Next-generation Public Transportation: Electric Bus Infrastructure Project

YOSHITAKA KAKUHAMA*1  JIN KATO*2
YASUSHI FUKUIZUMI*3  MASAHARU WATABE*1
TAKASHI FUJINAGA*4  TAKUYA TADA*5

The large-scale reduction of carbon dioxide (CO₂) in automobile exhaust is a key component in meeting ambitious targets for decreasing overall CO₂ emissions in Japan. Electric buses reduce CO₂ significantly through the modal shift of passengers from automobiles as well as through the intrinsic characteristics of their design. The reduction in battery charging time, construction of traffic infrastructure, and increase in convenience and comfort are essential elements in increasing the practicality and utilization of electric buses. The ability of the electric bus to act as an electrical power storage device is also an important factor in achieving a low-carbon society from the perspective of the increase in electricity demand and use of regenerative energy. This review includes a description of our participation in the “Verification Test of Community Renovation Using Environmentally Friendly Vehicles” directed by the Japanese Ministry of Land, Infrastructure, Transport and Tourism.

1. Introduction

The reduction of automobile exhaust carbon dioxide (CO₂), which accounts for 20% of the total CO₂ emissions in Japan, is a key in achieving the ambitious targets of reducing CO₂ emissions 25% by 2020 and more than 60% by 2050. Achieving the national objective of Japan becoming a low-carbon society requires the renovation of communities to ensure on-time schedules and quick transfers in the new electric bus system. The improvement in convenience and user-friendly service in electric buses is also necessary, which will include such aspects as the introduction of onboard information and communication systems, zero-emission, reduced noise and increase comfort. This will improve the modal shift from private automobiles to the public bus service that will in turn increase the number of bus users, increase bus service profits, and revitalize public transportation. The result will be a reduction in both traffic exhaust CO₂ and the number of vulnerable road users who are not well served by public transportation.

Replacement batteries for electric buses can be used in an electric power storage system for city electrical grids to help offset the increased demand for electricity caused by the large number of electric cars, and the increase of regenerative energy. This will contribute to achieving a low-carbon society.

Mitsubishi Heavy Industries Ltd. (MHI) considers the electric bus system to be a key component in the next generation of public transportation and achievement of a low-carbon society. MHI is participating in the “Verification Test of Community Renovation Using Environmentally Friendly Vehicles” directed by the Japanese Ministry of Land, Infrastructure, Transport and Tourism in collaboration with the cities of Kyoto and Aomori, and Aomori Prefecture between February and May 2011.

*1 Manager, Sustainability Energy & Environment Strategic Planning Department
*2 General Manager, Sustainability Energy & Environment Strategic Planning Department
*3 Deputy General Manager, Sustainability Energy & Environment Strategic Planning Department
*4 Senior Administrator, Advanced Mechanic Systems Department, Transportation Systems and Advanced Technology Division
*5 Engineering Manager, Power Train System Department, General Machinery & Special Vehicle Headquarters
2. Public Transportation’s Contribution to a Low-carbon Society

The electric bus used in public transportation is the source of significant reductions in CO₂ emissions. Figure 1 shows the benefits of electrifying bus service. The annual reduction of CO₂ is about 30 tons per bus. Moreover, switching from the automobile to bus results in a reduction of CO₂ emission to about one eighth for each person. This modal shift contributes to a significant reduction of automobile CO₂ exhaust (Figure 2). Achieving CO₂ reduction targets requires not only the electrification of bus service, but also a significant modal shift from private automobiles to public buses.

Figure 1  Benefits of bus service electrification

3. Revitalization of Public Bus Service

The use of regular-route buses in public transportation service is on the decrease and 80% of the services operate at a loss. This is probably because of increasing customer dissatisfaction with the reduction in on-time performance and the increase in travel time caused by increased congestion due to the increasing number of automobiles. As the number of bus passengers decreases, the frequency of bus service decreases, routes are eliminated or merged, and dependence on private automobiles rises.

