

# PV in Rural Electrification in China

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## 1. PV Role in Energy Supply

### 1.1. Conventional Energy Resources and Renewable Energy

Either in China or in the World , the conventional energy resources are limited. The primary energy reserves in China is less than the average level of the world, it is about only 10% of the world reserves. The prediction of main primary energy reserves both in China and in the world are shown in Fig. 1.

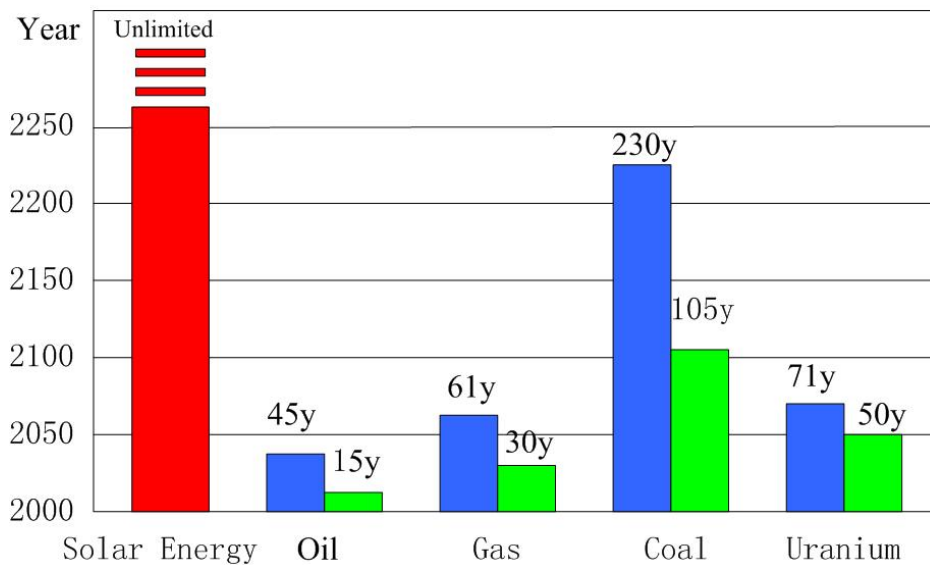


Fig. 1 Primary Energy Reserves in China and in the World

From long term view, Renewable Energy (RE) will become the main energy resources for human being. So RE is taken as future important energy resources to be developed by many developed and developing countries. Within the new renewable energy, wind power and solar PV are developed very fast and are the main field to be supported by many countries.

According to the expectation of JRC, PV will play a very important role in future power supply and will share 10% of total power supply in the world by the year 2030. RE will share about 30% in total energy consumption. By the year 2050, PV will share 20% in total power supply in the world and RE will share 50% in total

energy consumption in the world. Fig 2 shows the future expectation of energy demand in the world by the end of this century.

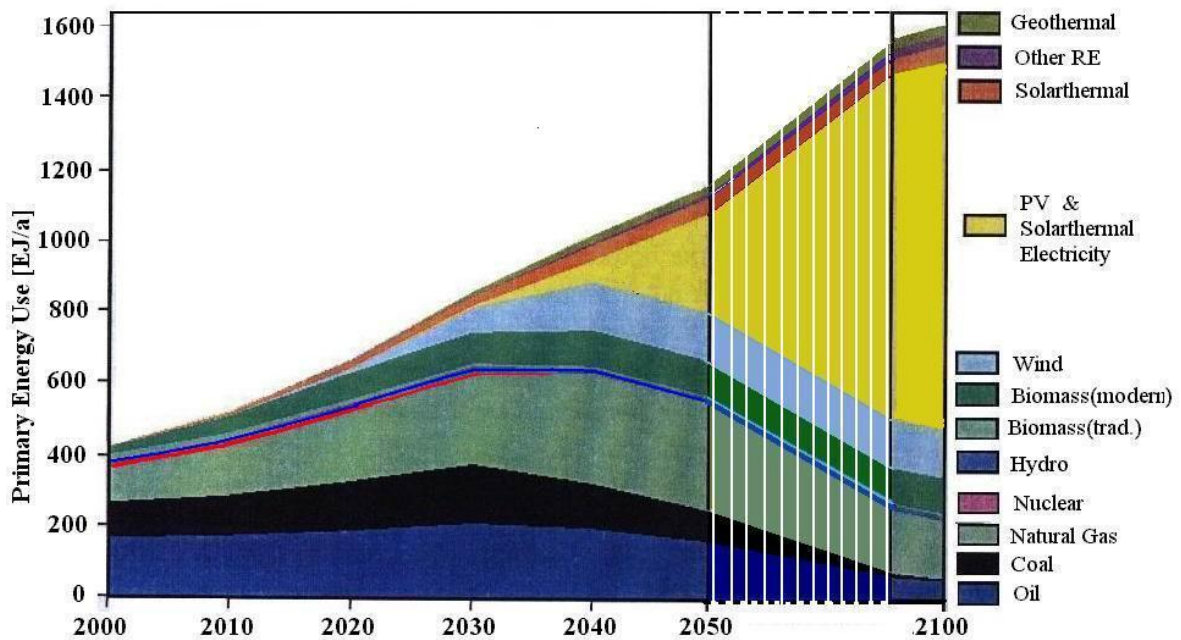


Fig 2. World Energy Expectation ( PVNET2003 )

China is a big country to produce energy and also one of the largest country to consume energy. In 2004, the total energy consumption in China is about 2 Billion Tce (tons coal equivalent) and it is 25% increase than the value of 2003. Among the total consumed energy, coal is 67.1%, oil is 22.7%, natural gas is 2.8%, and hydro power occupies 7.3%. In 2004, the imported oil was reach to 10,000 Tons which share about 40% of the whole oil consumption in China. Coal is the main role in the whole energy consumption and the share of each type of energy in 2003 are shown in Fig. 2.

