepted, this will be registered and proceed with ongoing monitoring and verification of emission reductions upon which an issuance certificate is made by the CDM-EB for the credits accrued from the project.

3.2 CDM projects in the transport sector

At the early phase of the Kyoto Protocol, the CDM was still at an embryonic stage and there were some studies on CDM promotion in the transport sector. Most of these studies, however, mainly discussed only the concept of the CDM project and did not provide any concrete methodology for baseline setting, or monitoring in a systematic way. For example, Edvard, S., et al in "Clean development mechanism as a vehicle for funding transport systems in developing countries" and Deborah, S., et al in "An initial view on methodologies for emissions baselines: Case study on transport" conceptually explained various potential CDM projects and investigated their feasibility.

At present, the CDM in the transport sector is in the early implementation phase, therefore, this paper skipped over reviewing the early studies. Instead, the paper focuses on recent studies on new methodological developments that have been submitted to the CDM Methodology Panel.

It is noticeable that to date, 66 new methodologies have been approved in total by the CDM Methodology Panel, among them, there has been only one transport-related new methodology approved (i.e., AM0031 — a new methodology for Bus Rapid Transit operation in Bogota, Colombia). There are 5 new transport-related methodologies under the consideration by the CDM methodology panel. Considering the total of 189 methodologies in the methodology section, it is obvious that sharing of transport-related projects is very small[8]. The transport-related CDM projects and corresponding new methodologies proposed are summarized in Table 1.

Among the transport-related CDM projects in Table 1, the projects entitled: NM0082-rev, NM0108, NM0129-rev, and NM0142-rev belong to the technological changing section that use new or alternative fuels such as Gaso-hole, Bio-diesel and CNG instead of fossil fuels. The projects entitled: NM0128, NM0158, and NM0201 belong to the behavioral change section while the project AM0031 belongs to both the technological and behavioral change sections (Biofuel of ethanol is introduced for gasoline vehicles).

Despite CDM providing a flexible mechanism for CO_2 emission reduction, it is vital lyimportant to clarify the problems on promoting CDM in the transport sector and to speculate on potential CO_2 mitigation projects in the view of CDM criteria — baseline certification, boundary verification, and monitoring, as well as with respect to the practical applicability of transportation engineering methodologies and technologies.

4. OBSTACLES AND POSSIBILITIES OF CDM PROMOTION IN THE TRANSPORT SECTOR

4.1 Problems in CDM promotion

Even though the CDM offers a possibility to increase funding for transportation projects, enhance local planning and project evaluation capacity, and expand technology transfer opportunities, the well known challenge lies in working through the methodological stumbling blocks of baseline, monitoring, and in addition towards feasible projects. Additionality requires proving the project is not at the baseline, demonstrating the project is not common practice and justifying all possible transportation systems and all barriers to overcome.

It is mandatory, in the CDM project baseline, to demonstrate what emissions would not occur without the project and the boundary of the system, and to identify variable trends of technology change, modal split, fuel and regulations.

The main reason of why there are so far only few transportation projects in the CDM is generally seen to be the complexity that makes difficulties on baseline certification, boundary verification and monitoring. The complexity is reflected from the dynamic and dispersive nature of the transport sector itself. Initially, the CDM is supposed to target physically fixed emission sources such as plants where fossil fuel is used. In the case of the transport sector, the emission sources are individual vehicles which are spatially dispersed and chronically dynamic. On one hand, the dispersed nature makes it difficult to certify emission source boundaries in most cases except in the case of targeting centrally controlled vehicles such as buses, garbage vehicles, and some commercial vehicles or in the special case of targetting isolated areas like small islands. The dynamic nature, on the other hand, makes uncertainies for emission calculation from vehicles running on the urban network. Moreover, the dispersed and dynamic natures make it hard to monitor vehicle emissions.

