MHI's Energy and Environment Business for Low-Carbon Society

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In April 2008, Mitsubishi Heavy Industries, Ltd. (MHI) established Sustainable Energy & Environment Strategic Planning Department. As energy- and environment-related products currently account for more than 60% of MHI sales, the Department plays an important role in comprehensively managing such products, taking the lead in new developments through the integration of products and related technologies, offering solution-oriented services to clients, and introducing new products and services to the market. This article describes MHI's mid- to long-term prospects and various developments and projects as related to energy and the environment, as well as MHI's vision for a future society.

1. Introduction

Following the 2006 release of Al Gore's award-winning documentary, An Inconvenient Truth, worldwide interest in environmental issues has continued to soar, especially with regard to limiting recognized causes of global warming, such as CO_2 emissions. As environmental and energy issues are integral to each other, solving such environmental issues translates into solving energy issues. Prior to the G8 Hokkaido Toyako Summit held in 2008, MHI forecasted a long-term trend in Japan's energy portfolio based on a long-term simulation of the country's CO_2 emissions control. In Japan, the limitation of CO_2 emissions involves energy security improvement through the reduction of external energy dependencies, which requires a departure from imported fossil fuels.

At the COP15 conference held at the end of last year, participating countries each presented their own voluntary targets based on individual situations, yet a universally binding action plan was not reached. The intentions of the U.S. and China, both of which possess abundant natural resources, are to avoid setting any restrictions on the use of such resources. While major renewable energy projects were announced in oil-producing countries in the Middle East, they were also seen as a means to achieve greater profits through limiting the domestic consumption of fossil fuels and, in turn, selling conserved resources to foreign markets after price increases. As energy strategies cannot be separated from CO_2 emissions, Japan's environmental issues must be viewed in the context of strategic approaches to energy management.

In 2008, MHI established Sustainable Energy & Environment Strategic Planning Department. The Department offers integrated solutions to clients by comprehensively interconnecting MHI energy- and environment-related products and technologies, taking the lead in new mid- to long-term technology developments, and reviewing MHI's long-term vision on energy issues.

2. Worldwide Trends in Global Warming Prevention

Individual targets for 2020 CO_2 emission reductions have been presented by each of the following governments (**Table 1**). China, in line with the COP15, also pledged to reduce its CO_2

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emission intensity per unit of GDP by 40 to 45 percent, as compared to the 2005 conference level.

The general trend is to place social investment into energy and the environment at the core of each nation's economic-stimulus measures, a chief example being U.S. President Obama's "Green New Deal" policy. The International Energy Agency (IEA) expects worldwide green energy investment to total 20 trillion yen annually between 2015 and 2030, and a further increase to 50 trillion yen annually between 2030 and 2050. New renewable energy projects proposed by the Chinese government, in particular, account for the largest investment plan thus far. China is expected to inject a total of 4 trillion yuan (approximately 57 trillion yen) in order to achieve a hydropower capacity of 300GW, a wind power capacity of 150GW, and a solar power capacity of 1,800 MW by 2020 (**Figure 1**).

Table 1 Mid-term reduction targets by country[1]

U.S.A.	17% by 2020 compared to 2005 level; 30% by 2025; 42% by 2030; 83% by 2050
EU	20% by 2020 compared to 1990 level
Russia	25% by 2020 compared to 1990 level
Japan	25% by 2020 compared to 1990 level
Canada	20% by 2020 compared to 2006 level
Australia	5 to 25% by 2020 compared to 2000 level
Norway	30% by 2020 compared to 1990 level
New Zealand	10 to 15% by 2020 compared to 1990 level
China	40 to 45% per GDP by 2020 compared to 2005
Brazil	36 to 39% relative to business as usual at 2020
Indonesia	26% by 2020
Korea	30% relative to business as usual at 2020
Mexico	50 million tons by 2012

