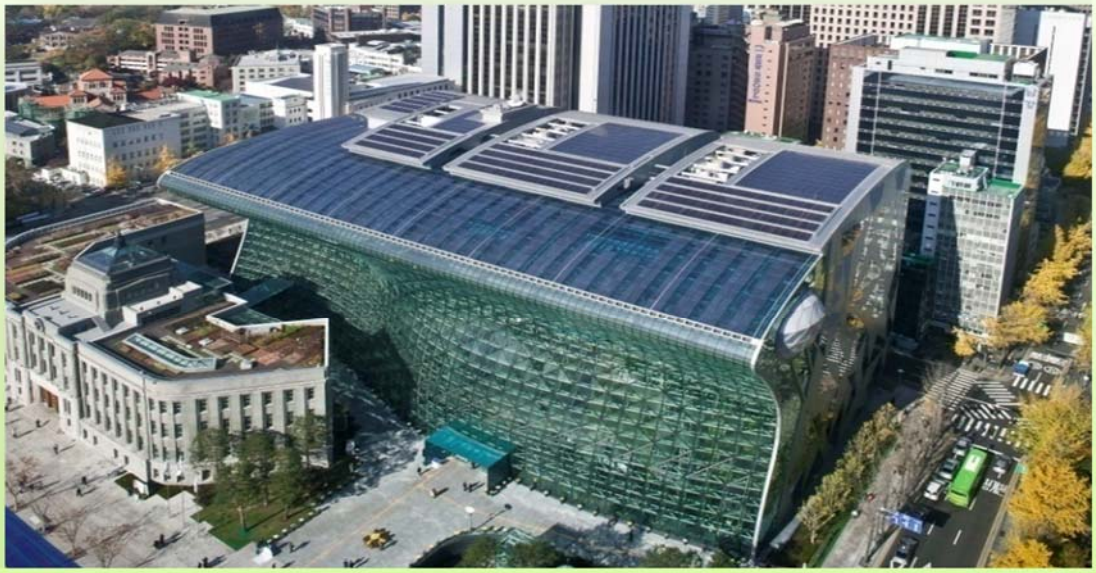
IEA INTERNATIONAL ENERGY AGENCY

National Survey Report of PV Power Applications in Korea 2015



PVPS

PHOTOVOLTAIC POWER SYSTEMS PROGRAMME

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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 member countries.

The IEA Photovoltaic Power Systems Technology Collaboration 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 participating countries and organisations can be found on the www.iea-pvps.org website.

The overall programme is headed by an Executive Committee composed of one representative from each participating country or organization, 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.

Introduction

The objective of Task 1 of the IEA Photovoltaic Power Systems Programme is to promote and facilitate the exchange and dissemination of information on the technical, economic, environmental and social aspects of PV power systems. Task 1 activities support the broader PVPS objectives: to contribute to cost reduction of PV power applications, to increase awareness of the potential and value of PV power systems, to foster the removal of both technical and non-technical barriers and to enhance technology co-operation. An important deliverable of Task 1 is the annual "*Trends in photovoltaic applications*" report. In parallel, National Survey Reports are produced annually by each Task 1 participant. This document is the country National Survey Report for the year 2015. Information from this document will be used as input to the annual Trends in photovoltaic applications report.

The PVPS website www.iea-pvps.org also plays an important role in disseminating information arising from the programme, including national information.

1 INSTALLATION DATA

The PV power system market is defined as the market of all nationally installed (terrestrial) PV applications with a PV capacity of 40 W or more. A PV system consists of modules, inverters, batteries and all installation and control components for modules, inverters and batteries. Other applications such as small mobile devices are not considered in this report.

For the purposes of this report, **PV installations are included in the 2015 statistics if the PV modules were installed and connected to the grid between 1 January and 31 December 2015, although commissioning may have taken place at a later date**.

1.1 Applications for photovoltaics

In Korea, photovoltaic system is mainly applied to the electric power generation.
Since the record-breaking year of 2008, that saw 276 MW of PV installations, the PV market remained stagnant in the next three years. This was mainly due to the limited FiT scheme which played initially an important role in the PV market expansion. However, 230 MW in 2012, 531 MW in 2013, 909 MW in 2014, and finally 1 011 MW in 2015, respectively, were installed, reaching the highest level of installations so far. Thanks mainly to the newly introduced RPS scheme (with PV set-aside requirement), the market started to react in 2013 and continued its development until 2015. At the end of 2015, the total installed capacity was about 3,5 GW, among those the grid-connected centralized system accounted for around 87,6% of the total cumulative installed power. The grid-connected distributed system amounted to around 12,4% of the total cumulative installed PV power. The share of off-grid non-domestic and domestic systems has continued to decrease and represents less than 1% of the total cumulative installed PV power. The total capacity of 3492,8 MW corresponds to 3.58% of total electricity generation capacity of about 97,649 GW, and the installed PV power of 1 011 MW in 2015 accounts for 22,8% of total power generation capacity newly installed in 2015, as can be seen in Table 3.

1.2 Total photovoltaic power installed

Table 1 shows the PV power installed in four sub-markets during 2015.

The annual installation data was obtained from the total capacity of the PV systems approved to install in the year of 2015 by the NREC (New & Renewable Energy Centre) at KEA (Korea Energy Agency). Small scale installations for off-grid domestic and non-domestic applications are not accurately monitored by the NREC, introducing some errors in the data of the tables. In Korea, PV installation statistics is categorized into two sectors, PV for “business” or PV for “self-use.” Thus in the tables, “grid-connected distributed” or “BAPV” is assumed as “self-use,” and “grid-connected centralized” or “ground-mounted” is assumed as “business.” Data for 2015 are the best estimated values as of August 31st, 2016. The electricity statistics data were taken from the “KEPCO (Korea Electric Power Corporation) in Brief,” published on May 4th, 2016.