It is obvious that the amount of CO_2 emission reduction is the main index for CDM projects. Generally, CO_2 emission reduction in the transport sector can be obtained either through technological intervention on the fuels vehicles use or behavior changes on vehicle activities. There are two CO_2 emission estimation methods corresponding to the two different mitigation perspectives. These are fuel based (top-down) and, driving pattern based (bottom-up)[9].

For example, fuel based approach. This is based upon previously aggregated fuel consumption data to determine emissions. The following approach, fuel consumption is multiplied by the emission factor of CO_2 for each fuel type. The fuel emission factor is developed based on the fuel's heat content, the fraction of carbon and hydrogen in the fuel that is oxidized and content coefficient respectively. Fuel use data can be obtained from several different sources including fuel receipts (but still have questions for accuracy), financial records on fuel expenditure, or a direct measurement of fuel use. If specific information on fuel consumption is not available, information on vehicle activity data (i.e. distance traveled) and fuel economy factors (such as kilometers per liter) can be used to calculate fuel consumption.

The second methodology is the distance based approach, and should be used in the case of fuel consumption where data cannot be obtained. In this method, emissions are calculated by using distance based emissions factors which vary by driving patterns; activity data could be expressed in the terms of VKT, passenger kilometers which generally can be acquired by various traffic engineering approaches ranging from the conven-

Table 1 The current CDM projects in the transport sector (as for June, 2005)

Project Name	Methodology Name	Initial Register No	Not Approved at Round	Resubmitted No	Under Consider-ation at Round	Approved at Round	Host Country	Annex 1 Country	Credit-ing Period (year)	GHG Emission Reduction (CO_2e ton/year)
Trans Milenio puclic transport system in Bogota, Colombia	Baseline Methodology for Bus Rapid Transit Projects	NM0052	Round 6	NM0105-rev		AM0031 Round 13	Columbia	Nether-land	10	333,286
Biodiesel production and switching fossil fuels from petro-diesel to biodiesel in transport sector - 30 TPD Biodiesel CDM Project in Andhra Pradesh, India	Production of Biodiesel from perenial non-edible oil crops	NM0069	Round 8	NM0108-rev	Round 15		India		7	25,984
Khon Kaen fuel ethanol project	Baseline methodology for the production of sugar cane based anhydrous bioethanol for transportation using Life Cycle Assessment.	NM0082 NM0082-rev	Round 8 Round 11	NM0185	Round 16		Thailand	UK	10	40,196
Auto LPG in India- a road transport sector fuel switching project	Baseline methodology for road transport sector in India	NM0083	Round 8				India		7	2,542,723
Sunflower Methyl Ester Biodiesel project in Thailand	Generalized baseline methodology for transportation Biofuel production with Life Cycle Assessment	NM0109	Round 10	NM0129-rev	Round 15		Thailand	Japan	10	44,217
Modal shifting in indus-try for transport of product/feedstocks	Baseline methodology for modal shifting in industry	NM0128	Round 12				Brazil		7	6,380
Palm Methyl Ester – Biodiesel Fuel (PME-BDF) production and use for transportation in Thailand	Baseline Methodology for Palm Methyl Ester or Coconut Methyl Ester Biodiesel Fuel Production for Transportation using Life Cycle Assessment approach	NM0142	Round 13	NM0142-rev	Round 15		Thailand	Japan	10	145,044
Mexico, insurgents avenne bus Rapid Transit pilot project	GHG emissions reduction in urban transportation project that affect specific route or bus corridors or fleets where fuel uasage is changed	NM0158	Round 14				Mexico	Spain	7	25,887
Cosipar transport modal shift project	Modal shift for transport of bulk goods within a two node network	NM0201			Round 17		Brazil	UK and Northern Ireland	7	6,739

