A Comparative Study on Multi-field Applications of BMPV in the APEC Region

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Background of report

After entering 21st century, all the APEC economies have witnessed rapid social and economic development, which results in increasing demand for energy. However, their energy structures are still dominated by fossil energy, which has led to growing pressure on environment.

Meanwhile, the APEC economies are situated within the rich solar resources and favorable conditions for development of solar PV power generation. They can learn the experience from each other to increase share of new energy sources in energy consumption and optimize the energy structures to minimize emissions of greenhouse gas and environment pollution.

In the past decade, due to policy support, technical advancement and continuous investment, the global PV industry has developed rapidly, achieving highly efficiency of solar cells, multiple increase in the production capability, high reliability of PV system equipment, reduction of production costs and multi-field application. The solar PV power generation has become a full-fledged energy application technology, and has been accepted by APEC economies. These members attempt to apply PV power generation in their respective fields and make it become an important way to reduce carbon dioxide emission and achieve sustainable development.

The APEC economies are at different development stages of economy and society, so their electricity infrastructures, PV application development stages and the roadmaps are different. Based on the actual situations, APEC economies have different priorities to application and development of different PV systems which range from off-grid PV systems for rural electrification in remote areas without access to electric grid or for the island areas which are not served by the electricity grid or suffer from shortage of electricity due to lack of electric grid infrastructures, distributed PV home systems to large-scale centralized grid-connected PV systems. Despite of this, how to increase share of solar PV power generation is the common goal of the APEC economies.

Centralized grid-connected PV systems are the main form of the PV power generation technology. They are installed on ground, occupy land and require a grid with strong transmitting capacity to supply electricity to users. Thus, to some extent, their application is constrained by transmitting capacity. Distributed PV systems installed on buildings are close to people activities, apply load-side interconnection and only depend on power distribution network, so they have become another important form of PV power generation. The unique advantage of the distributed BMPV systems is to introduce the concept of energy-production on buildings. These systems don’t occupy valuable land resources, replace the traditional way to use energy, achieve convenient access to energy and utilize safe and clean energy. They have profound significance to sustainable development in the APEC region.

Purpose of report

This project that is directed at the distributed BMPV systems reviews the experience and lessons from application of distributed BMPV systems in the APEC region and compares their relevant policies, market development status, technical economy and typical cases, in an effort to explore the best practice for APEC economies for reference.

This project is intended to guide APEC economies in formulation of relevant policies, planning and standards. It compares and evaluates the effectiveness of these policies to avoid detours during development of the policies by the economies. Meanwhile, the project results can help APEC economies to develop their industry chains and have positive influence on their economic development and environmental improvement.

For BMPV application, these pioneers APEC economies have accumulated many project cases of various installation forms in different fields over different periods, and moreover, relevant international organizations and financial institutions also have greatly supported the project development and case studies. The comprehensive analysis of the completed project cases can guide APEC economies in their project practice.

1. Solar Energy Resource in the APEC Region

Solar energy resource is sustainable green energy with high economic and social benefits.. Solar energy can be exploited in one of the three ways: photovoltaic power generation, solar thermal power generation and solar thermal utilization. Compared to solar thermal utilization, solar power is high grade energy, and photovoltaic power generation is noise free and can reduce emissions and fuel consumption, which will become the main approach of the world's energy supply.

The solar energy resources are abundant and widely distributed on Earth's surface. The average annual global solar irradiation is estimated to be 19 trillion tonnes of oil equivalent or 221 million TWh. Assuming an energy conversion efficiency level of 18 percent, this resource is still equivalent to 39.8 million TWh. Even at such conservative estimate, it still represents more than a thousand times the electricity demand for APEC region in 2050.

As shown in Fig. 1-1, it is obvious that the solar irradiation is the most abundant within latitudes of ±35° north and south of the equator, known as the Sunbelt, which facilitates development and utilization of solar energy resource including PV power generation.

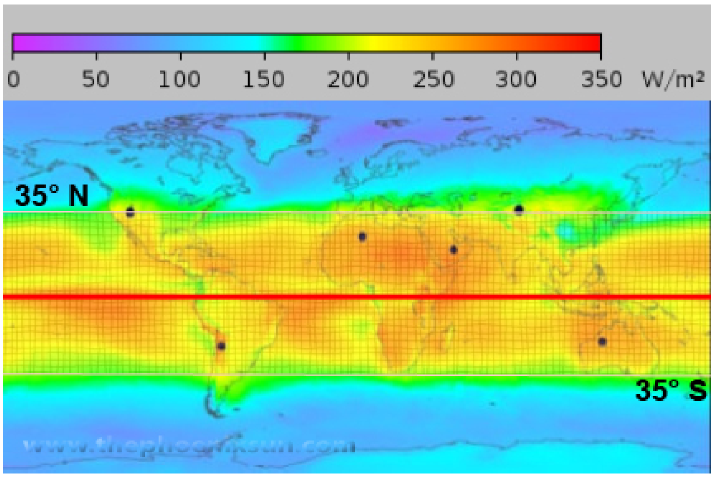


Fig.1-1 Resource distribution in the global Sunbelt

1.1 APEC economies in Sunbelt

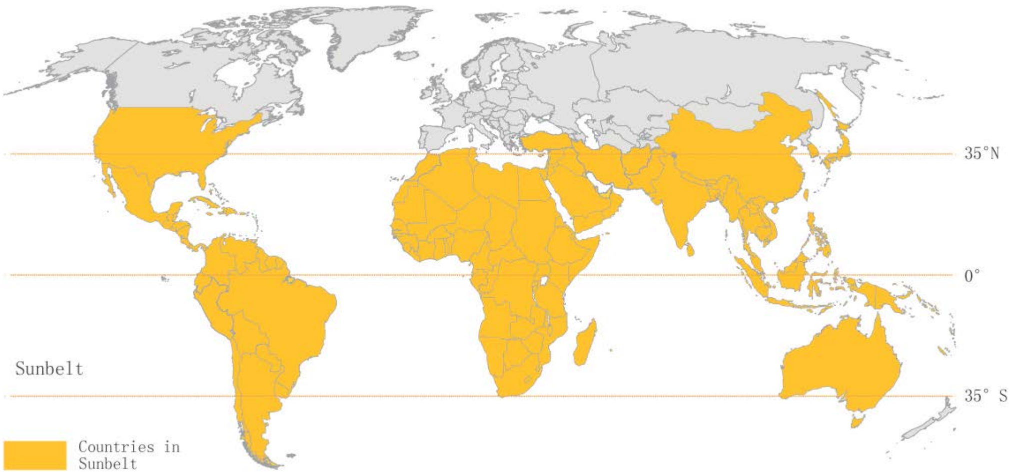


Fig. 1-2 Distribution of the countries and regions in the Sunbelt

The Sunbelt covers 148 countries or regions which account for 75% of the world's population and 40% of the global demand for electricity. They engage in large-scale economic activities and develop rapidly, with increasing energy consumption. Thus, development and exploitation of environment-friendly solar energy is one of the strategic measures for reducing environmental pollution, response to climate change and sustainable development.

Except for Canada, Russia and New Zealand, the rest of the APEC economies are located in or across the Sunbelt. Among them, more than 30% area of the US, Korea and Chile, 50% area of China, Japan and 90% area of Austrian are located above the Sunbelt, and the rest of the APEC economies are located within the Sunbelt.

Table 1-1 Basic situations of APEC economies in the Sunbelt

	APEC economies in Sunbelt	APEC economies NOT in Sunbelt	EU countries NOT in Sunbelt	Total countries in world
Number (2014)	18	3	28	201
Population (2014)	2.6 billion	0.18 billion	0.51 billion	7.0 billion
GDP(2014)	40.2 trillion	3.8 trillion	18.5 trillion	77.9 trillion
Electricity consumption (2014)	12030 TWh	1064 TWh	3166 TWh	23537 TWh
Photovoltaic power (2014)	75 TWh	2.2 TWh	92.9 TWh	185.9 TWh

As shown in Table 1-1, electricity consumption of APEC economies in 2014 was about 13094TWh, accounting for over 55% of the world's electricity consumption, and was 11.3 billion tons of oil equivalent; PV electricity output accounted for only 0.59% of APEC's electricity demand whereas the PV electricity output accounted for 3.0% of electricity demand of EU members beyond the Sunbelt, which was 5 times that of the APEC region.

The above data show APEC region with abundant solar irradiation has huge development potential for PV power generation.

1.2 Analysis on solar energy resources in the APEC region

1.2.1 Classification of solar irradiance

There are various methods for assessment of solar irradiance, so the calculated solar irradiance in different areas cannot be compared. The solar irradiance assessment shall be objective and normalized. The solar irradiation has a direct impact on PV efficiency and economy. In order to formulate the policies and estimate the economic returns, total annual insolation of China is classified into Class I-IV in this report according to the Chinese standard (QX/T 89-2008).

Table 1-2 Classification of solar irradiance

Total annual insolation	Classification
≥1750kW·h/(m^2·a)	Class 1
≥6300MJ/(m^2·a)	
1400～1750kW·h/(m^2·a)	Class 2
5040～6300MJ/(m^2·a)	
1050～1400kW·h/(m^2·a)	Class 3
3780～5040MJ/(m^2·a)	
＜1050kW·h/(m^2·a)	Class 4
＜3780 MJ/(m^2·a)	

1.2.2 Solar irradiation of APEC region

Fig. 1-3 shows the solar irradiance in the world. It can be seen that within the APEC region the solar irradiance of Southwestern United States, Western China, Central Southern Viet Nam, Australia, Peru, Chile, Mexico, Thailand, Malaysia, Papua New Guinea, Philippines belong to Class 1. .

Except the solar irradiance in the North Russian, the solar irradiance in northern Canada, Alaska of the United States, South Island of New Zealand belongs to Class 4, and that in North Island of New Zealand, Singapore, Japan, Korea, Brunei, Indonesia, Hong Kong and Chinese Taipei belongs to Class 2 or Class 3.

The solar irradiation of the APEC economies is as follows.

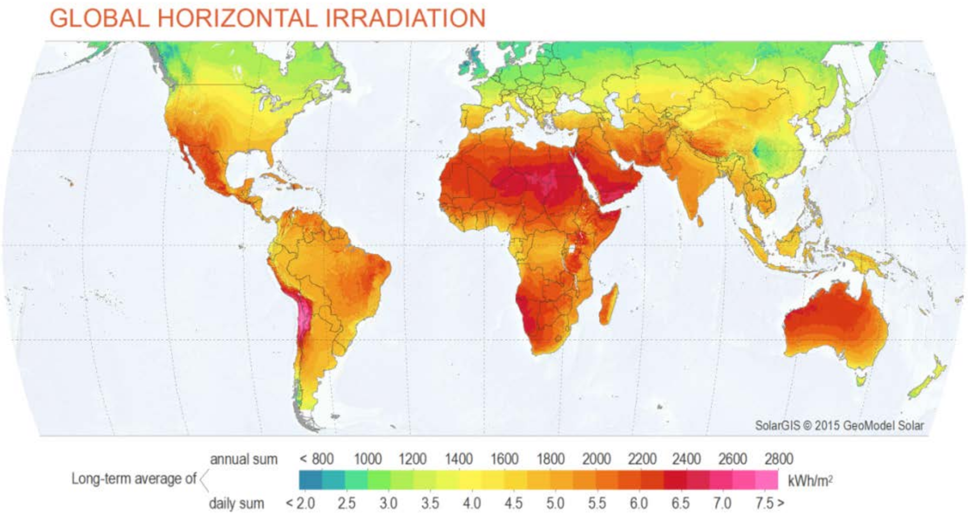


Fig. 1-3 Distribution of global solar irradiation.

1.2.2.1 Distribution of solar irradiation in the United States

In the United States, the most abundant solar energy resources concentrate in the southwest region, and gradually decrease toward the east and north, as shown in Fig.1-4.

Table 1-3 Distribution of solar irradiation in the United States

Classification of solar irradiance in this report *		Total annual insolation of the United States kWh/(m²·a)	Region
Total annual insolation kWh/(m²·a)	Class		
≥1750	1	2555～2920	Southwest United States: Arizona and New Mexico and the south of California, Nevada, Utah, Colorado and Texas
		2190～2555	Southeast United States: in addition to other parts of the above listed states, also including Utah, Wyoming, Kansas, Oklahoma, Florida, Georgia and South Carolina and Hawaii.
		1825～2190	Most of the north and east parts of the United States
1400～1750	2	1460～1825	Most part of Alaska
1050～1400	3	< 1460	Northernmost area of Alaska
＜1050	4		
Note*: as per the Chinese standard QX/T 89-2008, hereinafter the same.			

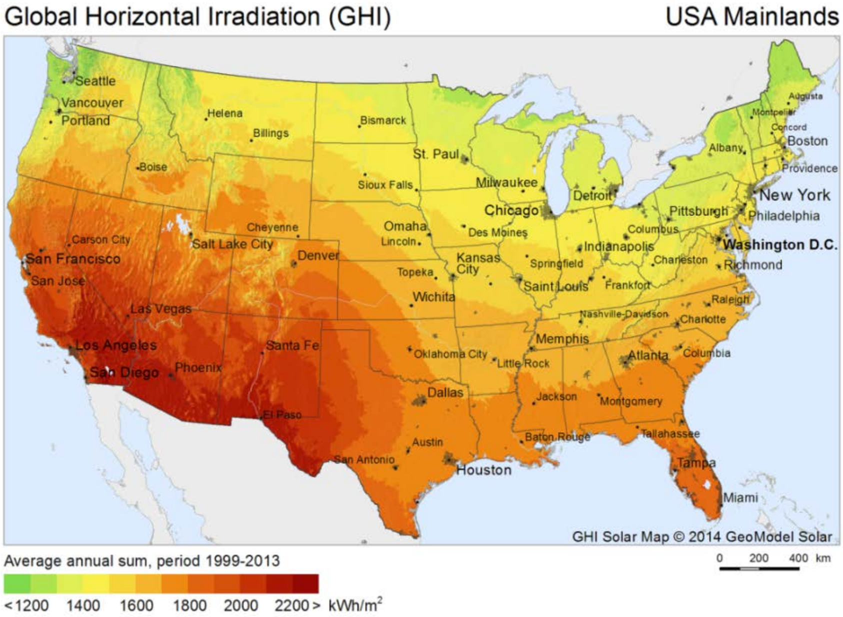


Fig. 1-4 The solar irradiance in the United States

1.2.2.2 Distribution of solar irradiation in Australia

Australia, located on the lower latitudes, mainly falls within the tropical and sub-tropical zone, and has the most abundant solar energy resources in the world.

Table 1-4 Distribution of solar irradiation in Australia

Classification of solar irradiance in this report		Total annual insolation in Australia (kWh/m^2)	Region
Total annual insolation kWh/(m^2·a)	Class		
≥1750	1	2100～2400	Central and northern regions of Australia
		1800～2100	Central south region of Australia
1400～1750	2	1500～1800	Southern and eastern Australia
1050～1400	3	< 1500	Part of the islands in southern Australia

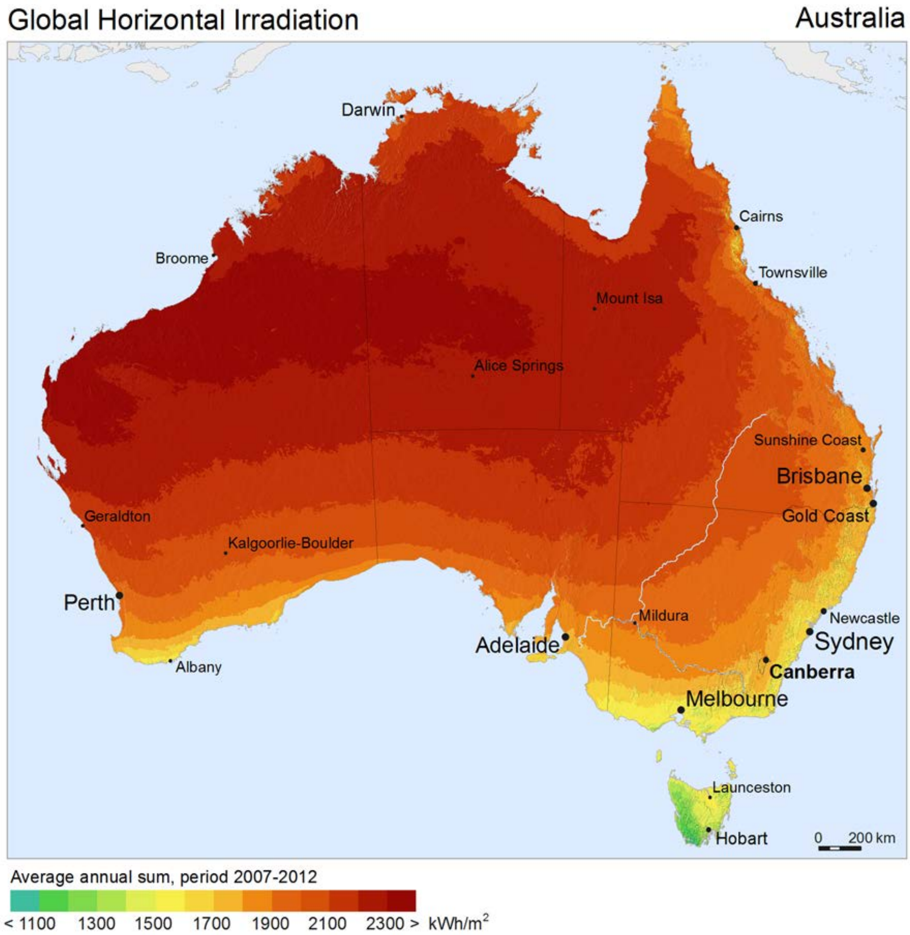


Fig. 1-5 The solar irradiance in Australia

1.2.2.3 Distribution of solar irradiation in Japan

Japan is marked by a long strip of land from south to north, and narrow from east to west, which is of a typical maritime monsoon climate. Based on this report, solar irradiance in the most part of Japan belongs to Class 2 or 3.

Table 1-5 Distribution of solar irradiation in Japan

Classification of solar irradiance in this report		Total annual insolation in Japan (kWh/m^2)	Region
Total annual insolation $kWh/(m^2 \cdot a)$	Class		
≥1750	1	--	--
1400～1750	2	1500～1700	Southwest Japan: include Okinawa Islands
		1450～1600	Southwest Japan: Kyushu Island, Shikoku Island, Chugoku region, southern coastal area of Kansai region; central and southern parts of the Central area.
1050～1400	3	1300～1450	Northwest Central Japan
		1250～1350	Northeast Japan: coastal area and

			Hokkaido region
		1150～1250	North of Central Japan and North of Northeastern Japan
<1050	4	---	---

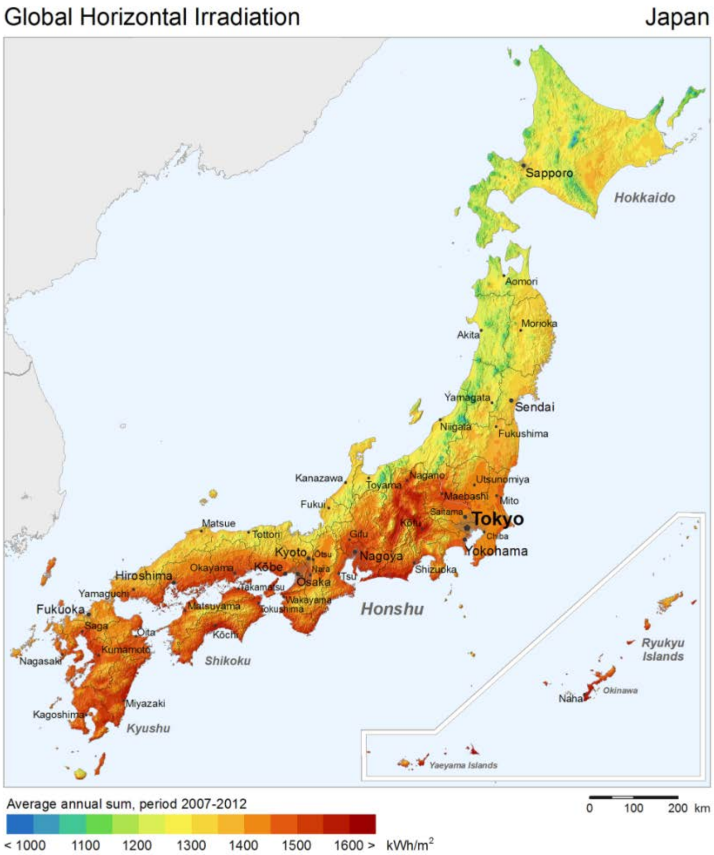


Fig. 1-6 The solar irradiance in Japan

1.2.2.4 Distribution of solar irradiation in Korea

Korea, located in the southern part of the Korean Peninsula, is mainly marked by a hilly terrain, ranging from a temperate monsoon climate in the north to a subtropical climate in the south, representing significant maritime characteristics. Its solar irradiance belongs to Class 3 and above.

Table 1-6 Distribution of solar irradiation in Korea

Classification of solar irradiance in this report		Total annual insolation（kWh/m²）	Region
Total annual insolation kWh/(m²·a)	Class		
⩾1750	1	---	----
		1550～1600	South Korea: Sothern coastal area and the islands
1400～1750	2	1500～1550	Central southwest Korea: South Gyeongsang Province, North Gyeongsang Province,

			Daegu metropolitan city; Southeast Korea: Ulsan metropolitan city, southern coastal area of South Jeolla Province, parts of plateau areas in the Central Jeolla Province, northwest and east parts of North Jeolla Province, south of South Chungcheong Province, south of North Chungcheong Province and Taejon Metropolitan City;
		1450～1500	Southwest Korea: south coastal region of Cheju Province, central and north area of South Jeolla Province, central and south areas of North Jeolla Province; Central Korea: north of South Chungcheong Province, north of North Chungcheong Province, southern and western coastal areas of Gyeonggi Province and south of Gangwon Province
		1400～1450	Northwest Korea: east–west coastal areas of Cheju Province, central and north of Gyeonggi Province Northeast Korea: central and northwest of Gangwon Province
1050～1400	3	1300～1400	Northeast Korea: western coastal area of Gangwon Province
＜1050	4	---	---

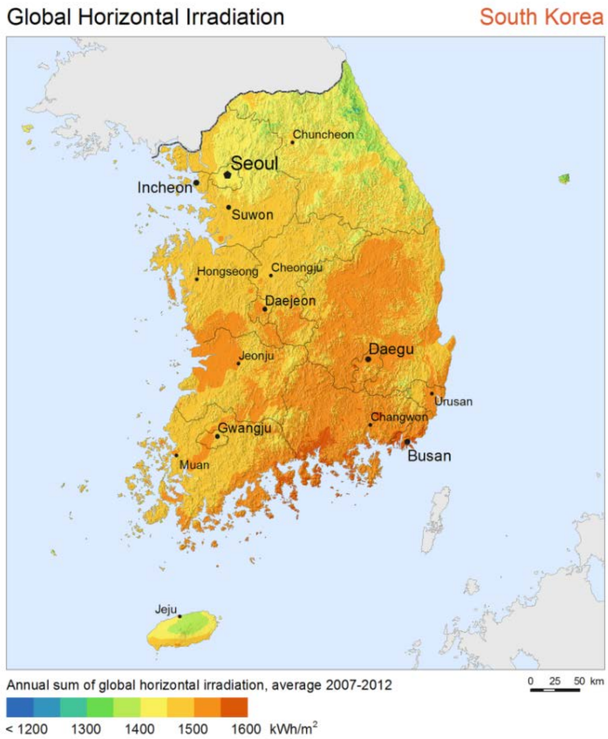


Fig. 1-7 The solar irradiance in Korea

1.2.2.5 Distribution of solar irradiation in China

In China, the total annual solar irradiation received on a surface at the ground is around 8×10^{15}kWh, and the total annual insolation is 930-2325kWh/m^2 with a median of 1628kWh/m^2. The solar energy resources are relatively good in over 2/3 areas of China, especially in Qinghai-Tibet Plateau, Gansu Province and Inner Mongolia, where the conditions for solar energy utilization are especially favorable. The total insolation received in all areas of China can be divided into Class 1-4 (*Assessment Method of Solar Energy* (QX/T 89-2008)).

The most abundant solar irradiation is distributed in the northwest of China, where the earliest distributed PV systems were installed. The PV systems are mainly developed and applied in the places such as desert, gobi or other large extensive land where annual total insolation exceeds 1600Wh/m^2, and PV power stations with a capacity of 50 million kW can be installed per 1km^2. The area of the gobi in China is about 570,000 km^2, of which only 5% can accommodate the PV systems with a capacity of 15 billion kW. According to the average annual utilization hours equivalent to 1600 hours in the gobi area in China, the annual power generation will be up to 2.4 trillion kWh (equal to the annual power generation of 29 the Three Gorges Hydropower Stations), and can satisfy 44% of the total electricity consumption in China in 2015 (according to the statistics released by National Energy Administration, the total electricity consumption was 5.5 trillion kWh in 2015). Theoretically, the PV systems installed in 15-20% of the Gobi desert area can satisfy total electricity consumption in certain period (the total electricity consumption of 2020 is estimated to be 8.1 trillion kWh).

According to the data released by China National Engineering Research Center for Human Settlement, the area of the available south walls and roofs is estimated to be 30 billion m^2. If 50% of the area is used, the building area for installation of the PV systems can reach 15 billion m^2. If 1kW distributed PV system per 25 m^2 is installed, the largest installed capacity of BMPV will be up to 600 million kW in 2020. According to the average annual utilization hours equivalent to 1500 hours in the installation area, the annual power generation can reach 0.9 trillion kWh and can meet 16% of the total electricity consumption of China in 2015.

Table 1-7 Distribution of solar irradiation in China

Classification of solar irradiance	Total annual insolation (kWh/m^2)	Region
Class 1	≥ 1750	Northwest China: the east of Qinghai, the south of Xinjiang, the north and central of Gansu, the north and the south of Ningxia. Southwestern China: Tibet Plateau, the southeast of Tibet Northern China: the northwest of Hebei, the north of Shanxi and the south of Inner Mongolia.
Class 2	1400–1750	North China: the south of Shanxi, the north and south of Hebei Eastern China: the south of Shandong and Fujian, the central and the north of Jiangsu, and the north of Anhui. Central China: Henan South China: the south of Guangdong Southwestern China: Yunnan North China: Jilin, Liaoning Northwest China: the north of Xinjiang, the north of Shaanxi, and the southeast of Gansu
Class 3	1050–1400	Southeast China: middle and lower reaches of Changjiang River, Fujian and Zhejiang South China: a part of Guangdong
Class 4	< 1050	Southwest China: Sichuan and Guizhou .

Fig. 1-8 indicates the distribution of solar energy resources in China, which features are as follows:

1) Both the high-value center and low-value center of solar energy are located within 22° - 35° N, with the Qinghai Tibet Plateau as the high-value center and Sichuan Basin as the low-value center.

2) The total annual insolation in the western region is higher than that in the eastern region, except the two autonomous regions of Tibet and Xinjiang Province. Generally, the total annual insolation in the south is lower than that in the north;

3) As most south areas are marked by cloudy and rainy weather and located within 30° - 40° N, the distribution of solar energy is opposite to the law of the change of solar energy with latitude that solar energy decreases with increase in latitude, but instead the solar energy increase with increase in latitude.

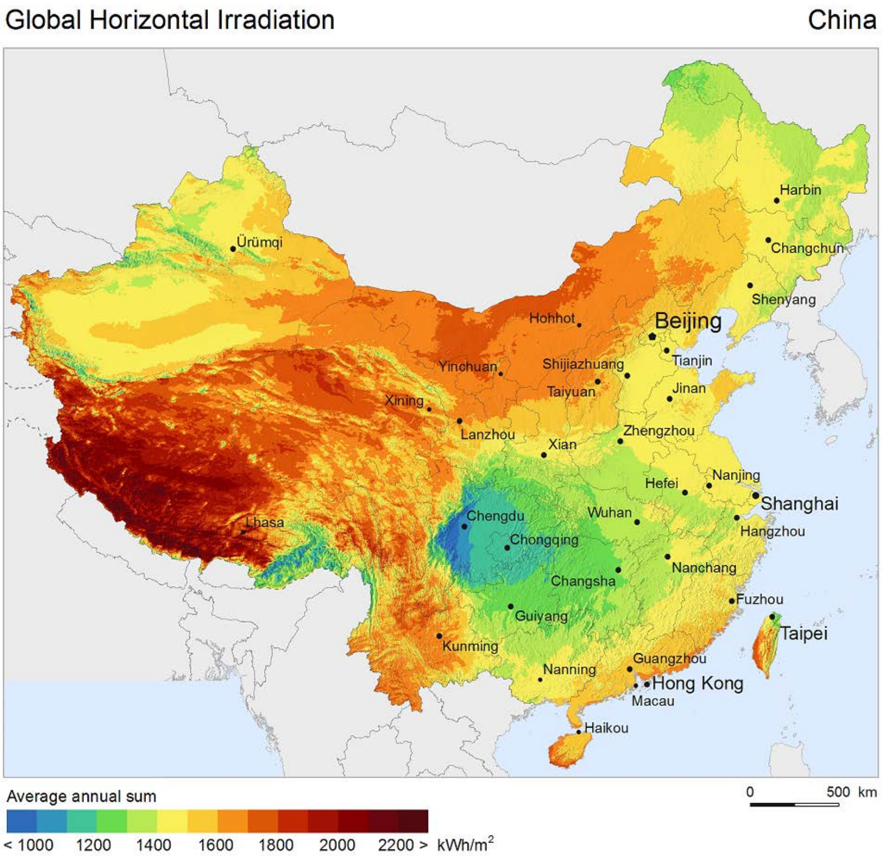


Fig. 1-8 The solar irradiance in China

Fig.1-9 through 1-12 show distribution of solar irradiance (I-IV) in the Chinese provinces.