Table 1: PV power installed during calendar year 2015

AC			**MW installed in 2015 (mandatory)**	**MW installed in 2015 (optional but HIGHLY NEEDED)**	**AC or DC**
Grid-connected	BAPV	Residential	87,233 MW		DC
		Commercial			
		Industrial			

	BIPV (if a specific legislation exists)	Residential			
		Commercial			
		Industrial			
	Ground-mounted	cSi and TF	924,239 MW		DC
		CPV			
Off-grid		Residential			
		Other			
		Hybrid systems			
		Total	1 011,472 MW		

Table 2: Data collection process

If data are reported in AC, please mention a conversion coefficient to estimate DC installations.	Data are reported in DC
Is the collection process done by an official body or a private company/Association?	Korea Energy Agency (KEA)/Korea Electric Power Corporation (KEPCO)/Korea Energy Economics Institute (KEEI)/Korea Photovoltaic Industry Association (KOPIA)/Korea Institute of Energy Technology Evaluation and Planning (KETEP)
Link to official statistics (if this exists)	www.energy.or.kr www.kepco.co.kr www.keei.re.kr www.kopia.asia www.ketep.re.kr
	Installation data are mainly collected from KEA; electricity data are mainly collected from KEPCO and KEEI; industry data are mainly collected by KOPIA; R&D data are mainly collected by KETEP

Table 3: PV power and the broader national energy market

MW-GW for capacities and GWh-TWh for energy	2015 numbers	2014 numbers
Total power generation capacities (all technologies)	97 649 MW	93 216 MW
Total power generation capacities (renewables including hydropower)	12 120 MW	10 941 MW
Total electricity demand (= consumption)	483 655 GWh	477 592 GWh

New power generation capacities installed during the year (all technologies)	4 433 MW	6 247 MW
New power generation capacities installed during the year (renewables including hydropower)	1 179 MW	968 MW
Total PV electricity production in GWh-TWh	3 598 GWh	2 556 GWh
Total PV electricity production as a % of total electricity consumption	0,74	0,54

Table 4: Other information

	2015 Numbers
Number of PV systems in operation in your country (a split per market segment is interesting)	Electricity Business : 924,2 MW Self-use : 87,2 MW (Residential : 21 MW, Buildings : 6 MW, Regional : 14 MW, Convergence : 5 MW, Public : 33 MW, RPS : 924 MW, Rental : 8 MW)
Capacity of decommissioned PV systems during the year in MW	Not monitored yet: Plan to keep track of decommissioned PV systems in Korea from 2017
Total capacity connected to the low voltage distribution grid in MW	
Total capacity connected to the medium voltage distribution grid in MW	
Total capacity connected to the high voltage transmission grid in MW	

Table 5: The cumulative installed PV power in 4 sub-markets

Sub-market	Stand-alone domestic	Stand-alone non-domestic	Grid-connected distributed (Self-use)	Grid-connected centralized (Business)
~2002	0	0	5,416	0
2003	0	0	563	0
2004	0	0	2,315	0,238
2005	0	0	3,766	1,224
2006	0	0	13,251	9,071
2007	0	0	16,505	28,842
2008	0	0	16,555	259,110
2009	0	0	24,181	142,657
2010	0	0	34,295	92,350
2011	0	0	35,835	42,983

2012	0	0	62,180	232,978
2013	0	0	63,298	467,422
2014	0	0	68,910	857,353
2015	0	0	87,233	924,239
TOTAL (MW)	0	0	434,303	3,058,467

2 COMPETITIVENESS OF PV ELECTRICITY

2.1 Module prices

A summary of typical module and system prices is provided in the following tables. Prices shown in Table 6 and Table 8 are the calculated average values.

Table 6: Typical module prices for a number of years

Year	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**
Standard module crystalline silicon price(s): Typical (KRW/W)	7 000	4 600	4 600	4 400	4 000	3 260
Lowest prices (KRW/W)					3 900	3 020
Highest prices (KRW/W)						
Year	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
Standard module crystalline silicon price(s): Typical (KRW/W)	2 600	2 400	1 400	1 000	974	974
Lowest prices (KRW/W)	2 400	2 000	1 200	800	634	634
Highest prices (KRW/W)						
Year	**2015**					
Standard module crystalline silicon price(s): Typical (KRW/W)	974					
Lowest prices (KRW/W)	634					
Highest prices (KRW/W)						

2.2 System prices

The price of grid-connected systems varied from 1 400 KRW/W to 2 300 KRW/W depending on the type and size of installations.

Table 7: **Turnkey Prices of Typical Applications – (KRW/W)**

Category/Size	**Typical applications and brief details**	**Current prices per W**
OFF-GRID Up to 1 kW		

OFF-GRID >1 kW		
Grid-connected Rooftop up to 10 kW (residential)	Grid-connected 3 kW Rooftop systems for residential applications	1 500 ~ 2 000 KRW
Grid-connected Rooftop from 10 to 250 kW (commercial)	Grid-connected (>10 kW) systems for commercial applications	2 200 ~ 2 300 KRW
Grid-connected Rooftop above 250 kW (industrial)		
Grid-connected Ground-mounted above 1 MW		
Other category existing in your country (hybrid diesel-PV, hybrid with battery…)	Grid-connected Ground-mounted 30 kW systems for electricity business applications	1 400 ~ 2 000 KRW

Table 8: National trends in system prices (current) for different applications – (KRW/W)

Price/Wp	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**
Residential PV systems < 10 KW	14 300	13 700	12 000	9 800	8 550	8 400	6 662
Commercial and industrial							
Ground-mounted							
Price/Wp	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
Residential PV systems < 10 KW	5 850	5 060	4 000	3 000	3 000	3 000	1 750
Commercial and industrial						2 900	2 250
Ground-mounted					2 400	2 120	1 700

2.3 Cost breakdown of PV installations

2.3.1 Residential PV System < 10 kW

Table 9: Cost breakdown for a residential PV system – local currency

Cost category	Average (KRW/W)	Low (KRW/W)	High (KRW/W)
Hardware			
Module			
Inverter			
Other (racking, wiring…)			
Soft costs			
Installation			
Customer Acquisition			

Profit			
Other (permitting, contracting, financing…)			
Subtotal Hardware			
Subtotal Soft costs			
Total			

2.3.2 Utility-scale PV systems > 1 MW

Table 10: Cost breakdown for a utility-scale PV system – local currency

Cost Category	Average (KRW/W)	Low (KRW/W)	High (KRW/W)
Hardware			
Module			
Inverter			
Other (racking, wiring, etc.)			
Soft cost			
Installation Labor			
Customer acquisition			
Profit			
Other (contracting, permitting, financing etc.)			
Subtotal Hardware			
Subtotal - Soft cost			
Total Installed Cost			

2.4 Financial Parameters and specific financing programs

Table 11: PV financing scheme

Average rate of loans – residential installations	3,7 ~ 4,0 %
Average rate of loans – commercial installations	3,7 ~ 4,0 %
Average cost of capital – industrial and ground-mounted installations	3,7 ~ 4,0 %

Table 11a: PV financing scheme – specific scheme in Korea

Description of a specific PV financing scheme (leasing, renting…)	Capital subsidy program (NRE loan) is aimed at tackling the up-front cost barrier, either for specific equipment for NRE use or facilities for NRE products, with low interest rate (typically 1.75% variable), grace period option (1 to 5 years) and amortization option. This subsidy loan can be used for financing facilities (installation, renovation, etc.), production funds as well as working capital.