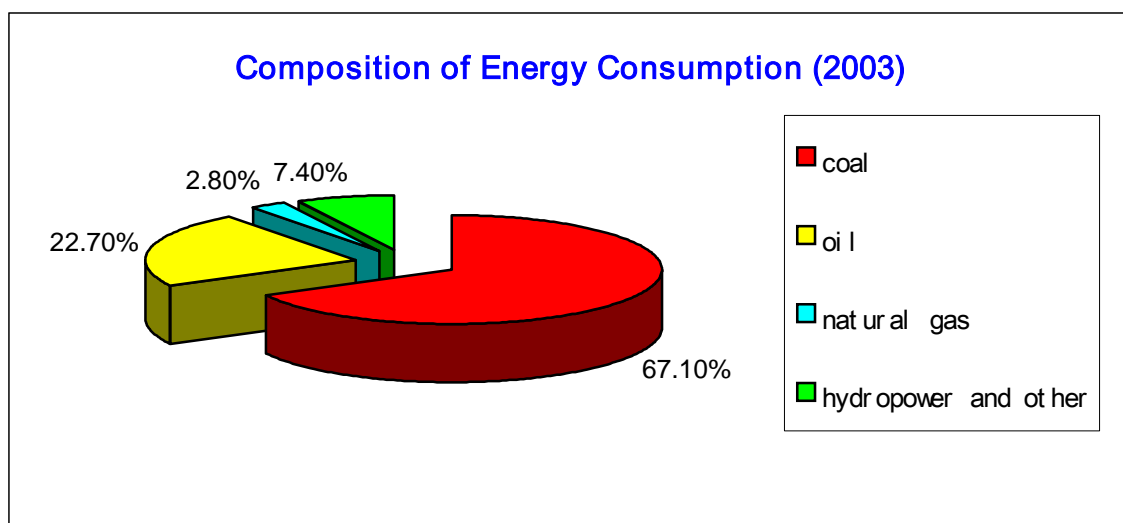


Fig. 2 Energy Consumption in China in 2003

Chinese government has given strong support to RE, mainly covering micro hydro power, wind energy, biomass, solar energy, geothermal energy and ocean energy. The current status of RE in China is as follows:

**Hydro Power :**The potential economic hydro power in China is 400 billion watt with annual power generation of 1700 billion KWh. In which, the micro hydro power (less than 50MW) resources are about 128 billion watt. By the end of 2004, 74 GW hydro power have been installed in wick 24 GW is micro hydro power.

**Wind Power :** China is facing to Pacific Ocean, the coastline is as long as 18000Km and season's wind is very strong. In the inland of China, there are many mountains which change the air pressure and make a wide distributed wind resources. According to the prediction made by weather station, there are about 250 billion watt potential wind energy inland of China. There are even more wind resources at coastline and it is estimated that the capacity will be 750 billion watt. The total developable wind energy is about 100 billion watt. By the end of 2004, the total capacity of the installed wind farm is 760MW. The installed stand-alone small wind generators in remote rural area is about 180000 sets and the capacity for such application is 40 MW.

**Solar Energy :** There are 2 types of using solar energy, solar thermal application and solar PV. By the end of 2004, the installed PV is 65MWp. Solar PV is mainly distributed at remote rural area and used for communication and transportation. Grid-connected PV is in demonstration stage currently. For solar thermal application, the installed solar water heaters by the end of 2004 are 65 million square meters which share 40% of the total area of solar water heater in the world. The annual manufacturing capacity of solar water heaters is 12 million square meters in China.

**Biomass :**Biomass includes the production through agriculture and forest, processing of industry waste, waste water and living rubbish. Currently, there have been 14 million sets of home biogas digester in rural area to produce 3.5 billion cubic meter of biogas annually, 2200 sets of large scale biogas engineering to produce 1.5 billion cubic meter of biogas per year and 2 GW of biomass power generation.

**Other renewable energy:** Besides wind power, hydro power, solar energy and biomass, there are geothermal energy, ocean energy, etc., but the scale is rather limited by now.

By the year of 2004, the total amount of renewable energy (wood or straw burning

are not included) is 130 million Tce and share 6.5% in total energy consumption in China. If only considering the hydro power less than 50 MW, the total amount is 56 million Tce and share 3% in total energy consumption.

RE is the sole energy resources in future to satisfy the energy requirement of sustainable development of human society. Currently, the technologies of micro hydro, wind power, solar water heater, solar PV and biogas production have been developed fast. The technologies of biomass fuel and power generation are under development and have bright future. It is expected that within 20-30 years in future, RE will become the main role in energy supply. The prediction of RE production by the year of 2010, 2020 and 2050 is shown in Table 1.

Table 1 Prediction of RE up to 2050 in China

Calendar Year	2004	2010	2020	2030	2050
Total Energy Demand ( $10^8$ TCE )	<b>20</b>	<b>23</b>	<b>30</b>	<b>50</b>	<b>70</b>
Macro-Hydro ( $10^4$ KW )	7400	11500	21500	25000	50000
Annual Production( $10^8$ KWh )	2300	3900	7300	8750	17500
Equal to ( $10^8$ TCE )	0.82	1.33	2.4	2.71	5.25
Micro-Hydro ( $10^4$ KW )	3400	5000	7500	10000	20000
Annual Production( $10^8$ KWh )	1000	1545	2300	3200	6400
Equal to ( $10^8$ TCE )	0.36	0.52	0.76	1	1.92
Wind Power ( $10^4$ KW )	76	500	3000	10000	40000
Annual Production ( $10^8$ KWh )	11.4	105	690	2300	9200
Equal to ( $10^8$ TCE )	0.0041	0.036	0.23	0.76	3.04
Biomass Power ( $10^4$ KW )	200	550	2000	5000	10000
Annual Production( $10^8$ KWh )	51.8	212	835	2250	5000
Equal to ( $10^8$ TCE )	0.013	0.072	0.28	0.7	1.5
Biogas ( $10^8$ m <sup>3</sup> )	50	110	240	400	1000
Equal to ( $10^8$ TCE )	0.036	0.079	0.17	0.3	0.8
Solar Thermal ( $10^4$ m <sup>2</sup> )	6500	15000	30000	50000	100000
Equal to ( $10^8$ TCE )	0.085	0.2	0.39	0.65	1.3
PV ( $10^4$ KW )	6.5	40	200	1000	10000
Annual Production( $10^8$ KWh )	0.78	4.8	24	140	1500
Equal to ( $10^8$ TCE )	0.00028	0.0016	0.0079	0.043	0.45
Others ( $10^8$ TCE )	0.029	0.065	0.26	3.837	6.74
Total ( $10^8$ TCE )	<b>1.35 (0.56)</b>	<b>2.3 (0.97)</b>	<b>4.8 (2.4)</b>	<b>10 (7.29)</b>	<b>21 (15.75)</b>
Share of RE ( % )	<b>6.5 (3)</b>	<b>10 (4.2)</b>	<b>16 (8)</b>	<b>20 (14.6)</b>	<b>30 (22.5)</b>

\*: 1KWh = 350g coal equivalent.

