IIIEE Master's Theses 2005:21

The Chinese Renewable Energy Law and BIPV's Introduction, Application and Development in China

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Thesis for the fulfilment of the
Master of Science in Environmental Management and Policy
Lund, Sweden, October 2005

Acknowledgement

This paper is written under the background of upsurge of appeal to renewable energy and publication of Chinese Renewable Energy Law(CREL). Even far away in Nordic country, I can feel the avid wave pursuing renewables in China and experienced the surprise and ecstasy when I first learnt the approval of CREL. This news, also attracted the keen eye-sights of energy expertises in IIIEE (International Institute of Industrial on Environmental Economics, Lund University) and my first idea to do something on China renewable energy was encouraged by these ardent people.

I am grateful to Professor Thomas B. Johansson, as my supervisor, his profound academic background and insight into China's energy issues gave me great help when I was confusing. My thanks also go to Professor Rolf Henriksson, his senior energy expertise and decades experience in this field, gave me timely direction and support as well as encouragement to my timid start. My acknowledgement goes to Professor Lars Hansson as well, he enthusiastically provided materials on externality of energy and good suggestions.

During the writing procedure of this paper, I also got different helps from several other experts, Mr. Lars Sjunnesson in Sydkraft AB, Mr. Luis Mundaca, Mr. Kes McCormick and Ms. Lena Neij in IIIEE. Here I express my thankfulness to them.

I also want to thank Chinese solar energy experts, Mr. Wang Sicheng in Beijing Jike New Energy Company. Mr. Zhao Yuwen and Mr. Wang Changgui in Chinese Solar Energy Association, they both gave me help for some technical questions. My thanks also go to the young fellows in Chinese Coal Information Research Institute, Sun Xin and Zhang Wenbo, Ding Yi in Beijing South-north Research Institute on Sustainablility(NGO), all gave me help during data collection and answered my confusion in coal information. I shouldn't forget the help from Suntech Photovoltaic Company in China. Zhu Zhiyang, as the technical engineer in Suntech, provided information on the latest progress of their production.

I would like to thank Dr. Winfried Hoffmann and his assistant, Sabine Rapp in German Solar Industry Association(BSi) and European Photovoltaic Industry Association(EPIA) and Ms. Agnieszka Kalinowska in Center of Photovoltaic, Warsaw University, Poland. They responded my questions in email promptly. I got help from our IIIEE alumni member too. Thanks Kollin Min from Seattle provided American latest policy on BIPV in Washington State and Kristy Heng from UK provided initial review on the IIIEE ARPEA II course paper and useful opinion. Special thanks to Lawrence Berkeley National Laboratory Energy Analysis Department, which provided me free CD of China Energy Book 6.0 and to ExternE office in Brussels, which provided 1-10 volums of ExternE publication freely. I also decided contribute these volums to IIIEE library after I finish this paper.

I cannot finish this paper without the continuous encouragement from my dearest family, my parents, my beloved wife Zhonghui and my sweetheart son, Ziyao. Thank you very much for accompany me going through the tough days when I was in depression, loneliness, anxiety and downcast. The internet connects us together. And thank you very much, my dad, for sifting environmental newspapers and journals in China and mailed to me.

During writing process of this paper, I contacted the leader in Chinese Development and Reform Committee who is in charge of stipulating the grid-connected electricity price for renewables. They showed great interest in my work and asked for exchange of the research result. I learnt this paper is synchronous with their research. For CREL will enter into force from 1st, January, 2006, they will publish the grid-connected electricity price for renewables at

the end of 2005. Therefore it gives another reason for the existence of this paper. I will be gratified if this paper can contribute a little for Chinese energy reform procedure and find its value to photovoltaic researchers, policy makers and their aides as well as college students.

In conclusion, I devote this boiling-down of four-month sweat and psyche to all who have helped me.

Zhengyang Zhang,

September, 2005

IIIEE, Lund University, Sweden

Abstract

This paper reviews building-integrated photovoltaic (BIPV) applications in China as one pathway toward diversification of the Chinese energy infrastructure. By analysing the potential of BIPV's penetration in Chinese urban areas and a scenario analysis in Beijing, this paper addresses the questions (1) Is BIPV feasible in China? (2) If the Chinese government chooses BIPV, what are the pros and cons? (3) How can obstacles be overcome to implement BIPV?

In terms of current PV technology, a 5 kWp PV system occupying about 40 m^2 rooftop area can produce c.a. 6 MWh electricity per year under average insolation levels in China. Given an approximate rooftop area in townships of roughly 4 billion m^2 in 2003, installation of PV systems on just one third of these rooftops would enable annual generation of approximately 200 TWh. This represents 14% of Chinese annual electricity consumption in 2002 for BIPV or rooftop systems alone, independent of large concentrated solar facilities such as PV power plants. BIPV remains in its infancy or as a novelty in Chinese cities as demonstration projects and the potential of PV energy is far from full commercial exploitation. Globally, manufacturing capacity for PV cells recently exceeded 1 GW and the fastest increment of PV is the grid-connected PV system in residential rooftops, namely, BIPV in most cases.

The Chinese Renewable Energy Law (CREL) is a landmark of Chinese government's endeavour to construct a harmonic society and transition to sustainable patterns of development. It supports a reduction in consumption of fossil fuels and seeks to stimulate renewable alternatives. Aiming for the enhancement of CREL this paper also analyses the background, contents and limitations of this law. Correlative recommendations for further improvement are given based on successful cases in other countries. To promote the rooftop programme of BIPV, economic incentives are discussed by adapting the German Feed-in Tariff to a scenario of a '100 000 Rooftop Programme' in Beijing, China. Quantitative analysis of application of BIPV technology in Beijing as a sample case shows it is feasible in China. The environmental, social and economical benefits show BIPV should be developed in priority among all the renewables in Chinese cities. Finally, several suggestions on actions are given for policy-makers.

Executive Summary

The last decade witnessed the 30% annual growth of global PV production and application. The leading countries are Japan, Germany and the USA. In the competition of this round, China obviously lagged behind. Recent years looming energy crisis in China and appealing for cleaner energy motivated the enaction of Chinese Renewable Energy Law (CREL) in 2005. This law indicates a great transition in the Chinese energy policy and can be regarded as a milestone on the road of sustainable development. Could this law be an inception to introduce cleaner electricity production and replace part share of old electricity production as well as to lead in a booming new market of PV application? The answer is positive, but a lot of works are left to do to live it up.

In this paper, Chapter 1 gives the background of Chinese energy context and the urgency to develop renewables. By analysing the Chinese energy structure, try to understand the roots of heavy pollution in urban areas. Coal combustion as the predominate pattern of energy consumption, will continue this status for decades in China. It's also the main reason resulted in GHGs emission, acidification and suspending solid dust (soot) pollution in most Chinese cities. Nevertheless, with the growth of economy, the demand for energy also expanded beyond expectation. Whether Chinese economy can repeat 1990s miracle, as like to keep the economy with higher increasing rate of 8-9% and meanwhile, keep the energy consumption increase rate lower 50% than economic increase, namely, remaining 5% or less energy annual increase become a challenge. The old energy structure of relying on fossil-fuel has been proved unsustainable and outdated. One way to solute this is to enhance energy efficiency, another way is to restrict fossil fuel, particularly coal's consumption and encourage renewable energy's share in the whole energy structure. To address the latter way, there are a couple of choices, such as wind power, small hydro and solar energy etc. This paper choose solar energy's application in urban area, taking into account the potential of solar resources and prerequisites of application, not least, this consideration is based on solar energy's unique characteristics which is distinctive from other renewables. As research objective, this paper tries to answer these questions:

Is BIPV feasible in China?

What are the incentives and barriers to develop BIPV?

How to support BIPV's application legally and financially to penetrate it from pilot to mainstream?

Chapter 2 reviews the history and technology of PV application in world spectrum as well as the progress of PV development and manufacture in China. The global PV industry developing trend is given in big picture. The newly produced PV cell shipment has exceeded 1GW in 2004, which indicates PV cell production is striding in GW level development annually. Along with the booming PV application in several markets such as in Germany, Japan and the US, many developing countries will be the potential participators. China's PV manufacture has got great progress in last 3 years and is growing continuously. The Chinese PV industry has accumulated considerable capacity and experience. To initiate a niche PV market in China is imperative and necessary.

In Chapter 3, by comparing CREL and other countries' counterpart law, analysing the merits and drawbacks of this Building Integrated Photovoltaic (BIPV) mode, try to find out the incentives and barriers of PV's application in buildings. To initiate BIPV programme in cities, how to attract households' and dwelling-owners' interests becomes a focal issue. It will decide

the successfulness of such programme. Options of economical means are discussed as supplementary statute to CREL.

Chapter 4 focuses on the incentives to develop BIPV in China. By comparing BIPV pattern and other renewable energy, chapter 4.2.1 explained perspective of pros and cons of putting PV's development in priority. The German 100,000 rooftop Programme was studied in detail in Chapter 4.3, from its theory to effect. This case study is used as a reference to develop BIPV in China.

Chapter 5 supposes a 100,000 Rooftop Programme is to implement in Beijing, China. Through investigation on solar resource, income condition and other context, it is very feasible to develop such a similar project. In particular, the BIPV system design is discussed in this Chapter. In theory, invest on a 5 kWp BIPV system seems have satisfying output of electricity and the investment on the extra 2 kWp has higher cost-benefit character than a mere 3 kWp system under current market condition.

Chaper 6 gives the benefit of BIPV through concrete calculation. The long term overlook of the external cost of coal consumption in China stems the development of renewable energy. Now even CREL enacts the direction of development, it is still necessary for policy-makers to learn the cost of externality overarching, the benefits and costs of action and non-action. Chapter 6.4.4 tries to garner the available research information about external cost by coal-combustion in China and referable information to China, and give comparison of benefit to develop BIPV against fossil-fuelled plants.

The benefit of implementing BIPV in cities could be: to abate coal consumption and mitigate a serial of fallout by coal-burning such as CO2 emission, SO2 and NOx discharging and suspending solid dust pollution. These benefits are all given in quantitative value in terms of a pilot scheme to implement in Beijing.

In addition, Chapter 6.3 answers the doubt of PV's energy pay-back time (EPBT). For most people's impression, PV production consumes lots of fossil fuel energy and need almost the whole life-cycle for energy pay-back. Actually with the fast development in PV technology, this point of view can't hold ground. The PV efficiency increment, mass production and modern quality control lowered the PV cost and meanwhile, enhanced efficiency makes today's PV product more effective under the sun. All the factors contribute the shortened EPBT. Nowadays the EPBT has shrunk to 3 years or shorter. After that time, the PV panel becomes pure net energy producer.

Chapter 7 presents options to provide financial support for BIPV's development. The German FiT (Feed-in Tariff) is adopted as a stereotype. The merits of FiT as well as drawbacks are discussed. The charging standard and scope is also computed under the assumption of Beijing scenario. The CDM (Clean Development Mechanism) is introduced as one of the channel to utilize international cooperation. Even though the PV electricity cost is affected very little by CDM fund, c.a. 0.5 Euro cents to 0.7 Euro cents /kWh[1], and the time limit till 2012, thus CDM cannot decide the PV electricity cost significantly. Then as a new angle of view, differentiated electricity charging system is recommended to speed the bridging of the cost gap between PV electricity and conventional electricity.

[1] this figure is in terms of CO2 price (5-7 Euros/ ton) and the CO2e coefficient in China now (1.068 kg/kWh)

Chapter 8 gives further recommendation to policy-makers. They are: set up roadmap of PV industry in China; Enforcing synergy between energy and construction department; To initiate capacity building of BIPV and phasing out irrational subsidy to fossil-fuels.

Finally, in a nutshell, the prerequisites to exploit this potential energy are enumerated. The necessary conditions seem all poised. Anyhow, the key action to catapult this pilot project is still up to the final decision of government, even though the economical, environmental and social benefits are more transparent now. With the increasingly growing demand for cleaner energy and reorganization of unsustainable way of fossil fuel consuming, it is almost certain the Chinese government will not let along this channel of clean energy production and keep the free resource untapped.

PV, as the once expensive representation in electricity generation, has become cheaper with the increment of shipment every year. Because of its clean, elegant way of electricity production, the seeking to find the cheapest way of converting solar light to electricity never stopped. But till now, the high price as the bottleneck stems its further enlargement and deter many countries' participation in this realm. It is far on the way to get its long-deserved share in marketplace. As the mainstream technology of PV efficiency still remains 16% or less, a suitable marketing policy to pull down PV electricity price and help it competitive to conventional utility price seems particularly important. Germany's triumph in FiT policy manifests political will (Renewable Energy Law) adding suitable economical incentive can be a feasible way at current phase. This road is also referable to other countries which are interested in developing their renewable energy with ambitious plans.

Abbreviations:

BACT: Best Available Control Technology

BAPV: Building Attached Photovoltaic

BAU: Business-as-Usual

BIPV: Building Integrated Photovoltaic

BOS: Balance of System

CDM: Clean Development Mechanism

CER: Certified Emission Reduction

CMM: Coal Mining Methane

CO_2: Carbon Dioxide

CREL: Chinese Renewable Energy Law

EPBT: Energy Pay-back Time

ERI: Energy Research Institute of China

EPIA: European Photovoltaic Industry Association

ET: Emission Trading

ETSU: Energy Technology Support Unit (Now renamed as Future Energy Solutions)

FiT: Feed-in Tariff

GHG: Green House Gases

HIE: Heat Island Effect

HVAV: Heating, Ventilating and Air Conditioning

IEA: International Energy Agency

IPCC: Intergovernmental Panel on Climate Change

JI: Joint Implementation

NASA: National Aeronautics and Space Administration

NDRC: National Development and Reform Committee of China

NGO: Non-governmental Organization

O&M: Operation & Maintenance

R&D: Research & Development

PBIP: Performance-based Incentive Programme

PR: Performance Ratios

PV: Photovoltaic;

RM: Raw Material

SAS: Stand-along System

SC-SI: Single Crystalline Silicon

SO_2: Sulphur Dioxide

T&D: Transmission & Distribution

VAT: Value-added Tax

VDN: German Association of Grid Operators

WTP: Willingness to Pay

WWF: World Wildlife Fund

Quantity Abbreviation: k Kilo (10^3); M Mega (10^6); G Giga (10^9); T Tera (10^{12});
P Peta (10^{15}); E Exa (10^{18})

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1. Introduction

1.1 Energy and Renewable Energy Policy

1.1.1 Energy Crisis in China

To date, the China industries are enduring the most serious energy crisis ever had in history. With the annual 9% growth, Chinese economy is merging rapidly with the world, and becomes one of the centres of manufacture. The negative effect accompanying with this consequence is the ever-growing energy demand. Because of historical tradition relying too heavily on coal as primary energy, the serious outcome of fossil fuel burning is day by day deteriorated environment and ascending menace to human's health.