2.5 Specific investments programs

Third Party Ownership (no investment)	
Renting	
Leasing	
Financing through utilities	
Investment in PV plants against free electricity	
Crowdfunding (investment in PV plants)	
Other (please specify)	

2.6 Additional Country information

Table 12: Country information

Retail Electricity Prices for an household (range)	123,69 KRW/kWh on the average
Retail Electricity Prices for a commercial company (range)	130,46 KRW/kWh on the average
Retail Electricity Prices for an industrial company (range)	107,41 kRW/kWh on the average
Population at the end of 2014 (or latest known)	50 431 100 as of June, 2015
Country size (km^2)	100 283 as of 2014
Average PV yield (according to the current PV development in the country) in kWh/kWp	1 314 kWh/kWp
Name and market share of major electric utilities.	KEPCO (100%)

3 POLICY FRAMEWORK

This chapter describes the support policies aiming directly or indirectly to drive the development of PV. Direct support policies have a direct influence on PV development by incentivizing or simplifying or defining adequate policies. Indirect support policies change the regulatory environment in a way that can push PV development.

3.1 Direct support policies for PV installations

3.1.1 New, existing or phased out measures in 2015

3.1.1.1 Description of support measures excluding BIPV, and rural electrification

Various incentives have been used to support PV development. The "Fourth Basic Plan for the Promotion of Technological Development, Use, and Diffusion of New and Renewable Energy (NRE)" based on the "Second Basic National Energy Plan" was still effective in 2015. This plan has the NRE target of 11% on primary energy basis by 2035 and NRE electricity target of 13.4% by 2035. In particular, among NRE sources, the portion of waste energy will decrease from 68.4% in 2012 to 29.2% in 2035, while PV will increase from 2.7% in 2012 to 14.1% in 2035, and wind power will increase from 2.2% in 2012 to 18.2% in 2035. In terms of NRE electricity mix, PV is expected to occupy 22% by 2035. To achieve these ambitious goals, the plan includes many subsidy measures including the development of "Eco-friendly Energy Towns," "Energy-independent Islands" and "PV Rental Programs." The RPS scheme launched in 2012 will be active until 2024 with the final NRE power generation goal of 10% by the obligators.

<Subsidy Programs for Power Business Facilities>

RPS Programme

The RPS is a mandated requirement that the electricity utility business sources a portion of their electricity supplies from renewable energies. In Korea, 18 obligators (electricity utility companies with electricity generation capacity of 500 MW or above) are required to supply 10% of their electricity from NRE sources by 2024, starting from 2% in 2012. The PV set-aside requirement was set to be 1,5 GW by 2015, and the goal was surpassed. In 2015 alone, about 924 MW (cumulative 2 361 MW) was installed under this programme. In a cumulative amount, about 68% of the total PV installations in Korea was made under RPS scheme, while total 497 MW (about 14%) was installed under FiT programme which was ended in 2011. The RPS is expected to be the major driving force for PV installations in the next few years in Korea with improved details such as boosting the small scale installations (less than 100 kW size) by adjusting the REC and multipliers, and unifying the PV and non-PV markets.

<Subsidy Programs for Privately-owned Facilities>

Home Subsidy Programme

This programme was launched in 2004 that merged the existing 100 000 rooftop PV system installation programme, and it aims at the construction of one million green homes utilizing PV as well as solar thermal, geothermal, small-size wind, fuel cells and bio-energy until 2020. In general, single-family houses and multi-family houses including apartments can benefit from this programme. The Government provides 60% of the initial PV system cost for single-family and private multi-family houses, and 100% for public multi-family rent houses. The maximum PV capacity allowed for a household is 3 kW. In 2015, total 21 MW PV systems were installed for 12 676 households with the budget of 18 218 million KRW under this programme.

Building Subsidy Programme

The Government supports up to 50% of the installation cost for PV systems (below 50 kW) in buildings excluding private homes. In addition, the Government supports 80% of initial cost for special purpose demonstration and pre-planned systems in order to help the developed

technologies and systems to diffuse into the market. In 2015, the budget spent for PV in this program was 8 170 million KRW, and total 299 buildings (6 MW) benefited from this programme. Various grid-connected PV systems were installed in schools, public facilities, welfare facilities as well as universities.

NRE Mandatory Use for Public Buildings

The new buildings of public institutions, the floor area of which exceeds 1 000 square meters, are obliged by law to use more than 15% (in 2015) of their total expected energy from newly installed renewable energy resource systems. Public institutions include state administrative bodies, local autonomous entities, and state-run companies. The building energy mandate percentage will increase up to 30% by 2020. Total 33 MW PV systems were installed by this programme in 2015.

Regional Deployment Subsidy Programme

The government supports up to 50% of installation cost for NRE (including PV) systems owned or operated by local authorities. In 2015, the budget spent for PV in this program was 22 684 million KRW, and total 247 projects (14 MW) were supported from this programme.

PV Rental Programme

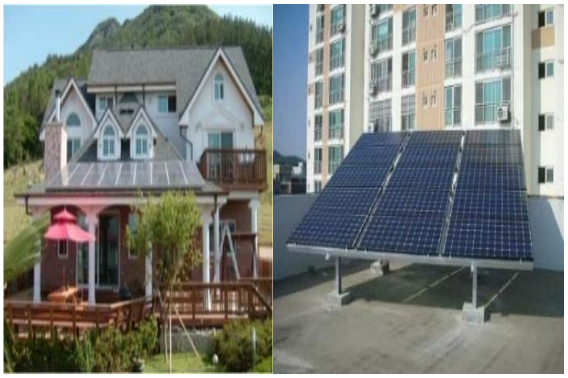
In 2013, MOTIE (through KNREC) introduced this new scheme to promote PV deployment and launched a few demo projects for 60 detached houses. The PV Rental program fully began since 2014. It is designed in such a way that the private companies take care of installations and after-services without government support, while consumers pay the PV rental fee. Household owners of using more than 350 kWh (monthly average) electricity can apply for this program. Owners pay PV system rental fee (monthly maximum: 70 000 KRW) which is on the average less than 80% of the electricity bill) for minimum 7 years and can use the PV system with no initial investment and no O&M cost for the rental period. PV rental companies recover the investment by earning PV rental fee from the households and selling REP (Renewable Energy Point) having no multiplier. Rental fee, rental period, REP price are properly set to motivate the participation of PV rental companies and consumers. In 2015, 8,6 MW PV systems (8 796 households) was installed by 6 participating companies under this programme.

