International Energy Agency

CO-
OPERATIVE PROGRAMME ON PHOTOVOLTAIC POWER SYSTEMS

Task 1

Exchange and dissemination of information on PV power systems

National Survey Report of PV Power Applications in Korea 2002

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May 2003

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i Foreword

The International Energy Agency (IEA), founded in November 1974, is an autonomous body within the framework of the organisation 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 research projects (Tasks) is the responsibility of Operating Agents. Eight tasks have been established, and currently five are active. Information about the active and completed tasks can be found on the IEA-PVPS website www.iea-pvps.org. a new task concerning urban-scale deployment of PV systems in being developed.

ii Introduction

The objective of Task 1 of the IEA Photovoltaic Power Systems Programme is to facilitat e the exchange and dissemination of information on the technical, economic, environme ntal 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 i nformation on trends in PV power applications in the twenty member countries and is ba sed on the information provided in the National Survey Reports which are produced ann ually by each Task 1 participant. This 2002 National Survey Report gives an overview of the key developments and achievements in the field of PV in Korea during the year 2002 .

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 Wp 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/m2, cell junction temperature of 25oC, AM 1,5 solar spectrum – (also see 'Peak power').

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

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 Wp or more.

Module manufacturer: An organisation 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 systems 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 (KRW : Korea Won)

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 annu al (monthly, daily) yield, where the reference annual (monthly, daily) yield is the theoret ical annual (monthly, daily) available energy per kW of installed PV power.

KERI: Korea Electrotechnical Research Institute

KEMCO: Korea Energy Management Corporation

KEPCO: Korea Electric Power Corporation

KIER: Korea Institute of Energy Research

KOPRA: Korean Photovoltaic Research Association

MOCIE: Ministry of Commerce, Industry and Energy

MOST: Ministry of Science and Technology

NRSE: New and Renewable Sources of Energy

1 Executive summary

- Installed PV power

The total installed power of PV systems in Korea was 5,41 MW at the end of 2002. The installed power in 2002 was 653 kW, which are much less than that achieved in the previous year (797 kW).

The PV market was still dominated by off-grid non-domestic sector that occupied about 77 % of total cumulative installed power. The share of off-grid domestic sector in 2002 was 9 %. Among the various off-grid non-domestic applications, marine applications were the largest sector of application in the y ear 2002, followed by highway emergency call box and street light lamps.

The share of grid-connected distributed system was raised to 14 % of total cumulative installed power. In 2 002, a total power of 237 kW was installed. This corresponded to 36 % of the annual inst alled capacity.

- Costs & prices

The PV module prices in 2002 remained unchanged, varying in the range of 6 500 to 8 000 KRW/W depending on the manufacturing company and the order volume. Depen ding on the PV system type installed, system prices ranged between 21 300 and 22 30 0 KRW/kW in the case of stand-alone systems. The price of grid-connected systems varied between 13 800 KRW/kW and 15 000 KRW/kW. The price of the 3 kW rooftop system was 15 000 KRW/W, the price was the same in the year 2 001.

- PV production

In 2002, two new companies produced 300 kW of PV cells. These companies started its production in 2002 with a capacity of 1.2 MW. Five companies including one started its o peration in 2002 produced about 780 kW of PV modules. The production volume was 10 % less than that of last year. Most of single and multi-crystalline silicon PV cells for module production was imported from foreign countries.

- Budgets for PV

The total budgets for R&D and D were remarkably increased in 2002, compared with tha t in the previous year. The government budgets in 2002 for R&D and demonstration/field test project were 4 055 MRKW and 5 469 MRKW, respectively. In addition, local authori ties provided 1 875 MKRW for the implementation of demonstration/field test project on t he basis of cost-shared project. For the first time the public budgets for market incentives were allocated to PV system in the year 2002. The government and the local authorities provided 1 820 and 390 MKRW, respectively.

2 The implementation of PV systems

The PV power system market is defined as the market of all nationally installed (terrestrial) PV applications with a PV capacity of 40 Wp or more. A PV system consists

of modules, inverters, batteries and all installation and control components for modules, inverters and batteries.