The demand for electricity before 2000 is not a big problem in China, or didn't get enough accentuation it deserved. While after 2001, the electricity demand increased in a 20% rate every year. In 2003, the electricity shortage became a serious problem and alarmed the over-burdened power supply system. Experts warned the electricity shortage would continue for several years. In 2002, the electricity production capacity in China is 356.57 GW, the coal fired plants account for 74.5%. The whole year electricity generation is 1654.2 TWh, the coal fired fuel accounted for 81.7%.(Shi Lishan, et al. 2004, p. 3) The most serious fact is most power plant didn't pay enough attention on the discharging standard. The stacks lack of necessary cleaning devices to filter flue gas. The coal burning in plants contribute 70% air particulate in China. This irrational energy structure brings worse outcome to the environment such as choking air in cities, acid rain and eutrophication to down wind area, and respiratory diseases threatening peoples' health.

Pattern Of Generation	**Installed Capacity**		**Electricity Generation**	
	GW	Percentage (%)	TWh	Percentage (%)
Coal Fired	265.54	74.5	1352.2	81.7
Hydropower	86.07	24.1	274.6	16.6
Nuclear	4.46	1.25	26.5	1.6
Sum	356.57	100	1654.2	100

Table 1-1. 2002 Electricity Capacity and Generation (Source: China's Electricity Science Institute)

We can find from the above table that renewable energy in China now is only included in the hydropower, all the renewable energy added together is lower than 3%[2], mainly produced by small scale hydropower and even less wind power, the PV electricity is too minimal to be mentioned in the whole energy structure. It is predicted in 2010, "there will be electricity shortage in capacity of 37 GW, accounts for 6.4% in total peak demand." (Shi Lishan, et al. 2004, p. 4) How to gap this difference of demand and generation, could the PV electricity be a potential power resource?

[2] this part is included in Hydropower in Table 1-1 as the renewable energy in China are mainly small hydros, the other renewables are too small to show up.

1.1.2 Chinese Energy Structure and Impact of Atmospheric Pollution

A country's energy consumption level will decide the emission quantity and furthermore, affect this area's environment and climate. As we can see from Table 1-1, the coal as the main fuel to produce electricity dominates the energy structure to 81.7%. Not only in the production of electricity, the coal takes account for the biggest share in the whole structure of energy consumption including all the areas. (Refer to figure 1-1.1.) The reason caused to this scenario is the historical tradition of coal-burning and consideration of cheaper price and abundant reservation. China is the 3rd country in coal reservation in the world, ranked behind Russia and the USA. According to 1996 coal detecting investigation, the detected coal reserves in China is 114.5 billion ton, accounting for 11.6% of the world. (Huang Shengchu et.al. (2003), p. 9). China is the biggest country in coal burning. The CO_2 emission amount ranks behind America as the second in the world. According to Chinese Coal Research Report, in 2000 the CO_2 emission is 3.052 billion ton, increased 33.3% than 1990's level. (Huang Shengchu et.al. (2003), p. 27) The CO_2 emission data are shown in Figure 1-2. Another consequence of coal-burning is the SO_2 emission. In 2001, the SO_2 emission reached 19.48 million ton, 90% of this amount could be attributed to coal combustion.

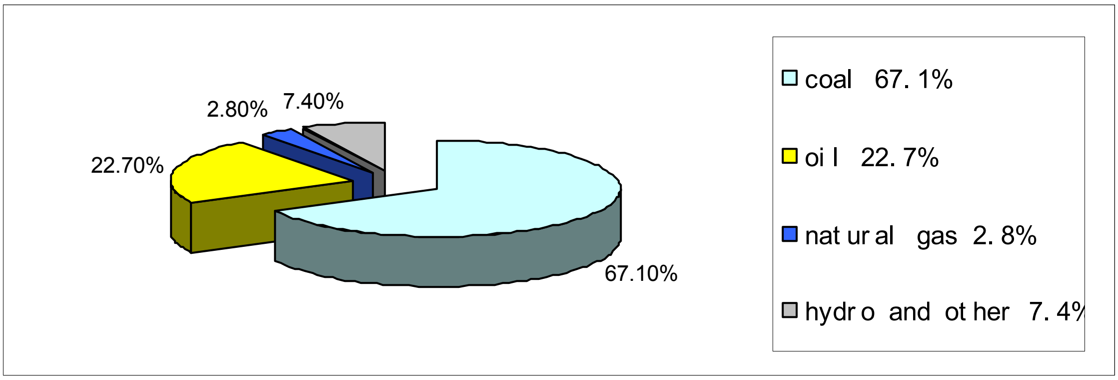

Figure1-1.1: Chinese Energy Structure in 2003 (Source: Shi lishan et.al. (2004), p. 2)

(Results dynamically generated 6-8-05 11:01:45)

Searchable Database Results

Climate and Atmosphere — CO2 : Total emissions (source: IEA)
Units: Million metric tons carbon dioxide

Reverse years

		2001	2000	1990
Region/Classification				
Asia (excluding Middle East)		7,402.81	7,337.45	4,985.47

	ISO	2001	2000	1990
Country				
China	CHN	3,126.88	3,176.11	2,389.29

Download | View Technical Notes | View General Notes [3]

Figure:1-1.2 China's CO_2 emission data (Source: IEA, data requested from http://earthtrends.wri.org)

The Influence to Environment of GHG and SO_2 in China

When all the world are marvelled by the Chinese fast growing economy with 8-9% GDP increase annually, who knows the environmental price paid behind the economic prosperity?

Since IPCC had already warned, it is very likely the anthropogenic-caused CO_2 and other GHGs emission will lead the world average surface temperature raise 1.4-5.8 degree till 2100. The temperature rising will cause averaged global sea-level rise about 0.09 to 0.88 meter and more weather-related disasters. (IPCC (2001), Summary for Policymakers, p. 32) Unfortunately, more and more evidences are growing to support this hypothesis and we can NOT shrug this warning off as alarmist's fuss or turn a blind eye to the over-consumption of fossil fuel.

According to IPCC's current robust findings, the global warming potential is possible related with the fast concentration of GHGs during the last century and based on the precautionary principle, it is advisable to uphold the position of "act now before it's too late". This position is also pursuant to Rio Declaration's principles signed by 175 countries in 1992. "In order to protect the environment, the precautionary approach shall be widely applied by states according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation." (Rio Declaration, Principle 15) China as one of the endorsement member countries definitely is responsible to live up to it and apply this principle in its environmental policy.

Anyhow, to discuss the climate change and GHG emission is too big a problem to do here. As IPCC's research outcome, there are still many uncertainties exist as well as their robust

[3] Figure 1-1.2 gives the 2001 CO2 data less than 2000. The reasonable explanation to this is the close of illegal small scale coal-mining in 2001. but another data of CO2 emission in 2000 is 3052 Mt provided by Chinese Coal Information Research Institute. (Huang Shengchu, 2003, appendix table)

findings. For detailed information can be obtained from IPCC's official website[4]. What I accentuate here is for policy-makers, the precautionary principle[5] should be adopted, no matter how close the relationship between global warming potentials and GHG emission is. The government should take actions now to diversify energy mix, reduce the speed of depletion of fossil fuels and decelerate the GHG concentration pace.

According to WWF's recent research on Himalayas glaciers, the retreat speed of glaciers have exceeded people's anticipation. In Shen Yongping's 2004 report on 612 statistical glaciers in Tibet Plateau, from 1990 till now, 95% of them are retreating, only 5% are in advancing. (Shen YP, 2004, p. 25). The recession speed is between 10 to 20 metres or more per year. The team leader of 2005 Himalayan Glacier Research Group, Kang Shichang, also proved that most of the melting areas in Himalaya glaciers are enlarging. The snowlines are rising up to several hundreds of meters. (News from http://www.ium.cn/show.php?id=458) The glaciers recession means over-melting ice and too much runoff into rivers in this area in flood season. The main rivers such as Chang Jiang and Yellow River in China and Mekong in Burma and Thailand are suffering from floods these years. In 2005, the flood in Hu Nan and Gui Zhou Province happened as early as in May, more than one month advance than usual. The worst thing is, after the depletion of Glaciers, these areas will suffer from drought for lacking of replenishment to rivers.

If the CO_2 caused global warming potential and thereby climate changes will likely have both positive and negative effect to human beings, the SO_2 caused acid rain is immediate to silviculture (forest), agriculture and aquaculture. In addition, the corrosion to buildings and culture relics is also significant in accumulation. Nowadays, about one third of China is affected by acid rain. (See Figure 1-3) The forest blights, agriculture reduces outputs and aquatic animals die where the acid rain falls. The loss of building corrosion and damage to cultural relic is hard to estimate for its vast effective area and invaluable character. The estimation is only limited on tangible assets such as the loss of silviculture and agriculture. The acid rain causes "RMB 4.3 billion loss in agriculture and RMB 16.2 billion loss in forestry ecological benefit every year". (Huang Shengchu et.al. (2003), p. 26)

Also the suspended particulate and brown gas cause by coal pollution lead in all kinds of respiration diseases and cancers. That loss is hard to calculate, for there is still no authoritative data available in China.

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[4] IPCC: http://www.ipcc.ch

[5] When evidence indicates that an activity can harm human health or the environment, we should take precautionary measures to prevent harm even if some of the cause-and-effect relationships have not been fully established scientifically.

------Miller, G T (2004) p. 186

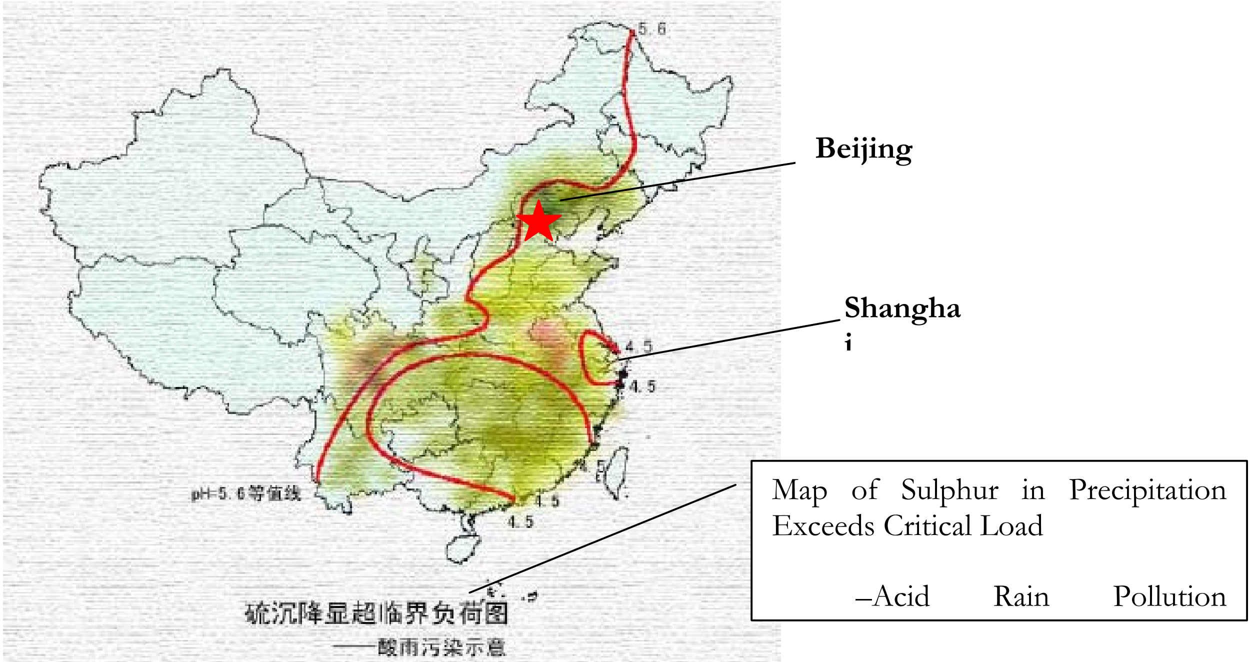

Figure 1-3 Acid Rain Contamination in China (Green Areas) with pH value indicator(Huang, 2003)

The figure 1-3 indicated areas in right of red line 5.6(pH value) belong to acid rain contaminated zones. Beijing is one of the effected cities inside these areas. The two red circles loop areas where precipitation pH value is below 4.5, which means heavily contaminated. The biggest city in China, Shanghai, is located in the small circle.

Table 1B.5. Sulfur Content of Coal by Type and Region, 1995

	Percent of Coal Resources by Sulfur-Content Category[1]						Total[2]	Average Sulfur Content (Dry Weight %)
	Extra-Low (<0.5%)	Low (0.5%-1.0%)	Low-Medium (1.0%-2.0%)	Medium (1.5%-2.0%)	Medium-High (2.0%-3.0%)	High & Extra-High (>3.0%)		
Steam Coal	39.35%	16.46%	16.68%	9.49%	7.65%	7.05%	96.68%	1.15%
Coking Coal	55.16%	13.71%	4.18%	3.29%	8.05%	9.62%	94.01%	1.03%
North	42.99%	14.40%	16.94%	10.74%	8.88%	3.57%	97.52%	1.03%
Northeast	51.66%	14.04%	19.68%	1.92%	2.05%	0.00%	89.35%	0.47%
East	46.67%	31.14%	3.70%	3.20%	4.72%	9.21%	98.64%	1.08%
South Central	65.20%	12.42%	7.66%	2.34%	5.50%	6.71%	99.83%	1.17%
Southwest	13.22%	10.71%	7.52%	2.68%	17.40%	43.61%	95.14%	2.43%
Northwest	66.23%	6.20%	2.50%	4.01%	9.31%	9.98%	98.23%	1.07%
National Average (weighted)	48.60%	14.85%	9.30%	5.91%	7.86%	8.54%	95.06%	1.10%

[1] Percent of toal coal resources.
[2] Categories do not sum to 100% in original data source.

