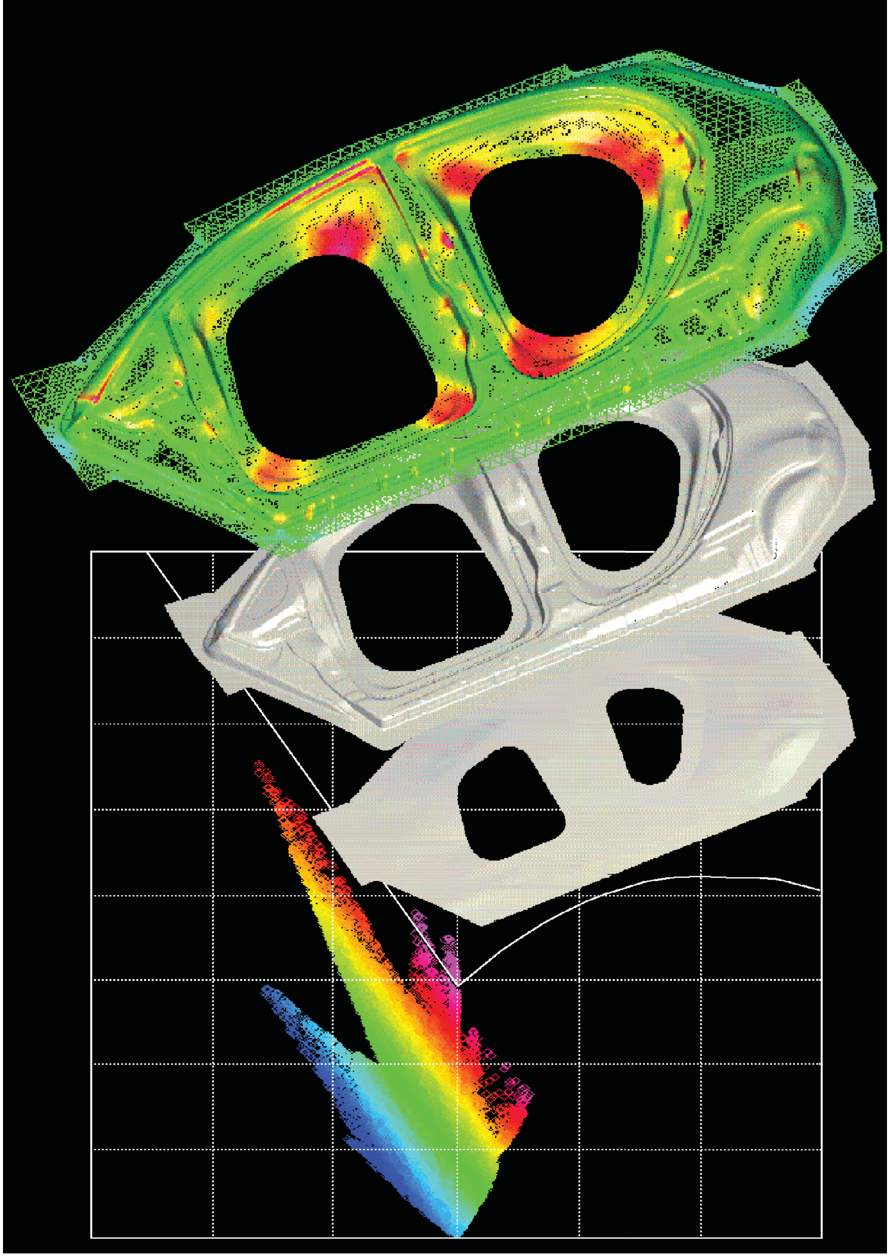

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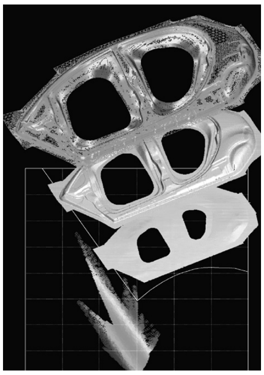

- **Cover Photograph**

The cover photograph shows a stamping simulation of the side outer panel for the Mitsubishi "i". Stamping simulations enable Mitsubishi Motors Corporation to predict splits, wrinkles, and other defects that may occur in the parts from sheet metal. They also enable us to predict thinning distribution, stress distribution, draw-in during stamping, and skid marks. By simulating stamping processes, we are able to identify and eliminate defects early in development programs, thereby promoting front-loading of work.

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Contents

Photo in the previous page
These images are the final design sketches of the Mitsubishi “i” (a new minicar that was launched January 2006) and Mitsubishi OUTLANDER (a new sport utility vehicle that was launched in October 2005). Many of the new technologies used in the “i” and OUTLANDER are featured in this edition of the Mitsubishi Motors Technical Review.

