# Present Status and Future Outlook of Energy-Creating Technologies

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ABSTRACT

Fuji Electric is promoting a new type of business management based on the keywords of "energy and the environment" and has adopted the following approaches to the creation of green energy. For geothermal power generation, Fuji is focused on developing technology for improving the corrosion resistance of turbines and on binary power generation. In the nuclear power field, Fuji is researching and developing a next-generation high-temperature gas cooled reactor that can be used for power generation, hydrogen production and the like. For solar cells, Fuji has begun full-scale mass-production aiming to popularize lightweight, flexible, film-type cells capable of being installed at a wider range of sites. Fuji has also commercialized a 100 kW phosphoric acid fuel cell named the FP-100i, and is expanding its range of applications to include disaster prevention, digestion gas use, hydrogen stations, etc.

## 1. Introduction

The global demand for energy is expected to continue to increase significantly in the future, particularly with the economic development of emerging countries and the growing population worldwide. The increase in demand for electrical power will be especially large, and in the International Energy Agency's (IEA) report for 2009 (World Energy Outlook 2009), demand through 2030 for electric power is forecast to increase at an annual rate of 2.5%, and 4.8 TW (terawatts) of additory generation capacity will be needed[(1)].

Meanwhile, in order to prevent climate change and realize a sustainable society, the reduction of greenhouse gas emissions has become a subject of paramount importance. If the consumption of fossil fuels continues to increase unabated, the atmospheric concentration of greenhouse gases will inevitably exceed 1,000 ppm $CO_2$-equivalent, and a 6 °C rise in global mean temperature and large-scale climate change are predicted to occur. According to the IEA report, in order to maintain a sustainable global environment, the global temperature rise must not exceed 2 °C, and in order to limit to 50% the probability of occurrence of a greater than 2 °C rise in global mean temperature, the atmospheric concentration of greenhouse gases must be stabilized at 450 ppm $CO_2$-equivalent. To reduce greenhouse gas emissions, efforts to create a global framework and to promote governmental policies for reducing greenhouse gas emissions have been actively advanced as a matter of urgency at the 15th Conference of the Parties to the United Nations Framework Convention on Climate Change (COP15) in Copenhagen. For government policies to address the serious threat of the climate change that is becoming apparent, economic stimulus policy has incorporated initiatives to promote a low carbon economy, and specific measures are being advanced.

To realize a low carbon society, the amount of energy consumption must be reduced and a green society established. In the energy creation sector where electrical energy is produced, more efficient thermal power using fossil fuels and using nuclear power generation that is free of $CO_2$ emissions is being promoted. Additionally, the adoption of power generation using renewable energy sources such as geothermal power, hydropower, wind power and solar light/thermal power, is actively being sought.

Fuji Electric is promoting a new type of business management based on the themes of "energy and the environment." In the energy solutions sector, Fuji is focused on the creation of green energy and on grid solutions, while in the environmental solutions sector, Fuji provides solutions for demand-side energy savings and for environmental policies. This special issue introduces some representative initiatives for energy creation in order to establish a low carbon society, and discusses the future outlook for energy creation.

## 2. Geothermal Power Generation

Geothermal resources are present in regions where the plates of the earth collide with each other and where volcanoes are common. Such areas are found in the Pacific Rim region, northeastern Africa, and in Europe in the Mediterranean region and Iceland. Thus far, geothermal power generation has been actively developed in the USA, Mexico, Europe (Italy and Iceland), Asia (Indonesia and the Philippines), Oceania (New Zealand), and so on (Fig. 1). In these regions, the development of geothermal power as a renewable energy source is expanding further. Moreover, even

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Fig.1 Promising areas for geothermal power generation

