QUANTITATIVE ANALYSIS OF THE GLOBAL CO2 EMISSIONS FROM TRANSPORT IN 2050 FOCUSED ON THE EFFECT OF THE MODAL SHIFT TO THE RAILWAY

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ABSTRACT

This study is based on a backcasting approach to reduce CO2 emissions from the transport sector around the world. Our image of the future for the backcasting study depicts a society where the CO2 emissions from the transport sector are reduced by 0-50% of the level of the year 2000 and the study further explored a series of policy packages and policy paths in order to reach to such an ideal future.
Our target of 0-50% reduction of CO2 emissions is based on the current political tendency of G8 leaders who declared at the G8 Summit in July 2009 that the G8 countries will reduce greenhouse gas emissions, in aggregate, by 80% or more by 2050. Since our study cover all the transport modes of the whole world, regional targets were derived by equalizing the amount of emissions per capita across the world in 2050. The scenario study was conducted under the rough assumption and estimation with respect to the effects of transport policies and mode share. The different characteristics of the trips of urban and non-urban transport were also taken into account. The analysis is basically carried out for two groups of the countries; developed and developing countries, so detailed circumstances of each country are not considered particularly due to lack of data.
The results of our backcasting analysis shows that by improving technology and modal shift, the amount of CO2 emissions in 2050 can be maintained to the level of the year 2000. Considering the serious increase of inter-city travel demand, particular focus should be applied to the construction of new railways especially in developing countries. Based on the observation of air demand in terms of seat-miles, about 30% of global air demand could be candidates of rail users in 2050. Our particular finding is that suppose 30% of total passengers can be carried by rail as a result of mode shift from auto and air, the total length of railways will have to be several times more than the length planned in India and in China at present.
In order to further reduce CO2 emissions from the transport sector around the world and to achieve the target of 50% reduction, more holistic approach will be required. Not to mention

more infrastructure such as railways but also it becomes important to reduce transport itself. here.

Keywords: CO2, backcasting, 2050,

INTRODUCTION

According to a report issued by the IPCC (2004), the transport sector accounts for 23% of the overall emission amount of energy-derived greenhouses gases, with CO2 emissions from land-based transport increasing at the second highest pace, after emissions from the electricity generation sector. On a country-by-country basis, the amount of CO2 emissions from the transport sector has been consistently growing around the world except in Japan and several developed countries in Europe. In 2008, the Institution for Transport Policy Studies, with the support of the Nippon Foundation, launched an international research project called Study for Transport System in a Low Carbon Society (STL). In this project, we evaluated the potential for reduction of CO2 emissions from the transport sector, which is generally said to be difficult to achieve, and conducted as specific analysis as possible of the necessary cost of policy measures for the reduction as well as the timing of their introduction and their effects.
In this report, we made a rough estimate of the potential for the reduction of global CO2 emissions from the transport sector and conducted policy analysis to study effective policies for the reduction. In the STL, this study is called global research and is undertaken by the Institution for Transport Policy Studies. Of the items handled in the global research, this report describes specific reduction options that would keep the amount of global CO2 emissions from the transport sector in 2050 almost unchanged at the level in 2000, specific policy packages necessary for doing so and support measures for developing countries, where traffic volume is expected to grow sharply.

BAU CASE

About BAU case in our study

In the global research of the STL, the baseline case in the IEA/ETP2008 is used as the BAU case. The CO2 emission amount in 2050 will be roughly double the 2000 level on a TTW basis. On a region-by-region basis, the emission amount in the developed world (including OECD members in North America, Europe and the Asia-Pacific region) will remain almost flat. However, in developing countries, especially China, India and other Asian countries, the CO2 emission amount will grow remarkably, indicating the importance of the implementation of reduction measures by those countries. Meanwhile, on a transportation mode basis, the amount of CO2 emissions from large trucks and aircraft, not to mention passenger cars, will also grow sharply. In order to significantly curb the amount of CO2 emissions from the transport sector in 2050, limiting emissions from these three transport modes will be essential.

