Automotive Technologies for Smart Cities and their Global Deployment

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OVERVIEW: In recent years, factors such as worsening environmental problems, including global warming and traffic congestion; resource and energy problems; population increases, primarily in emerging economies; and the aging of urban populations in developed economies have begun to bring major changes in the objectives of urban development. According to a survey by a research company, smart city projects aimed at overcoming these problems are underway at more than 400 locations around the world[1]. In response to these new developments, Hitachi is actively involved in utilizing ICT and other advanced technologies to deliver innovation to social infrastructure such as energy, mobility, and water. As part of smart city projects in the mobility sector, Hitachi is working on demonstration experiments and projects such as the use of EVs in community energy management.

INTRODUCTION

IN response to fossil fuel scarcity and global warming, the automotive industry has been conducting research into alternatives such as hybrid vehicles, electric vehicles (EVs), and fuel cell vehicles for some time. With a series of these having already entered commercial production, they are recognized as having established an important role for themselves in society, and are on their way to wider use. In the field of smart cities, these new automotive developments are seen as a formative part of "smart mobility," and work is also ongoing on their use as part of energy and social infrastructure.

The smart city represents an approach to infrastructure and urban development that seeks to utilize information and communication technology (ICT) to improve energy efficiency and provide a comfortable way of life. As a business, it extends over a wide area, from the provision of hardware through to services.

This article presents examples of development for commercialization taking place worldwide that treats the automobile as part of the energy and social infrastructure, and as one of the elements that make up a smart city. It also describes the outlook for the future.

ROLE OF AUTOMOTIVE TECHNOLOGIES IN SMART CITIES

In the field of automotive technology, advances have been ongoing for some time in technologies for electrification and in research into new fuel technologies to reduce dependence on fossil fuels, with progress being made in basic performance (driving, cornering, stopping, etc.) to provide overall driving performance and the means for mobility and transportation. In the case of electrification, technologies for hybrids and EVs have been adopted from other fields, such as railways, where they are already in use, with remarkable progress having been made in the core technologies of motors, inverters, and batteries (see Fig. 1).

Advances in ICT, meanwhile, have allowed the social infrastructure to deliver new possibilities to consumers by becoming more tightly interconnected than in the past. This trend is also evident in the automotive sector, with growing use of ICT in vehicle and traffic infrastructure and moves toward using increasingly advanced automotive technology and the resources it provides as part of the energy and social infrastructure. Also, the large amount of operational data collected from different types of sensors is giving birth to services that use these data. Along with all these changes, the development of technologies for integrating vehicles into the social infrastructure is proceeding on a global scale.

Recognizing these trends, Hitachi is proceeding with demonstration experiments in Japan and elsewhere, establishing projects that use vehicles as part of the energy and social infrastructure.

Hybrids, EVs, and other electrically powered vehicles emit low levels of carbon dioxide (CO_2) and help reduce dependence on fossil fuels. To make