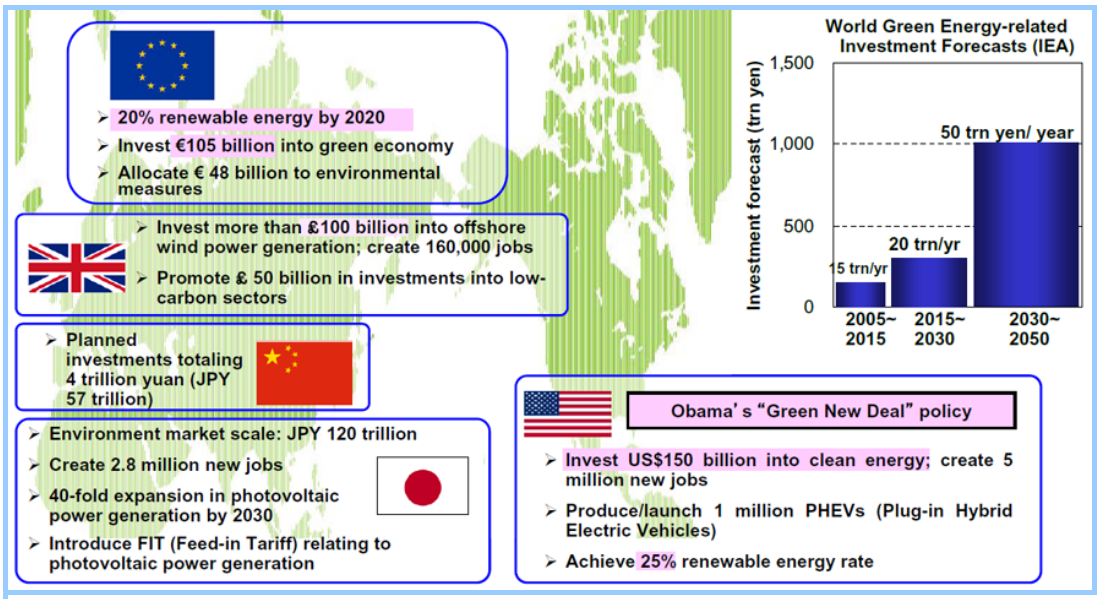
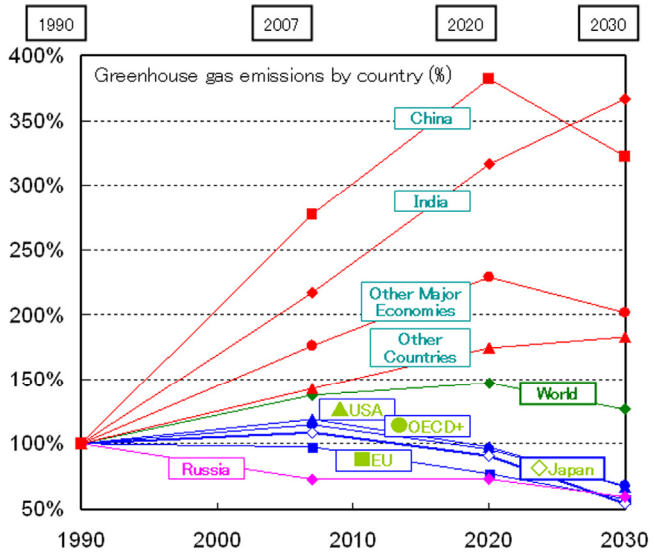


Figure 1 Targets and expected impacts of energy/environmental investments by country

The IEA's World Energy Outlook, released in November 2009, is one international guideline for global warming prevention. With the aim of limiting the global temperature rise to 2°C above pre-industrial levels and limiting the atmospheric CO_2 concentration to below 450 ppm (the "450 Scenario"), it establishes CO_2 reduction responsibilities based on the individual circumstances of each country and the energy portfolio standards needed to achieve these targets.