<Comparison between PV subsidy program and PV rental program>

	PV Subsidy Program	**PV Rental Program**
Government Subsidy	Certain portion of the Installation cost	No support
Consumer Expense	Certain portion of the installation cost	Rental fee
Leasing Company	Installation cost	Rental fee+REP sales income
Ownership	Household	Leasing company (Transfer of ownership to consumers after the contract period)

<Annual target of PV rental program>

Year	**2013**	**2014**	**2015**	**2016**	**2017**
Households	60 (Result)	2 007 (Result)	8 796 (Target)	7 500 (Target)	10 000 (Target)

	Detached houses only	Detached houses and apartments
		

Convergence and Integration Subsidy Program for NRE

This is a new NRE subsidy program started in 2013. A consortium led either by local authority or public institution with NRE manufacturing companies and individuals can apply for this subsidy program. This program is designed to help diffuse the NRE into socially disadvantaged and vulnerable regions and classes such as islands, remote areas (not connected to the grid), long-term rental housing district, etc. Local adaptability is one of the most important criteria, thus the convergence between various NRE resources (PV, wind, electricity and heat) and the complex between areas (home, business and public) are primarily considered to benefit from this program. Total 5 MW of PV systems was installed in 2015 with the 6 873 million KRW budget spent for 717 projects.

<Subsidy Programs in Common>

Capital Subsidy (NRE Loan) Programme

This program is aimed at tackling the up-front cost barrier, either for specific equipment for NRE use or facilities for NRE products. KEA (Korea Energy Agency, formerly KEMCO) through KNREC (Korea New & Renewable Energy Center) evaluates the proposal from the companies and provide the financing fund to participating financial institutions such as banks, and the participating banks lend money to the companies with low interest rate (typically 1.75% variable), grace period option (1 to 5 years) and amortization option. This subsidy loan can be used for financing facilities (purchase, installation, upgrade, etc), production funds as well as working capital. In 2016, total budget of 100 029 million KRW was allocated for NRE, and about 60% of the loan was provided for PV.

Investment Tax Credit

This program is aimed at promoting the energy savings for individuals and companies, and provides exemption of tax for the investment of energy-saving facilities (including NRE facilities). This programme will last until the end of 2016. Small-size enterprises get 6% tax exemption, medium-size enterprises get 3% tax exemption, and Korean national individuals get 1% tax exemption.

3.1.1.2 BIPV development measures

REC multiplier for BIPV installations

A government level discussion is on the way to provide the REC multiplier (greater than 1.0) for BIPV installations, and a new subsidy measure is expected to be introduced from 2017.

Zero Energy Building (ZEB) demonstration projects

The Ministry of Land, Infrastructure and Transport (MOLIT) launched the five nearly (greater than 90% self-support) ZEB demonstration projects in December, 2014 and is actively continuing total seven projects (5 residential and 2 commercial) in 2015 using both passive and active ingredients. Maximum 30 to 50% of the NRE installation cost is supported by the Government, and the building

owners get 15% tax (acquisition and property taxes) exemption for 5 years. The MOLIT has a plan to make the nearly ZEB as a mandatary requirement for all new buildings constructed since 2020 starting from the public buildings.

3.1.1.3 Rural electrification measures

Rural electrification measures are adopted and implemented mainly by the local authorities in Korea. For example, Incheon city implemented a project, installing PV power of 250 kW, small size (10 kW) wind power of 40 kW, energy storage of 1 125 kW in Backa island, and finished the project at the end of 2014 to make the island carbon-free. Similarly, PV power of 120 kW and wind power of 30 kW were installed in Jungma island, which will provide 388 000 kWh electricity annually. 1 200 kWh size ESS (Energy Storage System) was also installed, and the diesel power is now serving as the supplementary power for the island. These types of measures and programs are being gradually expanded by the most local governments in Korea. Energy-independent Islands project was jointly planned by central government and Gyeongbuk provincial government in 2014 and was launched in 2015 for Ulleungdo island, and will be expanded to more islands in Korea. Wind power, PV, geothermal and ESS will be combined to increase the NRE portion in Ulleungdo island from 3.6% in 2014 to 68% in 2017. 30 MWh ESS will be installed by 2017.

<u>Eco-friendly Energy Town Programme</u>

A new demo program has been launched by the Korean government (MOTIE, MOE and MSIP) in 2014 for three regions (Gwangju (MOTIE), Hongcheon (MOE) and Jincheon (MSIP)) of deploying the eco-friendly energy generation facilities to the avoiding facilities or sites such as waste incinerators and waste landfill sites. The Korean government has a plan to strengthen and expand this program into whole nation since 2015 by improving the program details from the lessons learned from the demo program.

<Eco-friendly energy town program contents>

Site	Program Contents
Hongcheon, Gangwon Province (MOE)	Recycling of animal and food wastes into biogas or fertilizer and reuse & sale; installation of 340 kW PV and 25 kW small-size hydro power in waste water treatment sites
Woonjeong, Gwangju City (MOTIE)	Installation of 20 MW PV in waste landfill sites; green villages (PV and solar thermal); new & renewable energy experience centre
Jincheon, Choongbuk Province (MSIP)	Installation of 950 kW PV and 10 kW fuel cell in waste water treatment sites; storage and reuse of solar thermal, geothermal and waste water thermal energy as heating source for winter season by using seasonal thermal energy storage system

3.1.1.4 Support for electricity storage and demand response measures

Korean government (MOTIE) launched the smart grid test-bed project in September, 2012 in Jeju island and invested 76,6 billion KRW (total 249,5 billion KRW including the 172,9 billion KRW investment from the private sector). The project ended in May, 2013, and it aimed at verifying the energy systems integration technology using smart metering devices. The project also aimed at developing business models for commercialization. The 2nd phase smart grid diffusion project is designed in 2014 and expected to be launched in 2016.