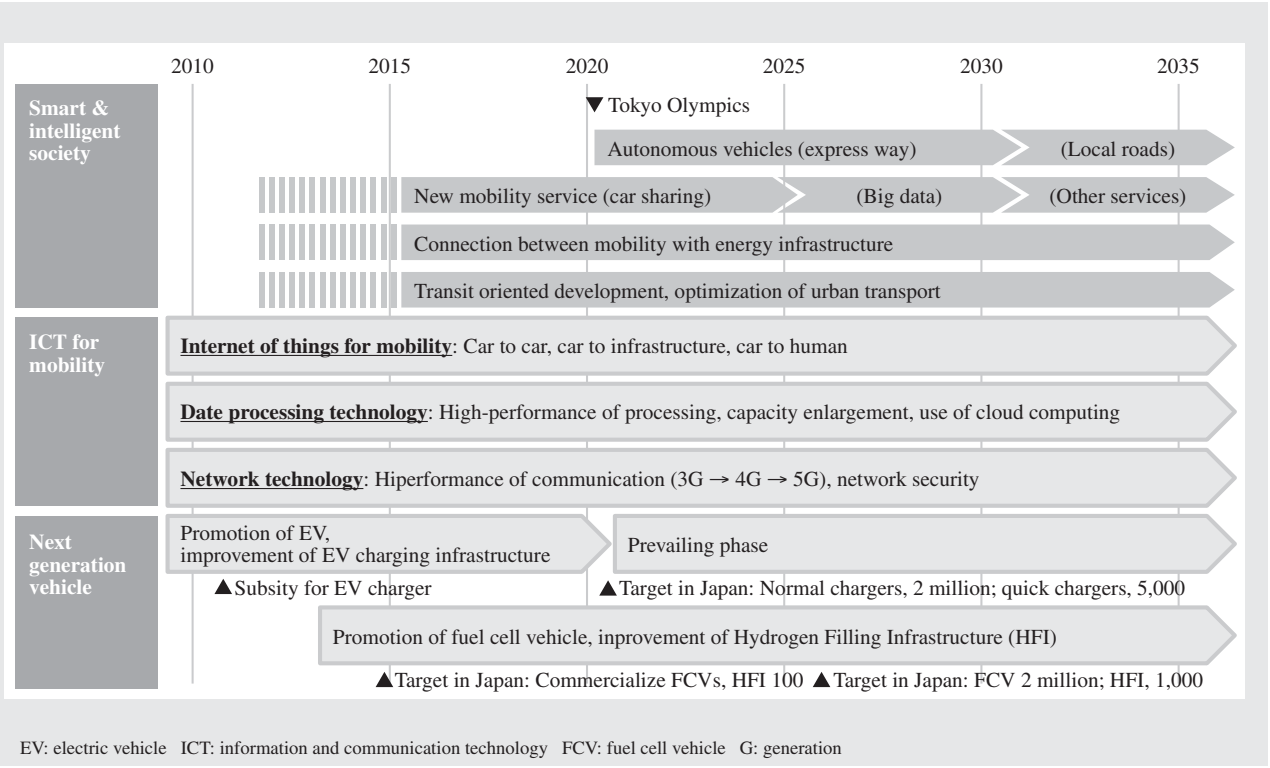


Fig. 1—Roadmap of Technical Developments Aimed at Fusion of Vehicles and Social Infrastructure.
The issues are being debated at a global level from a variety of considerations, including vehicles, infrastructure, fuel, and ICT.

the most of their potential to form part of the energy and social infrastructure, however, they require connections to the electric power supply infrastructure. The shorter range of current EVs compared to gasoline-powered vehicles means that charging infrastructure is also needed.

Rather than looking at the characteristics of EVs in direct comparison with gasoline-powered vehicles, Hitachi supplies a variety of EV solutions that can be used in ways that seek to make the most of these characteristics. The following sections describe some of these solutions.

EV Charger and EV Charging Management System

A variety of EV charging management solutions are required in order to suit the different scenarios for EV use. Hitachi supplies both normal chargers for use at homes or workplaces and quick chargers that allow the number of charging stations and their outputs to be configured based on the requirements of the site and its users. Hitachi is also working on the development of inductive charging technology that provides a non-contact means of charging from a power supply device built into the road, with ongoing development for the electric bus market.

Hitachi is also utilizing ICT to collect information on charger operation using charging management systems that provide centralized management of chargers via a network for the functions provided to EV users, and to implement mechanisms for member identification, billing, and settlement. Work is also proceeding on the energy and social infrastructure aspects of acquiring information about charger output in real time and utilizing it in community energy management.

V2H and V2G

Vehicle-to-X (V2X) initiatives aimed at using an EV connected to a charger as a stationary storage battery are taking place around the world. These use the charging or discharging of the EV's battery for purposes that include ensuring efficient use of electric power, power grid stabilization, and emergency power supply during disasters.