Source: Li *et al.*, 1996.

Table 1-2 Sulphur Content of Coal and Region in China (Data Source: China Energy Databook 6.0)

The impact of coal-burning to environment as well as the worrying of depletion of reservation results in the discussion of finding alternative energy and diversifying the energy supply structure. To develop renewable energy, alleviate the energy tension and at the same time, reduce the pollution to the environment became a consensus of Chinese government. The urgent mission now is to find the suitable renewable energy and the proper avenue in support, politically and economically. Amongst all the renewable energies, solar energy with the characteristic of the fastest in developing, most potential in amount and ubiquitous existing, attracts people's eyesight again.

The Effect to Hunan Health by TSP and PM_{10} in Chinese Cities

The atmospheric pollution in Chinese cities is typical coal-burning born air pollution. Though the pollution caused by transportation is rising, the coal incineration still takes account for 70% to atmospheric pollutions. (Huang Shengchu 2003, p. 24) This situation deteriorates during windless winter and spring days. Total suspended particulates (TSP) and PM_{10} (diameter lower than 10 μm particulate) are the two indicators of solid substances in air. Generally PM_{10} is included in TSP. For the data gap of PM_{10} proportion in Chinese cities, here I use TSP as the main indicator to assess the air pollution conditions.

Years of exposure to air pollutants can overload or break down human body's filter mechanism of respiratory system and cause respiratory diseases such as lung cancer, asthma, chronic bronchitis and emphysema. (Miller, 2004, p. 437) The particulates which are smaller than 5 microns can enter into lungs through respiration and melt into blood. Sometimes is the reason of blood toxicosis. The virus attached to these dusts can cause diseases and unsolvable dusts remain in lungs can cause cancer. So the TSP has significant harm to human health.

As early as 1997, the world bank had a report on Chinese ambient concentration of air pollutants. See Figure 1-1.3 From that, the TSP level is surprising higher than Tokyo, even the smog city of Los Angeles, which is well controlled on this point. Unfortunately, 7 years later, the TSP condition in Chinese cities still stays in high level around 400 μg/m3. (See Figure 1-1.4) According to Table 1-1.4 the Chinese ambient air pollution standard, most of the time in these cities the air quality stay below Class III. Therefore, to enforce the control of coal combustion and diminish coal consumption is crucial of atmospheric pollution level.

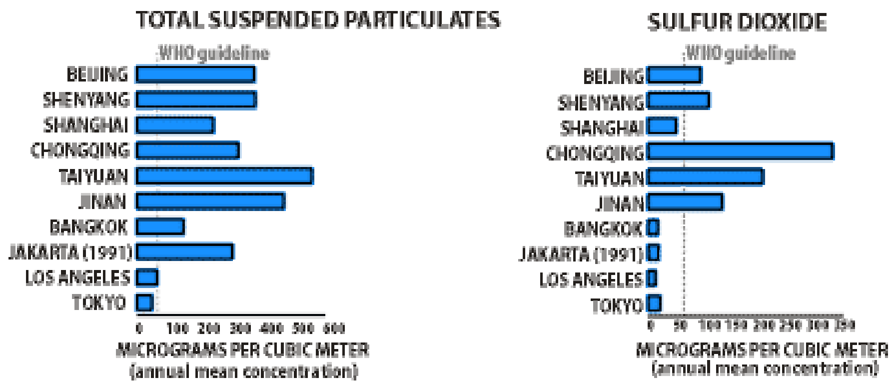

Figure 1-1.3 TSP level comparison of world cities (Source: The World Bank, Clear Water, Blue Skies: China's Environment in the New Century (The World Bank, Washington, D.C., 1997), Figure 1.1, p. 6.)

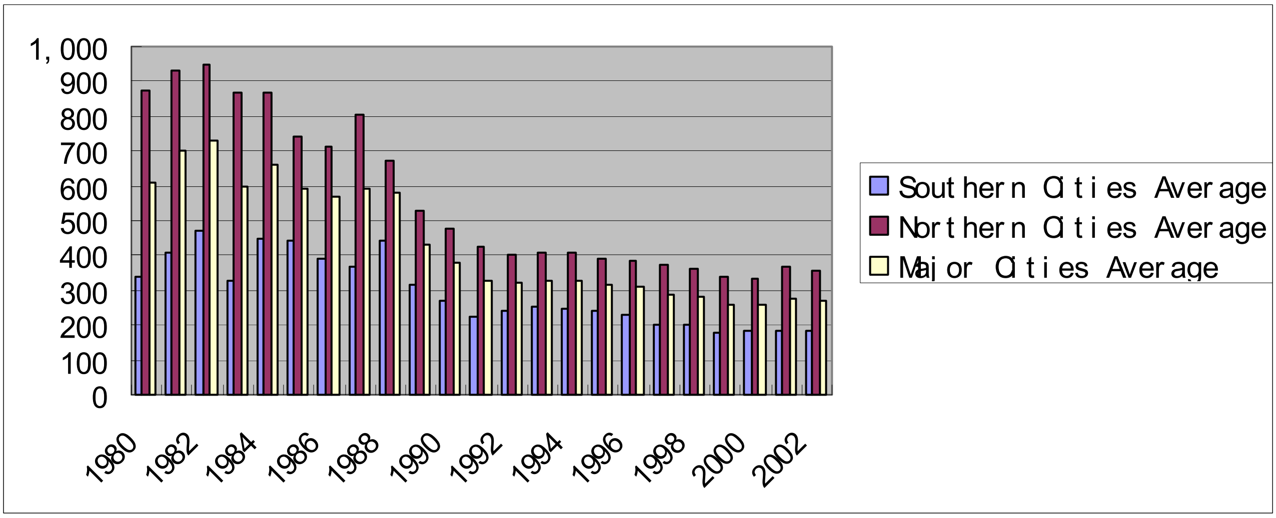

Figure 1-1.4 Comparison of TSP level from 1980-2002 in Chinese Cities (Unit in Y axis, μg/m3)

Source: China Energy Data book v 6.0 Chapter 8 Table 8B.5

Chinese Ambient Air Pollution Standards

	annual average	daily average	1-hour average	max. at any time
TSP (μg/m^3)				
Class I	80	120		300
Class II	200	300		1,000
Class III	300	500		1500
PM 10 (μg/m^3)				
Class I	40	50		150
Class II	100	150		500
Class III	150	250		700

Table 1-1.4 Chinese Ambient Air Pollution Standard

China Energy Data book v 6.0 Chapter 8 Table 8B.15

1.1.3 Energy Demand and the Necessity of Adjustment to Energy Structure

From 1980 to 2002, China's economy kept high increasing speed of around 9% annually, while energy consumption rate held a comparatively low speed of 5% increase per year.(see Appendix 6) Even though, to realize the GDP quadrupling in 2020 and a well-off sustainable society, the energy demand and supply chain constitute great challenge to current energy system.

What the next 15 to 20 years of coming will look like? Will it be possible to interfere into energy realm and reduce fossil fuel mainly coal consumption and simultaneously fulfil the high-speed development of economy? In the coming 20 years, the evolution of industry and energy structure will bring great uncertainties and varieties to China. These varying factors will affect China's energy development in various extents. If adopting traditional prediction method, it will be hard to trace the correct way and give a best accurate big picture of China's energy development. In the last decade, the scenario analysis method was adopted widely. To address the above-mentioned problems, The Energy Research Institute (ERI) of the National Development and Reform Commission (NDRC) of China deployed LEAP[6] model and gave 3 scenarios on energy area to predict the years to come till 2020.

It is estimated that till 2020, the population will get to 1.5 billion, the urbanization will be 51.8%, the energy demand will reach 3100 Mtce(S1). (ERI(2002), p. 11). In S1 scenario, the coal consumption will be 2008 Mtce, which is about 2 times of 1998 level. This result will bring 1900 Mt-C CO2 emission. See Table 1-3 and Table 1-3.2. From the resource perspective and environmental perspective, this scenario is hard to accept. In S3 scenario, the total energy demand is only 2319 Mtce, 782 Mtce less than S1. The coal consumption is only 1261 Mtce, taking account 54.4% in energy structure. Non-fossil fuel proportion takes 10.2% in energy quantity. CO2 emission is only 1265 Mt-C. Obviously, this scenario is well off to resource and environment, also need extra effort and reform on energy structure to realize.

Scenario	Items	**Energy Consumption (Mtce)**			**Annual Increase**	**Energy Proportion (%)**		
		1998	**2010**	**2020**	**1998-2020**	**1998**	**2010**	**2020**
S1	Coal	1031	1509.4	2007.9	3.1%	75.4%	69.6%	64.8%
	Oil	281.4	471.5	752.4	4.6%	20.6%	21.7%	24.3%
	N-Gas	19	80.4	155.4	10%	1.4%	3.7%	5.0%
	Non-Fossil FuelElectricity[7]	36.6	107.8	184.6	7.6%	2.7%	5.0%	6.0%
	Total	**1368**	**2169**	**3100**	**3.8%**	**100%**	**100%**	**100%**
S2	Coal	1031	1368	1648.3	2.2%	75.4%	67.3%	59.7%
	Oil	281.4	449.7	690.2	4.2%	20.6%	22.1%	25%
	N-Gas	19	107	225	12%	1.4%	5.2%	8.2%
	Non-Fossil FuelElectricity	36.6	110	198	8.0%	2.7%	5.4%	7.2%
	Total	**1368**	**2034**	**2762**	**3.2%**	**100%**	**100%**	**100%**
S3	Coal	1031	1193	1261	0.9%	75.4%	64.1%	54.4%
	Oil	281.4	420	573.3	3.3%	20.6%	22.6%	24.7%
	N-Gas	19	130	248.5	12.4%	1.4%	7.0%	10.7%
	Non-Fossil FuelElectricity	36.6	117.4	235.8	8.8%	2.7%	6.3%	10.2%
	Total	**1368**	**1860**	**2319**	**2.4%**	**100%**	**100%**	**100%**

Table 1-3 The 3 Scenarios of China 1998-2020 Energy Demand Sum and Structure (Source:ERI 2002)

[6] Long-range Energy Alternative Planning System

[7] Non-fossil fuel electricity refers to the electricity generated from renewable energy and nuclear, at current phase, it includes hydropower, wind power, PV etc and nuclear.

*S1: Scenario 1 supposes the energy efficiency is stimulated by economic development, but the market competition pressure limits the in-put into energy efficiency improvement. Cleaner fuel technology does not penetrate and apply widely under the restriction of cost and resources.

*S2: Scenario 2 is backed by Chinese 10-year outlook plan, and supposes all the goals stipulated by government can be met smoothly.

*S3: Scenario 3 is an ideal assumption. In this scenario, there are great improvement in energy efficiency, reform in economy and energy structure, great advancement in environmental protection and environmental technology R&D. On parallel, the policy effect of macro-adjustment and sustainability is prevailing. Externally, China keep a harmonic ambient with other countries and can get alien energy resources through global market as well as advanced technologies and devices etc.

Scenario	CO2 Emission (China) (Mt-C)				CO2 Emission Per Capita(t-C)			
	1998	2010	2020	Annual Increase	1998	2010	2020	Annual Increase
S1	871.7	1360.5	1900	3.6%	0.7	0.98	1.28	2.79%
S2	871.7	1259	1659	2.97%	0.7	0.91	1.13	2.20%
S3	871.7	1118	1265	1.71%	0.7	0.82	0.88	1.03%

Table 1-3.2 The 3 Scenarios of CO2 Emission in China 1998-2020 (Source: ERI 2002)[8]

In words, S3 scenario depicts a promising picture for China's development in a sustainable way. There are several key measures should be implemented as energy strategy in future years. Foremost one is energy efficiency, secondly, it might be to develop renewable energy as alternatives to reduce fossil fuel. In S3 scenario, the non-fossil fuel used for electricity generation should reach 8.8% increase annually to fulfil the 2020 goal. There might be small hydropower, wind-power and biomass etc as options. What I want to probe in this article, is the possibility of PV's application in urban niche market, which is close-related with peak load demand in electricity. Above all I want to point out is PV is not a panacea to solve energy shortage in China. In cost and scale perspective, it is still very weak and only performs very limited affection. But PV has its distinctive characteristics amongst all renewable energies. These distinctions endow PV conspicuous position which can't be overlooked in the process to renewable energy transition, despite of its limitations. However, PV stands for a vigorous force in renewables and in a long run, it will perform indispensable role in energy mix globally.

1.1.4 Electricity Consumption in Building and the Urgency to Develop Environmental Sound Building

With the economy's development, people's living quality has changed greatly. The energy consumption from household become a main part in the whole society's energy consumption, approximately 30% in urban. This is due to 3 reasons, as expressed by the Director of Chinese Architecture Association in Energy Saving Committee: (Tu Fengxiang, 2004)

i. people have more electrical and electronics facilities than yesterday. Air conditioner, TV, refrigerator, computer are very common in Chinese household now

ii. the living conditions are ameliorating fast. Now the total house area is 40 billion square meters, it is estimated till 2020, there will be 68.6 billion square meters. 95%

[8] Till now, the CO2 per capita emission in China is 2.5 metric ton, which is lower than world averge level of 3.9 in 2000. In S1 scenario, in 2020 the CO2 emission per capita will get 4.7, exceeding the world average. Whilst S3 scenario will keep the level lower than world average, namely 3.22 metric ton per capita.

new finished buildings in China don't measure up the energy saving standard. 99% existing buildings are high energy consuming type.

iii. People have higher request for room temperature now. The winter time temperature inside increase from 12 °C to 18-20 °C, summer time from 32 °C to 28-24 °C. This adds the working time of air conditioners and need more heatings in winter.

What is worse, the defect in building design or overlooking of energy saving in a long term made people seldom paying attention to this problem. The leakage of heat due to poor conservation function of windows and doors and more energy needed for lack of usage of natural ventilating contribute great loss in energy every year. The Chinese energy market seems in a morass of double worse condition: one is the energy crisis, the over-burdened supply and high proportion of fossil fuel consumption, the other is low efficiency building leakage causing great waste and low usage of renewable energy. It is the high time to consider the energy saving problem in buildings now. The already successfully applied BIPV mode in European countries and Japan seems an ideal solution.