Under this scenario, the universal focus for the next decade is mainly to improve energy consumption efficiency, followed by drastic abatement achieved through energy conversion portfolio change, ultimately leading to a peak in total global emission volumes by 2030. For example, China's CO_2 emission volume, having surpassed that of the U.S. in 2007 at 6 billion tons annually (in absolute values), is predicted to further rise to 8.4 billion tons by 2020 before declining. This scenario also predicts a gradual decline in emission volumes in developed countries, including Japan, continuing until 2020 and, subsequently, a more significant decline lasting ten years (**Figure 2**).

- CO_2 emissions: developed countries reaching a peak by 2020, while developing countries after 2020
- World's total emissions: reaching a peak after 2020



(Unit: 100 million tons)	1990	2007	2020	2030
World	209	288	307	264
OECD+	114	131	109	77
USA	48	57	47	32
EU	40	39	31	23
Japan	11	12	10	6
Major economic countries excluding OECD+	55	97	126	111
Russia	22	16	16	13
China	22	61	84	71
Other Countries	35	50	61	64
India	6	13	19	22

(1) OECD+: OECD countries and non-OECD EU countries
(2) Major economic countries excluding OECD+: Brazil, China, Middle Eastern countries, Russia and South Africa (countries expected to exceed per-capita GDP of $13,000 by 2020, excluding OECD+ countries)
(3) Others: all countries excluding (1) and (2)

Figure 2 CO_2 emission forecasts by country[2]

3. Japan's Long-Term Vision to 2050

MHI participated in the development of the "Energy and Environmental Vision 2050", a long-term outlook to 2050, presented by the Mitsubishi Research Institute, Inc. (MRI). Its simulated calculations based on the MRI-owned MARKAL-JAPAN-MRI energy model are conducted so as to minimize energy system costs. Using various constraints as input conditions, such as predicted demand, energy utilization technologies, and CO_2 reductions, the model generates an optimized energy system configuration that includes primary energy and power structures, import energy volumes, CO_2 emissions, and energy costs. It sets out what type of energy portfolio is required in order to meet established targets within a basic framework that prioritizes economic principles.

For the housing sector, the main goals are the installation of solar panels in 50 percent of housing units and all new housing units built with high thermal insulation by 2030; the promotion of energy-efficient appliance replacement; and the promotion of high-efficiency heating, kitchen, and hot-water supply equipment installation. Goals for the business sector include all new buildings built with high thermal insulation and energy-efficient air-conditioning systems by 2030; the promotion of high-efficiency air-conditioning, heating, and hot-water supply systems installation; and the promotion of energy-efficient office equipment. For the industrial sector, the goals are increased natural gas usage as a heat source for industrial-level boilers and heaters, and the utilization of heat pumps as low-temperature heaters. Transportation sector goals focus on realizing the shift from gasoline-fueled cars to hybrid, electric, and fuel-cell cars. The power generation sector is expected to engage in installing solar panels for housing units, utilizing more wind power generation, replacing existing nuclear reactors with 1.5 million kW-class reactors in addition to currently planned new reactors, upgrading traditional thermal power generation systems to high-efficiency LNG/coal gasification systems, and implementing carbon capture and storage (CCS) systems.

Realization of the afore-mentioned goals would enable a 60 percent reduction of CO_2 emissions by 2050, as compared to 2005 levels.

Use of primary energy is expected to reduce by approximately 80 percent from the current level, while fossil fuel dependency is expected to reduce by approximately 50 percent. Looking at the overall power structure, gross electricity generation will increase by 30 percent, due to further

electrification, with thermal power generation accounting for approximately 30 percent, nuclear power generation 40 percent, and renewable energy 20 percent. Increased electrification is a crucial factor for the realization of final energy consumption targets, requiring an increase of 25 to 40 percent above the current level of electrification (**Figures 3** and **4**).