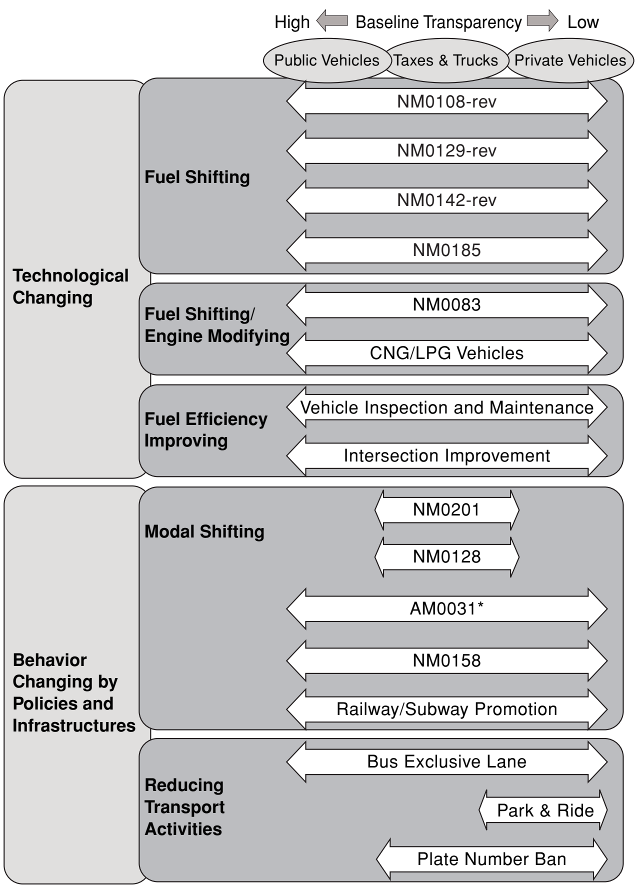
tional four-step model to state of practice or state of art traffic demand estimation models. However, existence errors of these models seem to hardly satisfy the requirement of the CDM on emissions estimation accuracy.

It is obvious that for calculating CO_2 emissions from the transport sector, it is necessary to have information of the amount of each type of fuel burned for transport purposes in the specified region and time period and the fuel economy of vehicles by the type of fuel burned, and the kilometers that drivers travel in the specific region and time period. However, all of these pieces of data are difficult to measure accurately in situations where the vehicles are not centrally controlled and affected by behavioral aspects.

4.2 Possibility of CDM promotion in the transport sector

Based on the review of new methodologies including new the methodology of NM0142 developed for CDM (authors involved in developing new methodology of NM0142), the paper qualitatively evaluates the potential and proposed possibly applicable CDM projects as shown in Figure 1.

According to Figure 1, in the case of biofuels alternative projects, the target vehicle can extend to the whole transport system (all diesel or gasoline vehicles) due to the carbon neutral nature of biofuels. Biofuels are used by blending with conventional diesel or gasoline at certain rates. Then, from the amount of Biofuels for producing biodiesel or bioethanol, the consumption of diesel or gasoline for the baseline can be obtained and emissions can be calculated by the top-down method. In the biofuel alternative projects, regardless of vehicle type, and vehicle activity just from the biofuel production data, emission estimation and monitoring can be conducted transparently. However, market penetration of biofuels is a prerequisite for the projects feasibility, therefore targeting certain types of vehicle is more sound from the view of sustainable supply.



* Also belong to fuel shifting way as used CNG for BRT buses and Ethanol for gasoline cars

Fig. 1 The conceptual model on possibility of CDM projects in transport sector

In the case of using CNG/LPG alternatives, vehicle engines should be modified (dedicated/retrofitted) at the same time with changing fuels. Dedicated vehicles are preferable but there are a few light-duty CNG vehicles available. For applying for a specific type of vehicle, retrofitting is an option. However, the efficiency of retrofitted vehicles is questionable on reduction of CO_2 emissions[10]. Therefore, dedicated CNG buses or garbage collection vehicles operating projects have a high certainty of being a candidate for CDM promotion as these kinds of vehicles are centrally controlled and have fixed routes that make boundaries clear, emission estimation transparent, and monitoring easy.

