

JAPAN

PV TECHNOLOGY AND PROSPECTS

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Fig. 1 – Mitsubishi Heavy Industries (MHI) Nagasaki Research and Development Center, 20 kW, Nagasaki City, Nagasaki Prefecture (photo RTS Corporation).

GENERAL FRAMEWORK

Japan's policy and measures on energy including PV power generation is based on the Basic Act on Energy Policy (Energy Policy Law) enforced in 2002, that stipulates 3 principles; securing a stable supply, environmental suitability and utilization of market mechanisms. Promotion of use of solar energy is listed in the "environmental suitability". In addition, the Basic Energy Plan was established in order to materialize these basic directions of the energy policy. Dissemination of PV Systems is defined in the "New Energy Innovation Plan" under "New National Energy Strategy" that is the foundation of Japan's energy strategy, laid out in 2006.

The "New National Energy Strategy" was established based on the basic recognition of the current status of energy, such as structural change in energy demand and supply. Numerical targets to be achieved by 2030 were set for achieving the "Establishment of energy security measures that people can trust and rely on the "Establishment of the foundation for sustainable development through a comprehensive approach for energy issues and environmental issues all together," and "Commitment to assist Asian and world nations in addressing energy problems." Specific activities are comprised of the four items:

- 1) Realizing the state-of-the art energy supply-demand structure,
- 2) Comprehensive strengthening of resource diplomacy and energy and environment cooperation,
- 3) Enhancement of emergency response measures and
- 4) Common challenges. New Energy is considered as one of the four major pillars of the structure in the "Realizing the state-of-the art energy supply-demand structure;" significantly contributing to the New Energy Innovation Plan.

The New Energy Innovation Plan clearly specifies the targets for year 2030 based on the following concepts:

- 1) "Specify renewable energy sources which particularly need to be promoted, such as PV, wind power and biomass, and give them strong support,"
- 2) "Development and enhancement of use of innovative technology for high-level utilization of energy,"
- 3) "Promotion of "demand" and "supply" expansion measures in response to dissemination stages,"
- 4) "To broaden thickness of industrial structure of new energy, etc. and improve economic efficiency of the entire new energy industry." As for the PV Systems, it is targeted to reduce the PV power generation cost to the level of thermal power generation by 2030. Promotional measures for the expansion of "demand" and "supply" through implementation support measures such as subsidies and taxation systems by stages of growth will continue. Also targeted is the creation of a group of PV-related industries.

Toward the dissemination of new energy, the "New Energy Law," established in 1997, defines the responsibility of the government and local authorities, energy consumers, energy suppliers and manufacturers of energy equipment. In addition, "Special Measures Law Concerning the Use of New Energy by Electric Utilities, the Renewables Portfolio Standard (RPS) Law" established in 2002, obliges energy suppliers to use a certain amount of electricity generated from new and renewable energy sources. The obligatory usage amount of new and renewable energy has been increased every year.

For technological development of PV Systems, technological targets for solar cell and PV Systems from the long-term perspective towards

2030 were established based on "PV Roadmap toward 2030 (PV2030)", a roadmap for technological development of PV Systems established in 2004.

Moreover, utilization and introduction of new and renewable energy are implemented as one of the measures to reduce greenhouse gas emissions toward 2010 under the "Kyoto Protocol Target Achievement Plan" endorsed by the cabinet in 2005.

NATIONAL PROGRAM

Government has implemented research and development (R&D), demonstrative research, model projects and dissemination measures toward further deployment of PV Systems, mainly through the efforts of the Ministry of Economy, Trade and Industry (METI) and the Ministry of the Environment (MoE).

METI has been promoting the technological development of PV Systems for cost reduction and acceleration of introduction. As for demonstrative researches, the Field Test Project on New Photovoltaic Power Generation Technology under the Field Test Project on New Energy Technology and Verification of Grid Stabilization with Large-scale PV Power Generation Systems have been conducted to demonstrate the effectiveness of PV systems employing novel PV modules, new components, advanced system technology and newly developed installation methods, etc. and enlarge the application area of PV systems. Projects for promoting the introduction of PV Systems are implemented to support local governments and private businesses.

MoE continuously promotes projects for the introduction of new energy and technological development to support local governments and private enterprises through establishing business model projects in local areas utilizing PV power generation technologies as model projects of countermeasures against global warming.