Promotion of Technical Development with Emphasis on the Environment

Tetsuro AIKAWA
Managing Director

Concern over the environment is growing as abnormal global weather and the depletion of natural resources threaten the world. The Kyoto Protocol came into effect last year and discussions on the environment have continued ceaselessly. The United States, which refused to sign the Kyoto Protocol, has started efforts to reduce domestic emissions of CO_2. Hence, the auto industry is actively working to develop environment-friendly technologies since the industry inevitably has a major impact on the environment. The auto industry showcased its environmental conservation efforts at the Tokyo Motor Show last autumn and at various other events around the world.

In January 2005 Mitsubishi Motors Corporation (MMC) announced its new revitalization plan, and in September announced a new slogan, the "*Kuruma zukuri no genten e*" (meaning "Pursuing the Origins of Car Engineering" in English. The English phrase is not used in the company's marketing efforts), which will be reflected in our products. MMC has resolved to make more attractive automobiles that offer both drivability and durability, and has promised customers to sincerely consider the environment in carrying out the plan.

As part of its environmental conservation work, MMC defined its environmental principle as a basic policy in 1999, drew up a 5-year medium-term environmental action plan in 2002 to execute that policy, and has taken various steps accordingly. For instance, the Design for Environment (DfE) promotes designing based on not only the reduction of CO_2 emitted while operating the vehicle and realizing cleaner exhaust emissions, but also on the reduction of CO_2 emitted during the production of automobiles, together with the maximizing of the recycling potential upon scrapping. In 2002, MMC set up a special division for automobile recycling to prepare for the Recycling Law which came into force in January 2005. MMC has already achieved a shredder dust recycling rate of 59.3 % in 2004, significantly exceeding the legal requirement of over 30 % in 2005 and later. Our environment-related actions and achievements are announced in the Environment Sustainability Plan in four categories: environment management, recycling, prevention of global warming and prevention of contamination of the environment.

The OUTLANDER model released last October includes specific environmental features. For instance, its exhaust emissions are 75 % lower than those mandated by Japan's 2005 LEV regulations and its fuel efficiency is 5 % higher than Japan's 2010 fuel efficiency standard, thanks to improved combustion and exhaust systems and minimized weight increase by adopting a newly developed platform. As for safety – another key factor of automobiles – even though the weight increase has been suppressed, the OUTLANDER series achieves safety equivalent to the highest 6☆ rating in the JNCAP safety performance comparison test by a public organization (result of in-company test), and the vehicle is designed to minimize the damage of a smaller car in the event of a crash and to improve protection for pedestrians. Meanwhile, the minicar model "i" released in January satisfied the voluntary regulation of the auto industry on Volatile Organic Compounds (VOCs) that cause the "sick-house syndrome" in order to improve the ambience inside the car. And for safety, since the "i" series adopts a rear midship layout, it creates a sufficient crush zone by using the front area without engine. Although the "i" series is a minicar, it meets the 5☆ safety rating of JNCAP (result of in-company test). These new technologies adopted on OUTLANDER and "i" are featured on this MITSUBISHI MOTORS TECHNICAL REVIEW.

The target low pollution model in the future environmental technologies is the next-generation electric vehicle "MIEV" which emits no gas at all. First of all, it makes exceptional use of space since the motor is contained inside a wheel and thus no large drive system is necessary. With this concept, it is easier to develop not only basic electric cars but also hybrid cars and fuel cell electric cars. The vehicle performance will also be significantly enhanced as the in-wheel motors can be controlled independently for each wheel without a transmission, differential gears or other complex drive systems. MMC will use lithium ion batteries with higher energy density to replace the conventional batteries. MMC will work hard to study the technologies required to achieve this target to make customers experience our minicar-based environment-friendly electric cars by 2010.

Today, company managers must be both environmentally and socially aware. As we promised in the revitalization plan last year, MMC will add "contribution to environmental preservation" to the "driving pleasure and safety" while putting the customer first. We will focus on achieving our targets and developing the required new technologies, which we will continue to announce in MITSUBISHI MOTORS TECHNICAL REVIEW. We hope you enjoy reading these articles.

TECHNICAL PERSPECTIVE

Technology Status and Future of Clean-Energy Vehicles

Eizo TABO* Takashi YOSHINA*
Yasufumi SEKINE* Reiko SAITO*

Abstract

Since the Kyoto Protocol to the United Nations Framework Convention on Climate Change (commonly known as the Kyoto Protocol) came into force in February 2005, the Japanese government has been working to satisfy the targets for reduction of carbon-dioxide (CO_2) emissions. Meanwhile, however, rapid motorization in China, India, and Southeast Asia can be expected to drive continued demand for automobiles and concomitant growth in energy consumption.