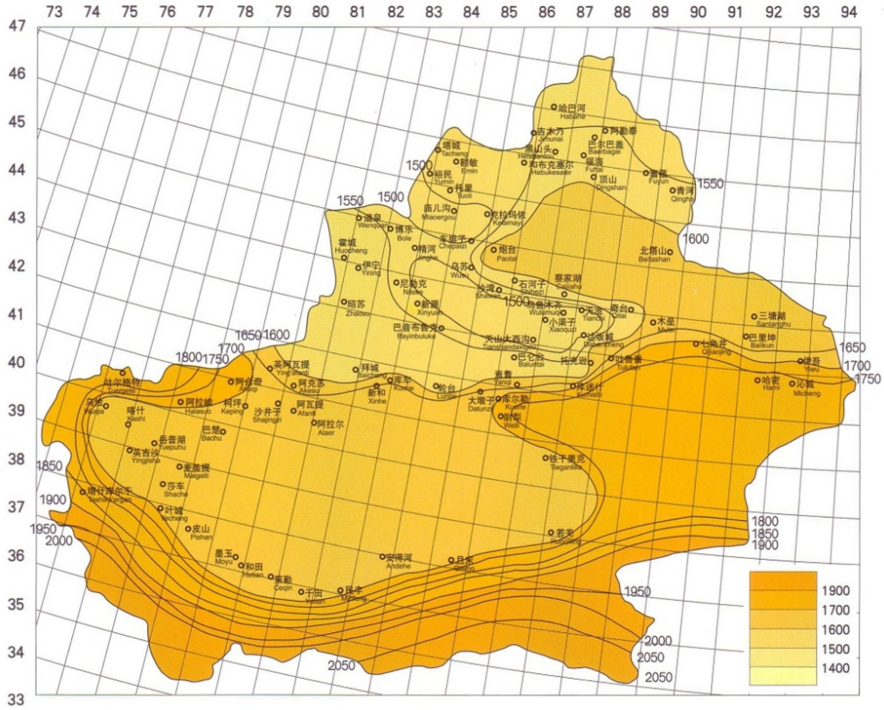


Fig. 1-9 Distribution of solar irradiance in Xinjiang (Class I)

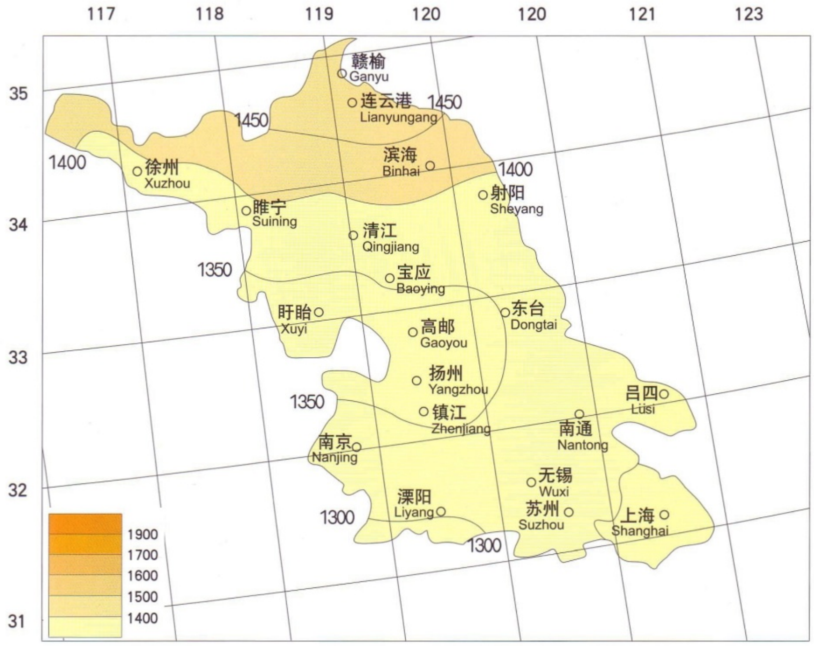


Fig.1-10 Distribution of solar irradiance in Jiangsu and Shanghai (Class II)

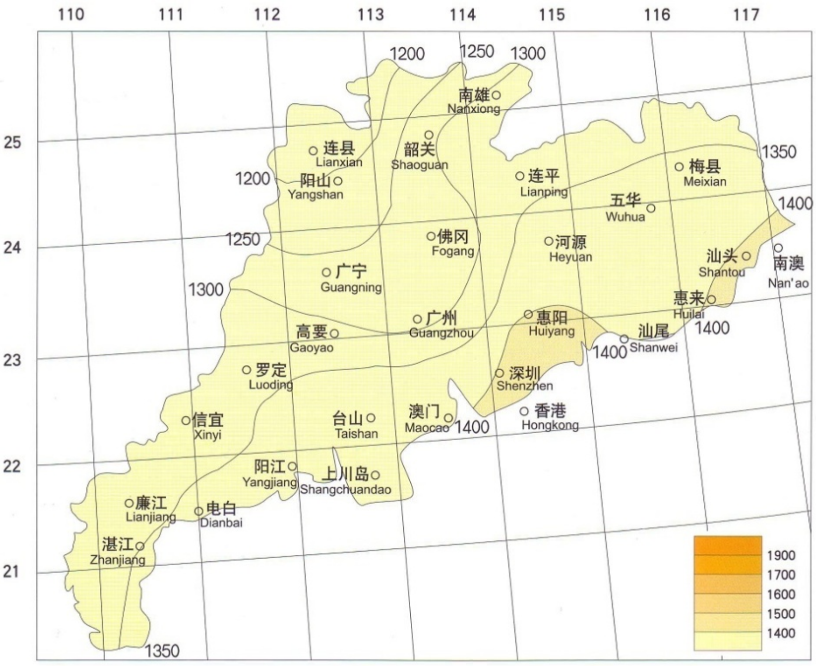


Fig. 1-11 Distribution of solar irradiance in Guangdong (Class III)

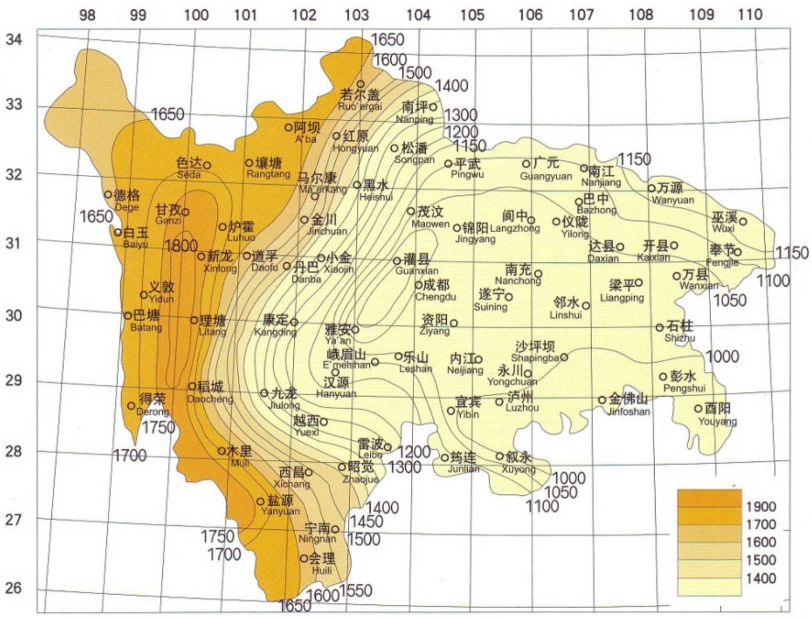


Fig. 1-12 Distribution of solar irradiance in Sichuan and Chongqing (Class IV)

Table 1-8 Solar energy resources in the provinces (Class I-IV)

Province	Total Area(hectare)	Area of Unexploited Land(hectare)	Total Reserves (10^{14}KWh)	Exploitable Capacity (10^{14}KWh)
Xinjiang (Class 1)	166489717.01	98620027.97	27.060	16.028966
Shanghai (Class 2)	823901.21	968.47	0.0769	0.000090

Jiangsu (Class 2）	10667388.34	148337.03	1.654	0.023000
Guangdong (Class 3)	17975234.85	972591.87	2.407	0.130236
Sichuan (Class 4)	56632471.95	7285646.63	7.36	0.877277

According to the data provided by the wind and solar energy resources center of China Meteorological Administration, the average annual sum of horizontal solar irradiation received on a surface at the ground in China was 1476.1kWh/m^2 in 2015, decreased by 24.8kWh/m^2 as compared to the average annual insolation in the years of 2004-2013, representing the historical lowest value since 2004.

According to distribution of total annual horizontal insolation in China and the provinces, the total annual insolation in the most areas maintained the same level or significantly fell as compared to that in the previous years, except in Hainan Province (increased by over 5%) and eastern Yunnan Province (increased by over 3%). Among them, the total annual insolation in northern Xinjiang Province and most parts of Heilongjiang Province decreased by over 3%, and in Eastern Guizhou Province, Hunan Province, Jiangxi Province, Fujian Province and other areas decreased by over 5%, and in Zhejiang Province decreased by 10% with the greatest fall.

The cloud cover increased in the most areas of China in 2015, and the monthly average number of cloudy days is 12 days, increased by 7.2% compared to the average value in the previous years. There are many factors affecting solar energy resources. In addition to the two main factors of cloud and aerosol, aqueous vapor, atmospheric composition and solar activity may also have an impact.

From the above comprehensive analysis, the solar energy resources and total exploitable solar energy in Western China is far more than that of Central/Eastern China. As the Western China is less developed than Eastern China, it has relatively lower demand for energy. These characteristics shall be fully considered in policy formation and energy planning. See the table below.

Table 1-9 Distribution of solar energy resource and power demand in East China, Central China and West China

	East China	Central China	West China
Including administrative regions [1]	11provincial administrative regions: Beijing, Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guandong and Hainan	8 provincial administrative regions: Heilongjiang, Jilin, Shanxi, Anhui, Jiangxi, Henan, Hubei and Hunan;	12 provincial administrative regions: Sichuan, Chongqing, Guizhou, Yunnan, Tibet, Shaanxi, Gansu, Qinghai, Ningxia, Xinjiang, Guangxi, and Inner Mongolia;
Percentage of national territorial area	11.3%	16.5%	72.2%
Population	38.58%	33.07%	28.35
Population density(person/km^2）	452.3	262.2	51.3
Percentage of GDP(100 million CNY) (in 2015)	401477.75（55.5%）	176497.43（24.4%）	145521.36（20.1%）

Ratio of national annual power consumption(2015)		~51.9%	~22.1%	~26.0%
Peak power price (CNY/kWh)（year）	Residential	0.49~0.70	0.48~0.59	0.42~0.55
	Commercial	1.20~1.42	1.07~1.35	0.94~1.12
	Industrial	0.80~0.95	0.68~0.85	0.53~0.68
Classification of solar irradiance		Cass II or III	Class II or III	Class I or II (except Sichuan and Guizhou)
Theoretical solar energy resource [2](10^{14}KWh) and percentage		15.03(10.2%)	21.40(14.6%)	110.34(75.2%)
Exploitable solar energy resource [3](10^{14}KWh)		1.500(3.7%)	0.146(6.1%)	36.245(90.2%)

Note [1]: The administrative division (East China\Central China\West China) conforms to the policy and is based on regional economy development.

[2] and [3]: Sourced from China Meteorological Administration

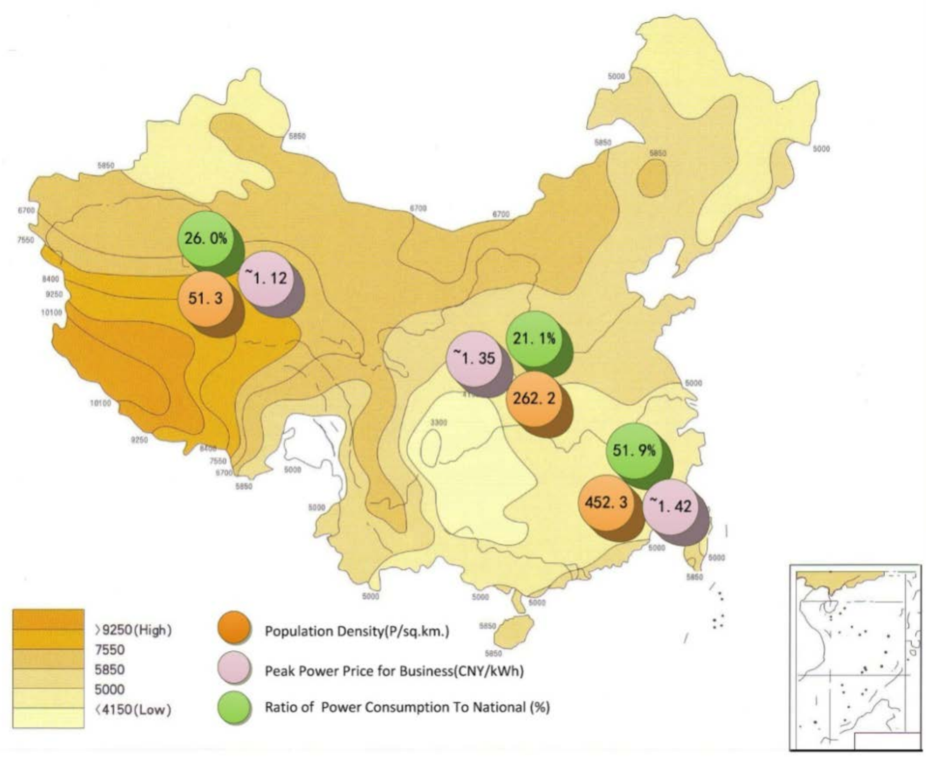


Fig. 1-13 Solar energy resource and electricity demand in in East China/Central China/West China *

Note*: 1) The small graph left bottom shows classification of solar irradiance;

2) The three dots of different colors in the figure: the green dot represents ratio to China's total annual power consumption; brown dot represents population density (unit: people/km^2); another dot represents peak power price;

The solar energy resources utilized by photovoltaic power generation that use fixed structures is the total solar insolation received by the PV modules installed at an optimum tilt angle (referred to as total solar insolation at optimum tilt angle on inclined planes). In 2015, the average total insolation on inclined planes was 1710.2 kWh/m^2, and 63.2 kWh/m^2 less than the average value of previous years of 2004-2013, and fell by 3.69%; the average annual number of utilization hours of the PV power stations that use fixed structures was 1368.2 hours in the first year, and was 50.5 hours less than the average value.

According to the spatial distribution map for the total radiation at optimum tilt angle on inclined planes and the first-year utilization hours of PV power generation, the total annual insolation at the optimum inclined surface in northeast China, North China, West China and most parts of southwest China was significantly higher than that in the southeast China in 2015.

1.2.2.6 Distribution of solar energy resources in South Asia and Southeast Asia

South Asia and Southeast Asia feature tropical climate, and are adjacent to the Ocean. With warm and humid climate, they have abundant solar energy resources.

Among the South Asian region, Viet Nam is marked by a long and narrow strip of land from south to north, with varied solar energy resource conditions. The annual solar resources are 1500-1700kWh/m^2 in the northeast part, 1750-1900Wh/m^2 in the northwest part, 1700-2000kWh/m^2 in the north of the central part, 2000-2600kWh/m^2 in south and west plateau areas in the central part and 2200-2500kWh/m^2 in the south part.

Thailand can be divided into 4 areas according to distribution of the solar energy resources. The northern mountainous area has total annual insolation of 1500-1700kWh/m^2, the central plains has total annual insolation of 1750-1900kWh/m^2, the northeastern plateau area has total annual insolation of 2000- 2600kWh/m^2 and the tropical islands in the southern peninsula has total annual insolation of 1700-2000kWh/m^2.

Malaysia, located in 1°-7° N, 97°-120° E, consists of Malay in the south of Malaya Peninsula and Sarawak and Sabah in the north of Kalimantan Island. It lies just north of the Equator, with high temperature throughout the year and good solar irradiation resources. It has annual insolation ranging from 1530 to 2030 kWh/m^2. The annual insolation is 1800-1900kWh in east Sarawak, Sabah, Penang, Kedah and Perlis, and 1700-1800 kWh/m^2 in Kelantan, north Terengganu and central Sarawak, 1600-1700 kWh/m^2 in Perak, West Kelantan, north and east Pahang, Malacca and Johore and 1500-1600 kWh/m^2 in Selangor, Sembilan, southwest Pengyue and southwest Sarawak.

Indonesia is crossed by the Equator (12°S-7°N), and more than 70% of its territory is in the southern hemisphere, extending from 96°E to 140°E in longitude. Indonesian islands are distributed dispersedly, comprising Kalimantan, Sumatra, Irian Island, Celebes, Java Island, Maluku Islands and Nusa Tenggara Islands. It has high temperature around the year, and good solar resources, with an annual insolation ranging from 1460 to 2000 kWh/m^2.

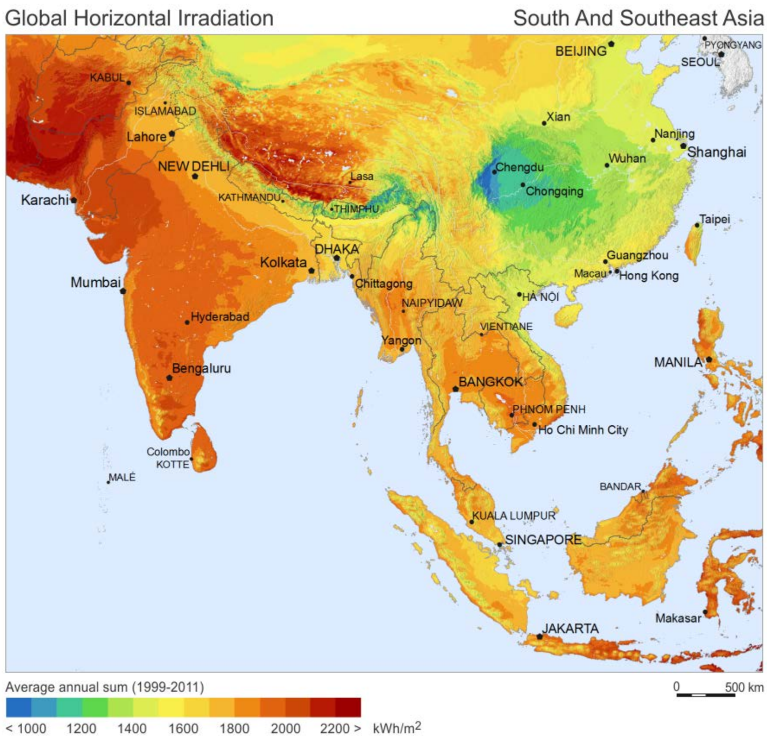
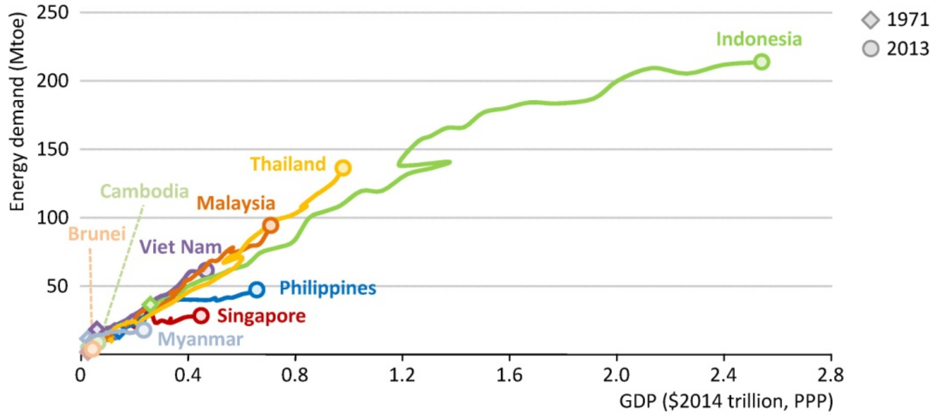


Fig. 1-14 The solar irradiance in South Asia and Southeast Asia

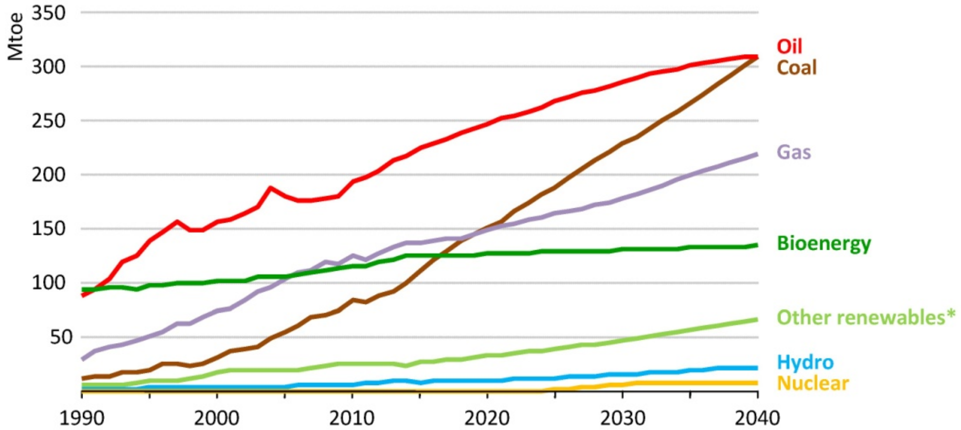
The above data show the solar irradiance of Viet Nam, Thailand, Malaysia and Indonesia belong Class 2 and above;

Southeast Asia is one of the pillars for growth of Asian economy, and also an emerging giant of the global energy market. During UN's Paris Climate Summit, IEA released the Southeast Asia Energy Outlook Southeast Asia. This region is rapidly developing, and its energy demand has changed significantly as compared to the past decade. From 2015 to 2040, the consumption of fossil energy in this region will account for 80%.



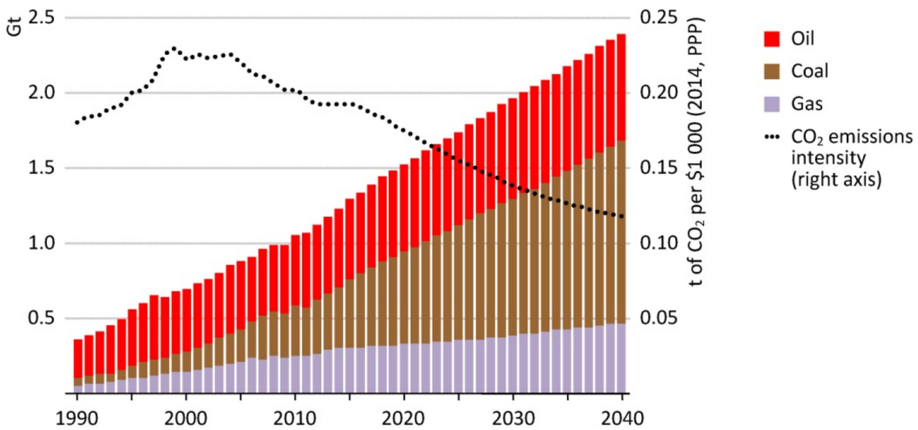
Note: Mtoe = million tonnes of oil equivalent.

Fig.1-15 Total primary energy demand and GDP in selected southeast Asian region, 1971-2013



*Includes solar PV, wind, and geothermal.

Fig.1-16 Growth in southeast region primary energy demand



Notes: t = tonnes; PPP = purchasing power parity; Gt=gigatonnes.

Fig. 1-17 CO_2 emissions from fossil fuels and CO_2 emissions intensity in Southeast Asia

The countries in Southeast Asia have diversified energy demand. For example, about 120 million people have no access to electricity, and 280 million people are without clean cooking facilities, and consumption of petrol and natural gas and coal aggravate environmental pollution. In the future, the electricity in this area will be generated from coal and natural gas, and coal power will increase. As the energy structure is being optimized, the percentage of electricity generated from petrol and natural gas will grow, and regional energy security should be considered. Thus, sustainable economic and social development will enable the regions and the countries to strategically change their energy policies.

To sum up, although share of the fossil energy will be still higher in the energy structure of South Asia and Southwest Asia for some time, the investment in and development of renewable energy which mainly consists of solar energy will become the development direction of their policies. The solar irradiance of South Asia and Southwest Asia belongs to Class II and above, and the solar energy resources are abundant. The regions have advantaged conditions and huge potential for change of energy structure.

2. Definition of BMPV and Its Classification

2.1. BMPV Definition and Its Main Characteristic

2.1.1 BMPV Definition

According to the relation with grids, the PV systems can be divided into centralized grid-connected PV systems and distributed grid-connected PV systems; according to the installation forms of modules in the PV systems, the PV systems can be divided into ground-mounted PV systems, BAPV and BIPV.

In the application cases, it has been found the ground-mounted PV systems have large installed capacity. The recent projects have been expanded from several MW to tens of MW and even hundreds of MW, and most are centralized grid-connected PV systems. However, the BMPV installation area is limited by volume, and ranges from several KW to several MW; their installation position is often near the load side, and most of BMPV are distributed grid-connected systems.

In order to facilitate analysis and research, BMPV is defined as the distributed PV systems which are either mounted on buildings or installed as free-standing structures. BMPV mainly consists of BAPV (Building Attached PV) and BIPV (Building Integrated PV).

In normal case, most electricity demand is from inside buildings or frequent activities of the personnel near the inside buildings. The BMPV systems are installed on user side and connected to grids to supply electricity. They have no transmission loss and lower costs. They are the most important and wide application of the distributed PV systems. In this report, the BMPV includes roofing PV system, PV curtain wall, solar home system, PV carport, greenhouse/botanic garden.

Thus, the BMPV data in this report are based on above categories.

**Note: the above categories in the countries or regions may have difference. For example, the small ground-mounted systems near the cities have been included in the BMPV systems. However, according to the observed cases from China, the proportion of the small ground-mounted systems is extremely low, and is less than 1%.*

2.1.2 What are trends of BMPV application development?

As the packaging technologies are developing towards high reliability, solar cells can be fully panelized under specific conditions, which enable PV modules to reach the utility scale. The PV technologies which can meet the requirements for safety and weather resistance tend to achieve grid parity and deliver conventional affordable renewables*.

A solar PV power system is formed by certain number of these independent PV modules in parallel or in string to expand the power stations from watts (W) to megawatts (MW). When these power generation systems reach a capacity exceeding MW, they will be installed in a larger area, becoming centralized PVPS, which are connected to utility grids to supply electricity to the grid in a centralized manner. However, the centralized PVPS needs to occupy large area of land, and has higher requirements for transmission capacity. When the centralized PVPS reach certain size, they have application constraints and cannot transmit the electricity at a full rate. .

**Note: ground-mounted centralized power stations can be understood as those stations without storage systems.*

Fig. 2-1 Centralized PVPS

Due to the mature technologies of the module production and power distribution network, the installed capacity of the distributed PV power stations can be gradient-less and step-less. As compared to the centralized PV power stations, distributed PV power stations have small size, are near the load, generate and consume electricity concurrently and are closely related to the areas where people activities are frequent. Thus, they have become a new and prospect form for power generation and energy utilization.

The distributed PV systems can be either off-grid or grid-connected. The off-grid systems often consist of solar modules, controllers, inverters, storage batteries and support systems. They are mainly used to satisfy needs of rural electrification in remote areas without access to electricity grids. The grid-connected systems are connected to utility grids through grid-connected inverters and controllers, and their generated electricity can be distributed to the nearby grid for consumption, without need of separate transmission lines. The grid connected systems can effectively reduce transmission costs and losses.

The roof PV systems with smart control storage units can increase distributed connection, solve the grid connection, improve stability of grid operation and develop the distributed grid-connected systems. The systems can achieve smart control, protection and management, and allow grid-connected operation and off-grid operation, and have a function of backup power that can be used in case of grid outage.

As compared to the centralized PV power stations, the distributed BMPV systems have significant characteristics listed in Table 2-1.

(a) PV curtain wall

(b) Roofing SHS

Fig.2-2 Distributed BMPV

Table 2-1 Comparison for characteristics of centralized PV power stations and BMPV systems

Centralized PV power station	BMPV system
Large-scale centralized PV plant, and easy to build and manage	Small scale and dispersed distribution, it is hard to build and manage
Long distance to transmit outside, needing transformer to higher voltage, leading to high transformation and line losses	Installed at the user side, near the loads, the PV power is sued directly, with little cost and losses.
Need much land to install the PV panels	Installed on the buildings

2.2. The Category of BMPV

As previously mentioned, the BMPV can be divided into BAPV and BIPV by the PV module arrays and installation mode.

2.2.1. BAPV

The BAPV are the systems which add the solar modules on the buildings such as a rooftops or external walls to generate electricity. These modules are not the part of the buildings, and attached to the builldings, Thus, BAPV systems are easy for installation, and have low cost, which don't change building functions. Now, they are the most widely used form of BMPV.

Fig. 2-3 Roofing PV system with standard PV module

Building attached photovoltaic (BAPV) systems is one of the product types that utilize solar panels, which are retrofitted onto building structures such as a rooftops or facades to generate electricity. BAPV systems are gaining popularity, as they aid in reducing the use of fossil fuels, offer weather protection, and do not affect building aesthetics where they are installed.

Over the years, government subsidies and continuous innovations of the APEC economies (the US, Japan and Australia) have fueled the application of BAPV and its market growth. The energy generated has wide applications in several sectors including residential, commercial, and industrial sectors. BAPV projects are generally constructed on rooftops with favorable conditions. As compared to BAPV stations mounted on pitched roofs, those installed on the flat roofs are the most economically efficient, as:

1) it could be installed at the optimum angle, thus acquiring the largest power generation;

2) it adopts the standard PV modules and has the best performance;

3) it does not interfere with the building functions and;

4) its cost on PV power generation is low.

2.2.2. BIPV

BIPV is another important form of the BMPV. As compared to the BAPV systems, BIPV is part of a building, for example, a part of closure system of building to prevent sunshine, water and preserve heat. The advantage of BIPV over BAPV systems is that the initial cost can be offset by reducing the amount spent on building materials and labor that would normally be used to construct the part of the building that the BIPV modules replace. This advantage makes BIPV become one of the fastest growing segments of the photovoltaic industry.