1.1.5 The Concept of BIPV and BIPV's Preliminary Stage in China-BAPV

BIPV is the abbreviation of Building Integrated Photovoltaics. According to US Department of Energy's definition, BIPV is "A term for the design and integration of photovoltaic (PV) technology into the building envelope, typically replacing conventional building materials. This integration may be in vertical facades, replacing view glass, spandrel glass, or other facade material; into semitransparent skylight systems; into roofing systems, replacing traditional roofing materials; into shading "eyebrows" over windows; or other building envelope systems." (http:// www.eere.energy.gov/ solar/ solar_glossary.html) The sample of BIPV can refer to Figure 1.1.5.

Figure 1.1.5 The sample of BIPV(With the Courtesy of BP Solar)

BIPV has special meaning to current China's energy context as well as the architecture market of years to come. On one side, BIPV employ solar energy to generate electricity and thermal energy for household, has distinct peak-shaving effect, on the other side, BIPV building pays more attention to heat-keeping and insulation, shading, ventilation etc in design, in short, BIPV building is more energy-saving than normal building.

BIPV and BAPV

BIPV is the product of high combination of PV engineering and architecture design. Strictly speaking, it must be in pursuance of building and engineering standard simultaneously as well as take into consideration of harmony of PV modules and building appearance. At current phase in China, it need time to develop BIPV standard coordinating with Chinese architectural standard. The fact of most PV systems are imported prolongs the process of alien products to merge into indigenous condition. So to spread PV system initially, it is probably taking the pattern of Building Attached PV (BAPV) system. See Figure 1.1.5-2, the sample of BAPV. That means, the PV system is installed after the building finished. The position would be rooftop, facade, skylight windows or window pane given consumers' preference and buildings' condition. To promote the fast penetration of PV application in residentials, it may be a good expediency. But actually, the market calls for higher integrated PV buildings, namely, the PV integration is considered as early as the building designing phase. The advanced consideration of adoption on PV material will avoid double envelope of the building, the PV module can replace part of facade, glazing and rooftop tiles etc, reducing the building cost. Currently, the market will be a mix of BAPV and BIPV for considerable period of time.

Figure 1.1.5-2 The sample of BAPV (With the Courtesy of BP Solar)

As a building complex combined energy, building material, electrical devices and aesthetic value, BIPV stands for the future developing trend on environmental sound design in architecture. PV system not only saves building material, but also acts as productive equipment in 20 to 30 years after installation. On contract to price rising of traditional energy, PV's value stands out more prominently, especially during peak hours demand. So from every perspective, the BIPV should be penetrated in Chinese architectural market.

1.1.6 A Great Leap: The Naissance of Chinese Renewable Energy Law (CREL)

To address the quandary, and to explore the alternative cleaner energy sources, Chinese government drafted Chinese Renewable Energy Law (CREL). This law took only two year from conceiving to approval and created a speedy record in Chinese legislation. It was ratified on 28th, Feb, 2005 and will enter into force from 1st, Jan, 2006. This law refers to several developed countries' successful examples and experiences in pushing renewable energies, and gives the framework to develop renewable energy in China as an energy strategy. From energy security and national interest perspective, this small step in legislation will lead to great leap in Chinese energy structure and consuming pattern. "Passing such comprehensive renewable energy legislation is a remarkable feat for any country."-Jan Hamrin, Executive Director of the

Centre for Resource Solutions (CRS).[9] As the first law aiming to frame the Chinese renewable energy strategy, CREL will promote the Chinese energy structure toward diversified and sustainable way in the years to come.

1.1.7 Solar Energy in China, a Promising Future

Till 2002, the installed PV capacity is only 42.5 MWp, and grid-connected system is 0.5 MWp in China (EPIA, 2004, p. 44). While the same period in EU 15 countries, the total installed PV capacity is 391.6 MWp, 316.5 MWp is grid-connected. Only Germany accounted for 258 MWp for grid-connected PV capacity. (EREC 2004, p. 120) The solar resources are abundant in China. There are two third territories in sufficient sun insolation yearly. Desert and half-desert area occupies 850,000 km^2, urban and rural rooftop area suitable for PV installation is 4 billion m^2. There are still 28,000 villages, 3 million people live with no electricity available conditions.(Shi Lishan, 2004, p. 16) Most of them live in remote areas where is far from grid connection. Comparing with building expensive utility infrastructure, separate PV system is economical. It is predicted by "Global installed capacity of solar power system would reach 205 GWp by 2020… and 30 GWp will be taken by developing countries" (EPIA 2004, p. 7). China's solar market would be 14% of the world. See the graphic bellow.

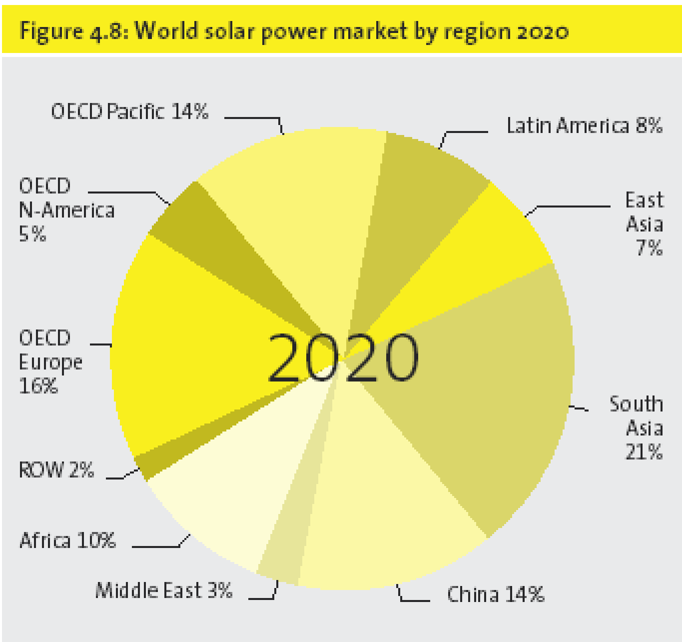

Figure 1-1.7 World solar power market by region 2020(EPIA 2004, p. 35)

[9] Dr. Jan Hamrin is Executive Director of the Presidio Center for Resource Solutions (CRS), a non-profit organization created to foster leadership in the implementation of clean energy and sustainable development practices through education, training and expert assistance. CRS domestic programs include: the Green-e certification program; and Green Pricing Accreditation Program. The International programs include: Regulatory/Policy Assistance Programs (including renewable energy policy assistance to China); and The Global Guardianship Initiative with the Nature Conservancy. http://www.resource-solutions.org

1.2 Research Objective

As we all see, the energy crisis is a fact now in China and this situation will continue lasting for decade. The coming decades may see great leapfrog in renewable energy development, though coal will still dominate the lion's share of Chinese energy structure. CREL gives the orientation for adjustment in order to realize sustainable developing economy. The paper by analysing the energy quandary, tries to seek a practical solution to lessen this tension by focus upon the BIPV's application in dwelling houses, discusses the potential incentives and barriers to implement this clean energy in civil rooftop. By comparing the CREL and German counterpart law, tries to find out the gap between the law and operational level. To mimic the real running scenario, a simulated BIPV project, 100,000 rooftop programme is designed at the situs of Beijing. Through this simulation, the feasibility is testified in depth.

1.3 Research Questions

Is BIPV feasible in China?

What are the incentives and barriers to develop BIPV?

Options to support BIPV application legally and financially to penetrate it from pilot to mainstream?

1.4 Methodology

In order to address the research question mentioned above, the relative back ground knowledge is introduced to give a big picture of PV industry and status quo in China. Then the CREL is analysed in detail which are related to solar energy. The case of Germany is employed to give a contrast. The tandem part conceives a niche market in Beijing, with a dissemination of a 100,000 rooftop programme. Through this example the author analyses the benefit and barriers of BIPV application in China, what is the key hindrance stemming the market. Quantitative calculations are employed to demonstrate the figures of cost and influential factors. The calculation also support the financial scheme, mainly Feed-in Tariff (FiT) persuadably. The advantages and drawbacks of FiT are mentioned. Finally, the further improvements are given.

1.5 Scope and Limitations

This paper mainly deals with the solar energy in electricity production, does not involve the solar thermal application in buildings. Solar thermal is also an important sector of utilization of renewable energy, but in China, the solar thermal collector has been developed prevalently and China is the largest solar thermal collector market and producer in world, while PV's application is quite lagged behind the other countries. Especially BIPV is still underdeveloped in China. That's why I paid so much attention on this sector.

In other countries, BIPV means PV system is part of the building and integrated into building design. PV panel becomes construction material such as tiles, facade ornaments and glass of pane and supplant these materials during design phase in order to get the highest saving in construction and be harmonic in aesthetics. But in China PV production hasn't been merged into building design. The construction industry lacks corresponding standard of BIPV design. This might need several years of process. In light of this reality, we adopt a compromising plan, that is, at the first phase of prompting "rooftop PV programme", the PV system may not be so strict follow the standardized BIPV. For this model, I prefer to call it Building Attached Photovoltaic (BAPV). Many systems may be installed after the buildings are finished in construction but prior to decoration. As we forecast, the combination of PV system design and building standard will be met in the near future along with the household PV system market expansion.

2. The Development of PV Technology and Cost Trend

2.1 The History and Theory of PV Electricity

PV electricity is a technology developed during space exploration research. Its theory is to employ photovoltaic cell, absorbing light energy and turning light to electricity directly. The PV cells were first used in satellites, space stations, space telescope such as Hubble space telescope and space shuttles, these applications are usually billions of dollars project, so the PV technology was so expensive at first and no one thought about to apply it in civil areas. "Interest in the use of photovoltaics for terrestrial applications began to grow after the first oil price shock in the early 1970s"(EREC, 2004, P104) With the development of technology, the cost of PV cell decrease fast and now, the PV electricity is used in many countries as a substitute to part of fossil fuels. Nevertheless, the PV electricity is still uncompetitive to electricity produced by fossil fuels and hydropower in countries where there is no subsidy and green tax to balance its cost, that's why it can't be as ubiquitous as the technology of Teflon, also developed during space technical research, so there are long ways to go for PV R&D in reducing manufacturing cost.

In some remote areas, where there is no grid connection available, PV electricity is a comparatively economic choice since it would be more expensive to build power infrastructure for only a few kilowatts. This is the example of off-grid application or stand along system (SAS). Such as wild rescue telephone system, remote island power supply and remote satellite terrestrial transfer devices etc. What's more attractive to today's R&D is the PV grid connection application, especially the integrated PV system with buildings. How to decrease the cost in this field and foster large scale of PV electricity market and result in "buy-down" effect, is the issue in most countries who are ambitious to develop photovoltaic energy.

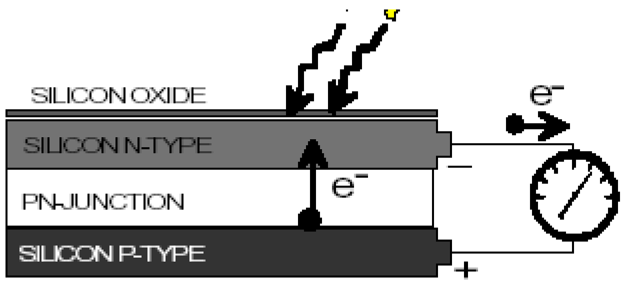

Figure 2-1 PV cell working theory demonstration (Andresen I, 2002, p4)

The theory of PV cell can be simply described as: a very pure silicon base doped with phosphorous (p) and boron(n), adding a space charge region in the middle layer which consist a p-n junction. When the solar photons hit the silicon atoms, the electrons will flee from one layer to another, thus a electric potential (voltage) is produced. The resultant electrical current can then be led out by metallic grid to external circuit. Though the voltage is very weak, but through upgrading, we can get the electricity desired. (Andresen I, 2002, p4) To increase power output, many PV cells can be connected together to form PV modules, which are further assembled into large unit called arrays.

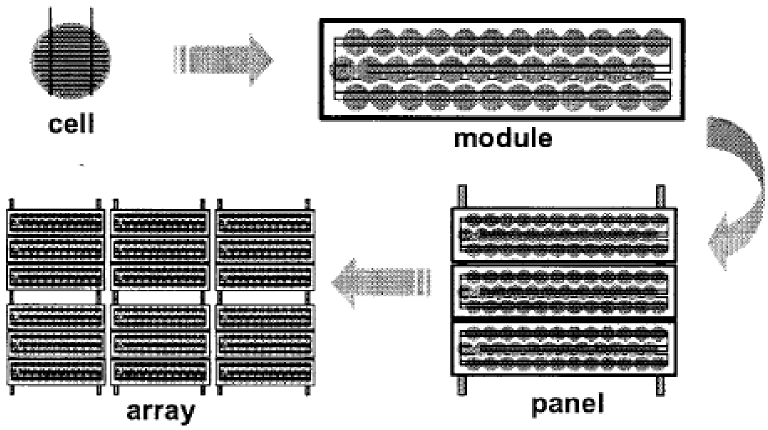

Figure 2-2 PV cell, module, panel and array. (Cap and Islands Self-reliance, p5)

2.2 The Main Types of PV Cell

The main types of PV cells are two: crystalline silicon and thin film. The former accounts for 84% shipment in production, while the latter stands for the development trend. (EREC, 2004, p105

Crystalline Silicon – This is the earliest developed PV cell, usually divided into mono-crystalline silicon (m-Si) and poly-crystalline silicon (p-Si). They are wafers cut from larger block of ingots. The efficiency of m-Si usually is 9-12%, p-Si is 12-16%.

There is the third PV cell developed recently, thin film PV cell, also called amorphous silicon. It is very thin silicon deposited on substrate (usually glass). Thin film cell has less conversion efficiency which is 3-8%, much lower than crystalline silicon cell. But thin film has cost prestige, it is anticipated a potential developing material in PV market.

2.3 The Cost Structure of PV Electricity

The BIPV system needs not only PV cells, but also several components to fulfil the whole process of electricity generation. These components are called PV balance of system (BOS), such as supporting racks, converters, storages, inverters, and meters etc. The cost of installation includes 60% of the cell module, 15% by the inverter, the other 25% by the module mounting structure and assemble unit. (EPIA 2001, part 2)

However, unlike most conventional electricity generators, the maintenance cost after PV system is very low. That's an advantage of PV system. (EREC 2004, p 111) Moreover, BIPV system is on site generator and consumption also occurs in distributed pattern, therefore omits the spending on transferring and distribution.