In the case of projects related to increasing fuel efficiency, like vehicle inspection and maintenance, the baseline transparency depends on the target vehicles. Public transport targeted projects assure data availability and emission can be calculated by the bottom-up method. On the other hand, private vehicles targeted projects are obviously uncertain on the data of vehicle kilometers travels. Projects like intersection improvement randomly impact on various vehicles that make the boundary unclear, hence the baseline is vague.

In the case of freight transport modal shifting like from trucks to railway or ships (e.g., NM0201, NM0128, and see Table 1), the situation is comparatively transparent due to the specific vehicles being considered. However, in the project of public transport promotion such as BRT or LRT operating, there will be an extensive impact on private vehicles that causes the boundary to be fairly wide. In the case of the projects involved with policy, land use, and infrastructure implementation, the boundary is assumed to be the territorial area or is decided by the jurisdiction of the project participants. However, the behavioral changes in the boundary are uncertain that make emissions estimation difficult.

It can roughly be drawn from the analysis above that projects with a fuel switch, especially the biofuels alternative projects, are most likely to be suitable under the current CDM framework due to the kind of projects that can be clearly defined to provide a possibility to overcome methodological problems. However, the development of a project design document (PDD) which includes baseline and monitoring methodology is still a long and complicated process.

4.3 Applicability of CDM baseline methodology

There is an approved CDM baseline methodology for public transport promotion such as Bus Rapid Transit (BRT) promotion. As a pioneer CDM project in the transport sector, it took more than 2 years (spanning initial and resubmission) to convince CDM- EM for approving the project and corresponding methodology. The methodology of AM0031 supposed to apply a Revealed Preference (RP) data based monitoring method to obtain future system patronage from which emission reductions due to mode shift can be calculated. However, mode shift effects are fundamentally behavioral and, in some cases, depend on second order influences, estimating their impact requires behavioral modeling techniques with significant uncertainties and difficulties. It can be thought that the approval of the project is attributed to the pioneer action in the sector in some extension. The methodology is tailored for the BRT construction and operating project in Bogotá, Columbia. It can only provide an application to other similar kinds of project in other areas which has similar conditions to Bogotá.

Biofuels alternative projects have more potential of becoming CDM projects compared to other projects due to the carbon neutral nature of biofuels, which promises the application of the top-down calculation method for a broader area. There are some proposal baseline methodologies for biofuels production and application for vehicles on the table of the CDM methodology panel. However, there has been still no approved methodology for this kind of project yet. The current trend for renewable energy for the transport sector can assure that the next transport-related CDM project should be an alternative fuel such as the use of biofuels promotion.

Table 1 shows the proposed and approved new methodologies regarding the use of renewable energy/biofuels, modal shift, etc., for CDM projects in the transport sector which is mainly concentrated in ASEAN and Latin American countries, e.g., Thailand, India, Columbia, Brazil and Mexico.

Nevertheless, it is interesting that there is no proposed CDM project in China where rapid economic growth stimulates motorization that causes vehicle CO_2 emissions to increase significantly. The critics of the Kyoto Protocol argue that without restrictions in China, the country would lead no net reduction in carbon worldwide and then India will soon be the top contributor to CO_2 emissions.

Therefore, the following section demonstrates an estimation of CO_2 emission reduction utilizing biofuels as an alternative energy usage for automobiles in Beijing, China so as to derive the potential application of the methodology developed for biofuel alternative projects and for the transparency of transport-related CDM projects in Beijing as an assumed case. This paper utilizes the similar method of the biofuel alternative project developed in Thailand for the Beijing case[11].

5. ESTIMATION OF CO_2 REDUCTION USING BIOFUEL APPLICABLE FOR CDM PROJECT: AN ASSUMED CASE STUDY OF BEIJING, CHINA

5.1 Background

Beijing, the capital city of China, was added to the list of world Mega cities in 2000 (cities with more than 10 million inhabitants). Beijing, the largest city in China in terms of both urban area and population, is developing rapidly and is playing significant roles in Chinese economic and social development.