Table 13: PV support measures (summary table)

	On-going measures residential	Measures that commenced during 2015 - residential	On-going measures Commercial + industrial	Measures that commenced during 2015 – commercial + industrial	On-going measures Ground-mounted	Measures that commenced during 2015 – ground mounted
Feed-in tariffs	Ended as of 2011F					
Feed-in premium (above market price)						
Capital subsidies	√		√		√	
Green certificates						
Renewable portfolio standards (RPS) with/without PV requirements	√		√		√	
Income tax credits	√		√		√	
Self-consumption						
Net-metering						
Net-billing						
Commercial bank activities e.g. green mortgages promoting PV						
Activities of electricity utility businesses	√		√		√	
Sustainable building requirements	√		√		√	
BIPV incentives						
Other (specify)						

3.2 Self-consumption measures

. Mandatory

PV self-consumption	1	Right to self-consume	
	2	Revenues from self-consumed PV	
	3	Charges to finance Transmission & Distribution grids	

Excess PV electricity	4	Revenues from excess PV electricity injected into the grid	
	5	Maximum timeframe for compensation of fluxes	
	6	Geographical compensation	
Other characteristics	7	Regulatory scheme duration	
	8	Third party ownership accepted	
	9	Grid codes and/or additional taxes/fees impacting the revenues of the prosumer	
	10	Regulations on enablers of self-consumption (storage, DSM…)	
	11	PV system size limitations	
	12	Electricity system limitations	
	13	Additional features	

3.3 Tenders, auctions & similar schemes

3.4 Direct Support measures

Opening of Negawatt Electricity Market

MOTIE announced the opening of DRR (Demand Response Resource) electricity trading market as of November 25, 2014 by approving the revision of 'Electricity Trading Market Operating Rules' on Oct. 3, 2014. This so-called 'Negawatt Electricity Market' was launched as one of 'the Six Energy-related New Industry Development Plan for Climate Change Response.' Now new businesses for trading saved electricity are expected to grow more since 2016.

3.5 Financing and cost of support measures

The cost of PV incentives in Korea is mainly covered by the central and regional governments (tax payers' money). Some costs are covered by the 18 RPS obligators indirectly affecting the electricity prices.

3.6 Indirect policy issues

International Policies Affecting the Use of PV Power Systems

Worldwide effort to reduce the greenhouse gas emissions led by the COP is indirectly affecting the use of PV power systems in Korea. The INDC (Intended Nationally Determined Contributions) of Korea is targeted at 37% (25.7% domestic; 11.3% from abroad) reduction (on BAU basis) in greenhouse gases by 2030, which was announced in COP21 in Paris, 2015.

Introduction of Favourable Environmental Regulation (Cap & Trade System)

The Cap & Trade system was introduced in Korea since January 1st, 2015. The greenhouse gas (GHG) emissions allowance for the first phase (2015-2017) is set at 1,687 billion CO_2 ton, defined as KAU (Korean Allowance Unit: 1 CO_2 ton). 1,598 billion KAU is allowed by companies before launching the Cap & Trade system, and 0,89 billion KAU is allowed during the first phase as spare amount. 573 460 million KAU for 2015, 562 180 million KAU for 2016, and 550 900 million KAU for 2017 will be allowed

as the total emissions in Korea. In the industry sectors, 730 850 million KAU for power plants and energy industry, 357 600 million KAU for steel industry, 143 700 million KAU for petrochemical industry, and 128 000 million KAU for cement industry are allowed. The Korean Ministry of Environment (MOE) announced the total 526 companies including POSCO steel company which will be subjected to the Cap & Trade system for the first phase in September, 2014.

KOICA (Korea International Cooperation Agency)'s ODA (Official Development Assistance) Projects

KOICA has several programs to assist and aid in installing new & renewable energy (NRE) facilities to non-IEA countries. These programs are launched to participate in the worldwide effort (e.g. UNFCCC) to mitigate and control the world's climate changes. The objective of the programs includes international collaborative actions to promote low-carbon green growth of East-Asian countries and technical support in NRE application sectors for developing countries. The countries benefited from these programs include Mongolia, Ghana, Morocco, Egypt, Tunisia, Bolivia, Ecuador, Uzbekistan and Iraq.

2030 Energy-related New Industry Development Plan

Korean government announced '2030 Energy-related New Industry Development Plan for Climate Change Response' on November 23, 2015. It is the five-year plan with detailed action items targeting specific goals for 2030 to achieve the Korea's INDC of 37% GHG reduction (on BAU basis). By 2030, Korean government plans to generate 100 trillion KRW new market, 500 000 new employments and 55 million tons of GHG reduction from the energy-related new industries. Key contents of the plan are listed below.

<Contents of 2030 Energy-related New Industry Development Plan>

Category	Contents
Energy Prosumer (12.8% of Power Generation)	Micro-Grid, Demand Resource Market (Nega-Watt Market), ZEB, Eco-friendly Town, Energy-independent Islands, Solar PV Home, etc.
Low Carbon Power Generation (40% of Coal Power Plants)	NRE Power Generation, Supercritical CO_2 Power Generation, Large-scale Gas Turbine, CCS, HVDC Transmission, Superconducting Cables, ESS, etc.
Electric Vehicle (1 million)	Battery Lease, Charging Service, Electric Car/Motocycle/Bicycle, Utilization of Waste Battery, Electric Vehicle Insurance, etc.
Eco-friendly Processes	Smart Factory (40 000), Hydrogen-reduced Steel Manufacturing, Eco-friendly Refrigerant, Waste Hot Water Utilization from Power Plant, LNG Cold Heat, etc.

4 HIGHLIGHTS OF R&D

4.1 Highlights of R&D

Although official statistics for national PV R&D budget was not released for 2014 and 2015, total PV R&D budget is estimated to be close to 200 billion KRW. Since 2008, Korean government has promoted the NRE development extensively under the slogan of "Green and Strong Nation," and government-led R&D programs have been consistently launched. Annual averaged growth of PV R&D budget for the period of 2009-2013 was 8.7%, which was similar to that in other sectors of national R&D. However, after peaking at 224,9 billion KRW in 2011, PV R&D budget started to decrease slightly each year due partly to the recession of worldwide PV market.

Total eight Korean ministries were involved in planning and managing the national PV R&D projects. The majority of PV R&D budget was managed by MOTIE and MSIP, and the rest was managed by other six government entities including Small and Medium Business Administration (SMBA) and Ministry of Education (MOE).

KETEP (Korea Institute of Energy Technology Evaluation and Planning) controls the biggest portion of the MOTIE-led national PV R&D budget and managed about 416 billion KRW for the period of 2008~2015 for total 427 short-term and mid/long term projects. About 51,2 billion KRW was invested in PV R&D through KETEP in 2015.

Below are the summaries of PV R&D projects operated by KETEP from 2008 to 2014 and the scope of national PV R&D. Major achievements from the national PV R&D projects are also highlighted below.