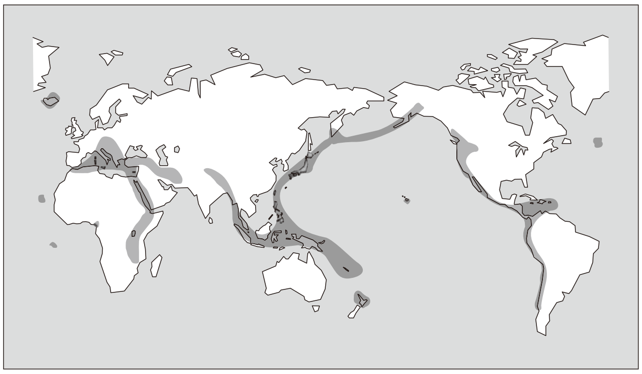
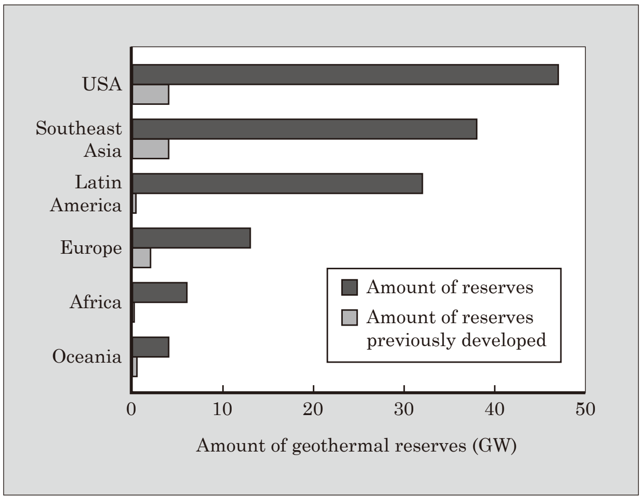


Fig.2 Amount of geothermal resource reserves(2)




on the Eastern Coast of Africa and in Latin American countries where the development of geothermal power is lagging, plans for geothermal power development are being advanced. Japan's geothermal resources are said to be the third largest in the world, but development has stagnated due to constraints imposed by the Natural Parks Law and so on, and the generating capacity developed thus far has remained at about 500 MW. In the future, the governmental adoption of policies that support development is expected to promote new development.

Fuji Electric delivered its first geothermal power facility in 1960 and, since then, has continued to focus on geothermal power, researching and developing high-efficiency geothermal turbines and specific anti-corrosion measures for geothermal turbines. Geothermal steam, in particular, contains substances that corrode turbines, and degrades performance as a result of scaling that adheres to the turbine blades. Fuji Electric has researched and developed turbine materials, coating technology and the like, which are strongly resistant to corrosion and wear, achieving good results. Furthermore, Fuji Electric has also established anti-corrosion technology for generators and electronic control equipment installed in a geothermal gas atmosphere, and has manufactured and delivered high performance, highly reliable geothermal power facilities. Recently, in addition to turbine power generating equipment, Fuji Electric has also been designing and manufacturing steam generating facilities for producing the optimal steam for turbine operation, as well as auxiliary equipment for these steam generating facilities, and is also working to realize a turn-key solution for the engineering of an entire geothermal power plant.

Fuji Electric has worked to develop large-capacity flash generators that generate electric power from geothermal steam fed directly to a turbine. In addition, Fuji Electric also developed binary power generation technology capable of effectively utilizing low temperature geothermal resources that had previously been unusable. Geothermal binary power is generated using the heat from geothermal steam to evaporate a medium that has a lower boiling point than water, such as pentane, and to drive a turbine. Binary power plants are medium or small-capacity geothermal power plants that can be used at sites where the geothermal resources are at a low temperature or the amount of steam is small, and they hold promise for the efficient utilization of idle energy that had been previously unused.

Enhanced Geothermal Systems (EGS) are attracting attention as a new type of geothermal power generation technology. Existing geothermal power generation extracts the resources of geothermal steam and hot water from high-temperature natural reservoirs underground. With EGS technology, hydraulic fracturing of hot rock is performed artificially by pumping water into the rock and capturing the resulting steam and hot water. EGS is being researched in the USA, Australia, Germany and elsewhere, and holds promise as a means for expanding geothermal usage in the future. The generation of power from geothermal resources is capable of providing stable power that is unaffected by weather, and as a renewable energy source capable of a high utilization rate, the development of geothermal resources is expected to become more active in the future (Fig. 2).

## 3. Nuclear Power (High-Temperature Gas-Cooled Reactor)

As a form of energy that does not emit $CO_2$, nuclear power is being developed throughout the world. Particularly in the US, the adoption of nuclear power is being planned to provide a stable supply of power and to help prevent global warming. The adoption of nuclear power is also been actively promoted recently in the Middle East and Asia. The nuclear power generation currently planned involves mostly light water reactors, but high-temperature gas-cooled reactors (HTGR) hold promise as next-generation reactors capable of using distributed resources and that will expand the range of applications for nuclear energy.