3.1 Improvement of Convenience

Breaking this vicious circle and revitalizing public bus transportation to make it more attractive require the renovation of communities. An increase in the convenience and comfort of buses traveling on regular routes will lure customers away from private automobiles. Some measures that could be used include achieving on-time schedules and quick transfers, introduction of dedicated or priority bus lanes, coordination of traffic lights to give buses priority, and restricting entry to urban areas to electric vehicles (EVs). Park and ride areas on the outskirts of cities connected to downtown areas by electric bus service are also necessary elements in achieving a modal shift from the automobile to bus (Figure 3).

Bus-use information such as arrival time, transit time, connection time, and traffic conditions can be provided by an on-demand communication system to improve customer convenience. Provision of tourist information, weather forecasts, and route-navigation information is important in tourist areas (Figure 4).
3.2 Improvement in Comfort

Because electric buses do not produce exhaust gas or much noise, passengers can embark and disembark in enclosed areas such as buildings. Bus stations could be inside train or subway stations, or in commercial facilities, and provide convenient passenger access way from wind, rain, cold, and heat (Figure 5).

![Figure 5 Indoor bus station](image)

4. Electric Buses with Exchangeable Batteries

Just like the automobile that needs a fueling facility such as a gas station, an electric vehicle with lithium-ion batteries needs a charging station. Most current electric vehicles require plug-in charging facilities, which present two problems that must be overcome for electric buses.

4.1 Rapid Charging Requirements

Rapid charging of electric buses means that the buses must be parked and out of service for a time that could be as long as an hour. Moreover, charging a bus requires several hundred kilowatts at some random time during the day. This may require increased access to electrical service or increased electrical capacity of power plants and the power grid.

4.2 Benefits of Battery Exchange

MHI is considering the use of a battery exchange system to address these issues (Figure 6). The time required to recharge a bus is reduced to the time to replace the battery package in the bus, about the same time required to refuel a conventional bus. In addition, charging the battery outside the bus eliminates the requirement for rapid charging and reduces the load on the electrical infrastructure, and thus its cost.

![Figure 6 Battery exchanger](image)
5. Compatibility with a Low-carbon Society

Up to now, the energy for transportation has been provided by fossil fuels. The electrification of vehicles will cause a surge in the electricity demand, and coupled with the increase in renewable energy such as photovoltaic generation and wind power, this will require countermeasures to reduce the effects of load fluctuation.

The batteries in the battery exchange system can be used as a stationary electric power storage facility to stabilize electrical grid operation and as a buffer for renewable energy sources. In addition, because the batteries are portable, they can be used for other applications such as providing power for outdoor events or in the event of a natural disaster. Thus, the battery exchange system can be regarded as a part of the social infrastructure. This presents the possibility of sharing the cost of the batteries with those who would pay for their secondary uses.

6. Trials

Four locations in Japan were selected for the “Verification Test of Community Renovation Using Environmentally Friendly Vehicles” directed by the Ministry of Land, Infrastructure, Transport and Tourism in 2010. MHI will conduct trials of the electric bus in Kyoto in February 2011 and in Aomori City and Aomori Prefecture in May 2011.

Figure 7 shows an overview of the test. The reduction of CO₂ will be measured for a real electric bus operating on a regular route. A survey will be taken of those monitoring the trial, and assessments of the surrounding traffic and pedestrians will be conducted.

In Aomori City and Aomori Prefecture, the bus will operate between the new Shin-Aomori bullet train station and Aomori station to evaluate the effect of cold weather.

7. Conclusions

The amount of CO₂ in automobile exhaust must be drastically reduced to meet the Japanese CO₂ reduction targets. The electrification of regular-route buses and the modal shift from private automobiles to electric buses are effective ways of achieving this goal.

Revitalizing current public bus transportation systems requires introduction of electric buses, renovation of communities to include exclusive bus lanes, improvement of on-time schedule and convenience, and improvement of comfort by locating bus boarding areas inside train stations or other facilities. Increasing convenience through the use of onboard communication systems and other methods are also effective methods.

Our battery exchange system has the advantage of drastically reducing both the charge time and the impact on the electrical infrastructure cost.

The battery exchange system is quite compatible with the future low-carbon society due to its ability to stabilize the power grid and permit the effective use of renewable energy sources.

MHI is participating in trials in Kyoto and Aomori directed by the Ministry of Land, Infrastructure, Transport and Tourism, and will proceed with the popularization of the electric bus system.