<Summary of national PV R&D of KETEP>

Year		2008	2009	2010	2011	2012	2013	2014	Total
Number of Projects (ea)	Short-term	26	32	54	67	49	39	33	300
	Mid/Long term	13	8	13	22	26	24	21	127
	Total	**39**	**40**	**67**	**89**	**75**	**63**	**54**	**427**
Government Budget (billion KRW)	Short-term	11,814	21,185	29,879	29,014	20,707	15,350	16,165	144,114
	Mid/Long term	44,863	11,100	19,584	47,759	56,577	48,246	43,490	271,619
	Total	**56,677**	**32,285**	**49,463**	**76,773**	**77,284**	**63,596**	**59,655**	**415,733**

The national PV R&D budget managed by KETEP increased dramatically in 2008 to more than 56 billion KRW compared to that of less than 10 billion KRW in 2007. This increased PV R&D budget initially concentrated on developing crystalline Si solar cells (14,781 billion KRW (46%) in 2009). The scope of PV R&D then expanded to a broader spectrum, reducing the Si solar cell related R&D (20,910 billion KRW (35%) in 2014), while increasing the thin film related R&Ds. The objectives of PV R&D also shifted from initially the solar cell focused R&D to a wider spectrum including R&Ds for PV systems, PV electricity generation and various PV applications in order to facilitate the diffusion of PV dissemination.

The government-led PV R&D initiatives generated several noticeable outcomes. Breakthrough and core technologies essential to various types of solar cells were developed, and Korean-made polysilicon manufacturing technology was acquired. Especially, the Korean-made polysilicon manufacturing technology was transferred to the mass production of polysilicon in Korea. Currently the market share of Korean-made polysilicon is among the top 3 in the world, and the export of Korean-made polysilicon is continuously increasing due to its high quality and cost-competitiveness.

PV inverters for grid connection was also developed from the national PV R&D, and these inverters are designed and fabricated in Korea and now are being used in the PV system installations in Korea. The rapidly changing global PV market situation due to oversupply of PV-related products (mostly originated from aggressive market entry by Chinese products) caused the change in Korean PV R&D support. In particular, the projects aiming to secure the economic competitiveness of PV system as a whole have been recently launched to reduce the LCOE (Levelized Cost of Energy). These projects are targeted to search for various types of business models to expand the PV arena. International joint R&D and demonstration projects were also launched, and a joint project for demonstrating the stand-alone grid PV systems was launched in August, 2015 with the State of Hawaii (having MOU signed between Hawaii and Korea), which utilizes the technologies developed in Korean islands.

Below is the summary of major achievements from KETEP's PV R&D.

<Major achievements from KETEP's PV R&D Programs>

Subject	**Major Achievements**
Polysilicon manufacturing and mass production technology	Acquisition of Korean-made, turn-key polysilicon mass production technology *OCI: World's top 3 in the production capacity - 52,000 ton/yr
Development of 150 ㎛ thick crystalline silicon solar cells	Acquisition of Korean-made fabrication equipment and materials technology *Cell sorter, Laminator, Tabbing & Stringer, EVA film
Development of PV inverters for grid connection	Acquisition of Korean-made design and fabrication technology *Commercialization and entry into both domestic and global market
Development of PV modules for desert applications	100 kW system in demonstration in the middle-eastern countries such as Oman and Saudi Arabia
Commercialization of DSC (Dye-Sensitized Solar Cell) modules	Acquisition of world's best DSC module reliability and core technologies for BIPV applications *Korean-made fabrication equipment and core materials; acquisition of mass production technologies
Development of stand-alone grid PV systems and demonstration of 100 kW PV power plants	Two 100 kW demo R&Ds are at one domestic site and at one foreign site targeting the emerging PV markets in USA (Hawaii, California, etc.) and south-east Asian countries. The project will be accomplished in 2017.

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

Table 14: Public budgets for R&D, demonstration/field test programmes and market incentives.

	R&D	**Demo/Field test**
National/federal		
State/regional		
Total		

5 INDUSTRY

5.1 Production of feedstocks, ingots and wafers (crystalline silicon industry)

Table 15: Production information for the year for silicon feedstock, ingot and wafer producers

Manufacturers (or Total National Production)	Process & Technology	Total Production	Product Destination (if known)	Price (if known)
OCI	polysilicon (Siemens)	52 000 ton	Mainly to China	Around 18 USD /kg in a spot price
Hankook Silicon	polysilicon (Siemens)	15 000 ton	-	-
Hanwha Chemical	polysilicon (Siemens)	13 000 ton	-	-
Samsung MEMC Polysilicon (SMP)	polysilicon (FBR)	13 000 ton	-	-
Total	**Polysilicon Feedstock**	**93 000 ton**		
SKC Solmics	mc-Si ingots	150 MW	-	-
Woongjin Energy	sc-Si ingots	1 000 MW	Mainly to USA	-
Nexolon	mc-Si ingots	1 750 MW	-	-
Total	**Silicon Ingot**	**2 900 MW**		
SKC Solmics	wafers	130 MW	-	-
Woongjin Energy	sc-Si wafers	500 MW	Mainly to USA	-
Nexolon	mc-Si wafers	1 750 MW	-	Below 1 USD /sheet
Total	**Silicon Wafer**	**2 380 MW**		

KCC has the polysilicon production site in Saudi Arabia. PTC, the joint venture with Saudi, has the capacity of 3 000 ton. Hanwha Q-cells is operating a 800 MW ingot and wafer capacity plant in China.

5.2 Production of photovoltaic cells and modules (including TF and CPV)

Module manufacturing is defined as the industry where the process of the production of PV modules (the encapsulation) is done. A company may also be involved in the production of ingots, wafers or the processing of cells, in addition to fabricating the modules with frames, junction boxes etc. The manufacturing of modules may only be counted to a country if the encapsulation takes place in that country.

Total PV cell and module manufacture together with production capacity information is summarized in Table 16 below.

Table 16: Production and production capacity information for 2015

Cell/Module Manufacturer (or Total National Production)	Technology (sc-Si, mc-Si, a-Si, CdTe)	Total Production (MW)		Maximum Production Capacity (MW/yr)	
		Cell	Module	Cell	Module
Wafer-based PV manufactures					
LG Electronics	sc-Si	900	900	1 000	1 000
Hyundai Heavy Industries	mc-Si	450	450	600	600
Shinsung Solar Energy	mc-Si	400	120	420	150
E&R Solar	mc-Si	80	50	200	50
DCT	mc-Si	0	0	45	0
Solarpark Korea	mc-Si	0	480	0	600
S-Energy	mc-Si	0	400	0	500
HanSol Technics	mc-Si	0	280	0	350
Luxco	mc-Si	0	180	0	200
LS IS	mc-Si	0	100	0	150
Daeyoo SE	mc-Si	0	100	0	120
SDN	mc-Si	0	80	0	100
JSPV	mc-Si	0	80	0	80
Topsun	mc-Si	0	120	0	120
T&Solar	mc-Si	0	40	0	50
Solartech	mc-Si	0	24	0	30
BJ Power	mc-Si	0	13	0	30
Solarriver	mc-Si	0	16	0	20
Kyung Won	mc-Si	0	0	0	30
Hanwha Q-cells	mc-Si	0	0	1 500	1 000
Sub Total		**1 830**	**3 433**	**3 765**	**5 180**
Thin film manufacturers					
None				0	0
Cells for concentration					
None				0	0
TOTALS		**1 830**	**3 433**	**3 765**	**5 180**

LG Electronics is offering the series “MonoX NeOn”, whose front side efficiency of commercially available bifacial cells is more than 21%. Other cell manufacturers (e.g. Shinsung Solar Energy) are focusing on PERC (Passivated Emitter Rear Contact) technology to produce high efficiency cells in mass production. On top of that, some specially designed products are promoted to win a foothold. For instance, some players have been developing and marketing the on-water PV systems and the PV modules appropriate for desert environment such as in middle-east areas.

