

Development Progress of the Toyota Fuel Cell Hybrid Vehicle

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ABSTRACT

Since 1992, Toyota Motor Corporation (TMC) has been working on the development of fuel cell system technology. TMC is designing principal components in-house, including fuel cell stacks, high-pressure hydrogen storage tank systems, and hybrid systems. TMC developed the '02 model TOYOTA FCHV, the world-first market-ready fuel cell vehicle, and started limited lease of the vehicles in 2002. In 2005, TMC developed a new model of TOYOTA FCHV which obtained vehicle type certification in Japan, and is currently available for leasing.

TMC has improved the cruising range and cold start/drive capability of the TOYOTA FCHV, and conducted public road tests to evaluate the performance. The improved TOYOTA FCHV successfully traveled from Osaka to Tokyo (approximately 560km, 350 miles) on a single fueling of hydrogen. In addition, the cold weather tests carried out in Hokkaido and North America have verified its starting/driving capability at subfreezing temperatures including -37°C .

Although many obstacles remain towards commercialization of fuel cell vehicles, TMC is committed to overcome the obstacles. This paper describes TMC's approaches toward solving the challenges of cruising range and cold start/drive capability.

INTRODUCTION

Several issues must be solved before sustainable mobility can be achieved. Especially, the issues of energy supply and demand and the carbon dioxide (CO_2) emissions are crucial. Considering that most of the current vehicles rely on oil, TMC is making efforts to develop various technologies to solve the issues.

Fuel cell technology is one of the most promising avenues to achieve sustainable mobility. A fuel cell generates electrical power with hydrogen and oxygen, without emitting gases such as CO_2 , NO_x , or PM in driving, and is therefore regarded as the ultimate in clean

power generation. Furthermore, a fuel cell features high energy efficiency and is envisioned as a next-generation power train. While there are still many issues currently impeding the commercialization of fuel cell vehicles, the prospects of solving the technical challenges of cruising range and cold start/drive capability are improving. TMC is conducting public road tests with test vehicles to verify the solutions.

This paper first discusses TMC's approach towards achieving sustainable mobility. Then it describes the present state and challenges of the TOYOTA FCHV, and finally describes the efforts and results of improved cruising range and cold start/drive capability.

CHALLENGES FOR ACHIEVING SUSTAINABLE MOBILITY

ENERGY SUPPLY AND DEMAND

Trends of conventional oil consumption and discovery are shown in Fig.1. Since 1980, consumption has exceeded the rate of discovery and it is not predicted that the amount of future discovery will rapidly increase. Consequently, it is expected that oil supply will peak in the near future, and thus it may be difficult to continue using conventional oil-dependent transportation.

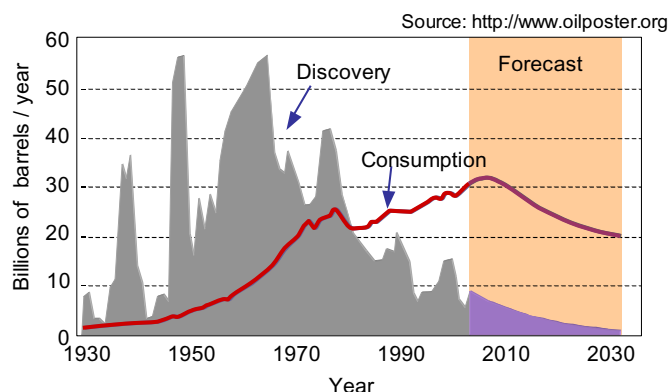


Fig.1. Estimates of conventional oil demand and supply

REDUCTION OF CO₂ EMISSIONS

Fig. 2 shows the changes in atmospheric CO₂ concentration over the last 10,000 years. This graph illustrates an abrupt rise of CO₂ concentration since the 19th century – the beginning of the Industrial Revolution. Scientific consensus estimates that the principal cause is due to CO₂ emissions by using fossil fuel. As Fig. 3 shows, the transportation sector accounts for approximately 20% of CO₂ emissions.