Building-integrated photovoltaics (BIPV) are photovoltaic materials or systems that are used to replace conventional building envelopes such as roofs, skylights, or curtain walls. They are increasingly being incorporated into the construction of new buildings as a principal or auxiliary source of electrical power, although existing buildings may be retrofitted with BIPV modules as well.

BIPV modules are often customized, and their design and production should meet the requirements for building appearance, safety, light transmittance and insulation, so the costs are relatively higher, and power per unit area decreases. The BIPV modules have building functions and can replace the building elements to reduce building costs. The cost saving can be called BMPV margin efficiency.

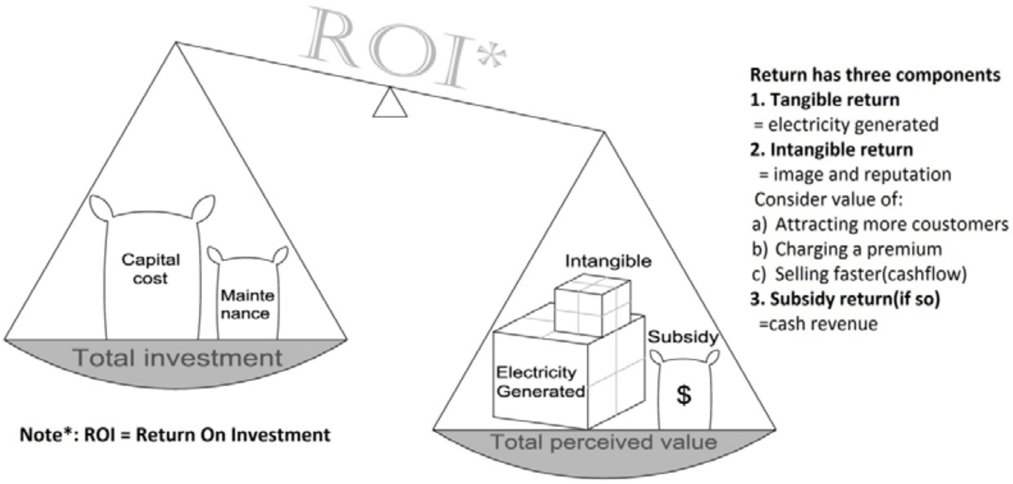


Fig. 2-4 Value-added effect and margin efficiency of BIPV

The advantage of integrated photovoltaics over more common non-integrated systems is that the initial cost can be offset by reducing the amount spent on building materials and labor that would normally be used to construct the part of the building that the BIPV modules replace. These advantages make BIPV one of the fastest growing segments of the photovoltaic industry.Building-integrated photovoltaics (BIPV) are photovoltaic materials that are used to replace conventional building materials in parts of the building envelope such as the roof, skylights, or facades. They are increasingly being incorporated into the construction of new buildings as a principal or auxiliary source of electrical power, although existing buildings may be retrofitted with BIPV modules as well.

Building Integrated Photovoltaics (BIPV) is about multifunctional building elements that generate electricity. BIPV therefore brings the worlds of construction and photovoltaics together with all the challenges and chances inherent to such a change of paradigm. After more than 20 years of R&D [2], the market for building-integrated photovoltaics (BIPV) has kicked off with very interesting products and elegant showcase projects. The birth of this market has been based on an enormous progress in PV technology development (cost-wise and performance-wise), together with the vision of some leading architects and industries.

Fig. 2-5 Corridor with colorful thin film PV module

BIPV can be categorized into following two major types of integration in terms of the building itself.

Functional integration refers to the role of the PV modules in the building. For this reason we can speak about multi-functionality or double function criteria. Photovoltaic modules are considered to be building integrated, if they represent a component of the building envelope providing a function as defined in the European Construction Product Regulation CPR 305/2011. Thus the building performance of the BIPV module is required for the integrity of the building's functionality.

Aesthetical integration, on the other hand, refers to the architectural concept, which is hard to define in a specific way. The aesthetical integration has to be considered as a capability of the PV solution to define the linguistic/morphological rules governing the signs, the structure and the composition of the building's architectural language. In contemporary architecture the appearance is one of the first factors of recognizability. In order for "Solar Architecture" to be successful it has to comply with the architectural standards of today.

BIPV is mainly integrated into three types of buildings: pitched/sloped roof, a flat or curved roof and façade, which are described as follows:

Fig. 2-6 Three main applications for BIPV

A pitched/sloped opaque roof is made up of angled and sloped parts. This method of construction is common all over the world: it is known as a "discontinuous" roof due to the presence of small elements (tiles, slates, etc.). Simultaneously these small elements must have main physical building properties such as water tightness. Due to the size of the roof, inclination of installation and orientation towards the sun, the roof is perfectly suitable for PV installation. A lot of constructive solutions have been developed over the last years, moving from a first generation PV system (building attached photovoltaic, BAPV) towards the most recent watertight solar tiles where PV modules replace the traditional tiling layer. Categories within this application area include solar glazing, in-roof mounting systems, full roof solutions, large tiles small tiles, and metal panels.

A flat or curved roof, also known as “continuous roof”, is characterized by an uninterrupted layer with the main function to be water resistant. Usually waterproof membranes are used as a water barrier. In the first applications, the PV was mainly placed on top of the roof. Lightweight and self-bearing systems represent the second generation of PV applications. Flexible waterproof membranes, solar floors and other solutions can easily be used for integrating PV in the building envelope. Categories within this application area for BIPV include solar glazing, metal panels and PV membranes.

Curtain wall: Increasing requirements regarding energy efficiency in buildings results in a growth of PV applications in the façade segment. PV power generation serves as a substitute for traditional materials in most common façade systems (e.g. cold façade or curtain walls), both opaque or transparent. Moreover, in transparent curtain walls, PV plays a key role with respect to the comfort of the indoor microclimate (for reducing overheating in summer and allowing solar gains in winter), which is of major concern for their installation. Besides it enhances the comfort by increasing natural lighting. Categories within this application area include solar glazing, accessories, warm façades and cold façades.

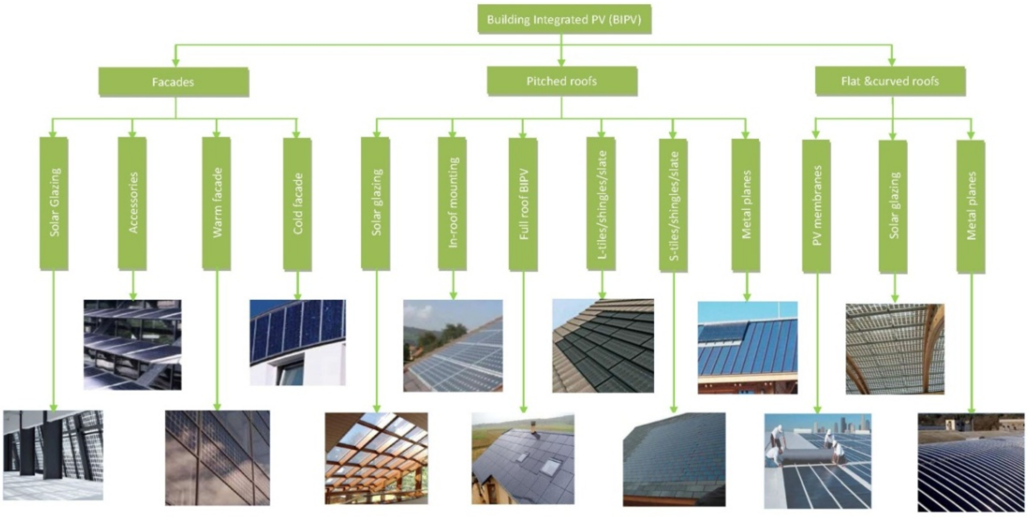


Fig. 2-7 Main application methods and product types of BIPV system

2.3. Main Features on Multi-field Application of BMPV

In general, electricity load curves, input voltage and electricity prices are different for the residential and non-residential users (such as commercial and industrial buildings, agricultural greenhouse). The façade or roof structures for installation of the PV systems are different, so the efficiency is different. The features of BMPV on different types of buildings are as follows.

	BAPV		BIPV		
Type of buildings	Residential	Industrial and Commercial	Agriculture Greenhouse	Facade	Skylight
Advantages of systems	1) Small scale; 2) Easily grid-connected 3) Designed with standard panels, and easily installed; 4) The modules installed on the roofing can reduce	1) Designed with standard panels, and easily and flexibly installed. 2) More stable than grids, In case of grid failure, continue to supply electricity.	1) Effectively use solar and land resources, and improve the rate of multipurpose utilization of land; 2) satisfy the electricity demands for greenhouse lighting,	1) Combine with the traditional building envelope to save costs; 2) Besides power generation, there are additional functions such as heat preservation	1)Combine with the traditional building envelope to save costs； 2) Besides power generation, there are additional functions such as heat preservation and insulation,

	the indoor temperature to 2 - 10℃, and decrease building heat and operation loss of air conditioning		ventilation and heating; 3)Design and select solar modules with different light transmittance according to different needs for plant light;	and insulation, noise prevention. Effectively reduce energy consumption of buildings 3) Design based on the building needs delivers overall appearance effect	noise prevention. Effectively reduce energy consumption of buildings
Disadvantages of systems	1)Higher initial cost 2) Need maintenance. If owners lacks relevant knowledge or willingness to maintain the, system, the system will not properly function and have low, efficiency and short service life;	1) small scale, dispersed installation and difficult to manage and maintain in a unified and timely manner, which may cause low efficiency and short service life;	1) Higher construction costs; 2)Conflict between light transmittance and generation efficiency;	1) Relatively higher costs; 2) Not installed at the optimal tilt angle, so the efficiency is relatively lower; 3) Nonstandard panels so difficulty installed; 4) Higher requirement for safety	1) Relatively higher costs 2) Not installed at the optimal tilt angle, so the efficiency is relatively lower 3) Higher requirement for safety

Fig. 2-8 Agricultural greenhouses with BMPV

Fig. 2-9 Industrial building with BMPV

Fig. 2-10 PV carport

3. The Development Status of BMPV Market

3.1. Global PV market

According to the latest IEA report, the global PV installed capacity reached 177GW by the end of 2014, which is more than 50 times increase than 3.7GW of 2004.

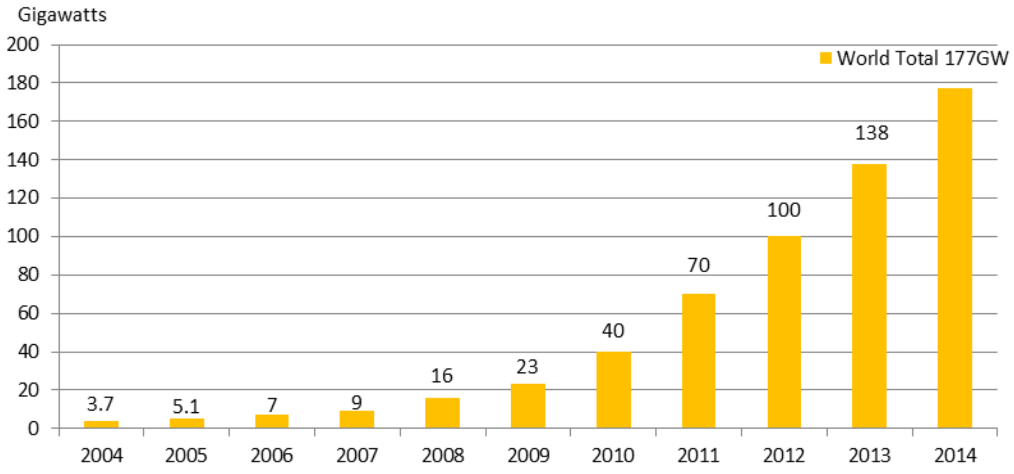


Fig. 3-1 Solar PV Global Capacity Statistics (source: REN21 Renewable Energy World White Paper 2015, 20150618)

The newly increased global installed capacity in 2014 stays at 38.7GW (IEA data) with China, Japan and the US keeping their leading roles as 2013, enjoying installed capacity of 10.6GW, 9.7GW and 6.2GW respectively. The installed capacity of European market has dropped for three years consecutively due to further slump of German and Italian market despite of the strong growth of PV installed capacity of the UK, keeping an overall installed capacity of about 7GW. Moreover, Indian, South Africa, Chile and some other emerging markets developed vigorously in 2014.

From the aspect of installed gross capacity, Germany came the first with an installed capacity of 38.2GW, followed by China and Japan with 28.1GW and 23.3GW respectively. According to statistics, more than 20 economies by 2014 reached more than 1GW PV installed capacity, marking a great increase compared to only 9 economies in 2013.

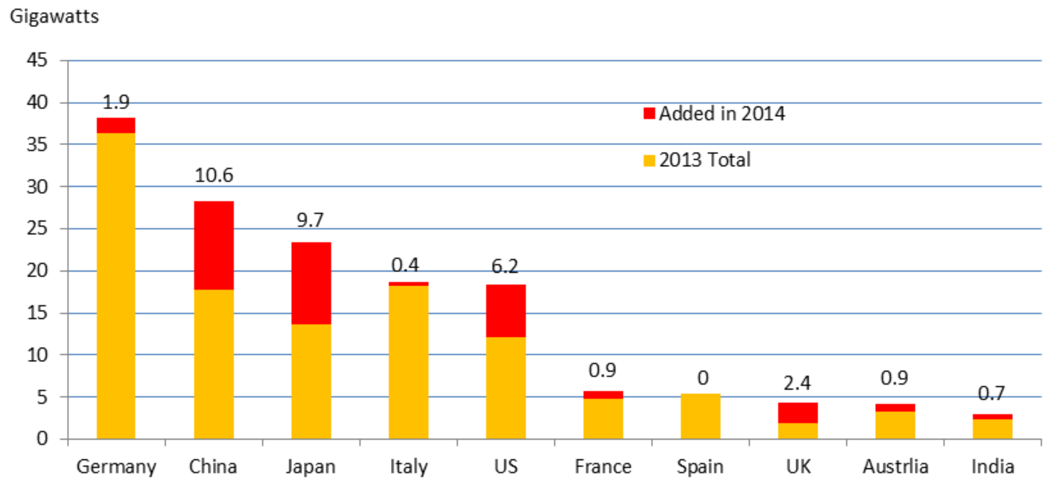


Fig. 3-2 Solar PV Capacity and Additions, Top 10 Countries, 2014

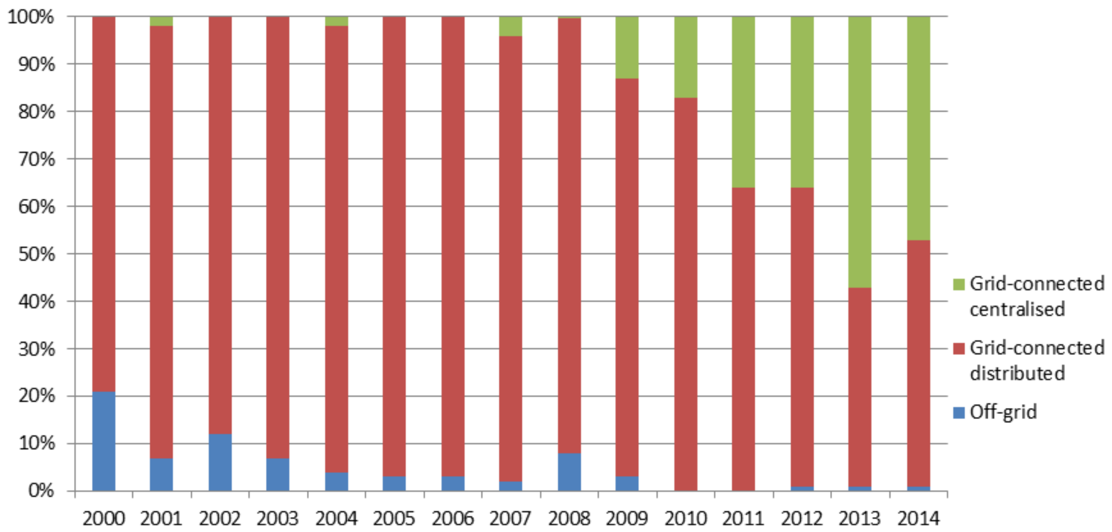


Fig. 3-3 Share of Grid-connected and off-grid installations 2000- 2014

Fig. 3-3 shows share of global PV installations in 2000-2014. Except 2013, the share of distributed PV installations accounted for more than 50% of the total.

Due to increasing conversion efficiency, decreasing PV module costs, and applications of new materials and technologies, distributed PV will continue to dominate the market. Distributed PV and associated energy storage systems are increasing, and have reached parity in in some areas, and have replaced expensive diesel generation in developing countries; therefore, distributed PV power supply will be selected by more and more users (households and businesses). This means that an increase of nearly 1.7 billion kilowatts of installed capacity will be reached in the following 25 years.

Fig. 3-4 shows the market share of PV applications in 2014, in which the newly installed capacity of ground-mounted PV station accounted for 48%, residential BMPV applications accounted for 20%, and non-residential BMPV applications accounted for 32%. The market share of BMPV applications accounted for 52% in 2014, marking a significant increase in 2013. BMPV application (including residential and non-residential applications) has always been the main type in PV market.

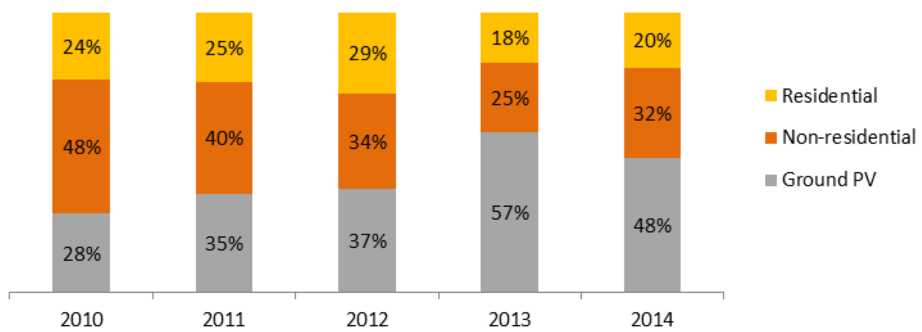


Fig. 3-4 Market share of all PV applications 2014

BMPV application is the dominant application form in the global PV market in 2014. The newly added installed capacity of BMPV applications in Japan, Germany and the United States ranked top 3 in 2014, accounting for 59%, 56% and 53% respectively. Although China introduced policies regarding distributed PV to encourage the applications, at present they are mainly used in industrial buildings, and households application is still on the initial stage. As Chinese residents understand the products for household photovoltaic power generation, household photovoltaic power generation will embrace rapid development.

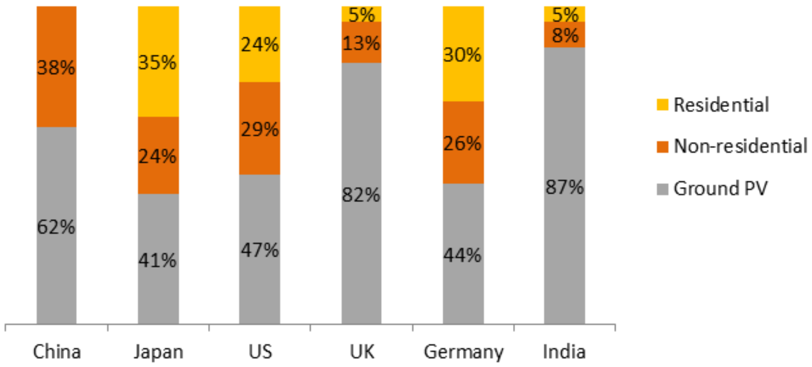


Fig. 3-5 Market share of PV applications in the countries in 2014

3.2. The development status of BMPV market in the APEC region

According to the statistics of 2014 installed capacity, the APEC region enjoys the highest speed in developing PV power stations. In addition to the economies including China, Japan, the US, Australia, Korea, etc. ranking top 10 in newly increased installed capacity, Canada, Chile, Malaysia, Thailand and Mexico, etc also witnessed rapid increase in PV installed capacity. Preliminary estimate shows that the installed capacity of the APEC region in 2014 was 29.8GW, accounting for about 76% of the newly increased; and the overall installed capacity was about 80GW, about 44.9% of cumulative installed capacity. The rapid development can be attributed to government support for PV industry as well as related supportive policies implemented in the APEC member economies.

APEC economies are of varied socio-economic development level, which leads to a wide gap in distributed PV applications and market development. Japan, the United States, China, Australia and Korea are ranked top 5 in terms of BMPV installed capacity. In 2014, Japan rose to the first place with its BMPV installed capacity of 6589MW, in which BIPV installed capacity reached 60MW, and the market was dominated by BAPV system applications in residential and industrial & commercial buildings. The United States followed as the 2nd place with its BMPV installed capacity of 2227MW. The installed capacity of China stood at 2050MW, with market dominated by BAPV system in industrial & commercial buildings. The installed capacity of Australia stood at 825MW, which enjoyed the highest BMPV penetration rate. Canada with rooftop PV system as its major application form reached BMPV installed capacity of 141MW. Latin American region such as Chile, Mexico and Peru also have witnessed the rapid development.

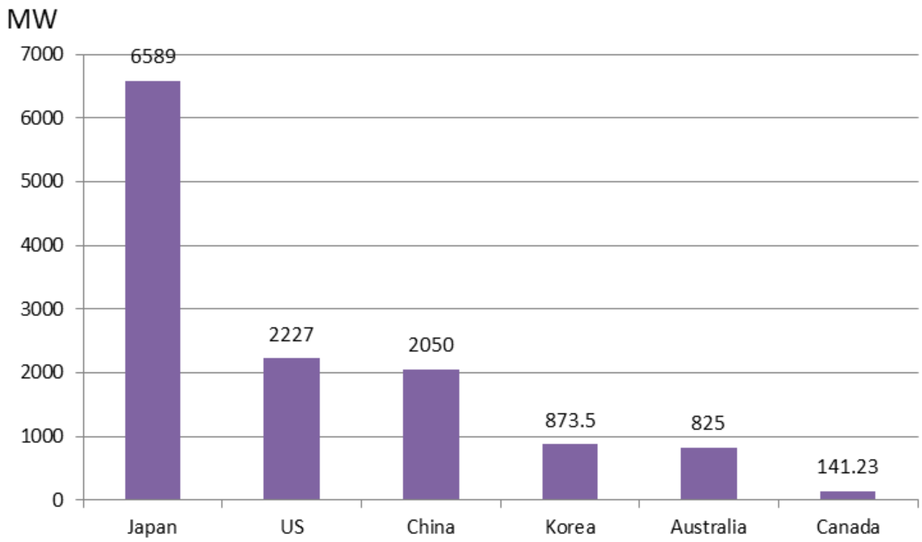


Fig. 3-6 Top 6 APEC economies in BMPV application market in 2014

China, Japan and the United States have a huge PV power market, and BMPV applications in developed countries such as the United States and Japan are becoming mature; in emerging economies like China, BMPV applications in residential and commercial buildings is in a stage of rapid development with introduction of government incentive policies, optimization of investment and financing mechanism and rising public awareness. Australia has the highest residential solar PV market penetration in the world. The development of BMPV market in small and medium economies like Korea and Malaysia has been driven by their respective incentive policies.

As stated in Chapter 2, the BMPV system has become the major distributed PV application form, and the installed capacity of grid connected BMPV is equivalent to that of distributed PV systems. The development of BMPV market in China, Japan, the United States, Australia, Malaysia and Korea will be briefed below.

3.2.1. BMPV market in China

In 2014, with the introduction of a number of national support measures, the application market for various types of PV was further expanded. China's annual PV grid-connected installed capacity in 2014 reached 10.6GW (8.55GW of ground-mounted PV and 2.05GW of distributed PV), maintaining the same level as 2013, and accounting for a quarter of the global newly added installed capacity. China has been the largest PV application market in the world over the past two years. By the end of 2014, China's cumulative PV grid-connected installed capacity reached 28.05GW, a 60% increase over last year, ranking second in the world after German, and 4.67GW were from cumulative installed capacity of distributed PV, accounting for 16.7% of the total cumulative installed capacity.

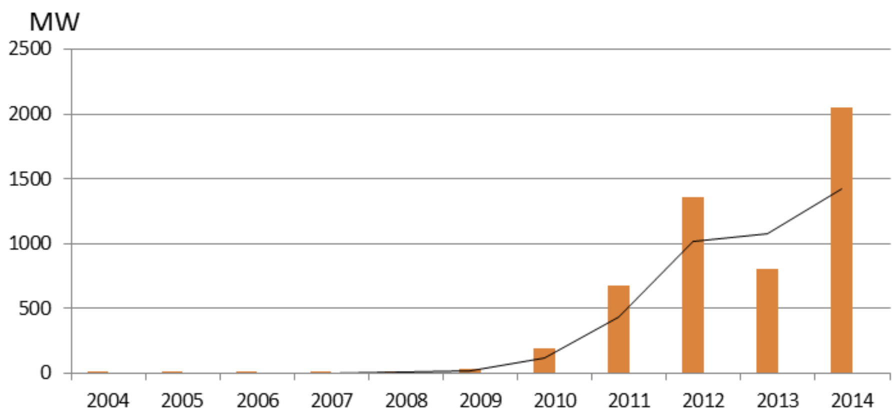


Fig. 3-7 Annual added installed capacity of BMPV in China in 2000-2014

According to the latest data released by National Energy Administration of China, by the end of 2015, China's PV installed capacity reached 43.18GW, including 37.12GW of ground-mounted centralized PV and 6.06GW of distributed PV, and China has become the largest producer of PV power. In 2015, the ground-mounted PV installed capacity was increased by 13.74GW and the distributed PV installed capacity was increased by 1.39GW. For 2015 cumulative PV installed capacity of the provinces (autonomous regions and cities) in China, see Fig.3-8.