2.1 Applications for photovoltaics

The PV market was still dominated by off-grid non-domestic sector that occupied about 77 % of the cumulative installed PV power. However, the market share of this sector has been decreasing year by year. Among the various off-grid non-domestic applications, telecommunication was still the largest sector of application, followed by marine applications such as lighthouses. In the year 2002, marine applications were the largest sector of application, followed by highway emergency call box and street light lamps. Another important applications include PV systems for the aviation warning lamps of the high-voltage transmission tower, environment-monitoring equipment such as water-borne pollution, sewage, weather and traffic signaling and forest fire monitoring.

For off-grid domestic application, three PV systems with total capacity of 85 kW were installed at remote islands in 2002. The share of this sector is about 9 % of the total cumulative installed PV power.

In 2002, more than 20 grid-connected distributed systems with a capacity in the range 3 kW to 53 kW were installed. Among them 16 systems were for public office building and 5 systems were rooftop systems for residential houses. The share of grid-connected distributed system was raised to 14 % of the total cumulative installed power. In 2002, the total installed power of this sector was 237 kW, representing 36 % of the total PV market. In 2001 only nine systems with total capacity of 168 kW were installed. This sector has been intensively promoted under the framework of demonstration project or local energy development project supported by the government and local authorities.

Figure 1 shows the share of 3 sub-markets during the year 2002 and in total.

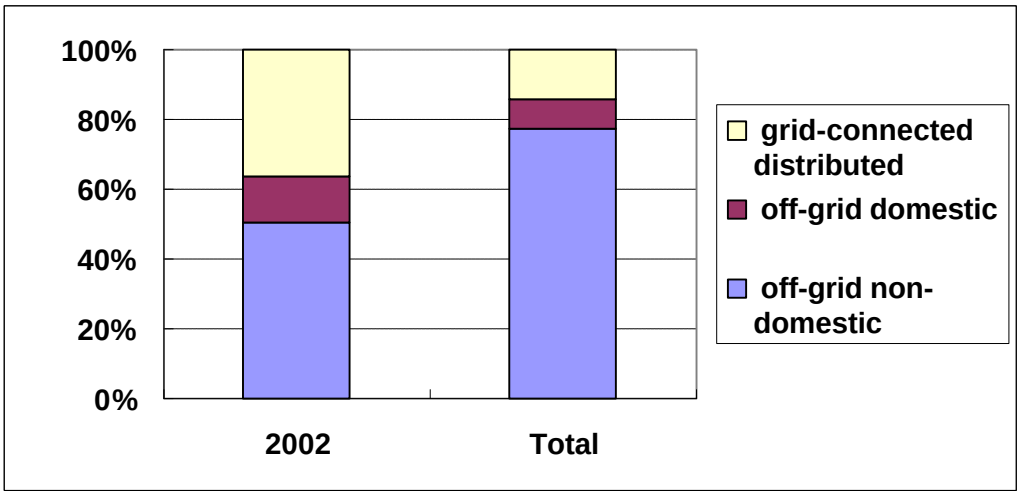

Figure 1: The share of sub-markets during 2002 and in total cumulative power

2.2 Total photovoltaic power installed

The total cumulative installed PV power for each sub-market on the 31 December of each year from 1992 is shown in Table 1 and Figure 2. The total installed power of PV systems in Korea was 5 410 kW at the end of 2002. The total PV power installed during the year 2002 was 653W, which is about 18 percent less than that achieved in the previous year (797 kW).

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

Sub-market/ application	31 Dec 1992 kWp	31 Dec. 1993 kWp	31 Dec. 1994 kWp	31 Dec . 1995 kWp	31 Dec. 1996 kWp	31 Dec . 1997 kWp	31 Dec. 1998 kWp	31 Dec. 1999 kWp	31 Dec 2000 kWp	31 Dec 2001 kWp	31 Dec 2002 kWp
off-grid domestic	59	149	175	219	256	296	306	316	316	376	461
off-grid non-domestic	1 412	1 482	1 506	1 550	1 757	2 046	2 410	2 855	3 288	3 857	4 188
grid-connected distributed	0	0	0	0	100	133	266	288	356	524	761
grid-connected centralized	0	0	0	0	0	0	0	0	0	0	0
TOTAL	**1 471**	**1 631**	**1 681**	**1 769**	**2 113**	**2 475**	**2 982**	**3 459**	**3 960**	**4 757**	**5 410**

