International Energy Agency

CO-OPERATIVE PROGRAM ON PHOTOVOLTAIC POWER SYSTEMS

Task 1

Exchange and dissemination of information on PV power systems

National Survey Report of PV Power Applications in Japan

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i Foreword

The International Energy Agency (IEA), founded in November 1974, is an autonomous body within the framework of the Organization for Economic Co-operation and Development (OECD) which carries out a comprehensive programme of energy co-operation among its 23 member countries. The European Commission also participates in the work of the Agency.

The IEA Photovoltaic Power Systems Programme (IEA-PVPS) is one of the collaborative R & D agreements established within the IEA and, since 1993, its participants have been conducting a variety of joint projects in the applications of photovoltaic conversion of solar energy into electricity.

The twenty participating countries are Australia (AUS), Austria (AUT), Canada (CAN), Denmark (DNK), Finland (FIN), France (FRA), Germany (DEU), Israel (ISR), Italy (ITA), Japan (JPN), Korea (KOR), Mexico (MEX), the Netherlands (NLD), Norway (NOR), Portugal (PRT), Spain (ESP), Sweden (SWE), Switzerland (CHE), the United Kingdom (GBR) and the United States of America (USA). The European Commission is also a member.

The overall programme is headed by an Executive Committee composed of one representative from each participating country, while the management of individual Tasks (research projects / activity areas) is the responsibility of Operating Agents. Information about the active and completed tasks can be found on the IEA-PVPS website www.iea-pvps.org.

ii Introduction

The objective of Task 1 of the IEA Photovoltaic Power Systems Programme is to facilitate the exchange and dissemination of information on the technical, economic, environmental and social aspects of photovoltaic power systems. An important deliverable of Task 1 is the annual International Survey Report on PV power applications. This report gives information on trends in PV power applications in the twenty member countries and is based on the information provided in the National Survey Reports which are produced annually by each Task 1 participant. The public PVPS website also plays an important role in disseminating information arising from the programme, including national information. These guidelines are intended to assist national experts and other participants of Task 1 in the preparation of their annual PVPS National Survey Reports.

As the International Survey Report is based on the National Survey Reports it is important that experts follow these guidelines when preparing their national reports. The International Survey Report is an external publication of the IEA-PVPS Implementing Agreement so it must not contain confidential information. Similarly, the National Survey Reports are now presented on the public PVPS website and Task 1 participants should make their own arrangements with their sources on how to treat confidential information (e.g. by ensuring anonymity of the data).

National Survey Reports should be produced by the end of May to enable the International Survey Report to be published by the end of August.

When preparing their national reports, experts must ensure that all the data are as accurate and correct as possible and follow the definitions given in these guidelines. All sections must be completed as comprehensively as possible.

iii Definitions, symbols and abbreviations

For the purposes of the National Survey Reports, the following definitions apply:

PV power system market: The market for all nationally installed (terrestrial) PV applications with a PV power capacity of 40 W or more.

Installed PV power: Power delivered by a PV module or a PV array under standard test conditions (STC) – irradiance of 1 000 W/m^2, cell junction temperature of 25^{o}C, AM 1,5 solar spectrum – (also see 'Rated power').

Rated power: Amount of power produced by a PV module or array under STC, written as W.

PV system: Set of interconnected elements such as PV modules, inverters that convert d.c. current of the modules into a.c. current, storage batteries and all installation and control components with a PV power capacity of 40 W or more.

Module manufacturer: An organization carrying out the encapsulation in the process of the production of PV modules.

Off-grid domestic PV power system: System installed in households and villages that are not connected to the utility grid. Usually a means to store electricity is used (most commonly lead-acid batteries). Also referred to as 'stand-alone PV power system'.

Off-grid non-domestic PV power system: System used for a variety of applications such as water pumping, remote communications, telecommunication relays, safety and protection devices, etc. that are not connected to the utility grid. Usually a means to store electricity is used. Also referred to as 'stand-alone PV power system'.

Grid-connected distributed PV power system: System installed on consumers' premises usually on the demand side of the electricity meter. This includes grid-connected domestic PV systems and other grid-connected PV systems on commercial buildings, motorway sound barriers. etc. These may be used for support of the utility distribution grid.

Grid-connected centralized PV power system: Power production system performing the function of a centralized power station.

Turnkey price: Price of an installed PV system excluding VAT/TVA/sales taxes, operation and maintenance costs but including installation costs. For an off-grid PV system, the prices associated with storage battery maintenance/replacement are excluded. If additional costs are incurred for reasons not directly related to the PV system, these should be excluded. (E.g. If extra costs are incurred fitting PV modules to a factory roof because special precautions are required to avoid disrupting production, these extra costs should not be included. Equally the

additional transport costs of installing a telecommunication system in a remote area are excluded).

Field Test Programme: A programme to test the performance of PV systems/components in real conditions.

Demonstration Programme: A programme to demonstrate the operation of PV systems and their application to potential users/owners.

Market deployment initiative: Initiatives to encourage the market deployment of PV through the use of market instruments such as green pricing, rate based incentives etc. These may be implemented by government, the finance industry, utilities etc.

NC: National Currency

Final annual yield: Total PV energy delivered to the load during the year per kW of power installed.

Performance ratio: Ratio of the final annual (monthly, daily) yield to the reference annual (monthly, daily) yield, where the reference annual (monthly, daily) yield is the theoretical annual (monthly, daily) available energy per kW of installed PV power.

National Survey Report of PV Power Applications in Japan

1 Executive summary

In 2003, there are the following activities regarding introduction and promotion of photovoltaic power (PV) systems.

1) The Ministry of Economy, Trade and Industry (METI) enforced the Law Concerning the Use of New Energy by Electric Utilities (Renewables Portfolio Standard (RPS) Law) as a new policy to promote and deploy new and renewable energy.
2) Application number of “Residential PV System Dissemination Program” reached 50 000 level and installation of total 200 MW of PV systems are expected.
3) Local governments that support dissemination of residential PV system have increased.
4) “Field Test Projects on Advanced Photovoltaic Power Generation Technology” was started as a succeeding program of “PV Field Test Program for Industrial Use”,.
5) In addition to “Demonstrative Research on Clustered PV systems” in which PV systems are to be installed in 600 residences in a selected area, “Demonstrative Research into Regionally Combined New Energies” was started.
6) Solar cell and PV module manufacturers significantly increased their production capacity to correspond growing demand of solar cells and PV modules 2 years in a row.
7) Electric utilities extended introduction of PV systems through “Green Power Fund”.

Installed PV power

PV market in Japan, especially installed capacity for grid-connected PV systems, continues to increase satisfactorily in 2003. The total installed capacity in 2003 reached to 222 781 kW, 21% increase from 2002 (184 029 kW). The breakdown of installed PV systems in 2003 is 146 kW for off-grid domestic application, 6 100 kW for off-grid non-domestic application, and 216 535 kW for grid-connected distributed application, especially for residential sector. No grid-connected centralized application was installed. A primary factor of this increase was that the application number of “Residential PV System Dissemination Program” grown to the scale of 50 000.

Costs & prices

The prices of solar cells, PV modules and PV systems are steadily decreasing owing to Government’s financial support policies on research and development (R&D) and dissemination measures for PV systems and expansion of production capacity by PV manufacturers. Average prices of PV modules for residential PV system decreased to 446 JPY/W in 2003 by about 4% from 463 JPY/W in 2002. In addition, typical prices of PV systems decrease to about 800 JPY/W in 2003 from 840 JPY/W in 2002 (about 5% decrease) for PV systems with more than 10 kW capacity for public and industrial facilities use, and to 680 JPY/W in 2003 from 710 JPY/W in 2003 (about 6% decrease) for 3-5 kW PV systems for residential use.

PV production

2003 production volume of solar cells and PV modules in Japan increased substantially for 7 consecutive years, and recorded 366,9 MW. The production volume of solar cells and PV modules in 2002 was 253,6 MW. Japan has been the largest PV production country in the world since 1999, overtaking USA, and the share of Japan in the worldwide PV production exceeded 40%.

The breakdown of production volume was as follows: 85,6 MW of single crystalline silicon (sc-Si) solar cells, 261,4 MW of multicrystalline (mc-Si) solar cells, 19,8 MW of amorphous silicon (a-Si) solar cells, and 0,0 MW of other solar cells. The market share of crystalline Si solar cells is approximately 95%. mc-Si solar cells have been overwhelmingly dominating the solar cell market in Japan for last 9 years and kept the status with the growth of the solar cell market in Japan. Crystalline Si solar cells have been significantly growing in quantity, with the backing of growth of the PV market for electric power use owing to the Government's "Residential PV System Dissemination Program", "Field Test Projects on Advanced Photovoltaic Power Generation Technology" and "Project for Promoting the Local Introduction of New Energy", introduction of PV systems by electric utilities through "Green Power Fund" and demand of general industrial applications such as traffic signs, telecommunication equipment, as well as expansion of export. a-Si solar cells began to be used for electric power application on a larger scale.