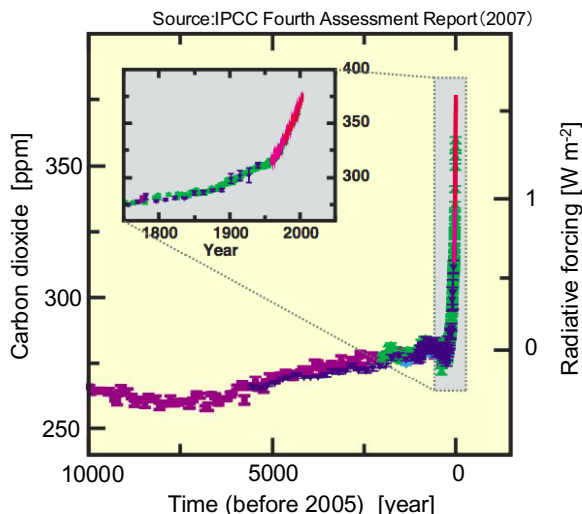


Fig.2. Concentration of CO₂ over the last 10,000 years

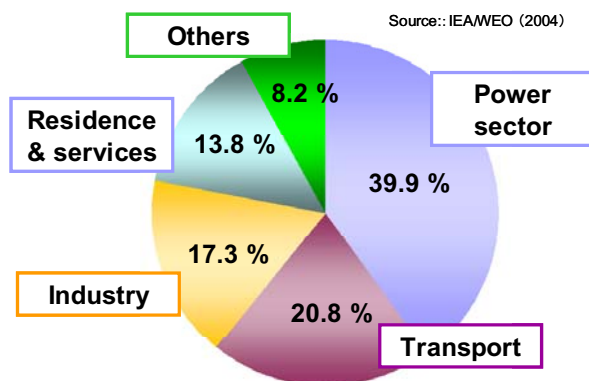


Fig.3 Energy related CO₂ emissions (2002)

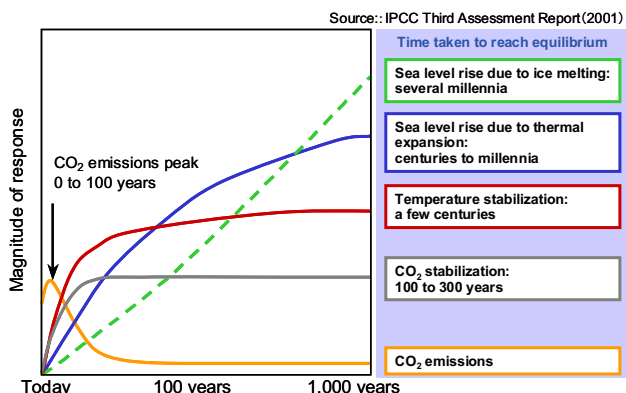


Fig.4 Predicted environmental effects of CO₂ emissions

Fig. 4 is a projection of long-term environmental effects of CO₂ emissions. The diagram shows that the rise in sea level would continue for approximately 1000 years even if CO₂ emissions were to be substantially reduced immediately. This is because it will take a significant amount of time before the concentration of CO₂ stabilizes. Therefore, immediate and long-term measures to reduce CO₂ emissions are required.

EFFORTS BY TOYOTA MOTOR CORPORATION

Fig. 5 shows TMC's approaches to tackle the issues of energy supply/demand and CO₂ emissions. For the next few decades, it would be difficult to rely on only one energy source, and therefore, technologies to meet diversified energy sources are required. TMC is making efforts to develop power trains compatible with diversified energy sources including bio-fuels, synthetic fuels, electricity and hydrogen as well as to improve conventional gasoline and diesel engines. In addition, improvement of efficiency is important to reduce CO₂ emissions. TMC believes that hybrid technology, which can improve efficiency of all types of power trains, is a core technology and thus is integrated with the fuel cell system.

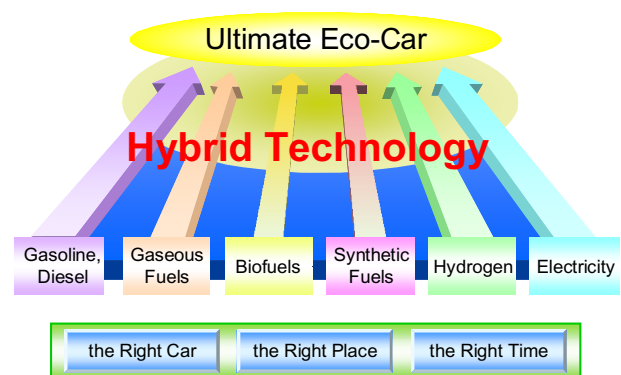


Fig.5 Toyota's approach

TOYOTA FUEL CELL TECHNOLOGY

A hydrogen-powered fuel cell is one of the most important solutions to achieve sustainable mobility.

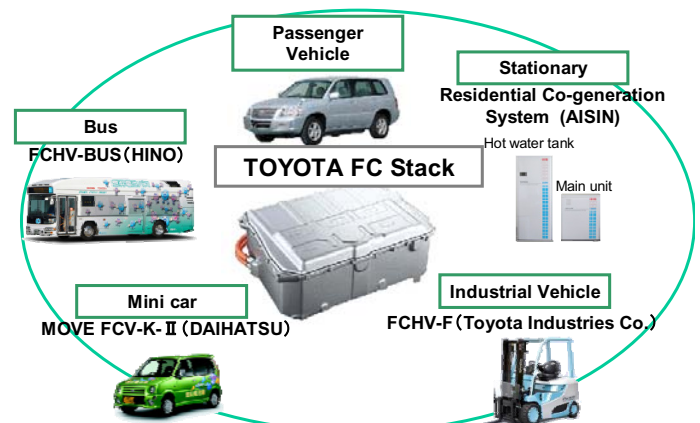


Fig. 6 Toyota's fuel cell technology

Fig.6 shows the applications that utilize Toyota fuel cell technology. The principal fuel-cell-related components are developed and produced in-house by TMC. In addition, TMC is developing not only passenger vehicles, but also buses, home cogeneration systems, and industrial forklifts in corporation with TOYOTA group companies.