In demonstrations in Japan and elsewhere, Hitachi is building bidirectional mechanisms that utilize group control of EVs, photovoltaics (PV), and storage batteries to make effective use of the supply capabilities of these consumer resources. The aim is to provide load adjustability by timing power consumption and discharge so that it does not inconvenience consumers,

and to do this by establishing EV virtual power plants (VPP) that perform integrated management and control of a number of EV batteries together with vehicle-to-home (V2H) and vehicle-to-grid (V2G) systems. The intended uses for these systems include reducing the high cost on outlying islands in particular for maintaining emergency generators that are used only a few times a year, and compensating for the fluctuating output of renewable energy. It is anticipated that systems like these will be installed in the future to achieve local production for local consumption and autonomous decentralized control.

Car Sharing

Because the EV fleet needs to reach a certain size before these vehicles can be used as part of the energy and social infrastructure, the wider adoption of EVs is the key to their use for this purpose. Car sharing is being introduced as a policy that can help achieve this. It is a system for sharing particular cars between a number of people in which each participant pays for their share of the operating costs, such as fuel, insurance, parking, and tax, in accordance with their level of use. Car sharing typically involves allocating vehicle use over shorter periods of time than car rental, with users able to access the service for as little as a few hundred yen each time in the case of brief trips. It also allows users to make reservations via methods such as the Internet and to pick up and return vehicles at the appointed times through a trouble-free automated and unstaffed process.

In Europe and America, car sharing is contributing to a decline in total car ownership and distance traveled, thereby providing benefits that include helping to alleviate urban traffic congestion, promote greater use of public transportation, improve air quality and other urban environmental problems, reduce city parking problems, and prevent global warming.

Hitachi is developing car sharing services that use technologies such as ICT, machine-to-machine (M2M) communications, and the use of non-contact-type integrated circuit (IC) cards for personal identification, and is seeking to expand the use of services that take advantage of affinities with EV features such as short range and low fuel costs.

Utilization of Big Data in Automotive Sector

With wider use of technologies such as M2M communications and sensors, the infrastructure is being put in place for the high-speed processing of large amounts of data. Work is also starting on the utilization of vehicle-based traffic volume, congestion, and other information in the form of big data.

Hitachi is developing services that are optimized for car owners, such as analyzing and processing vehicle information (including driving distance, fuel consumption/power consumption, and state of charge) at a data center based on a contract between the vehicle owner and manufacturer to provide environmental and driving safety assessments based on driving history.

EXAMPLE APPLICATIONS IN DEMONSTRATION EXPERIMENTS AND PROJECTS

It is anticipated that the use of automotive technology in energy and social infrastructure will continue to expand. This section describes some of the demonstration experiments and projects being conducted by Hitachi in Japan and elsewhere that provide leading-edge examples of this trend.

In addition to verifying the technology, these projects are being undertaken in close collaboration with local infrastructure companies, regional and local governments, and academic institutions in the regions concerned and present a model of building business concepts from the upstream stage. However, the actual services being introduced are primarily being implemented from the downstream perspective of users and consumers, requiring the establishment of business models that are more flexible than those of the past.

Okinawa EV Charging Management Service

As of July 2013, this service operates 385 EVs and 31 quick charging stations in Okinawa Prefecture. The provision of charging infrastructure is being handled by AEC Co., Ltd., a company in Okinawa Prefecture, and the service uses Hitachi Solutions, Ltd.'s EV charging management system.

AEC Co., Ltd. and Hitachi Solutions, Ltd. took advantage of Okinawa Prefecture's demonstration project to develop the Smart EV Navi (provisional name) cloud service that combines route search and energy management. The demonstration experiment commenced in February 2013. For EVs to gain wider acceptance, they will need to overcome users' range anxiety. This requires judgments on when and where drivers can charge their EV so that they can keep driving without running out of battery power, and

how they can make their own decisions reflecting both vehicle range and information about nearby charging stations. When a driver uses a navigation application on a device such as a smartphone or tablet to search for their destination, the cloud service automatically determines the state of charge of their EV and the available range, and uses this to calculate the route. The route calculation provides the fastest route, one that includes the location of the most convenient charging stand in the case when charging is required, and advises on the estimated arrival time.