Hanwha Q-cells started to invest in Korea to establish cell and module manufacturing plants. In addition to its existing manufacturing plants in China and Malaysia, Hanwha Q-cells built cell and module factories with annual production capacities of 1 500 MW and 1 000 MW, respectively in 2015.

Most module companies in Korea have been purchasing cells from China and Taiwan. LG Electronics is providing total in-house cells to produce its modules, and Hyundai Heavy Industries is utilizing most in-house cells to produce modules, though some cells are sold. Shinsung Solar Energy is using in-house cells, but the ratios of using in-house cells are low. Around 80% of produced modules in Korea were exported to other countries, and the main export region was Japan and USA.

Hanwha Group is operating cell and module production overseas. Hanwha Chemicals merged with Chinese company (Hanwha Solarone) and German company (Hanwha Q-cells). In 2014, these two companies merged again to form a single company (Hanwha Q-cells). With this merger and acquisition, Hanwha Q-cells became world's No. 1 in cell production capacity and No. 4 in module production capacity. Hanwha Q-cells' cells and modules are produced in China and Malaysia with the total nameplate capacities of 3 900 MW and 4 200 MW, respectively.

5.3 Manufacturers and suppliers of other components

PV inverters (for grid-connection and stand-alone systems) and their typical prices

Korean inverter players dominate local market because after sales service is important in PV inverter business. As the volume of Korean market is under expansion, however, some foreign players like Chinese companies have shown interest in Korean PV inverter market. Korean manufactures of PV inverters have increased their capacities, and the price for home system is currently below USD 800/3 kW.

Storage batteries

In Korea, LG Chemical, Samsung SDI and SK Innovation are the major developers and suppliers of ESS (Energy Storage System). While their storages are mainly based on lithium ion system, new entrants such as OCI, Lotte Chemical are developing energy storages based on vanadium-Redox flow battery.

Korean government is promoting the ESS business in Korea by designating the ESS as an energy-related new industry item. In line with that, Korean players are making attempts to combine ESS and energy management business with renewable energy supply. Accordingly, it is expected that new business models like ESS lease service will be introduced in 2016.

Battery charge controllers

DC switchgear

Supporting structures

6 PV IN THE ECONOMY

6.1 Labour places

Table 17: Estimated PV-related labour places in 2014

Research and development (not including companies)	
Manufacturing of products throughout the PV value chain from feedstock to systems, including company R&D	
Distributors of PV products	
System and installation companies	
Electricity utility businesses and government	
Other	
Total	

6.2 Business value

Table 18: Value of PV business

Sub-market	**Capacity installed *in 2014* (MW)**	**Price per W** *(from table 7)*	**Value**	**Totals**
Off-grid domestic	*X*	*Y*	*a = X x Y x 1 000 000*	
Off-grid non-domestic			*b*	
Grid-connected distributed			*c*	
Grid-connected centralized			*d*	
				a+b+c+d
Export of PV products				*e*
Change in stocks held				*f*
Import of PV products				*g*
Value of PV business				***a+b+c+d+e+f-g***

In Korea, the PV industry value chain for crystalline silicon solar cells is completely established from raw materials (polysilicon), ingot and wafers, cells, modules, systems and power plants. Among these, polysilicon production capacity is currently No. 3 in the world. The Korean-made products are mostly exported to foreign countries including China, EU, Japan and USA.

7 INTEREST FROM ELECTRICITY STAKEHOLDERS

7.1 Structure of the electricity system

Short description of the electricity industry landscape	- Vertically integrated structure - Retailers and network businesses integrated (monopoly) - Public ownership - Regulated by central government

7.2 Interest from electricity utility businesses

Since 2012, the RPS scheme started and replaced the FIT scheme which lasted until 2011. Total 18 companies including electricity generation companies, electricity generation business companies and other corporates have participated mandatorily. In 2012, only 64.7% of the first year's RPS duties were attained, while 95.7% of RPS PV set-aside amounts were attained. This caused the cost of REC (Renewable Energy Credit) for PV to drop significantly together with the fast falling PV product prices. The electricity utility businesses would like to have more PV to replace the non-PV RPS to lower the cost and fulfil their duties. This trend continued in 2015, and the REC cost dropped even further, now the REC cost is below 80 000 KRW/kW.

In the RPS scheme, REC weighting factor is introduced to balance the utilization/dissemination and promotion of technology development. In determining the PV REC weighting factors, considerations were given to address the following four issues: 1. Influence on environment, technology development and industry revitalization, 2. Cost in electricity generation, 3. Potential amount, 4. Effect on greenhouse gas emission reduction. In practice, however, there exist some mismatches and conflicts to hinder the RPS participants from fulfilling their duties. Some regions with large potential PV source have either low REC weighting factor or under strict regulation. The first year's RPS practice revealed many of these problems encountered by the electricity utility businesses. Thus Korean government decided to simplify the REC weighting factor scheme in 2014, and from 2015, the new simplified REC weighting factor scheme has been in effect.

Electricity utility businesses in general are still hesitant to participate aggressively in the PV deployment and are asking for more support from the Government. Complementary measures have been prepared in 2014 to resolve some of the issues surfaced in 2012 and 2013.

PV rental program (third party ownership) is introduced in 2014, and grew fast in 2015. A so-called "Negawatt" market was also introduced in 2014 and was fully operational in 2015. This is an electricity trade scheme not on a production or supply basis but on a saving and peak time trading basis.

KEPCO, the largest and only electricity business company in Korea, participated in many PV related activities including "Energy-independent Islands Project" and "Korea Smart-grid Project." Especially after the announcement of "2030 Energy-related New Industry Development Plan," KEPCO started to actively engage in the various NRE development and dissemination projects.