In realizing a low-carbon society, the promotion of electric cars, nuclear power, and renewable energy will play a crucial role. Promoting electric cars requires actions such as technological advances that include cost reduction, enhanced subsidy programs to encourage consumer purchases, and improved infrastructure such as urban charging stations. The promotion of nuclear power utilization requires the consensus of opinion and operating rate improvements. Renewable energy, such as photovoltaic power generation, needs to be promoted through technological advances that include cost reduction, enhanced subsidy programs to encourage consumer purchases, establishment of a secondhand market, and stabilization of power systems. As such, concerted efforts by the private and public sectors are essential for realization of a low-carbon society. The next chapter further describes key technologies for this challenge.

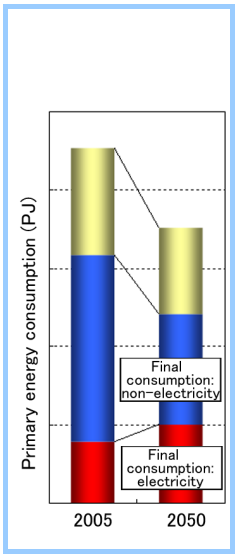


Figure 3 2050 energy balance[3]

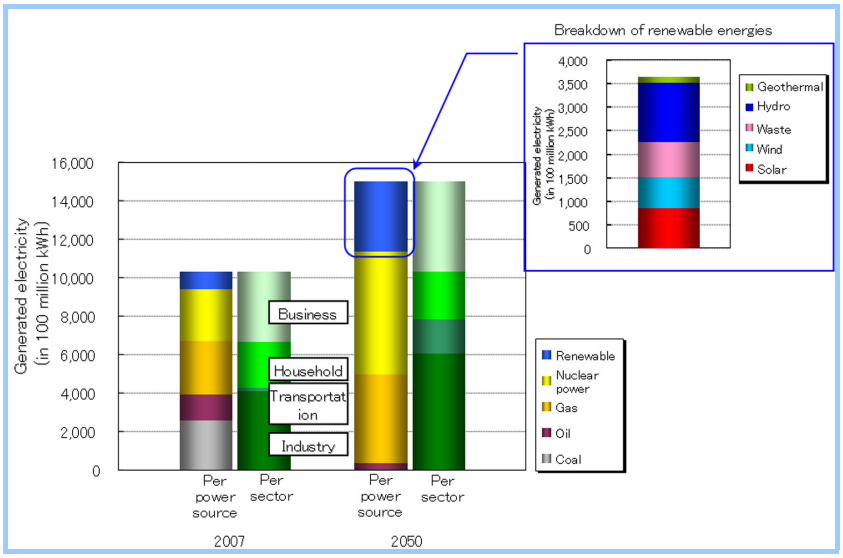


Figure 4 2050 energy portfolio[3]

4. Key Technologies for the Realization of a Low-Carbon Society

Overall, fossil fuel-based thermal power generation facilities are economical when initial construction-related investment costs are considered. To maximize such economic advantages, the focus of development must be on further efficiency improvements.

In the field of gas turbines, MHI's flagship products (**Figure 5**), MHI has completed development of, and launched activities geared toward, the commercial production of the "J-series" gas turbine. With an operating temperature of 1,600°C at the turbine inlet, the J-series gas turbine features the world's largest power generation capacity and highest thermal efficiency. With the adoption of thermal-barrier coating technology and improvements in cooling technology, the J-series gas turbine is able to withstand temperatures that are 100°C higher than the existing 1,500°C-class G-series gas turbine. The aerodynamic performance of turbine blades has also been improved through an enhanced 3-dimensional design. The compressor is designed to provide a higher compression ratio, while the combustor uses steam-cooled technology originally developed for the G-series gas turbine. The turbine element for the J-series, based on the G-series design, also adopts new technologies derived from an ongoing national project that aims to develop core technologies for a 1,700°C-class gas turbine. With a thermal efficiency well above 60 percent in combined-cycle applications (lower heating value), its performance level is the highest in the world. The power generation capacity of the J-series GTCC can reach 1.2 times that of the G-series GTCC, the largest single output capacity previously available. Additionally, nitrogen oxide (NOx) emissions for the J-series are maintained at levels of the existing series in order to address environmental issues.