In addition to investment to hardware, the actual BIPV system also include Feasibility Study 5%, Development 8%, Engineering 28%, miscellaneous fee 5%, PV model and balance of system(BOS) together accounts for 54%. See Figure 2.3 The Break-down of BIPV Cost. That is not enough for merely reduction of PV cell price, only when the total components and engineering cost reduce synchronically, can realize the reduction of PV electricity cost.

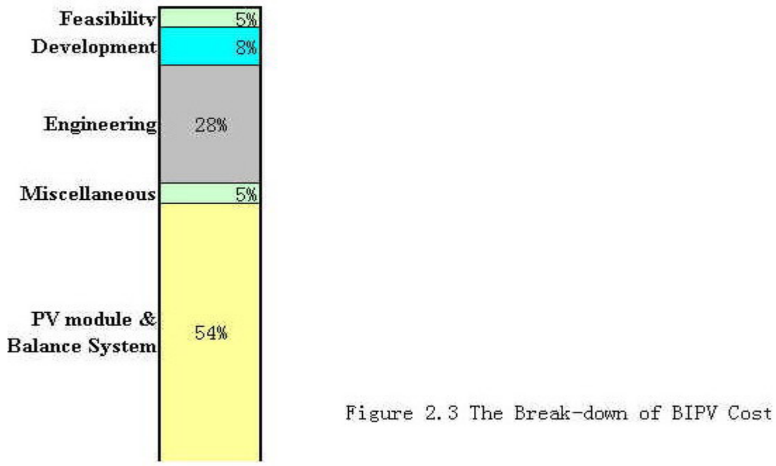

Figure 2.3 The Break-down of BIPV Cost

Data Source: PV3 Solar Design Programme (Appendix 9)

2.4 The Cost Trend and Market Growth

The cost of PV cell and PV modules are falling steadily over the last 20 years. The decrease rate is approximately 5% per year, "and is projected to continue to fall for the next 20 years". (EREC 2004, p111) BIPV systems are more competitive than stand-alone PV(SAPV) systems because BIPVs are grid-connected, do not need storage battery group. "As with any technology, the development of a learning curve will lead to cost reduction." (EPIA 2004, p112) The simulation of PV module learning curve is showed in Figure 2.4.1. "the decrease in cost is expected to be around 20% every time the total installed capacity is doubled." The current capital cost of a typical installed PV system ranges from Euro 5/Wp to Euro 8/ Wp." (this price includes BOS, author's note) and is expected falling bellow US$ 1/Wp in 2020. (EREC 2004, p112)

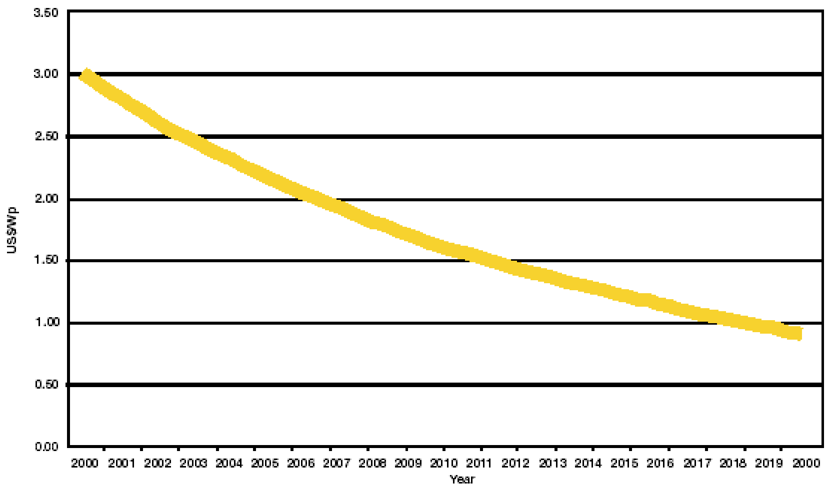

Figure 2.4.1 Module cost reduction in US $/Wp (EPIA 2001)

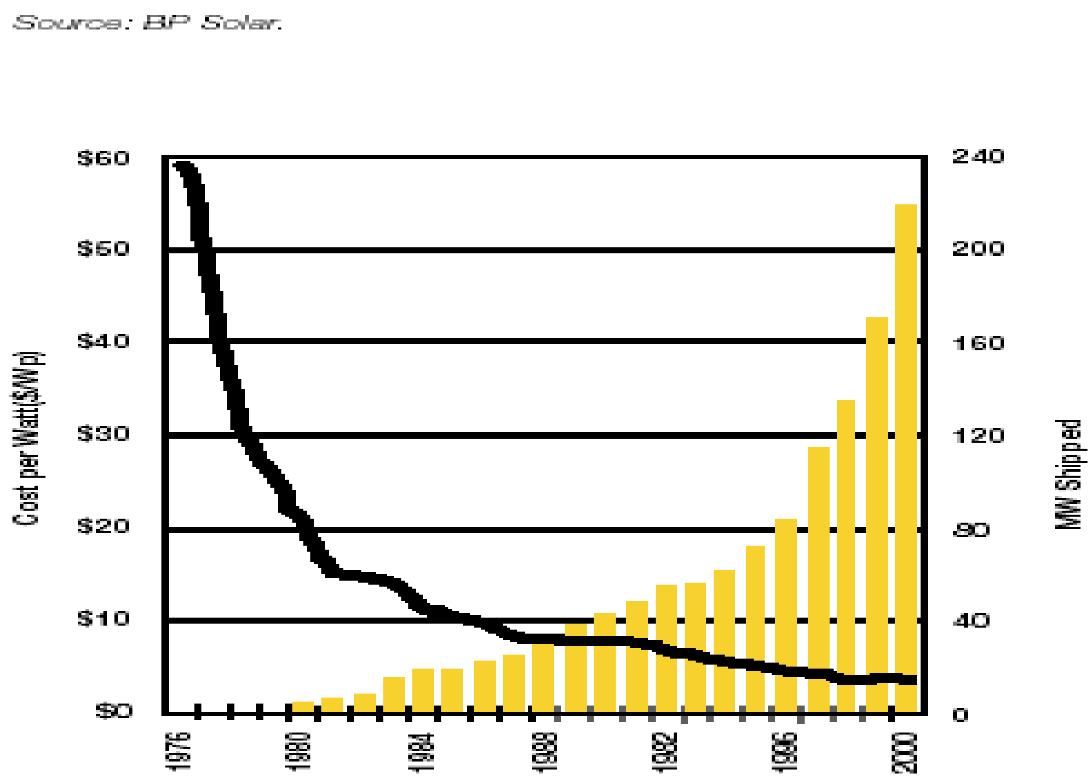

Figure 2.4.2 The falling cost of PV as shipment increase. (EPIA 2001)

What have discussed above are the cost trend of PV module. Actually the focal issue is the price of PV electricity. When the PV electricity will be competitive to conventional electricity is the core part we really concern. As Dr. Hoffmann, W's research, the PV electricity will probably become competitive after the year 2020. See Figure 2.4.3 by Dr. Hoffmann.

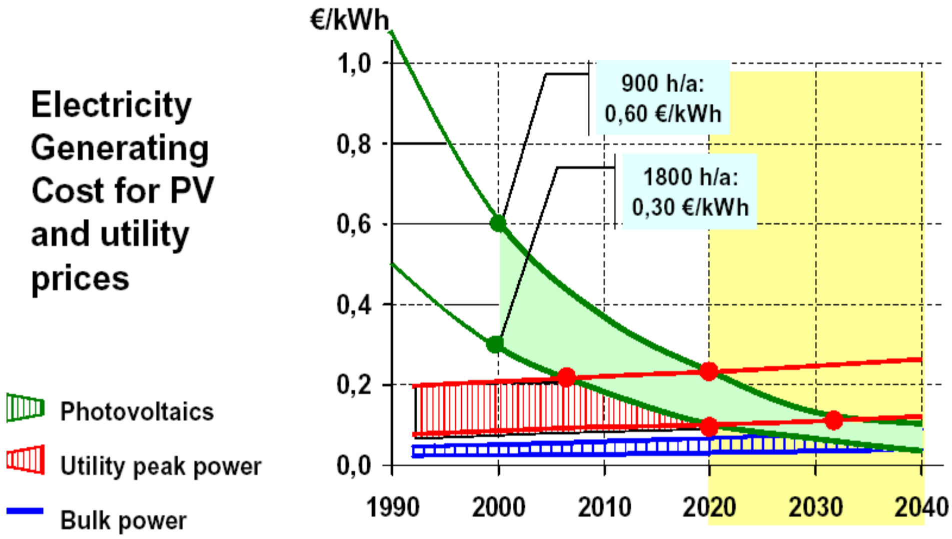

Figure 2.4.3 Electricity Generating Cost for PV and Utility Prices (Dr. Hoffmann, W 2004, presentation, Bangkok)

According to Hoffmann's assumption, the scenario of "the PV electricity generating costs based on private investments are lower than utility prices" will most likely happen "as most PV generated kWh are produced in peak hour time and future electricity bills will charge higher prices during peak times compared to the standard flat rate."(European PV Association's Position Paper, 2005, p6) The fossil fuelled energy is increasing steadily and PV electricity is declining continuously, definitely they will reach a equilibrium point. See Figure 2.4.3. When this point will be met depends on the solar insolation intensity. As Hoffmann's theory, some areas such as southern Europe might be earlier to reach the competitive price for PV electricity, approximately in 2015, other regions, e.g. central Europe might take another 10 years, namely, approximately in 2025. But without question, PV electricity will be competitive to traditional electricity in decades.

Encouraged by the prosperity of several leading countries' market, the world PV production has geared up. The top PV manufactures such as Sharp and Kyocera finished enlargement of production capacity recently. The global PV cell shipment in 2004 got to 1,265 Megawatt (1.265 GW), which increased 67% year-on-year comparing with 2003. (See Figure 2.4.3-2) This is a marvellous and gorgeous frog-leap. But we must also realize soberly that even PV develops very fast, it is based on a comparatively small basis. The PV electricity's share in global electricity is so meagre that in 2003, the photovoltaic in addition with geothermal, wind, wood and waste in electricity generation totally take account for 1.9%[10] in the electricity sum. Meanwhile, this shows the potential of photovoltaic is inestimable. But one point can be predicted is that photovoltaic will perform significant role in the future decades on global energy stage. In terms of EPIA/Greenpeace scenario, till 2020, the key result of photovoltaic will be:

"Global solar electricity output in 2020:

282 TWh = 10% of EU-25 electricity demand in 2003 = 1.1% of global electricity demand

Detailed Projections for 2020:

- PV systems capacity: **205 GWp**
- 2.25 million full-time jobs world wide
- Prices for grid connected PV systems reduction to Euro 2 per Wp
- Cumulative carbon savings
- 730 million tonnes of CO2 /year" (Excerpted from Solargeneration: www. solargeneration.de)

This scenario is ideal and optimistic. Of course, it need arduous endeavour from industrial and governmental aspects.

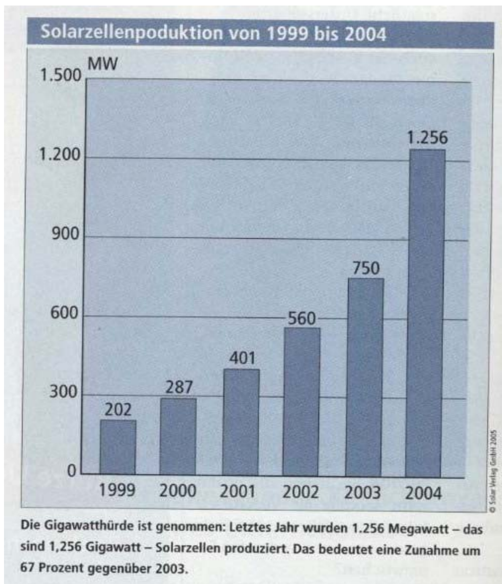

Figure 2.4.3-2 PV cell Production from 1999 To 2004 Globally[11] *(Photon 2005 March)*

[10] according to IEA, the 2003 solar, wind, geothermal, wood and waste for electricity generation is 310 TWh out of 15852 TWh global sum.

[11] Translation: the hurdle of one GW has been taken: Last year, 1 256 Megawatts (= 1.256 Gigawatts) of solar cell were produced. This is an increase of 67 % compared to 2003

2.4.1 PV production in China and Application Status

The inception of PV research began in 1958. The first application of PV cell was in “Dong Fang Hong II” satellite in 1971. (Shi Lishan el. Al. 2004,p7) The beginning of PV research was not late in China. The first terrestrial application was in voyage guiding lamp in Tian Jin Port in 1973. However, after that till 1985, the PV research and development in China trapped into a stagnation period. The “75 project”(the Seventh Five Year Plan) from 1986 to 1990 affirmed the strategy to develop energy, communication, semi-conductor etc in priority, the PV industry increased evidently. Several PV production line were introduced from abroad, the PV capacity increased to 4.5 MWp /year, sales quantity reached 0.5 MW /year. After that, Chinese government initiated several PV project such as “Brightness Engineering”, Power Construction Project in Western Tibet’s non-electricity villages etc. The PV module began applied in communication, oil exploration, rural area and civil area. To 2001, the cumulative application has exceeded 20 MWp.

In 2002, the ex National Planning Committee initiated “Song Dian Dao Xiang”(Electrification of Western Non-electricity Rural Villages) programme. The budget of this programme is 26 billion RMB, adopting PV and Wind farm hybrid plan. Finally the programme solved seven western provinces (Tibet, Gan Su, Si Chuan, Xin Jiang, Qing Hai, Shan Xi, and Internal Mongolia) nearly 800 counties with electricity problem. This project also stimulated the PV production in China. The PV module assemble capacity achieved 100 MWp quickly. The 2002 whole year sale reached 20 MWp. After the “Song Dian Dao Xiang” programme, there is no big action in PV application market. In Figure 2.4.4, we can see the annual installation decrease abruptly. This application status is quite out of proportion with the annual PV shipment in manufacture.