Hitachi is currently considering the development of an additional waypoint search function along with greater integration with tourist and other local information. It plans to conduct a further demonstration in Okinawa Prefecture in February 2014.

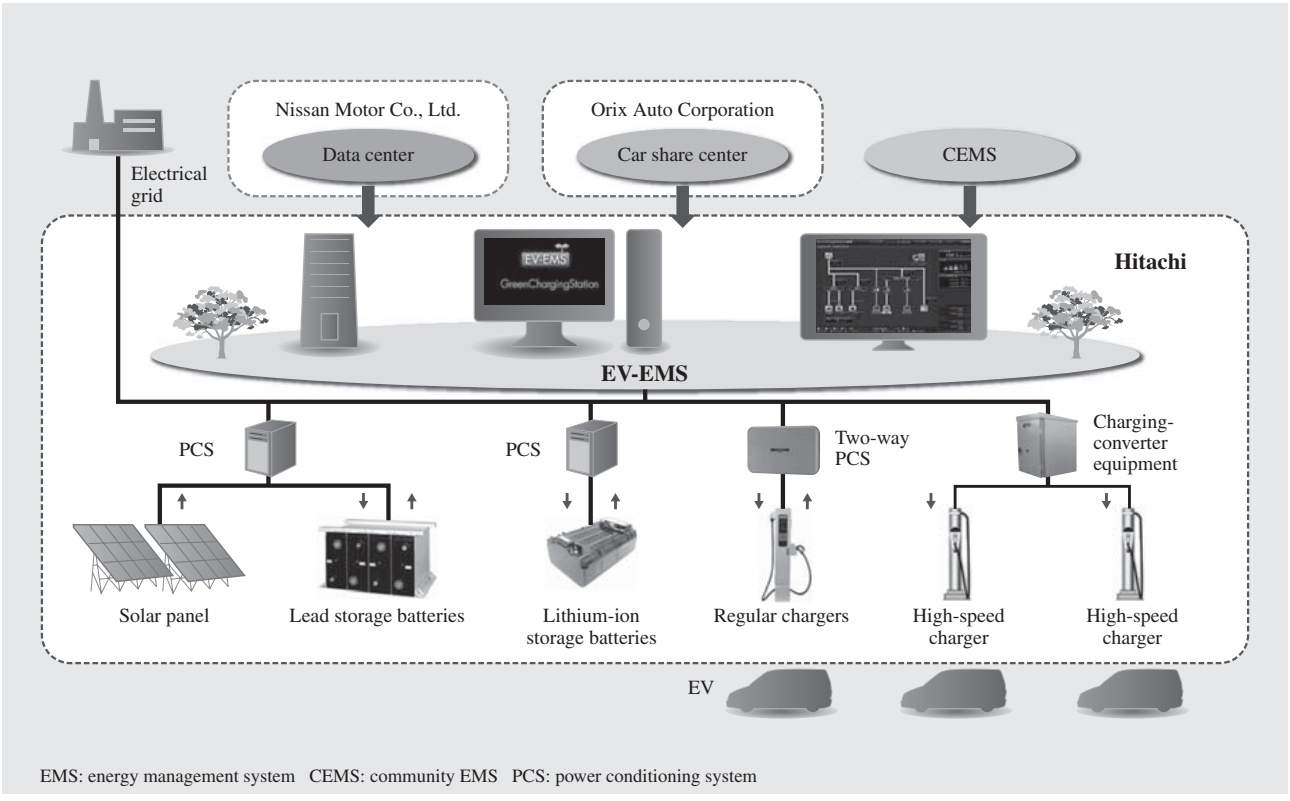
Demonstration Experiment in Yokohama

In Yokohama, Hitachi is participating in The Yokohama Smart City Project and a car sharing project using ultra-light mobility (EVs). The Yokohama Smart City Project is an energy management system for charging stations that coordinates EVs together with storage batteries, PV generation systems, and chargers installed at charging stations. Its aim is to perform appropriate management and control of the various equipment and systems (see Fig. 2). Following its launch in October 2013, it is expected that the service will manage around 100 ultra-light mobility (EV) vehicles and serve 10,000 members in the future. The car sharing project is a new EV business model that includes one-way travel between stations.