Budgets of PV

2003 national budgets for photovoltaics of the Ministry of Economy, Trade and Industry (METI) totaled 24 050 MJPY (35 100 MJPY in 2002), of which was 7 420 MJPY (7 300 MJPY in 2002) for R&D, 3 760 MJPY (4 600 MJPY in 2002) for demonstration/ field test programs, and 10 500 MJPY (23 200 MJPY in 2002) for market incentives. METI reviewed the status of the initial market of PV system and decreased 2003 budget for market incentives by almost half. Thus, total budgets for PV market incentives, R&D and demonstration/ field test programs were significantly decreased compared to 2002 budgets. The budgets for major 2003 national programs of METI are as follows;

1) Research and development of photovoltaic power generation technologies: 7 420 MJPY
2) Residential PV System Dissemination Program: 10 500 MJPY
3) PV Field Test Program for Industrial Use: 260 MJPY
4) Field Test Projects on Advanced Photovoltaic Power Generation Technology (New): 3 500 MJPY
5) Demonstrative Research on Clustered PV Systems: 2 370 MJPY
6) Project for Supporting New Energy Operators: 38 820 MJPY
7) Project for Promoting the Local Introduction of New Energy: 12 710 MJPY
8) Project for Promotion of Non-profit Activities on New Energy and Energy Conservation: 1 140 MJPY
9) Project for Establishing New Energy Visions at the Local Level: 1 320 MJPY
10) Project for Supporting Regional Activities for Prevention of Global Warming: 590 MJPY

The budgets for 6), 7), 8), 9) and 10) include ones for PV and other new energies.

In addition to METI, the Ministry of Land, Infrastructure and Transport (MLIT), the Ministry of Education, Culture, Sports, Science and Technology (MEXT), the Ministry of the Environment, Defense Facilities Administration Agency (DFAA), and Postal Service Agency (Current Japan Post) are promoting introduction of PV systems, but the detailed budgets are not published.

Many local governments and municipalities have implemented their own subsidy programs that can be added to the Government's subsidy, but their budgets are unknown.

2 The Implementation of PV systems

2.1 Applications for photovoltaics

PV systems installed in 2003 have been increasing for the second year running by introduction of PV systems to individual houses, public facilities, industrial facilities and commercial buildings by financial support programs of METI. Especially, residential PV systems, mainly in range of 3-5 kW per house, have increased to a scale of more than 50 000 systems par annum. As new trends in residential PV systems, introduction of PV systems in public housings by local governments, concentrative mass introduction of PV systems in newly developed residential areas by housing developers and introduction of PV systems in collective housings also started. In 2003, the demand for residential PV systems accounts for more than 80% of total in Japan. PV systems for public facilities, accounts for about 4%, steadily installed year after year. 10-50 kW PV systems have been installed mainly to kindergartens, schools, governmental offices, hospitals, welfare facilities, libraries, parks, public halls and water treatment plants. Furthermore, 10-500 kW PV systems for industrial use have been installed to rooftops and roofs of factories, warehouses, laboratories and so on. 10-100 kW PV systems for commercial buildings have been installed to rooftops, roofs and exterior walls of headquarters, business offices and branch offices. Introduction of PV systems into service stations and railroad facilities has started. Installation of PV systems for industrial buildings, commercial buildings and other industrial facilities accounts for about 3% in total. For newly constructed buildings, building integrated PV systems, have been applied to roofs, rooftops, exterior walls, canopies, louvers and so on. Besides, off-grid non-domestic PV systems without governmental support are utilized as power sources for telecommunication, traffic sign, remote monitoring, ventilating fan, lighting and the like.

2.2 Total photovoltaic power installed

Table 1 shows cumulative installed capacity of PV system by application. In 2003, total installed capacity reached 859 623 kW. Installed capacity for each application is as follows: 1 101 kW for off-grid domestic, 77 792 kW for off-grid non-domestic, 777 830 kW for grid-connected distributed, 2 900 for grid-connected centralized.

Thus, grid-connected distributed PV application leads the PV market in Japan. As for off-grid domestic market, there are PV applications for mountain cottages, remote area, islands and certain applications for public and industrial uses, but the market scale is small. Main PV applications in the off-grid non-domestic market

include power supplies for streetlight, telecommunication, remote monitoring, pumping, emergency measure for disaster, agriculture, traffic sign, ventilating fan and the like. The off-grid non-domestic market has already been established as a commercial market in Japan. As for grid-connected centralized application, PV systems for demonstration have been installed so far, but no grid-connected centralized PV systems have been installed since 1995. Grid-connected distributed market has remarkably expanded year after year mainly because PV system installations to private houses, apartment houses, public and industrial facilities and commercial buildings have been increased with the financial support of METI, and other ministries, government offices and local governments which have been taking the lead in installing PV systems to their own facilities. The development of PV market has been based on 3-5 kW residential PV systems and 10-100 kW scale PV systems for public facilities, industrial facilities and commercial buildings. The activities for introduction of PV systems by supply side have been spreading to housing manufacturers, battery manufacturers, building material manufactures and construction companies from PV manufacturers. As a result, the user-oriented PV market in Japan has been developed and activated. The users have been fostering better understanding of PV systems year after year, and this trend is spreading among individuals, large companies, small and medium-sized enterprises (SMEs), retailers and non-governmental organizations (NGOs).

Table 1 The cumulative installed PV power in 4 sub-markets.

Sub-market/ application	31 Dec. 1992 kW	31 Dec. 1993 kW	31 Dec. 1994 kW	31 Dec. 1995 kW	31 Dec. 1996 kW	31 Dec. 1997 kW	31 Dec. 1998 kW	31 Dec. 1999 kW	31 Dec. 2000 kW	31 Dec. 2001 kW	31 Dec. 2002 kW	**31 Dec. 2003 kW**
Off-grid domestic	150	200	250	300	350	400	450	500	550	600	955	**1 101**
Off-grid non-domestic	15 260	19 170	23 260	29 360	35 890	44 900	52 300	56 200	63 000	66 227	71 692	**77 792**
Grid-connected distributed	1 220	2 300	5 130	10 820	20 500	43 100	77 750	149 000	263 770	383 086	561 295	**777 830**
Grid-connected centralized	2 370	2 600	2 600	2 900	2 900	2 900	2 900	2 900	2 900	2 900	2 900	**2 900**
Total	19 000	24 270	31 240	43 380	59 640	91 300	133 400	208 600	330 220	452 813	636 842	**859 623**

2.3 Major projects, demonstration and field test programs

Main demonstration programs implemented in 2003 were “Residential PV System Dissemination Program”, ”PV Field Test Project for Industrial Use”, “Field Test Projects on Advanced Photovoltaic Power Generation Technology”, “Project for Promoting the Local Introduction of New Energy”, “Project for Supporting New Energy Operators”, “Project for Promotion of Non-profit Activities on New Energy and Energy Conservation”, “Project for Supporting Regional Activities for Prevention of Global Warming” and “Eco-School Promotion Pilot Model Project” (See also Table 1 in Annex B).

(1) Residential PV System Dissemination Program

“Residential PV System Dissemination Program” started on April 1997 as a succeeding program of “Residential PV System Monitor Program” to enlarge the scale of dissemination of PV systems.

“Residential PV System Dissemination Program” aims to subsidize the PV installation cost for individuals on the condition that they provide the operation data of their PV systems. The subsidy has three categories: 1) an individual who is going to install PV systems to one’s own house, 2) a housing supplier of housing development complex or a supplier of houses built for sale and 3) a local public organization who is going to introduce PV systems to public houses. Less than 10 kW PV systems with reverse power flow, connected to low voltage grid are eligible for subsidization. Subsidy per 1 kW in 2003 was 90 000 JPY.

In 2003, application number surpassed 50 000 for the first time, and 52 863 applications corresponding to 201,4 MW of residential PV systems were accepted. Residential PV systems have been installed to 115 765 houses and cumulative installed capacity reached 421,4 MW at the end of 2002. In 2002, 38,262 applications were accepted, and total 141,4 MW of residential PV systems were installed. Residential PV systems were installed to 25 151 houses (91,0 MW) in 2001, 20 877 houses (74,4 MW) in 2000; 15 879 houses (57,7 MW) in 1999; 6 352 houses (24,1 MW) in 1998; to 5 654 houses (19,5 MW) in 1997; to 1 986 houses (7,5 MW) in 1996; to 1 065 houses (3,9 MW) in 1995 and to 539 houses (1,9 MW) in 1994.

(2) PV Field Test Project for Industrial Use

This program started in 1998. The aim is; 1) to install trial PV systems using new technologies effective to introduce to industrial sector, such as industrial facilities, 2) to demonstrate availability for introduction of PV systems by collecting data and analyzing a long-term operation under demonstration test and 3) further standardization and diversified introduction applications toward full scale deployment of PV systems. Eligible recipients for subsidy are private company, local public organizations and other organizations, which are going to install modular type PV systems and novel application of PV systems. Half of PV installation cost is subsidized.

PV systems, mainly 10-100 kW PV systems, have been installed to schools, welfare facilities, manufacturing plants, warehouse, office buildings, private facilities, and so on.

Installation of PV systems was finished in 2002 and collection and analysis of the data have been conducted since 2003.