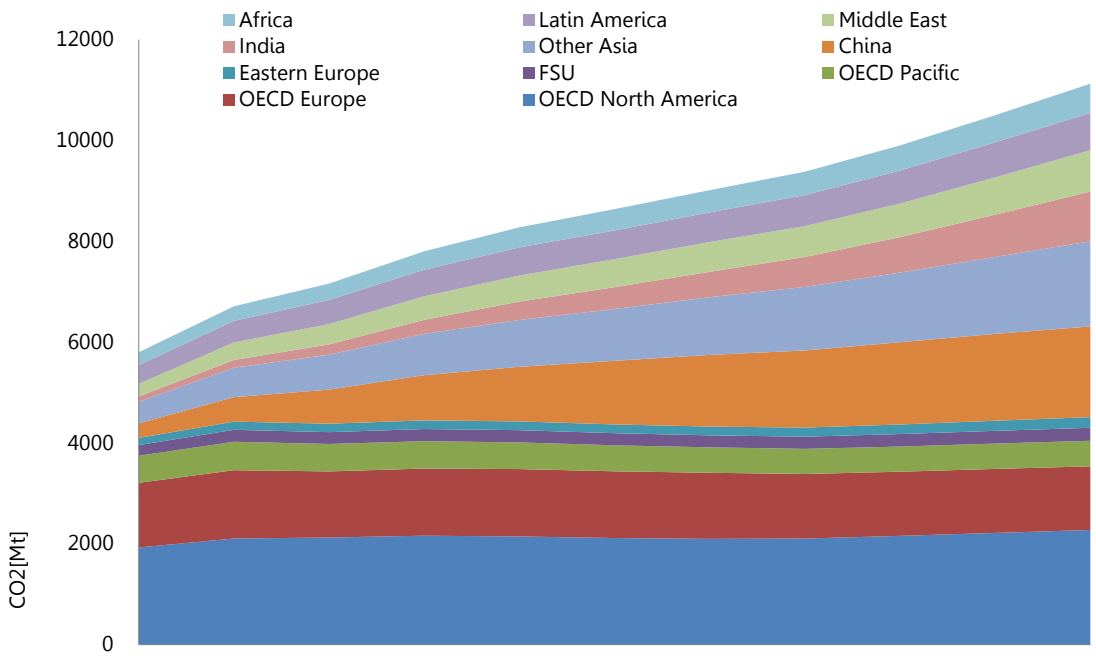

Figure 1 – CO2 Emissions from Transport Sector by region (BAU)

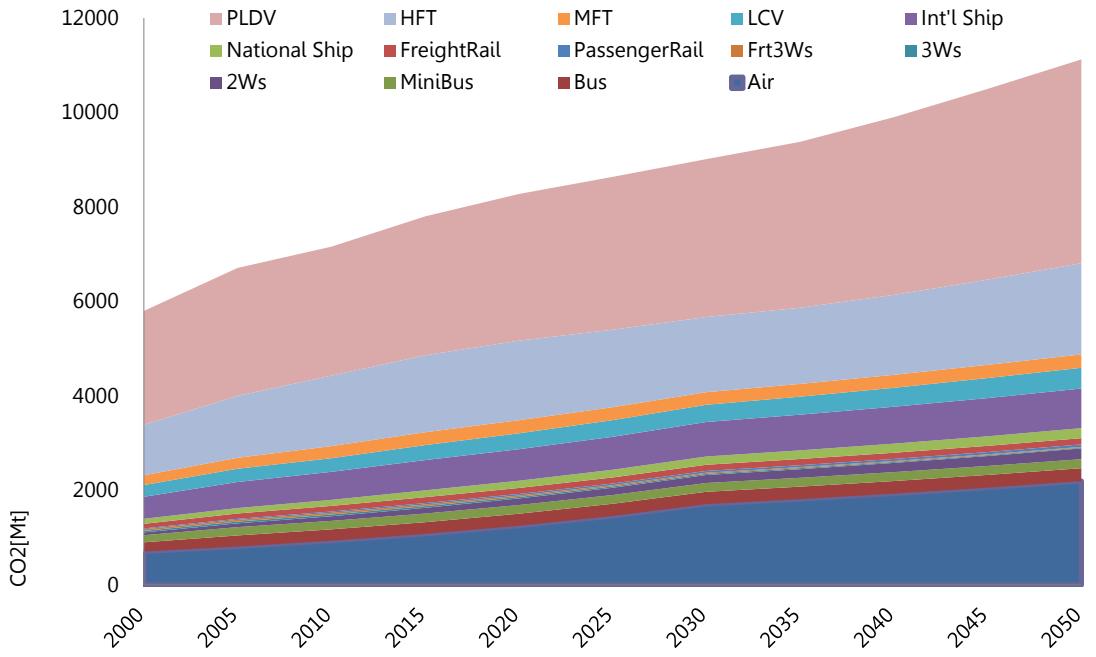

Figure 2 – CO2 Emissions from Transport Sector by mode (BAU)

Further improvement expected in energy-saving technologies

The BAU scenario does not assume that existing technologies will remain unchanged. For example, regarding vehicles, the fuel consumption amount of conventional ICEs in 2050 is assumed to be 60% or less of the level in 2000. This implies that the energy efficiency gap between conventional ICE vehicles and hybrid vehicles will significantly narrow. In addition, an improvement of around 30% is assumed for energy-saving technologies related to aircraft, regarding which fuel efficiency improvement is expected to be relatively small. A fuel efficiency improvement is also assumed with regard to trucks and buses. Even so, the CO2 emission amount is estimated to increase consistently under the BAU scenario as shown in the diagram because an increase in the traffic volume in developing countries will outweigh a decrease in CO2 emissions to be achieved as a result of improvement in energy-saving technologies.