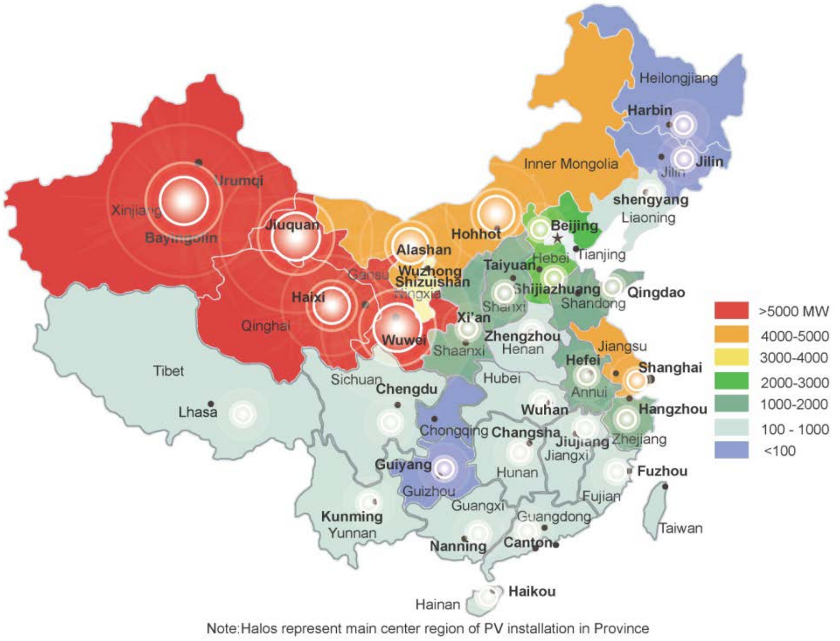


Fig. 3-8 Distribution of PV cumulative installed capacity by the end of 2015

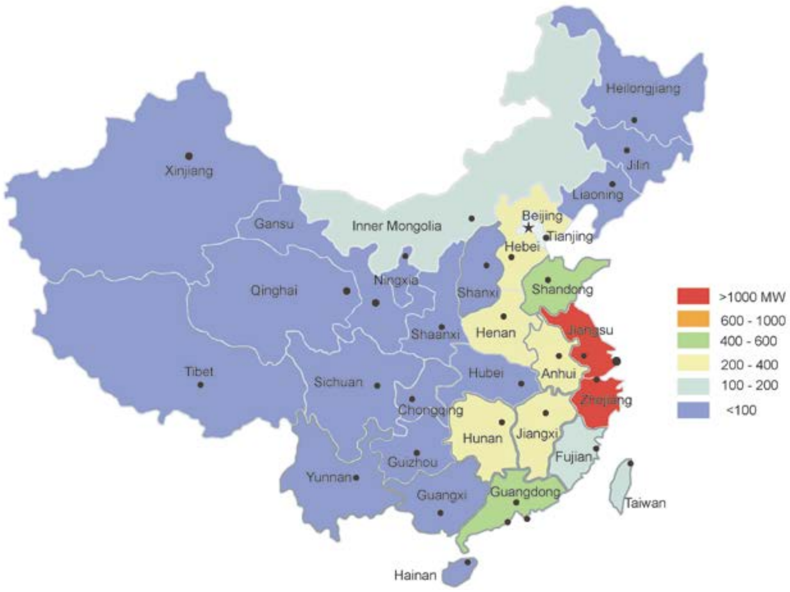


Fig. 3-9 Distribution of cumulative installed capacity of distributed PV by the end of 2015

Table 3-1 Information on construction of PV power stations in China by the end of 2015

Area	Province (autonomous region/city)	Cumulative installed capacity (MW)		Added installed capacity (MW)	
			Distributed power station		Distributed power station
	Total	43180	6060	15130	1390
East China	Beijing	160	140	20	20
	Tianjin	120	90	30	0
	Hebei	2390	270	890	0
	Liaoning	160	90	60	30
	Shanghai	280	70	40	40
	Jiangsu	4220	1180	1650	330

	Zhejiang	1640	1220	900	510
	Fujian	150	120	30	0
	Shandong	1330	440	730	60
	Guangdong	630	560	110	60
	Hainan	240	50	50	0
	Subtotal	**11320**	**4230**	**4510**	**1050**
Central China	Heilongjiang	20	10	10	10
	Jilin	70	10	10	10
	Shanxi	1130	20	690	10
	Anhui	1210	320	710	80
	Inner Mongolia	4890	180	1870	0
	Jiangxi	430	260	40	0
	Henan	410	270	180	110
	Hubei	490	60	350	0
	Henan	290	290	0	0
	Subtotal	**8940**	**1420**	**3860**	**220**
West China	Guangxi	120	70	30	0
	Chongqing	0	0	0	0
	Sichuan	360	30	300	20
	Guizhou	30	0	30	0
	Yunnan	650	20	300	0
	Xizang	170	0	20	0
	Shaanxi	1170	50	620	60
	Gansu	6100	40	930	40
	Qinghai	5640	0	1510	0
	Ningxia	3090	30	920	20
	Xinjiang Autonomous Region	4060	40	1310	0
	XPCC	1600	0	790	0
	Subtotal	**22990**	**280**	**6760**	**140**

Table 3-2 Statistics on total electricity consumption by province until 2015

Area	Province (autonomous region/city)	2015GDP (CNY100 million)	Installed capacity of distributed PV (10^3KW)	2015 total electricity consumption (100 million kW)	Population density (people per km)
	Total	***676708***	***6060***	***55500***	
East China	Beijing	22968.60	140	952.7	1322
	Tianjin	16538.19	90	800.60	1270
	Hebei	29806.10	270	*3097.0*	391
	Liaoning	28743.40	90	1984.89	297
	Shanghai	24964.99	70	1405.55	3826

	Jiangsu	70116.38	1180	5114.70	743
	Zhejiang	42886.00	1220	3554.0	522
	Fujian	25979.82	120	*1611.0*	307
	Shandong	63002.30	440	*4246.4*	620
	Guangdong	72812.55	560	*4975.0*	597
	Hainan	3702.80	50	*240.2*	255
	Subtotal	**401521.13**	**4230**	**27982.04**	----
Central China	Heilongjiang	15083.70	10	868.97	81
	Jilin	14264.00	10	651.96	147
	Shanxi	12802.58	20	1737.2	183
	Anhui	22005.60	320	1639.8	494
	Inner Mongolia	18032.79	180	2542.87	21
	Jiangxi	16723.80	260	1087.26	272
	Henan	37010.25	270	2879.62	565
	Hubei	29550.19	60	1665.16	313
	Henan	29047.20	290	1447.63	318
	Subtotal	**194520.11**	**1420**	**14520.47**	----
West China	Guangxi	16803.12	70	*1286.5*	201
	Chongqing	15719.72	0	*846.0*	363
	Sichuan	30103.10	30	*2027.0*	167
	Guizhou	10502.56	0	*1168.8*	199
	Yunnan	13717.88	20	1650	118
	Xizang	1026.39	0	*318.8*	2.5
	Shaanxi	18171.86	50	1221.73	233
	Gansu	6790.32	40	*1116.2*	57
	Qinghai	2417.05	0	658	8
	Ningxia	2911.77	30	*843.6*	100
	Xinjiang Autonomous Region	9400.00	40	1602.9	13
	Subtotal	**127563.77**	**280**	**12739.53**	**---**

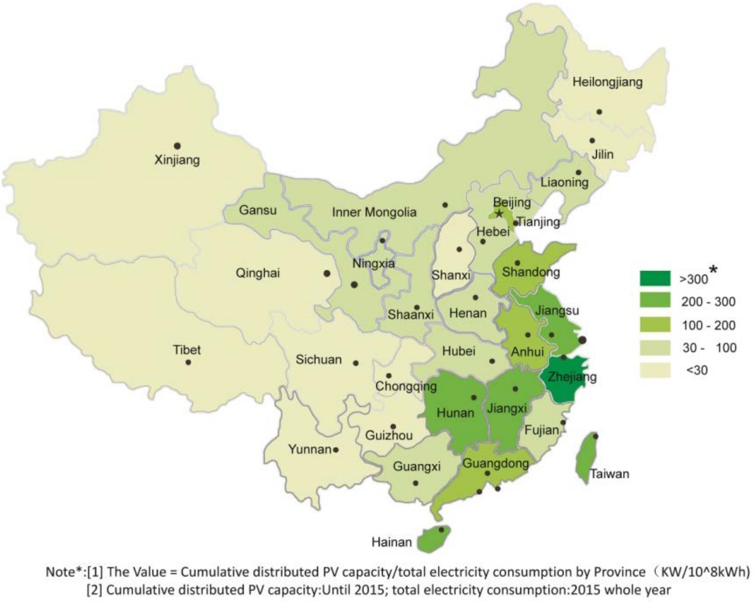


Fig.3-10 Analysis on development potential of distributed PV market by province

From the above, China's installed capacity (15.13GW) was up 40% year over year; China's added installed capacity ranked 1st in the world in the three years, and China's cumulative installed capacity ranked 1st in the world. The ground PV power stations dominate the China's PV market, and are concentrated in the West China where the solar irradiation is abundant; the distributed PV are concentrated in the Central China and East China which feature high population density, developed economy, high electricity demand and high electricity rate. Besides, PV applications have been gradually diversified, and PV is combined with poverty alleviation, agriculture and climate environment.

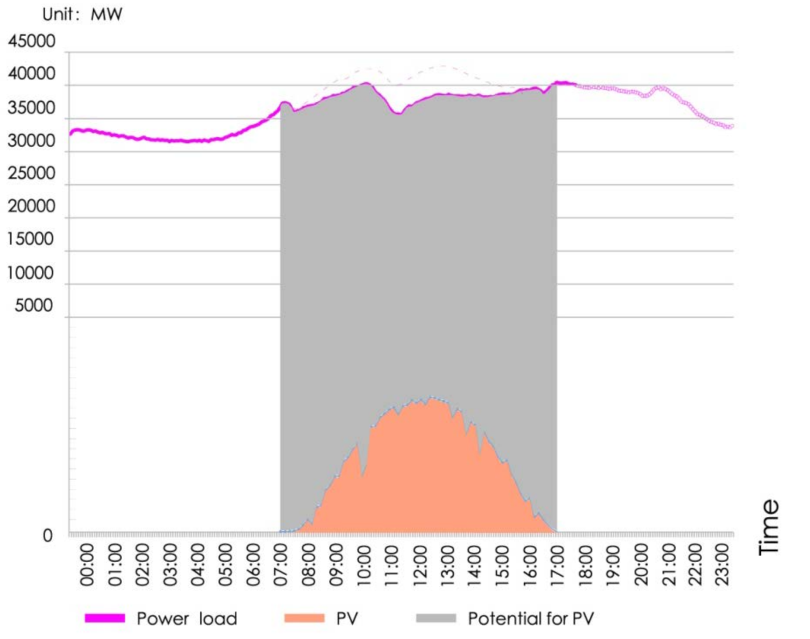


Fig.3-11 Daily power load of Jiangsu in winter

China's market share of distributed PV is increasing. Currently, in addition to Chongqing, Guizhou, Qinghai and Xizang, other provinces also have distributed PV power generation projects. There are more than 12 provinces, each of which has an installed capacity of over 100MW. China has become the world's important distributed PV market. According to the analysis, the ratio (Pe) of the installed capacity of the distributed PV to the total electricity consumption [1] is higher in Jiangsu [2], Zhejiang, Hainan, Jiangxi and Hunan, and however, the highest penetration level of PV power among the five provinces is less than 5%, and that of the distributed PV power generation is less than 2%. It becomes clear that there still remains considerable potential for development of distributed PV power generation.

Note: [1]: The Pe indirectly represents contribution of the distributed PV systems to the electricity *demand:*

[2] By the end of 2015, the maximum electricity load of Jiangsu exceeded 81GW, and its penetration level of renewables was 9%. The PV power generation exceeded 4.22GW (distributed PV was up to 1.2GW, accounting for 28%). The installed capacity of Xinjiang was up to 20GW, and maximum electricity load of 25GW.

3.2.2. BMPV market in the United States

American PV market has always been driven by grid-connected PV installations. By the end of 2014, 6212MW capacity was added to grid-connected PV systems, which make cumulative installed capacity reach around 18317MW. The cumulative total installed capacity of distributed PV reached 8573 MW, accounting for 46.8% of the cumulative total PV installed capacity. There are 644038 interconnected distributed PV systems.

Several utilities in the U.S. lease customer roof space for PV installation with generated electricity being fed directly back to the grid, which is generally considered as playing a beneficial “strategic” supporting role for the regional power grid. This emerging business has blurred the boundaries between large centralized power plant and distributed PV power plant. One of the largest rooftop programs in distributed PV applications is located in California and has a target capacity of 250MW, consisting of multiple 1 MW to 5 MW subsystems.

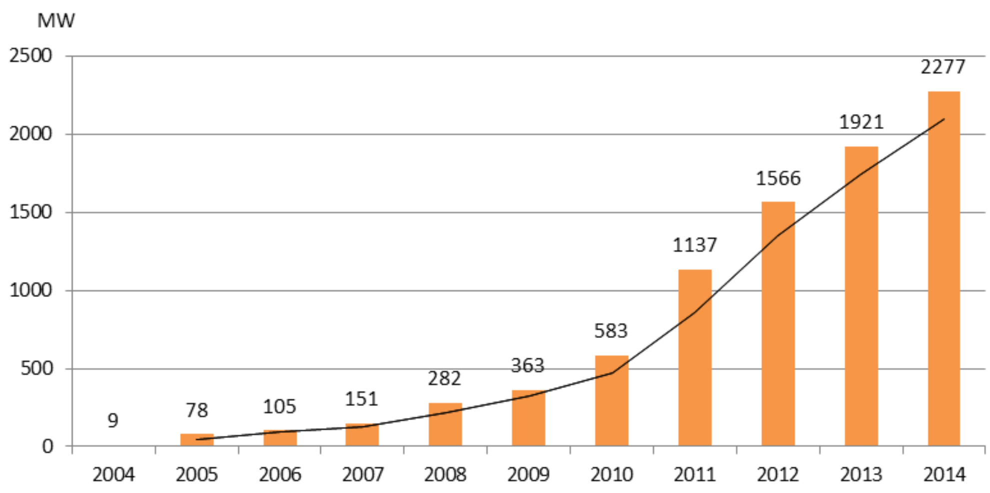


Fig. 3-10 Change trend of annual added BMPV installed capacity of the United States in 2004-2014

3.2.3. BMPV market in Japan

The annual installed capacity in Japan reached 9740 MW (DC-base) in 2014, about 40% increase from the previous year (2013: 9686MW). Almost all the PV systems were of grid-connected type. Breakdown of the annual installed capacity of 2014 by applications: 1.4 MW for off-grid systems, 9739MW for grid-connected systems, in which 6589MW were from distributed PV systems.

The cumulative PV installed capacity by the end of 2014 reached 33923MW, in which 124MW was from off-grid systems and 23214MW was from grid-connected systems. The applications of distributed grid-connected PV systems hit a new record of 18184MW, and the residential PV systems have always been developing rapidly. By the end of 2014, the cumulative residential PV installed capacity reached 5000MW.

Cumulative PV installed capacity as of the end of 2014 reached 23 339 MW. Cumulative PV installed capacity by application is; 8,8 MW for off-grid domestic, 116 MW for off-grid non-domestic and 23 214 MW for grid-connected.

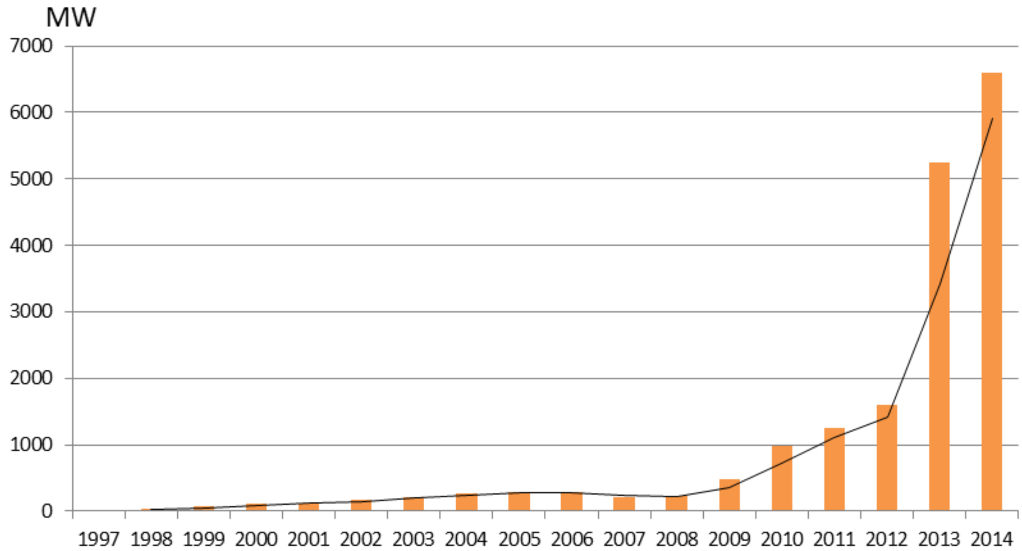


Fig. 3-11 Changing trend of the annual added BMPV installed capacity of Japan in 1997-2014

As a developed country, Japan has higher energy demand but deficient land resources. Thus, its PV market is mainly occupied by BMPV which has higher share.

3.2.4. BMPV market in Australia

By December 2013, the residential PV installed capacity of Australia reached 3GW. In 2014, the installed capacity of its residential rooftop solar PV power generation system reached 4GW, 4 times over that of 2011. More than 173,000 PV systems were installed; currently, most are small BMPV.

The Australian market for PV installations experienced modest growth in 2014. In 2014, the majority of installations took advantage of incentives under the Australian Government's Renewable Energy Target (RET) mechanisms, with further drivers provided by grants and financial assistance from the Australian Renewable Energy Agency (ARENA) and the Clean Energy Finance Corporation (CEFC). The market for rooftop systems on private residences declined in volume, though it remained as the primary market segment. The decline in residential volume was fully offset by growth in commercial systems, which were less than 100kW in size. The market grew dramatically for systems greater than 100 kW, owing largely to the installation of several utility-scale systems funded over the previous years, but is not expected to be sustained at this level. Average system size has continued to grow steadily as residential system sizes increase and as a growing number of businesses invest in PV.

Fig. 3-12 Solar home systems in Australia

Though the PV power has reached grid parity compared against retail electricity tariffs in many parts of Australia, the tariff is still stabilized. Besides, high market penetration of residential PV systems in residential segment is constraining the sustained growth of PV power in this sector.

Fig. 3-14 illustrates penetration levels approaching 40% of residential PV systems in Brisbane and surrounding areas – the situation is similar across the Capital area of Australia . For this reason, the Australian PV industry is increasingly turning its attention towards commercial power plants, which represented over 20% of capacity installed in 2014.

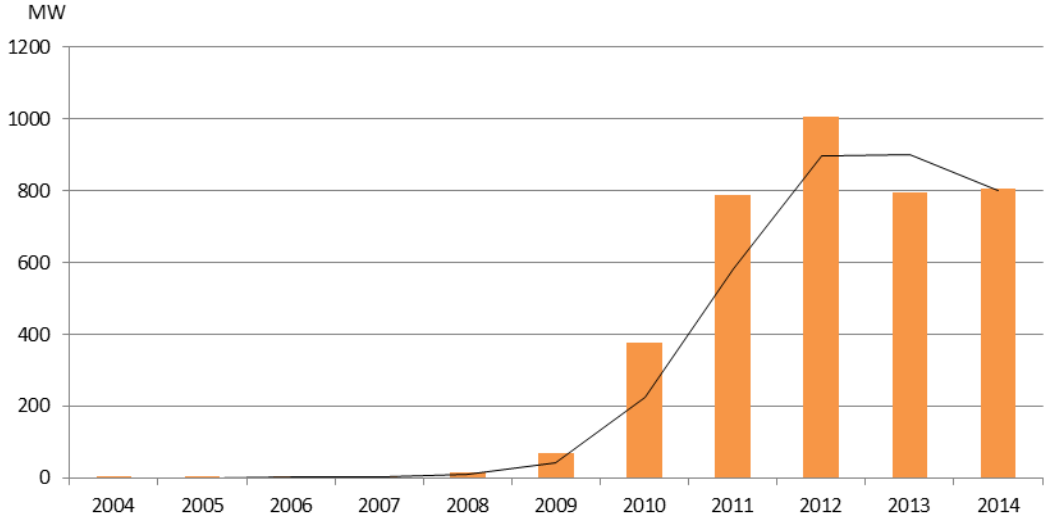


Fig. 3-13 Changing trend of 2004- 2014 annual increase in BMPV installed capacity of Australia

Though PV has reached grid parity against retail electricity tariffs in many parts of Australia, electricity prices have stabilised, and high market penetration in the residential segment is constraining sales to this sector.

Figure 3-14 illustrates penetration levels approaching 40% of residential dwellings in Brisbane and surrounds – the situation is similar across Australian capital cities. For this reason, the Australian PV industry is increasingly turning its attention towards commercial installations, which represented over 20% of capacity installed in 2014.

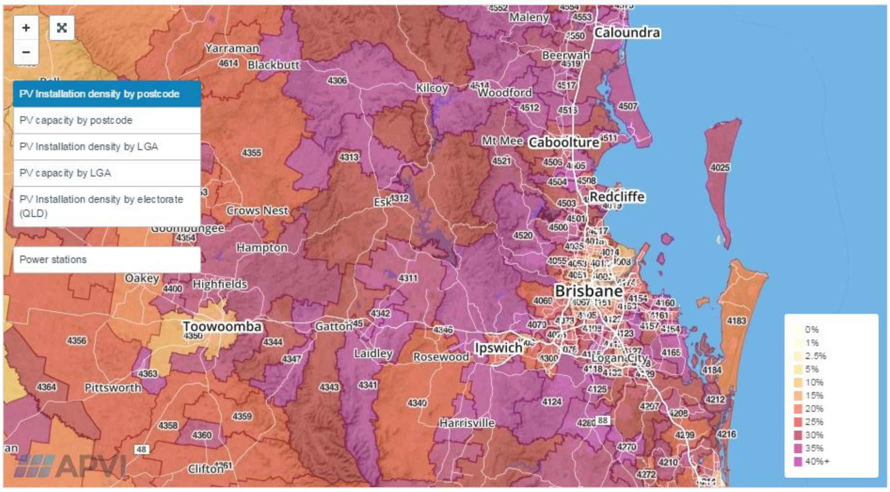


Figure 3-14: Penetration Levels exceeding 40% (Source: APVI)

3.2.5. BMPV market in Malaysia

Before 2006, most of the PV installed systems are off-grid systems funded by the government for rural electrification. From 2006 to 2010, Ministry of Energy, Green Technology and Water (MEGTW) and Global Environmental Fund (GEF) jointly initiated the "Malaysia building integrated PV (MBIPV)" program to build domestic market and promote installation of BIPV grid-connected system. The installed capacity of BIPV grid-connected systems reached 2MW upon completion of the program.

The MBIPV program ended in 2011, and FiTs was formally implemented on December 1, 2011. The residential rooftop PV program was introduced in September 2012 to promote the application of photovoltaic system in the rooftop and residential fields to achieve sustainable energy development. In this context, the distributed grid-connected system continues to grow, which will eventually reach 1.25GW PV installed capacity by 2020.

Malaysian PV market is absolutely dominated by distributed grid-connected PV systems. By the end of 2014, the cumulative installed capacity reached 160MW, accounting for over 95% of the total; however, over the years not a single ground-mounted centralized power station project was built, as shown in Fig. 3-15.

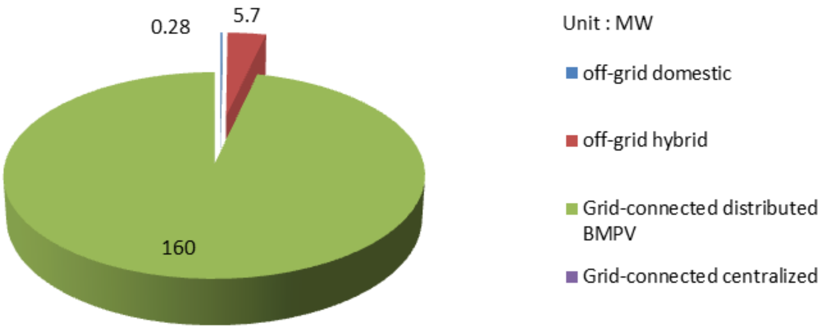


Fig. 3-15 The Malaysian cumulative installed PV power in submarket by 2014

3.2.6. BMPV market in Korea

By the end of 2014, the total PV installed capacity stood at around 2.4GW, in which, the centralized grid-connected PV power stations accounted for 87% of the cumulative PV installed power, and the distributed grid-connected PV system accounted for 13% of the cumulative PV installed power.

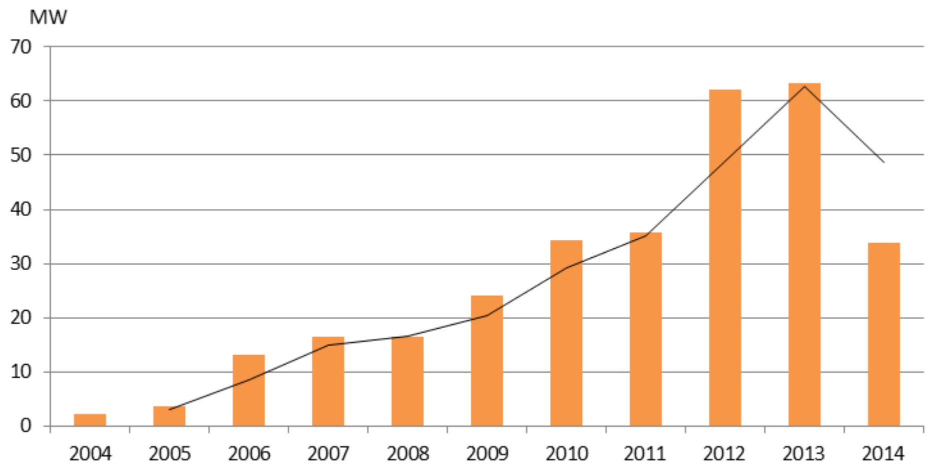


Fig. 3-16 Changing trend of the annual added BMPV installed capacity of Korea in 2004-2014

3.3. Driver for BMPV development

3.3.1 Photovoltaic power generation will become the main source of energy and electricity in the future.

Based on the report issued by the Office of Science, United States Department of Energy in April 2005, energy ranks first in the list of world's top 10 focus issues (energy, water, food, environment, poverty, terrorism and war, disease, education, democracy and population). The world's population is about to reach 10 billion by 2050, resulting in energy demand of 40- 60TW installed capacity, which can only be achieved by relaying on renewable energy. However, the world’s potential water resources are 4.6TW, economic recoverable resources is only 0.9TW; the actual exploitable wind energy and biomass resources are 2TW and 3TW respectively. Solar energy is the only energy source to satisfy human energy demand, which has a potential resources reaching 120000TW, and actual exploitable resources were up to 600TW (nuclear power is a largely controversial topic, and only 3TW nuclear energy can be exploited by using the current nuclear fission technologies. It is still unknown whether controllable nuclear fusion technology can be achieved.)

According to the IEA study, if countries from all over the world reach a climate agreement, renewable energy will account for more than 50% of the total energy source, and solar PV power generation will account for more than 20% of the total electricity by 2040; until 2050 PV installed capacity will account for 27% of the global power generation installed capacity to become the largest source of power. It can be concluded that PV power generation will become the main source of energy and electricity in the future, which shall be developed firmly.

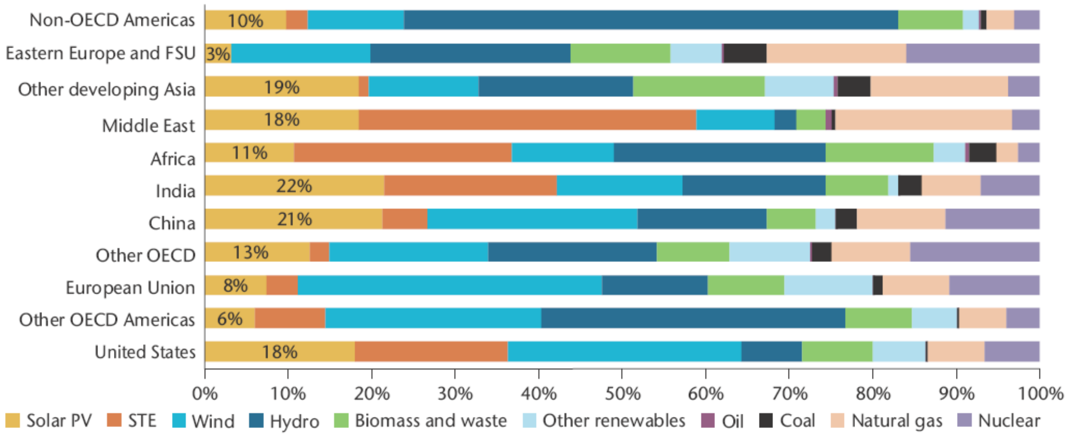


Fig. 3-17 Forecast of the proportion of solar PV power generation in the energy structure in 2050 in various regions around the world (IEA)

According to *2015 Global Renewable Energy Development Report* (REN21), at the beginning of 2015, at least 164 countries have renewable energy development goals, and about 145 countries have promulgated supporting policies regarding renewable energy; PV power generation has become a" favorite" for its advantages among various types of renewable energy. By 2014, 62 economies developed PV power generation, and more than 20 economies have over 1GW PV installed capacity.

In 2013, the global renewable energy power generation continued to develop rapidly and approached to 5070TWH, accounting for 22% of the world (22.6% in 2014), and its generating capacity exceeded that of natural gas for the first time in history, with milestone significance. The growth in the markets of hydropower and solar energy grew is the most notable, and the solar energy is expected to become the main energy by 2030, and will become the leading energy by 2050.

3.3.2. BMPV technology with competitive technical economy

As compared to other PV systems, distributed PV systems have advantages in electricity consumption and transmission, and in combination with energy storage and smart technologies, they can improve penetration level of grid connection. These systems have competitive technical economy and have become an affordable PV system.

See Chapter 4.3 in this report.

3.3.3 Huge potential of available BMPV resources

According to the forecast of IEA PV roadmap, the market share of residential and commercial PV systems (both form the BMPV system in this document) will continue to grow. By 2020, the installed capacity of residential PV systems will account for 56.2% of the cumulative installed capacity, while commercial PV systems will account for 10.5%, and both will account for 66.7%, representing two thirds of the PV market. By 2050, the residential PV systems will account for 43.7% of the cumulative installed capacity, while commercial PV system will account for 12.8%, and both will account for 56.5%. As shown in Table 3-3, the IEA forecast indicates that the application of BMPV always occupies leading position in terms of the development of PV market.

Table 3-2 Forecast of PV installed capacity by the end user department

PV Capacity(GW)	2020	2030	2040	2050
Residential	118	447	957	1380
Commercial	22	99	243	404
Utility	49	223	551	908
Off-grid	21	103	267	463
Total	210	872	2019	3155

Take China as an example. By end of 2014 the BMPV system cumulative installed capacity is 5.13GW, accounting for 18%. Compared to Germany 73.7%, Japan 67.6% and America 35.8% respectively, China still has great market potential. According to the statistics by National Energy Administration of China, approximately 300GW of PV systems can be installed on Chinese buildings and 80GW of PV systems can be installed in provincial level and above industrial parks only.

However, according to *China Statistical Yearbook 2012*, considering the speed of urbanization, the newly added building areas, available areas, base of building energy consumption and other factors, the forecast is as follows: by 2020, according to the forecast of 2 billion m^2 newly added build-up area 2016-2020, the total build-up area in China will be about 71.4 billion m^2 by 2020, in which the urban housing build-up area is 38.5 billion m^2 while the rural housing build-up area is 32.9 billion m^2. By 2020, the build-up area available for installing PV systems will amount to 30.4 billion m^2, and about 3TW PV systems can be installed.

3.3.4. Breakthrough of key supporting technologies

Distributed PV power generation has intermittence and fluctuation. When PV power is connected to the grid, it can affect power structure and planning & design of distribution network, operation control of distributed power generation, distributed energy storage and high use efficiency of energy at the user side. Therefore, it is necessary to coordinate structure optimization of the distribution network, as well as improve relevant technologies in regard to grid connection of distributed PV power and MicroGrid.

(1) Grid connection technology

For example, Germany has successively established relevant guidelines, such as *Technical Guideline Generating Plants Connected to the Medium-Voltage Network* to guide development of distributed PV power plants and grid connection. The relevant grid connection technical standards are very clear and rigorous, including active power control, reactive power control, electric energy quality, protection parameters setting, grid failure analysis, and other aspects, and shall specify quantization of all indicators, and explain and describe distributed PV system dispatching mode of different installed capacity and different connection voltage classes, and define grid connection commissioning procedure and contents. This provides basis for power grid enterprises and owners of distributed power projects in early planning and design, and make them comply with detailed requirements of grid connection technical standards in the project construction to achieve quick grid connection of distributed power, and ensure safe and stable grid operation.

(2) Supporting grid

The distributed PV power generation is self-sufficient, but still there are a large number of distributed PV systems connected into grid. Therefore, investment and reconstruction for distribution network should be constantly strengthened to meet the requirements of distributed power grid connection. In addition, short-term weather change will significantly affect PV electricity output in some areas, and the fluctuation of PV power generation may result in significant growth in peak load regulation capacity and grid spare capacity. Thus, the construction of high-capacity long-distance power transmission channel shall be strengthened, and the grid capacity to integrate the distributed power can be increased by upgrading large grid support and power distribution network.

(3) Energy storage technology

Storage technology is the strategic supporting technology to change future energy structure and electricity production and consumption pattern. It can suppress intermittence and stochastic fluctuation in power generation of solar and other renewable energy, effectively regulate peak and fill valley and improve power quality, so as to realize power stability of solar power generation, and make it become a high quality power supply.

In terms of energy form, the storage method of electric energy can be roughly divided into physical energy storage and chemical energy storage. The physical energy storage can be subdivided into mechanical energy storage and electromagnetic field energy storage: mechanical energy storage consists of pumped-storage, compressed air energy storage, and flywheel energy storage; electromagnetic field energy storage includes superconducting magnetic energy storage and super capacitor energy storage. The chemical energy storage can be subdivided into electrochemical energy storage and hydrogen energy storage: electrochemical energy storage includes lithium ion battery energy storage, all vanadium flow batteries and lead-acid battery energy storage. Currently, except relatively mature pumped storage technology, other high-capacity storage technologies are still in the experimental demonstration stage even in the preliminary research stage. Many key technical problems need be solved.