The budgets for major national PV programs implemented in FY2007 are as follows:

- 1) New Energy Technology Development: 4 580 MJPY
- 2) Field Test Project on New Photovoltaic Power Generation Technology: 10 800 MJPY
- 3) Verification of Grid Stabilization with Large-scale PV Power Generation Systems: 3 500 MJPY
- 4) Project for Supporting New Energy Operators: 31 600 MJPY
- 5) Project for Promoting the Local Introduction of New Energy: 4 500 MJPY
- 6) Project for Establishing New Energy/Energy Conservation Visions at the Local Level: 1 300 MJPY
- 7) Project for Promotion of Non-profit Activities on New Energy: 70 MJPY
- 8) Demonstrative Project of Regional Power Grids with Various New Energies: 500 MJPY
- 9) Model Project of Promotion of PV Power Generation for Global Warming Countermeasures (Solar Promotion Program): 4 800 MJPY
- 10) Project for Developing Technology to Prevent Global Warming: 3 300 MJPY



Fig. 2 - Matsumoto Station, 30 kW, Matsumoto City, Nagano Prefecture (photo: RTS Corporation).

The budgets for items 1), 4), 5), 6), 7), 8), 9) and 10) include ones for PV and other new and renewable energy.

R, D & D

R&D

Two Projects started in FY2006 under "4-Year Plan for Photovoltaic Power Generation Technology Research and Development (FY2006 - FY2009)" have been continued in 2007; 1) R&D for Next Generation PV systems and 2) Development of PV Systems Technology for Mass Deployment, Phase II. Interim assessment of these projects will be conducted in the end of FY2007. In addition, Technological development of each issue has also been continued under PV Systems Advanced Practical Technology following FY2006.

1. R&D for Next Generation PV Systems

This project aims at establishing elemental technologies to achieve the target PV power generation cost set in PV2030: 14 JPY/kWh in 2020, 7 JPY/kWh in 2030. Based on the outcome of the "Development of Advanced Solar Cells and Modules" in the previous term (FY2001 - FY2005), technological development of 5 types of solar cells as elemental technologies of next generation photovoltaics have been conducted aiming at higher conversion efficiency, further cost reduction and improvement of durability. Types of solar cells include thin-film CIS solar cells, thin-film silicon solar cells, dye-sensitized solar cells (DSCs), next-generation ultra-thin crystalline silicon solar cells and organic thin-film solar cells. In parallel with these topics, fundamental research projects to develop ultra-high efficiency solar cells using quantum dot nanostructure and other technologies have been underway.

2. Development of PV Systems Technology for Mass Deployment, Phase II

This project is a successor of Development of PV Systems Technology for Mass Deployment in the previous term, aiming at developing

technological infrastructure for supporting extensive utilization and mass deployment of PV Systems. Under this project, research studies to develop evaluation technologies for performance and reliability of PV cell/ module and evaluation technologies of electricity output from PV Systems were continued. In addition, as environmental technologies for manufacturing processes of PV Systems and disposal of used PV modules, studies on life cycle assessment (LCA) and development of recycle technology of solar cell were also continued.

3. PV systems Advanced Practical Technology

This project aims at developing industrial technology to accelerate practical application of outcomes of preceding technological developments. In FY2007, the following technological developments were continued: recycling technology of silicon feedstock for solar cell, manufacturing technology of spherical silicon solar cell, high-performance inverter, demonstration of autonomous PV Systems technology, etc. FY2007 is the final year for this project so that new proposals were not solicited.

DEMONSTRATION

7 major demonstration programs were implemented in FY2007:

- 1) Field Test Project on New Photovoltaic Power Generation Technology,
- 2) Demonstrative Project on Grid-Interconnection of Clustered Photovoltaic Power Generation Systems,
- 3) Demonstrative Project of Regional Power Grids with Various New Energies,
- 4) Verification of Grid Stabilization with Large-scale PV Power Generation Systems,
- 5) Development of an Electric Energy Storage System for Grid-Connection with New Energy Resources,
- 6) International Cooperative Demonstration Projects for Stabilized and Advanced Grid-connection PV Systems and
- 7) International Cooperative Demonstration Projects Utilizing Photovoltaic Power Generation System