Model Project for Electric Bus Operation in Hitachi City

To promote the use of electric buses in smart cities, Hitachi is participating in a demonstration in Hitachi City as part of the Next-generation Energy Technology Demonstration Projects of the New Energy Promotion Council.

The aim is to build a solution for electric buses based on an electric bus operation management system that includes a driving status monitoring function and forecast power consumption function to support activities such as scheduling, operational management, charging management, and battery optimization for electric buses.



EMS: energy management system CEMS: community EMS PCS: power conditioning system

Fig. 2—Overview of The Yokohama Smart City Project.
The project is developing a charging system that incorporates photovoltaic power generation and storage batteries, and energy management that coordinates EVs and charging systems.

As electric buses fitted with large-capacity batteries can also serve as a power supply source at times of emergency, the project will undertake activities aimed at realizing smart mobility through the coordination of the electric bus operation management system, community energy management systems (CEMSs), EV chargers, EV charging management systems, and other resources.

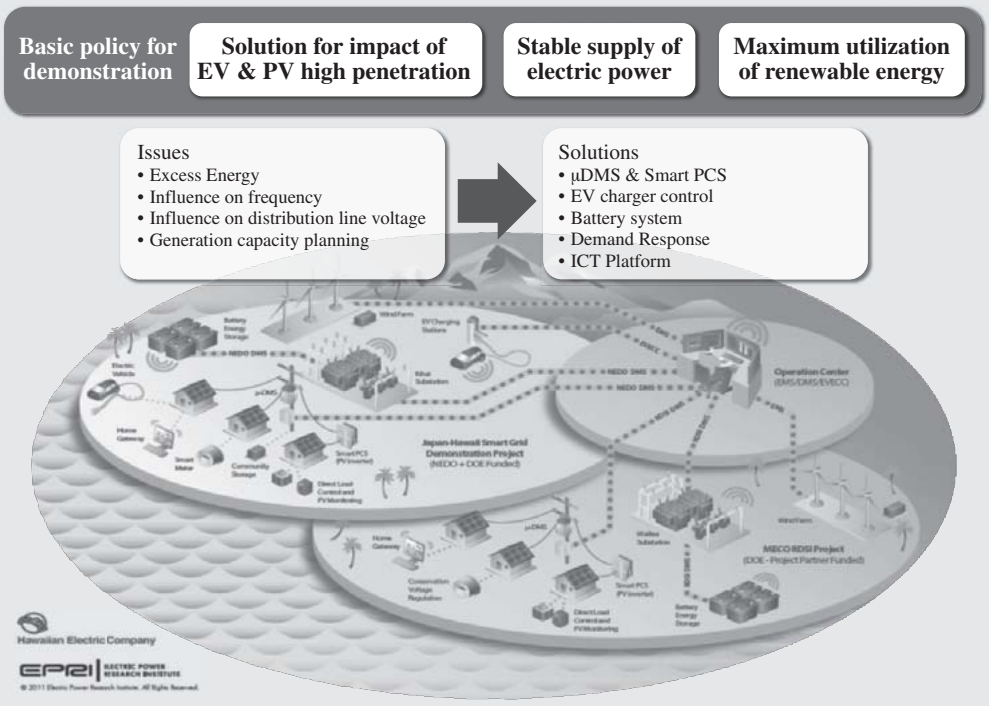
Smart Community Demonstration Project in Spain

Together with Mitsubishi Heavy Industries, Ltd. and Mitsubishi Corporation, Hitachi has been entrusted by the New Energy and Industrial Technology Development Organization (NEDO) to participate in the "Smart Community Demonstration Project in Spain." Based in Malaga (in the Autonomous Community of Andalusia) and consisting primarily of 200 EVs, nine quick charging stations, and an EV management center, the aim of this overseas demonstration project is to build next-generation transportation infrastructure with the potential to make major reductions in CO_2 emissions. System operation commenced on 25, April 2013, and demonstrations are set to continue until the end of December 2015.