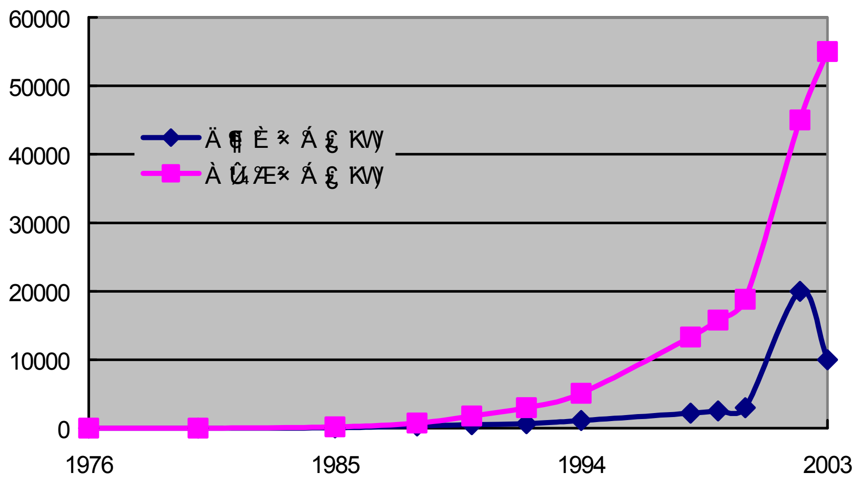

Figure 2.4.4 China PV cell cumulative installation (Square) and annually installation (Diamond)

Source: (Lishan, Shi et. al .2004, p. 10)

Crystal Si PVcell and system in China					
Year	Production Capacity(MWp) per Year	National Sale (MWp) per Year	Price (RMB/Wp)	System Price(RMB/Wp)	Native PV Industry Value(Billion RMB)[12] per Year
2000	4.5	2.1	42	80	0.17
2003	100	10	30	60	0.6
2005	150	29	25	40	1.2
2010	250	180	20	30	2.4
2020	15000	9800	16	24	235

Table 2.4.1 PV Cell and Module Price trend prediction (Lishan, Shi, et.al. 2004, p. 45)

2.4.2 Recent Development of PV Manufacture in China

Because of the limited indigenous market and negligible application, the PV industry in China is unnoticeable for a long period. But in 2005, the situation changed as a nova company appeared. Suntech Photovoltaic Corporation (the following parts will abbreviated as Suntech), a new established company in Wuxi, Zhejiang province, became a black horse in this field and arose the world's attention. In 2004, Suntech was announced by Photon magazine as the 10th company among PV cell shipment top 15 in the world. It reached 50 MW in production capacity at that time and that's their first debut to catch the world's eye-sights. Their products are mainly mono-crystalline PV cell and polycrystalline, with efficiency of 17% and 16% respectively. The PV module efficiency meets 14%. Their products have passed necessary certificates required for international market, such as ISO, TUV, CE and IEC. That means Suntech's products are competitive with the other international competitors in quality as well as price. When this paper is being written, Suntech had finished the second enlargement of production line. Now the production ability is 150 MW, ranks No. 6 amongst top 15 in March, 2005 in the world. (See Appendix 1, the PV production Ranking by Photon International Magazine). It is announced by another Chinese national owned PV company, Bao Ding Yingli Photovoltaic, that they will reach 70 MW production ability by the end of 2005. Thus can be seen that the production ability of 150 MW predicted by Chinese Photovoltaic Association would be exceeded easily in 2005. Another PV manufacture factory, Zhongdian Photovoltaic Company, with a first term of 100 MWp project, is under construction in Jiang'ning High-tech Development Area in Jiangsu Province.(China Environment News, 8,7,2005). Boasting these two big PV corporations(Suntech and Zhongdian), Jiangsu Province is ambitious to position itself a leading role in China's PV industry. It is predicted that in several years, the PV production capacity of China will enter top 3 in the world and pull down the global PV cell price for the massive production and cheaper labour cost. Comparing with the steady increase of global PV module demand, the local market can't digest so big production now. 90% of Suntech PV products are exported to other countries. The localization of PV production calls for the initiate of a localized PV application market. The introduction of BIPV to China is at the right time and imperative.

From the Table 2.4.1, the module price is RMB 40 /Wp in 2004, this figure is consistent with my investigation of current market in China. As the commonly agreed perspective of PV industry, the $ 2/ Wp of PV module cost is a breakeven point for PV electricity production. (Steven ,L, et. al. 1998, p. 235) The PV electricity would be competitive to fossil fuelled powers below that point. As Table 2.4.1 shows, that price will be met after 2020. But with the

[12] Note: the original data have some calculation error. This is the corrected result after consulting the author.

speedy development of PV cells production in China, that goal will be met 5 years earlier or less than the prediction.

With the 30% annual increase in global PV market, with the fast growing manufacture scale of PV cell and modules in China, China's PV market remains large and potential. Along with all the factors to initiate PV's application are getting ready, should China's market still keep untapped? It is high time for Chinese government to play an active role and hit the road now.

2.4.3 Chinese Government's Commitment on Renewables

In June, 2004, the "International Conference for Renewable Energies" was held in Bonn, Germany. In the Action Plan of this Conference Chinese delegates standing for Chinese government declared a 10% renewable target by 2010 and 17% till 2020. (Waldau, A.J, 2004, p. 10). According to Ma Shenghong[13]'s presentation in this conference, during the 11th Five-year-plan(2006-2010), it is planned to install 1 GW PV system in China. Comparing with the accumulated capacity from 1980 till now, this is really an ambitious plan.

Because of the irrational energy structure has lasted for decades, the reliance on coal as the main energy source will continue within this century. Coal is not likely to be abandoned as the abundance of coal reservation and cheap, stable price. Nevertheless, that does not mean the government will do nothing on adjustment of energy structure. Except take action on introduce of cleaner coal technology, there will be great movement on renewable energy, in particular of PV or BIPV penetration.

2.4.4 The Indispensable Role of Government in Developing Renewables

"As experience shows, government do have a vital role to play in both establishing a realistic and supportive policy framework, and in accelerating the development of PV-specific green power schemes."(*European PV Association's Position Paper 2004, p. 9)*. The reasons lie in three aspects.

First, the market price can't manifest the externality cost of fossil-fuelled electricity. When "the invisible hand of market will not do an optimal job", "to ensure a more optimal welfare, external costs need to be internalized in the prices or the price mechanism needs correction through regulation"(ExternE, Vol 1, p. 4). As the cost of renewables such as PV electricity is prohibitive at the taking-off phase, the price of PV electricity is uncompetitive to traditional electricity. What's more, the coal-fuelled plants even get subsidies from government to lower price and enhance industrial products competitiveness. That makes the price even more distorted. To redress the unfairness of the price system and make a level environment for competition, it is necessary to frame some financial schemes in favor of renewables and shorten the gap between them. This adjustment can not realize by the power of market, because the market tend to seek the lowest price and highest profit. The government acts as indispensable role to make policy leaning to renewables. By redressing the price bias of conventional energy, the renewable energy's advantages of environmental-benign characteristic can thus be embodied.

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[13] Ma Shenghong, professor, vice-director of Beijing Jikedian Renewable Energy Development Centre, China

Second, the renewable energy and market are unfledged -- they need support to develop to sustainable by themselves. The PV market develops fast, but the scale is still minimal in energy share. The great annual increase is partly due to the small accumulation in capacity of the beginning. To enlarge the market and avoid the paradox context like disproportional indigenous market and shipment, the government should make a serial of policy in favor of PV's development. To realize a buy-down effect, it is imperative to initialize a local market in stead of exporting-oriented production of PV cell. Scale application is proved by experience as effective driver of technology advancement and price decrease, in particular when the technology and market are in infancy. PV's application in China's domestic market calls for government to enact relative policies in favour of capacity building in a short time.

Third, to develop renewable energy is the need of security for energy supply chain. The replying on fossil fuel is not sustainable and not environment sound as well. The local reservation of coal is only "114.5 billion tons, which can only sustain for 114 years."(Huang Shengchu, 2003, p. 1). The energy guzzling structure of industry needs more and more energies for the years to come. The fossil fuel cannot fulfill the China's need in the future. The seeking for fossil fuel abroad and competition with other countries in purchasing fossil fuels escalate international fuel price and add the venture of conflict. Not least, the reliance on importing energy mode is unsafe for a country's economy. PV electricity comes from endless energy source, with no emission during operation and endless raw material for PV production (PV cell is mainly made from silicon, one of the richest elements on earth). From strategic point of view, PV should be encouraged in development and should be put in priority of energy agenda.

3. Analysis of Chinese Renewable Energy Law(CREL)

3.1 The Development of Energy Related Law in History

After the "World Environment and Development" Conference in Rio in 1992, the Chinese government paid more attention on environment protection and accentuated the development of renewable energy. The State Department approved "Ten Policies on China's Environment Development" in August, 1992. In this document, to develop and spread solar energy, wind energy, geothermal, tidal power as well as biomass energy etc in pursuance of local circumstance were broached out in writ large. The "21 Century Agenda – Chinese white Book of Population, Environment and Development in 21 Century" was published in March, 1994. This White Book indicated "Renewable energy is the basis of future energy", "Putting renewable energy's development into priority in national energy strategy", "disseminate energy-saving and develop new energy and renewable energy" etc. In 1995, the first Electrical Power Law in China said in Article 5, "The electrical power in construction, generation, utilization should protect environment, deploy new technology, decrease pollutant emission, prevent pollution and other harm. The nation encourages and supports using renewable energy and clean energy to produce electricity."

Anyhow, these laws or regulations have a common defect, i.e. too general to execute in reality. Or in other word, they lack operational law terms to implement. Therefore, ten years have passed but the renewable energies' share still stays almost unmoved. The lagged law suits had stemmed the development of renewable energy greatly. It is pressing to enact a dedicated law for renewable energy. It is not until 2003, to draft a special law for renewables was put forward by some delegates in National Parliament conference and got warm responses. This proposal and consequent acclamation from delegates caused high level policy-makers' concern and eventually led to the coming-out of Chinese Renewable Energy Law(CREL).

3.2 Main Content of CREL

3.2.1 Introduction of CREL

"With the recent passage of China's new Renewable Energy Law, one of the world's largest economies has now made one of the largest state-sponsored commitments toward renewable energy." These words comes from Renewable Energy Access, a world famous renewable energy website. The remark on CREL shows the world's long time expectation for China's action on energy structure adjustment and reconsideration on their energy consuming pattern.

The CREL is constituted by 8 chapters. They are:

Chapter 1 General, including Article 1 to Article 5

Chapter 2 Resource Survey and Development Plan (Article 6 to Article 9)

Chapter 3 Industry Guidance and Technology Support (Article 10 to Article 12)

Chapter 4 Promotion and Application (Article 13 to Article 18)

Chapter 5 Price Management and Fee Sharing (Article 19 to Article 23)

Chapter 6 Economic Incentives and Supervisory Measures (Article 24 to Article 27)

Chapter 7 Legal Responsibilities (Article 28 to Article 31)

Chapter 8 Miscellanmeous (Article 32 to Article 33) (Excerpted From CREL English Version)

3.2.2 Key Chapters

In Chapter 1, Article 1 give the purpose of CREL: In order to promote the explore and development of renewable energy, increase energy supply, improve energy structure, ensure energy security, for the sake of protecting environment, realise the sustainable development of economy and society.

Article 2 Renewable energy in this law refers to non-fossil fuel energy of wind energy, solar radiation, hydropower, bio-energy, geothermal energy, tidal power etc.

This law does not apply to the direct burning of straw, fire-wood and dung etc in low efficient stove. This is the first time to define the renewable energy in Chinese law distinctively. The definition of renewable energy is accurate and appropriate. To exclude low efficient biomass burning in wide rural areas is positive to discard lagged burning pattern and promote clean, high-efficient cooking and heating penetration.

Chapter 5 regulates price management method and nation-wide equalization scheme.

Chapter 6 regulates economical incentive and monitoring measures.

Chapter 7 regulates responsibility in law.

3.3 Advantages and Limitations of CREL

CREL as the first renewable energy law in China, established the framework for renewable energy development. So it has a pioneering prestige and inevitably has some limitations.

3.3.1 Advantages

Or in other word, I would like to analyse some advantageous points for polar energy deploying.

1. In Chapter 4, Promotion and Application, Article 13 said that the nation encourages and supports using renewable energy to generate electricity and connect to grid. This clause authorizes the PV grid-connected model and endorses it in law. As we have known, one of the greatest barriers is the connection to utility grid which was argued for a long time. The opponents say it will be too complicated to install such equipments and count the input and output. Actually the techniques of grid connected pattern have matured and found many niche applications in European countries. Usually for a BIPV system, there will be an electronics LED screen with digitals indicating the working conditions of the system. The user can get the output and consumption information from a glance.

2. In Chapter 4, Article 14 Electricity companies shall sign grid connection contract with legally licensed enterprises that use renewable energy for electricity generation. They shall purchase full quantity of renewable electricity in their grid coverage situs and provide grid

connection service for these enterprises. This prescription set the responsibility of utility in legislative binding, which clarifies the long-term obscure partition of utilities responsibility. They will have no excuse to reject the application for purchase of renewable energy and grid connection.

3. In Chapter 4, Article 17 the nation encourages commercial and personal unit to install and use solar thermal system, solar heating and cooling system, PV system etc.

Real estate developing enterprises should provide necessary facility for solar usage in architecture design and construction in pursuance of previous technical regulation. This point gives support to BIPV's application in construction realm.

It also regulates for already constructed building, the inhabitants can install technical and standard qualified solar system under the condition of not impairing the building quality and safety.

4. In Chapter 5 Price Management and nation-wide equalization, article 19 the "green electricity" price should be differentiated by Price Management agency in Nation Department according to variable renewable energy and production district, and do some suitable adjustment with the renewable development technology. The grid electricity price should be published to public.

5. In Chapter 5, Article 20, the power plants can equalize the price difference of the higher part of purchasing "green electricity" according to Article 19 than the traditional energy electricity price.

6. In Chapter 5, Article 21, the power plants can equalize the grid connection cost of purchasing "green electricity" and other relative cost. These cost can be calculated into transmission cost and paid back from electricity sale.

7. In Chapter 6 Economic Incentives and Monitoring Measurement, there are mainly 3 Article for stimulating development.

Article 24, the national financial budget establishes dedicated fund to support the following:

1) Scientific and technological research, standard establishment and pilot project for the development and utilization of renewable energy;

2) Construction of renewable energy project for domestic use in rural and pasturing areas;

3) Construction of independent renewable power systems in remote areas and islands;

4) Surveys, assessments of renewable energy resources, and the construction of relevant information system;

5) Localized production of the equipment for the development and utilization of renewable energy.