Efficient use of coal resources and clean coal energy are vital to future energy security. MHI has long engaged in developing integrated gasification combined-cycle (IGCC) technologies (**Figure 6**). MHI's IGCC system is based on air-blown gasification technology, which the company has further refined to achieve the world's highest transmission and power generation efficiency. MHI has already delivered a 250 MW IGCC demonstration plant to Clean Coal Power R&D Co., Ltd., located in Iwaki, Fukushima Prefecture, a company jointly established by 10 domestic electricity providers. The Nakoso demonstration plant has already completed more than 2,000 hours of continuous operation and has proven its high reliability and operability. MHI also participates in the IGCC+CCS plant development by ZeroGen Pty, Ltd., of Australia, by undertaking a feasibility study of the project. This will be the world's first commercial-scale IGCC power plant with CCS capability.

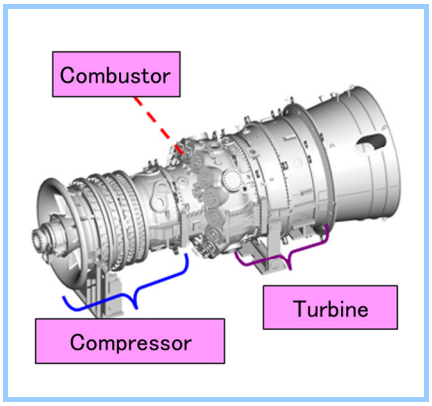


Figure 5 501 J-series gas turbine

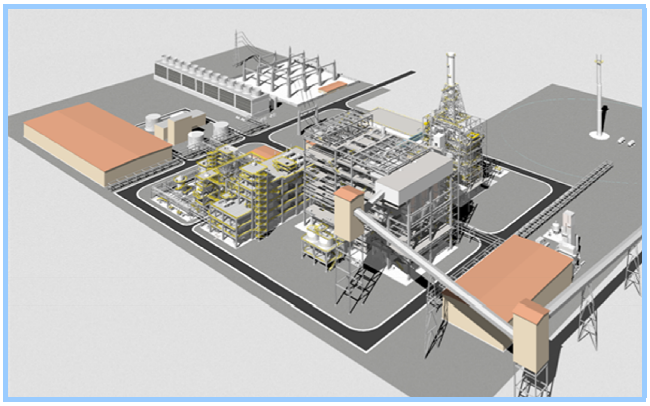


Figure 6 Exterior image sample of IGCC commercial unit

Nuclear power, with its economic efficiency and zero CO_2 emission power generation process, is regarded as the most important instrument for the realization of a low carbon society. MHI has built 24 PWR plants since 1970 and the Tomari-3 nuclear power plant of Hokkaido Electric Power Company, MHI's newest PWR plant, began commercial operations at the end of last December. MHI continues to provide extensive after-sales services to these plants in operation. Luminant, a U.S. electricity company, also signed a MOU with MHI. Under the agreement, both parties have begun contract negotiations concerning the use of two US-APWRs, MHI's revolutionary pressurized water reactors, at the Comanche Peak Nuclear Power Plant. One of the key issues to be addressed with regard to nuclear power generation is spent fuel disposal. Consequently, MHI has been conducting research and development in nuclear fuel recycling technologies.