Take China as an example. Before 2020: the large-scale energy storage technologies in China still mainly depend on pumped storage; during 2020-2030: the lithium ion battery, flow battery and lead acid battery in electrochemical energy storage may play an important role and enter the stage of commercial application, and flywheel energy storage may be commercially applied to improvement of electric energy quality. After 2030: superconducting magnetic energy storage may be commercially applied to improving electric energy quality and enhance power system stability. Super-capacitor energy storage will be commercially applied to improvement of electric energy quality and MicroGrid. The new type of compressed air energy storage that does not use underground cavern or natural gas will have a place in energy storage field, and large compressed air energy storage willed widely used in the areas with suitable geographical conditions.

(4) Innovation of power system technologies

Technology innovation of power systems will greatly promote application of solar PV power generation. Virtual power station and smart grid belong to the new technologies.

A virtual power station is a power supply mode to achieve real-time balance between supply and demand in power supply area through interaction between power grid and communication network and coordination of multiple power sources (i.e., dual networks and multiple sources). Its major advantages are: (1) For connection with many distributed PV systems, the virtual power station can easily achieve overall consumption and balance in the power supply area; (2) in the utility grid, the power supply area can be used as one power supply for dispatch and control to prevent a large amount of distributed power sources in power grid dispatching, and this reduces the difficulty in power grid dispatching; (3) the virtual power station generally has a large scale and good predictability of output power, providing a convenient way for distributed PV system to enter the power market.

Smart power grid is characterized by robustness, high reliability, high economic effectiveness, environmental protection, transparent development and good interaction. It can achieve dynamic balance between the power generation side and the power consumption side can be realized in a larger area. In combination with smart metering technology, it improves the dynamic response performance for balance between supply and demand. Application of electric vehicles can provide considerable storage terminals for the smart power grid. All of these technologies can increase penetration rate of power generation of distributed PV and other renewable energy. In case of failure of utility grid, the smart microgrid technology allows the microgrid to supply power to the users when being disconnected from the power grid. This can improve the reliability of power supply to the users and provide customized power supply.

3.3.5 Standards for sound BMPV development

Large-scale application of PV technologies is attributed to the development of various PV-related technologies, including technologies of material, batteries, packaging and integration. Development of various PV technologies spurs establishment of unified standards. Establishment of standards can unify and standardize evaluation of PV technologies, and ensure large-scale application of PV technologies. Meanwhile, it also plays a key role in improving product quality and reducing cost.

Standards and certifications are closely linked. The standards serve as a basis for product certification and popularization of standards is realized by certification. The certification standards for solar PV modules are mainly classified into two categories, i.e., safety certification standards (such as IEC61730 and UL1703) and product performance standards (such as IEC61215 and IEC61646).

Based on the above standards, relatively common certifications include TUV, CE, VDE & MCS (EU certification), UL & ETL (America certification) and CQC & CGC (China certification).

The PV industry standards have been implemented since 1975. The main drivers of this historical process are: NASA's Jet Propulsion Laboratory (JPL), EU's Joint Research Centre (JRC), National Renewable Energy Laboratory (NREL) of the United States Department of Energy and International Electrotechnical Commission (IEC).

(1) JPL/JRC/NREL

In implementation of the FSA Project by JPL during 1975–1986, Block (I-V) Specification is derived, which becomes the first quality test specification for crystalline silicon terrestrial PV modules in the PV industry. Block test sequence is originated from the NASA test methods on solar battery modules for aerospace. In 1980, JRC developed the CEC201 test specification. In 1981, JRC developed the CEC501 test sequence. In 1982, JRC released CEC502 and mentioned outdoor tests for the first time. In 1988, NREL issued the IQT test sequence for thin film components.

(2) UL

In 1986, UL of the United States issued the UL1703 safety standard for photovoltaic modules, which becomes the basic standard for access to the US market. Compared to the quality reliability standard test, this test pays more attention to whether the PV modules after tests will cause harm to persons. On March 15, 2002, the third edition was released. In 2014, it was further modified and the UL1703:2014 edition was released which was greatly modified in fire testing.

(3) IEC

In 1981, the International Electrotechnical Commission (IEC) established the Technical Committee 82 (TC82) for preparation of solar PV power system standards, which is responsible for study of quality test standards for PV modules.

IEC61646 was formulated in 1996 and the currently used edition is the second edition published in 2008. IEC61646 is the test standard for thin film modules, most of the content and the test process are the same as those in the IEC61215, and the greatest difference with IEC61215 is addition of light soaking test.

The first edition of IEC61215 was formulated in 1993 and the edition currently used is the second edition published in 2005. IEC61215 is a performance test standard, which specifies 18 tests of crystalline silicon modules.

IEC61730 was formulated in 2004. It is divided into two parts: IEC61730-1 and IEC61739-2. The Part-1 is for structure inspection and the Part-2 is for experiment. IEC61730 is a safety standard which is applicable to crystalline silicon modules and thin film modules.

If PV systems are installed on buildings or structures, the building safety restrains distributed systems. The safety performance of such PV systems should be higher than those installed on the ground-mounted station. BMPV standard system covers construction materials, products, test methods, design, construction, operation & maintenance, grid connection, etc. The published and implemented standards include:

DIN EN 15316-4-6-2009: Heating systems in buildings-Method for calculation of system energy requirements and system efficiencies-Part 4-6: Heat generation systems, photovoltaic systems

IEC 60364-7-712-2002: Electrical installations of buildings - Part 7-712: Requirements for special installations or locations; Solar photovoltaic (PV) power supply systems

NFPA 70 National Electrical Code: ARTICLE 690 Solar Photovoltaic (PV) Systems

JIS C8981-2006: Standards for safety design of electrical circuit in photovoltaic power generating systems for residential use", JIS C8956-2011 Structural design and installation for residential photovoltaic array (roof mount type)

Technical Code for Application of Photovoltaic System of Civil Buildings (JGJ 203-2010)

Code for Operation and Maintenance of Building Mounted Photovoltaic System (JGJ/T 264-2012)

In addition, some important standards are in the stage of development, such as prEN 50583

Photovoltaic in Buildings (*Draft*).

Standards play a very important role in promoting photovoltaic application. The standards specify the application principles and the minimum requirements, and make the related product manufacturing technologies and testing technologies more systematic. Better product reliability and safety are realized and cost is reduced dramatically. All countries should adopt mutually accepted standards. Governments should reserve some funds for standard preparation and strengthen infrastructure construction, including existing laboratories (test equipment and test ability) and public testing platforms, etc.

4. BMPV Policies and Technical Economy

4.1. Impacts of polices on BMPV application

1 Description of policies and measures and their comparison

Compared to the traditional fossil energy, the cost of power generation by renewable energy is higher, so it is the same with PV power generation system; therefore the support from the governments and financial institutions of APEC economics is required. According to the IEA (2010) classification, the policies supporting PV electric power market include feed-in tariff (FIT), direct capital subsidies (DCS), Green Electricity Scheme (GES), Photovoltaic Green Electricity Scheme (PVGES), Renewable Portfolio Standard (RPS), Photovoltaic RPS (PVRPS), photovoltaic investment fund (PVIF), tax credit (TC), net-metering scheme (NM), Electric Utility Activity (EUA) and sustainable building requirements (SBR). Among them, FIT, DCS, RPS, TC, SBR and GES are commonly used for promoting PV application, and most countries adopt FiT which gain highest support

FEED-IN TARIFFS (FiT)

The concept of FiTs is quite simple. The electricity produced by the PV system and transmitted to the grid is sold at a predefined price during a fixed period. In theory, the price could vary based on the inflation rate, but this is rarely the case. It is assumed that the electricity generated by the PV system can be fed to the grid and is not entirely consumed locally. The most successful examples of FiT systems can be found in China and the UK.

DIRECT CAPITAL SUBSIDIES (DCS)

PV is by nature a technology with limited maintenance costs and no fuel costs, but it requires higher upfront investment. This has led some countries to put in place the policies that reduce that up-front investment in order to incentivize PV. in the recent years, DCS has been enacted in Australia, Belgium, Sweden, Japan, the USA, Italy and China. These subsidies are, by nature, part of the government expenditures and they are limited in order to spare expenditure. Such subsidy scheme is more suitable for off-grid systems than FIT is.

RENEWABLE PORTFOLIO STANDARDS-RPS (RPS)

“Renewable Portfolio Standard” (RPS) aims at promoting the development of renewable energy sources in competitive electricity markets. The authorities define a share of the electricity to be produced by renewable sources that all utilities have to adopt, either by producing themselves or by buying specific certificates on the market. These certificates are sometimes called “green certificates” and allow renewable electricity producers variable subsidies for their electricity production, based on the market price of these certificates. This system exists under various forms. In the USA, some states have established RPS which, in certain cases, can guarantee the share of PV electric power. In Belgium and Korea, each MWh of PV electric power is attached to a specific number. A coefficient is used to calculate the proportion of PV electric power, depending on the the type of renewable energy and the size of power plant.

TAX CREDITS (TC)

Tax credits can be considered same as direct subsidies, since they allow reducing the upfront investment. Tax credits have been used in many countries including Canada, USA, Belgium (by 2010), Switzerland, France, Japan and Netherlands. Italy used a tax credit in 2013 in the commercial BMPV industry. These are highly dependent on the government budgets and are highly sensitive to the political environment.

SUSTAINABLE BUILDING REQUIREMENTS (SBR)

With around 70% of PV units installed on buildings, the building industry has a major role to play in PV development. Sustainable building regulations could become a major incentive to develop PV in countries where PV is competitive. These regulations include requirements for new building developments (residential and commercial) and also, in some cases, the norms for properties for sale. PV may be an option for reducing the energy footprint of the building or specifically mandated as a necessary element in building development.

Table 4-1 Comparison of the major policies for BMPV system market

	FiT	**DCS**	**GES**	**RPS**	**TC**	**SBR**
Policies	Monetary reward is offered, and is paid by the power company at a price higher than the retail price of electric power.	Direct fiscal subsidies can compensate equipment cost or total cost.	Users are allowed to purchase PV electric power from the power company at the negotiated price.	It is mandatory that the public power supply is from renewable energy	The cost of PV unit installation or all cost thereof is deducted from the payable tax.	For a newly built building or property sale, PV is required to reduce energy consumptio n of the building.
Target customers	Customers access to the network	Users with limited fund, e.g. households and public agencies	Residents and commercial power consumers	Relevant responsible parties, particularly power retailer	Then entity responsible for taxpaying, e.g. the salaried class and enterprises	New building developme nt; properties for sale
Executive body	Charging and manageme nt by the power sector	Government al authority is in charge of application, approval and payment	Commercial business of power company; project review by public administrative authority	Support through public administrati on by the supervisory authority	Manageme nt by the existing taxation authority	Manageme nt by the local housing approval authority
Economic and political consideratio ns	Internalizati on of the external effects of energy supply	Upfront capital investment is considered as major obstacle to PV power generation	Promote the commercializati on and marketization of PV electric power sale	This can be viewed as distortion of electricity market	Consistent with the benefit of direct capital subsidy and some negative impacts are avoided	It depends on the acceptance level of asset price and architectura l culture

A large part of the PV market remains dominated by FiT schemes (more than 70%) while subsidies aimed at reducing the upfront investment which represents around 16% of the incentives. With some success in Belgium, the Netherlands, Denmark and the USA, netmetering accounted for 2% of the world market in 2012. In 2013, this situation didn't change much and netmetering schemes stayed below 3%. Various forms of self consumption incentives exist in other countries (and are often improperly called "net-metering"), such as Italy where the Scambio Sul Posto had installed capacity of around 430 MW in 2013.

2014 historical

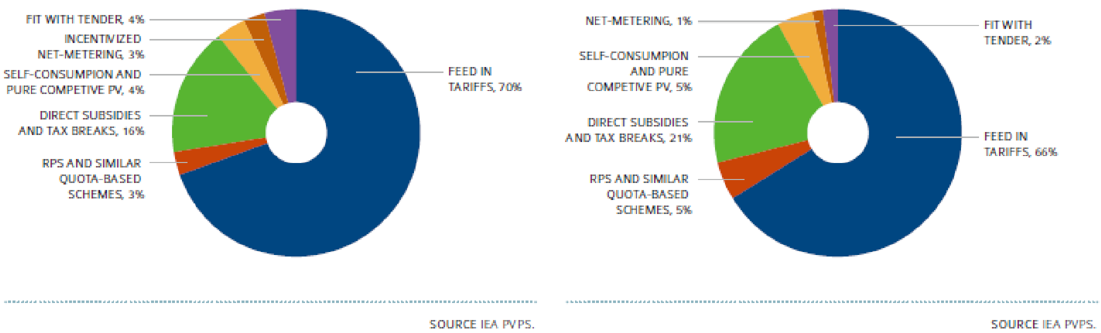


Fig. 4-1 Major policies for BMPV system market

Until now, the most successful PV deployment policies are FiT (most of the time without tendering process) and direct capital subsidies (including tax breaks). The growth of such policies in Japan (FiT), China (FiT+direct capital subsidies) and the USA (tax breaks, net-metering) shows how important these incentives remain. Other support measures remained anecdotic in the PV development history.

Table 4-2 Implementation of BMPV support policies in some countries

	AUS	AUT	BEL	CAN	CHN	DEN	FIN	FRA	GER	ISR	ITA
LOWEST FEED-IN TARIFFS LEVELS(USD/kWh)	0.05	0.13	-	0.25	0.1	0.07	-	0.09	0.38	-	-
HIGHEST FEED-IN TARIFFS LEVELS(USD/kWh)	0.54	0.17	-	0.35	0.16	0.11	-	0.36	0.41	-	-
INDICATED HOUSEHOLD RETAIL ELECTRICITY PRICES(USD/kWh)	0.27	0.27	0.27	0.06-0.15	0.09	0.4	0.21	0.19	0.38-0.41	0.15	0.21-0.27
DIRECT CAPITAL SUBSIDIES	+	R	R	R			+	R	+	*	R
GREEN LELCTRICITY SCHEMES	+	+	R	+					U	*	
PV-SPECIRC GREEN ELECTRICITY SCHEMES	+	+	R								
RENEWABLE PORTFOLIO STANDARDS	+										
PV SPECIAL TREATMENT IN RPS											
FINANCING SCHEMES FOR PV/INVESTMENT FUND	+	+	R						+		+
TAX CREDITS			+					-			+
NET-METERING/NET-BILLING/SELF-CONSUMPTION INCENTIVES	R	+	R	+	+	+		R		+	+
COMMERCIAL BANK ACTMTIES	+							+	+		+
ELECTRICITY UTILITY ACTMTIES	+			+					+		+
SUSTAINABLE BUILDING	+	+		+	+	+			+		+

REQUIREMENTS
NOTES: 1 NUMBERS ARE ROUNDED VALUES IN USD ACCORDING TO AVERAGE EXCHANGE RATES. U SOME UTILITIES HAVE DECIDED SUCH MEASURES. R SUCH PROGRAMMES HACE BEEN IMPLEMENTED AT REGIONAL LEVEL. L SUCH PROGRAMMES HACE BEEN IMPLEMENTED AT LOCAL LEVEL (MUNCIPALITIES). * THIS SUPPORT SCHEMES IS STARTING IN 2015. + THIS SUPPORT SCHEMES HAS BEEN USED IN 2014. − THIS SUPPORT SCHEMES HAS BEEN CANCELLED IN 2014

Table 4-3 Implementation of BMPV support policies in some countries (continued)

	KOR	MEX	MYS	NLD	NOR	POR	SPA	SWE	SWI	THA	TUR	USA
LOWEST FEED-IN TARIFFS LEVELS(USD/kWh)	-	-	0.3	-	-	0.09	-	-	0.15	0.17	0.14	+
HIGHEST FEED-IN TARIFFS LEVELS(USD/kWh)	-	-	0.31	-	-	0.19	-	-	0.27	0.21	0.14	+
INDICATED HOUSEHOLD RETAIL ELECTRICITY PRICES(USD/kWh)	0.12	0.11-0.14	0.1	0.23	0.11-0.16	0.3	0.25	0.27	0.17	0.07-0.1	0.17	0.09-0.37
DIRECT CAPITAL SUBSIDIES	+						+	+		+	+	+
GREEN LELCTRICITY SCHEMES				+				+	U			U
PV-SPECIRC GREEN ELECTRICITY SCHEMES									+			+
RENEWABLE PORTFOLIO STANDARDS	+				+			+				+
PV SPECIAL TREATMENT IN RPS	+											+
FINANCING SCHEMES FOR PV/INVESTMENT FUND				+		+						+
TAX CREDITS			+	+			+		+			+
NET-METERING/NET-BILLING /SELF-CONSUMPTION INCENTIVES		+		+		+		U	+		+	
COMMERCIAL BANK ACTMTIES			+						+	+		+
ELECTRICITY UTILITY	+		+					+	+			+

ACTMTIES					
SUSTAINABLE BUILDING REQUIREMENTS	+	+		+	U

NOTES:

1 NUMBERS ARE ROUNDED VALUES IN USD ACCORDING TO AVERAGE EXCHANGE RATES.

U SOME UTILITIES HAVE DECIDED SUCH MEASURES.

R SUCH PROGRAMMES HACE BEEN IMPLEMENTED AT REGIONAL LEVEL.

L SUCH PROGRAMMES HACE BEEN IMPLEMENTED AT LOCAL LEVEL (MUNCIPALITIES).

* THIS SUPPORT SCHEMES IS STARTING IN 2015.

+ THIS SUPPORT SCHEMES HAS BEEN USED IN 2014.

— THIS SUPPORT SCHEMES HAS BEEN CANCELLED IN 2014

In order to evaluate the different incentive policies of all countries, European Photovoltaic Industry Association (EPIA) published an investigation report, in which policies such as “feed-in tariff”, “initial investment subsidy” and “quota system” were evaluated and the results showed that “feed-in tariff” policy has advantages over policies in terms of simple and easy operation, guaranteeing the investor’s benefits, utilization efficiency of funds and the actual successful effects.

Table 4-4 Evaluation of various PV incentive policies

	Investor’s benefit guarantee	Simple and easy operation	Actual successful effect	Utilization efficiency of funds	Guarantee of different technical combinations
Quota system of renewables	😞😞😞	😞😞😞	😞😞😞	😞😞😞	😞😞😞
Feed-in tariff	😋😋😋	😋😋😋	😋😋😋	😋😋😋	😋😋😋
Investment subsidy	😞	😞😞	😞	😞	😞
Voluntary purchase	😋	😞😞	😋	😞😞😞	😋😋😋

2 Significance and application of FiTs

FiTs is intended to encourage scientific research, project development and extensive application of solar power generation. These subsidies have become legal obligations in some countries to compensate difference between the solar power generation and regular feed-in tariff and enable the solar power supply projects with premature technologies and high development/operation costs to gain long-term stable reasonable return, so as to attract the component/system operators and investors to enter this industry, thus promoting the sustainable development of this industry.

According to the statistics, the installed solar PV capacity increased during implementation of FiTs, and the share of power generation from new energy increased. This trend demonstrated that FiTs have been recognized and accepted.

From implementation of FiTs, the system installation costs decreased sharply. Taking a country as an example, after it implemented FiTs, the system installation costs reduced by 30%, and meanwhile FiTs reduced by 9% which was much lower than the decrease rate of the installation costs.

Especially during early implementation of FiTs, due to lack of experience, the policy resulted in sharp decline of costs and increase of installed capacity, and the policy lagged behind. Obviously, this was due to too small decrease rate of the FiTs. When China launched Golden Sun Pilot Project in 2008, the installed capacity expanded and the costs decreased dramatically. However, the FiTs policy lagged behind. The government invested huge fund.

From the above, FiT must be adjusted as costs decreased. FiT schemes must be modified in a timely manner. Decrease mechanism for FiT scheme is imperative.

From the government's perspective, efforts can be made from the following aspects:

(1) The projects with small installed capacity are developing rapidly. Thus, the decrease can be started from the subsidies for less than 50kW projects first and then to 50-250kW projects. The subsidies and the decrease mechanism shall depend on the installed capacity.

(2) For the private, public or other different projects, different subsidies shall be introduced. New subsidy measures shall be suitable for new PV systems of the comprehensive PV projects.

(3) EER (energy efficiency ratio) shall be introduced to the PV systems which supply electricity to buildings to reduce energy consumption of buildings.

From the above, the governments shall formulate flexible subsidy mechanisms and adjust the subsidy policies with reduction of costs and expansion of market scale. If necessary, learn the experience of advanced countries, and use automatic adjustment tools to revise the policies rapidly, smoothly and reasonably in an effort to minimize the fund investment, expand the market, cut the costs and develop the technologies.

4.2. BMPV policies in APEC region

APEC economies greatly vary in social and economic development level, so their BMPV development level is also different. It is necessary to find typical problems of their BMPV development and the causes, and learn the experience from the advanced countries to create suitable BMPV development roadmap for each APEC member.

4.2.1 BMPV policies of China

To promote the distributed BMPV industry, the Chinese government is now vigorously exploring new ways and has enacted a number of incentive policies.

(1) CDM (Clean Development Mechanism) **phase**

Due to the influence of international environment, launch of international projects and government-supported projects and the booming market, CDM is a win-win option widely welcomed in China and has laid a solid foundation for BMPV industry in China.

In 1995, the Chinese government issued the first policy document to support the PV industry, *Outline for Development of New Energy and Renewable Energy (1996-2010)* which set the objectives of developing wind energy, solar energy and other new and renewable energy sources. This marked the beginning of the PV industry policies of China.

On January 1, 2006, *Renewable Energy Law* and *Interim Measures for Pricing and Cost Sharing for Renewable Energy Power Generation* (Implementation Rules) formally took effect, which stipulates that the Chinese power grid companies must purchase all the electricity generated by renewable energy sources at full price and presents cost sharing policy that the PV electricity price above the conventional electricity price is compensated by the utility grid. This marked a new era of the renewable energy industry in China.

On May 30, 2006, *Interim Measures for Management of Special Funds for Renewable Energy Development* was promulgated that stipulates that the special funds are provided as subsidies or subsidized loans. Building heating and cooling, development and utilization of the renewable energy sources for power generation are key projects to be supported. This policy does not specify specific subsidy amount, but it guides the subsequent policies and brings benefit to PV industry in China.

On September 4, 2006, the Ministry of Finance and Ministry of Construction issued the *Interim Measures for Management of Special Funds for Renewable Energy Application* that clearly stipulates the principles for utilization of special funds for renewable energy supported buildings, the key sectors to be supported, coverage scope of fund and types of subsidies and it is the first policy which lists "photovoltaic conversion and lighting using solar power integrated into buildings" as key projects supported by the special funds. This policy is constantly driven and fund management is refined to provide subsidies for pilot cities and pilot counties respectively.

(2) Golden Sun Pilot Project phase

At the beginning of 2009, the Chinese government launched the Building Integrated Photovoltaic Project and Golden Sun Subsidy Project, which started the era of Golden Sun Pilot Project.

Table 4-5: China's PV Policies in "Golden Sun Pilot Project" phase

Date	Issued by	Document name	Main contents
March 23, 2009	Ministry of Finance, Ministry of Housing and Urban-Rural Development	*Suggestions on Accelerating Application of Building Integrated Photovoltaic*	It clearly indicates application of BMPV is the top priority in new energy development in China. BMPV can solve energy issues and promote energy conservation, emission reduction and environmental protection.
March 23, 2009	Ministry of Finance	*Interim Measures for Management of Fiscal Subsidy Funds for Application of Building Integrated Photovoltaic*	It is intended to establish the installation standards for BIPV industry, promote BIPV in urban areas, provide subsidies for PV power generation in rural and remote areas, popularize BIPV application technologies; it also specifies a subsidy of 20 yuan/W for BIPV pilot projects with more than 50 kW capacity.
July 16, 2009	National Energy Administration, Ministry of Finance, Ministry of Science and Technology	*Notice regarding Executing Golden Sun Pilot Project* and *Interim Measures for Management of Fiscal Subsidy Funds for Golden Sun Pilot Project*	It stipulates, in principle, any grid-connected PV power generation projects can receive subsidy equal to 50% of the total investment on the photovoltaic power generation system and the supporting power transmission works, and off-grid PV power systems in remote areas without access to electric power grid, the subsidies can reach 70% of the total investment on the system. Launch of the Golden Sun Pilot Project motivated PV photovoltaic companies in China.
September 21, 2010	Ministry of Finance, Ministry of Science and Technology, Ministry of Housing and Urban-Rural Development, National Energy Administration	*Notice regarding Strengthening Management of Golden Sun Pilot Project and Other Building Integrated Photovoltaic Pilot Projects*	Major adjustment to the relevant policies in regard to equipment tendering, project adjustment, subsidy criteria, grid connection and other key links. In December of that year, it was announced to build 13 PV power generation demonstration parks in China.
January 27, 2011	Ministry of Finance, Ministry of Housing and Urban-Rural Development	*Notice regarding Executing Building Integrated Photovoltaic Pilot Projects*	Provide a subsidy of 6 yuan/W to compensate costs of project installation and other expenses; equipment suppliers receive subsidy equivalent to 50% of the agreed bid price to compensate costs of crystalline silicon modules, grid-connected inverters, lead-acid storage battery and other key modules and the owners receive a subsidy equivalent to 50% of the minimum bid price of crystalline silicon

			modules to compensate costs of non-crystalline silicon modules. Meanwhile, the crystalline silicon component, grid connected inverter, lead-acid storage battery and other key components must be purchased from listed suppliers in a national public tendering.
March 8, 2011	Ministry of Finance, Ministry of Housing and Urban-Rural Development	*Notice regarding Promoting Application of Renewable Energy Supported Buildings*	It specifies the objectives for promoting the renewable energy supported buildings in the "twelfth five-year" plan: renewable energy accounts for 15% of the total energy consumption of buildings by 2020. Meanwhile, it also defines the proportion of renewable energy supported buildings as constraint index to assess the development of echo-friendly districts and green towns.
July 24, 2011	National Development and Reform Commission	*Notice regarding Improving Feed-in Tariff Policies for Photovoltaic Power Generation*	All the solar photovoltaic power generation projects without tendering adopt nationally unified feed-in tariff and confirm a solar photovoltaic power generation project of an owner through concession bidding.

The advanced subsidy for the Golden Sun Project has always been controversial for triggering vicious competition and other negative events such as fraudulent subsidy request, demolition after construction and large proposal for small projects, which affect sound and sustainable development of the industry. In May 2013, the Ministry of Finance issued the *Notice regarding Clearing the Fiscal Subsidy Funds for Golden Sun Pilot Project*, which marked end of the historical mission of the Golden Sun Project.

(3) Distributed PV demonstration areas

In July 2013, the State Council issued *Suggestion on Advancing Sound Development of Photovoltaic Industry* to promote application of photovoltaic power on the consumer side, to incentivize various power consumers to build distributed photovoltaic power generation systems on the principles of "self-consumption, surplus power to electricity grid and regulation by grid", to offer feed-in tariff for distributed photovoltaic power generation systems according to generating capacity, to set the benchmark feed-in tariff for region-specific photovoltaic power stations based on the resources conditions and construction costs, and to establish the price and subsidy criteria through tendering and other forms, which can incentivize the photovoltaic companies to reduce cost and boost the photovoltaic market in China.

As some regions didn't fully implement the policies, lacked support measures, or had no sound work mechanism, the Chinese government enacted further supportive policies regarding normalized management, financial service, subsidy amount and subsidy methods during the period of 2014-2015.

Table 4-6: Photovoltaic related policies enacted by the Chinese government (2014-2015)

Date	Issued by	Document name	Main contents
September 2, 2014	National Energy Administration	*Notice regarding Implementing the Policies on Distributed Photovoltaic Power Generation*	"15 new policies" on distributed photovoltaic power generation systems and emphasis on development of distributed photovoltaic power demonstration areas, encourage various forms of distributed PV applications, and enhance safety assessment and management of photovoltaic products, photovoltaic power generation projects and building-mounted photovoltaic power generation installations.

September 10, 2014	National Energy Administration	*Notice regarding the Requirements for Accelerating Development of Distributed Photovoltaic Power Generation Demonstration Areas*	It incorporates BMPV power generation applications into assessment and reward/penalty system for energy conservation and emission reduction.
October 9, 2014	National Energy Administration	*Notice regarding Enhancing Construction, Operation and Management of Photovoltaic Power Plants*	Enhance planning and management of photovoltaic power plants, coordinate and promote construction of large photovoltaic power plant base and develop new financial products and services related to photovoltaic power plants.
October 28, 2014	National Energy Administration	*Notice regarding Normalizing the Order of Investment and Development of Photovoltaic Power Plants*	Emphasize preventing speculation in investment and development of photovoltaic power plants and maintain standardized and orderly construction of photovoltaic power plants.
March 25, 2015	Ministry of Industry and Information Technology	*Code of Practice for Photovoltaic Manufacturing Industry (2015 Edition)*	Rigorously control simple expansion of photovoltaic manufacturing projects and specify that newly built and extended PV manufacturing projects shall strictly comply with environment impact assessment system.
March 16, 2015	National Energy Administration	*Notice regarding Issuing Implementation Scheme for PV Power Generation Construction of 2015*	In 2015, the newly built distributed PV station projects can with the specified capacity can receive renewable energy subsidy. No restriction of construction scale is imposed on distributed rooftop PV power generation projects.
April 7, 2015	National Development and Reform Commission, Ministry of Finance	*Notice regarding Improving Emergency Power Mechanism and Power Demand Side Management in Urban Comprehensive Pilot Projects*	Guide and encourage users to implement online monitoring of power consumption and promote electric power services.
June 1, 2015	National Energy Administration, Ministry of Industry and Information Technology, Certification and Accreditation Administration	*Suggestions on Promoting Application of Advanced Photovoltaic Technologies and Products and Upgrade of the Industry*	The “forerunner” program is executed for the markets of specific sizes every year and the projects are required to use advanced technologies and products. Support technological progress of photovoltaic power generation through fiscal funds and government procurement
December 22, 2015	National Development and Reform	*Notice regarding of Improving the Policies on Standard Feed-in Tariff of Onshore Wind*	Clearly, the standard PV electricity price in Area I and Area II are reduced by 10 cents and 7 cents respectively and Area III by 2 cents in 2016. It specifies that a distributed

	Commission	*Power and Photovoltaic Power*	photovoltaic power generation project installed on building roof or in ancillary spaces can choose to use either “ self-consumption and surplus power to electricity grid” mode or “fully grid connected” mode. The projects already operating in the former mode can be changed to the “fully grid connected” under certain circumstances. The electric power generated by the “fully grid connected” projects will be purchased by the grid companies at the local standard feed-in tariff specified for photovoltaic power plants.