In 2002, 207 systems, 4 800 kW in total were installed. The breakdown of installations in 2002 was 184 systems, 4 200 kW for modular type and 23 systems, 600 kW for novel application type. 218 PV systems, 4 890 kW were installed in 2001, 149 systems, 3 680 kW in 2000, 93 PV systems, 2 790 kW in 1999, 73 PV systems, 1 940 kW in 1998. Cumulative installed number of PV systems was 740, 18 100 kW in total at the end of 2002.

(3) Field Test Projects on Advanced Photovoltaic Power Generation Technology
This field test program started in 2003, aiming at adopting new technologies into PV systems for public and industrial facilities and accelerating further development. The object of the program is to promote introduction of middle scale PV systems with output capacity of 10 kW and over, improve the performance, and reduce the cost. Under the program, four technologies are defined as follows: 1) PV system with new type modules (Next generation PV modules with solar cells using new materials and new type PV modules with improved functions); 2) PV system with building material integrated (BIPV) modules (New type BIPV modules such as roof-integrated, wall-integrated PV module, etc.); 3) PV system with new control system (designed to improve generation performance and raise added values by modification and addition of functions to the conventional generation system) and 4) PV system aiming at higher efficiency (PV system with higher system efficiency by improving components, design and installation method).

Eligible applicants for the projects are private businesses, local authorities and organizations. 50% of the installation cost is subsidized.

In 2003, total 148 projects accounting for 4 480 KW were selected. The number of project by each type of technology is: 1 for new type modules (10 kW), 14 for building material integrated modules (370 kW in total), 3 for new control system (60 kW in total) and 148 for higher efficiency (4 040 kW in total). As for generation capacity, more than half of the PV systems (79) were 10 kW scale. Number of PV systems with 100 kW and over were 10, totaling 1 790 kW. The largest PV system was a 500-kW PV system aiming at higher efficiency installed at a factory. Average capacity of 148 projects was about 30 kW.

(4) Project for Promoting the Local Introduction of New Energy
This project, started in 1997, aims at accelerating new energy introduction by supporting the regional projects established by local governments for introduction of new energy. Local governments and municipalities using this program have been increasing year by year.

Eligible applicants are local public organizations who are going to introduce and promote new energy: PV power generation, wind power generation, use of solar thermal energy, differential temperature energy, natural gas co-generation, fuel cells, wastes generation, use of waste thermal energy, production of wastes fuel and clean energy vehicles. The recipient of subsidy under this program is allowed to install the system within 4 years, so that new energy can be introduced in multi-fiscal years. PV systems with 50 kW output and over are subsidized. In addition, PV system with 10 kW output and over for “Eco-School Promotion Pilot Model Project” described in (8) of this section are also subsidized. Up to half or one third of system installation cost is

subsidized for the project of new energy introduction, depending upon cases, and fixed amount (up to 20 MJPY) is subsidized to the projects for enlightenment and introduction activities.

In 2003, 101 systems including 70 PV systems (8 311 kW) were qualified. In 2002, 66 systems in total were subsidized and 26 PV systems (2 617 kW) out of them were installed. In 2001, 15 PV systems (3 206 kW in total) out of 37 systems were subsidized. In 2000, 14 PV systems (2 118 kW in total) out of 28 qualified systems were installed in city halls and water treatment plants, primary schools and so on. The accumulated capacity of PV system installed and to be installed from 1998 to 2006 will be 18 306 kW, 148 PV systems in total.

(5) Project for Supporting New Energy Operators
This project started from 1997 aims at accelerating new energy introduction by supporting the industrialists who launch introduction of new energy, such as PV, wind power, solar thermal energy, differential temperature energy, natural gas co-generation, fuel cells, wastes generation, use of waste thermal, production of wastes fuel, from a viewpoint of energy security and global environmental protection.

Eligibles for the guaranteed debt or the subsidy are private businesses who set about new energy introduction. A third of system installation cost is subsidized and the guaranteed debt is 90% of a debt.

In 2003, 39 systems including 2 PV systems were qualified and total capacity of PV systems was 217 kW. In 2002, PV system was 1 out of 25 qualified systems and its capacity was 25 kW. In 2001, a 140 kW PV system out of 34 qualified systems was subsidized. In 2000, 26 systems were qualified, but there was no PV system. In 1999, a 100 kW PV system out of 32 systems and in 1998, a 116 kW PV system out of 18 systems were qualified. PV systems introduced under this project are mainly installed to factories.

(6) Project for Supporting Regional Activities for Prevention of Global Warming
The program was established in 2001 aiming at supporting the activity of prevention against global warning initiated by local institutions. The targeted sectors are local governments, local communities, environmental NPOs and so on, and are provided the subsidy of less than half or one third of facility installation cost for power generation, utilization of heat and energy efficiency, depending on cases.

In 2003, 15 PV systems were qualified out of 38 projects conducted in 17 areas. In 2002, PV systems were qualified in 12 out of 34 projects in 14 areas. In 2001, PV systems were qualified for 14 out of 34 projects in 15 areas.

(7) Project for Promotion of Non-profit Activities on New Energy and Energy Conservation
This project was newly established in 2000. It aims at promoting new energy introduction by supporting projects conducted by NGOs, and the like for third parties, who introduce new energy facility. The amount of the subsidy is half of the eligible cost.

In 2003, 129 PV systems totaling 1 346 kW were qualified. In 2002, 82 PV systems, 776 kW in total were qualified. In 2001, 25 PV systems, 211 kW in total were qualified. PV systems introduced under this project were mainly installed in kindergartens,

nurseries and religious facilities such as temples and shrines. Installations of PV systems by this project have been increasing year after year.

(8) Eco-school Promotion Pilot Model Project
This project initiated in 1997 with the partnership of METI and Ministry of Education, Culture, Sports, Science and Technology (MEXT). The project aims at implementing pilot model projects to demonstrate and promote environmental-friendly schools, providing students with environmental education and improving school facilities.

Eligible projects are for (a) new energy utilization, including PV, solar thermal, wind power, geothermal and fuel cells, (b) energy conservation, (c) symbiosis with nature and (d) utilization of wood building materials.

The MEXT provides the subsidy of fixed cost for investigation of fundamental planning, the subsidy of a half of cost for new construction of the school and one third of cost for rebuilding or retrofitting. METI's subsidies described above are available for PV system installation in new construction and renovation of schools.

PV systems were installed to 68 schools (525 kW) in 2003. 49 schools (741 kW) in 2002, 38 schools (620 kW) in 2001, and 36 schools (790 kW) in 2000, 16 schools (370 kW) in 1999, 11 schools (350 kW) in 1998, and 13 schools (450 kW) in 1997.

2.4 Highlights of R&D

2003 was the 3rd year of the new 5-year plan on technical R&D for photovoltaic power systems, which was initiated in 2001. The R&D area of the new 5-year plan are categorized the following four areas: 1) Advanced Solar Cell Technologies, 2) PV System Technology for Mass Deployment, 3) Innovative PV Technology and 4) Development of Advanced Manufacturing Technology of PV systems.

R&D on Advanced Solar Cell Technologies aims at “establishing the technologies that can secure lower PV generation cost level than the electricity charge for household” by 2005 and developing manufacturing technologies of thin film solar cells and the like that can be expected further cost reduction. Specific R&D topics include 1) development of manufacturing technologies for thin film c-Si modules (improvement of the quality by VHF plasma CVD, development of light-trapping structure for hybrid cells), 2) development of manufacturing technologies for thin film CIS cells (improvement of the quality by selenization, improvement of yield by vapor deposition), 3) development of manufacturing technologies for super-high efficiency crystalline compound cells (GaAs cells with 40% of conversion efficiency, development of solar concentrator modules), and 4) R&D of processing technology of high efficiency crystalline silicon solar cells (improvement of the quality of silicon ingot, super-thin slicing of silicon ingot, improvement of efficiency (20%) in mc-Si solar cell.

R&D on PV System Technology for Mass Deployment focus on evaluation techniques of performance, reliability, durability and safety of solar cells, modules and PV systems in consideration of full-scale PV introduction, and R&D on effective use of limited resources and reduction of environmental burdens. Specific R&D topics include 1) evaluation technologies of solar cells, 2) evaluation technologies of PV system, 3) processing technologies of reusing and recycling of PV systems, and 4) research on electromagnetic immunity (EMI) of PV systems.

R&D on Innovative PV Technology is conducted in order to put innovative technologies into practice, which are expected to realize substantial cost reduction with new materials, new structures and new processing technology based on innovative concepts aiming at mass deployment of PV systems after 2010. Specific R&D topics are as follows: 1) new materials for solar cells (mc-SiGe, $FeSi_2$, carbon-based thin-film, organic thin solid film, and chalcogenides, III-V-Nitrides semiconductor material), 2) solar cells with new structure (nanostructure Si (amorphous Si + crystalline Si), spherical micro silicon solar cell, high light-trapping thin-film silicon, wide bandgap microcrystalline SiC, dye-sensitized cells with higher performance, thin-film Si solar cell using glass fiber substrate), and 3) New process (thin-film Si Cat-CVD deposition, thin-film CIS plating deposition, thin-film Si prepared by lateral-crystallization).

Development of Advanced Manufacturing Technology of PV Systems is aiming at applying the established PV system manufacturing technology at 250 JPY/W into mass production within a few years. Earlier realization of mass production and cost reduction is expected. Specific R&D topics are as follows: 1) mass production of mc-Si substrate (wafer), 2) production of low-cost silicon feedstock for solar cells and 3) production of a-Si solar cells on plastic film.