1. Field Test Project on New Photovoltaic Power Generation Technology

Since FY2007, "Field Test Project on New Photovoltaic Power Generation Technology" has been implemented under the New Energy Technology Field Test Project. This program aims at leading dissemination of medium-scale PV systems by installation of PV systems employing advanced technologies on a trial basis and promoting further improvement of performance and cost reduction of those PV systems. This program is positioned as a successor of Field Test Project on Photovoltaic Power Generation Systems for Industrial and Other Applications. Under the program, the following 4 model technologies are defined:

- 1) PV Systems with new modules,
- 2) PV Systems with building material integrated modules,
- 3) PV Systems with new control systems and

- 4) PV Systems aiming at higher efficiency. Introduction of PV systems for public facilities and industrial uses are promoted under this program. 262 projects were selected and PV systems totaling 7 161 kW were installed in FY2004. In FY2005, as METI enhanced this application area as a prioritized area for PV power dissemination, the number of the selected projects significantly increased to 457; totaling 17 709 kW. In FY2006, 675 projects, totaling 19 454 kW were selected. In FY2007, 374 projects, totaling 21,058 kW were selected. Cumulative installed capacity of field tests conducted from FY1992 - to FY2007 is expected to exceed 90 000 kW.

2. Demonstrative Project on Grid-Interconnection of Clustered Photovoltaic Power Generation Systems

This program started in FY2002 for a 5-year scheme to install grid-connected PV systems equipped storage batteries into 600 households to conduct demonstrative research of a large-scale and intensive introduction of on-grid PV systems. The program aims at establishing grid connection technologies for grid-connected PV systems intensively installed to one area, seeking establishment of environment for mass deployment of PV systems. The specific research objectives are 1) development of technology to avoid restriction of PV Systems output by using storage batteries, 2) analysis and evaluation of higher harmonics, 3) analysis and evaluation of existing devices for mis-actuation function to prevent islanding operation as well as development and evaluation of novel devices to detect islanding, 4) development of applied simulations and 5) evaluation of characteristics of power generation and economical efficiency. Installation of 553 residential PV systems totaling 2,129 kW was completed by the beginning of FY2006. In FY2007, operation test of output control, evaluation of new devices for mis-actuation function to prevent islanding operation and so on have been continued and final reports have been compiled. This project is scheduled to be completed in FY2007.

3. Demonstrative Project of Regional Power Grids with Various New Energies

This program was launched in FY2003 to intensively install various types of distributed power sources such as PV systems, wind power systems and fuel cells, etc. in one area, aiming at demonstrating various issues such as ensuring quality of electricity, balance between supply and demand of electricity, stability and economical performance of distributed power sources. In FY2003, 3 demonstrative sites were selected across the country: Aichi Prefecture (total 2 225 kW of distributed power generation systems including PV systems totaling 330 kW), Aomori Prefecture (total 714 kW of distributed power generation systems including PV systems totaling 130 kW and Kyoto Prefecture (total 850 kW of distributed power generation systems including a 50-kW PV system). Demonstrative operation of the power generation systems was started in FY2005. The power generation systems installed on the premises of the 2005 World

Exposition (EXPO 2005), Aichi, Japan, were relocated to Central Japan Airport City in Tokoname City of Aichi Prefecture and the demonstrative research was resumed from August 2006. This project is scheduled to be completed in FY2007.

4. Verification of Grid Stabilization with Large-scale PV Power Generation Systems

This demonstrative research aims at establishing a system to stabilize power output of MW-scale PV systems without giving negative impact on the quality of grid electricity and validating its effectiveness and usefulness. In addition to these objects, the final goal of this research is the development of technologies to make the business using future MW-scale PV plants feasible. A 5-MW scale project in Wakkanai City of Hokkaido Prefecture and a 2-MW scale project in Hokuto City of Yamanashi Prefecture were selected and construction was launched in both sites. By the end of FY2007, 2 MW part of the 5-MW PV plant in Wakkanai City and 0,6 MW part of the 2-MW PV plant in Hokuto City will start operation.

5. Development of an Electric Energy Storage System for Grid-Connection with New Energy Resources

This project is a 5-year project between FY2006 and FY2010 on development of electricity storage technologies with the aim of minimizing output fluctuation of power generation using new energy. Technological development covers 4 issues as follows:

- 1) development of technologies for practical application,
- 2) development of elemental technologies,
- 3) development of next-generation technologies and
- 4) research of common fundamental technologies. Under these themes, development of large-capacity lithium ion battery and nickel hydride battery has been conducted.