Compared to the “Golden Sun Project” phase, the policies in the distributed photovoltaic power demonstration area phase has no major change, except that initial investment subsidy is changed to subsidy per kWh after completion. The support subsidy is still focused on the “distributed” photovoltaic projects.

In 2013, due to implementation of FiTs*, China completed 11.8W installed capacity. Among it, 73% of installed capacity was from ground power stations which are located in the northwest area. From this, application and development of distributed PV needs policy support, and the barriers which occur during the policy implementation should be removed in an effort to achieve goals within time limit.

* The centralized ground power stations are subsidized according to the classification of solar irradiation: CNY 0.9/KWH (2000-2200hour) and CNY 1/KWH (1100-1400 hour).

The FiTs for the distributed power generation is based on China’s average irradiance. If 80% of electricity is self-generated and self-consumed and 20% of electricity is fed to the grids, the subsidiary is CNY 0.42/KWH.

4.2.2 BMPV policies of the USA

USA is the solar power market with the greatest potential. Since 1974, it has enacted the laws to promote sustainable development of energy resources, including *Solar Energy Research Act*, *Solar Photovoltaic Energy Research, Development and Demonstration Act, Energy Tax Act, Tax Reform Act and Energy Policy Act*. During the early 1980s, the country started to implement the Photovoltaics for Utility-Scale Applications Program (PVUSA), BMPV Program, Million Solar Roofs Initiative and “Net Metering scheme”, which substantially boosted the BMPV industry.

On the whole, USA did not implement nation-wide FIT subsidies. Instead, the federal government and local government implemented the policies such as investment subsidy, tariff subsidy, tax credits for photovoltaic investments, accelerated depreciation credit, Renewable Energy Certificate (REC), net metering and enforceable Renewable Portfolio Standard (RPS). The BMPV market in USA is mainly supported by the tax credit policies enacted by the federal government (until the end of 2022) and 44 states have implemented the “net-metering scheme” policy as a supporting measure. At least 6 states and 17 public utility departments have executed the power purchase agreement (PPA) which is similar to FiTs. Twenty-two states provide capital subsidies, 29 states have established the RPS (Renewable Portfolio Standard) and 21 states have presented the requirements for photovoltaic industry. Meanwhile, the public utility departments of 6 states are formulating the VOST (value of solar tariff) policy which is scheduled to supersede the “net-metering scheme” policy. In most cases, these policies are funded by indirect public finance or the public utility departments.

(1) Photovoltaic industry policies of USA

The policies enacted by the federal government to support renewable energy development include the federal fiscal incentives, laws, standards and obligatory targets.

(a) The federal fiscal incentives are different from the solar power subsidy policies enacted in other 75 countries or regions. Such incentives include tax credit/preference and loan guarantee. Tax preference and credit are the primary fiscal incentives enacted by the federal government to promote renewable energy development. The federal government has established the special funds to support renewable energy development and energy efficiency improvement and such funds currently include the Tribal Fund of United States Department of Energy and American Rural Energy Fund, as shown in Table 1.

Table 4-7 Main federal fiscal incentive programs

Policies	Federal fiscal incentive program	Expiry date
Accelerated depreciation	Federal accelerated depreciation cost recovery system	Undefined
Tax preference	Federal subsidy for energy-saving residence	Undefined
	Photovoltaic investment tax credit (ITC)	2022
Cash subsidy	Tribal Fund of United States Department of Energy	Undefined
	American Rural Energy Fund	Undefined
Loan preference	loan guarantee of Department of Energy	Undefined
	Rural energy loan guarantee	Undefined

(b) Federal laws, standards, obligatory targets and other administrative policies

In addition to the fiscal incentives, the federal government has also enacted a number of laws, standards, obligatory targets and other administrative policies to expand the market for renewable energy development. USA has enacted nearly 10 federal laws in regard to renewable energy, which has greatly boosted renewable energy development. The federal government has also enacted mandatory standards and obligatory targets which include *Renewable Portfolio Standard*, *Electric Appliance Energy Efficiency Standard*, *Green Energy Purchase Objectives* and *Standard for Grid Connection of Small Generators*.

(2) Fiscal incentives and administrative policies for photovoltaic development of the states in USA

In addition to the federal PV fiscal incentives, the states of USA have also enacted a number of fiscal incentives. Among the state-level fiscal incentives, the most important one is tax preference. The fiscal incentives are mostly focused on tax preference, primarily for property tax. The second most important incentives are capital reimbursement and loan preference. Here we take the top 10 states that had the greatest accumulative installed capacity in 2012 for example to describe the state-level policies for supporting renewable energy.

Table 4-8 State-level fiscal incentives for solar power industry in USA

Region	Fiscal incentives	Contents of policies	Type
California	Proper tax credit	The residents in California purchasing civilian photovoltaic system are granted property tax credit up to the purchase cost of such systems.	Tax preference
	Proper tax credit for solar power system	It is applicable to civilian, commercial and industrial solar heating equipment; the equipment cost can be deducted prior to taxation.	Tax preference
	Incentives for solar power	From 2007, installation subsidy of approximately USD 3.3 billion are provided for the photovoltaic systems installed in households and connected to commercial power grids can obtain The initial subsidy is USD 2.8 per watt. Such subsidy is then reduced by 7% annually until it is revoked in	Capital subsidy

		2016.	
Arizona	Energy project investment by utility departments	The schools, governmental agencies and other organizations using photovoltaic energy for lighting and heating are entitled to obtain low-interest loan at 1% interest for a maximum of 15 years	Loan preference
	Non-residential solar power tax credit	The schools, governmental agencies, non-profit organizations and agricultural/industrial enterprises are granted corporate income tax credit equal to 10% of the equipment installation cost.	Tax preference
	Proper tax credit for energy equipment	The added value tax on purchase of any heating, cooling or lighting equipment using solar power can be fully deducted prior to property taxation.	Tax preference
	Sales tax credit for solar power equipment	The heating, cooling and lighting equipment using solar power are exempt from consumption tax.	Tax preference
New Jersey	Sales tax credit for solar power	The heating, cooling and lighting equipment using solar power are exempt from consumption tax.	Tax preference
	Property tax credit for renewable energy system	The added value tax on purchase of any heating, cooling or lighting equipment that utilize solar power can be fully deducted prior to property taxation.	Tax preference
	Solar energy and renewable energy securities	Solar energy and renewable energy securities	SREC
Nevada	Revolving loan projects	The commercial, industrial and governmental organizations using solar heating equipment and solar thermoelectric equipment are eligible to obtain low-interest loan at 1% interest for a maximum of 15 years.	Loan preference
	Sales tax and use tax credit for renewable energy	The commercial, industrial and governmental organizations using solar thermoelectric equipment need to pay the consumption tax and use tax at only the tax rate of 2.25% in Nevada.	Tax preference
North Carolina	Incentives for solar power	The consumers having roof-mounted solar systems can receive USD 0.18 per kWh subsidy and RECs if the generation capacity reaches 500 kW,	Capital subsidy
	Loan for energy improvement	The loan with low interest of 1% for energy improvement is provided for the commercial and other non-civilian organizations participating in renewable energy projects in North Carolina. The loan can be up to USD	Loan preference

		500,000, and must be paid back within 10 years.	
Massachusetts	Solar energy and renewable energy securities	Solar energy and renewable energy securities	SREC
	Alternative energy and energy conservation patent exemption	All the incomes from sale or tenancy of stored energy and from the American patent on alternative energy development can be deducted prior to taxation.	Tax preference
Pennsylvania	Incentives for solar power	This program offers loan, fund and loan guarantee for the solar technologies and energy-efficiency-enhancing technologies.	Loan preference
	Solar power rebate program	This program offers capital reimbursement for the residences and small commercial residences that install solar and photovoltaic heat collection systems.	Capital subsidy
Hawaii	Fixed-price policy	Feed-in tariff system	FiT
	Green infrastructure securities	In July 2013, Hawaii passed the legislation to allow commercial organizations, economic development departments and tourism departments to issue green infrastructure securities to provide low-interest fund for clean-energy installations.	Loan preference
New Mexico	Tax credit for solar power market development	Residents and agricultural enterprises that install photovoltaic and solar heat collection systems can be exempt from 10% of individual income tax.	Tax preference

4.2.3 BMPV policies of Japan

Japan is one of the few developed countries in Asia. Due to lack of resources, it attaches great importance to development research of new energy resources, especially solar energy,

Many years ago, the Japanese Government launched the program “Seventy Thousand Roofs”, in which the installed capacity of PV systems reached 37MW$_P$. After implementation of such policy, Japan became the largest producer of photovoltaic modules in that year. In 1993, the Japanese Government launched the New Sunshine Project which was implemented at the beginning of the next year. The key content of such project is: government provides subsidy and low-interest loan and purchases surplus electricity. After implementation of the relevant policies since 1993, Japanese BMPV building market surpassed that of America, and Japan occupied the largest share of the global photovoltaic market in the next 7 years. The subsidy for residential PV market was suspended from 2005 to the end of 2008, but from 2009 the Japanese Government launched a new residential PV subsidy policy, and total budget was close to 21 billion yen. However, the non-residential PV subsidy policy has not been suspended since 1994. Commercial enterprises and public infrastructure owners who qualify are eligible for a subsidy equal to specific proportions of PV system installation costs, with 1/3 for the former and 1/2 for the latter. For new PV technology experimental area, the Japanese Government provides higher subsidies which account for 50% of PV system installation costs.

In the ten years after 1997, the Japanese Government successively released a series of documents to encourage development research of new energies, e.g. *Act* on *Special Measures for New Energy Power Generation by Electricity Utilities*, *Act on Renewable Energy Portfolio Standard* and *Act on Special Measures on Promoting New Energy Power Generation*. The *Act on Special Measures for New Energy Power Generation by Electricity Utilities* mandates the lowest percentage of sales of electricity generation by renewable energy or installed capacity, and an increase of 12.2 billion kWh in renewable energy power generation in 2010 and 16 billion kWh in 2014.

In 2000, Japan set up “green electricity fund” which mainly serves as subsidy for installation and promotion of PV power generation system,. The fund has greatly contributed promotion of BMPV application. In the subsequent five years, this fund was provided for nearly 600 public buildings and facilities with total installed capacity exceeding 12,000 kW. Until 2006, 130 public buildings and facilities were added and the total installed capacity exceeded 2000kW.

In 2008, Japan launched a “solar power generation” program to promote the development of domestic solar photovoltaic power generation from the perspectives of suppliers and demanders. The suppliers shall enhance technological development, establish technical guidance standards and promote construction of energy parks, while the demanders shall step up efforts to develop domestic PV markets, not only continue to increase utilization of residential PV power generation but also promote construction of large-scale PV power stations by electricity utilities.

After Fukushima nuclear crisis in 2001, the Japanese Government reviewed its past energy policies and paid more attention to development of the photovoltaic industry in order to reduce its reliance on nuclear power. The major ministries such as METI issued and implemented relevant preferential policies to accelerate development of photovoltaic industry.

(1) Ministry of Economy, Trade and Industry (METI)

From fiscal year 2012 to now, METI promotes application and popularization of residential and industrial PV systems through support or measures such as “measure for support and instruction of subsidy for residential PV systems”, “feed-in tariff (FIT) policy of renewable energy” and “subsidy plan of introducing renewable energy generation systems as partial recovery measure”.

(a) Subsidy measures to support and introduce residential PV systems

METI provides subsidies to individuals and companies that have installed residential PV systems. The subsidy was 35,000 yen/kW or 30,000 yen/kW in fiscal year 2012. The subsidy of 35,000 yen/kW is provided for PV power generation systems with the selling price of 35,000 yen/kW and 475,000 yen/kW, and the subsidy of 30,000 yen/kW is provided for PV power generation systems with the selling price of 475,000 yen/kW and 550,000 yen/kW,. However, the PV systems that can receive the subsidy must meet specific conditions, for example the maximum output capacity must be less than 10kW.

(b) Feed-in tariff (FIT)

The FIT policy came into effect formally from July 1, 2012. In 2012, on-grid price of solar power systems with the capacity of more than 10kW was 42 yen/kWh before tax, and subsidy period was 20 years; feed-in tariff of solar power system with the capacity of less than 10kW was 42 yen/kWh before tax, and the subsidy period is 10 years. All power consumers shall share purchase cost equally.

Release of such policy led Japanese PV market into a new stage of growth. Before then, PV application framework of Japan is mainly based on fiscal subsidy plan and purchase plan of surplus photovoltaic power. Therefore, it has many restrictions in accelerating price cut and popularization of PV power generation systems. Now, FIT plan that comes into effect formally ensures time limit of subsidy for purchase, which makes profit possible. Users can actively introduce PV power generation system as one part of business operation. The popularization and application of PV system has gradually been driven by final users instead of being dominated by suppliers.

The new FIT rates took effect, which was approved by METI. According to the provisions by METI, the payment period for residential PV installations under 10kW and commercial PV installations over 10kW was 10 years and 20 years respectively.

Table 4-9 FIT rates for eligible PV installations

Year	Payment period	10kW (excluding tax)	
		Residential	Commercial
April 1 2014-March 31, 2015	20 years (residential 10 years)	37 yen/kWh;	32 Yen/kWh
April 1 2013-March	25 years	38 yen/kWh;	36 yen/kWh

31 2014			
April 1 2012-March 31 2013	25 years	42 yen/kWh;	

The new FiT rates for the commercial solar installations over 10kW reduced by 11%, and under 10kW decreased by approximately 2.7%. In 2015, Japan's PV installed capacity reached 11GW, only next to China. Japan has

However, recently Japan government starts to introduce the bid system; domestic energy agencies are worried about auction may cause sharp reduction of future PV installations in Japan's market.

(c) Subsidy plan to introduce renewable energy generation system as partial recovery measure

To create job opportunities and stimulate the renewable energy industry, especially the development of renewable energy industry in these areas damaged by Great East Japan Earthquake, METI has implemented such subsidy plan in the damaged areas. According to the subsidy plan, the PV system output capacity shall not be less than 10kW or combined output capacity from many stations shall not be less than 10kW.

(2) Ministry of Environment (MOE)

Under the framework of relevant laws on global warming countermeasures", MOE always advocates use of natural energy to reduce carbon emissions. In fiscal year 2012, MOE formally started to implement "establishment and introduction of demonstration community projects utilizing off-grid and distributed renewable energy", and support industrial sectors, academia and government departments to install off-grid and distributed energy systems using renewable energy. The subsidy is half of total project cost. In fiscal year 2012, a total of 4 projects were selected. The budget of 6 billion yen in fiscal year 2012 was distributed to "Technical Development Projects Against Global Warming" to support the private companies, public research institution and universities to conduct technological research and development of low-carbon traffic and low-carbon houses through use of PV power generation and renewable energy sources.

(3). Ministry of Land, Infrastructure, Transport and Tourism (MLIT)

MLIT has introduced measures for providing renewable energy systems (e.g. PV power generation) and constructing green governmental buildings for state institutions and governmental organs. The private sectors shall submit the project proposals concerning reduction of carbon oxide emissions of buildings (e.g. office building) and residential buildings. In addition, the subsidy plan shall also be implemented to help supplement maintenance cost of fixed amount. Meanwhile, MLIT achieves the goal of zero-energy home by improving energy-saving performance of building and facilities or using renewable energy system.

4. Ministry of Agriculture, Forestry and Fisheries (MAFF)

MAFF requires implementing the PV system installation subsidy plan for agriculture, forestry and fishery-related facilities to apply and promote renewable energy technology in these sectors. In 2012, MAFF implemented the project of "establishment of early renewable energy supply mode of rural areas" to achieve application and promotion of independent and distributed energy supply systems and revitalize rural areas that rely on the first sector. Besides, MAF also supports the application example of renewable energy technologies such as PV power generation project using resources in rural area.

Table 4-10 Japanese BMPV incentive policy system

Japanese BMPV incentive policy system	**Incentives for whom**	**Contents of policy**
Economic policy	Consumers, enterprises and developers	Subsidy, fund and low-interest loan
Industrial policy	Photovoltaic enterprises, local government and consumers	Technological support, Seventy Thousand Roofs Program, New Sunshine Project and low-carbon campaign plan

Support service policy	Consumers, enterprises, developers and local government	*Act* on *Special Measures for New Energy Power Generation by Electricity Utilities*, *Act on Special Measures on Promoting New Energy Power Generation* and *Act on Renewable Energy Portfolio Standard*

In general, Japan is a typical country that stimulates the development of national BMPV industry mainly through direct governmental subsidy. Besides incentives to enterprises, the Japanese Government also pays attention to encouraging consumers in promoting BMPV development. In early of the 21st century, Japan exhibited various achievements in BMPV, built many demonstration projects, and provided strong support, for example spending nearly 5 billion yen (account for nearly 15% of total budget). The Solar Ark completed in 2008 has become the largest BMPV project at that time which fully reflects energy saving and aesthetics. First of all, it played a great role in promoting BMPV development.

4.2.4 BMPV policies of Australia

As early as in 2000, the Australian Government released solar energy support policies, including 150 million AUD subsidy plan for household and community PV systems. The ordinary household can get a subsidy up to 8000 AUD if they install solar power generation systems, which greatly increased popularization rate of PV system.

The preferential policies released by the Australian Government have a great influence on rapid development of PV market in Australia since 2010. Main support policies include:

(1) National renewable energy target: In July 2009, the Australian Government released a new national renewable energy target program, which increases the mandatory renewable energy target by more than 4 times to reach 45000GWh by 2020. In June 2010, the Australian Government divided the national renewable target of 45000GWh into two parts: large-scale renewable energy target and small-scale renewable energy scheme, which were executed as of January 1, 2011.

The large-scale renewable energy target mainly involve large renewable energy projects like wind farm and commercial solar and geothermal energy projects. It aims to fulfill use of renewable energy in most areas of the country in 2020. From 2011 to 2030, the annual budget for large-scale renewable energy target is 4,000GWh every year, and will reach 41,000GWh in 2020. The small-scale renewable energy scheme is mainly directed for small generation units like small PV systems, wind power generation systems, small hydropower stations and solar heater systems.

The Australian Government believes resultant force of the two separated renewable energy targets will be more helpful to promote utilization and popularization of renewable energy technologies within the target period than the single national renewable energy target (45,000GWh).

(2) Solar Homes and Communities Plan: it mainly provides governmental subsidies for household or community buildings. According to the plan, one household that install 1kW PV power generation system will be eligible for a subsidy up to 8000 AUD; if a 2kW PV power generation system is installed in community building, the Government will provide a subsidy equal to nearly 50% of the PV system cost. According to the subsidy policy, only the household with annual income below 100,000 AUD can get such subsidy.

The application for Solar Homes and Communities Plan is divided into two stages: One is qualification review before purchase and installation (“application before approval”); the other one is subsidy application after installation. Although this Plan terminated on June 9, 2009, a large number of application forms for review had been received a few days before termination. Therefore, PV power generation system installation would be continued in 2011. For this plan, the final sum is estimated to reach 1.1 billion AUD. This plan has a great influence on the Australian PV market. Especially, for 69.7MW PV power generation system installed in 2010 a governmental subsidy of 500.8 million AUD was provided. Most of PV system modules installed were used for grid-connected PV systems, and only 8.95kW power generation system is off-grid system. By 2010, a total of 153.58MW PV power generation systems were installed.

(3) Feed-in tariff policies of the states and local governments in Australia: the states and local governments in Australia released new feed-in tariff policies. See Table 1 for details:

Table 4-11 Australian State and Territory Feed-in-Tariffs in 2014

	Start Date	Size Limits	Rate AUD c/kWh	Scheme end	Type	Eligibility
Victoria						
Premium FiT (closed 1 Jan 2012)	1 Nov 2009	5 kW	60	2024	Net	Residential, community, small business
Transitional (closed 30 Sept 2012)	1 Jan 2012	5 kW	25	31 Dec 2016	Net	Residential, community, small business
Standard (closed 30 Sept 2012)	1 Jan 2012	100 kW	Retail rate	31 Dec 2016	Net metering	Residential, community, small business
New Standard	1 Jan 2013	100 kW	8 (updated each year)	1 Jan 2015	Net	Residential, community, small business
Comments			Customers lose their FiT and revert to the New Standard FiT if they change their system size or move house. It is compulsory for retailers to offer at least the New Standard FiT rate.			
South Australia						
Groups 1, 2 & 3 (closed 30 Sept 2011)	1 July 2008	10 kVA 1Ø 30 kVA 3Ø	44	30 June 2028	Net	A facility that consumes less than 160 MWh/yr
Group 4 (closed 30 Sept 2013)	1 Oct 2011	10 kVA 1Ø 30 kVA 3Ø	16	30 Sept 2016	Net	A facility that consumes less than 160 MWh/yr
Group 5	1 Oct 2013	10 kVA 1Ø 30 kVA 3Ø	5,3 (updated each year)	Open ended	Net	A facility that consumes less than 160 MWh/yr
Northern Territory						
Alice Springs Solar City FiT (closed 31 May 2013)	May 2008	2 kW	Ranged 45,76 to 60,40 from 2008/09 to June	30 June 2013	Gross	Alice Springs residential, business

			2013			
Net metering	1 June 2013	30 kVA	Retail tariff	Open ended	Net metering	NT wide
Comments	The Alice Springs PV systems were provided as a package, with the largest being 2 kW. The FiT consisted of the retail peak rate (increased over time) plus AUD 0,2265/kWh.					
Queensland						
Solar Bonus Scheme (closed 10 July 2012)	1 July 2008	10 kVA 1Ø 30 kVA 3Ø	44	1 July 2028	Net	Consumers with less than 100 MWh/yr
New SBS	11 July 2012	5 kW	around 6	Open ended	Net	Consumers with less than 100 MWh/yr
Comments	The SBS net amount was not be mandated for SE Qld after 1 July 2014. Customers may default to the new SBS FiT if they change their system size or move house.					
New South Wales						
Solar Bonus Scheme 60 (closed 27 Oct 2010)	1 Jan 2010	10 kW	60	31 Dec 2016	Gross	Residential
ACT						
Gross FiT (closed 31 May 2011)	1 March 2009	30 kW	50,05 (<10 kW), 40,04 (10-30 kW), after 1 July 2010 45,7 (<30 kW)	20 years after connection	Gross	Residential, business
Gross FiT (closed 13 July 2011)	1 April 2011	30-200 kW	34,27	20 years after connection	Gross	Residential, business
Net metering (closed 30 June 2013)	14 July 2011	30 kW	Retail tariff	30 June 2020	Net metering	Residential, business
Solar Buyback Scheme	1 July 2013	30 kW	7,5	Open ended	Net	Residential, business
Comments	Although the Gross FiT (30 kW) was closed on 31 May 2011, <30 kW systems were made eligible for the Gross FiT (30-200 kW) from 12 July 2011 to 13 July 2011 to allow these systems to access the cap originally set aside for systems 30 kW to 200 kW.					

(4) Solar City Program: The Solar City Program of the Australian Government is an innovative

demonstration project to show how to use new methods such as technology (e.g. PV power generation), behavior change, energy pricing to achieve sustainable development of future energy in various cities and areas in Australia. This program is under the responsibility of Department of Climate Change and Energy Efficiency who also establish partnerships with the governments at all levels, enterprises and local communities. Main solar cities include Adelaide, Alice Springs, Blacktown, Central Victoria, Morand, Perth and Townsville. Each solar city attempts to implement a unique energy plan, such as taking measures to improve energy utilization efficiency for household and enterprise and conducting community education by using solar technology to better energy utilization in the increasingly energy-dependent world etc.

(5) Solar Schools Program: National Solar Schools Program in Australia is aimed to assist schools in taking relevant measures to cope with climate change. This program provides governmental subsidies of 50,000 AUD for eligible primary schools and middle schools to encourage them to install energy saving systems such as solar and other renewable energy systems, solar heaters and rainwater reservoirs, etc. The successful application mainly depends on three factors: monetary value, environmental benefit and education returns. Final evaluation will determine the application that best meet these factors and then financial assistance is provided.

The Australian schools have great passion about this program. Since this project was launched on July 1, 2008, about 7000 schools have been registered and are interested in participating in this program. Until April 2011, the Government provided an aid of 128 million AUD for over 2800 schools to encourage them to install PV system and other energy-saving systems, and among them nearly 2000 schools have completed installation of energy-saving systems.

(6) Bushlight: this is an Australian Government-funded national, non-profit project. This project is aimed to install renewable energy systems for remote indigenous inhabitants located in central and northern Australia. The community residents are required to receive relevant education and training before installation and during operation of each system.

After 2011, the support by the Australian Government for PV market has gradually decreased and the focus has been placed on how to standardize or manage the markets not subsidized by the Government and high popularization rate of PV power in power sector.

So far, most of PV incentives or measures are directed at small-scale residential PV systems. Thanks to system cost reduction, market price and better solar irradiation, the PV systems in some areas have achieved parity and the market can be driven even without FiT, The Solar Flagships Program highlights large-scale PV systems. The state governments are also interested in large-scale commercial PV market. This will help to match with power load curve and lay a solid economic foundation for this industry.

4.2.5. Distributed BMPV policies of Malaysia

Although Malaysia has huge potential for development of renewables, the fossil fuel is still the primary energy source.

In 2000, Malaysia’s primary energy mix is oil and natural gas (92%), followed by coal and hydro (3%). Between 2000 and 2010, the fossil fuel caused CO_2 emission to increase by 64%, from 130 million tons to 185 million tons, and the produced electricity and heat energy accounted for 49%. In 2010, total power generation is 125TWh, and the average emission of CO2 per MWh was 0.73 tons. Between 2000 and 2020, due to Malaysia industrialization, the annual average energy demand will increase by 4.8%, and accordingly, the relevant electricity demand will increase from 17.2% to 20.3%.

From 2000, Malaysia government started to implement renewables incentives. In Malaysia’s 8th Five Year Plan, the government takes the measures to increase share of the renewables in order to enhance energy security and improve environment. From 2001, the licensing and grid connection for the small-scale renewable projects was simplified, and taxes were reduced or exempted to increase investment efficiency of renewables, and the tax relief period for pilot projects is 5 years.

The Malaysia’s 9th Five Year Plan enhanced support for renewables. From 2006 to 2010, the Ministry of Energy, Green Technology and Water (MEGTW) and Global Environmental Facility (GEF) jointly initiated the “Malaysia building integrated PV (MBIPV)” program, which is funded by United Nations Development Programme after application by GEF; the Program is expected to promote installation of building integrated PV grid-connection systems, to establish PV power generation policy framework for fostering the domestic market before end of this program and to achieve 2MW BIPV grid-connection systems. First of all, this MBIPV program directly promotes establishment of “National Renewable

Energy Policy and Action Plan (NREPAP)" of MEGTW. This Program is aimed to achieve the goals: installed capacity of renewable energy systems represents 6% of total installed capacity and the power generation accounts for 5% of total power generation in 2015 and installed capacity and power generation will be doubled ,and the PV systems accounts for about 1/3 in 2020.

The green technology financing (GTFS) scheme started in 2010 as part on the programmes under the national green technology policy to accelerate the expansion of green investments by providing easier access to financing from the private and commercial financial institutions. The scheme offers a 60% guarantee of the financing amount and a rebate of 25% on the interest/profit rate charged by the financial institutions. The GTFS is available until 31 December 2015 or upon reaching a total financing approval amount of MYR 35 billion whichever is earlier.

The Malaysia's BMPV programme consists of the four parts, including the specific actions to overcome various difficulties.

1) Established BMPV information service, public awareness and building volume; popularized the demonstration projects among the government, public and industries; established Malaysia Photovoltaic Industry Association during the popularization.

2) Developed BMPV market and infrastructures: completed the demonstration projects and thousands of SURIA roofing and sold them to the public who offered high price, boosted the user and commercial BMPV markets. The goal of the BMPV market is to reach 1.5MW installed capacity. In addition, the demonstration projects promoted the development of the Malaysia's electric design and installation standards, and the testing center evaluated installed systems.

3) BMPV policies and financial support: established the financial framework for promoting PV system application. The financial support included PV system grid connection, net-metering scheme, tax credits and other incentives

4) BMPV research and industry support: encouraged application and research of BMPV, established testing facilities, bought convenience to businesses, promoted BMPV industry development, and attracted foreign investment.

The programme was ended in 2010, and new support mechanism was executed in 2011. Until August 2011, the Malaysia's BMPV installed capacity exceeded the goal and was up to 2054kW, increased by 33% as compared to 1545kW. The supported six demonstration projects have total installed capacity of 140KW (125kW), and the 19 showcase projects have total installed capacity of 390kW (exceeding the goal of 205kW); annual BMPV projects exceeded 50, which are as three times as the goal. The thousands of Suria roofing projects were auctioned through seven rounds, and a total of 1524 kWp were awarded and completed (exceed the goal of 1215kW). This is synchronized with the international PV markets, and the costs of the BMPV projects were decreased by 39%, which exceeded the goal 20%.

From 2004, the BMPV projects invested by foreign funds exceeded USD 4 billion, and created 500 jobs. Malaysia's PV manufacturing ranked 5th place in the world. Above all, BMPV projects extended the renewable energy polices and action plan. The tenth Five Plan approved in 2010 contributed to adoption of the Renewable Energy Act in 2011. This Act established the FiT policy. The FiT rates vary in installed capacity and application technologies. The policy will continue to increase application of BMPV and renewables.