Traffic congestion and air pollution have been the two major problems facing Beijing for decades. From 1991 to 2002, the annual growth rate of registered vehicles in Beijing was 14% (the growth rate was only 1.2% in Hong Kong). By the end of 2005, the number of vehicles was 2.53 million, with the growth rate at around 15%. By 2010, it is estimated that Beijing will have 3.8 million cars, 2.8 million of which will be privately-owned. Ultimately, car ownership will be about 150 cars for every 1000 people. (At present, there are 20 cars per 1000 people in China, compared to an average world level of 120 cars to 1000 people.) Rapid growth of the vehicle stock in Beijing is one of the main reasons for the increase in air pollution and CO_2 emissions caused by vehicles. Thus, a Biofuel alternative to vehicles in Beijing is seen to be an efficient way of mitigating CO_2 and other air pollutant emissions.

5.2 CDM promotion necessity in China

China takes center stage among developing countries on the climate change arena due to its large quantity of CO_2 emission. The increasing energy demand due to the drive of the rapid economic growth makes China become the second largest CO_2 emitter after the United States. The transport sector is a rapidly increasing energy consumption field with the 15% average annual vehicle increase rate[12].

The Chinese government has made long-term hard efforts to promote renewable energy and the Law on Renewable Energy was formally issued in 2003[13]. In daily practice, the Chinese government has supported the development and utilization of new energy and renewable energy such as biofuels, solar energy, wind power and geothermal energy. The CDM can provide an opportunity for absorbing in investment and technology from developed countries.

5.2.1 General description of biofuel use for the CDM project

Biofuel is a generic term for fuels that can be produced from or are made up of a renewable material of plant or animal origin. Often they are substitutes or partial substitutes for fossil (or mineral) fuels. Biofuels used in transport are typically bioethanol which is used as a gasoline substitute and bio-diesel which is used as a diesel substitute.

Gasoline consuming private vehicles are the greatest increasing factor on road transport in Beijing. Therefore, the paper assumes the case on which bioethanol or E10 is to be an alternative fuel to the gasoline consumed vehicles in Beijing.

It is assumed that bioethanol will be provided by the plant in the inner Mongol province where bioethanol produced from sweet sorghum is cultivated in rural area of Huhhot city and E10 will be blended at a refinery plant in Beijing. The bioethanol production plant is built with technology transferred from the German government. The project period is assumed to be 10 years starting from 2011 to 2020 and 2 million tons ethanol per year can be provided.

5.2.2 The CDM project boundary

The CDM project boundary delineates vehicles which consume gasoline and running in Beijing during the project period. Gasoline consuming vehicles in Beijing can classified into five types:

1) Light duty gasoline vehicle (LDGV): gasoline cars carrying 12 or less people;
2) Light duty gasoline trucks 1 (LDGT1): gasoline trucks whose gross vehicle weight is less than 6000 pounds and carrying more that 12 people;
3) Light duty gasoline trucks 2 (LDGT2): gasoline trucks whose gross weight is between 6001 pounds and 8500 pounds;
4) Heavy duty gasoline vehicles (HDGV): gasoline vehicles whose gross weight is more than 8500 pounds;
5) MC: Motorcycles.

The methodology follows a lifecycle approach, and therefore the project boundary encapsulates all emissions related to the production and combustion of both bioethanol and gasoline. The boundary seeks to incorporate CO_2 emissions from the combustion of gasoline and also nitrous oxide and methane emissions from the production and cultivation of sweet sorghum.