6. International Cooperative Demonstration Projects for Stabilized and Advanced Grid-connection PV Systems

This program is an international program of demonstration and technological development using PV power generation, aiming at stable electricity supply by mainly constructing micro-grid with higher share of capacity of the PV Systems within entire capacity. Collaborative projects on demonstration and technological development has been conducted in China, Thailand, Indonesia, Malaysia, etc.

7. International Cooperative Demonstration Projects Utilizing Photovoltaic Power Generation Systems

This is an international program of demonstration and technological development using PV power generation. Under this program, cooperative demonstrative research project is underway in China mainly aiming at improvement of reliability of the PV Systems and other issues through cooperation with developing countries whose natural conditions and distinctive social systems are rarely seen in Japan.

IMPLEMENTATION

The Ministry of Economy, Trade and Industry (METI)

1. Residential PV Systems Dissemination Program

“Residential PV Systems Monitor Program” initiated in FY1994 was renamed “Residential PV Systems Dissemination Program” in FY1997 to develop the initial market of residential PV Systems. The program was terminated in FY2005. The subsidy amount was 20 000 JPY/kW and 36 754 residential PV systems, totaling 136,3 MW were installed in FY2005. During the 12 years (FY1994 to FY2005), the total number of PV systems installed under this support measure reached 253 754, totaling 931 575 kW in total. The program highly contributed to the creation of the initial market of residential PV Systems in Japan.

2. Project for Promoting the Local Introduction of New Energy

This program aims at accelerating the introduction of new and renewable energy in local areas by supporting projects for installation of facilities as well as projects for awareness towards dissemination, which are implemented based on plans for introduction of new and renewable energy in areas designated by local government and nonprofit private institutions. Subsidy is provided for facilities using new and renewable energy such as PV power generation, wind power generation, use of solar thermal energy, differential temperature energy, natural gas co-generation, fuel cell, biomass, utilization of snow and ice and clean energy vehicles. In FY2007, subsidy for waste power generation, use of waste thermal energy and production of wastes fuel was discontinued. Instead, small- and medium-sized hydroelectric power generation (with a capacity of 1,000 kW) and geothermal generation (only for binary cycle power generation) became qualified for subsidy. PV systems with 10 kW of output capacity and over are qualified under the program. Recipients can receive the subsidy, the lower amount of either half of installation cost or 340 000 JPY/kW (in case of specific public body, supported by the local government, one third of installation cost or 220 000 JPY/kW). Projects for awareness towards dissemination are subsidized with a fixed amount (or within half of installation cost). 572 systems in total were subsidized between FY1997 to FY2006, of which 254 systems were PV systems. Total capacity installed was 23 012 kW. In FY2007, 119 systems in total were newly qualified, of which 49 systems were PV systems. Total capacity installed was 945 kW. Local governments or nonprofit institutions understand the benefit of introduction of new and renewable energy through this program and introduce PV systems to school buildings and public facilities, etc. over several fiscal years.

3. Project for Supporting New Energy Operators

This program aims at accelerating the introduction of new and renewable energy by supporting private institutions who install facilities using new and renewable energy, such as PV power generation, wind power generation, use of solar thermal energy, differential temperature energy, natural gas co-generation, fuel cell, biomass, utilization of snow and ice, etc. In FY2007, subsidy for

waste-related facilities was discontinued. Instead, small- and medium-sized hydroelectric power generation (with a capacity of 1 000 kW) and geothermal generation (only for binary cycle power generation) became qualified for subsidy. The subsidy is one third of installation cost or below, and 90 % of the debt is guaranteed. The capacity of an eligible PV system is 50 kW and over (10 kW and over is also eligible in case of combined installation with other facilities). 277 systems in total were qualified from FY1998 to FY2005, of which 12 systems were PV systems, 826 kW in total. In FY2006, 54 systems were selected, of which 2 systems were PV systems, and the total installed capacity was 160 kW. Recipients of FY2007 subsidy have not been announced yet.

Besides these programs, METI has been supporting local governments for their projects to develop their own visions for the introduction of new and renewable energy and to nonprofit organizations (NPOs) for their awareness activities to introduce new and renewable energy.