With regard to solar photovoltaic power generation, a study suggests that fossil fuel price increase, coupled with lower costs of photovoltaic power generation facilities, will lead to grid parity – the point at which the cost of photovoltaic-generated electricity is equal to that of electricity generated by existing power generation facilities – between 2015 and 2020. Once grid parity is reached, the widespread use of photovoltaic power will be accelerated according to economic principles. MHI has been expanding sales of a rooftop unit called the Eco Sky Roof, which combines solar heat recovery and MHI's previously developed thin-film tandem solar panels that are capable of maintaining power generation efficiency even on cloudy days. The Eco Sky Roof is a hybrid system that effectively uses photovoltaic power (electricity) and heat gained from a house by securing an air-flow path under the solar panels, thus allowing faster recovery on investments such as solar panel installation expenses, a factor that is currently driving up overall costs (**Figure 7**).

MHI has been undertaking the development of a solar thermal turbine that directly heats ambient air with captured solar energy, converting it to power for use in large-sized solar heating systems designed for sun-belt areas around the world. It employs the Brayton cycle, as with gas turbines, enabling electricity generation at a higher temperature than existing models. Its resulting high cycle efficiency allows the system to be more economical, requiring a smaller reflector area for the same output compared with existing systems (**Figure 8**).

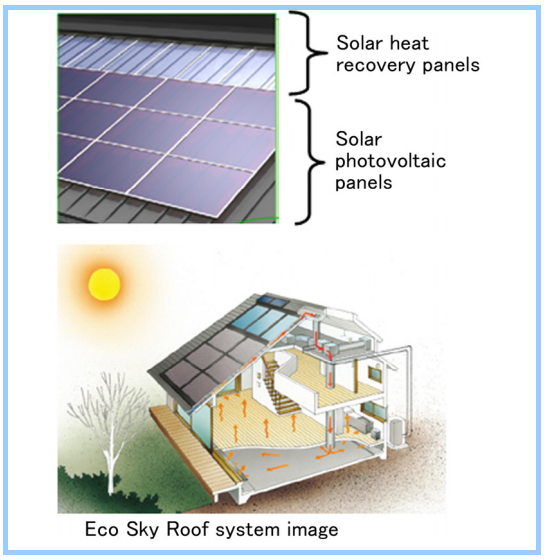


Figure 7 Eco Sky Roof system image

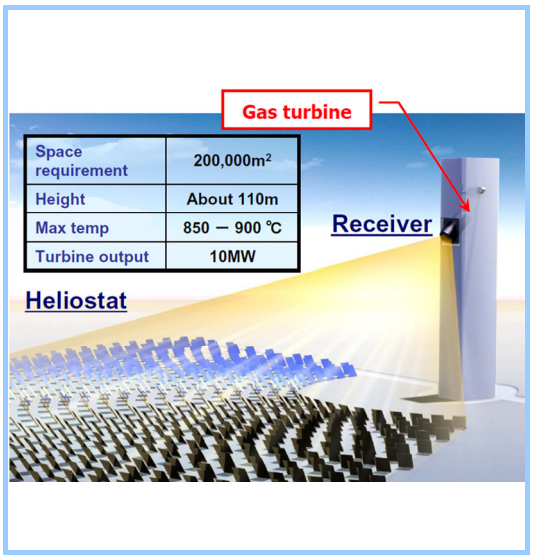


Figure 8 Solar heating system using gas turbines

With wind power generation further expanding in areas such as Europe, China and the U.S., offshore wind turbine projects are gaining momentum. A shift from land to offshore wind farms is expected to intensify in Europe, as various wind power projects are being negotiated for the areas around oil fields in the North Sea. MHI is moving forward to meet various needs in both on-land and offshore-based power generation. One of the key concerns in offshore power generation is that its economic competitiveness is determined by how efficiently such facilities are constructed in rough waters. Also important is its performance reliability in a harsh offshore environment. In partnership with marine solution providers, MHI is tackling various challenges in the offshore wind turbine business, making full use of MHI's accumulated marine technologies, such as shipbuilding (**Figure 9**).