REDUCTION SCENARIO

The vision of transportation in 2050 under the reduction scenario

Large-scale use of public transport systems and the diffusion of EFVs are elements of the vision of transport in 2050 under our reduction scenario. Under the reduction scenario, 60% of the passenger transport volume in urban will be served by such public transport systems as railways and buses. We regard the widespread use of public transport systems as a measure effective for developed countries not only as a means to improve the environment for urban-area transport and reduce the amount of CO2 emissions from the transport sector but also as a means to realize what U.S. President Obama calls a “livable community,” namely as a means to invigorate urban life. With regard to vehicle transport, we assumed that electric vehicles will replace conventional ICE vehicles as the mainstay mode of transport. We assumed that in developing countries, the diffusion of electric vehicles with a necessary minimum performance will realize a new mode of urban-area transport. Regarding inter-city transport, promoting a modal shift from air transportation as well as from vehicles will be an important reduction measure. Under our reduction scenario, we assumed that half of air transport of less than 1,000 miles in distance will shift to railways as a result of the introduction of high-speed railway systems as represented by the maglev system. We also assumed that inter-city transport and non-urban-area transport of both passengers and freight by vehicle will be replaced by transport using low-CO2-emission hybrid vehicles or other EFVs. These changes will make it possible to keep the amount of CO2 emissions from the transport sector in 2050 almost unchanged at the level in 2000. This would be equivalent to half the level in the BAU case.

Emissions from the transport sector in our scenario

As shown above, the results of the global research indicate that the diffusion of energy-saving technologies and large-scale modal shift will make it possible to keep the amount of CO2 emissions from the transport sector in 2050 almost unchanged at the level in 2000. To

be more specific, around 60% of the emission reduction amount will be attributable to the diffusion of technologies and the remaining 40% or so to modal shift to public transport and other modes of transport. Moreover, the research has shown that in this case, the emission amount in developing countries will exceed that in developed countries by 2030. Although the emission amount in developing countries will remain higher than that in developed countries until 2050, the per-capita CO2 emission amount in the former countries will remain lower than that in the latter countries in 2050 in this case. Although the gap between these two groups will narrow, the per-capita CO2 emission amount in developed countries will be approximately four times as large as that in developing countries in 2050.

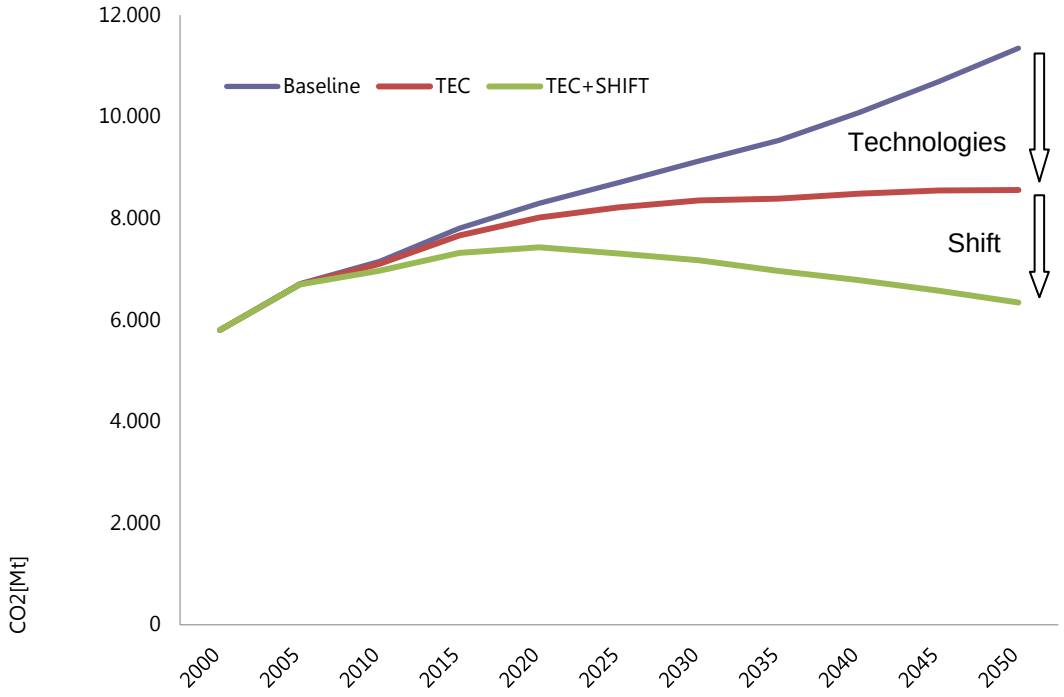

Figure 3 – CO2 Emissions from Transport Sector by reduction option (Reduction scenario)