## 1.2. Power Supply in China (2004, 2010, 2020)

Before 2000, the power supply in China is satisfied to meet requirement. Since 2001, the economic growing very fast in China and 20% increase in power requirement annually. In 2003, power shortage becomes a serious problem and will be more serious in future. The power installed capacity in 2004 is 442.8 GW totally in China in which coal power is 324.9 GW and shares 73.4%; The power generation is 2.19 TWh in China in 2004 in which coal electricity is 1.81 TWh to share 81.7%. Table 2 shows the power generation sectors in China in 2004:

**Table 2. China Power Generation in 2004**

Type	Installed Capacity ( GW )		Generated Electricity ( TWh )	
	Capacity	Share	Electricity	Share
	( GW )	( % )	( TWh )	( % )
Coal	324.9	73.4	1.81	82.5
Hydro	108.3	24.4	0.33	15.0
Nuclear	6.84	1.5	0.05	2.3
Others	2.80	0.6	0.006	0.3
Total	442.8	100	2.19	100

According to the economic growing speed of China, it is not enough just rely on coal, hydro and nuclear power and there is a gap to be filled with RE power generation. Table 3 shows the power generation by the year of 2010, 2020 and 2050 expected by China Electric Power Research Institute. And the Table 4 shows the gap of power requirement by the year of 2010 and 2020.

**Table 3. China Power Generation by the Year of 2010, 2020 and 2050**

Year	Capacity ( GW )	Generated Electricity ( TWh )
2004	4.42	2.19
2010	685	3.14
2020	1112	5.09
2050	2000	9.27

**Table 4. Power Generation by the year of 2010 and 2020 ( GW )**

Type	Coal	Hydro	Nuclear	Gas	Gap	Total
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2010	500	100	16.4	15.7	52.9	685
	73%	14.6%	2.4%	2.3%	7.7%	100%
2020	750	170	53	48	91	1112
	67.4%	15.3%	4.8%	4.3%	8.2%	100%

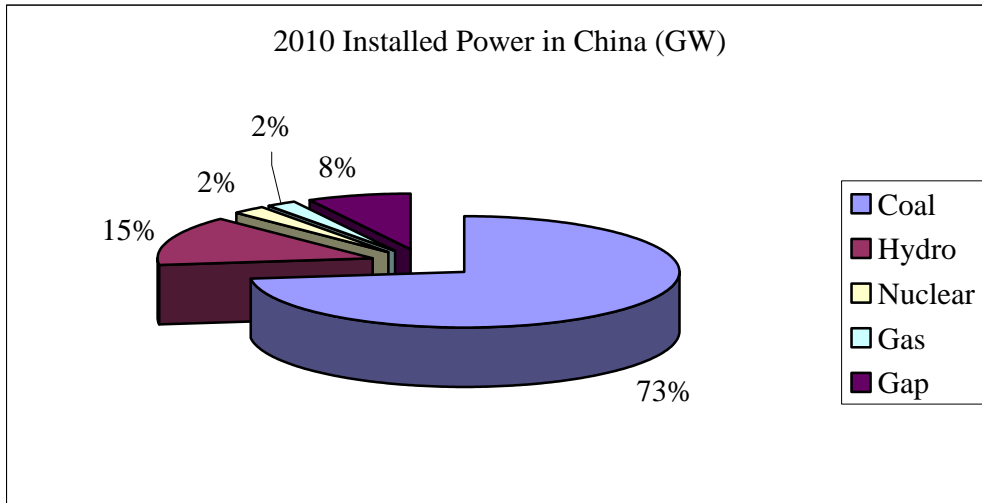


Fig 3. Predicted Power installation by the year of 2010

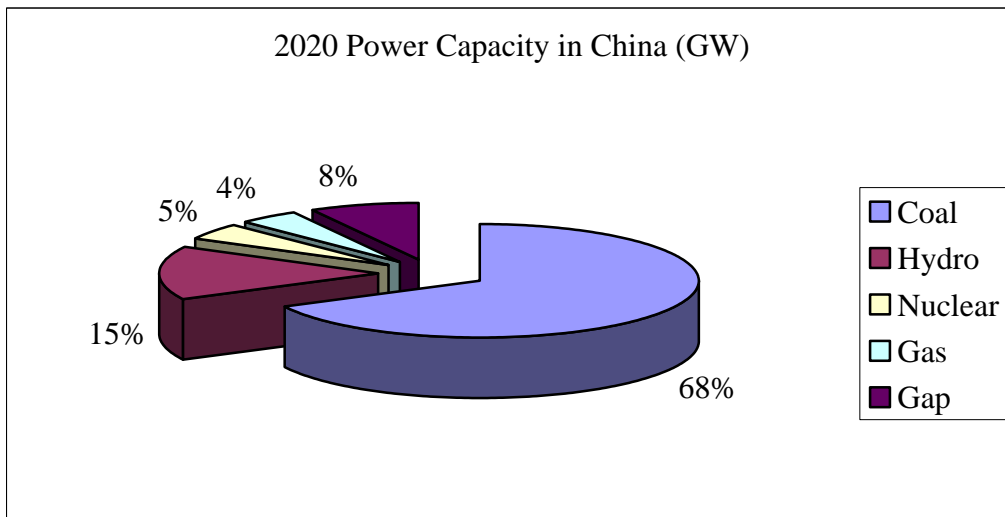


Fig 4. Predicted Power installation by the year of 2020

Solar PV will play a role in future power supply in China. It is expected that by the year of 2010, the total installed PV will reach to 400MWp and by the year of 2020, the installed PV will be 2GWp and by 2050, the number will be 100GWp. According to the prediction by China Electric Power Research Institute, RE power generation will share 25% in total power supply by the year of 2050 in which, PV will share 5%. Table 5 shows the situation.