Article 25, Financial agencies can provide favourable loans with financial subsidised interest to project that enlisted in national renewable energy development guidance catalogue and conform to credit loan condition.

Article 26, the nation will give favourable tax policy to project enlisted in national renewable energy development directive directory.

3.3.2 limitations

It doesn't give a quantified middle-term or long-term aim. Comparatively, the German Renewable Energy Act gave 2010 and 2020 aim at Article 1. Obviously this problem is aware by stipulators. For compensation, the CREL's Chapter 2, Article 8 designated Pricing Administration in State Department to make middle and long term renewable energy development plan and submit it for ratification. The drawback is it will take another period to prepare and adds uncertainty for enterprises who want to exploit this market as forerunners.

CREL only gives a framework of renewable energy development. Concerning the concrete implementation, there are a lot of practical rules need to be stipulated. Such as the CREL only permits grid connection for green electricity, but how to allocate the equalization of price difference, how to avoid fraudulency(free riding the high price to gain extra profit), such things need a mass of preparing work in legislation.

The CREL doesn't regulate the quantity of subsidy, nor the favourable tax proportion. Comparing the national investment on coal-fired plant, the investments on PV project are so "stingy". In fact, the PV industry needs a lot of capital injection to take off. According to 2004 Chinese PV industry report, from 1995 to 2003, the investment on PV project is only 2.2 billion RMB, approximately 0.22 billion Euro. But EC from 1994 to 1998, the investment exceeded 3.6 billion Euro. From 1999 to 2003, the European PV project got another 2.85 billion euro for take-off. But 1999-2003 in China, the investment on coal-fired plant is 224 billion RMB, about 18.7 billion Euro(8000RMB/kWh, $31.11*10^6*8000*90\%$). According to published Electricity Construction Project Declaration, in 2003, there were 41 new project approved by authority, the total installing capacity is 31.11 G Wh, within which 90% is coal-fired. What a huge comparison. So the CREL did not regulate an approximate investment really weakens the enforcement of this law.

Even though CREL has some limitations and didn't avoid the common shortcoming of previous laws completely, it strode a big step in renewable energy development in China. The Chinese government has realized the necessity of complementary laws and had designated expertise ad hoc group working on it.

3.4 Suggestion on implementation of CREL

BIPV is deemed as the biggest market application in the future for PV electricity. Many countries have put huge amount of capital in this field, try to push it growing faster and penetrating to larger application. But in China, this potential of market is still untapped. The recent energy crisis prompt Chinese government to seek new sources of energy, PV and other renewable energy are all in the framework for exploration. The CREL solved several law issues such as grid connection, buy back of PV electricity by utility etc, but the next step is implementation. There are still many law suits secondary to CREL for action phase left open. That's what we need to consider carefully.

3.4.1 Subsidy and Financial Support Plan

The BIPV system investment need large amount of investment initially. As conceived plan, one way of channelling could be surcharges drawn back from "green pricing" added in electricity price annually. A successful application is FiT system in several EU countries. Though there is argument on FiT for it contradicts to liberalized market price, it is proved effect to prompt renewable energies' development when they are too weak to be sustainable by themselves.

To promote the renewable energies application, it is necessary to enact by law about the subsidy standard and other financial aiding. That will pave the way for action. The biggest limitation of CREL is no regulation on subsidy rate. This is understandable for this law was pushed out in hasty and many details are time-consuming to elaborate. But the subsidy and financial aid is foremost for it will decide if the law is successful in implementation. Without that the investors will not be attracted. So it is imperative to enact relevant financial schemes as soon as possible. The other issue is the financial scheme should be independent from governmental budget for sustainability in case of reduction of budget.

3.4.2 Technical Standard

BIPV is a novel thing in China. The lack of experience on BIPV application need more attention paid on technical standard to secure a healthily and smoothly developing market.

At present phase, BIPV market is still in infancy, and the completely integrated with building PV is very limited, though it's the developing orientation. The retrofit of existing building applying PV will occupy considerable share of market for a long time. So, when regulating technical standard, both models (BIPV and BAPV) should be attended.

To standardize the market, a certificate system (CS) should be established in harmony with technical standard. The indigenous CS can prevent financial drainage from local market, protect law-abiding companies, phase-out unqualified producers and secure consumers' interest.

China has a very huge market demand in inhabitant housing, whilst the architecture market is not standardized. The various developing level of building companies adds the difficulty to implement a high unified standard. It is very important to combine the PV engineering standard with architectural design and building criteria when the technical standard is making for PVs. The PV criteria should also connect with CS standard and restrict the permission of unqualified companies to enter this field. In one word, a complete technical standard will secure the steady and healthy development of BIPV market and foster a mass of mature customers of high-end.

3.4.3 Incentives to Attract Household Participation

The government should raise a similar programme like German 100,000 rooftop Programme. We suppose it is called Chinese 100,000 Rooftop Programme temporarily. To push the programme forward, there must be incentives to households. As the initial investment is still high or even risky for most families, to make the carrot attractive enough is especially important. Otherwise the programme may lack of participation from household and in jeopardy of abortion. The incentives could be:

i. First batch of buyers can enjoy rebate up to 50% of total cost. As the quota is limited, they will take on "first come, first-served" basis. This measure will incite purchasers' enthusiasm. At the beginning stage of the programme, the participants' remarks on this systems are crucial important. Their impression will decide the subsequent purchasers' tendency.

ii. Interest subsidy from government. The rate of interest will affect the PV electricity as well as payback time of loan. A favourable interest rate will lessen the investors' burden and encourage their investing willingness. This policy must be combined with other incentives, for low interest is not the key factor influencing investors. Only if the pay back is secured and profit is foreseeable could be the inducement igniting their interest. Other wise the profit is big enough and worthy to take a risk.

iii. If the former two approaches are still too meagre to stimulate households' interest, the last coup should be "feed-in tariff" (FiT). As had been proved effective in many European countries especially in Germany, FiT performed significant role in promoting renewable energy development after 1990s.

The concept of "feed-in tariff"(FiT) means "regulatory, minimum guaranteed price per kWh that an electricity utility has to pay to a private, independent producer of renewable power fed into the grid."(J.P.M. Sijm, 2002, p6) This concept was appeared with German "Electricity Feed Law"(EFL) in 1991. From 1991 to Mar, 2000, the FiT for wind and solar energy is the same level in Germany, respectively 8.49 Eurocent(1991), 8.66 Eurocent(1994), 8.77 Eurocent(1997) and 8.23 Eurocent(2000). (J.P.M. Sijm, 2002, table 3.1, p. 7)[14] This price subsidy is almost fixed with only small fluctuation. Actually the FiT was annually fixed. This subsidy level is suitable for wind powered electricity in light of wind electricity's cost then, but hardly had any effect on solar electricity for the cost of solar electricity is far beyond this subsidy level.

In 2000, a new Act called "Renewable Energy Law"(REL) took the place of EFL. REL rose the FiT from 1990s' 9 Eurocents to 50 Eurocents. What's more, the tariff adopted a 5% annually decrease as an incentive to technology advancement.)

How could German 100,000 Rooftop Programme be so successful? The FiT took a significant role in the capacity hiking of PV system, particularly after 2003 the FiT adjusted again for optimization. Obviously there are three steps of PV installation. One is before 2000, the "100,000 Rooftop Programme" just started. The yearly increase is below 25 MWp in 1999. From 2000 to 2003, for the introduction of FiT, the second step of PV installation ranged from 45 to 140 M Wp. As the third step, the PV installation got an explosive increase in last year for the revised FiT policy. The newly installed PV capacity met more than 350 MWp in 2004. (see Figure 3.4.3, European PV Association' Position Paper, 2005, p. 4). The total accumulative installation reached 720 MWp. The inspiration of Germany's success could be:

[14] initiative data source: IWR(1999) in German. http://www.uni-muenster.de/energie/re/wf/E_Preis.html

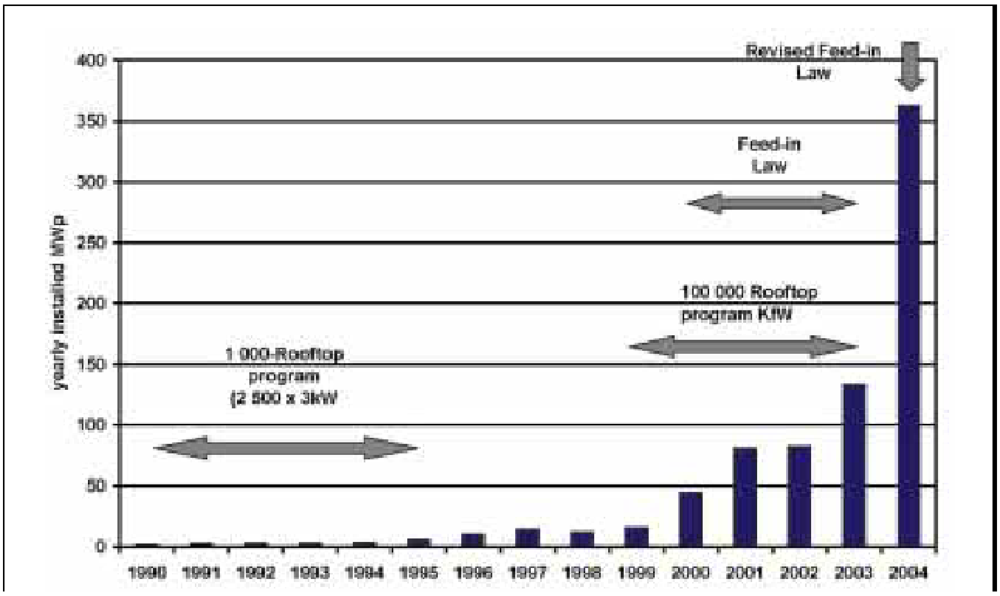

Figure 3.4.3 Market Pull by the "100,000 Rooftop Programme" and FiT in Germany (Source: EPIA)

1. German FiT pulls down the high price of PV electricity in the pattern of buy-back. Thus lower the threshold of competitiveness of PV electricity to fossil fuelled electricity. The uncounted externality of fossil fuel get somewhat redressed in this comparison.

2. German FiT provide a fix long term of guarantee of pay-back time for PV system investment. The 20 year or longer contract keeps this policy stable and foreseeable.

Considering these incentives, no wonder the PV system is so attractive to residential purchasers.

3.4.4 Mandatory Regulation on Utility Company

To date, the dealing of electricity including generation and selling are both monopolized by national company. The electricity companies are the biggest polluters and beneficiaries now. They should be responsible to take action on restriction of fossil fuel and develop renewable energy. The policy can refer to UK's Energy White Paper and request domestic energy suppliers must reach 10% in proportion of renewable energy in electricity production till 2010. (Energy White Paper 2003, UK, p. 45) This will give some pressure to them and take action on helping to develop renewable energy.

In CREL, mandatory regulations on utility company have loomed a little bit, but still not enough. For example, Article 13 and 14 regulate the responsibility of utility.[15] If not prescribe a portfolio or proportion of quantity, it is very hard to judge the fulfilment or the action may just remain on papers. The mandatory regulation should not only prescribe implementation amount, but also stipulate the punishment if prescribed aims didn't reach. Thus can the utility company get impetus to act. Otherwise under the market mechanism, to pursue the maximum profit will leave no space for renewable energies' development.

[15] See Chapter 3.3.1.

3.4.5 Establish Dedicated Fund to Patronize National Backbone Enterprise on PV research and Silicon Production

The fund can come from the green pricing in electricity. The objectives of patron are:

1. the PV research lab to develop new technology in manufacture and enhancing efficiency of PV cell.

2. the leading enterprises to produce high quality silicon slices and thin-film PV cells

These two objectives are aiming to solve the lagged status of Chinese PV industry: one in R&D, one in key raw material. For a long time, Chinese PV cell production was using the solar level silicon as feed stock coming from semiconductor industry. With the enlargement of PV cell industry, this raw material supply cannot fulfil the production need. It is urgent to establish dedicated solar silicon production line to keep abreast the development of PV cell manufacturing.

To provide research fund to labs belong to PV manufacture is more efficient than previous modus operandi. First the PV manufactures are familiar with market, and experienced in consumer request, so they can develop market-oriented products. Thus it can avoid research on market-divorced products, and enhance the fund's application efficiency.

Second, the PV manufactures are clear about their products' defects. Aiming for the defects, moderate fund in-put can accelerate the learning process of PV industry and drive further price decrease.

Third, decreased price and enlarged market will avail the development of fund scale, forming a positive cash flow cycling.

3.4.6 To Start a Moderate-scale Pilot BIPV Scheme in Niche Market

Taking account the large scale of China's energy market, too small pilot scheme can't be representative and no good for experience accumulation. So a moderate-scale is appropriate in a long run, otherwise the pilot scheme will lose its meaning. A niche market may happen in a big city with good solar resource and other supporting factors. According to the scale of the pilot, the niche market can also enlarge to the spectrum of several adjacent provinces.

Such a pilot scheme has multi-fold benefits. First of all, it is effective to prevent the renewable energy laws from showiness or formalism. Second, a national market is crucial to indigenous industry growth and vice versa, a stable indigenous market provide PV industry solid turnover. Today many PV manufactures are grown up with such original experience when they were beginning. This phenomenon has been proved in many countries. e.g. in early 80s of last century, the 6 MW Carissa Plain project in America cultivated two big PV companies, ARCO solar(today integrated into Shell Solar) and Solarex (today with BP Solar). In Japan, the enormous PV production began in the middle 90s with the project of Sunny Programme and Sharp Solar company is the biggest one in the world now.(Hoffmann, W, et. al. 2004, p2) Third, a local market can crease job opportunities and also stimulate relative careers on society. A niche market will be discussed in Chapter 5 in detail.

4. Incentives to Develop BIPV in China

4.1 Building Conditions in China

As the biggest populated country, China's population are increasing in a rate of 10 million per year, and will reach the summit of 1.55 billion people in 2030, then begin to decline slowly. Such a big population is a huge burden to limited resources. The population number reflects on dwelling, it's also a astronomical figure. Now there are 40 billion m2 building for dwelling, and according to Chinese Real Estate 2004 Report, the new building area are increasing 5% annually from 2005 to 2020, the newly dwelling area will be 12.04 billion m2 during this period. The problem is, the existing buildings now are in low condition of energy-saving. During the last two decades, Chinese people just solved "Eatting and Dressing" problem, most people's concerns are the enlargement of dwelling, the energy-saving design in a long term was overlooked. But as the energy crisis menacing over, if we still close our eyes to this problem, we will definitely regret in the future. Because the more high energy consumption buildings are built, the more we will pay in future years.