Against this backdrop, automakers have a responsibility to develop and promote Low Emission Vehicles (LEVs) as a means of helping to preserve the natural environment. Like other automakers, Mitsubishi Motors Corporation (MMC) needs to take a clearly defined approach to LEV development and promotion from a long-term standpoint.

This paper gives an overview of MMC's LEV-related efforts together with information on the Japanese government's LEV strategies, the current situation regarding Clean Energy Vehicles (CEVs), and the outlook for future LEV developments.

Key words: *Technical Trend, Low-Emission Vehicle, Clean Energy Vehicle*

1. Introduction

In recent years, the effects of global warming have become increasingly evident in the form of rising air temperatures, rising sea levels, and melting permafrost. The Intergovernmental Panel on Climate Change has attributed most of the global warming in the last 50 years to human activity[(1)], and it has been reported that the greenhouse gas that most seriously exacerbates global warming is CO_2[(2)].

When the Kyoto Protocol came into force in February 2005, the Japanese government established a Kyoto Target Achievement Plan. This plan calls for adoption of LEVs to be promoted as a way to achieve a reduction of about three million tons in CO_2 emissions by FY 2010[(3)]. Consequently, there is a need for a rapid increase in LEV adoption.

Further, in November 2005 Japan's Ministry of Economy, Trade, and Industry (METI) compiled a super-long-term energy strategy that calls for CO_2 emissions in the household and transportation sectors to be reduced to zero by 2100. This document reflects an assumption that worldwide oil production will peak in 2050 and a belief that societies must end their dependence on oil by the same year. With regard to automobiles, the strategy calls for Fuel Cell Vehicles (FCVs) and Electric Vehicles (EVs) as a proportion of total automobiles to be increased to 40 % by 2050 to enable CO_2 emissions to be reduced to zero by 2100.

Given the aforementioned circumstances, the positioning of LEVs in the socioeconomic structure is going to become increasingly important.

2. Overview of LEVs

There is no universal, clear-cut definition of a LEV. Generally speaking, though, LEVs are taken to include vehicles that emit only small quantities of atmospheric pollutants such as Hydro-carbon (HC), nitrogen oxides (NOx), and particulate matter (PM) and vehicles that additionally emit only small quantities of CO_2. LEVs are categorized either as LEVs (gasoline and diesel vehicles that are designed for reduced exhaust emissions) or as CEVs [EVs, Compressed Natural-Gas (CNG) vehicles, Hybrid Electric Vehicles (HEVs), and other vehicles that use clean alternatives to conventional fuels].

The Japanese central government and a number of Japanese local authorities have introduced certification and purchase-subsidy programs to promote the spread of LEV adoption.

2.1 Major Japanese government incentive programs for promotion of LEVs

In a March 2002 outline of strategies for combating global warming[(1)], the Japanese government targeted adoption of 3.48 million LEV units by 2010. In the Kyoto Target Achievement Plan[(3)], which it established in April 2005, the government set a revised target of 2.33 million units. To achieve this target, the government is implementing incentives that encourage the purchase of LEVs. Some of the schemes are described hereafter.

2.1.1 Green automobile taxation system[(4)]

This incentive is administered by the Ministry of Land, Infrastructure, and Transport (MLIT) and came into effect in 2001, when Japan introduced a certification system for LEVs. Under the present taxation system, anyone purchasing a low-emission and low-fuel-

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Table 1 Overview of Japan's green automobile taxation system (FY 2006 – 2007)

Tax type	Applicable vehicle types	Tax reduction*1	Period
Annual automobile tax	EVs, FCVs, CNG vehicles, methanol vehicles and gasoline vehicles (including HEVs and LPG vehicles) qualifying for a 4☆ LEV rating*2 and having fuel efficiency at least 20 % better than standard*3	– 50 %	April 2006 to March 2008*5
	Gasoline vehicles (including HEVs and LPG vehicles) qualifying for a 4☆ LEV rating and having fuel efficiency at least 10 % better than standard*4	– 25 %	
Automobile acquisition tax	Gasoline vehicles (including LPG vehicles) qualifying for a 4☆ LEV rating and having fuel efficiency at least 20 % better than standard	Personally owned vehicles (excluding minicars): – ¥15,000 Commercially owned vehicles; minicars: – ¥9,000	April 2006 to March 2008
	Gasoline vehicles (including LPG vehicles) qualifying for a 4☆ LEV rating and having fuel efficiency at least 10 % better than standard	Personally owned vehicles (excluding minicars): – ¥7,500 Commercially owned vehicles; minicars: – ¥4,500	
	EVs, methanol vehicles, CNG vehicles, HEVs, FCVs	HEVs (passenger cars): – 2.2 % Others: – 2.7 %	April 2005 to March 2007

<Reference> The standard automobile acquisition tax rate is 5 % for personally owned vehicles (excluding minicars) and 3 % for commercially owned vehicles and for minicars.