By reference to German FiT, the Malaysian Government implemented a new feed-in-tariff (FiT) for renewable energy in 2011. Solar energy is one of the key government-supported sectors. The FIT policy requires the installed capacity of PV systems reach 1.25GW in 2020. FiT is from renewable energy fund which is sourced from 1% renewable energy tax paid by power consumers with the monthly power consumption of over 300 kWh, and the fund was estimated to reach USD 80 million in 2012.

Table 4-12 Malaysian FiTs for renewables in 2011

Installed capacity	Contract period (year)	FiT ($/Kwh)	Annual decline rate
0-4 kW	21	0.302	8 %
4-24 kW	21	0.295	8 %

24-72 kW	21	0.290	8 %
72-1000 kW	21	0.280	8 %
1MW-10MW	21	0.233	8 %
10MW-30MW	21	0.209	8 %
Additional subsidy for rooftop power stations	21	0.064	8 %
Additional subsidy for BIPV	21	0.061	8 %
Additional subsidy for local modules	21	0.007	8 %
Additional subsidy for local inverters	21	0.002	8 %

The Malaysian Government reduced the FiT rates in 2014. The FiT rate for the installations under 24kW was decreased by 8% and that above 24kW was decreased by 20%. The adjusted FiT rates didn't include the bonus of local modules and inverters.

Table 4-13 2014 Malaysian FiTs

Size	Incentive		
	Rooftop	BIPV	Ground-mounted
＜4kW	MYR1.0888/kWh	MYR1.2544/kWh	MYR0.9166/kWh
4~24kW	MYR1.0664/kWh	MYR1.2320/kWh	MYR0.8942/kWh
24~72Kw	MYR0.8944/kWh	MYR1.0600/kWh	MYR0.7222kWh
72kW~1MW	MYR0.8699/kWh	MYR1.0355/kWh	MYR0.6977/kWh
1~10MW	MYR0.7194/kWh	MYR0.8850/kWh	MYR0.5472/kWh
10~30MW	MYR0.6618/kWh	MYR0.8274/kWh	MYR0.4896/kWh
Bonus for local modules		0.0500MYR/kWh	
Bonus for local inverters		0.0500MYR/kWh	

The Malaysian Government also encourages private enterprises to participate in the development of renewable energy industry, and successively provides many financial incentives like small renewable power program to provide more opportunities for medium and small private enterprises and assist them in entering the international market. The National Green Technology Centre is also founded to help the enterprise to develop green energy technology.

Besides, Malaysia also provides high tax credit for renewable energy developers. Malaysia implements the preferential policy to exempt domestic large solar developers from paying enterprise tax for 10 years and exempt tax on their machines and equipment for 5 years. This greatly attracts global investors to enter Malaysian solar industry.

Overview of the FIT in Malaysia：Malaysia's Feed-in Tariff (FiT) system obliges Distribution Licensees (DLs) *to buy from Feed-in Approval Holders (FIAHs) the electricity produced from renewable resources (renewable energy) and sets the FiT rate. The DLs will pay for renewable energy supplied to the electricity grid for a specific duration.

By guaranteeing access to the grid and setting a favourable price per unit of renewable energy, the FiT mechanism would ensure that renewable energy becomes a viable and sound long-term investment for companies industries and also for individuals.

Note*：Key terminologies in FiT

1) Distribution Licensees: Companies holding the licence to distribute electricity (e.g. TNB, SESB, NUR).

2) Feed-in Approval Holder: An individual or company who holds a feed-in approval certificate issued by SEDA Malaysia. The holder is eligible to sell renewable energy at the FiT rate.

3) FiT rate: Fixed premium rate payable for each unit of renewable energy sold to Distribution Licensees. The FiT rate differs for different renewable resources and installed capacities. Bonus FiT rate applies when the criteria for bonus conditions are met.

4) Indigenous: Renewable resources must be from within Malaysia and are not imported from other countries.

5) Duration: Period of which the renewable electricity could be sold to distribution licensees and paid with the FiT rate. The duration is based on the characteristics of the renewable resources and technologies. The duration is 16 years for biomass and biogas resources, and 21 years for small hydropower and solar photovoltaic technologies.

4.2.6. BMPV policies of Korea

A record on installed capacity of 276 MW was set in 2008, but the PV market remained stagnant in Korea during the next three years. This is mainly because FiT policies playing an important role initially in the PV market expansion were limited. However, the highest ever levels were achieved again with installed capacities of 230 MW in 2012, 530 MW in 2013 and 909 MW in 2014. This mainly thanks to the newly introduced RPS policy. The market started achieving traction in 2013 and continued its development in 2014.

In January 2012, Korea’s Renewable Portfolio Standard (RPS) officially replaced the FiTs. Besides the RPS, Korean building subsidy program-”One Million Green homes Programme”, as well as regional development subsidy programme and programme for mandatory installation of New and Renew-able Energy (NRE) systems in public buildings also support PV system installation. .

RPS is a mandated requirement that the electricity utility business source a portion of their electricity supplies from renewable energies. In Korea, electricity utility companies exceeding 5000 MW are required to supply 4.5% of their electricity from NRE source by 2016 in Korea, and gradually increases to 10% by 2022. PV has its own RPS set-aside quota of 1.2 GW for the period between 2012 and 2014.

RPS renewable energy requirements in Korea

2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
2.0%	3.0%	3.5%	4.5%	5.0%	6.0%	7.0%	8.0%	9.0%	10.0%

PV installation capacity requirements in Korea

2013	2014	2015	2016
450MW	690MW	1040MW	1200MW

Since the record-breaking year of 2008, that saw 276 MW of PV installations, the PV market remained stagnant in Korea during 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, 530 MW in 2013 and finally 909 MW in2014, 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 in 2014.

At the end of 2014, the total installed capacity was about 2,4 GW, among those the grid-connected centralized system accounted for around 87% of the total cumulative installed power. The grid-connected distributed system amounted to around 13% 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.

Since January 2012, Korea’s Renewable Portfolio Standard (RPS) has officially replaced the FiTs. Besides the RPS, Korea supports PV installations by the ‘One Million Green homes Programme’, a building subsidy programme, a regional develop-ment subsidy programme, and the New and Renew-able Energy (NRE) Mandatory Use Programme for public buildings.

The RPS mandates utilities with more than 5000 MW generation capacity to supply 3 % of their electricity from NRE by 2014, gradually increasing to 10 % by 2022. The renewable energy mix in the Korean RPS is defined as the proportion of renewable electricity generation to the total non-renewable electricity generation. PV has its own RPS set-aside quota of 1.2 GW for the period between 2012 and 2014 (originally 2015). About 410 MW were installed under this programme in 2013, while for 2014, about 550 to 600 MW could be allocated under it.

4.3. Technical and economic analysis of BMPV

The latest data published by Bloomberg New Energy Finance show that the global clean energy investment has had five-fold growth in the past 10 years, one half of which is from the Asian-Pacific region. Among various new energy sources, solar energy is the cleanest and most common energy source for power generation. Most countries in the Asian-Pacific region have abundant solar energy resource, with huge development potential.

The APEC member economies are widely distributed and there is great difference in their economic development. According to the current electricity demand in the APEC region, on the one hand, more than 60% of the population in the APEC region live in urban areas (Fig. 4-1 shows the urbanization level of APEC member economies) and there is a growing demand for electricity in such areas along with the development of economy and continuous expansion of urban population, and on the other hand, some economically underdeveloped countries or island countries have to meet the electricity demand for the islands and population without access to electricity grid as soon as possible due to backward grid facilities and high costs arising from electricity consumption.

Technically and economically, small-scale distributed BMPV systems installed at user side which provide two-way electricity transmission not only have high efficiency, small transmission loss and flexible operation, but also can reduce costs in long distance transmission and distribution and thus have good economic efficiency. As the costs of modules are being cut and the generating efficiency are being improved, the systems will become a significant trend in cities and remote areas without access to utility grid in APEC region, and an important strategy to solve energy crisis as well. According to IEA estimates, the installed capacity of rooftop solar PV systems will increase by approximately 5 times, from less than 90 million KW in 2013 to 500 million KW in 2040. In the developed countries, the households and enterprises in the regions with abundant sunlight and higher retail price will install BMPV power systems first. BMPV power generation will develop fast in Australia, the US and Japan. Although the BMPV power investment costs are relatively higher, decrease in system costs and increase in electricity demand and abundant solar resources drive the wide application of BMPV systems in China, Malaysia and other developing countries.

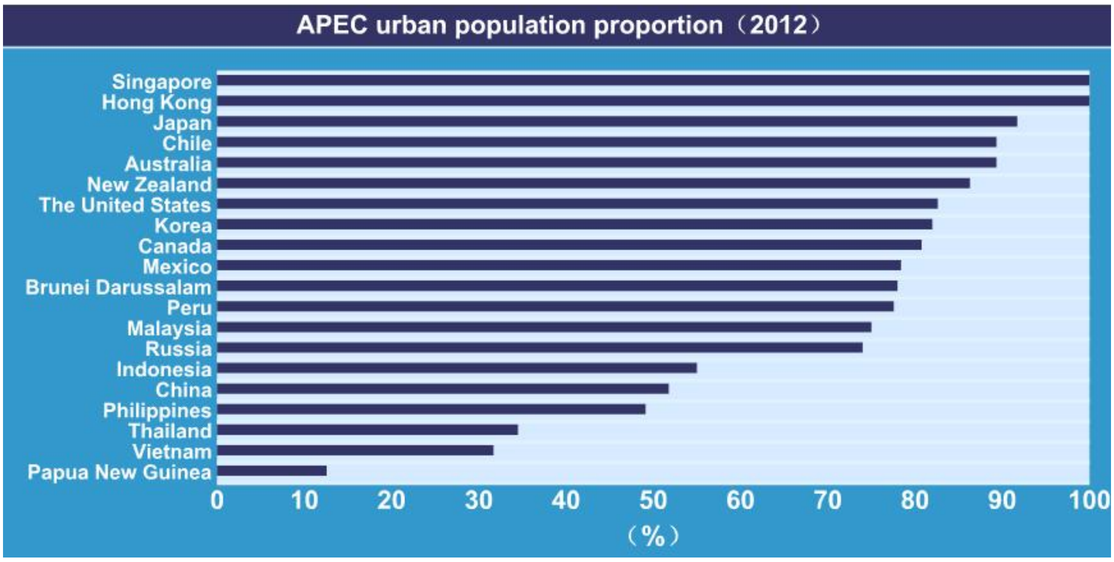


Fig. 4-2 APEC urban population proportion (2012)

4.3.1. Distributed PV system and utility grid

1. Power grid structure of countries

Nowadays, electric energy of all power plants is transmitted to the terminal distribution cabinet via a grid. Generally, the interconnected network of electricity generation consisting of transmission, transformation and distribution equipment and the corresponding auxiliary systems and electricity consumption is called electric power grid, “grid” for short.

From the late 19th to mid-20th century, the grid industry has developed the grid dominated by AC generation and transmission and distribution technologies and 220KV and below grid mainly consisting of city power network, isolated power network and small grid in the ten years Since the mid-20th century, the scale of power grid has been constantly increased, and the transnational interconnected power grids like such as the North America interconnected power grid, the European interconnected power grid and the interconnected power grid from Russia to the Baltic Sea, have been formed, and the 330KV and above ultra-high-voltage AC/DC transmission system has been established. By the end of 2013, the total length of 220KV and above transmission lines in the world was about 2.5 million km and the transformer capacity was approximately 12 billion KVA.

Table 4-14 Global power grid structure

	Number of countries or regions/ population (100 million)	Total installed capacity (100 million KW)/power consumption (trillion kWh)	Max. voltage class (KV)	Total length of 100KV and above transmission line (10,000 km)	Total length of 220KV and above transmission line (10,000 km)
Asian power grid	48/40	24 /10	1000		150
European power grid	34/7	10.07/3.35			30
North America power grid	9/5	12	765	76	
South America power grid	14/4	2.4/1	750		25
African power grid	50/10	1.5/0.7	765		3

Oceanian power grid	14/0.3	0.75/0.3	500		3

In Asia, take China's interconnected power grid as an example. By the end of 2013, the length of the 220KV and above transmission lines and the transformer capacity of power grid were 543,000 km and 2.72 billion KVA respectively in China, with the installed capacity, length of transmission line, voltage class, etc. ranking the first in the world. The six interprovincial large-scale grids (the Northeast Power Grid, North China Power Grid, Central China Power Grid, East China Power Grid, Northwest Power Grid and South China Power Grid) have been formed in China and a complete long-distance transmission power grid has been basically established.

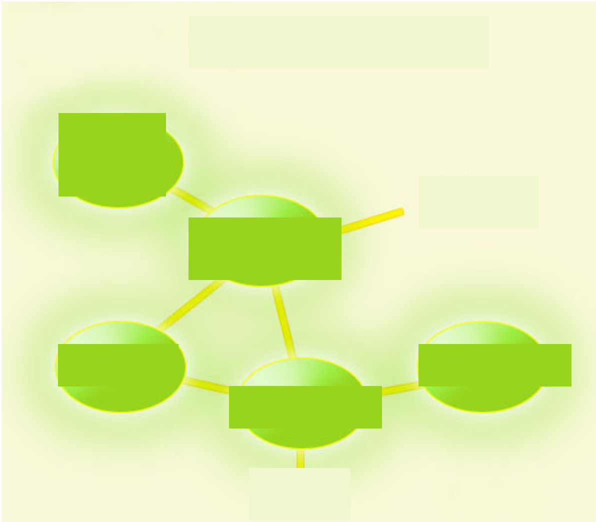


Fig. 4-3 Diagram of North China Power Grid

Compared to the development mode of centralized PVPS, which is "large-scale, centralized development and long-distance, high-capacity transmission", distributed PVPS is connected to low voltage power grids in a decentralized manner and the electricity is consumed locally. The grid-connection, transmission and consumption of BMPV are environment-friendly, safe and stable. The distributed PV development has been full-fledged in developed countries.

2. Power transmission and distribution costs

At present, the unbalance between light energy resource distribution and local economic development and serious separation between producers and consumers are the global concerns. For the traditional central power generation technology, the electricity generated cannot be directly supplied to the user unless it is supplied via the transmission and distribution network. With further expansion of power grid, the proportion of power transmission and distribution cost in the total cost is increasing. China's evaluation results show that the average transmission and distribution price is 0.14-0.16 yuan/kW.h and the transmission and distribution price generally accounts for about 25% of the retail electricity price. The distributed PV systems that are installed at the user side rarely need transmission lines or only need very short transmission lines, and the costs in power transmission and distribution is almost close to zero. Therefore, the distributed PV systems not only avoid the loss of transmission and distribution lines, but also reduce or save additional costs in transmission and distribution. In addition, the costs of civil works and installation are low. The distributed PV systems can deliver flexible, convenient, reliable and affordable power to users.

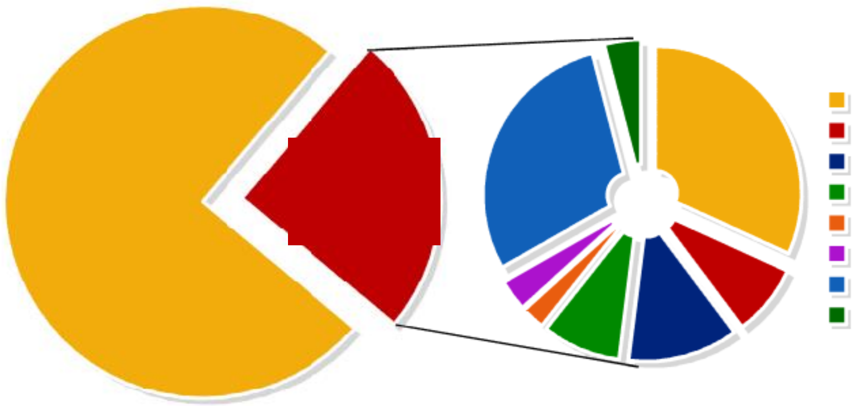


Fig. 4-4 Structure of China's retail electricity price

4.3.2. Comparison of costs of various types of PV systems

The centralized and distributed PV systems (BAPV and BIPV) are all composed of PV array, header box, inverter, transformer, reactive compensation device, control system and so on. However, they have different installation conditions and system positioning. Thus, there is huge difference in terms of their construction and operation. Table 4-2 shows the comparison of cost structures of three types of PV systems.

Table 4-15 Comparison of cost structures of various types of PV systems

Cost type System type	Centralized PV system	Distributed PV system (BAPV)	BIPV
PV module	No special requirement	No special requirement	Need to meet the building requirements, with higher cost.
Header box	Need to meet the environmental requirements in outdoor installation	Need to meet the environmental requirements in outdoor installation	Need to meet the environmental requirements in outdoor installation
Inverter	Centralized inverter.	String inverter.	String inverter.
Transformer	Require transformer in 110KV or above grid-connection	Require transformer in local grid-connection.	Not require separate transformer in local low voltage grid-connection
Relay protection	Require 400V, 35KV or above protection device	Normally require 400V protection device, and provide above 400V protection device as appropriate.	Normally require 400V protection device and provide above 400V protection device as appropriate.
Reactive power compensation device	Required	Not required	Not required
Control system	Relatively centralized, easy and relatively low cost	Decentralized, more devices, complicated system, relatively high cost	Easier system, and relatively low system cost.
Installation cost	Relatively centralized,	Relatively decentralized;	A part of building, and

	ground-mounted and lower cost	installed on industrial buildings, and higher cost.	highest installation cost.
Land acquisition cost	Large-area land acquisition.	Use of rooftop and other resources.	No need of land acquisition.
Grid supporting facilities	Need to build corresponding power transmission lines according to the voltage class of system, and the cost is relatively high.	Generally connected to the existing power grid, and reformation is required when the capacity is not enough.	Generally connected to the existing power grid, and reformation is required when the capacity is not enough.
Transmission loss	Greater loss due to long-distance high-voltage power transmission	Local consumption, excess power to grid and smaller loss	Local consumption, excess power to grid and smaller loss

To sum up, both BAPV and BIPV are at the user side to supply power to local load, with relatively small line loss and low costs in power transmission and distribution. Besides, both can fully use the building surface, and PV cells are used as building materials to minimize the costs in building and land acquisition. However, centralized power stations with the same installed capacity are more efficient and have lower operation costs as compared to the distributed PV systems.

4.3.3. Levelized cost of electricity analysis of BMPV system

In order to accurately analyze the current cost and market competiveness of BMPV power generation systems, the levelized cost of electricity (LCOE) analysis is introduced, which is the main index to evaluate the economic efficiency of various types of power generation technology. LCOE calculations enable us to clearly see the cost level of unit generating capacity of PV project. For a BMPV power generation project, LCOE is the composite cost of unit generating capacity of the project, namely the ratio of all costs incurred to total generating capacity during the project operation period.

According to LCOE explanations made by Fraunhofer-ISE, the calculation formula of LCOE is shown as follows:

$$\mathrm{LCOE}=\frac{I_0+\sum_{n-1}^{N}\frac{A_n+T_n}{(1+i)^N}-\frac{V_n}{(1+i)^N}}{\sum_{n-1}^{N}\frac{Y_n}{(1+i)^n}}$$

Where: LCOE is the levelized cost of electricity; I_0 is initial investment; An is the total operating expenditure of the t-th year; Tn is other costs; Vn is the scrap value of fixed assets; Yn is the power generation of the same year; i is the discount rate; n is the of the financial analysis year; t is the system life (1, 2, 3, …, n).

1. Case analysis

In LCOE comparison and analysis, BMPV power generation projects are selected from 3 regions (China, the United States and Malaysia) with different degrees of economic development.

Table 4-16 LCOE case analysis of BMPV power generation projects

Economies	US	Malaysia	Malaysia	China	China
System capacity (kW)	27600	4	12.5	10000	20000
Building type	Utility	Residential	Commercial	Commercial	Agriculture

Technical type	Crystalline silicon	Thin film	Crystalline silicon	Crystalline silicon	Thin film
Building time	2009.10	2013.7	2014.6	2013.8	2015.4
Unit investment cost (USD/W)	5.51	1.99	1.59	1.3	1.906
Annual operation and maintenance cost (USD/kW)	27.5	25	15.84	15.6	19.1
Power generation of the first year (MW.h)	23371.68	3.821	20.23	10800	25480
Annual attenuation rate of the system (%)	0.7	0.7	0.86	0.85	0.7
Discount rate (%)	7	7.5	7.5	8	8
Operational life	25	25	25	25	25
LCOE (USD/kW.h)	0.613	0.2219	0.104	0.134	0.166

Note: based on the average exchange rate of 2014.

2. Sensitivity analysis of influence factors

Currently, the BMPV power generation technology is becoming mature. In order to reach grid parity for BMPV power generation system as soon as possible, reduction of the LCOE of a project is an urgent issue to tackle. For the BMPV power generation projects, the typical factors affecting LCOE include the unit cost of project, power generation, attenuation rate of system, O&M costs, and service life of vital equipment such as inverter. In the above-mentioned cases, taking the projects in China as an example, the initial investment and power generation are the two most sensitive among the many factors affecting the total BMPV power generation cost and also have the greatest impact on the power generation cost; discount rate is in the next place; and tax rate has the minimum impact. Thus, we can see that, in the government's incentive policies, the change of amount of subsidy for initial investment has a great impact on power generation cost and the impacts of loans discount interest and tax credit & exemption are relatively smaller. In terms of project financing, the initial investment density has a great impact on the cost, but it relies on the price fall of PV system module and such decline is limited in a short time.

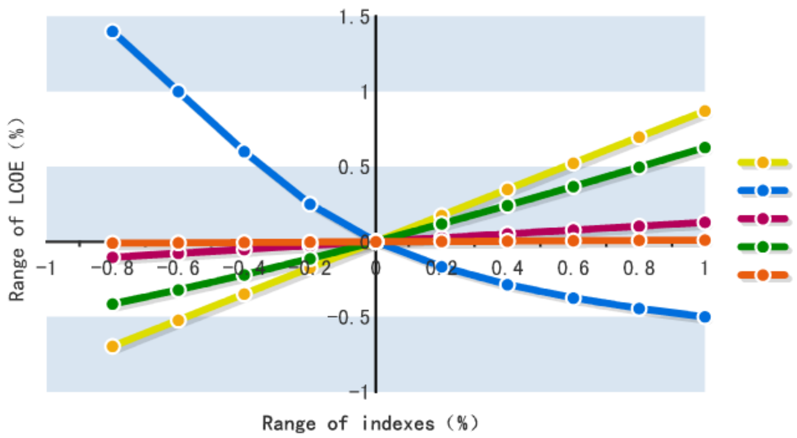


Fig. 4-5 Sensitivity analysis of cost influence factors on BMPV

4.3.4. Analysis on grid parity of BMPV power generation systems

1. Feed-in tariffs for power generation from traditional energy in main APEC economies

Electricity prices for consumers vary widely among APEC economies. Based on available data of 2014, electricity prices for industry were the lowest in the United States (USD 70.14 per MWh) and the highest in Japan (USD 188.12 per MWh). Electricity prices for households were USD 80 per MWh in China and USD 269 per MWh in Australia.

Table 4-17 Electricity prices in selected APEC economies in USD/unit

Country	Electricity for industry (MW.h)	Electricity for households (MW.h)
Australia	---	269
Canada	80	96
Chile	103.84	151.44
Japan	188.12	253.26
Korea	---	109.61
Mexico	121.46	90.08
New Zealand	---	236.05
United States	70.14	125.02
China	182	80
Malaysia	---	130

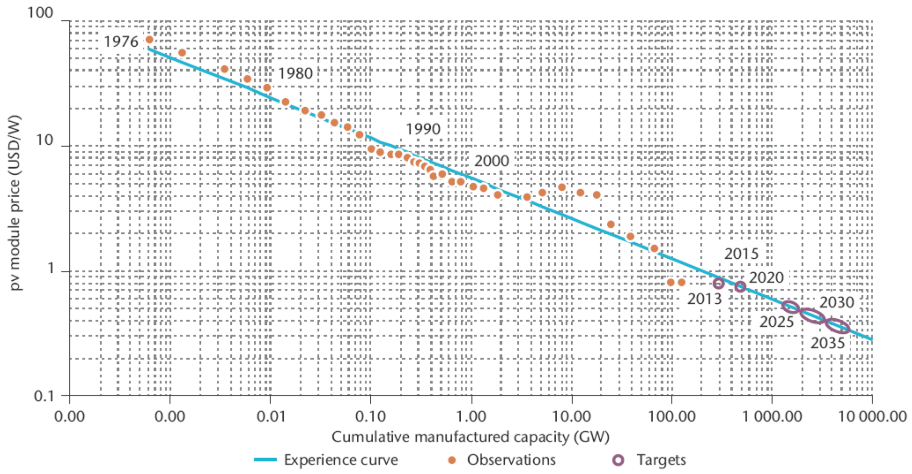
Data source: *IEA: Key World Energy STATISTICS 2015*, *Quarterly Energy Prices June 2015*

Average real electricity prices increased by 1.9% in 2014 from 2013 levels. Prices for industry increased by 2.2% and prices for households by 1.6%.

Source: Page 6 of *EXCERPT FROM ELECTRICITY INFORMATION_2015 edition*

2. Variation trend of LCOE of BMPV system

Higher investment cost of the system is currently a critical factor affecting the cost per kilowatt hour. However, the continuous technological improvement of PV power generation industry and the constant expansion of its scale have laid industrial and technological foundation for large-scale application of PV power generation system. Based on forecasts of IEA, Fig. 4-5 shows the trend of change in PV module price with capacity and time.



Notes: Orange dots indicate past module prices; purple dots are expectations. The oval dots correspond to the deployment starting in 2025.

Fig. 4-6 IEA Roadmap module price forecast

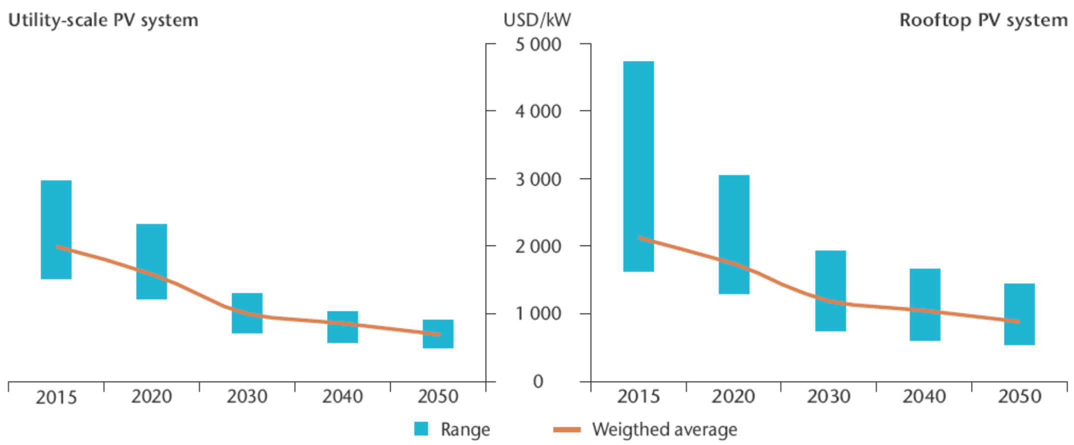


Fig. 4-7 IEA trend forecast of investment cost of PV system

According to IEA estimates, the investment costs of both utility-scale centralized PVPS and BMPV systems will be probably reduced nearly a half by 2050 with the decline in the prices of raw materials, improvement of the conversion efficiency of cells and expansion of the global PV market.

Table 4-18 Trend of LCOE of new utility-scale centralized power station by 2050

USD/MWh	2020	2025	2030	2035	2040	2045	2050
Minimum	96	71	56	48	45	42	40
Average	133	96	81	72	68	59	56
Maximum	250	180	139	119	109	104	97

Note: All LCOE calculations in this table rest on 8% real discount rates as in ETP 2014 (IEA, 2014b). Actual LCOE might be lower with lower WACC.

Table 4-19 Trend of LOCE of BMPV power station by 2050

USD/MWh	2020	2025	2030	2035	2040	2045	2050
Minimum	108	80	63	55	51	48	45
Average	157	121	102	96	91	82	78

Maximum	422	301	231	197	180	171	159

Note: All LCOE calculations in this table rest on 8% real discount rates as in ETP 2014 (IEA, 2014b).

NO.39 TechnologyRoadmapSolarPhotovoltaicEnergy_2014edition

Source: Page 24 of *Technology Roadmap Solar Photovoltaic Energy_2014 edition*

3. Analysis of grid parity for BMPV system

The power generation cost of BMPV system is denoted by one curve and the power generation cost of traditional energy is denoted by the other curve. As time goes by and the technology is improved, the power generation cost curve of BMPV systems will continuously go downward while the power generation cost curve of traditional energy will constantly go upward. These two curves will eventually meet at a certain point and this cross point is the point of grid parity for PV power generation system.

Fig. 4-6 shows roadmap of grid parity for BMPV power generation systems after overall consideration of PV power generation technology progress and change in conventional power cost. The selected 10 APEC member economies which are different in terms of region, economic type and development level are taken as an example. The electricity tariffs for households in such economies are within the range of USD 80-270/MWh. Considering the electricity tariff rise year by year due to factors such as inflation, the electricity tariffs for households in these countries will cross the mean value curve of LCOE of BMPV system at a certain point around 2030, namely the grid parity for BMPV power generation system will be reached, which can be seen from the curves in the figure below.