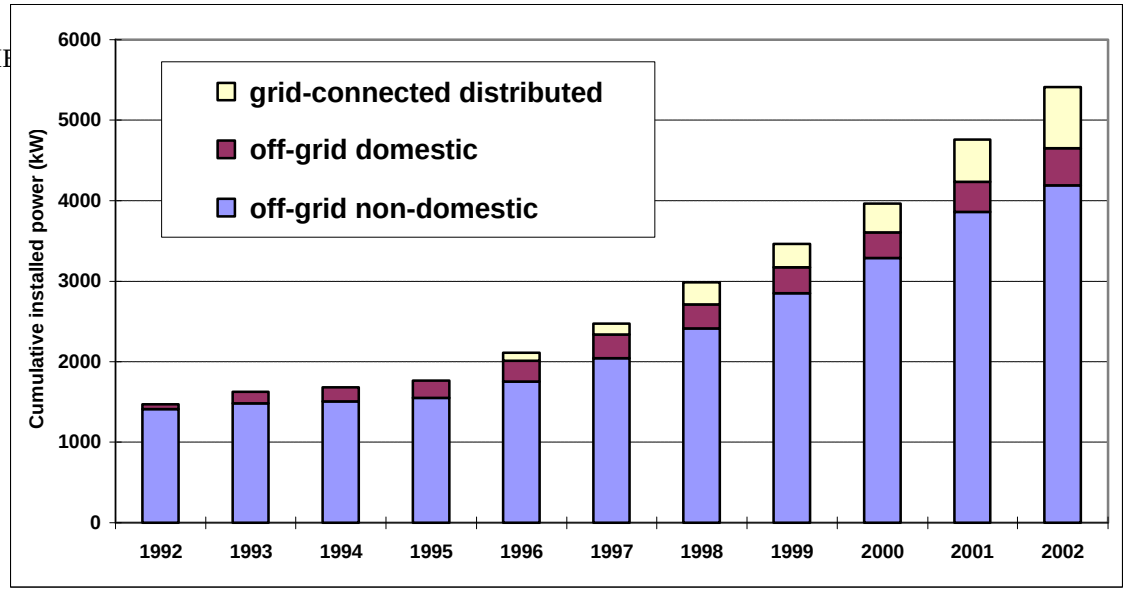

Figure 2 : The cumulative installed PV power in 3 sub-markets

2.3 Major projects, demonstration and field test programmes

Since 1993 the MOCIE (Ministry of Commerce, Industry and Energy) has been implem enting, via the KEMCO, demonstration and field test of various renewable energy tech nologies. In addition, the government has been encouraging and supporting local auth orities to implement their own demonstration or field test projects under the framework of "Local Energy Development Project". This project in part aims to raise public aware ness on renewable energy technologies and to develop indigenous renewable energy sources for each region. In both of these projects, the PV technology has always been at the top priority.

During the year 2002, ten grid-
connected systems with a capacity of 3 to 10 kW were installed under the demonstrati on project of renewable energy technologies. Among them five were rooftop systems of 3kW-
capacity for residential houses and five were for public office buildings including gover nment office, police station and universities.

Under the local energy development project, a wide variety of PV systems including off -grid domestic, non-domestic and grid-
connected systems were constructed. The focus was put on grid-
connected distributed systems owned by local authorities, public organisations and ind ividuals. A 53-kW grid-
connected system installed on the roof of the Chosun University's dormitory building a nd a 30-
kW system installed on the roof of Energy Pavilion at the site of the International Cave Exposition in the city of Samcheok, Gangwon Province, were representative example s. At the Cave Exposition site, a 107-
kW system has already been constructed in 2001. In addition, two PV-
diesel hybrid systems with a PV capacity of 60 kW and 22.5 kW, respectively, was con structed and started its operation during the year 2002.