In addition, demonstrative research on clustered PV systems (600 PV systems in total) was started as a new R&D topic in 2002. The power system in a district where PV systems are clustered tends to induce over-voltage and give influence on the grid, which have possibility to be obstacles for mass dissemination of PV systems. Thus, this research is programmed to develop technologies to resolve these problems. The research is aiming at demonstrating a general power system, where PV systems are intensively grid-connected. The specific research topics are 1) development of technology to avoid restriction of PV system output, 2) analyses and evaluation of higher harmonics, 3) analyses of mis-actuation of function to prevent islanding operation and 4) development of applied simulations.

2.5 Public budgets for market stimulation, demonstration/field test programs and R&D

The 2003 budgets for PV systems are mainly based on the national budgets on R&D, demonstration programs and market incentives. The budget for R&D was allocated to "Technology Development of PV Systems", "PV system technology for Mass Deployment", "Advanced Manufacturing Technology", "Demonstrative Research on Clustered PV system", etc. The budget for demonstration and filed test was allocated for "Field Test Project on Advanced Photovoltaic Power Generation Technology" and "PV Field Test Project for Industrial Use (new installation of the system was completed in 2002)". The budget for market initiatives is put emphasis on "Residential PV system Dissemination Program". Moreover, PV systems can be installed using the budgets of Introduction and "Project for Promoting the Local Introduction of New Energy" and "Project for Supporting New Energy Operators". However, as these budgets include other new energies, they are not included in Table 2. Also the budget for "International Joint Cooperative Demonstration Projects of PV Power Generation System" (1 900 MJPY) and the budget for PV system introduction by other ministries and government offices except METI are not included in Table 2. The budgets by local governments are complementarily appropriated for market incentives. The number of local governments having complementary budgets is increasing year by year and reached 262 in 2003. The amount of subsidy varies by municipalities (e.g. 50 000 Yen/kW, 75 000 Yen/kW, etc.), and details are unknown.

Table 2 Public budgets (in National Currency) for R&D, demonstration/ field test programmes and market incentives.

	2001			2002			2003		
	R&D	Demo/ Field Test	Market	R&D	Demo/ Field Test	Market	R&D	Demo/ Field Test	Market
National[1] (MJPY)	6 360	2 060	23 510	7 400	4 500	23 200	9 790	3 760	10 500
Regional (MJPY)	-	-		-[2]	-	-[2]	-	-	-[2]
Total	6 360	2 060	23 510	7 400	4 500	23 200	9 790	3 760	10 500

[1]:The figures in Table 2 shows METI's budget. The budgets of other ministries and government offices except METI are unknown.

[2]: 262 municipalities are implementing additional subsidy program on residential PV systems, but the budget are unknown.

3 Industry and growth

3.1 Production of silicon feedstock, ingot and wafer for solar cells

Table 3 shows the production volume and production capacity of manufacturers of silicon feedstock, ingot and wafer for solar cells in Japan. Tokuyama is the only manufacturer for silicon feedstock. Mitsubishi Sumitomo Silicon (SUMCO) and M.Setec are manufacturing Si wafers for solar cells. Kawasaki Steel started commercial production of silicon ingots for solar cell from 2001. Metal Reclaim started to manufacture sc-Si wafer from 2003. Besides these producers, Kyocera manufactures Si ingot and wafers for in-house use. With demand expansion of solar cells since 2000, companies newly started to manufacture Si ingots and wafers for solar cells have been increasing.

Table 3a shows the process of each manufacturer. Technical data of typical silicon product for solar cells are described in Table 3b. Table 3c shows the new developments and products in 2003. Table 3d shows the expansion plan.

Table 3 Production and production capacity information for silicon feedstock, ingot and wafer manufacturers (2003).

Manufacturer	Process & technology [1]	Total Production (t or MW)	Maximum production capacity (t/yr or MW/yr)	Product destination
M.Setec	sc-Si ingot (CZ process [2])	565 t	620 t/yr	N.A.
	sc-Si wafer	60 MW	65 MW/yr	N.A.
JFE Steel	Cast mc-Si ingot (Directional solidification process)	350 t	400 t/yr	N.A.
Sumitomo Mitsubishi Silicon (SUMCO) [5]	mc-Si ingot (EMC process [3])	300 t	300 t/yr	N.A.
	mc-Si wafer	25 MW	25 MW/yr	N.A.
Metal Reclaim	sc-Si wafer (CZ process [2])	20 MW	20 MW/yr	N.A.
Tokuyama	Silicon feedstock for solar cell (CVD process [4])	About 1 000 t	About 1 000 t/yr	N.A.
Kyocera	mc-Si wafer	72 MW	76 MW/yr	In-house use

[1]: mc: multicrystalline, sc: single crystalline

[2]: Czochralski process

[3]: Electro magnetic casting process

[4]: Chemical Vapor Deposition process

[5]: The product is manufacturing by SUMCO Solar (affiliated company of Sumitomo Mitsubishi)

Table 3a Process and technology for feedstock, ingot and wafer manufacturers (2003).

Manufacturer	Process & technology
M.Setec	- Si feedstock (purchased from the outside) → sc-Si ingot (CZ process)→ sc-Si wafer
JFE Steel	- Polysilicon (purchased from the outside) → cast mc-Si ingot (directional solidification process) → mc-Si wafer [1]
Sumitomo Mitsubishi Silicon (SUMCO)	- Si feedstock (purchased from the outside)→ mc-Si ingot (Electromagnet casting) → mc-Si wafer
Metal Reclaim	- sc-Si ingot (CZ process, purchased from the outside)→sc-Si wafer
Tokuyama	- Metal grade silicon (imported) → $SiHCl_3$ → Polysilicon (Precipitation by CVD process)
Kyocera	- Si feedstock (purchased from the outside) → mc-Si ingot → mc-Si wafer

[1]: A part of production

Table 3b Specification of the products for feedstock, ingot and wafer Manufacturers (2003).

Manufacturer	Product	Specification
M.Setec	sc-Si wafer (P-type)	125 mm x 125 mm, 0.5-12 Ùcm, 220-400 ìm
	sc-Si wafer (N-type)	104 mm x 104 mm
	sc-Si wafer (N-type)	125 mm x 125 mm
JFE Steel	mc-Si ingot	16 blocks from 690 mm x 690 mm x 230 mm h
		25 blocks from 690 mm x 690 mm x 230 mm h
Sumitomo Mitsubishi Silicon (SUMCO)	mc-Si wafer (P-type)	150 mm x 150 mm, 0,5-2,0 Ùcm, 300 ìm
		155 mm x 155 mm, 0,5-2,0 Ùcm, 270 ìm
		155 mm x 155 mm, 0,5-2,0 Ùcm, 240 ìm
Metal Reclaim	sc-Si wafer (P-type)	126 mm x 126 mm, 3-6 Ùcm, 270 ìm
		126 mm x 126 mm, 3-6 Ùcm, 220 ìm
	sc-Si wafer (N-type)	104 mm x 104 mm, 0,5-3 Ùcm, 265 ìm
		104 mm x 104 mm, 0,5-3 Ùcm, 295 ìm
Tokuyama	Silicon feedstock for solar cell	N.A.

Table 3c New products or new development of silicon feedstock, ingot and wafer manufacturers (2003).

Manufacturer	New product/ new development
M.Setec	- sc-Si wafer (125 mm x 125 mm) from 165 mm ö ingot
JFE Steel	- Nothing to report
Sumitomo Mitsubishi Silicon (SUMCO)	- mc-Si wafer (P-type, 155 mm x 155 mm, 0,5-2,0 Ùcm, 240 ìm)
Metal Reclaim	- sc-Si wafer (P-type, 126 mm x 126 mm, 3-6 Ùcm, 220 ìm)
Tokuyama	- Finished the basic research of Vapor to Liquid Deposition (VLD) process

Table 3d Plans for expansion for silicon feedstock, ingot and wafer manufacturers.

Manufacturer	Process & Technology	Production capacity in 2003 (t/yr or MW/yr)	Production capacity in 2004 (MW/yr)	Production capacity from 2005 onwards (MW/yr)
M.Setec	sc-Si ingot	620 t/yr	1 260 t/yr	1 848 t/yr
	sc-Si wafer	65 MW/yr	80 MW/yr	115 MW/yr (2005)
JFE Steel	Cast mc-Si ingot	400 t/yr	500 t/yr	600 t/yr
Sumitomo Mitsubishi Silicon (SUMCO)	mc-Si wafer	25 MW/yr	35 MW/yr	Under consideration
Metal Reclaim	sc-Si wafer	20 MW/yr	60 MW/yr	130 MW/yr (2005)
Tokuyama	Silicon feedstock for solar cell	1 000 t/yr	1 000 t/yr	New production technology will be examined in a demonstrative plant by 2006
Kyocera	mc-Si wafer	76 MW	120 MW	-

3.2 Production of photovoltaic cells and modules

Table 4 shows the outline of major PV cell and module manufacturers in Japan. In 2003, PV cell and module manufacturers are 9, i.e. Sharp, Kyocera, Sanyo Electric, Mitsubishi Electric, Kaneka, Canon, Matsushita Ecology Systems (former Matsushita Seiko), Mitsubishi Heavy Industries (MHI) and Hitachi. Hitachi completed the plant for bifacial silicon solar cell and started commercial production. As for module manufacturers, Showa Shell Sekiyu (Shell Solar Japan from January 1 of 2004) and MSK are manufacturing mass production modules for residential PV systems and PV systems for public and industrial facilities. In addition, Asahi Glass, Kobe Steel, and FujiPream newly entered the market as module manufacturers specialized in building-integrated PV modules.
Table 4a shows PV module production processes of the manufacturers in Japan. Table 4b shows technical data of typical modules for residential and power uses. Table 4c shows the present status of PV module certification of module manufacturers. Table 4d shows new developments and products of PV cell and module manufacturers in Japan. Table 4e shows plan for future expansion in module production capacity. Table 4f shows average prices of PV modules for residential PV system.