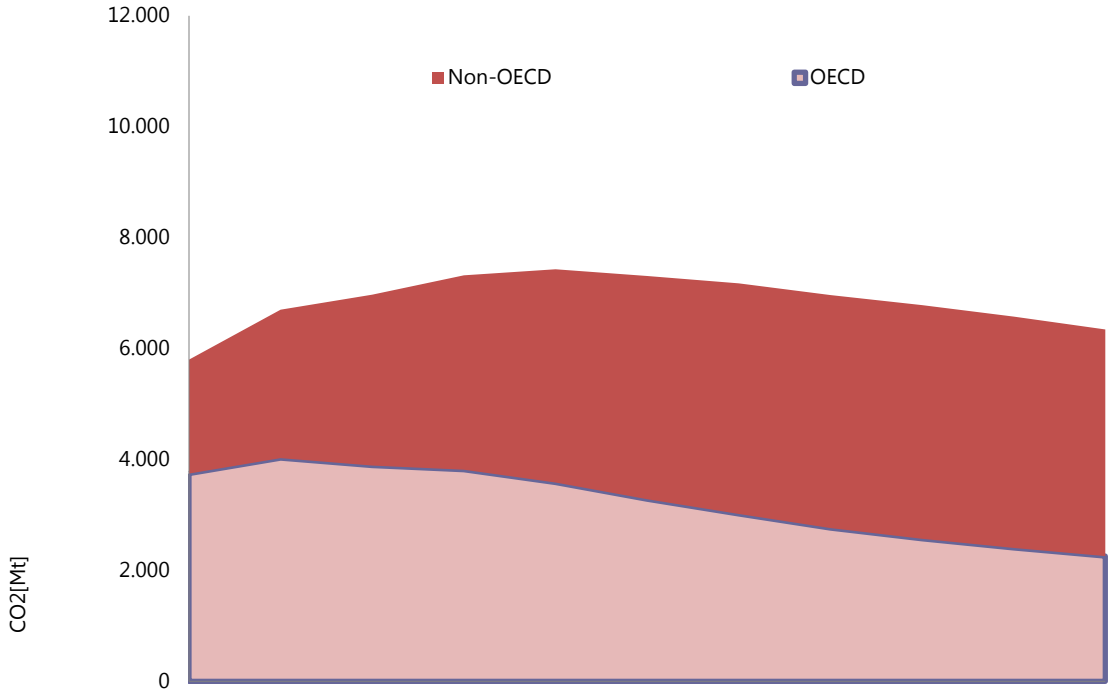

Figure 4 – CO2 Emissions from Transport Sector by region (Reduction scenario)

In the table below, we show the values of the key variables we used under the reduction scenario. The key points of this scenario are the aggressive introduction of electric vehicles in urban areas and the promotion of a large-scale modal shift regarding both inter-city and intra-city transport.

Table I – Key reduction options of our reduction scenario

Classification	Technologies	Mode	Assumed situation in 2050
Diffusion of technologies	Electric Vehicle	Passenger Light Duty Vehicle	80% in urban and 5% in non-urban will be EVs.
		Light Commercial Vehicle	40% of vehicles will be EVs
		2 Wheels	All vehicles in urban will be EVs.
	Fuel Cell Vehicle	Middle/Heavy-Freight Truck	20% of vehicles will be Fuel Cell Vehicles.
	Hybrid Vehicle	PLDV, LCV, MFT, HFT	Most of the vehicles other than EVs and FCs will be hybrid vehicles.
Modal shift	PLDV	In urban, 60% will have shifted to railways in major cities and to buses in other cities. In non-urban areas, 30% will have shifted to railways and 10% to buses.	
	Bus/Mini Bus	In urban, buses will have shifted to railways to an extent that reduces their shares to those in Tokyo. In non-urban areas, 30% of buses and 20% of minibuses will have shifted to railways.	
	Air	13% will have shifted to railways	
	MFT, HFT	15% of MFT and 30% of HFT will have shifted to railways.	
Others	Shipping	15% of Int'l and Domestic Maritime will transport at 85% speed of current level.	

In light of the above changes, let us look at the reduction scenario as broken down into the scenarios in urban and non-urban areas. Thus, we can see that compared with the baseline

scenario, urban-area transport in both developed and developing countries will show a dramatic decline in the CO2 emission amount. In developed countries, the amount of emissions from non-urban-area transport will also decline, while an uptrend will unfortunately continue in developing countries in 2050, although the increase will be limited.