*1: Reductions in annual automobile tax are shown as percentage reductions in payable tax amounts. Reductions in automobile acquisition tax are shown as yen reductions in payable tax amounts or as percentage reductions from the standard tax rates (e.g., 3 % for commercially owned vehicles).

*2: Vehicles with exhaust emissions at least 75 % lower than those permitted by Japan's 2005 regulations

*3: Vehicles with fuel efficiency at least 20 % better than that required by Japan's 2010 standard

*4: Vehicles with fuel efficiency at least 10 % better than that required by Japan's 2010 standard

*5: The tax reduction is applied the year after a vehicle is newly registered.

*6: It is possible to receive the above preferential treatments for both the annual automoble tax and automobile acquisiton tax, but it is impossible to receive multiple preferential treatments for the automobile acquisition tax.

consumption vehicle benefits from a reduction of annual tax and acquisition tax. When a certain number of years has passed following the vehicle's registration, the annual tax is levied at an increased rate. Thus, the system not only encourages initial LEV purchases but also promotes the replacement of old vehicles with new ones.

In December 2005, the government unveiled a FY 2006 tax-system outline involving continuation of the automobile green taxation system in FY 2006. The taxation system will have revised terms: A 25 % reduction in annual automobile tax applies to any vehicle that has exhaust emissions 75 % lower than Japan's 2005 regulations (4☆ LEV rating) and has fuel efficiency at least 10 % better than Japan's 2010 fuel-efficiency standard. And a 50 % reduction in annual automobile tax applies to any vehicle that has exhaust emissions 75 % lower than Japan's 2005 regulations (4☆ LEV rating) and has fuel efficiency at least 20 % better than Japan's 2010 fuel-efficiency standard. An overview of the green taxation system to be implemented from FY 2006 to 2007 is given by **Table 1**.

2.1.2 Subsidy system for adoption of CEVs(5)

This system was released in FY 1998 by METI and is substantially revised every three years (The next review is scheduled for FY 2007.). It receives annual government funding of ¥8 – 10 billion. (The budget for FY 2006 is ¥9 billion.)

Under the system, anyone purchasing a CEV receives a subsidy roughly equal to half of the price difference between the CEV and the conventional model on which it is based. Also, subsidies are provided for construction of natural-gas supply stations, battery-charging facilities, and other types of infrastructure for CEVs. The system has subsidized the purchase of numerous HEVs and CNG vehicles. An overview of the CEV subsidy system is given by **Table 2**.

2.2 The current state of CEV development and adoption

Fig. 1 shows the numbers of CEVs (EVs, HEVs, and CNG vehicles) in use in Japan from FY 2000 to 2004. The number of CEVs increased from about 60,000 in FY 2000 to 230,000 in FY 2004. Also as shown, HEVs account for the majority of the CEVs on Japan's roads. FCVs and methanol vehicles numbered only a few dozen in FY 2004.

An overview of development, sales, and launches of CEVs by Japan's major automakers from 1990 to 2005 is given in **Table 3**. The table was compiled using information released by the Japan Automobile Research Institute (JARI) and information released by the automakers. Although it is not shown in the table, the following schedules are announced: Toyota and Honda will actively launch HEVs in 2006 or later; Mazda will launch hydrogen-engine vehicles in 2006 or later; MMC and Subaru will launch EVs in the minicar category in 2010.

2.2.1 HEVs

A HEV has multiple power sources, whose respective advantages are combined in a way that is intended to limit both exhaust emissions and fuel consumption. The most common HEV power-source combination is an internal-combustion engine and an electric motor. The configuration of the power sources can be series, parallel, or series-parallel (**Fig. 2**).