Table 2: Summary of major projects, demonstration and field test programmes

Project Date plant start up	Technical data/Economic data	Objectives	Main accomplishments until the end of 2002/problems and lessons learned	Funding	Project management	Remarks
Local Energy Dev. Project *Grid-connected system* *Gwangju City Chosun University's dormitory building* *2002*	*grid-connected* *power: 53 kW* *single crystalline silicon PV cells* *area: 450 m^2* *orientation: S* .	*Demonstration of grid-connected system*		*Government 85%* *Gwangju City 23%*	*Chosun University*	
Local Energy Dev. Project *Samcheok City* *Energy Pavilion* *2002*	*grid-connected* *power: 30 kW* *multicrystalline silicon PV cells* *area: 1 080 m^2* *orientation: S*	*To raise public awareness of PV*		*Government 70%* *Samcheok City 30%*	*Samcheok City*	*Constructed at the same site of existing 107-kW largest PV system in Samcheok International Cave Expo*

Section 2.4 Highlights of R&D

The PV R&D projects are mainly supported by the MOCIE, and some basic research projects are supported by the MOST. The KEMCO is a leading organisation in management of R&D projects as well as demonstration projects. The KEMCO is operating the KOPRA made up of experts from research institutes, universities and industries. The KOPRA has been carrying out feasibility studies and making suggestions to the government, concerning all aspects of PV.

The R&D projects implemented in 2002 included various categories. In short term covering the period 2001-2004, the key project has been to develop solar cells mass production technology and BOS systems for 3-kw residential rooftop system. In the mid- and long-term, two projects have been implemented. One has been the technology development related to BIPV, the other one aimed to develop polycrystalline thick-film silicon using solution growth.

Some basic R&D projects on thin-film solar cells have been carried out by research institutes and universities. The materials included CIGS, amorphous silicon (a-Si), polycrystalline silicon (p-Si), organic materials and TiO_2 for dye-sensitized PV cells. In the case of CIGS solar cells leaded by the KIER, co-evaporation processes were studied with an objective to develop low-cost and high-efficiency solar cells. The fabrication of p-Si by Hot-wire CVD was also studied by the KIER.

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

The total budgets for R&D and D were remarkably increased in 2002, compared with those in the previous year. The Government budgets in 2002 for R&D and demonstration/field test programme were 4 055 MRKW and 5 469 MRKW, respectively, as shown in Table 3. In addition, local authorities provided 1 875 MKRW for the implementation of demonstration/field test programme. In general, the government provides up to 70 % for demonstration project and up to 80 % for local energy project of the total initial investment of the installations on the basis of cost-share projects.

For the first time the public budgets for market incentives were allocated to PV system in the year 2002. The government and the local authorities provided 1 820 and 390 MKRW, respectively. The incentives were offered to individuals and private companies that applied for the construction of rooftop or BIPV systems through local energy development projects. Besides, the government provided every year low-interest loans for renewable energy production or application facilities. However, its conditions were not favourable for PV, and mainly applied to solar water heater or waste incineration facilities.

Table 3: Public budgets (in Million KRW) for R&D, demonstration/field test programmes and market incentives.

	R & D	Demo/ Field test	Market
National/federal	4 055	5 469	1 820
State/regional		1 875	390
Total	4 055	7 344	2 210

3 Industry and growth

3.1 Production of photovoltaic cells and modules

The status of PV cells and module production in 2002 is summarized in Table 4. Until 1999, High Solar Company (independent from former LG Siltron Co. in May 1999) continued to ma nufacture PV cell, but this company stopped its operation in the year 2000. In 2001, there w as no PV cell manufacturer in Korea. However, two new companies after having completed th e construction of PV cell manufacturing facility, started its operation in 2002. These companies with a production capacity of 1.2 MW produced 300 kW of single crystalline silicon PV cells in 2002. Over the half of the products was exported and a part of the products was supplied to d omestic PV module manufacturers,

Five companies including one started its operation in 2002 produced about 780 kW of PV modules. The production volume was 10% less than that of last year. Most of single and multi-crystalline silicon PV cells were imported from foreign countries. In 2002, the total production capacity was 2 000 kW(I shift). In the previous year the production capacity was also 2 000 kW and production volume was 850 kW.

S-Energy (Independent from former Samsung Electronics Co.) manufactured four types of modules with a peak output of 50 to 80 W using mc-Si PV cells imported from BP Solar. The 75 W has a dimension 1 204 L x 538 W x 38 mm D, and a structure glass/EVA/solar cells/EVA/tedlar. This company announced the completion of development of rooftop PV modules and started field test of these modules in 2003. This company is planning to install large size laminator for the manufacturing of large size module. LG Industrial System Co. produced a various types of PV modules with a peak output power in the range of 43 to 100 W using sc-Si PV cells imported from Siemens Solar Industries in USA. The module has a typical structure glass/EVA/solar cells/EVA/back sheet, which is similar to that of S-Energy. Haesung Solar manufactures small PV modules with an output power ranging 1 to 50 W using PV cells of which one part purchased from Neskor Solar, and some imported from abroad. The module manufacturing process is also similar to that of the former two companies.