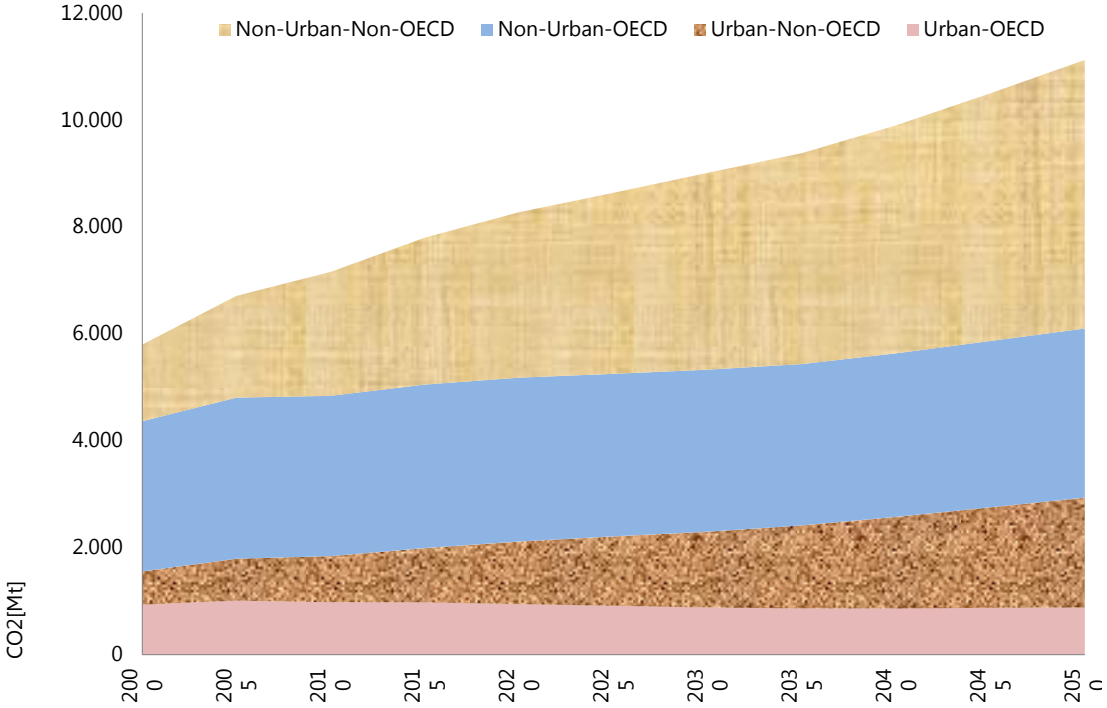

Figure 5 – CO2 Emissions from Transport Sector by region and urban/non-urban (BAU)

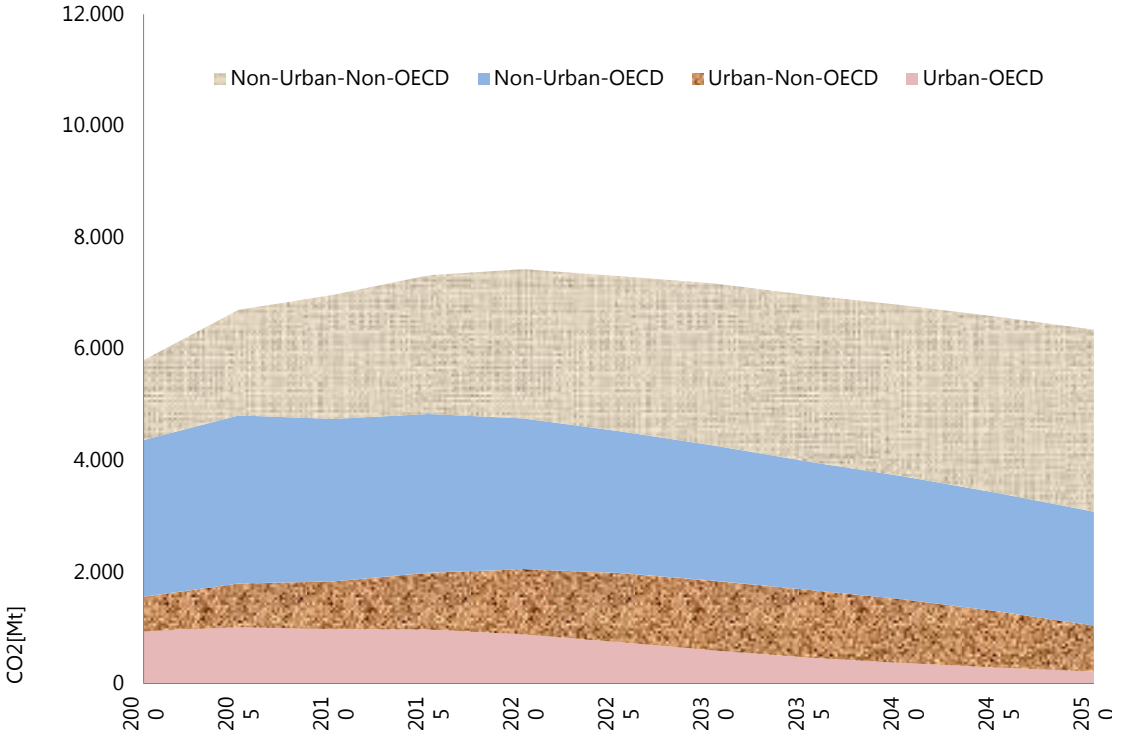

Figure 6 – CO2 Emissions from Transport Sector by region and urban/non-urban (Reduction scenario)