The Ministry of the Environment (MoE)

The Ministry of the Environment (MoE) is promoting projects to reduce CO₂ emissions by use of natural energy under the "Law Concerning the Promotion of Measures to Cope with Global Warming," enforced in FY1998. MoE established the "Solar Promotion Program," a package program for the introduction of PV Systems; to implement measures to reduce CO₂ emission by PV technology in FY2005 and continued the program in FY2007 as the 2nd phase. The major subprograms for dissemination of PV Systems under the "Solar Promotion Program" are 1) the Town-wide CO₂ 20 % reduction projects, 2) Model project for shared use of MW-scale solar (3 areas were selected for 3-year projects from FY2006. PV system installation projects with total capacity of 3 MW was implemented), 3) Model project for advanced introduction of renewable energy (MoE and METI jointly support regional projects for CO₂ reduction), 4) Project of environment-friendly renovation of schools, 5) Project for pioneering introduction of PV Systems by local governments, 6) Solar Mileage Club Program and 7) CDM/JI project survey which was newly established in FY2007 to roll out in the Asian region. In addition, MoE implements "Model Project for a Virtuous Circle for Environment and Economy" aiming at achieving city planning including introduction of PV Systems, developed by local communities and the "Project for developing technology to prevent global warming" to develop practical technology for introduction of renewable energy, etc.

The Ministry of Land, Infrastructure and Transport (MLIT)

Under the "Guideline for Planning Environmentally-Friendly Government Buildings (Green Building)" as well as the Kyoto Protocol Target Achievement Plan, construction of green government buildings, buildings for central ministries and agencies and local government offices equipped with PV Systems and other new and renewable energy systems has been promoted. In addition, MLIT started to utilize PV systems under several measures: promotion of environment-friendly houses and buildings for global environment



Fig. 3 - Wakkanai Photovoltaic Demonstration Facility (Under Constructed), 2 MW (end of FY2007), 5 MW (end of FY2010), Wakkanai-City, Hokkaido Prefecture (photo RTS Corporation).

conservation, introduction of navigation aids using clean energy and a program to reduce CO₂ emissions in road projects.

The Ministry of Education, Culture, Sports, Science and Technology (MEXT)

MEXT continues "Eco-school Promotion Pilot Model Project" initiated in partnership with the former Ministry of International Trade and Industry (currently known as METI) in FY1997 and has been promoting the introduction of PV systems to elementary schools, junior high schools and kindergartens. 611 schools all over Japan were designated as the Eco-school pilot model schools by the end of FY2006 (March 2007); of which 388 schools installed PV systems with output capacities of 10 kW and over each. In FY2007, 77 schools were newly selected as the pilot model schools and PV systems are to be installed at 51 schools of them. METI, MoE and the Ministry of Agriculture, Forestry and Fisheries (MAFF) has been jointly working on this project in promoting model projects of environment-friendly schools.

Local Governments and Municipalities

The movement to actively work on environmental issues has been spreading among local governments and municipalities year by year. Prefectures and other local governments began to set their own target for the introduction volume of new energy following the national target for PV Systems introduction (4 820 MW) one after another. More than that, local authorities have started their own programs for dissemination of PV Systems. Support activities for dissemination of PV systems have also been promoted on the municipality level and over 300 municipalities continue to provide their own subsidy or preferential loan programs for residential PV systems even though the national support program for residential PV systems was terminated. In the Saga Prefecture, the amount



Fig. 4 - GG Solar Building, 10 kW, Chuo-ku, Fukuoka City (photo RTS Corporation).

of electricity generated from residential PV systems for home consumption is certified as green power and the prefectural government purchases the certificate. In the Shiga Prefecture, the prefectural government provides additional support on the amount of electricity sold from residential PV systems to utilities. The Metropolis of Tokyo set a target to reduce CO₂ emissions by 25 % in 2020 compared to that of 2000, under a plan called "Tokyo towards 10 years later" and announced a plan to introduce 1000 MW of solar energy.

Utilities

Electric utilities in Japan continue the introduction of PV Systems to their own facilities and net-billing to buy-back surplus PV electricity at the same rate as the retail price of electricity.