The PV module prices in 2002 remained unchanged, varying in the range of 6 500 to 8 000 KRW/W depending on the manufacturing company and the order volume. Table 4a shows t he trends of average module prices between 1994 and 2002.

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Table 4: Production and production capacity information for the year for each manufacturer

Cell/Module manufacturer	Technology (sc-Si, mc-Si, a-Si, CdTe)	Total Production (MWp)		Maximum production capacity (MWp)	
		Cell	Module	Cell	Module
1 Neskor Solar	sc-Si	0.12		0.7	
2 Photon Semiconductor & Energy	sc-Si	0.18		0.5	
3 S-Energy Co	mc-Si		0.35		0.5
4 LG Industrial System Co.	sc-Si		0.25		0.5
5 Haesung Solar Co	sc-Si, mc-Si		0.1		0.5
6 SolarTech Co.	sc, mc-Si		0.075		0.5
Thin film manufacturers					
1					
TOTALS		0.30	0.775	1.2	2.0

Table 4a: Module prices in current kilo KRW/W between 1994 and 2002.

Year	1994	1995	1996	1997	1998	1999	2000	2001	2002
Module price(s): Current	9,4	9,4	8,2	8,5	9,2	7,5	7,1	7.2	7,2
Constant									

3.2 Manufacturers and suppliers of other components

Two companies manufacture the inverters for grid-connected system: Hex Power Systems, Samwha Engineering. The former produced various products with a capacity 1 – 50 kW. These companies also produced the inverters for stand-alone systems. The price of inverters for grid-connected applications is shown in Table 5. In the case of inverters for stand-alone systems, the price is about 2 MKRW/kVA for a size larger than 10 kVA. There is one PV battery manufacturer, Global High-tech Co. that produces lead-acid batteries of tubular plate stationary type. The unit price of the battery with a capacity 2 000Ah/100hr is 910 kKRW. Concerning the supporting structures, PV system installers used their own type of support structures made from anodised aluminium or galvanized steel. That is why the price of the supporting structures is so multifarious.

Table 5: Price of inverters for grid-connected PV applications.

Size of Inverter	<1 KVA	1-10 KVA	10-100 KVA	>100 KVA
Average Price per kVA (KRW)	2.83 MKRW	2,23 MKRW	2,03 MKRW	1,60 MKRW

3.3 System prices

Depending on the installed PV system type, system prices ranged between 21 300 and 22 300 KRW/p in the case of stand-alone systems, as shown in Table 6. The price is 22 300 KRW/W for a street lighting PV system with a unit power capacity of 200 W. The price of grid-connected systems varied between 13 800 KRW and 15 000 KRW. The price of the 3 kW rooftop system was 15 000 KRW/W which is the same that in the year 2001.

Table 6a shows the price trends of 10 kW-capacity PV rooftop system for building.

Table 6: Turnkey Prices of Typical Applications

Category/Size	Typical applications and brief details	Current prices per Wp in KRW
OFF-GRID Up to 1 kWp	Forest fire monitoring, Street lighting 200 W	22 300
OFF-GRID >1 kWp	Remote island	21 300
GRID-CONNECTED Specific case	3 kW roof-mounted system	15 000
GRID-CONNECTED Up to 10 kWp	Building rooftop 10 kW	14 300
GRID-CONNECTED >10 kWp	Building rooftop 30 kW	13 800

Table 6a: National trends in system prices (current NC) for 10 kW-capacity building rooftop system.

YEAR	1997	1998	1999	2000	2001	2002
Price : KRW/W	17 330	18 000	16700	15700	14 700	14 300

3.4 Labour places

The estimated full time labour place equivalents in PV related activities are as follows:

a) Research and development (not including companies); 47
b) Manufacturing of PV system components, including company R&D; 103
c) All other, including within electricity companies, installation companies etc.; 35

c) All other, can be broken down into:

c1) Distributors, system and installation companies; 27
c2) Utilities and government; 8

3.5 Business value

The value of PV business in Korea was estimated to be 11 088 MKRW. This value was calculated from the PV power installed to which PV cell export was added and from which the value for PV cell and module import was subtracted.