The demonstration project will include demonstrations of an energy management system, which has a vital role in ensuring a reliable supply of power for EVs, an ICT platform that provides coordination between the EV infrastructure and energy management system, and a new comprehensive service system based on data collected at the EV management center. Hitachi intends to package the knowledge gained from these demonstrations, and to work with its partners in Japan and Spain to expand its scope of application in Spain and other countries and to deploy the system in other locations with similar lifestyle and culture.

Japan-U.S. Island Grid Project

Hawaii is by far the most oil-dependent state in the USA, with electricity tariffs three times higher than those on the mainland due to the rising price of oil. (As of August 2013, the price of a gallon of gasoline on Maui was $4.60 compared to $3.56 on the mainland). Also, because the state depends mainly on imports for fuel and industrial products, consumer prices



μDMS: micro distribution management system

Fig. 3—Smart Grid on Maui.
This demonstration project seeks to combine quality of life (QOL) with the creation of a low-carbon society on the island of Maui in The State of Hawaii.

Fig. 4—EV Chargers on Maui.
Installation of infrastructure on Maui is continuing in preparation for demonstrations.

are roughly 1.5 times higher than the US average, making them the highest in the country. Against this background, a project has been launched on the island of Maui aimed at encouraging the large-scale use of EVs, maximizing use of renewable energy, and ensuring the security of electric power supply. Together with the State of Hawaii, the County of Maui, Hawaiian Electric Company, Inc., Maui Electric Company, Ltd., the University of Hawaii, and US National Laboratories, Hitachi has been entrusted by NEDO to participate in its Japan-U.S. Island Grid Project in Maui (project name: JUMPSmartMaui) (see Fig. 3) (System operation commenced on 17, December, 2013, and demonstrations are set to continue until the end of March 2015).

The project is helping to establish the infrastructure for EVs on the island by installing quick charging stations at 20 locations, and will use the energy storage capacity of EVs for excess energy absorption and to stabilize renewable energy. There are also plans to expand the project to include a VPP function that contributes to the energy supply and demand balance for the islandwide of Maui through the integrated management of a decentralized energy resource (see Fig. 4).

CONCLUSIONS

People's way of life is coming to a turning point, with the era in which prosperity could be pursued without regard for the limited nature of energy resources coming to a close, and society recognizing that there is a limit to how long we can continue to take energy for granted. The electricity shortages that Japan has faced since the Great East Japan Earthquake have directed considerable attention toward smart cities.

Although debate so far has focused primarily on technical considerations, the scope is now expanding to include non-technical discussions with a central role for consumers, covering such matters as customer value creation, supply chain management, and customer engagement, and also discussions focusing on what to do about things like systems and regulations. As a result, smart cities are moving on from the planning and demonstrating phases of the past to the phase in which business models are established and actual work proceeds.

Hitachi is proceeding with the fusion of automotive technology with energy and social infrastructure, establishing solution packages that take advantage of things like the characteristics of EVs through leading-edge examples such as the demonstration projects in Spain, Hawaii, and elsewhere, and seeking to deploy these globally. In the future, it is anticipated that new social value will be created by fusing these with a wide range of social infrastructure, including fuel cells and autonomous driving systems.

REFERENCE

(1) Nikkei BP Clean Tech Institute et al., "The World's Smart Cities 2012," Nikkei Business Publications, Inc. (Oct. 2011) in Japanese.

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