
# Technology of Renewable Energy

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*The Kyoto Protocol aimed at the prevention of global warming took effect from February 16, 2005, and moves for the introduction of renewable natural energy are being intensified in Japan and other countries. This paper introduces the natural energy equipment that Mitsubishi Heavy Industries, Ltd. (MHI) has developed, in particular devices that work on geothermal, solar and wind energy.*

## 1. Introduction

The conditions affecting renewable natural energy have changed drastically during the past year or two. Since April 2003, the law on special measures concerning new energy used by electric utilities (Renewable Portfolio Standard (RPS) Law) has been fully enforced, making it mandatory for electric utilities to utilize a minimum fixed percentage of electric power generated by new energy, etc. This new law is expected to achieve the result that by the year 2010, 1.36% of electric power sold will be generated by new energy.

The crude oil price, which showed an upward movement in 1999, has continued to rise steadily since last year until the price of West Texas Intermediate (WTI) (crude oil produced in Texas) exceeded $60 per barrel at the crude oil futures market of the New York Mercantile Exchange.

The LNG price that is linked to the crude oil price is also rising. In addition, the coal price which has hitherto remained stable is also moving up. These increases in petroleum fuel prices are largely due to political instability, a fall in the crude oil surplus production capability of the Middle Eastern countries and a sharp increase in demand by BRICs such as China.

The Kyoto Protocol, which is intended to prevent global warming, took effect on February 16, 2005. Accordingly, prospects for the introduction of renewable natural energy are increasing in view of global environment problems, and its uses are expanding to areas in which it may become economically viable, although this has never been the ease before. Renewable natural energy is, therefore, once again attracting attention in many countries. This paper will deal in particular with the prospects for business utilizing geothermal, solar and wind power from among the natural energy-related businesses of MHI.

## 2. Geothermal energy

Expectations for power generation by geothermal energy as an alternative to petroleum oil are growing all over the world. The industrialization of power generation by geothermal energy on a large scale is in progress in the US, the Philippines, Indonesia and Mexico(1). Japan is well known as a volcanic country with abundant geothermal energy. In 1924, a 1 kW power generating test plant in Beppu started power generation by geothermal energy for the first time in Japan. This plant is now demonstrating its utility by producing power domestically with a minimum of environmental pollution.

Power generation by geothermal energy is now at the stage of solving its main problem of how to generate inexpensive power efficiently from this energy offered by nature and of how to make it pay for itself economically.

In 1967, MHI constructed the Kyushu Electric Power Co., Inc. Otake Geothermal Power Station with a production of 12.5 MW. This Otake Power Station, Japan's first hot water type geothermal power plant, served as the foundation for the subsequent rapid development of geothermal power generation in Japan.

In 1977 MHI constructed Japan's largest geothermal power plant producing of 55 MW for the Kyushu Electric Power Co. Hachoubaru Power Station. At Hachoubaru, the double flash method was adopted to utilize the energy of the hot water which had previously been wasted, increasing the output by about 20% as compared with the former single flash method. Furthermore, the two-phase flow spouting from the production well was conveyed to the power plant without separating it into hot water and steam, resulting in reduction of the conveyance pipeline facility and in further increase of economy. This system, known as the Hachoubaru system, is now being adopted widely in newly constructed plants (**The photo above**).

At present there are 418 geothermal power plants in the world, of which 91 plants were constructed by MHI with a high share of 21%. In July 2005, MHI delivered a 19.2 MW power plant to a site near Lake Taupo in New Zealand.

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## 3. Solar energy

In 1999 Japan's photovoltaic module production was the highest in the world, and since then it has increased to almost half of the world's annual production (approx. 700 000 kW). The world's annual total production also increased by approximately 60% during the period from 2003 to 2004, supporting the expansion of the solar cell market. The world's total capacity of solar cell facilities in 2003 was approx. 1.8 million kW, of which Japan occupied 48%, Germany 23% and the US 15%. Thus, Japan occupies top place in the world for solar cell facility production.