HTGRs can use high-temperature heat in the range of 700 to 950 °C, and as power generation plants, can therefore realize power generation with nearly 50% efficiency using a direct gas-turbine cycle. HTGRs are also capable of producing hydrogen directly from water using a thermo-chemical process, or can be used as a source for the high-temperature steam supplied as process heat to a chemical plant. HTGRs have potential for expanding the range of uses of nuclear power, which has been limited to generating electricity in the past, and by positioning nuclear power as a primary energy source that replaces fossil fuels, to reduce $CO_2$ emissions dramatically. For this reason, HTGR technology is actively being developed in Japan and overseas. The modular HTGR, which has limited output and is able to take advantage of the inherent safety characteristics of HTGRs, has become the mainstream nuclear reactor being developed in countries throughout the world. Because the maximum heat output of the reactor is limited to about 600 MWt (300 MWe electric power), in the case of an accident, the reactor will shutdown naturally and remove heat naturally, and has no risk of releasing massive amounts of radioactive matter that would require evacuation of the public. Accordingly, HTGRs can be constructed in proximity to the regional demand for electric power and can also be constructed as distributed power sources.

Since the project planning stage, Fuji Electric has participated in the development and design of a High Temperature Engineering Test Reactor (HTTR) operated by the Japan Atomic Energy Agency (JAEA) as Japan's first HTGR. During the actual construction, Fuji Electric designed the reactor core, performed safety analyses, and was in charge of the design, fabrication and construction of major equipment such as the reactor internal structure, the fuel handling and storage system, the radiation monitoring system, and so on. Based on the technical know-how acquired through this experience, Fuji Electric is moving ahead with research and development that aims to realize a HTGR on a practical scale, targeting a reactor outlet temperature of 950 °C and heat output of 600 MWt.

The US Department of Energy has launched a HTGR project, and has begun to plan research and development in order to realize this project. Fuji Electric will also participate as a member of the HTGR conceptual design team.

As part of a long-term efforts aimed at preventing global warming and supporting the upcoming hydrogen economy, in cooperation with relevant national and international agencies, Fuji Electric will continue to promote activities that aim for practical applications of HTGRs.

## 4. Thin-Film Amorphous Silicon Solar Cells

Circumstances surrounding solar cells have changed significantly over the past decade. Worldwide production has increased more than 20-fold. The solar cell market has also transitioned from one centered on Japanese manufacturers, to a diverse market supplied by many manufacturers from Japan, USA, Europe, and China and other Southeast Asian countries, and in addition to crystalline silicon solar cells, thin-film silicon and other types of new solar cells are now being produced in large quantities.

Turning to national policies for promoting the widespread use of thin-film amorphous solar cells, in Europe, with the adoption of a feed-in tariff (FIT) system mainly in Germany, the usage of solar cells is rapidly increasing. Even in the US where solar cell adoption rates have been sluggish, with the 2009 change in governing party, the solar cell industry is poised to gain momentum.

In Japan, thus far, widespread adoption has been promoted mainly for residential use. Additionally, as support for public and industrial uses of solar power has increased, a "new buyback program for photovoltaic power" was launched in November 2009, and surplus power is beginning to be purchased at higher prices than before. Moreover, in response to the recent change of the governing party in Japan, the "renewable energy all-quantity buyback program" cited in the manifesto of the Democratic Party is being discussed, and specific measures for expanding adoption of solar power technology are under consideration.

Fuji Electric began developing solar cells in 1978, and initially developed a-Si single and a-Si tandem solar cells that used glass substrates. Since 1993, however, Fuji's development efforts have shifted to thin-film amorphous silicon solar cells (a-Si/a-SiGe) that use inexpensive plastic film substrates. Based on the successful results of technical development, Fuji Electric completed the construction of a dedicated plant for solar cell production in Kumamoto Prefecture, Japan and began full-scale mass-production in November 2006.

Fuji Electric's solar cells (Fig. 3, Fig. 4) use plastic film as their substrate material, and as a result, exhibit the previously unobtainable characteristics of