**Table 5. Electric Power Capacity by 2050**

Type	Capacity ( GW )	Share ( % )	
Coal	1000	50%	
Nuclear	240	12%	
Gas Power	100	5%	
Large Hydro	160	8%	
Micro Hydro	200	10%	<b>RE</b>  25%
Biomass Power	100	5%	
Wind Power	100	5%	
Solar PV	100	5%	
<b>Total</b>	<b>2000</b>	<b>100%</b>	

## 2. World PV Industry

In the last decade , world PV market grows very fast and annual shipment increase is more than 30% in the last 8 years. In the year of 2004, PV shipment reaches to 1200MWp and the annual increase even reaches to 61.2%. Fig 5 shows the total PV shipment in the world from 1990 to 2004.

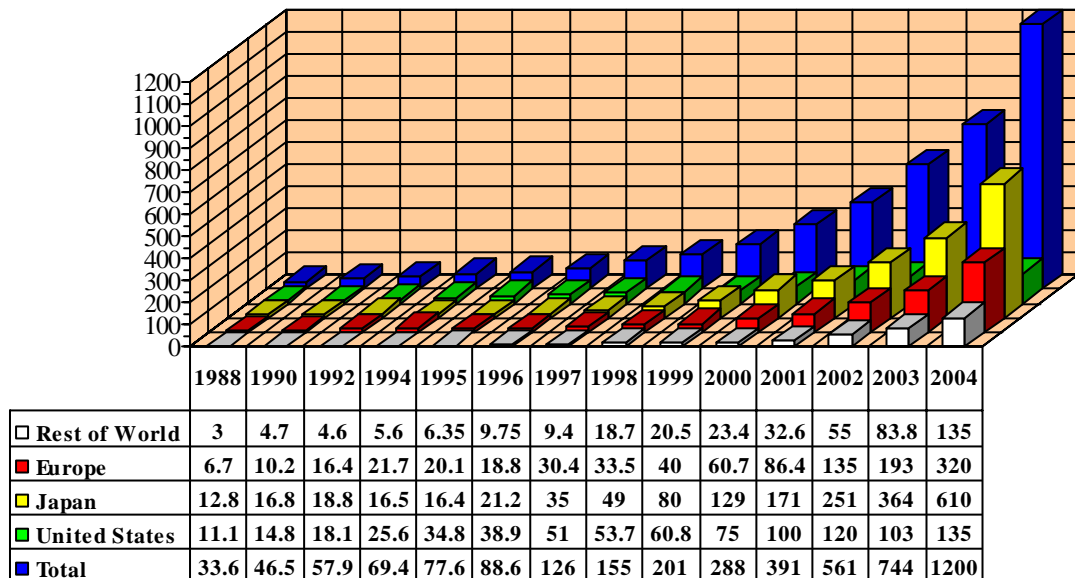


Fig. 5 World PV Shipment ( PVNET2004 )

**Table 6, PV Shipment and Cumulative in Last 10 years ( GWp )**

Year	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Annual Ship.	0.078	0.089	0.126	0.155	0.201	0.287	0.391	0.561	0.744	1.2
Increase ( % )	11.8	14.2	42	23.1	30	42.9	35.7	44	32.5	61.2
Cumulative	0.577	0.665	0.791	0.946	1.147	1.435	1.825	2.387	3.131	4.331

Data Source - PV News Paul Maycock

PV market growth in the world mainly due to policy driving in Germany, Japan and US and more than 60% of PV is used in grid-connected sector.

PV roadmap has been set by PV leading countries, like US, Japan and Europe. The comparison of the targets between China and other countries is given in Table 7 and Table 8:

**Table 7. Prediction of the Cost of Power Generation by PV**

Year	2004	2010	2020
Japan (Yen/KWh)	30	23	14
Europe ( Euro/KWh )	0.25	0.18	0.10
US ( ¢/KWh )	18.2	13.4	10.0
China ( Yuan/KWh )	3.8	3.0	2.0

**Table 8. Roadmap of PV Installation ( GWp )**

Year	2004	2010	2020
Japan	1.2	5.0	30
Europe	1.2	3.0	15
US	0.34	3.0	15
China	0.065	0.4	2
World	4.0	14	70

### 3. PV Market in China

#### 3.1. PV Market Development

China started research on solar cell in 1958 and it was firstly used on satellite in 1971. Solar cell terrestrial application was start in 1973 for beacon light at Tianjin Harbor. Before 1980, PV industry in China was nearly nothing and the annual

production is less than 10KW with very high selling price. During 6th (1981-1985) and 7th (1986-1990) national five-year plans, Chinese government starts to give financial support to the PV industry. Various PV demonstrations were installed during that time, such as: solar powered microwave relay stations, army communication systems, cathodic protection for sluice gates and oil pipelines, countryside telephone stations, PV village power systems and solar home systems, etc..

In the year of 2002, PV has more chance than before since the “Song Dian Dao Xiang” (Sending Electricity to the Un-electrified Townships) program was launched by NDRC. The project has provide electricity to more than 700 un-electrified townships in the western 7 provinces (Tibet, Xinjiang, Qinghai, Gansu, Inner-Mongolia, Shaanxi and Sichuan). The total installed PV was 15.5MWp in which 240KW are small wind power. This program has greatly stimulates the growth of PV Industry. The PV shipment in 2002 was about 20MWp (see Fig. 6) and the cumulated power of PV in whole China reached to 55MW. From 2003 to 2005, PV Industry in China growth very quick and production capacity goes up due to European market, mainly German market. By the end of 2004, Chinese PV module production capacity had been reach to 400MWp and the annual shipment of PV modules were 200MW in which, only 5MW was installed in China while most of them shipped to Europe. Market development of PV in China is shown in Table 9 and Fig. 6.