4. Framework for deployment (Non-technical factors)

4.1 New initiatives

- Utility perception of PV

The KEPCO, under restructuring, separated power generation unit in 2001, and is planning to privatize these units in the near future. The KEPCO and power generating companies have co ntinu-
ously had an interest in the PV, through the direct involvement in the construction of PV plant i n remote islands and the related technology development on grid-connection of PV.

- Change in public perceptions of PV

The public acceptance for the PV has been slowly increasing due to its environment friendlines s. The number of individuals who apply for the installation of rooftop PV systems with financial support from the government and local authorities is much increased. The KEMCO and the KI ER have been providing various informations to all the parties including the general public. Dur ing the year 2002, several conferences, exhibitions and other events held in Korea contributed to raise the public perception of PV. Among them, the solar toy car and BIPV design competiti on targeted for high school boys and university students, respectively, attracted much attention from mass media. These events were held in parallel with the APEC new & renewable energy exhibition in Seoul, in October 2002.

- Major new projects or initiatives

In the year 2002, the government allocated much more budgets for demonstration and local energy development projects encouraging PV installation. Selected several enterprises and individuals could benefit this projects by receiving government/local authorities subsidies in constructing rooftop residential PV systems. The MOCIE announced the buy-back scheme in May 2002, a few months earlier than the announcement of “Solar Land 2010 Program”. The feed-in-tariff for PV electricity is 716.4 won/kWh, but the buy-back scheme is applicable only to a PV system with a capacity larger than 3 kW. This tariff is about 15 times higher than the average trading price of 48.8 won/kWh. It is also noticeable that the tariff for PV electricity is highest among all the renewable electricity.
In July 2002, the Korean Ministry of Commerce, Industry and Energy (MOCIE) opened to the p ublic “Solar Land 2010 Program” which aims at the acceleration of R&D and dissemination of PV power systems in Korea and fostering PV as a new exporting industry as well. The key of t he program is to install 30,000 rooftop PV systems of 3 kW capacity until the year 2010.

4.2 Indirect policy issues

International environmental issue such as “The Framework Convention on Climate Change” h as, until now, no tangible effects on the PV market. Taken into consideration the reality that th e energy sector is responsible for the major part of the greenhouse gas emissions in Korea, it i

s inevitable to accelerate the use of clean energy. Therefore, these issues will undoubtedly ha ve a great impact on the promotion of PV market in the near future.

4.3 Standards and codes

There are 17 Korean Standards (KS) related to the qualification of PV components such as sol ar cells and modules, battery, power conditioner, and one of them is related to the performanc e evaluation of stand-
alone systems. However, there are no specific standards or technical regulations available for grid-connected PV system construction and operation. Before starting the dissemination of 3- kW rooftop PV system, all related laws and regulations should be examined in detail and revis ed. The KIER and the KERI are entrusted with this project from the MOCIE starting from the e nd 2001.

5 Highlights and prospects

The “Solar Land 2010 Program”, which was announced in July 2002, intends to enhance the in stallation target with the long-
term vision. So, the installation target was set to be 10,000 systems until 2006, 20,000 system s until 2008 and 30,000 until the year 2010. As a preparatory step for its implementation, the g overnment allocated much more budgets for demonstration and local energy development proj ects encouraging PV installation in the year 2002,
One PV cell company, Photon Semiconductor & Energy, disclosed its plan to increase its prod uction capacity to 5 MW/shift during the year 2003. One new company named ATS Solar Syst ems has completed PV module manufacturing line in the end of 2002 with an annual productio n capacity of 1.5 MW/shift in order to enter into PV market starting from the year 2003.

Annex A Method and accuracy of data

All data on installed power, industry status and budgets were obtained from manufacturers, ins tallers, the government and local authorities. To manufacturers and installers a questionnaire was sent. Because the data to collect and the data sources were limited, there was nearly littl e possibility of data missing or double counting. The accuracy of data is ± 5 % for the installed PV capacity and the cell/module production. Data on R, D & D funding are correct. The numbe r of labour places is estimated from the information collected from many sources.