POLICY PACKAGES

Concept of Policy Packages in This Study

Our greatest focus of attention in the selection of a policy package is the relationship between the transport needs and supply capacity. In developed countries, there is presumably a sufficient transport supply capacity to meet the transport needs. In this situation, if we are to promote a shift from one mode of transport to another mode, the new mode needs to be attractive in terms of cost and other features. Therefore, if we are to promote a shift from vehicles to railways, an effective policy measure will be either to enhance the attractiveness of railway transport or to make vehicle transport less attractive. The former can be achieved by increasing access and safety, improving punctuality and enabling more efficient use of travel time, for example for reading a book and performing business tasks. The latter may be achieved by imposing additional costs through the levy of a congestion tax, a fuel tax and a vehicle acquisition tax in addition to introducing direct constraints such as restrictions on entry into designated areas.
However, in developing countries, the transport supply capacity is not sufficient to meet the transport needs. In this case, we refrained in our research from selecting a policy that would limit the use of an existing mode of transport simply because of the introduction of a new mode of transport. This is because we are strongly conscious of the need for the sustainable

development of developing countries that is advocated by the UNFCCC. On the other hand, if public transport is introduced in developing countries, the number of users is highly likely to grow even if it is not so attractive as would be desired in developed countries. However, rather than representing a shift from vehicle transport, this will be largely a result of the realization of latent transportation needs. Therefore, the needs for vehicles may not decline much.
In light of the above, we formulate a policy package for reducing the amount of CO2 emissions from the transport sector in developed and developing countries with regard to each of urban area transport and non-urban-area transport. case.

Policy Packages for Urban Transport

Introduction of public transport systems

When a developed country introduces a public transport system, it is necessary to adopt a mode of transport with high value added and implement measures to restrict vehicle transport at the same time. The value of transport does not depend entirely on the level of the transport fare. In the case of railways, for example, it is necessary to enhance the overall value by improving the security situation in areas around the railway line and enabling efficient use of travel time, not to mention improving access to stations and coordination with other transport systems. In addition, with regard to urban areas with a high transport density, it is essential to actively introduce taxes on the acquisition and ownership of vehicles (an acquisition tax, ownership tax, car parking tax and fuel tax) so as to put the use of vehicles at a disadvantage, as the ratio of the transport volume that can be covered by public transport systems is likely to be high in such areas. However, with regard to large cities (with low transport density) that are based on the premise of widespread use of vehicles and small and medium-size cities, it is reasonable to think that the role of vehicles should not be discounted, as the transport volume that can be covered by public transport systems is limited due to poor cost efficiency. In this case, it is necessary to implement aggressive measures to promote a shift to EFVs, including electric vehicles, rather than merely restricting the acquisition and ownership of vehicles.
In developing countries, the number of users of public transport may rise steadily if certain conditions (e.g. routes, fares, punctuality, comfort and security) are met. Put another way, the most important thing to do in developing countries is to introduce public transport quickly and on a large scale before the transport needs are satisfied. This is because if a shift to a public transport system is to be promoted after the transport needs have been satisfied, the system will probably be required to have high value added so as to encourage a modal shift, resulting in a high cost just like in developed countries. In addition, it is important to put the use of vehicles at a disadvantage in order to increase the use of public transport. However, in developing countries, where the transport needs have not yet been satisfied, it will be appropriate to impose constraints on the use of fossil fuels, which are significant sources of CO2 emissions, rather than merely curbing the use and ownership of vehicles. For example, possible options include restricting the use of fossil fuels and vehicles that run on fossil fuels and providing preferential treatment to the acquisition of EFVs.

Introduction of electric vehicles

It would be difficult for public transport alone to cover the whole of the transport needs in urban areas. Therefore, vehicles will need to cover some portion of the transportation needs that cannot be covered by public transport. Electric vehicles, which do not emit exhaust gases while running and whose fuel economy is not undermined by traffic congestion, represent one of the few technologies that resolve the problems that have long haunted urban-area vehicle transport. However, experts have warned that the price of batteries for electric vehicles may remain relatively high in 2050 and their driving range with a single battery charge may be shorter than the range of existing gasoline-powered vehicles. Therefore, electric vehicles will not always be superior to conventional ICE vehicles. Consequently, aggressive measures will be necessary in order to promote a shift to electric vehicles. Possible options include providing preferential treatment to the acquisition of electric vehicles (imposition of a high tax on the acquisition of non-electric vehicles) and imposing a high tax on fossil fuels and a fee on the entry of vehicles running on fossil fuels into urban areas, similar to the road pricing introduced in London. It would be out of the question to raise the electricity rate and impose a tax similar to the conventional fuel tax. The above-mentioned preferential measures should also be applied to other EFVs.

However, it will be difficult to introduce electric vehicles in developing countries. Given the expected prices of electric vehicles in 2050, only a small group of developing countries will be able to introduce electric vehicles on a large scale. Therefore, we propose the introduction of simple electric vehicles which can be recharged at home and which are suited only to intra-city transport because of the limited driving range and speed. We do not regard the introduction of such electric vehicles as a transit measure. It will represent the introduction of a new mode of urban-area transportation. Electric vehicles that have been increasingly used in major Chinese cities in recent years are an example of this simple type of electric vehicle. In order to promote the diffusion of this new type of vehicle, which runs in a speed range different from the range of existing vehicles, it will be necessary to create a dedicated lane for the vehicle and provide preferential tax treatment.