Table 4 Production and production capacity information for each module manufacturer (2003).

Cell/Module manufacturer	Technology [1]	Total Production (MW)		Maximum production capacity (MW)	
		Cell	Module	Cell	Module
Sharp	sc-Si	42,6	30,5	248	225
	mc-Si	155,2	149,1		
	a-Si	0,1	0,1	-	-
Kyocera	mc-Si	72	72	76	76
Sanyo Electric	a-Si/sc-Si	30	29	33	30
	a-Si	5	5	5,5	5,5
Mitsubishi Electric	mc-Si	42	42	50	50
Matsushita Ecology Systems	sc-Si	0,6	0,6	3	3
Hitachi	sc-Si	0,02	0,01	5	3,5
MSK	mc-Si		12		15
	sc-Si		40		50
	a-Si		3		5
Showa Shell Sekiyu	sc-Si		1,0 [2]		6,0 [3]
	CIS	(Experimental facility)	(Experimental facility)	(Experimental facility)	(Experimental facility)
Kobe Steel	mc-Si		0,4		2
Thin film manufacturers					
Kaneka	a-Si	13,5	13,5	20	20
Mitsubishi Heavy Industries	a-Si	4	4	10	10

Canon	a-Si/ìc-Si	0	0	10	10
Total		365,02	402,21	460,5	511

[1]: mc: multicrystalline, sc: single crystalline, a: amorphous, ìc: microcrystalline
[2]: including modules for consumer appliances
[3]: 3-shifts for PV modules for power generation

Table 4a PV module production processes of manufacturers (2003).

Cell/module manufacturer	Description of main steps in production process
Sharp	- Purchase of sc-Si wafer → sc-Si cells → Modules - Purchase of mc-Si wafer → mc-Si cells → Modules - Purchase of Si feedstock → mc-Si wafer → mc-Si Cells → Modules
Kyocera	- Purchase of Si scraps → mc-Si wafer → mc-Si cells → Modules
Sanyo Electric	- Purchase of feed stock → sc-Si wafer (import) → aSi/ sc-Si cells → Modules - Purchase of sc-Si wafer → a-Si/ sc-Si cells → Modules
Mitsubishi Electric	- Purchase of mc-Si wafer → mc-Si cells → Modules
Matsushita Ecology Systems	- Purchase of sc-Si wafer → sc-Si cells → Modules
Hitachi	- Purchase of sc-Si wafer → sc-Si cells → Modules
MSK	- Purchase of mc-Si, sc-Si and a-Si cells → Modules
Showa Shell Sekiyu	- Import of sc-Si cells → Modules
Kobe Steel	- Purchase of mc-Si cells → Modules
Thin film manufacturers	
Kaneka	- Purchase of SiH_4 gas & substrate (with TCO) → Thin-film a-Si cells → Modules
Mitsubishi Heavy Industries	- Purchase of SiH_4 → a-Si cells → Modules
Canon	- Purchase of stainless steel substrate & SiH_4 gas → a-Si/îc-Si cells → Modules

Table 4b PV modules for residential and power uses (2003) (1/2).

Module Manufacturer	Typical module data						Residen-tial use	Power use
	Cell technology	W x L x D (mm)	Weigh t (kg)	P_{max} (W)	V_{op} (V)	I_{op} (A)		
Sharp	sc-Si	1 200 x 802 x 55	14,0	167	41,24	4,05		-
	sc-Si	1 200 x 802 x 46	12,5	150	28,64	5,24		-
	sc-Si	1 200 x 802 x 46	12,5	132	26,80	4,93		-
	mc-Si	1 165 x 990 x 46	14,5	150	20,50	7,32		-
	mc-Si	1 200 x 802 x 46	12,5	132	26,78	4,93		-
	mc-Si	1 200 x 802 x 46	12,5	130	26,75	4,86		-
	mc-Si	802 x 945 x 46	100	9,9	20,30	4,93		-
	mc-Si	990 x 1 165 x46	146	14,5	20,42	7,15		-
	mc-Si	1 004 x 1 323 x 46	167	16,5	23,53	7,1	-	
	mc-Si	802 x 1 200 x 46	120	12,5	25,70	4,67	-	
	sc-Si	530 x 1 200 x 35	87	8,5	17,58	4,95	-	
	mc-Si	530 x 1 200 x 35	80	8,5	17,14	4,67	-	
	sc-Si	1 575 x 826 x 46	185	17,0	36,20	5,11	-	
	sc-Si	1 575 x 826 x 46	175	17,0	35,40	4,95	-	
	mc-Si	1 575 x 826 x 46	165	17,0	34,60	4,77	-	
	mc-Si	1 499 x 662 x 46	123	14,0	17,2	7,16	-	
	mc-Si	1 190 x 792 x 46	125	12,5	26,00	4,80	-	
Kyocera	mc-Si	1 290 x 990 x 56	16,0	167	23,2	7,20	-	
	mc-Si	1 290 x 990 x 36	15,0	158	23,2	6,82		-
	mc-Si	1 425 x 652 x 56	11,9	120	21,7	7,45		
	mc-Si	972 x 345 x 20	3,7	41	7,20	8,00		-
	mc-Si	1 296 x 345 x 20	4,8	55	9,60	8,00		-
Sanyo Electric	a-Si/sc-Si	1 319 x 894 x 35	14,0	190	54,8	3,47		
	a-Si/sc-Si	1 415 x 345 x 35	6,0	45	12,9	3,49		
Mitsubishi Electric	mc-Si	1 271 x 827 x 38	13,0	134	19,4	6,91		
	mc-Si	1 271 x 827 x 38	13,0	130	19,3	6,74		
	mc-Si	1 248 x 803 x 46	12,5	134	19,4	6,91		
	mc-Si	1 248 x 803 x 46	12,5	130	19,3	6,74		
	mc-Si	1 270 x 675 x 37	11,0	100	15,3	6,56		
	mc-Si	1 338 x 539 x 40	8,5	75	11,4	6,56		
Matsushita Ecology Systems	sc-Si	645 x 1 185 x 36	14	111	41	3,4	-	
Hitachi [1]	sc-Si	868 x 1 120 x 9	19	96 74	21,3 21,8	4,5 3,4	-	
MSK	sc-Si	802 x 1 580 x 50	18	180	35,6	5,05		
	sc-Si	802 x 1 195 x 50	14	135	26,7	5,05		
	mc-Si	802 x 1 580 x 50	18	160	34,5	4,64		
	a-Si	950 x 980 x 10,5	23	38	58,6	0,648	-	
Showa Shell Sekiyu	sc-Si	869 x 982 x 35	11	109	34,6	3,15		
	sc-Si	527 x 1 200 x 34	7,6	75	17,0	4,4		
	mc-Si	1 012 x 1 290 x 36	16,5	158	23,2	6,82		-

[1]: upper line: surface, under line: rear face

Table 4b PV modules for residential and power uses (2003) (2/2).

Module Manufacturer	Typical module data						Residen-tial use	Power use
	Cell technology	W x L x D (mm)	Weigh t (kg)	P_{max} (W)	V_{op} (V)	I_{op} (A)		
Kobe Steel	mc-Si	1 892 x 1 283 x 50	50	300	60	6,4		
	mc-Si	1 605 x 1 336 x 50	41	275	73,1	5,1		
	mc-Si	1 282 x 644 x 35	8,5	100	42,5	3,2		
	a-Si	1 000 x 600 x 22	14	27	49	1	-	
TF manufacturers								
Kaneka	a-Si	920 x 950 x 38	13,5	58	63	0,92		
Mitsubishi Heavy Industries	a-Si	1 110 x 1 410 x 35	21	100	108	0,93		

Table 4c Present status of certification of module manufacturers (2003).