Table 9. PV Domestic Market Development Since 1976

Year	1976	1980	1985	1990	1995	2000	2002	2004	2005
Annual Install( KW )	0.5	8	70	500	1550	3300	20300	10000	5000
Cumulative ( KW)	0.5	16.5	200	1780	6630	19000	45000	65000	70000

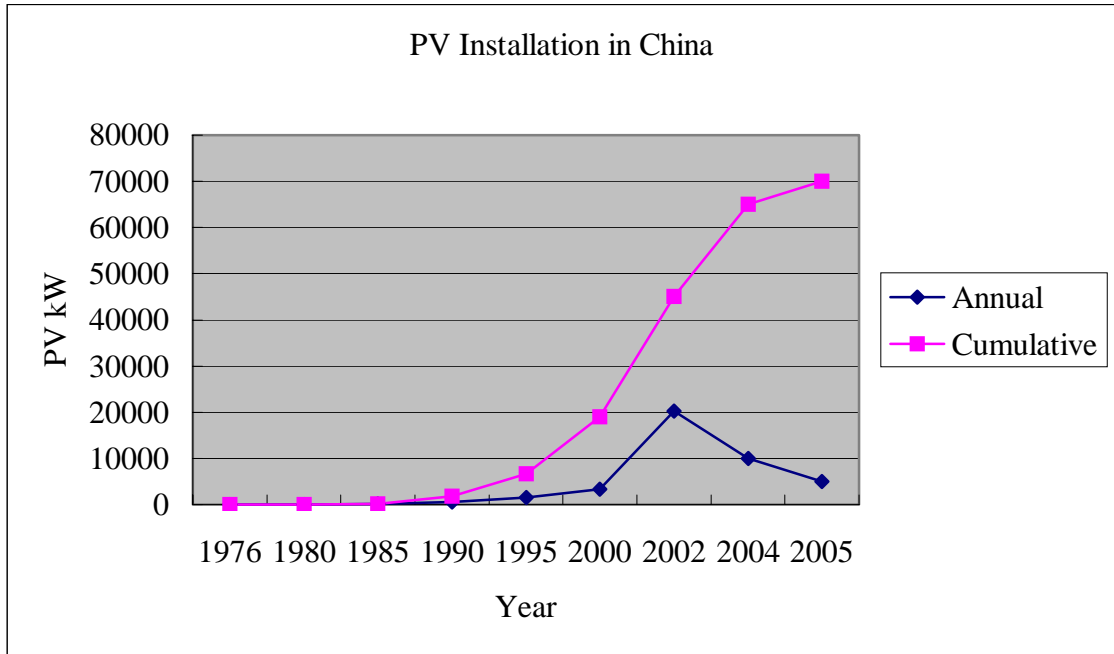


Fig.6 Development of PV Annual Installation and Cumulative in China

### 3.2. PV Market Share in 2004

The major driving factor for the solar PV industry in China is the domestic PV market demand. The main applications sectors are:

#### **Communication and Industrial Uses (36.9%);**

- ◆ Microwave relay stations
- ◆ Optical fiber communication systems
- ◆ Wireless communication stations
- ◆ Satellite communication and TV receiving systems
- ◆ Telephone exchanges for rural areas
- ◆ Military communication systems
- ◆ Signal systems for railways and highways
- ◆ Power systems for beacons
- ◆ Weather or earthquake monitoring stations

- ◆ Hydrological observation systems
- ◆ Cathode protection for sluice gates and oil pipelines

**Rural Electrification (approximately 46.2%):**

- ◆ Stand-alone village PV systems
- ◆ Wind-PV hybrid power systems
- ◆ Solar home systems
- ◆ Solar lighting kits
- ◆ Solar water pumping
- ◆ Community power (Schools, Hospitals, Restaurants, Hotels, Shops, Karaoke and TV Show Rooms, etc.)

**Grid connected application (4.6%):**

Grid connected PV includes Building Integrated PV (BIPV) in urban application and Large Scale PV in Gobi desert. Currently, this application is in the demonstration phase, with total amount to 3 MWp by the end of 2004.

**PV Products (12.3%):**

- ◆ Solar road lamp
- ◆ Solar battery chargers
- ◆ Solar watches and calculators
- ◆ Solar clocks
- ◆ Solar yard lanterns
- ◆ Ventilators in cars
- ◆ Solar-powered automobiles
- ◆ Solar-powered yachts
- ◆ Solar toys

Table 10. Market Shares of PV in 2004

Market Sector	Installed PV (MWp)	Market Share (%)
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Rural Electrification	30	46.2
Communication & Industry	24	36.9
PV Products	8	12.3
BIPV	2.8	4.3
VLS-PV	0.2	0.3
Total	65	100

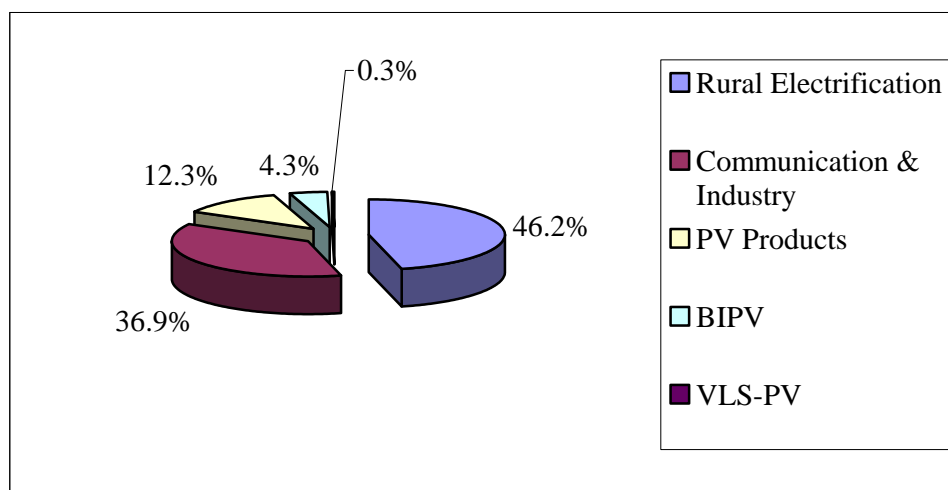


Fig.7 Market Shares of PV in 2004

Among those application sectors, about 50% (communication and PV products) is commercial market, another 50% (Grid-connected PV and Rural Electrification) is now financed by government and will require policy support for a long term in the future due to PV's high cost.

### 3.3. Future Prediction of PV Market

China is a country with limited conventional energy resources and has big gap in power supply in future. We must take PV as strategic energy and give strong support to its development. According to government program, the cumulated PV installation in China will be 400MW by the year of 2010, and 2GW by 2020. If Chinese Renewable Energy Law is fully implemented, it will not be difficult to reach this target. PV market share has been set in the government program (2010, 2020).