Fig.3 Saitama Super Arena

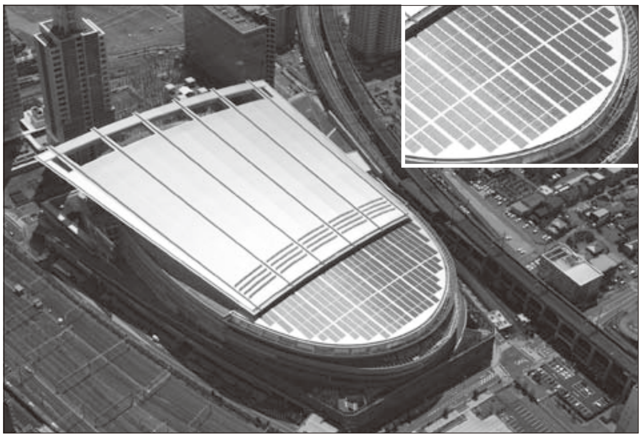


Fig.4 Academic Plaza of Kumamoto Prefectural College of Technology

being "lightweight" and "flexible", and open up a new range of applications such as to gymnasiums and factories, i.e., large roof and building wall areas, where the installation of solar cells had previously required reinforcement of the building. Also, breakage is not a concern since glass is not used as the surface material, and therefore applications requiring a high level of safety, such as highway soundproofing walls, are also being considered. Furthermore, because the module surface is covered with embossed plastic, the amount of light reflected is less than that of glass, and installations at airport facilities or the like where low glare (low reflection) is required in order to ensure the safety of operations are also being considered. In the future, to expand this business further, product development must focus on improving the output of the modules and on meeting customer needs. Through accomplishing these goals, Fuji Electric also aims to contribute positively to protecting the global environment.

## 5. Fuel Cells

The "FP-100i" 100 kW fuel cell power plant that Fuji Electric began selling in 2009 was awarded the "Nikkei Superior Products and Services Award" in that same year. In addition to the conventional application as co-generation equipment that uses city gas and digester gas as fuel, with the aim of expanding the market, fuel cells are being equipped with additional features for disaster response support, compatibility with byproduct gases, hydrogen supply support, and so on. Inside a power plant, a fuel cell is equipped with a reformer so as to be compatible with a variety of fuels such as city gas or digester gas. By maintaining a reserve of LP gas, operation will normally proceed with city gas being used as the fuel, but in the case of an emergency or disaster where the electricity or city gas supply is shut off, the fuel source can be changed to LP gas so that operation can continue.

In the case where the pure hydrogen byproduct from a salt electrolysis plant or the like is used as fuel, highly efficient power generation with fuel cell output efficiency of 48% can be realized, and a $CO_2$ emissions reduction effect of approximately 760 t annually is expected. A 100 kW fuel cell capable of using pure hydrogen fuel began operation in 2010 as a demonstration test. As a pioneer of the future hydrogen energy era, a fuel cell equipped with a hydrogen supply function is suitable for applications involving small hydrogen stations. In the case where digester gas is used as fuel, so-called green hydrogen can be produced stably without generating any $CO_2$. Also, digestion gas power generation fueled by digester gas generated from sewage treatment plants has been operating successfully since 2002. As carbon-neutral power, a 100 kW fuel cell is expected to provide a $CO_2$ reduction effect of about 800 t annually. Certified by Japan's "Green Power Certificate" system, the investment costs for these fuel cells can be recouped within a short time period.

Fuji Electric established a factory system in April 2009 for producing 20 units annually of the FP-100i, and by promoting their widespread usage through the aforementioned application development, intends to contribute to reducing $CO_2$ emissions.

## 6. Postscript

In addition to the above, in order to realize a low carbon society Fuji Electric is also pursuing various other initiatives for energy creation.

In the thermal power generation sector, Fuji Electric is advancing research and development to increase the efficiency of turbines and generators, and in the gas combined power generation sector, is collaborating with Siemens to develop high-efficiency high-performance gas combined cycle power plants.

In the hydropower sector, Fuji Electric is advancing the research and development of highly efficient hydropower facilities in collaboration with Voith Hydro, and plans to offer energy creation solutions via a global network.

Wind power is also being adopted throughout the world as a natural energy source that does not emit $CO_2$. In addition to onshore wind power facilities, offshore wind power generation is also actively being planned for the future, and individual turbines of larger capacity (3 MW and greater) are being produced. Building on its considerable accumulated technical expertise in power electronics, Fuji Electric is advancing the development of high performance power conditioners and permanent magnet generators. In the wind power sector, Fuji Electric's work is also centered on the most important components.

Additionally, with the introducing of large amounts of natural energy, new challenges have emerged, such as stabilization measures for the power system. Fuji Electric has already responded to this challenge by introducing a power stabilizer in a wind power plant, and has realized good results in stabilizing the power system. Furthermore, Fuji is also working on smart grid technology, a promising technology for the future, and grid solutions.

Through providing these energy solutions, Fuji Electric is determined to make positive contributions towards the goal of realizing a low carbon society.

**References**

(1) International Energy Agency, World Energy Outlook 2009.

(2) Global Geothermal Markets and Strategies, Emerging Energy Research.