5.2.3 The project baseline and baseline emission estimation

The Beijing municipal government has planned to implement a series of measures to improve the air quality by the 29th Olympic Games in 2008. Thus the baseline scenario must concern the improved fuel economy and emissions factors according to the national or municipal emissions standards. The measurements include:

1) The fuel economy of some lighter vehicles (including LDGV, LDGT1) in 2020 can reach the current level of Japan or Europe. The years when the standards are going to be implemented are 2008, 2013, and 2018.
2) The fuel economy of other heavier vehicles (including LDGT2, HDGV) will improve 1.0% annually. The fuel economy of MCs will improve 0.8% annually.
3) Emission standards, which are respectively equivalent to Euro 3, Euro4, and Euro 5, will be implemented in 2007, 2010, and 2015.

Total vehicle fleet in 2020 is estimated at 5.8 million, and HDGVs shows a great increase at the number of 3.5 million, reaching almost 60% of the total vehicle numbers. As a result, the total fuel consumption in 2020 will reach 12,470 million tons/year with average yearly increase of 360 million tons. Among them gasoline consumption occupies 86% of the total fuel consumption at 10,724.2 million tones in 2020[14]. Thus from the carbon neutral nature of the E10 blended ethanol, the GHG emissions from 10% of the total gasoline consumption and corresponding upstream emission are to be emission for baseline. Many researchers show that the lower calorific value of ethanol is compensated with higher combustion efficiency, leaving no net effect on fuel economy. Total baseline emissions are thus determined as:

$$BE = AH * Q * EFP \quad (1)$$

Where:

BE = Baseline emissions (ton CO_2e);

AH = Volume of bioethanol produced by the project activity and used in transportation in the host country (kiloliter);

Q = Factor showing volume of gasoline that is displaced by bioethanol when bio-ethanol is blended with gasoline;

EFP = Gasoline lifecycle emissions coefficient (ton CO_2e/liter).

To calculate the lifecycle emissions from gasoline for the specific country where the project activity is located, the country specific data must be used. However, in the absence of such data, the project used the default values of 2.5 CO_2e/kilo liter[15] ('well to wheel' as gasoline produced within the country). As a result, the baseline GHG emission is 67.822 million tons CO_2e during the project period.

5.2.4 Emission reduction with the CDM project

The CO_2 emission reduction can be obtained through the differences between baseline and the CDM project emission. The project emission is the lifecycle emissions of sweet sorghum based anhydrous bioethanol and any additional emissions from the transport of bioethanol to the place of blending of bioethanol and gasoline in the gasohol fuel mix. The following categories of GHG emissions have been identified:

1) CO_2 emission from diesel consumption during agricultural operations (preparation, planting, harvesting etc);
2) CO_2, CH_4 and N_2O emissions associated with fertilizer production and use;
3) CO_2 emission associated with the transport of sweet sorghum to the sugar/bioethanol factory;
4) CO_2 emission from the industrial production of bioethanol;
5) CO_2 emissions associated with the transport of bioethanol to the place of blending/distribution.

Total project emissions are calculated as below:

$$PE = (AH^{*} EFA/1000) + PP + ETE \qquad (2)$$

Where:

PE = Project emissions (ton CO_2e);
AH = Volume of anhydrous bioethanol produced and used in transportation (kiloliter);
EFA = Emissions from agricultural operations (kg-CO_2e/kl);
PPE = Emissions from the industrial production of bioethanol (ton CO_2e);
TE = Additional emissions from the transportation of bioethanol to the blend/distribution location (ton CO_2e).

The following default data are applied for project GHG emissions calculation[16]. Those are diesel consumption in agricultural operations (62.5 l/ha), corresponding emission factor of 0.39 kg CO_2e/kg for fertilizer. Soil emissions estimated at an emission factor of 9.79 kg CO_2e/ton sweet sorghum. Thus emissions associated with transport of sweet sorghum from fields to factory are estimated as 1.86 kg CO_2e/ton sorghum. Based on the report of Shenyang Agricultural University of China (SAU), 5180 liters ethanol can be produced per hectare of sweet sorghum[17].