This outstanding accomplishment is the result of the Japanese Government's systematic research and development, verification testing and institutional encouragement for the introduction of renewable natural energy, as well as manufacturers' untiring efforts to improve efficiency and reduce costs. For instance, the power generation cost per kWh in 1994 was approx. 140 yen, but ten years later in 2004 it was reduced to approx. 46 yen, or to one-third. The cost reduction attained has dramatically changed the conventional concept that "solar cells are friendly to the environment but bad for economy." This cost reduction has contributed not only to an increase in solar cell facilities in Japan but also to the adoption of solar cell facilities in many places throughout the world.

Solar cells are now spreading fast not only to developed countries where accommodations for interconnection to existing systems have already been developed technically and institutionally but also to developing countries in Asia and Africa, for example, and Pacific Ocean island countries which are not yet covered by power transmission networks, as a convenient and clean power source. In particular, technical and economical assistance by developed to less developed countries is indispensable to the spread of solar cells in countries of the latter category. Such assistance was once referred to as an ideal model for Official Development Assistance (ODA) activities.

Basically, solar cells may be considered to have a bright future. As demand increases, the supply of silicon ingot for poly-crystalline silicon is beginning to fall short. This concern is beginning to become reality as the price of poly-crystalline silicon has risen from 3 000 yen per kg in 2004 to approx. 5 000 yen this year. If the poly-crystalline silicon price continues to rise, the advantages of cost reduction mentioned above may be outweighed possibly slowing down the spread of solar cells in the world. As countermeasures, the development of thinner cells and improved efficiency thereof are in progress with a view to efficient utilization of materials.

MHI has developed a technique to produce a thin film silicon solar cell having the world's largest surface area (1.1 m x 1.4 m), and started its commercial production two years ago in Isahaya City, Nagasaki Prefecture. This type of solar cell has been installed not only in domestic public and commercial buildings/facilities and private residences but also in overseas countries such as Germany, Australia and the Middle East.

The main characteristic of MHI's solar cell production is the manufacture of solar cells directly from gas using plasma and chemical reaction. The thin film silicon solar cells produced by this method require approximately 1/1 000 of the amount of silicon required for the micro-crystalline type solar cell, so that the above-mentioned material shortage problem is no longer significant.

In addition, compared with the crystalline type, the thin film type excels in temperature characteristics during the summer and generates more power annually. In view of this advantage, delivery of thin film type solar cells including those from MHI is increasing in Germany, where power generated by photovoltaic modules is bought at higher prices (**Fig. 1**).

In order to encourage introduction of solar cells, New Energy and Industrial Technology Development Organization (NEDO), together with the Industry-Government-University, is making efforts toward further cost reduction.

**Fig. 1 400 kW solar cell power plant in Germany**
Approximately 4 000 thin film type 1.1 m × 1.4 m photovoltaic modules produced by MHI are working satisfactorily.

## 4. Wind energy

Of all renewable energy type power generation methods, wind power generation excels in economy and heads the class in successful large-scale introduction. In 2004, 6 747 units of large-size wind turbines with a total capacity of 8 154 MW were constructed in the world, reaching an accumulation total of 73 884 units with a total capacity of 47 912 MW (**Fig. 2**)[3].

In Denmark, 20% of power demand has already been generated by wind power, and in Germany the figure is 6%. Wind power in Europe has grown sufficiently to sustain a not insignificant part of total power demand. In the United States also, a strong wind power generation introduction promotion system (production tax credit (PTC) by which the 1.8 cents/kWh tax is returned depending on the quantity of power generation) has been extended until the end of 2007, and a large boom on a 3 000 MW/year scale is taking place.

In Japan too, regular introduction of wind farms having tens of units with capacities of tens of thousands of kW has begun, starting with the construction of the Tomen Power Tomamae wind farm in October 1999 (**Fig. 3**). As of the end of 2004, 924 units of wind power turbines with a total capacity of 926 MW were operating at 315 locations[4]. Recently, more wind power turbines have been introduced to the metropolitan district, sometimes presenting familiar background scenes in movies and TV dramas and CMs. At present, the restriction on interconnection to the existing power transmission network is a cause of concern, but after 2007, when the moratorium by the RPS Law is to be removed, until 2010, introduction of wind power is expected to move quickly toward the Government's target of 3 GW.