TOYOTA FCHV

OVERVIEW

Table.1 shows a current vehicle placement of TOYOTA FCHV, and Table.2 shows an overview of the TOYOTA FCHV specifications. The '02 model TOYOTA FCHV was introduced as a world-first market-ready fuel cell vehicle in December 2002, with four units offered for limited lease within Japan, and two in California. In July 2005, TMC began leasing a new model of the TOYOTA FCHV ('05 model) which acquired vehicle type certification under the Japanese government's amended safety standards. The total number of leased vehicles has reached 39, and 62 units including test vehicles have been driven on public roads. And now, TMC has developed an improved TOYOTA FCHV with longer cruising range and enhanced cold start/drive capability. In particular, the cruising range of this vehicle has achieved 780km in the 10-15 Japanese test mode due to 25% more fuel economy and 90% increase of usable hydrogen by adopting 70MPa high-pressure hydrogen tanks. The improved TOYOTA FCHV successfully traveled from Osaka to Tokyo (approximately 560km, 350 miles) on a single fueling of hydrogen.

Table. 1 Vehicle placement of TOYOTA FCHV

	Japan	USA	Total
 02 model Since Dec/02	11	7	18
 05 model Since July/05	12	9	21
Sub total	23	16	39
Test Vehicle ('02-06)	14	9	23
Total (incl. test vehicle)	37	25	62

Table. 2 TOYOTA FCHV specifications

		Improved FCHV	'05 model FCHV	'02 model FCHV
Vehicle	Overall length/width/height (mm)	4,735/1,815/1,685	←	←
	Weight (kg)	1,880	←	1,860
	Seating capacity (person)	5	←	←
	Maximum driving range* (km)	780	330	300
Performance	Maximum speed (km/h)	155	←	←
	Name	Toyota FC Stack	←	←
Fuel Cell	Type	Polymer electrolyte	←	←
	Output (kW)	90	←	←
Motor	Type	Permanent magnet	←	←
	Maximum Output (kW)	90	←	80
	Maximum torque (N-m)	260	←	←
Fuel	Type	Hydrogen	←	←
	Storage system	High-pressure hydrogen storage tanks	←	←
	Maximum storage pressure (MPa)	70	35	←
Battery	Type	Nickel-metal hydride	←	←

*In the 10-15 Japanese test mode ;Inner test data

FUEL CELL HYBRID SYSTEM

Fig.7 shows the hybrid system of the TOYOTA FCHV. The differences from a hybrid system for a gasoline engine are: (1) a fuel cell stack is mounted in place of the gasoline engine, and (2) all energy transfer is carried-out electrically while a gasoline hybrid is controlled with mechanical power. The fuel cell stack and the high-voltage battery pack are connected in parallel to the inverter that powers the electric motor. (The high-voltage battery pack is connected through a converter.) The output of the fuel cell and high voltage battery is controlled so that efficiency is optimized depending on the driving mode.

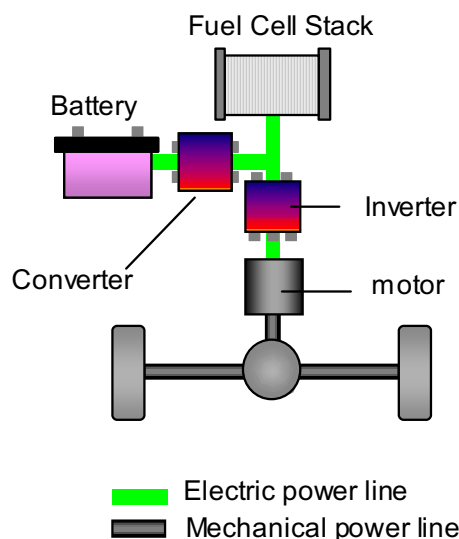


Fig.7 Fuel cell hybrid system

FUEL CELL SYSTEM

In order to generate electricity with the fuel cell stack, ancillary systems such as a hydrogen supply system and a cooling system are needed. The enclosed part Fig.8 is the diagram of the fuel cell system. This system consists of a fuel cell stack, hydrogen and air supply systems, and a cooling system.

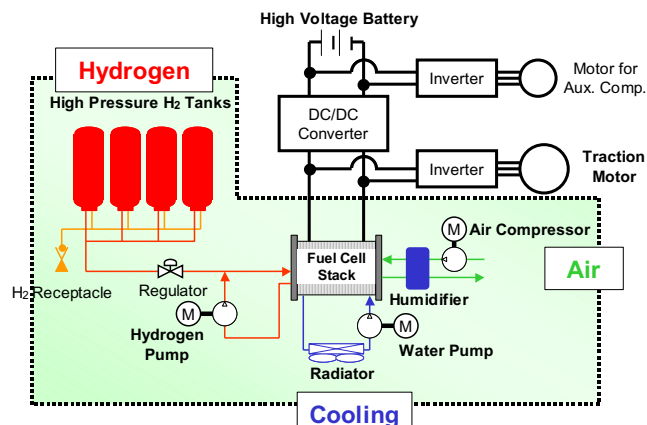


Fig.8 Fuel cell system