Electricity-focused next-generation energy network systems will stimulate advances in nuclear and renewable energy-based power generation, while encouraging further low-carbon transformation (electrification) in the industrial, business, consumer, and transportation sectors. One of the key elements of this innovation is that of electricity storage technologies. In the future it is possible that batteries for electric vehicles may serve as a buffer for unstable changes in electricity, resulting in the widespread use of batteries as an effective energy source on a society-wide scale. With its decision to enter the lithium-ion secondary battery market, MHI plans to launch full-scale mass production by 2011. The company's forklift business has already begun using batteries manufactured on a sample production line and launched hybrid forklift trucks last year (**Figure 10**).

Figure 9 Wind turbines

Figure 10 Hybrid forklift trucks

Heat pump systems, another important technology for electrification in these sectors, also significantly reduce energy consumption and CO_2 emissions. MHI offers heat pump solutions across a wide range of sectors, including industrial waste heat utilization and heating and cooling systems for residential units.

Improving energy-efficiency in the household sector is considered essential, as Japan's household energy consumption accounts for 15 percent of domestic use of energy and is increasing each year. With the household being the most elemental unit of energy infrastructure, MHI, together with a Group company, Ryoju Estate Co., Ltd., developed the "Eco Sky House", a super-energy-saving next-generation residence, based on core technologies that enable innovative use of natural energy. A habitability assessment is currently being conducted at the model house in Yokohama. Equipped with both electricity and thermal energy storage systems, the house is being tested to verify its highest possible level of energy self-sufficiency and to evaluate individual performances and the optimum combination of installed equipment (**Figure 11**).

Once highly advanced residential systems become prevalent and an energy infrastructure that integrates electric vehicles is established, a comprehensive overhaul of energy networks will be required in order to have full control in processing a significant volume of nuclear and renewable energy. As such, one of MHI's future challenges will be to build such next-generation infrastructures that effectively utilize characteristics of individual energy-saving systems.

MHI considers electricity storage to be one of the key technologies essential to developing next-generation low-carbon energy infrastructures (**Figure 12**).