Moreover, the expected shift to short-distance vehicle transport following the introduction of electric vehicles will produce positive effects under our reduction scenario. This is because electric vehicles' limited driving range will work to restrict the inter-city vehicle transport volume. In regions where an inter-city railway network, including high-speed railway lines, has been introduced before the introduction of electric vehicles, the arrival of electric vehicles will constitute a factor that ensures active use of railway transport. In regions where a railway network is being built, the introduction of electric vehicles will stimulate the development of railway infrastructure. We believe that a broad framework of a sustainable transport system can be established only after a firm policy for inter-city transport has been adopted.

Table 2 – Policy packages for urban transport

Purpose	Policy measures	Developed countries	Developing countries
Promoting use of public transport	Infrastructure building	++	+++
	Transport fares		
	Setting of low fares	++	+++
	Improvement of access to stations		
	Safe sidewalks, street lamps, improvement of security	+++	+++
	Short distance to stations (a large number of stations)	+++	+++
	Improvement of connections with other transport systems	+++	+++

	Park and ride	+++	+++
	Introduction of public transport systems with high value added		
	Reduction of vibrations (track maintenance and improvement of train car performance)	+++	
	Train cars that enable the use of wireless LAN and have power outlets	+++	
	Elimination of accidents and improvement of safety, punctuality and comfort	+++	+++
	Train service frequency, use of electronic tickets, etc.	+++	
Restricting ownership of vehicles	Increases in taxes		
	Vehicle acquisition tax	+++	+
	Vehicle ownership tax	+++	+
	Car park tax	+++	+
	Restriction on ownership (grant of car license numbers by lottery)	+++	+
Restricting use of vehicles	Restriction on entry into downtown areas	+++	++
	Road congestion tax and road pricing	+++	++
	Fuel tax (including carbon tax)	+++	++
	Car park tax	+++	++
	Vehicle ownership tax	+++	++
Promoting introduction of EFVs	Fossil fuel tax (set at a high level)	+++	+++
	Tax on acquisition and ownership of fossil fuel-based vehicles (set at a high level)	+++	+++
	Tax exemption for electricity		+++
	Tax exemption for acquisition and ownership of EFVs	+++	+++
	Establishment of a lane dedicated to small EVs	+	+++
Promoting development of EVs	Support for development of high-performance, low-cost batteries	+++	++

Policy Packages for Non-urban Transport

Inter-city transport

Public transport will be introduced in urban areas facing such problems as traffic congestion and exhaust gas pollution, albeit to varying degrees. However, it is not easy to justify the enormous initial investment necessary for the construction of inter-city railways. This is because in most cases, inter-city railway transport is introduced in order to resolve the saturation of the existing transport capacity compared with the actual and potential demand, promote regional development or build region-to-region links. However, from the perspective of the fight against global warming and energy conservation, high-speed railway transport, to which vehicle and air transportation can be shifted, is a very effective means to reduce CO2 emissions. Therefore, we believe that it is necessary to aggressively promote the introduction of inter-city railways from the perspective of the fight against global warming.

Expansion of railway networks

We believe that railways are the mode of transportation that should attract the most attention as an option for urban-area transport in developed countries. Furthermore, high-speed railway networks are very important for the promotion of a modal shift from air transport. Under existing high-speed railway systems, such as Japan's Shinkansen and France's TGV, trains can run at speeds of around 300km per hour. If a superconducting maglev system is introduced, the maximum speed can be raised to 500 km per hour, which will enable high-speed railway transport to compete with air transport on routes of up to around 1,000 miles in distance. In order to promote a shift to railway transportation, it will be necessary to enhance the attractiveness of railways compared with competing modes of transport as in the case of

the promotion of a modal shift regarding urban-area transport. Especially, the policy concerning access to stations is closely related to the selection of a mode of urban-area transport. In major cities where a public transport system is available, it will be essential to ensure smooth connections with it. Meanwhile, in areas where vehicles are used as the mainstay mode of transportation, it will be important to at least ensure better access to railway stations than access to airports, for example by building huge parking lots with low fares (for a park and ride). Moreover, promoting the use of rental cars and car-sharing will be an effective means to facilitate transport to and from railway stations. It will also be effective in promoting railway transport to implement policy measures that put the use of competing modes of transportation such as vehicles (expressways) and air transportation at a disadvantage.

Railways are a very important mode of inter-city transport in developing countries as in developed countries. In China and India, passenger railway services are operated with a fairly high transport density because the cost is relatively low. However, from a long-term perspective extending to 2050, it will be necessary to promote an increase in train speeds and electrification, not to mention improve safety and comfort. Basically, implementing a policy measure that puts the use of vehicles, a competing mode of transport, at a disadvantage is not an unconditionally desirable option in a situation where the needs for mobility have not been satisfied. However, in reality, the superiority of vehicles with regard to short-distance transport in particular is likely to prevent a modal shift unless the use of vehicles is put at a certain degree of disadvantage. The use of air transport will also need to be put at a certain degree of disadvantage if railway transport is to be promoted.