Table 11. Market Shares of PV in 2010

Market Sector	Installed PV (MWp)	Market Share (%)
Rural Electrification	250	63
Communication & Industry	60	15

Solar Street Light	5	1
PV Products	25	6
BIPV	40	10
VLS-PV	20	5
Total	400	100

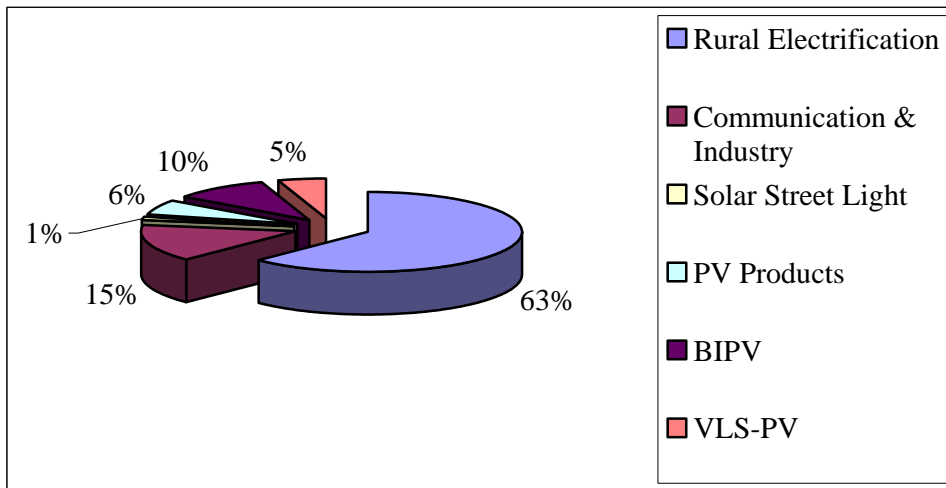


Fig.8. Market Shares of PV in 2010

Table 12. Market Shares of PV in 2020

Market Sector	Installed PV (MWp)	Market Share (%)
Rural Electrification	500	28
Communication & Industry	400	22
Solar Street Light	20	1
PV Products	80	4
BIPV	600	34
VLS-PV	200	11
Total	2000	100

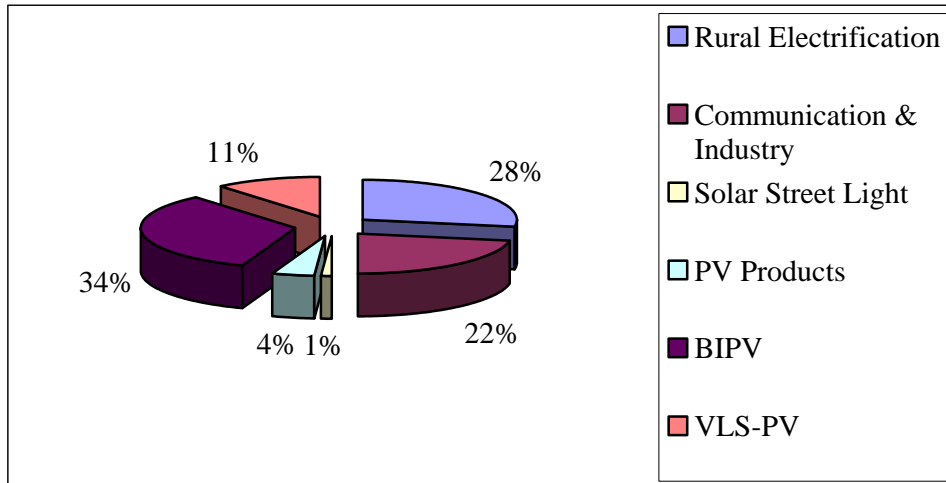


Fig.9. Market Shares of PV in 2020

### 3.4. Prediction for Cost Reduction of PV in China

Table 13 Expectation of PV Installation and Electricity Produced

Item	Calendar Year		
	2005	2010	2020
Annual PV Installation (MW)	5	130	200
Cumulated PV Installation (MW)	70	400	2000
Annual Electricity Produced (TWh)	0.084	0.48	2.4
Module Price (Yuan/Wp)	35	25	16
Price for Stand-alone PV (Yuan/Wp)	80	60	40
PV Electricity Price (Yuan/kWh)*	8	5	3

\*: Electricity Price of PV is for Grid-connected Application.

## 4. PV Projects in Rural Electrification

### 4.1. Electrification Project for Un-electrified Countries

Project of PV power for Un-electrified Counties started in 1990 and ended in 2001. This project was sponsored by State Electric Power Company, original Ministry of Electric Power. Through this project, 7 PV stations with total capacity of 505KWp have been built up in Tibet.

The average initial cost of the PV stations is 130-140 Yuan/Wp (40-45 Yuan/Wp for solar modules). Comparing the cost of inland of China, project in Tibet is 30% higher in transportation, installation and local civil construction.

Table 14. Summary of the Project of PV Power for Un-electrified Counties

County	Capacity ( kW )
Naqu	100
Bange	70
Nima	20
Shuanghu	105
Geji	50
Gaize	80
Cuoqin	80
<b>Total</b>	<b>505</b>

#### 4.2. Argli PV Project in Tibet

Argli District is located in the most western part of Tibet with average elevation of 4500m. The land tertiary of Argli is 305,000 km<sup>2</sup> and has 72452 in population (0.24 people in one km<sup>2</sup>). There are 7 counties in Argli District and the eastern 3 counties are in posturing area and the western 4 counties are in half agricultural and half posturing area.

Argli has the best solar resources in China, even in the world and the annual solar irradiation is 8000 MJ/m<sup>2</sup>, equal to 2200kWh per year.

Approved by premier Li Lanqing in 1999, Argli PV project was launched in 2001 to build up 38 PV powered village power systems, 11018 SHS, 30 solar pumping systems and 10 satellite TV stations. The total capacity of PV installed in this project is 450.36KWp.

The detailed information of this project is listed in Table 15 and Table 16.

Table 15. Village Power Systems

County	Village Power Stations	Total Capacity ( kW )
Pulan	5	25
Zhada	6	30
Ger	6	30
Ritu	4	20
Geji	6	30
Gaize	6	30
Cuoqin	5	25
<b>Total</b>	<b>38</b>	<b>190</b>

Table 16. SHS and Other Applications

County	20Wp SHS	1kWp TV Station	1kWp Solar Pumping	Capacity (kWp)
Pulan	745	2	3	19.9
Zhada	900	1	3	22
Ger	1060	2	3	26.2
Ritu	1455	1	3	33.1
Geji	2232	1	6	51.64
Gaize	2457	1	7	57.14
Cuoqin	2169	2	5	50.38
Total	11018	10	30	260.36

The unit price for village power systems, TV stations and solar pumping systems is 150,000 Yuan/KWp and for SHS, the unit cost is 80 Yuan/Wp. Total investment of Argli PV project is 60 million Yuan. The share of the investment is given in Table 17.