7.3 Interest from municipalities and local governments

The Capital city, Seoul has been campaigning "One Less Nuclear Power Plant for Seoul" since 2011 and conducted many programs to reduce the electricity consumption and to increase the NRE dissemination. This plan is to reduce the energy consumption in Seoul as much as 2 million toe (equivalent to the energy supplied by on nuclear power plant). As a result, Seoul's energy consumption was reduced to total 2.04 million toe as of June, 2014. Seoul revived a modified type of FIT scheme to facilitate the PV deployment in the energy production area. The second phase of "One Less Nuclear Power Plant for Seoul" began in

2015 targeting total 4 million toe reduction, and the goals involve the 20% electricity independence rate (currently 13%) of Seoul by 2020. In particular, total 40 000 mini-PV (typically 250 W) power plants in households will be installed, and citizen crowd-funded PV power plants were launched in 2015.

Chungbuk Province's slogan is "A Land of Life and Sun." In this province, more than 50% of Korean-made PV modules are produced. This province met a goal of installing 170 MW of PV power by 2013 and has a plan to construct a PV R&D hub in the province. Chungbuk Technopark is located in the neighbouring Cheongju city and actively engaged in PV module testing and certification. KIER (Korea Institute of Energy Research) is also located in the neighbouring metropolitan city, Daejeon.

The metropolitan city, Daegu is advocating "Solar City" as its slogan, and hosting many world renowned international meetings, conferences and expos. Recently, Daegu hosted "Solar City Congress," and has been regularly hosting IGEEC (International Green Energy Expo and Conference) every year. The "22nd World Energy Congress" in 2013, "7th World Water Forum" and "ISES Solar World Congress" in 2015 were held in Daegu. Solar Cell/Module RIC (Regional Innovation Centre) is located in Yeungnam University in the neighbouring Gyeongbuk province which also emphasizes Green Energy Industry as its new growth engine industry. Daegyeong PV test-bed located at GERI (Gumi Electronics & Information Technology Research Institute) also resides in Gyeongbuk Province. Gyeongbuk province chose "Energy Parts Industry" as its strategic industry for the future. Gyeongbuk province prepared a plan for "Sunlight Energy Farming" in 2014 to secure a small but regular income for rural households (relatively disadvantaged from recent FTA with foreign countries) using low interest rate fund from provincial government and REC purchasing agreement with KHNP (Korea Hydro & Nuclear Power). The project was successfully launched in 2015.

Jeonnam Province selected "NRE Industry" as one of its major leading industries of the region and has invested its resources to promote PV industry development and PV deployment. Jeonnam province has the best insolation in Korea. Honam PV test-bed at Jeonnam Technopark and KITECH (Korea Institute of Industrial Technology) Jeonnam Branch are both located in the neighbouring city, Gwangju. GEI (Green Energy Institute) is also located in the neighbouring city, Mokpo.

8 HIGHLIGHTS AND PROSPECTS

Since the record-breaking year of 2008, that saw 276 MW of PV installations, the PV market remained stagnant in the next three years. This was mainly due to the limited FiT scheme which played initially an important role in the PV market expansion. However, 230 MW in 2012, 531 MW in 2013, 909 MW in 2014, and finally 1 011 MW in 2015, respectively, were installed, reaching the highest level of installations so far. Thanks mainly to the newly introduced RPS scheme (with PV set-aside requirement), the market started to react in 2013 and continued its development until 2015. At the end of 2015, the total installed capacity was about 3,5 GW, among those the grid-connected centralized system accounted for around 87,6% of the total cumulative installed power. The grid-connected distributed system amounted to around 12,4% of the total cumulative installed PV power. The share of off-grid non-domestic and domestic systems has continued to decrease and represents less than 1% of the total cumulative installed PV power. The total capacity of 3492,8 MW corresponds to 3.58% of total electricity generation capacity of about 97,649 GW, and the installed PV power of 1 011 MW in 2015 accounts for 22,8% of total power generation capacity newly installed in 2015.

In 2015, most of the Korean PV manufacturers in all value chain sectors gained profit in their businesses, and the main exported items were polysilicon feedstocks and modules. The production capacities of Korea in each PV value chain sectors as of 2015 are 93 000 ton/yr of polysilicon feedstock, 2 900 MW/yr for silicon ingots, 2 380 MW/yr for silicon wafers, 3 765 MW/yr for silicon solar cells and 5 180 MW/yr for silicon PV modules, respectively. OCI became No. 3 in the world in polysilicon production capacity, while Hanwha Q-cells became No. 1 in Si solar cell production and No. 4 in PV module production in the world.

When it comes to Si solar cell efficiency, LG Electronics is offering the series “MonoX NeOn”, whose front side efficiency of commercially available bifacial cells is more than 21%. Other cell manufacturers (e.g. Shinsung Solar Energy) are focusing on PERC (Passivated Emitter Rear Contact) technology to produce high efficiency cells in mass production.

Hanwha Q-cells completed construction of the silicon solar cell manufacturing plant of 1.5 GW size and PV module manufacturing plant of 1.0 GW size in 2015, and started its commercial operation in 2016, expanding its business activities in Korea.

Korean government continued its support to strongly promote the PV deployment, R&D, infrastructure building and market promotion. Among these, the government-driven RPS scheme and R&D support of about 200 million KRW per year plays a major role in boosting PV deployment and technology development. KRICT (Korea Research Institute of Chemical Technology) together with UNIST (Ulsan National Institute of Science and Technology) holds the world record in perovskite solar cell efficiency (22.1%), and LG Electronics holds the world record in single junction GaAs solar cell efficiency (27.5%).

Korean government announced ‘2030 Energy-related New Industry Development Plan for Climate Change Response’ on November 23, 2015. It is the five-year plan with detailed action items targeting specific goals for 2030 to achieve the Korea’s INDC of 37% GHG reduction (on BAU basis). By 2030, Korean government plans to generate 100 trillion KRW new market, 500 000 new employments and 55 million tons of GHG reduction from the energy-related new industries. PV will take a very important role in energy-related new industry development, targeting a cumulative PV installations of 17.5 GW by 2035, which will provide 22% of total NRE generated electricity.

Various incentives have been used to support PV development. Under the Forth Basic NRE Plan, many new subsidy measures including the development of “Eco-friendly Energy Towns,” “Energy-independent Islands” and “PV Rental Programs” are launched in 2014 and implemented in 2015, and these subsidy measures and programs are expected to expand in the following years. The RPS scheme launched in 2012 will be the main driving force for PV deployment, which will be active until 2024 with the final NRE supply goal of 10% by the obligators.

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