Improvement of truck technology and driving

Trucks account for a large ratio of the amount of CO2 emissions from the transport sector, and the ratio tends to increase in line with economic development. However, the improvement of the fuel efficiency of trucks has lagged compared with the improvement in the fuel efficiency of passenger cars. It is necessary to accelerate the development of technologies related to trucks, which are far fewer than passenger cars, for example through governmental support for the development of such technologies. In addition, a review of the way of driving trucks is also important. According to the results of some tests, semi-automated fleet driving of trucks on expressways improves the fuel efficiency of the trucks that run at the top and tail of the fleet by 20% and that of trucks that run in-between by 50%. Moreover, promoting a “noble use” of biofuels will be an important policy measure from the perspective of the WTW energy efficiency.

Non-urban area transport

In villages and towns, it will be difficult to introduce public transport on a large scale because of poor cost efficiency. In addition, as the population density there is low, the distance travelled at a time tends to be long. It is hard to imagine that electric vehicles will match the needs for such transport under all circumstances. Therefore, we assume that non-urban-area

transport will mostly use vehicles, including electric vehicles and hybrid vehicles. In this case, it will be important to promote a shift to hybrid vehicles. The importance of this approach is likely to be greater in countries with a vast geographical area.

Table 3 – Policy packages for non-urban transport

Purpose	Policy measures	Developed countries	Developing countries
Promoting introduction of inter-city railways	Infrastructure building	++	+++
	Transport fares		
	Setting of low fares	++	+++
	Improvement of access to stations		
	Safe sidewalks, street lamps, improvement of security	+++	+++
	Short distance to stations (a large number of stations)	+++	+
	Improvement of connections with other transport systems	+++	+++
	Park and ride	+++	+++
	Promotion of car sharing	+++	+++
	Introduction of public transport systems with high value added		
	Electrification and an increase in train speeds	+++	+++
	Reduction of vibrations (track maintenance and improvement of train car performance)	+++	+
	Train cars that enable the use of wireless LAN and have power outlets	+++	+
	Elimination of accidents and improvement of safety, punctuality and comfort	+++	+++
	Train service frequency, use of electronic tickets, etc.	+++	+
	Selection of the organization responsible for railway operation, and education		+++
	Establishment of necessary legislation		+++
Restricting ownership of vehicles	Increases in taxes		
	Vehicle acquisition tax	+	
	Vehicle ownership tax	+	
	Car park tax	+	
	Restriction on ownership (grant of car license numbers by lottery)	+	
Restricting use of vehicles	Tax on expressway congestion and road pricing	+++	++
	Fuel tax (including a carbon tax)	+++	++
	Car park tax	+++	++
	Vehicle ownership tax	+++	++
Promoting introduction of EFVs	Fossil fuel tax (set at a high level)	+++	+++
	Tax on acquisition and ownership of fossil- fuel-based vehicles (set at a high level)	+++	+++
	Tax exemption for the acquisition of hybrid vehicles	+++	+++
	Tax exemption for electricity used for hybrid vehicles	+++	+++
	Tax exemption for acquisition and ownership of EFVs	+++	+++
Restricting use of air transport	Airport usage tax	+++	+
	Fuel tax (including a carbon tax)	+++	+
	Aircraft usage tax	+++	+
Developing truck technology	Support for development of technology to improve fuel efficiency	+++	++
	Support for development of driving assistance technology	+++	++
	Introduction of the “Top Runner” system	+++	+++
Developing high-speed railway systems	Support for development of high-speed railway systems (e.g. the maglev system)	+++	+
Developing policy expertise	Formulation of comprehensive transport plans	+	+++
Development of power generation	Development of Power generation enough for the diffusions of EVs		+++

AFTERWORD

Need to curb the transport volume while maintaining economic growth

We have quantified variables while taking great care to avoid curbing the transport volume. This is because we have in mind the need to minimize the impact on economic development and the UNFCCC's call for the sustainable development of developing countries. However, if we are to aim for greater reduction in CO2 emissions than the existing goal, it will become necessary to seriously consider the possibility of decreasing the transport volume. One example is streamlining distribution through the supply chain management. Locating workplaces and homes close to each other and promoting the "compact city" scheme are also promising policy measures, as they reduce the distance of transportation. However, it will take a long time to put these policy measures into practice and it will be difficult to quantify their effects. We plan to assess their effects and announce the assessment results in a final report.

Changes in non-transport fields will have a significant impact on transport

In a society with widespread use of electric vehicles as envisioned by us, a change in the power source mix will have a very significant impact on the reduction of CO2 emissions from the transport sector, although it is difficult to quantify the impact because we have not made assessment on a WTW basis in this research. In particular, the introduction of renewable energy, nuclear power generation and CCS (Carbon dioxide Capture and Storage) technologies in developing countries that currently rely on fossil fuel-based power generation would by itself reduce CO2 emissions by more than 10%. Moreover, next-generation video-conference technology that is expected to be realized in line with the advancement of IT technology could significantly reduce transport related to business trips and meetings. However, this convenient means of communication, as easy to use as telephones, may only realize latent transport needs, so it alone may not significantly decrease the frequency of business trips. In our final report, we also plan to announce the results of our assessment of the impact of such changes as well as the potential of measures and policy packages to restrict the transport volume.

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