Since a HEV has multiple power sources or energy sources, the chassis structure is complex and therefore

Table 2 Overview of Japan's CEV subsidy systems

Applicable purchased items	Administering body	Amounts of subsidies and tax reductions	Conditions
EVs, HEVs	Japan Automobile Research Institute	• New vehicle Up to half of price difference between vehicle and base conventional-fuel model • In-use vehicle converted for CNG use Up to one third of cost of conversion from gasoline/diesel use to CNG use	• Only private use • Leased vehicles are eligible. • Regional public bodies may not apply. • Minimum requirement for distance driven: 6,000 km/year (This requirement applies only to HEVs. It was abolished for EVs in FY 2005.)
CNG vehicles	Japan Gas Association		
Electricity stand	Japan Eco-Service Stations Association	Commercial use: up to ¥3.5 million Non-commercial use: up to half of cost of purchase and installation	As of November 2005, rapid chargers are ineligible for subsidies.
CNG stand		Commercial use: up to ¥90 million Non-commercial use: up to half of cost of purchase and installation	Running costs are subsidized.

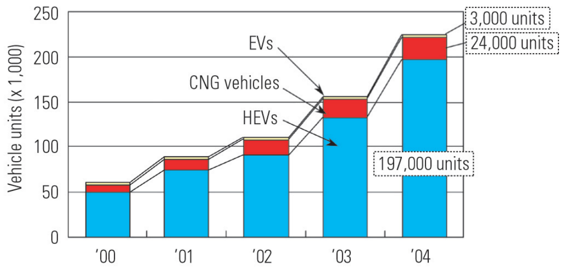

Fig. 1 Numbers of CEVs on Japan's roads

HEVs are rather expensive as compared with the conventional vehicles. However, their ability to be fuelled at existing gasoline stations means that they have become far more prevalent than other CEVs. (There were about 197,000 HEVs on Japan's roads in FY 2004.).

2.2.2 EVs

An EV has a secondary battery that powers an electric motor for propulsion. It creates a smaller environmental burden than any other type of vehicle since it runs with zero exhaust emissions.

Fig. 3 shows comparison of gasoline vehicles, HEVs, and EVs as "well-to-wheel" CO_2 emissions (total CO_2 emissions from energy production to vehicle propulsion). As shown, for performance levels corresponding to an engine displacement of 1,500 cc an EV's "well-to-wheel" CO_2 emissions are about 1/3 of those of a gasoline vehicle and about 2/3 of those of a HEV. The CO_2 emissions corresponding to electricity generation were calculated in accordance with the proportions of generation techniques used by Japan's 10 electric power companies (In FY 2002, the proportions were as follows: thermal; 60 %, nuclear; 31 %, hydroelectric; 9 %.). As the generation efficiency improves and the proportion of generation systems with emitting lower CO_2 increase, CO_2 emissions corresponding to EVs will become even smaller.

Fig. 4 shows comparison of gasoline vehicles, HEVs, and EVs as running costs. The calculations assume (a) performance levels corresponding to a compact passenger car with an engine displacement of 1,500 cc; (b) a gasoline cost of ¥120 per liter; (c) a daytime electricity cost of ¥22/kWh; and (d) a nighttime electricity cost of ¥6/kWh. They show that the running cost for an EV is 1/3 (with daytime charging) or 1/10 (with nighttime charging) of that for a gasoline vehicle and that it is 2/3 (with daytime charging) or 1/5 (with nighttime charging) of that for an HEV.

EVs are clearly superior in terms of environmental compatibility and running costs. As shown in **Fig. 1**, however, the number of EVs registered in Japan (even including micro EVs) is only slightly more than 3,000 Units. The scarcity of EVs can be attributed to strongly negative perceptions (that EVs have extremely short range, must be charged for long periods, are extremely costly, and so on) that have caused by the lead-acid batteries which most EVs on the market use.

A switch from lead-acid batteries to nickel-metal-hydride and lithium-ion batteries has resulted in higher performance from smaller batteries, in longer range, in shorter charging durations, and in lower vehicle weights. **Fig. 5** shows the progress made in development of batteries for EVs and HEVs. Whereas EV batteries must offer high energy density, HEV batteries must offer high power density. Lithium-ion batteries for EVs currently have about four times the energy density of lead-acid batteries. By about 2010, they are likely to have about six times the energy density of lead-acid batteries. Their high energy density enables lower vehicle weights. Their increased performance has made it possible to produce electric minicars and compact cars that have 200 km range.

2.2.3 FCVs

In a FCV, an electric propulsion motor is powered by electricity that is generated inside the fuel cell by a chemical reaction between hydrogen and oxygen in the atmospheric air (**Fig. 6**). The theoretical efficiency of the fuel cell is as high as 80 %, and the substance emitted by a FCV is only water vapor. However, there are several outstanding downside issues, namely a scarcity of hydrogen supply infrastructure, high vehicle production costs, and the difficulty of storing hydrogen safely and efficiently. The general public is not likely to widely adopt FCVs before about 2020 or 2030. (As of FY 2004, there were only 47 FCVs, which consisted of experimental units and units produced for limited sale, in Japan.)