Table 17. Investment Sharing of Argli PV Project

Source of Fund	Amount ( Million Yuan )	Fund
NDRC (SPCC)	20	Grant
MOST (SSTC)	10	
SEPC (MEP)	10	
Local DRC (SPC)	20	
Total	60	

#### 4.3. SDDX (Sending Electricity to Un-electrified Townships) Program

In 2002, the state launched Township Electrification Program (Song Dian Dao Xiang program). Within 2 years, 292 small hydropower stations with 292.7MW in capacity and 721 PV and PV/wind hybrid village power (VP) systems with 15.5MW have been set up to provide electricity to 300 thousands un-electrified households covering 1.3 million people in 7 Western provinces (including 42 villages at Army Farm in Xinjiang). The total investment amounted to 4.7 billion Yuan RMB (1.67 Billion Yuan spend on PV and wind) among which 2.96 billions were funded by central state debt and the rest were provide by local governments. It is the largest rural electrification project in the world by utilization of renewable energy and also the largest solar PV power project in China. The main data is listed in Table

Table 18. SDDX Data for PV and Wind/PV Hybrid Systems

Province	Number of VP Sys.	Installation Capacity (kW)	Unit Cost (Yuan/kW)	Total Investment (Million Yuan)
Shaanxi	9	100	110,000	11.00
Qinghai	112	2715	100,000	271.50
Gansu	23	995	120,000	119.40
Xinjiang	110	1417.4	100,000	141.74
Army Farm	49	960.8	100,000	96.08
Inner-M	42	752	90,000	67.68
Sichuan	46	1816.7	90,000	163.50
Tibet	329	6763	118000	798.03
Total	720	15519.9	103500	1668.94

SDDX project is the largest rural electrification project in the world by utilization of renewable energy and also the largest solar PV power project in China to provide electricity to the remote rural villages without access to electricity. It is amazing to complete such a huge in two years covering project bidding, equipment purchase, equipment manufactory, equipment transportation, civil work, equipment installation, staff training and station operation. SDDX has solved the living power consumption difficulties in the remote area and has accelerated the local economic development, improved the living level. It is an important contribution to accelerate the modernization locally. Additionally, the adoption of new energy is significantly to the environment protection, which is a good demonstration of environment freindly awareness.

#### 4.4. World Bank/ GEF REDP Project

**Targets:** WB/GEF provided \$27,000,000USD of grant to subsidize SHS by \$1.5USD/Wp. Plan to distribute 350,000 sets of SHS in western china and total planed capacity is 10MWp.

##### **Key Issues of REDP Project:**

- 1) 300,000 SHSs have been sold during 2002 – 2005 to provide electricity to 280,000 un-electrified households.
- 2) Approved system integrators are allowed to apply subsidy with receipts, list of the sold systems with detailed information of customers and the list of the key components with series number provided by manufacturers;
- 3) Technology Improvement (TI) Component of the project to help manufacturers to improve the quality of their products (\$3.5 Million USD);
- 4) Capacity Building (\$2.0 Million USD):
  - Establish standard for SHS;

- Strengthen testing laboratory (all approved components must pass the test by qualified Test Lab. 5 Laboratories has been supported.);
- Training on quality (ISO9000), financial management and technology;
- Market Development: advertising, exhibition, study tour, conference, etc.. ;
- Service network establishing.

#### **4.5. Other International Project**

##### **GEF/UNDP Project (2000-2004)**

- Capacity Building and Business Model
- Demonstration of Business Model by Wind/PV hybrid Power Systems in Xinjiang.

##### **Shell Solar Silk-Road Project (2002-2006)**

- (China-Netherlands Cooperation Project)
- 10000 sets of 50Wp SHS.
- Grand from Netherlands Government: 13,790,000Euro by providing solar modules and controllers.

##### **GTZ/KFW Financial Supporting Project (2003- )**

- Total Investment: 20,000,000 Euro.
- Village Power Systems were built in Yunnan, Xinjiang, Qinghai and Gansu.
- Training Program: Technology and Business Model.

##### **China-Canada Cooperation Project (2002-2005)**

- 3.5 Million Canadian Dollar Grand
- Training and Demonstration of village power

##### **NEDO Project (1998-2002)**

- 12 Solar Powered Schools

##### **US DOE Project (1994-1996)**

- SHS in Gansu, Wind/PV hybrid power system in Inner-Mongolia

### **5. Market Opportunities in Rural Electrification**

Chinese government has launched SDDX program in 2002, that is the largest rural electrification project by PV and wind in the world and plan to do SDDC (sending electricity to un-electrified villages) project in next 10 years. 400MW of PV and small wind will be installed during 2006 – 2015 to provide electricity to about 4 million un-electrified households in remote places. The capital investment will be granted by government and it is estimated to be 3.2 billion Yuan. It is really a good chance for PV, but following factors must be carefully considered:

- Different financing way between village power systems and solar home systems;
- Who will be the ownership of the property of PV systems?
- Where to get money to cover the cost for battery replacement? For no grant from government to pay afterward O&M cost.
- Who will be the RESCO to take duty of O&M and afterward service?
- Tariff collection and business models;
- Quality control and certification issues;
- Service network and spare parts availability for SHS;
- Training.

## **6. Problems and Barriers**

### **6.1. Village Power System**

The main characters of village power (VP) systems by PV or PV/Wind hybrids are: High initial investment, long life time (over 20 years) and long-term stable running without fuel consumption. With the characters as flexible construction scale, short construction time and uncomplicated management, they are a relatively ideal model to address the electricity supplying theme to rural area. But due to the remote location, it is difficult to maintain. There are many failure stories caused by the bad unsuccessful management both in China and the world. Nowadays over 700 PV and PV/Wind hybrid powers stations having been established in China are facing challenges of subsequent management and achieving stable operation over 20 years. There are lots of un-clarified issues such as,

- The ownership of the power systems?
- Will the tariff be charged? And what is the price level?
- Who will be the operator to do the daily operating and maintenance? What about the salary? Who will pay the salary? Who will train the operator? How to keep the operator stable?
- After the duty years of system integrator, who will take over the technical support responsibility?
- What kind of management model shall be conducted to guarantee the long-term reliable operation?
- How to finance the battery replacement for the lifetime of the sealed lead-acid battery is only about 5-6 years?
- How much for all expenses covering O&M? How much shall be supported by state? How much can be covered by tariff collecting or other commercial way?