They also established the "Green Power Fund" in October 2000, aiming at introducing and promoting PV systems and wind power generators. The utilities bill an additional charge as a contribution at 500 JPY/share/month to the supporters among their customers, and contribute the same endowment as the amount of their supporters' contribution for installation of PV systems and wind power generators. From FY2001 to FY2006, 752 public facilities including schools across Japan were subsidized by the fund and the total capacity installed was 15 112 kW. In FY2007, 122 sites were selected, and installation of PV systems totaling 1 716,9 kW are underway.

Electric utilities achieved to purchase required amounts of electricity generated from new and renewable energy for FY2006 designated under the RPS Law that was enforced in FY2003. Usage amount of electricity generated by new and renewable energy by utilities for FY2006 was 6 507 TWh in total, including 541 TWh from PV power generation. The accredited facilities for power generation using new energy under the RPS Law was 333 898 systems totaling 4 756 MW. Among them, PV systems are 332 852, accounting for 1 232 MW of generation capacity.

Financial Institutions

Some banks and other financial institutions provide preferential financing at a low interest rate for introduction of residential PV systems and houses equipped with PV systems. The number of such financial institutions has been increasing year by year. In addition, financial institutions themselves started to introduce PV systems to their own branch offices and other facilities, which is an increasing trend. Moreover, there is an increasing trend of expanding environmental financing for business activities working on environmental issues.

INDUSTRY STATUS

In 2007, a series of activities to strengthen a group of PV related-industries were observed in Japan's PV industry; 1) capacity expansion and new entries by raw material and silicon wafer manufacturers, 2) large scale production capacity increase and extension of overseas production sites, in addition to improvement of PV cell/ module performance by early-started solar cell manufacturers, 3) start of production and production capacity increase by new entrants of thin-film PV module manufacturers, 4) burgeoning of system integrators, 5) production capacity increase and new entrants in components of PV cell/ module, 6) emergence of manufacturers who produce full turn-key manufacturing equipment for solar cell production lines.

PV cell/module manufacturers continued actively working on their business. Highlights of PV cell/module manufacturers in 2007 are as follows.

Sharp announced a plan to first increase its solar cell production capacity at Katsuragi Plant from 600 MW/year to 710 MW/year and then to construct a thin-film silicon PV module plant with capacity of 1 000 MW/year in Sakai City, Osaka Prefecture, annexed to a plant

for large-sized liquid crystal display (LCD) panels. First, capacity of a thin-film PV module production line at Katsuragi Plant will be increased to 160 MW/year; then the technology cultivated there will be introduced to the new Sakai Plant. Furthermore, Sharp announced a plan to double the production capacity of the PV module factory in the UK to 220 MW/year.

Kyocera will increase domestic production capacity to 500 MW/year by 2010. Production capacity of PV module plant in Mexico will be increased to 150 MW/year.

Sanyo Electric announced a plan to launch a new PV module plant in Shiga Prefecture with the capacity of 40 MW/year, in response to the growing demand. Sanyo also plans to establish the "Advanced Photovoltaic Development Center" in the aim of commercialization of next-generation thin-film silicon PV module.

Mitsubishi Electric plans to enhance its solar cell production line towards establishing a production framework with the capacity of 250 MW/year.

Kaneka completed the construction of a new thin-film silicon PV module production line with the capacity of 55 MW/year, with a plan to further increase the production capacity to 130 MW/year. Fuji Electric Systems plans to increase production capacity of flexible thin-film silicon PV module from 15 MW/year to 150 MW/year. Showa Shell Sekiyu decided to construct the second plant for CIGS PV module with the production capacity of 60 MW/year and announced a plan to increase production capacity to 80 MW/year in total.

Honda Motor started a full-scale production of CIGS PV module entered into the residential PV Systems market. Clean Venture 21 established a commercial plant of spherical silicon solar cell.

Fujipream established a plant to exclusively produce concentration-type spherical silicon solar cell.

MSK's Fukuoka Plant was acquired by its employees and started operation as a new company "YOCASOL". In the area of the silicon feedstock/ wafer, manufacturers have been increasing production capacities and many new players are entering the market.

Mitsubishi Materials, one of the major polysilicon manufacturers, announced a plan to increase manufacturing at production plants both in Japan and the USA.

Japan Solar Silicon, one of the group companies of Chisso achieved polysilicon for solar cells with 6N purity by SiCl₄ zinc reduction process.

M. Setek entered into the business of polysilicon for solar cell and started production.

With the metallurgical process of polysilicon production, Nippon Steel entered into the business and other companies have been active in this area.