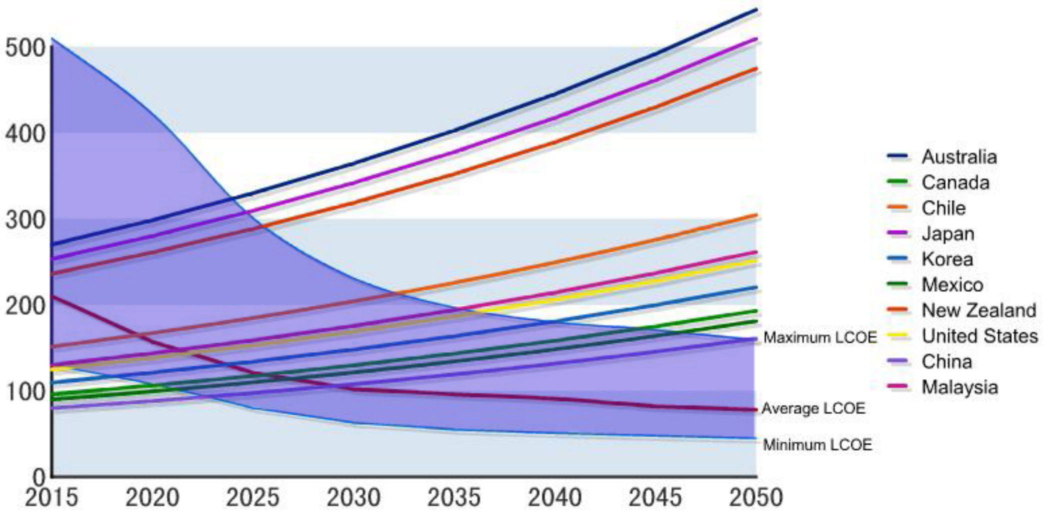


Fig. 4-8 Grid Parity Analyses in Selected APEC economies in USD/unit---- residential segment with an increment rate of 2.0%/year of inflation rate

5. Key BMPV Case Analysis

About 447 distributed cases in the APEC regions are looked up randomly. The cases are mainly from China, the US, Malaysia, Japan and other countries, in which sixteen cases come from questionnaires, and the rest are from online survey. According to the analysis, the distribution of the module type, installed capacity and installations is shown as follows:

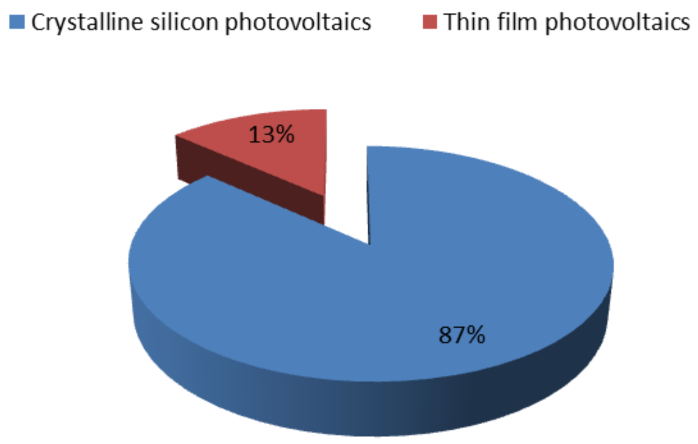


Fig. 5-1 Proportion of module types in BMPV samples

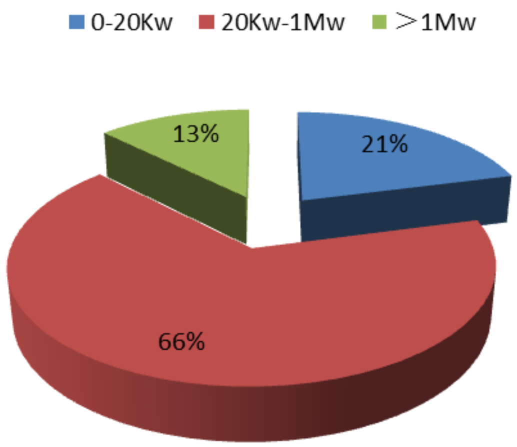


Fig. 5-2 Distribution of installed capacity of BMPV samples

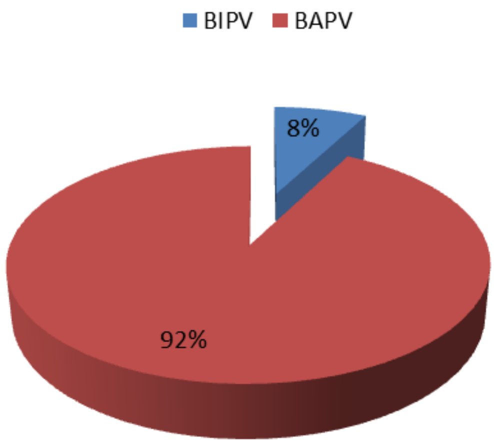


Fig. 5-3 Proportion of BAPV and BIPV

5.1. BAPV case analysis

5.1.1. Anhui Shoufu Villa BAPV Project

1) Project information and evaluation

Table 5-1 Anhui Shoufu Villa BAPV Project

Project name	Shoufu Villa BAPV	Site	Huaibei City, Anhui, China
Design time	May 2015	Finish time	September 2015
Building height	12m		
Architectural types	□ residential ■ commercial □ industrial		
PV installation area (m^2)	3080m^2		
BIPV or BAPV	□ Building Integrated PV ■ Building Attached PV		
Application area	□ curtain wall ■ roof top □ solar tile □ green house □ canopy □ others		
Installed capacity (W)	264KWp		
Type of PV module (Crystalline silicon or thin film) and the Supplier	CIGS thin film PV module by Hanergy		
BOS provider	Growatt		
Architect	(to be supplemented)		
EPC	Hanergy		
Project Owner	Huaibei Shoufu Real Estate Development Co., Ltd.		
Description of features	*This case is a demo green building with innovational energy-saving and environment-friendly materials, including thin film solar power generation system* on the rooftop. *The PV SYSTEM well integration with roofing*, *and keep the appearance of building well matched with the building original style.*		
Analysis of Investment Revenue	The total installed capacity is 264kWp, and the total investment is about 3.19 million yuan. The converted investment cost is 12.08 yuan/Wp. The annual average power generation is calculated to be 325,000 kWh and the static payback time is 10 years. The internal rate of return (IRR) of own fund of the Project is 10% within 25 years.		
Sharing of experience	1. In the project design, the solar power generation is considered as an important measure for building energy conservation. The building rooftop is quite suitable for installation of solar power generation systems.		

	2. The solar power generation system is designed and constructed by the villas developer in order to ensure uniform building appearance and high construction efficiency. 3. It is one of the first China's solar power generation projects for residential buildings. It scales up application of CIGS thin film products and is the first large-scale application of civilian solar energy in China.

2) Project photo

Fig. 5-4 Shoufu Villa BAPV Project

5.1.2. Yunfu ICBC BAPV Project

1) Project information and evaluation

Table 5-2 Information of Yunfu ICBC BAPV Project

Project name	ICBC distributed PV power generation project in Yunfu City	Site	Jianshe Road North, Yunfu City
Design time	August 2015	Finish time	November 2015
Building height	20m		
Architectural types	□residential ■commercial □industrial		
PV installation area (m^2)	400m^2		
BIPV or BAPV	□ Building Integrated PV ■ Building Attached PV		
Application area	□ curtain wall ■ roof top □ solar tile □ green house □ canopy □ others		
Installed capacity (W)	33KWp		
Type of PV module (crystalline silicon or thin film) and the Supplier	Single-crystalline silicon PV module by LERRI Solar		

BOS Provider	Guangzhou East Power Co., Ltd. etc.
Architect	
EPC	The IT Electronics Eleventh Design & Research Institute Scientific and Technological Engineering Corporation Limited
Project Owner	Yunfu Branch of Industrial & Commercial Bank of China Limited
Description of Features	The rooftop has an area of about 400 m^2 with concrete structure. There is no large structure on it. The height of parapets around the rooftop is 0.85m. According to the preliminary investigation, the rooftop meets the BAPV installation conditions. The rooftop is covered with one hundred and twenty 275Wp highly efficient single-crystalline silicon PV modules. One set of 30kW inverter is used for output of the 380V AC and is connected to the corresponding distribution cabinet busbar of the building; The proposed total installed capacity of the rooftop is 33KWp and the estimated annual power generation is 30,400 kWh. This project provides high-quality clean energy for Yunfu Branch.
Analysis of Investment Revenue	The total installed capacity is 33kWp, the total investment is about 250,000 yuan, and the converted investment cost is 7.5 yuan/W. The annual average power generation is calculated to be 30,400 kWh, the static payback time is 6.51 years, and the internal rate of return (IRR) of own fund is 12.85% within the 25 years.
Sharing of Experience	Design, construction, operation management, benefit calculation and so on 4. Elaborate the preliminary investigation, pay attention to details of the floor and rooftop, hear Owner's requirements and finalize the optimal scheme according to professional design and evaluation. 5. Focus on quality of the power station during construction. The construction should meet the national standards and ensure the project can operate 20-25 years. 6. According to the actual situations of this project, optimize human resources, select experienced installation team, ensure rapid construction and save cost. 7. In measurement and calculation, the local electricity price and the electricity price paid by the Owner shall be known in various ways. The economic benefits of the PV power generation system shall be calculated in combination with the power consumption of the Owner and the PV power generation.

2) Project photo

Fig. 5-5 Yunfu ICBC BAPV Project

5.1.3. Wuxi Commercial Rooftop BAPV Project

1) Project information and evaluation

Table 5-3 Wuxi commercial rooftop BAPV Project

Project name	Jiangsu Wuxi 100kW distributed power station	Site	Wuxi, Jiangsu
Design time	March 2014	Finish time	December 2014
Building height	4m		
Architectural types	□residential ■commercial □industrial		
PV Installation Area (m^2)	1200		
BIPV or BAPV	■ Building Integrated PV □ Building Attached PV		
Application area	□ curtain wall ■ roof top □ solar tile □ green house □ canopy □ others		
Installed capacity (W)	100kW		
Type of PV module (Crystalline silicon or thin film) and the Supplier	Crystalline silicon PV module by Trina Solar		
BOS Provider	Trina Solar		
EPC	Trina Solar		
Project Owner	Envision Energy		
Description of Features	This is distributed PV power generation demonstration project in Jiangyin. Based on the Apollo PV^{TM} cloud platform, it uses the technologies such as the Internet of Things, intelligent control and intelligent sensing for monitoring the generation condition, equipment status and performance of the power station, matching calculation and		

	real-time integrated dispatching to improve the efficiency of energy generation and consumption In the future, the advanced functions such as power generation & consumption prediction and energy trading will be actively demonstrated. The Project will be built into an energy management platform to connect it to multiple enterprises and integrate application with development to promote the development of energy internet.
Analysis of Investment Revenue	The Project has a total investment of 800,000 yuan. In the first year of operation, 110,000 kWh of electricity was generated (electricity generation hours: 1,100 hours), and the internal rate of return (IRR) of total investment reaches above 12%, which is much higher than the level of the same region in the industry (average electricity generation hours in the same region: 1000 hours and the average IRR in the same region: 10%).
Sharing of Experience	1. At the early stage of the power station construction, carefully evaluate about 300 risk points from 7 dimensions of the resource and operation periods of the power station according to Apollo Rating™, control key potential risk points and take actions to ensure the power station quality from the source. 2. At the early stage of power station site, used the Apollo Meteorological Digital Model™ to accurately predict the electricity generation in the 25-year life cycle of the power station, so as to guide the investment decision and power station design; 3. During the operation period of the power station, monitor real-time the operating indexes, equipment condition and performance of the power station based on the Apollo PV™ cloud platform to effectively guide the operation and maintenance and increase the power generation, and achieve maintenance-free site as possible and minimize O&M costs. 4. Conduct periodical post-evaluation, find out root cause of power loss of the power station, conduct economic analysis of the technological upgrading programs, select relevant measures and improve overall performance and dynamic economic efficiency of the power station

2) Project photo

Fig. 5-6 Wuxi commercial rooftop BAPV

5.2. BIPV case analysis

5.2.1. Hanergy Solar Headquarter Building BIPV System

1) Basic information

Table 5-4 Information of Hanergy Office Building BIPV Project

Project Name	Hanergy headquarter building	Site	Beijing, China
Design Time	August 2014	Finish Time	May 2015
Height	(to be supplemented) m		
Architectural Types	□ residential ■ commercial □ industrial		
PV Installation Area	(to be supplemented) m^2		
BIPV or BAPV	■ Building Integrated PV □ Building Attached PV		
Application Area	■ curtain wall ■ roof top □ solar tile □ green house □ canopy □ others		
Installed capacity	600kW		
Type of PV module (Crystalline silicon or thin film) and the Supplier	α-Si thin film PV module by Hanergy		
BOS Provider	Sungrow power		
Architect	East China Architectural Design & Research Institute		
EPC	Jiangsu Tianmao Construction Engineering Co., Ltd.		
Project Owner	Hanergy		
Description of Features	The facade design of the building is combined with the application of PV solar energy technology and the main exterior decoration materials are the unit-type solar PV modules. The curtain wall plates on the first and second floors of the building are arranged diagonally at angle of 45°. The frame is constructed with space truss and the glass back face and the façade of the fit curved surface is designed to be connected through four points. The PV modules are installed in different directions to form a scaled configuration. The horizontal included angle between the PV panels on the		

	3F façade of the building is adjusted according to the different façade mesh or column grids on the original building façade to display entire wave-shaped facade,
Sharing of Experience (Project Design, Construction, Operation and Maintenance)	Combination of new energy utilization with the architecture is the core innovation idea of BIPV application. This Project fully reflects the concept of green and environmental protection as well as building elegance. The dragon-shaped building is surrounded by scale-like curtain walls of double curved surface, just like a dragon flying between "rainbow bridge" and "great wages". On the condition that the layout of the existing building functions is not changed, the environmental-friendly building façade with uniform style and harmonious color can be achieved through rational use of different types of modules and overall design.

2) Project photo

Fig. 5-7 Hanergy Solar Headquarter Building BIPV Project

5.2.2. BIPV Roofing System for the Shanghai World Expo Theme Pavilion

1) Basic information

Table 5-5 Information of BIPV roofing system for the Shanghai World Expo Theme Pavilion

Project Name	The Theme Pavilion of Shanghai World Expo	Site	Shanghai, China
Design Time	December 2007	Finish Time	March 2010
Height	27.95m		
Architectural Types	□ residential ■ commercial □ industrial		
PV Installation Area	24000m^2		
BIPV or BAPV	■ Building Integrated PV □ Building Attached PV		
Application Area	□ curtain wall ■ roof top □ solar tile □ green house □ canopy □ others		
Installed capacity	2825kW		
Type of PV module (Crystalline silicon or thin film) and the Supplier	Multi-crystalline silicon PV module by Suntech-power		
BOS Provider	Sungrow power		
Architect	TJAD (Tongji Architectural Design (Group) Co. Ltd.)		
EPC	Suntech-power		
Project Owner	Shanghai Municipal Government		
Description of Features	The roofing of the theme pavilion consists of 6 V-shaped folded-plate units along the north-south direction. The wave length of each folded-plate unit for the wave-shaped roofing is 36m, and the rise of arch is 3m. Solar panels are arranged in a form of diamond on the surface of V-shaped folded-plate. There are 11,392 standard polycrystalline silicon PV modules and 3,312 irregular modules with 85 kinds of specification and capacity of 2597kWp, and 1,130 transparent polycrystalline silicon standard modules packed by double-faced glass and 330 irregular modules, with 69 kinds of specification, and total capacity of 228kWp.		
Sharing of Experience(Project Design, Construction, Operation and Maintenance)	The Project is single building integrated PV with the largest installed capacity in the world. Both non-transparent single-glass structure PV modules and transparent double-glass PV modules are adopted in the Project to meet		

	the requirements of architectural appearance and indoor lighting effect. The PV modules of different specifications and complicated installation structure are integrated into the building. In design of project, the idea of building integrated PV is introduced, and the planning, design, and completion of the PV system are synchronized. The main features of the Project are as follows: 1. Solar PV modules matching with the building appearance; 2. PV system with large installed capacity and high power generation; 3. Modules of various kinds and many irregular modules that can ensure consistency of color with the whole system and uniform array appearance; 4. Smart electrical system that can ensure connection of irregularly-shaped modules to the system. 5. Simple, smart, useful and reliable mounting system, which is easy to install. 6. Aesthetically designed and well concealed cable route.

2) Project photo

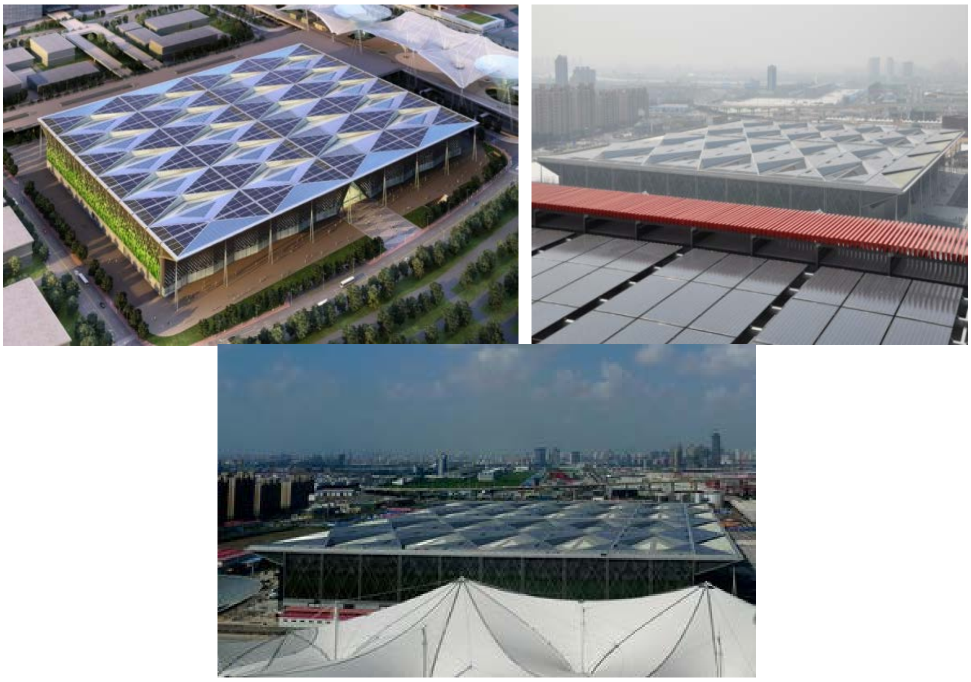


Fig. 5-8 BIPB roofing for the Theme Pavilions of Shanghai World Expo

5.2.3. Jinhuaxing Factory Buildings Roofing BIPV Project in Chinese Taipei

1) Basic information

Table 5-6 Information of Jinhuaxing Factory Buildings Roofing BIPV Project in Chinese Taipei

Project Name	Jinhuaxing Factory Buildings Roofing BIPV Project	Site	Hunei District, Gaoxiong City
Design Time	October 2012	Finish Time	September 2013

Height	12m
Architectural Types	□ residential □ commercial ■ industrial
PV Installation Area(m^2)	2,112 m^2
BIPV or BAPV	■ Building Integrated PV □ Building Attached PV
Application Area	□ curtain wall □ roof top □ solar tile □ green house ■ canopy □ others
Installed capacity(W)	99,190 W
Type of PV module (Crystalline silicon or thin film) and the Supplier	CIGS thin film PV module
BOS Provider	DELTA ELECTRONICS, INC.
Architect	Li Xuanqi Architects
EPC	TARAY SOLAR
Project Owner	Jin Hua Chen Metal Engineering Co., Ltd.
Description of Features	This system is the first roofing BIPV project in Chinese Taipei. It is the first to install the CIGS thin-film modules of BIPV double glass on the building rooftop to replace the traditional metal sheeting, and thus the rooftop material and labor costs are reduced. The factory building rooftop is provided with PV green-energy power generation facilities and the electricity from it is sold to Power Company. This project can gain profits and satisfy self-consumption.
Sharing of Experience(Project Design, Construction and maintenance)	The PV module installation area in the Project is 2,112 m^2, with a peak installed capacity of 99.19 kWp. The rainwater recovery system, glass curtain wall, LED lighting and other green building equipment are provided in the factory building. This project uses PV modules to replace the traditional metal sheeting to reduce the rooftop materials and wages. The rooftop can withstand a weight of 200kg and can be used to generate power and gain profit. The Owner can obtain profit from the investment but also commits to environmental protection. Many enterprises are attracted to follow. In the future, another 3 BIPV curtain factory buildings will be constructed.

2) Project photo

Fig. 5-9 Jinhuaxing factory buildings roofing BIPV project in Chinese Taipei

5.2.4. Seoul City-Hall BIPV Project

1) Basic information

Table 5-7 Information of Seoul City-Hall BIPV Project

Project Name	**Seoul City-Hall**	Site	Jung-Gu, Seoul
Design Time	2006. 5.	Finish Time	2012. 9.
Height	42m (13th, total floor area 71,000 m^2)		
Architectural Types	□residential ■commercial □industrial		
PV Installation Area(m^2)	1,600m^2		
BIPV or BAPV	■Building Integrated PV □Building Attached PV		
Application Area	■ curtain wall ■ roof top □ solar tile □ green house □ canopy □ others		
Installed capacity(W)	200 kW_p		
Crystalline or thin film PV module and the Supplier	G-G crystalline silicon PV module by Beebong E&G		
BOS Provider	EAGON Corp.		
Architect	Kerl Yoo, Iarc Corp.		
EPC	EAGON Corp.		

Project Owner	Seoul City
Description of Features	Seoul City-Hall has the supreme grade of green building in South Sorea, and 25％ of the energy consumed is from the sustainable energy. There are two types of PV panels installed on the building, C-Si PV single glazing with a sky light glass, and C-Si PV double glazing on the facade.
Analysis of Investment Revenue	＄728,210
Sharing of Experience(Project Design, Construction, Operation and Revenue Measurement)	-One of the fully building-integrated PV installations in Korea -Considered day lighting intake into building using semi-transparent PV modules -Annual average production 196,351kWh, Payback time 72.6years

2) Project photo

Fig. 5-10 Seoul City-Hall rooftop and curtain wall BIPV

6. Challenges and Comments

6.1. Challenges

1. The countries have also implemented policies to support their PV development, such as preference for use of their domestic products for BMPV systems, relaxing restrictions on market access conditions for their domestic products and adoption of different subsidy criteria. These protectionism measures may

lead to trading conflict among the countries and hold back overall development of the PV industry

2. The APEC economies define and classify BMPV according to the relevant standards and stability of their respective power grids, and thus BMPV depends on regional situations and installed capacity. For a specific regional grid in some an area, user load profile may not match with the distributed BMPV power connected into the grid instantly, under such circumstance, due to availding the impact to the grid, solar spilling may cause to be a problem.

3. For policy-supported BMPV and financed BMPV, the ownership of roofing and benefit of power investor on roofing PV system may be separated. Such as the complexity for stakeholders, it is not easy to calculate returns from PV systems, subsidies and profits.

4. The formulation of incentive polices for a specific period in a country may be a challenge, sometimes of that simplified fixed FIT, may work in ineffective way. There are many factors should be put into consideration In the policy formulation, including technological development, conventional energy price varies and so on. Thus, some countries take measures of combined policy and adjustable rates for the continuous promotion of BMPV application.

5. As some PV system weight exceeds the allowable load of buildings or structures, tailored mounting systems are required. This results in increase in PV system cost. Furthermore, standards for BMPV operation and maintenance and safety are more rigorous. Thus, cost of the systems in design may increase.

6. BMPV system power generation model is more complicated. Different model may cause different power generation. Due to various solar modules and systems in BMPV application, as well as different solar irradiance in installed plan, the same systems may have great deviation in power generation. This results in user complaint and difficult adaptability of fund support policies.

7. In the last decade, the solar irradiance varies greatly in some regions around the world. For example, according to the evaluation results in regard to China, the variation in some areas exceeded 30%, and this situation was also found in other areas of APEC, which causes a great difference among the same BMPV systems and affects popularization of BMPV.

6.2. Comments

1. BMPV power system installations have relatively lower proportion in APEC economies and there is a huge potential for market development. Different APEC economies are in different stages of BMPV power development. They should work together in promotion of basic research for BMPV technologies, selection of policies and roadmap, establishment and popularization of standards, and sharing of market operation mode and cases, and should more actively share their outcomes and information and make joint effort to improve environment during development of global economy.

2. The APEC economies situated within abundant solar irradiation resources and favorable conditions for development of PV power generation. The progress in PV power generation technologies, continuous decline in the cost and mature large-scale application have laid a foundation for the APEC economies to develop the PV power generation systems and have profound significance in energy safety and energy structure optimization, as well as reduction of air pollution and greenhouse gas emission. Thus, new energy application shall be fully considered in future urban planning an energy development program.

3. It is very important for APEC economies and regions to execute suitable BMPV development roadmaps according to their actual situations. The recent years the proofing rapid development of global PV industry rely on continuous increase in efficiency of solar cells, system reliability, decline in production costs and expansion of PV application fields. Thanks to cost reduction, the areas with higher energy price and better solar energy resources are the first to achieve parity. For the areas where parity cannot be reached, APEC economies should continue to implement the support policies specific to these areas to create sustainable profit model with stable return and lower risks and make the PV power market become mature.

The governments shall consider the following aspects:

* Set feasible development objectives;

* Adopt fiscal and financial support measures suitable for their countries and regions, clarify interests among financing institutions, stakeholders, producers and contractors, and make them become beneficiaries and boosters;

* Adopt BMPV application technology roadmap suitable for their countries;

* Continuously adjust FIT support roadmap to adapt to technical progress and cost reduction;

* With arrival of parity, the subsidy policy will be ended. However, as compared to ground-mounted BMPV stations, BMPV needs to be subsidized by governments within a certain period.

4. As compared to the large ground-mounted PV power station, BMPV power generation that has been most widely applied breaks through the limit of land resources and the constraints of long-distance power transmission, and overcome shortage of electrical infrastructures. BMPV power generation system can be conveniently popularized and applied and can better integrate time and space, power generation and consumption. According to the case analysis, the residential, industrial and commercial areas all have huge space to install distributed PV power generation systems. BMPV systems are closest to electricity load and fed from the user side, which is the effective roadmap for APEC economies to jointly develop PV power station. Furthermore, the PV power generation system, which can be installed at a place where electricity is most needed and can be connected at the user side, is an effective way for the APEC economies to develop PV clean energy together. Thus, the countries and regions shall combine the infrastructure construction and new energy in actual PV application.

5. As an emerging field, the solar PV power generation has no mature, complete and systematic standard systems. The whole product chain standard system structure and the key modules standards need to be improved. In the published photovoltaic technology standards, most are technical standards for PV products, which are mainly formulated by the developed countries and referenced by the developing countries. The popularization and implementation of technical standards for PV products has guaranteed the performance of PV products and healthy development of solar PV industry. However, the technical standards and specifications for PV system, which standardize the performance and quality of PV power generation and directly affect the PV market, are not complete and perfect. According to this study, distributed BMPV systems are the important form of the PV application, which deeply integrate PV and buildings, and the relevant products and system technologies will continue to develop. The developed countries have established complete BMPV standards, but, considering difference of building engineering specifications and power distribution network structures of APEC economies, in combination with the characteristics of the countries, APEC economies should establish their own standard systems for promoting PV application.

6. PV application market mainly serves end users. Thus, modules producers and system integrators or the third party (grid utilities) and relevant parties should enhance cooperation and gather together in the downstream, increase investment in energy Internet, smart grid and so on, and meanwhile provide better service for supply side and demand side to meet needs of end users. This can increase grid connection of BMPV and accelerate application and development of BMPV

7. Technically, the following shall be accelerated; ① increase efficiency and long-term reliability of PV modules, and safety of the modules installed on buildings; ② develop new system equipment (BOS) for easier and quicker connection to grid, and increase grid connection of new energy through smart grid technologies.

8. In terms of PV module application technologies, crystalline silicon PV modules are still the mainstream product. The thin-film modules require great technological improvement, but tend to be applied in large scale. Besides, the thin-film power generation technology has unique advantage of building integration. The thin-film modules are thinner, lighter and tend to be used as building materials, which offer diversified choices for architects. Architects can combine advantage of BMPV application with architectural aesthetics of buildings and optimize building functions in the application process, so as to obtain wide acceptance.

Future Work

During performance of this project, we have found some important interaction mechanisms between some important technologies, the market and the policies should be elaborated or investigated, and further work is needed to achieve targets of EWG18/2015A and provide reference for APEC economies to apply BMPV.

1. **Obstacles for BMPV application and popularization**

In the APEC region, BMPV application is extremely unbalanced. Besides the difference in their economic development and policy roadmaps, many other factors (electricity infrastructures and investment and financial mechanisms) also play an important role in the BMPV application. If these factors lag behind, the BMPV application will be hindered.

The causes of the obstacles should be studied and analyzed to provide reference for stakeholders to establish and execute the relevant measures for removal of obstacles and to accelerate the BMPV application and popularization.

2. **Improvement in study of BMPV application cases**

In recent years, APEC economies have completed BMPV application cases and accumulated experience in practice. In the EWG18/2015A report, the typical BMPV cases of some APEC economies are summarized and analyzed. The time from planning, design and construction to operation of the BMPV systems is too long, and this report lacks information on the stability of system operation. Thus, analysis and study of the BMPV cases should be improved. During long-term operation or life cycle of the systems, the experience in BMPV implementation, completion and operation should be summarized and analyzed to enrich the system case data, and provide more accurate reference for relevant stakeholders.

In addition, the BMPV application and development in the APEC economies are different. Thus, we consider that establishing BMPV case database is necessary. The input cases are from the different members, different periods and different types of completed systems. The complete information can be used to compile the BMPV Application Technology Manual, which can guide the members to implement BMPV projects.

3. Study on unified classification and assessment standards of solar energy resources in APEC region

Solar irradiation has a direct impact on efficiency and economy of the PV application. Thus, this report preliminarily analyzes and describes the solar energy resources in the APEC region. During the study, we have found the classification and assessment methods of solar energy resources are different among the APEC economies, and there is no unified standard. Thus, the solar irradiation calculated from the different APEC economies cannot be compared.

In order to ensure objective standard assessment of the solar irradiation and promote the exchange on policies and technologies of the PV systems among the APEC economies, it is recommended that unified standard shall be established for the APEC region to assess distribution of the solar irradiation in the APEC region and guide the APEC economies to compare and learn the PV application experience from each other.

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