Further in the future, the introduction is expected to increase to 10 GW including offshore wind power generation by 2020, and up to 20 GW in 2030[5]. In June 2004, the Agency for Natural Resources and Energy also announced the "New Energy Industry Vision" so that wind power generation is now attracting attention from the viewpoint of domestic industry cultivation[6].

Since the start of operation of the 40 kW wind power turbine at its Koyagi Plant of Nagasaki Shipyard & Machinery Works in 1980, MHI has been going ahead with its wind turbine development and supply on its own proprietary technology and had delivered 1 820 units of wind turbine with a total capacity of 1 038 MW to eight countries of the world by April 2005. This amount exceeds the accumulation of wind power turbines introduced in Japan. MHI's market shares in 2004 are 32% (the highest) in Japan, and 31% (second-highest) in the United States[3].

Wind power turbine design has generally been based on IEC 61400-1, but this standard was originally based on performances in flat European coastal areas where stable westerly winds prevail. This discrepancy with the Japanese climate has begun to cause equipment troubles. In particular, the accident involving collapse of a wind turbine on Miyako Island, Okinawa Prefecture caused by Typhoon No. 14 in September 2003 was viewed with concern by the Ministry of Economy, Trade and Industry and the Ministry of Land, Infrastructure and Transport, and accordingly promotion of standardization toward "Japan type wind turbines," as shown in **Table 1** herein, as well as related research and development were decided upon.

MHI, the only Japanese manufacturer of large type wind power turbines, is cooperating in activities such as improvement of the reliability of wind power turbines and is at the same time developing and offering wind power turbine technology suited to Japan's climate such as Smart-Yaw, which is typhoon-resistant, and active tower vibration restriction through control of fluctuating wind load.

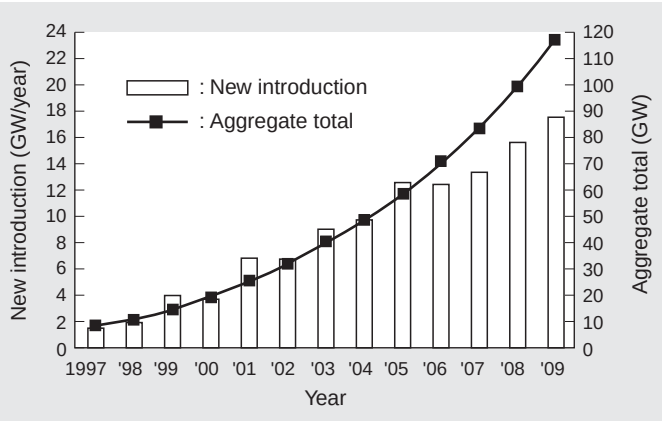


**Fig. 2 Progress of introduction of world wind power generation[3]**

**Fig. 3 Kamaishi wide region wind farm, the largest in Japan**
42 900kW: Mitsubishi MWT-1000A wind turbine 43 units.

**Table 1 Standardization of wind power generation**

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|---|---|
| Accident information and statistics concentration | NEDO Wind Power Generation Utilization Ratio Upgrading Investigation Committee established in March 2003 |
| Major accident reporting made mandatory | Notice from Nuclear and Industrial Safety Agency in November 2004 |
| Japan type wind power generation guideline compilation project | Publicly invited by NEDO Research and Development in June 2004 |
| Wind power plant anti-wind design/engineering guideline | Expected to be prepared by Japan Society of Civil Engineers by end of 2005 |

## 5. Conclusion

MHI intends to remain aggressively involved in the introduction of renewable natural energy technology from the global viewpoint of environmental problems such as greenhouse gas (CO2), and will lead Japan with reduced energy resources to becoming the world's most advanced natural energy technological country.

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