Regarding the emissions from industrial production of bio-ethanol, the bio-ethanol factory will use electricity and steam that will be generated from the bagasse produced by the factory. As such this is renewable and industrial emissions are zero. For transportation to end use emissions, it is assumed that the blended E10 'well to wheel' complete through railway, and energy consumption value for a train is 111.1 kwh/100,000 ton km, the corresponding CO_2 emission factor is 371.95 g CO_2e/kwh. With respect to leakage from upstream and downstream, here we assume that the leakage can be ignored.

As a result, the project generates 8.697 million ton CO_2e within the project period. The emission gap between baseline and project is seen to be emission reduction by the project. Thus the project can reduce GHG emissions by 59.12 million ton CO_2e in 10 years. Table 2 shows the emission reduction result of the assumed project.

Table 2 The estimation of emission reduction result with the CDM project

Year	Baseline Emission (CO_2e Million tons)	Project Emission (CO_2e Million tons)	GHG Emission Reduction (CO_2e Million tons)
2011	6.782	0.87	5.912
2012	6.782	0.87	5.912
2013	6.782	0.87	5.912
2014	6.782	0.87	5.912
2015	6.782	0.87	5.912
2016	6.782	0.87	5.912
2017	6.782	0.87	5.912
2018	6.782	0.87	5.912
2019	6.782	0.87	5.912
2020	6.782	0.87	5.912
Total	67.820	8.70	59.120

5.2.5 Project economic analysis

Here we apply the carbon price of 8 US$ per ton CO_2e for analyzing the impacts of the CER to the economic feasibility of the project. Thus, the project gains additional carbon benefits from CER is 472.96 million US$ totally, and 47.30 million US$ per year during the project period.

The reference year (the year when production is supposed to start) is considered as 2005. The calculations for the Net Present Value (NPV) are performed over the period 2005–2025. However, carbon benefit is considered only within the CDM project period. The discount rate is set at 8% and the ethanol price is 0.43 US$/liter. The NPV and Internal Rate of Return (IRR) are shown in the same kind of project as 4.4 million US$ and 8.3% respectively without carbon benefit consideration[17]. The project obviously lies within the critical area from an economic point of view. However, with the carbon benefit, the IRR is up to 11% and the project shows economic feasibility.

6. CONCLUSIONS AND DISCUSSIONS

The Kyoto Protocol with its CDM provides a way to encourage developed/industrialized countries to foster climate friendly projects in developing countries. However, while the CDM in general is currently expanding rapidly, transport is so far hardly represented in the CDM project portfolio. One of the main reasons for this discrepancy seems to be the high complexity of transportation projects which render methodology development difficult. Especially those projects that belong to the behavioral changing category have to take into account numerous different factors. Forecasts of future emissions are uncertain due to the various factors they depend on, resulting in doubtful baselines. Vital assumptions cannot be fully verified and it seems to be challenging to monitor the diverse impacts on emissions.

Even though there has been an approved methodology for BRT promotion which intervenes in behavioral change in the transportation system, the prerequisites for a CDM project in transport sector in the current CDM scheme has shown preference for technological intervention and narrowing the system boundary, targeting CO_2 emissions reduction not focusing on reducing activity or smoothing traffic flow. It can therefore be concluded that fuel switch methodologies in the transport sector are relatively straightforward and do fit well in the present CDM once the general uncertainties are resolved. Especially, Biofuel switch projects showed a high priority of being a CDM project in the current CDM framework.

However, behavioral changing related land use development and transport avoidance is at the core of sustainable transport policies. The CDM also has the main objective of stimulating sustainable development in host countries. Therefore, integrating representing sustainable transport policies and measures with the CDM framework is a main task for CDM in post Kyoto Protocol. Additional research is needed to further examine the role of the CDM in sustainable transport policy. Studies need to examine to what extent the CDM can be a stimulus for introducing sustainable transport measures at a local level.

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