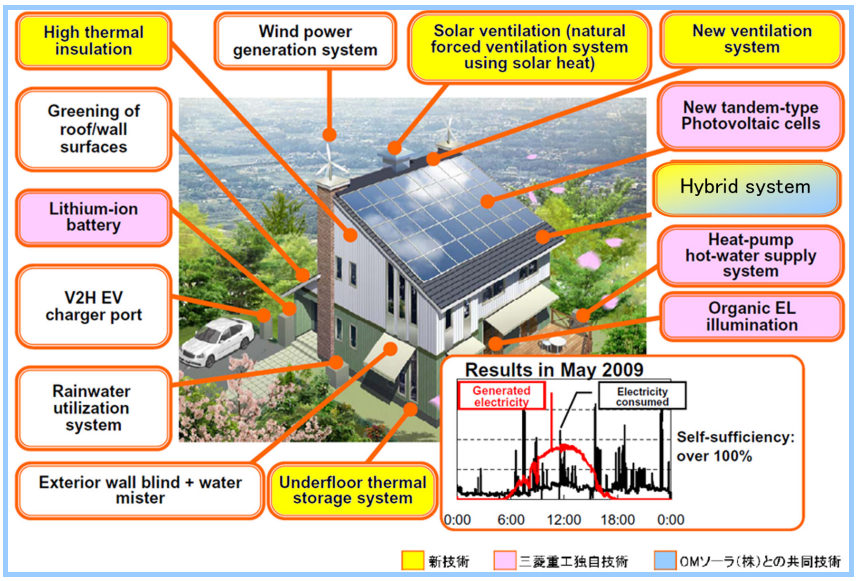


Figure 11 Eco Sky House

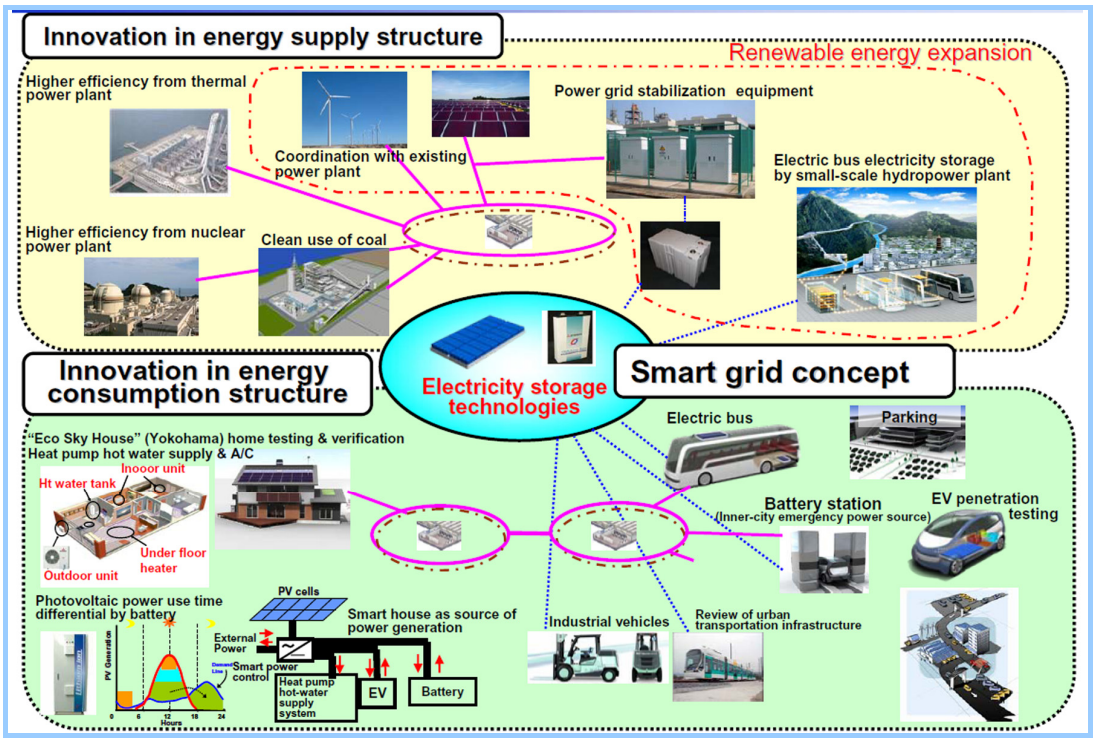


Figure 12 Key electricity storage technology

5. Vision of a Future Society

The creation of a clean, comfortable living environment can be achieved through society-wide use of the above-mentioned technologies, optimal use of dispersed renewable energy, development of periphery-level low-energy systems combined with effective thermal power utilization, and well-balanced integration of existing centralized power systems with further improved efficiency. MHI's vision of a future society, shown in Figure 12, includes various new businesses that are expected to emerge and grow.

6. Conclusion

Offering individual technologies or products will no longer be sufficient for future energy- and environment-related businesses. Instead, these businesses will be expected to deliver acquired multi-faceted integration capabilities. Therefore, collaborative projects involving several corporations are likely to become more prevalent in the energy industry. MHI possesses wide-ranging technologies and established integration capabilities. The aim of MHI is to further expand business that contributes to society through various approaches, including the formation of external partnerships.

Although the multi-faceted solutions discussed in this report may take some time in coming to fruition, due to cost barriers, a heightened sense of global environmental awareness has already led to wider recognition that such costs are to be assumed by society as a whole. While the recent COP15 regretfully failed to achieve a binding global agreement, there remains a constant expectation of further energy and environmental business expansion in individual countries.

As previously noted, environmental and energy issues are integral to each other. For the realization of a comfortable, safe and clean future society, MHI continues to seek optimal ways to turn technologies that simultaneously solve energy and environmental issues into economically feasible solutions.

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