JFE Steel plans to construct a 300-t/year plant of polysilicon for solar cell.

Dow Corning Toray expanded sales of polysilicon for solar cells, in which the US headquarters is engaged, to a full-scale operation.

SUMCO decided to supply multicrystalline silicon wafer for solar cells, in addition to that for semiconductors, and announced a plan to construct a new plant of silicon wafer aiming to achieve 1 GW/year production.

Sumitomo Corporation formed a business alliance with a Chinese company for single crystalline silicon ingots for solar cells.

Osaka Fuji Corporation decided to establish a new plant to process wafers for solar cells.

Not only in the area of silicon ingot and wafer but also in the area of BOS (Balance of System) and production equipment for solar cells, a number of companies are entering into the business and aggressively expanding production as well as establishing business partnerships.

Denal Silane plans to increase production capacity of monosilane gas.

Jemco plans to double the production capacity of columnar crystalline silicon ingot.

Ferrotec decided to produce quartz crucibles in Norway and strengthen production of single crystalline silicon ingot puller.

Covalent Materials decided to increase production of quartz crucible for solar cells.

Other manufacturers are also active in the area of BOS and production equipment, as follows:

EVA: Bridgestone, connector for PV modules: SMK, Honda Tsushin Kogyo, wiring units: Onamba, solar cell production line: SES, PV cell/module production equipment: NPC (listed on TSE MOTHERS of the Tokyo Stock Exchange), PV cell/module testing equipment: Iwasaki Electric, Yamashita Denso, crystalline silicon solar cell production equipment: Noritake.

Ulvac entered into the business of thin-film silicon PV module production equipment, receiving a series of orders from PV manufac-

turers in Taiwan and China. Accordingly, Ulvac established a PV module line for evaluation and plans to expand its production sites. In the PV Systems distribution industry, residential PV Systems have been selling well, despite completion of the government's subsidy program.

Sekisui Chemical achieved sales of 58 000 PV systems by the end of 2007.

Daiwa House, PanaHome and Sumitomo Forestry have started the sales of all-electrified housing one after another, with PV Systems as standard equipment.

NTT Facilities has been promoting the construction of large-scale PV systems as part of national projects.

Itochu acquired Solar Depot, a US company selling PV systems and entered into the PV business.

As systematic introduction of PV systems has started on the user side, movements towards full-scale PV dissemination will be continuously pursued.

MARKET DEVELOPMENT

Through the measures for introducing PV Systems, mainly implemented by METI, the market development of residential PV Systems and PV Systems for industrial and public facilities is underway. The size of the residential PV market grew to the level of 50 000 systems/year through government support programs for introducing residential PV systems implemented for 12 years. Cumulative installed capacity at the end of FY2006 was 1 277 MW installed at approximately 350 000 houses. Even after the program was completed, the PV market in Japan didn't shrink but leveled off. PV manufacturers are working on expansion of the market for residential PV Systems for both newly built and existing houses by minimizing the price increase of PV Systems despite the soaring price of silicon feedstock due to the polysilicon shortage. In the newly built residential house market, pre-fabricated house manufacturers enhance efforts for energy conservation and reduction of CO₂ emissions. Accordingly, some housing manufacturers adopted PV Systems as standard equipment and this trend has expanded to major housing companies, who are advertising PV-equipped housing on TV commercials to increase sales across the country. In particular, the new concept of zero-utility charge house equipped with PV system contributes to the expansion of purchasers who recognize economical efficiency in running cost of the house as well as the environmental value. In the PV market for existing houses, PV manufacturers are developing and establishing a distribution channel consisting of local builders, electric contractors, electric appliances stores and roofers, etc., while seeking purchasers of residential PV systems all over Japan.