Module manufacturer	Certification of modules	Certification of plant
Sharp	IEC 61215 UL 1703 TÜV Safety Class II	ISO 9001-2000 ISO 14001 UL 1703 TÜV Safety Class II
Kyocera	IEC 61215 (certified by TÜV) ISO 9000 UL 1703 TÜV Safety Class II	IEC 61215 (certified by TÜV) UL 1703
Sanyo Electric	IEC 61215 (a-Si/sc-Si) ISO 9000 (a-Si/sc-Si) UL 1703 (a-Si/sc-Si) TÜV Safety Class II (a-Si/sc-Si)	IEC 61215 (a-Si/sc-Si) ISO 9000 (a-Si/sc-Si) UL 1703 (a-Si/sc-Si) TÜV Safety Class II (a-Si/sc-Si)
Mitsubishi Electric	IEC 61215 UL 1703	ISO 9000
Matsushita Ecology Systems	-	ISO 9000
Hitachi	(IEC 61215: to be certified in 2004)	(IEC 61215: to be certified in 2004)
MSK	IEC 61215(sc-Si and mc-Si)	ISO 9000
Showa Shell Sekiyu	UL 1703 (sc-Si : to Autumn of 2003) JET-PV (under assessment)	JET-PV (sc-Si : under assessment)
Kobe Steel	ISO 9000 (mc-Si)	ISO 9000 (mc-Si)
Thin film manufacturers		
Kaneka	IEC 61646 (a-Si) UL 1703(a-Si)	IEC 61646 (a-Si) UL 1703 (a-Si)
Mitsubishi Heavy Industries	IEC 61646 ISO 9000	IEC61646 ISO 9000
Canon	-	-

Table 4d New developments and new products of manufacturers (2003).

Cell/Module manufacturer	New developments an new products
Sharp	- Joint development of 100-kW inverter with Daihen - Commercialization of FY 2003 version of residential PV systems (flat type system focusing on aesthetic appearance, PV systems with new concept) - Commercialization of solar home system (SHS) for village electrification in overseas - Organized a design competition for housings, buildings and products utilizing PV system - Enhancement of production capacity of sc-Si solar cell (248 MW) - Production of modules in Europe was started
Kyocera	- Commercialization of a residential PV System employing small-sized and light weight PV modules (Two types of PV modules with narrow width in order to efficiently install onto roofs. Each module has a roof tile-like tier and excels in design). - Commercialization of a display using color LCD for output for residential PV system - Development of a mounting fittings for folded plate roof (PV system can be installed on the folded plate roof using the fitting without a support structure. Parts and installation work can be reduced)
Sanyo Electric	- Commercialization of higher output PV module (200 W) - Development of solar cell with large surface area (125 mm x 125 mm) - Commercialization of a flat-shaped support structure - Development of lead-free PV modules
Mitsubishi Electric	- Enhancement of 134 W PV module series - Commercialization of a lower capacity power conditioner (1,8 kW)
Matsushita Ecology Systems	- Double-glass PV modules
Hitachi	- Commercialization of bifacial solar cell - Commercialization of bifacial PV modules
MSK	- Development and commercialization of see-through a-Si modules and its applied product
Showa Shell Sekiyu	- Commercialization of 75 W and 80 W sc-Si modules for residential, power generation and consumer uses - Commercialization of mc-Si modules (158 W) for residential use - Development of thin-film $CuInSe_2$ (CIS) modules
Kobe Steel	- Development of building material-integrated PV modules
Thin film manufacturers	
Kaneka	- Development of see-through modules - Development of rooftop greening system using PV module
Mitsubishi Heavy Industries	- Development of mass production technology of a-Si cells with larger surface area
Canon	- Development of a-Si/ìc-Si/ìc-Si cell

Table 4e Plans for future expansion of production capacity.

Manufacturer	Production capacity in 2003 (MW)	Production capacity in 2004 (MW)	Production capacity from 2005 onwards (MW)	Technology
Sharp	248	300	-	sc-Si & mc-Si cell
Kyocera	76	120	-	mc-Si
Sanyo Electric	30	63	133 (2005)	a-Si/sc-Si
Mitsubishi Electric	50	90	130	mc-Si, sc-Si
Matsushita Ecology Systems	3	3	Not yet determined	sc-Si
Hitachi	5	5	7 (- 2005)	sc-Si cell
MSK	50	80	100 (-2005)	sc-Si
	15	40	80 (-2005)	mc-Si
	5	10	20 (-2005)	a-Si
Showa Shall Sekiyu	6,0	6,0	6,0	sc-Si
	-	-	20 (-2010)	CIS
Kobe Steel	2	2	-	mc-Si
Thin film manufacturers				
Kaneka	20	20	45 (-2005)	a-Si
Mitsubishi Heavy Industries	10	20	100 (-2010)	a-Si, ìc-Si
Canon	10	10	Not yet determined	a-Si/ìc-Si

Table 4f Typical module prices (JPY/W) for residential use for a number of years.

Year	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Module prices	966	950	927	764	646	656	670	600	548	484	463	446

3.3 Manufacturers and supplies of other components

While about 20 companies distribute inverters (power conditioners) for PV systems, more than 10 companies manufacture inverters in Japan. Most of them are manufacturers of electric appliances, power supply systems, electric components and general electric machines. Sharp, Sanyo Electric, Mitsubishi Electric, Omron, Japan Storage Battery, Matsushita Electric Works, Sanyo Denki, Sansha Electric Manufacturing, etc. are producing inverters for residential PV system. The capacity of most inverters for residential use in the market mainly ranges from 3 to 5 kW. Standardization and mass production of inverters for residential PV systems have been promoted as well as miniaturization and weight saving.

10-500 kW PV systems have been installed for public and industrial facilities. As New Energy and Industrial Technology Development Organization (NEDO) promoted standardization of 10-kW inverters under the “PV Field Test for Public Facilities” and “PV Field Test Program for Industrial Use”, large numbers of 10-kW inverters are supplied for this area. The manufactures of these types of inverters are as follows: Japan Storage Battery, Sanyo Denki, Kyocera, Nichicon, Furukawa Electric, Yuasa Corporation, Nissin Electric, Fuji Electric, Sansha Electric Manufacturing, Nippon Electric Industry, Mitsubishi Electric Corporation, etc. Inverters with over 10 kW of output capacity as one unit are a few because the application is limited for special purposes, and the cost of those inverters are relatively high due to customized production. Generally, 10-kW inverters are connected in parallel for PV installations up to 200 kW.

In these circumstances, Sharp commercialized a 100-kW inverter to correspond to increase of output capacity of PV systems. If dissemination of PV systems with 100 kW and more output capacity will be advanced, standardization and cost reduction of 100 kW scale inverters are expected as well as 10-kW inverters. Table 4g shows the prices of inverters sold for grid-connected PV application.

In Japan, grid-connected PV systems dominate the market, so that, the demand for batteries and inverters for stand-alone PV systems are limited to special use. The standardization is not in progress in this area and installation number is a few.

Table 4g Price of inverter for grid-connected PV applications.

Size of inverter	Average price per kVA in 2002 (JPY)	Average price per kVA in 2003 (JPY)
<1 kVA	-	-
1-10 kVA [1]	90 000	80 000
10-100 kVA [2]	130 000	120 000
>100 kVA	200 000	200 000

[1] : Single phase, 3-5 kW for residential use

[2] : 10-100 kVA. In case of > 100 kVA, three phase 10 kW unit is used.

3.4 System prices

Table 5 shows the typical application of PV systems and the price by category. Table 5a shows the trends in system prices from 1992. The standardization of grid-connected systems has progressed with the growth of the PV market in Japan, and the prices have been reducing. On the other hand, the off-grid system prices are determined case by case because there are various types of application areas and each market scale is small.

Table 5 Turnkey Prices of typical applications (2003).

Category / Size	Typical applications and brief details	Typical price (JPY/W)
Off-grid [1] Up to 1 kW	Telecommunications, lighting, traffic and road signs, pumps, ventilating fans, remote monitoring, navigation signs, clock towers, etc.	Depending on cases
Off-grid >1 kW	Agricultural facilities, communication facilities, disaster prevention facilities, mountain cottages, park facilities, remote area housing, lighthouses, etc.	Depending on cases
Grid-connected up to 10 kW	Residences, park facilities, small public facilities, etc.	680 JPY/W
Grid-connected >10 kW	Plants, warehouses, commercial buildings, larger public facilities, road buildings, railway facilities, etc.	800 JPY/W

[1] : Prices do not include recurring charges after installation such as battery replacement or operation and maintenance

Table 5a National trends in system prices.

Year	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Public & Industrial (>10 kW) JPY/W	4 300	3 400	2 800	2 400	1 500	1 300	1 190	1 040	1 010	900	840	800
Residential (3-5 kW) JPY/W	-	3 500	1 920	1 510	1 090	1 060	1 070	940	860	770	710	680

3.5 Labor places

Estimated labor places are as follows;

a) Research and development (not including companies): about 300
b) Manufacturing of PV systems components, including company R&D: about 3 000
c) All other, including within electricity companies, installation companies etc.: about 8 000

3.6 Business value

Table 6 shows business value of the domestic market of PV systems.

Table 6 Business value of PV system market.