All of those issues above should be addressed clearly.

## 6.2. Solar Home Systems (SHS)

Solar home systems are the different case compare with Village Power Systems. For example, capital investment will not be fully granted by government and the end user must share certain part of capital from 10% to 50%, even more in some cases.. The ownership of the SHS should belong to the end user. Then, the end user must pay the afterward service and spend their own money for spare parts and battery replacement after the warrantee period. The main barriers for SHS are:

## 6.3. Policy Barrier

### 6.3.1. Renewable Energy Law and Implementation Rules

The Renewable Energy Law was approved by Chinese People's Congress on February 28<sup>th</sup>, 2005. The key items and concepts related with off-grid PV are:

**Article 15**—The Government supports the construction of independent renewable power systems in areas not covered by the power grid to provide power service for local production and living.

**Article 20**—The excess between the expenses that power grid enterprises purchase renewable power on the basis of the price determined in Article 19 hereof and the expenses incurred in the purchase of average power price generated with conventional energy shall be shared in the selling price. Price authorities of the State Council shall prepare specific methods.

**Article 22**—For the selling price of power generated from independent renewable energy power system invested or subsidized by the Government, classified selling price of the same area shall be adopted, and the excess between its reasonable operation, management expenses and the selling price shall be shared on the basis of the method as specified in Article 20 hereof.

January 4<sup>th</sup>, 2006, “The Temporary Implementation Rules for Setting up Feed-in Tariff of Renewable Energy Power and the Sharing of Expenses in Purchasing Electricity of Renewable Energy Power” was issued by NDRC. In this regulation, some rules related to off-grid PV systems are given as bellow:

**Article 12**— ----- the excess between the expenses spend on O&M of off-grid RE power systems invested by government and the local average selling price of grid power shall be compensated in the way of adding additional green power price to the ordinary selling price of electricity to the whole electricity users in China.

From above law and regulations, we can see:

For off-grid PV in rural electrification, the capital investment will be granted by government (SHS will be shared by end user in capital) and the extra cost incurred

from afterward service and O&M will be subsidized by adding green power price to the whole grid in China.

### 6.3.2. Difficulties in Implementation of Renewable Energy Law

RE Law and Implementation Regulations are good, but by now only on paper. There is no any real example of PV projects have enjoyed above policy by now. PV is more difficult to follow RE Law than wind power that has been accepted by utility company for years.

By now, utility company has not formally accepted PV power and only several demonstration systems are allowed to tied with grid for testing purpose. To be formally accepted by utility company, the following works and efforts need to be further done on PV:

- Set up reasonable feed-in tariff;
- Establishing acceptance rules and standards for connecting PV to the grid;
- Persuade Utility company to accept PV and purchase the PV electricity with the set reasonable feed-in tariff;
- Sharing the extra cost to the whole grid in China.

So, only have RE Law be published is not enough, hard efforts need to be done to go through the way of implementation of RE Law and set up practical mechanisms.

## 7. Conclusions and Recommendations

### 7.1. Conclusions

- 1) PV will play a very important role in future power supply in China, especially in rural electrification;
- 2) Even the capital cost of PV in rural village power projects will be granted by government, the high cost in O&M and afterward service still need to be subsidized for the collected tariff will never cover the cost. To remove this barrier, implementation of RE Law is the soluteion. A lot of efforts need to be done for such purpose and demonstration is required to go through the way of policy and set up realistic mechanism.
- 3) SHS is the different case compare with VP systems and it should follow the market mechanism to distribution.

## 7.2. Recommendations

### 7.2.1. For Centralized Village Power Stations

- 1) Capital investment will be covered by central and local government;
- 2) Identify the project owner before launching the project ;
- 3) System integrator should be selected by owner through bidding ;
- 4) According to RE law, tariff level for VP systems should be set jointly by local government, project owners and local Price Bureau and it should be the same with grid covered places ;
- 5) RESCO will be selected by owner through bidding to be in charge of O&M on site, technical support and battery replacement, etc. ;
- 6) After installation, the acceptance of VP systems shall be done jointly by project owner, system constructor and RESCO ;

The VP system running cost will be subsidized according to the power output (kWh);

- 7) Extra running cost higher than collected tariff need to be added to the electricity selling price of whole grid in China as Green Power price. The Green Power price will be collected by Grid Company and handed over to central government to store in special account. The VP system running cost will be subsidized from this fund.
- 8) Monitoring mechanism needs to be established. Consigned by project owner, the monitoring unit will check the service situation conducted by RESCO and re-checking the real power output.
- 9) RESCO must submit annual report to apply tariff subsidy and such report is only valid with the approval and signature of monitoring unit.

### 7.2.2. For Solar Home Systems

For Solar Home Systems (SHS), the business mechanism or market mechanism must be introduced. GEF/World Bank REDP project has established a very good example and base practice for SHS in China. The recommendations are as follows:

- Firstly, identify the project sponsor ;
- SHS here include: PV Home systems, wind home systems and wind/PV hybrid home systems.
- The initial cost of the power system can be shared by central government, local government and end users. About 10% to 50% should be shared by the end users and the home used electronic devices will be purchased by themselves, like TV sets, lights and washing machine.
- Ownership of the SHS will belong to the end users.
- Project sponsor will select system suppliers through bidding ;
- Identify the duties of the SHS suppliers, at least the duty should cover: system supply, system installation, training to the users, service network establishing ( at least to the county level), spare parts availability, 2 years warrantee , etc..
- Battery renew will be paid by the user himself and the system supplier need to provide products with good quality and reasonable price.
- Independent monitoring unit is required to monitor the duties and services conducted by the system suppliers.
- Government should provide budget to strengthen quality control, standard development, products test, establish qualification and certification system, service network establishing and training both to service technicians and end users.