Through the long-term field test projects, PV systems for non-



Fig. 5 - Intensively installed PV system for houses, Pal Town Jyosai-no-Mori, Total 2 130 kW, 553 houses (Average: 3.85 kW per house, Ota City, Gunma Prefecture (photo Otacity Land Development Corporation).

residential use, such as for public and industrial facilities, have been making progress year by year in many aspects: economical efficiency, grid-connection technology, design and installation as well as system efficiency. Consequently, opportunities for market expansion have been increasing and diversified in such areas as application, design, installation sites, power generation capacity and introducers of PV Systems and the market development of non-residential area is in progress. As for the installation sites, PV Systems have been added to a wider variety of places: public facilities (schools, government office buildings, community buildings, water purification plants, welfare and medical facilities) and industrial facilities (factories, warehouses, laboratories, office buildings, commercial buildings). In addition to these sites, recently, PV systems have been installed to agricultural facilities (greenhouses), commercial facilities (shopping malls, family restaurants), railway facilities (station buildings and platforms), road facilities (parking lots and expressway toll booths), financial facilities (banks, etc.), transport facilities (logistics centers, etc.) and resort facilities (hot-spring resorts, etc.). The size of a PV Systems has been increased to as large as 5-MW. The range of those who installed PV systems are widely varied, from large companies to individual owners in the private sector and from public-interest organizations to nonprofit organizations (NPOs). Some companies have been introducing PV systems to their factories and offices nationwide and installing additional PV systems to existing PV-equipped facilities. Installation of large-sized PV systems is also on the rise. The number of such companies has been increasing year by year. In NEDO's Field Test Project on New Photovoltaic Power Generation Technology in FY2007, total capacity exceeded 20 MW, of which 2 007 kW was installed by Toyota Motor Corporation and 1 000 kW by Electric Power Development.

FUTURE OUTLOOK

The government of Japan revised the Basic Energy Plan foreseeing around 10 years ahead in 2007. The Plan emphasizes the importance of energy security reflecting recent global circumstances such as the tight situation of energy demand and supply, soaring prices of energy and countermeasures against global warming. The main pillars of the Plan include the following:

- 1) promotion of nuclear power generation and expanded installation of new and renewable energy,
- 2) aggressive development of diplomacy on resources toward the stable supply of fossil fuels such as oil,
- 3) enhancement of energy conservation strategy and initiative for forming an international frameworks to work on measures against global warming and 4) strengthening of technological capabilities.

New and renewable energy is positioned as "the complementary energy for the time being; which the government will promote measures aiming at making new and renewable energy one of the key energy sources in the long run." For that, the government announced the creation of strategic efforts for implementing technological development to reduce costs, to stabilize the grids and to improve performance in collaboration among industrial, academic and governmental circles. Furthermore, in order to expand introduction of new energy, the following measures are included, depending on different stages of market growth:

- 1) take-off support (technological development, demonstration tests),
- 2) creation of initial demands (model projects, support for installation of facilities),
- 3) initiative in installations (at public institutions-related facilities),
- 4) support for market expansion (legal actions such as the RPS Law),
- 5) formation of industrial structure (promotion of venture businesses to enter into the market, fostering peripheral and related industries),
- 6) maintenance of promoting environment for dissemination (awareness for dissemination, public relations and information service).

In addition, the government reviewed the RPS Law which obliges utilities to use a certain amount of new energy, and set the target for the period between FY2011 and FY2014. In the revision, final target for FY2014 was set based on the former target of 12,2 billion kWh by FY2010 as a benchmark, by increasing 950 million kWh every year, to reach the ultimate goal of 16 billion kWh. The revision adopted a special preferred measure to double-count the RPS equivalent volume for PV power generation in order to improve the system management of the RPS Law. It is expected this measure would be a new tailwind for the dissemination of PV Systems. Moreover, the government proposed a long-term target of counter-measures against global warming; cutting global greenhouse gas (GHG) emissions by half from the current level by 2050, announced "Cool Earth 50 - Energy Innovative Technology Plan" to achieve the target and selected 20 research topics to be promoted as priorities. "Innovative PV Technology" was selected as one of the research topics aiming to improve conversion efficiency of solar cells from current 10 - 15 % to over 40 % and reduce power generation cost of solar cells from current 46 Yen/kWh to 7 Yen/kWh. The efforts for "innovative PV technology" will start from FY2008.

Meanwhile, it is assumed that the PV manufacturers will enhance their efforts for full-scale dissemination of PV Systems by working on 1) further cost reduction of the PV system, 2) detailed product development suitable for each application area, and 3) development of new application area, through technological development, enhancement of production capacity and collaboration with other industries using PV Systems.

Thus, in addition to these efforts by the national government and industry, and with support from users of PV Systems, including other ministries, agencies, local authorities, private companies and individuals, further deployment of PV Systems in Japan will continue into the future.