Year	1999	2000	2001	2002	2003
Business value	76 500 MJPY	84 900 MJPY	110 000 MJPY	150 000 MJPY	170 000 MJPY

4 Framework for deployment (Non-technical factors)

4.1 New initiatives

a) Promotion initiatives
"Field Test Projects on Advanced Photovoltaic Power Generation Technology" was newly started in 2003 in addition to the ongoing promotion programs of PV systems, such as "Residential PV System Dissemination Program", "PV Field Test Project for Industrial Use", "Project for Promoting the Local Introduction of New Energy", "Project for supporting New Energy Operators" and "Project for Supporting Regional Activities for Prevention of Global Warming". This new project aims at expansion of dissemination of middle scale PV systems with 10 kW and over of output capacity, which have not been widely diffused, compared to residential PV systems. Under this project, introduction of new types of PV systems are promoted by private companies and local governments, etc. Improvement of the performance, cost reduction and enlargement of application area of PV systems are expected.

b) New plan of PV system introduction
New Energy and Industrial Technology Development Organization (NEDO) started "Demonstrative research on Clustered PV system", a new demonstrative research project of intensively installed PV systems. Under the project, PV systems, 1 800 kW in total will be installed in 600 residences. NEDO also started to conduct "Demonstrative Research into Regionally Combined New Energies" at 3 sites in Japan. In the selected sites, multiple new energy systems such as PV systems, fuel cells and wind power generators are installed and grid-connected, and researches to solve technical issues arising from the installation are conducted.

Local governments promote installation of PV systems utilizing "Project for Promoting the Local Introduction of New Energy". For example, Metropolis of Tokyo announced a plan to introduce total 5 220 kW of PV systems into 8 water treatment plants. Hyogo Prefecture has a plan to introduce total 350 kW of PV systems in 8 prefectural office buildings. Iwate Prefecture decided to install total 250 kW of PV systems in 3 sites. In addition, The Ministry of Land, Infrastructure and Transport (MLIT) promotes to introduce PV systems following "the Guidelines for Planning Environmentally-Friendly Government Building (Green Government Office Buildings)". Defense Facilities Administration Agency (DFAA) started installation of PV systems to the surrounding houses of air bases for a countermeasure for noise.

c) Utility perceptions to PV

Electric power companies adopted net billing system and have been buying back surplus electricity by PV from their customers at the selling price of electricity since 1992 on a voluntary basis. Other initiatives, such as green pricing, rate-based incentives have not been studied in Japan. During FY 2002 (April 2002 to March 2003), electric power companies bought surplus PV power of 182 136 MWh.

Utilities have been interested in PV systems earlier, and introduced PV systems to their own facilities every year. As of the end of March 2003, accumulative introduction of PV systems by 10 electric power companies and Electric Power Development (J-Power) reached 339 systems. The accumulated capacity installed was 4 689 kW.

Moreover, utilities introduced “Green Power Fund” to promote utilization of natural energy in October 2000. Electric power companies contribute to the Fund the same amount as the total sum collected on the basis of 500 JPY/month per share from their customers who support the purpose of “Green Power Fund”. The Fund is utilized to introduce PV and wind power plants. In 2003, 159 PV systems, 2 856 kW in total were qualified through “Green Power Fund” and installed to schools, hospitals and other public facilities. 87 PV systems, 1 431 kW in total and 39 PV systems, 830 kW in total were installed in 2002 and in 2001 respectively, through “Green Power Fund”.

d) Changes in Public perceptions of PV
Public perception to PV and awareness for introduction of PV system in Japan is getting more positive through ambitious and strong policies, programs of PV introduction and promotion, and publicities via media such as television and newspapers. For example, in case of “Residential PV System Dissemination Program”, the number of applicants has been growing year by year, especially since the number of introduced PV systems broke through 10 000 in 1999. The application number for “Residential PV System Dissemination Program” in 2003 reached over 50 000 at 52 863 (201 365 kW). Furthermore, willingness to contribute to the environment by businesses is increasing, and introduction of PV systems by businesses has been increasing through “PV Field Test project for Industrial Use”.

In 2000, “Project for Promotion of Non-Profit Activities on New Energy and Energy Conservation” was introduced to support NPOs who work on introduction of new energy facilities at regional level. Under the program, NPOs can introduce PV systems into regions. Through grass-root movement, PV introduction also has started.

e) Others
Housing manufacturers, building material manufacturers, construction companies and power supply equipment manufacturers set about developing houses and components with PV systems, and are playing a role of PV promotion. In addition to this, local electric equipment stores, electric appliance stores, roofers, etc. started sales and installation of PV systems, and the distribution chain of residential PV systems is being formed.

4.2 Indirect policy issues

In 2002, the National Diet enacted “the Basic Law on Energy Policy”. The Law guides the nation under 3 energy policy principles: stable energy supply, environmental harmony and market mechanism. PV is on the list as a measure to the environmental

harmony. In 2003, based on this policy, the basic plans were laid out focusing on following items: 1) diversification of petroleum supply sources, 2) diversification of energy sources such as nuclear energy and renewable energy, 3) energy conservation, 4) stockpile, 5) security of energy supply systems, etc.

The Ministry of Economy, Trade and Industry (METI) enforced “the Law Concerning the Use of New Energy by Electric Utilities (Renewables Portfolio Standard (RPS) Law)” in April 2003 as a measure to promote further dissemination of new and renewable energy. The RPS Law obliges electric power companies to expansion of use of electricity generated from new energy. The target minimum ration of renewable energy usage in 2010 is 12 200 GWh, which accounts for 1,35% of net sales energy demand.

4.3 Standards and codes

In 2003, new standards, codes and guidelines were not published. However, Japan Electrical Safety & Environment Technology Laboratories (JET) started a certification program of PV modules, “jetPVm certification” in October 2003. In the certification, tests for accrediting performance and reliability of manufactured PV modules are implemented. In the certification process, inspection of the PV module plant is required in order to confirm compliance of manufacturing system with domestic standards (consistent with international standards, IEC 61215 and IEC 61646). Manufacturers of PV modules can obtain the trust from end-users in Japan by this certification. In addition, it is expected that PV manufacturers can easily obtain certification in overseas through the framework of international cross certification. At the same time, Importing PV modules manufactured in overseas to Japan will be facilitated. Moreover, JET conducts a certification program for the performance and reliability of grid connection protecting unit (power conditioner) for small-sized residential PV systems. This certification aims at accrediting protecting and controlling functions for grid connection stipulated in “Guideline of Grid Connection Requirement (an instruction issued by the chief of public utility department of Agency for Natural Resources and Energy (ANRE) of METI in 1986, revised in 1998)”.

The following Japanese Industrial Standards (JIS) and Technical Report (TR) are at the stage of discussion and will be published in the near future.
Note) Technical Report (TR) is aiming at forming consensus and earlier establishment for JIS by providing information on standardization of PV power generation technology, in which technological innovation has been advanced

Discussion of following standards was almost finished.
- Draft revision of “Glossary of terms for photovoltaic power generation (JIS C 8960)”
- Draft revision of “General rules for photovoltaic array (JIS C 8951)”
- Draft revision of “Indication of photovoltaic array performance (JIS C 8952)”
- Standardization of “Estimation method of generated output of PV system”
- Standardization of “Structural design and installation method of roof-type PV system”
- Standardization of “Safety design of electric system of residential PV system”
- Standardization (to be JIS) of “Design guide on structures for photovoltaic array (TR C 0006-97)”
- Standardization (to be JIS) of “Design guide on electrical circuit for photovoltaic array (TR C 0005-97)”

Discussion is underway for the following standards.
- "General rules for stand-alone photovoltaic power generating system (JIS C 8905)"
- "Measuring procedure of photovoltaic system performance (JIS C 8906)"
- "On-site measurements of photovoltaic array I-V characteristics (JIS C 8953)"
- "Measuring procedure of power conditioner efficiency for photovoltaic systems (JIS C 8961)"
- "Testing procedure of power conditioner for small photovoltaic power generating systems
  (JIS C 8962)"
- Draft TR of "On-site measurements of photovoltaic power generating systems
  (tentative translation)"

5 Highlights & Prospects

In order to achieve the national target introduction volume of PV system, 4 820 MW in 2010, the Japanese Government continues to support R&D, market incentive measures and to create a better condition for promotion of introduction of PV systems by watching the trend of dissemination status and cost reduction of PV systems. In the policies on R&D, technological development for cost reduction and mass deployment of PV systems are enhanced. As for dissemination measures, subsidy programs for introduction of PV systems for residence, public facilities and industrial uses are continued in order to establish and expand the initial market. However, as the initial market for residential PV systems is being established, “Residential PV System Dissemination Program” is scheduled to be finished at an early date. The RPS Law established in 2002 was enforced in April 2003 and expansion of utilization of new energy by utilities is expected. In addition, the Government takes the lead in installation of PV systems in governmental facilities, aiming at CO_2 reduction in response to “Law concerning the promotion of procurement of eco-friendly goods and services by the national and local governments and other entities (Law on promotion of green procurement)” and “Law Concerning the Promotion of the Measures to Cope with Global Warming”.

Electric utilities will continuously promote introduction of PV systems into public facilities through “Green Power Fund”.

PV manufacturers are planning to increase their production capacity, extend production sites, reduce manufacturing cost, commercialize various types of PV modules and PV systems fitting for the users’ demand, and improve conversion efficiency of solar cells, in order to establish and enlarge self-sustained PV market. Moreover, the PV manufacturers will create a new industrial structure in corporation with peripheral industries.

The Government is discussing Long-Term Energy Supply and Demand Outlook, strategies of technological development of new energy, a vision for new energy industry with an eye to FY 2030. New promotion measures and new national target will be established in 2004.

Annex A Method and accuracy of data

The work was performed in collaboration with PV modules and BOS components manufactures, housing manufacturers, government agents running PV programs / projects. The data were collected by hearing and questionnaires.

As regards off-grid sector, some of these systems implement PV modules that have a capacity lower than 40 W. In this report they are included because it is very difficult to distinguish the application types and rated voltages.

The accuracy of data is ±15% for cumulative installed PV power, ± 10% production and production capacity.

Annex B: Table 1 Summary of major projects, demonstration and field test programs (1/5).

Project Data plant start up	Technical data/ Economic data	Objectives	Main accomplishments until the end of 2003/ problems and lessons learned	Funding	Project Management	Remarks
Residential PV System Dissemination Program (1994-)	- Grid connected, residential - Eligible system rate 1994~1996: ≤4~5 kW 1997 : ≤4 kW 1998~1999: ≤10 kW 2000 : ≤4 kW 2001 :≤10kW 2002 :≤10 kW 2003 :≤10 kW - Subsidy: 2001: 120 000Yen/kW + consumption tax 2002: 100 000Yen/kW + consumption tax 2003: 90 000Yen/kW + consumption tax	- Perception to PV - Dissemination of PV - Creation of the initial market for residential PV system - Collection of PV operation data	- 52 352 residential PV systems were installed in total from 1994 to 2000 (189,0 MW). - 25 151 PV systems were installed in 2001 (91,0 MW). - 38 262 PV systems were installed in 2002 (141,4 MW). - 52 863 PV systems were accepted in 2003 (201,4 MW). - Better understanding to PV has been promoted. - Cost of systems reduced to 680 000 JPY/kW. - Novel types of building integrated PV modules such as roof material integrated and triangular-shaped PV modules were developed. - Commercialization of Housings equipped PV systems as standard equipment was promoted. - Education for installers of residential PV systems was advanced.	- METI[1], ANRE[2] - Budget: 1994 2 030 MJPY 1995 3 310 MJPY 1996 4 056 MJPY 1997 11 110 MJPY 1998 14 700 MJPY 1999 16 040 MJPY 2000 14 500 MJPY 2001 23 560 MJPY 2002 23 200 MJPY 2003 10 500 MJPY	- NEF[3]	- Applications for residential PV system subsidy have been increased year by year. - Total budget 1994 to 2003 was 122 956 MJPY. - Title of “Residential PV System Monitor Program” changed to” Residential PV System Dissemination Program” in 1997.

[1] : ANRE: Agency of Natural Resources and Energy

[2] : METI: Ministry of Economy, Trade and Industry

[3] : NEF: New Energy Foundation

Annex B: Table 1: Summary of major projects, demonstration and field test programs (2/5).

Project Data plant start up	Technical data/ Economic data	Objectives	Main accomplishments until the end of 2003/ problems and lessons learned	Funding	Project Manage-ment	Remarks
PV Field Test Project for Industrial Use (1998-)	- Grid connected, residential (10 kW and over) - Industrial facilities, such as factory, warehouse, commercial building - Subsidy: 50% of installation cost - Eligible systems - Modular type: combined systems with 10 kW PV unit - Novel application type: systems with thin film solar cells, building integrated PV systems.	- Collection and dissemination of operational data - Cost reduction - Standardization of PV systems - Demonstration of new type PV system	- From 1998 to 2002, 15 610 kW of 644 modular type PV systems and 2 490 kW of 96 novel application types were installed to factories, warehouses, laboratories, commercial buildings, schools and so on (new installation was finished in 2002 and data collection and analysis is conducted in 2003). 1998: 73 cases (1 940 kW) 1999: 93 cases (2 790 kW) 2000: 149 cases (3 680 kW) 2001: 218 cases (4 890 kW) 2002: 207 cases (4 800 kW) - Perception of industries is being spread. - Cost of PV systems for public facilities and industrial use reduced to 820 000 JPY/kW. - Better understanding to PV has been promoted in the local residents. - Variety of novel types of PV systems were installed.	- ANRE, METI - Budget: 1998 2 400 MJPY 1999 2 410 MJPY 2000 4 000 MJPY 2001 1 990 MJPY 2002 4 500 MJPY 2003 260 MJPY	- NEDO[4]	- Total budget 1998 to 2003 was 15 560 MJPY. - Installed capacity 1998 to 2002 by sector Private companies: 295 cases (7 760 kW) Public-service corps.: 123 cases (3 750 kW) Local governments: 322 cases (6 590 kW) Total: 740 cases (18 100 kW) - Installation was finished in 2002. - Monitoring is conducted since 2003.

[4]: NEDO: New Energy and Industrial Technology Development Organization

Annex B: Table 1 Summary of major projects, demonstration and field test programs (3/5).

Project Data plant start up	Technical data/ Economic data	Objectives	Main accomplishments until the end of 2003/ problems and lessons learned	Funding	Project Management	Remarks
Project for Promoting the Local Introduction of New Energy (1997-)	- New energy in general - Eligible PV systems: grid-connected (50 kW and more) - Subsidy: 50% or one third of installation cost - Eligible: Local governments	- Enhancement of promotion of new energy to public facilities - Education and promotion of new energy to local inhabitants	- 52 systems (7 378 kW) were installed in from 1997 to 2001. - 26 PV systems (2 676 kW) out of 66 qualified systems in 2002. - 70 PV systems (8 311 kW) out of 101 qualified systems in 2003. - 148 PV systems totaling 18 306 kW will be installed during 1998~2006. - Planned installation of multiple numbers of PV systems in local governmental offices, schools, libraries, water purification plants, etc. can be implemented. - Qualification of larger-scale PV systems with more than 100 kW output was started.	- ANRE, METI - Budget: 1997: 2 200 MJPY 1998: 4 380 MJPY 1999: 6 760 MJPY 2000: 6 430 MJPY 2001: 11 500 MJPY 2002: 12 700 MJPY 2003: 12 710 MJPY	- NEDO	
Project for Supporting New Energy Operators (1997-)	- New energy in general - Eligible PV systems: grid-connected (50 kW) - Subsidy: a third of installation cost or guaranteed debt	- Support of private industries who introduce new energy - Encouragement of introduction of new energy by private industries	- 2 PV systems were installed in a commercial building (118 kW) and a delivery center (100 kW) from 1997 to 2001. - One 25 kW PV system out of 25 qualified systems was installed in 2002. - 2 PV systems out of 39 qualified systems was installed to a factory (200 kW) and a wind power plant (17 kW) in 2003.	- ANRE, METI - Budget: 1997: 1 123 MJPY 1998: 5 390 MJPY 1999: 10 340 MJPY 2000: 11 490 MJPY 2001: 14 040 MJPY 2002: 23 620 MJPY 2003 38 818 MJPY	- NEDO (-2002) - METI (2003 -)	

Annex B: Table 1 Summary of major projects, demonstration and field test programs (4/5).

Project Data plant start up	Technical data/ Economic data	Objectives	Main accomplishments until the end of 2003/ problems and lessons learned	Funding	Project Management	Remarks
Eco-school Model Promotion Pilot Project (1997-)	- New energy use school (PV, solar thermal, etc.) energy efficient school etc. - Eligible Energy: New energy including PV - Subsidy: Investigation; fixed cost (METI's subsidy is available for PV system installation) - Eligible: Local government	- Demonstration and promotion of environment-friendly school - Environmental education to students	- PV systems (2 580 kW) were installed to 114 schools in 1997 to 2001. - PV systems (741 kW) were qualified to 49 schools in 2002. - PV systems (525 kW) were qualified to 68 schools in 2003. - Schools introduced PV systems were expanded to 231. - Students understand PV system were increased. - Environmental education was implemented and enhanced.	- METI: METI's subsidy is available for PV systems installed under Eco-school Infrastructure Promotion Pilot Project (Reference) - Budget of MEXT[5]: 1998 28 MJPY 1999 28 MJPY 2000 28 MJPY	- MEXT[5] - ANRE	- The project will be continued by 2006. - PV systems (3 865 kW) were installed to 275 sites in 133 national universities and technical colleges in 1998 to 2001.

[5]: MEXT: Ministry of Education, Culture, Sports, Science and Technology

Annex B: Table 1 Summary of major projects, demonstration and field test programs (5/5).

Project Data plant start up	Technical data/ Economic data	Objectives	Main accomplishments until the end of 2002/ problems and lessons learned	Funding	Project Management	Remarks
Project for Supporting Regional Activities for Prevention of Global Warming (2001~)	- Eligible Project: Multiple businesses that plan to introduce new energy facilities or energy-efficiency facilities during single fiscal year - Subsidy: Up to 1/2 or 1/3 of installation cost - Eligible entrepreneurs: Local governments, local communities, environmental protection NPOs, entrepreneurs, etc.	- To establish model cases to arrest global warming by leadership of regions - To promote businesses to wider regions	- 2001: 14 PV systems out of 34 projects in 15 regions were qualified - 2002: 12 PV systems out of 34 projects in 14 regions were qualified - 2003: 15 PV systems out of 38 projects in 17 regions were qualified	- METI Budget: 2001 466 MJPY 2002 466 MJPY 2003 590 MJPY	- NEDO	