For most developed countries, the design for energy-saving building began as early as the first oil crisis in 1973. The Chinese building market lagged too much in this field. Till now, 98% buildings are not energy-saving. Due to low insulating functional material of wall, single glazing design, non-consideration on ventilation, and direct exposure to sun-shine roofs, Chinese building are twofold or threefold in energy consumption than European houses. This poor design make people use more air conditioners in summer and need more heating hours in winter. As we all know, the artificial indoors environment relying on air conditioner is not comfortable comparing with natural design employing more natural conditions.

4.2 Incentives to Develop BIPV

As we have seen, the building leakage of energy has become a potential threat which makes the energy crisis worse. Is there a solution? Could BIPV be an answer?

4.2.1 The Priority to Consider BIPV as Renewable Energy in Urban Area

At current phase, PV panel seems the most suitable solution to release the strained electricity supply, especially at peak load time. BIPV's Production Curve has perfect similarity with Electricity Load Curve, namely, BIPV has the obvious peak-shaving effect.

	Energy Source	Electricity Transfer Loss	Transportation of RM[16]	Pollution during energy production	Limitation of Geography
Rooftop PV	Free	None	none	none	none
Wind Power	Free	yes	none	Noise	yes
Biomass	Not-free	yes	Consume fossil fuel	CO2, soot, dioxin etc	yes
Geothermal	Free	yes	none	none	yes
Small Hydro	Free	yes	none	little	yes

Table: 4.2.1 PV and Other Renewables' Comparison

From Table 4.2.1, put aside the cost of generation, the other renewables have their contingent conditions to implement. e.g. biomass needs lots of wood fuel as raw material and consume fossil fuel for transportation, which is not economically profitable if the power plants over 100 kilometres from energy source[17]. Secondly, China is not a forest abundant country, the forestry coverage is less than 14%. This figure is below the global average level of 31%.(China Sustainable Development Report(1997)). The scanty forest reservation decides the limitation to develop biomass as renewable energy. Wind power, geothermal and small hydro are all confined by natural resources, which are not suitable for everywhere. For hydro power, another adverse limitation is the seasonal variation of water level. The flooding summer and icy winter affect the output significantly.

Recently, the appeal to develop wind power is rising. The real competence of renewables in fact lay between wind power and PV panel. But wind power is not appropriate to develop in urban area. One reason is as mentioned above, it is limited to geographical condition. In China, the wind-rich resources are scattered in Tibet, Inner Mongolia and eastern coast. For some inland cities, they do not posses this advantage. The other drawback of wind power is its stochastic character. It is hard to predict and the happening of wind is not always synchronous with the peak demand. Thus add the difficulty of grid incorporation. Second, wind power need extra investment to construct utility infrastructure for most wind farms locate at remote areas. For off shore wind farms, the construction of electrical cable under sea bottom is necessary. The transfer loss in lines is also considerable (about 7-8%). BIPV connects to local already constructed utility grid. And the electricity is consumed on site, avoid transfer loss. Third, the O&M cost is quite high for wind power electricity. In Europe, the average O&M cost is 0.5-1.1 Eurocents/kWh range over the entire life of a turbine.(EREC, 2004, p169). In china, because most wind turbines are imported, this O&M cost would be twofold of that figure, around RMB 0.1-0.22 /kWh. But PV system need little maintenance, the cost of O&M may be negligible. Fourth, if installed in cities, wind mill may produce noise and magnetic irradiation, which disturbs life of residents and cause complain and boycott. PV system has no rotating parts and no pollution during electricity generation. Fifth, the wind turbines range from 30 kW to 1000 kW, which is too big for private household and house owners. The wind power electricity can only be competitive when the wind mill reaches certain power level. PV

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[16] Raw Material, noted by author

[17] A study (1998) by VTT (Finland) arrives to raw material (wood) cost figures of 2-3 €cents/kWh(e) for transportation between 20 and 40 km; this is to be increased by 30% for transportation up to 100 km. "the raw material must be gathered from an area the radius of which is typically less than 100 km" Antti Asikainen, *Cost factors of Fuel Chip Production*, University of Joensuu/VTT Energy Faculty of Forest, VTT symposium 208, Espoo, 2000

system is more flexible, ranging from 0.5 kW to 5 kW as usual residential small scale, and also could be larger for solar power plant. Sixth, Wind mill is complicated to install. Except the necessary electrical adjustment to merge into utility mix, the building process of pillars, concrete base, installation of turbines and fans are also a big challenge, especially to date the height of big wind mill reaches 100 metres and diameter of fans exceed 15 metres.(EREC, 2004, p179) The installation of wind mill is particular difficult for offshore turbines, whereas PV systems can be installed quickly and easily for modular design. So, PV system is more favourable to develop in cities. It is necessary to make PV-tilted policy in urbane area.

4.2.2 PV Panel's Triple Functions (Killing 3 Birds with One Stone)

PV panel can be installed on rooftop or façade of the building. One function of PV is the conversion from light energy to electricity. That's its basic function.

Second, the PV panel is a very good shading to summer sunlight. PV modules designed as shadings can block direct radiation from entering the building, permitting only diffuse light enter into the rooms. There is another semi-penetrated PV panel which can absorb most direct radiation and allow diffuse light only going through. The shading PV absorbs most light and keep the building cool like the shadowing function of trees. The difference is the blocked light doesn't go away but partly turns into electricity. The amount of turning depends on the light intensity and PV's transition efficiency.

The third function is the PV cell integrated with building's envelope, saves the construction material, such as floating glass, marble stone façade and tiling. The PV panel can be designed in different shapes or even various colours to fulfil various needs.

4.2.3 Environmental Sound Design

BIPV design pays more attention on energy-saving aspects comparing with traditional design. The combination of PV modules with shading , lighting and cooling diminish most possibility of using air conditioners and electrical heaters, which lower the energy consumption and emission.

1. PV panel integrated with glazing

Figure 4.2.1 PV integrated with glazing (Andresen I,2002, p11)

In this design, the PV grid with window pane produces offbeat effect. On one hand avoid the direct sun project into room, on the other hand does not affect the diffuse lighting. To enhance the design, I think the PV grid can be installed as adjustable in angle, so in cloudy days can let more light come in.

2. PV integrated with sky window

This office interior view demonstrates the quality of light transmitted by the approximately 5% translucent BIPV panel skylight.

Figure 4.2.2 PV integrated with skylight (Eiffert P and Kiss G, 2000, p31)

3. The Synthesis of Other Area Knowledge

Different from ordinary design, BIPV accentuate the insulation of heat and preventing partial over-heat. High quality insulation materials are used when conceiving during design phase. More background knowledge of air fluid physics, aerography and geophysics is applied in designing for natural ventilation function. See figure 4.2.3.

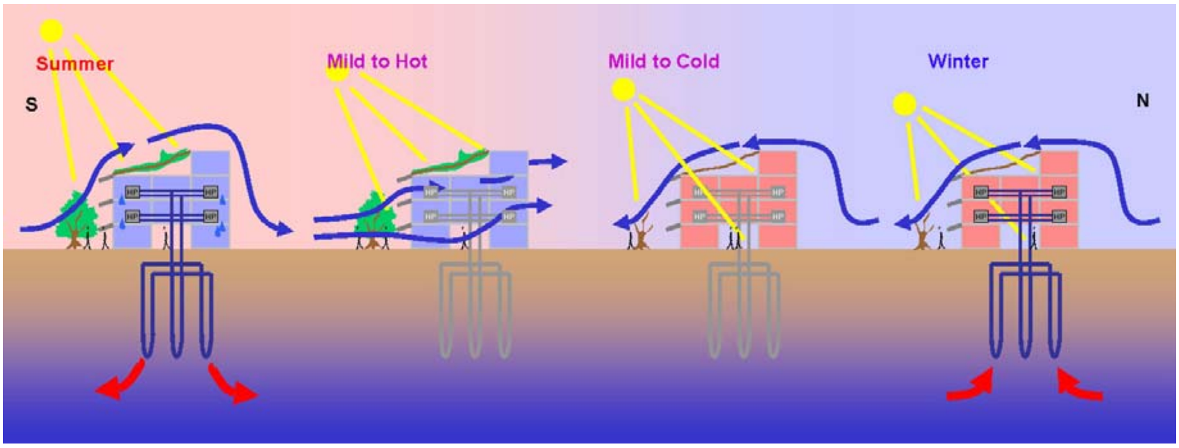

Figure 4.2.3. The ventilation and geothermal consideration.
Source: MIT Building Technology(http://chinahousing.mit.edu/english/approach/index.html)

Though this part has no necessary relation with PV, when we assess the benefit of BIPV, the energy saving in BIPV should also be an important composition.

Conspicuously, BIPV is a combination of engineering and architecture. ("Combining technology and architecture", Sick F & Erge T, 1996, p. 6). BIPV, both in energy-saving design and harnessing of renewable energy, makes very sense to today's Chinese architecture market and potential PV market.

4.2.4 Low Cost of O&M and Cost-free Energy Source

Comparing with traditional electricity production, the maintenance cost is low. The lifespan of a PV system is 20 to 30 years. The usually maintenance is cleaning the PV panel with garden hose or this part could be omitted in district with regular raining. The other maintenance work includes testing battery voltage and refilling battery with distilled water. (Sick F & Erge T, 1996, p. 207). This job can be done by consumer himself. In a grid-connected system, if there are no storage batteries, this job can also be avoided. The holistic maintenance cost is about 5% of the system cost during the life span, including replacement of damaged components out of warranty. What's more, the PV need no further invest on raw material. The source of energy is sunlight, namely, no pollution and noise during running, and not least, totally free.

4.2.5 A Back-up Electricity Source

BIPV system is usually grid-connected. But if a storage part (lead-acid battery) is added, it can work during electricity power failure as well as night when there is no light energy for PV conversion. This function is useful for some districts where the grid supply is not stable or natural calamities frequently cause power interrupted.

4.3 A Case Study: Germany's "hundred-thouand-rooftop" Programme

4.3.1 A Brief Glance of 100,000 Rooftop Programme

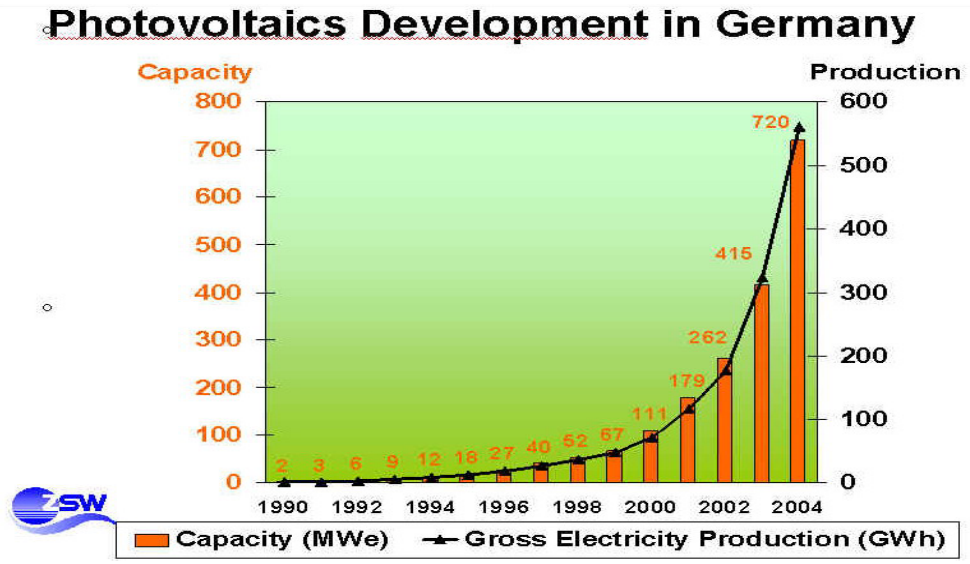

Figure 4.3.1 Photovoltaics Development in Germany(Langniss O, 2005, presentation in iiiee, Lund)[18]

[18] Note: the 2004 installed capacity is 363 MW in Figure 3.4.3, which differs 720-415=305 MW in Figure 4.3.1. The former data is statistic from German PV industry and the latter data comes from German official publication. The PV industry intended the bigger one for it exceeded Japan's installed capacity and became No. 1 in 2004. (email from Dr. Langniss)

The German 100,000 rooftop programme was launched in 1999 and successfully finished in 2003. The project aimed to "develop a total generating capacity 300 MWp", "…the incentives comes through a guaranteed ten-year low-interest loan(currently 1.9% per annual)". This project got accelerated development after Apr, 2000 for the Renewable Energy Law (REL). According to REL, the buy-back price is Euro 0.5 per kWh during the lifetime of the PV generator, with a decrease rate of 5% annually for the cost reduction. The fact proved the combination of PV rooftop programme and REL is an effective attraction. Over 4000 applicants competed for 2000 PV loans and used up Euro 92 million budget. The others had to wait. During 2000 alone, more than 8000 PV systems were installed with a total capacity of 41.66 MW. The average size is 5.18 kWp, with over 100 plants in the 50-120 kWp size. This indicated the PV market is motivated. . (EREC, 2004, p. 116-117) What's more, the German market didn't stop with the finish of 100,000 rooftop programme. After that, KfW (Reconstruction Loan Company) Group continues to provide attractive loans to families for PV funding under their CO2 Reduction Programme. Commercial customers can get loans under their KfW environmental programme.(Durrschmidt et al. 2004, p. 23).

The triumph of German 100,000 Rooftop Programme can be proved by the following figures:

1. From 1999 to 2003, 350 MWp[19] installed capacity exceeded anticipation of 300 MWp.

2. The PV system price decreased 20% from 1999 to 2004 and keep on declining.

3. Thousands of employment accompanied with this area

4. The financial support multiplication (subsidy, low interest loan, Feed-in Tariff)

(Shi Lishan 2004, p. 50)

Another characteristic of rooftop programme in Germany is the high grid connection. "92% PV system is connected to grid." (EREC 2004, p. 120). Not least, the money paid by the electricity company to buy the high price green electricity from private homes comes from "Green Price", which is added in normal electricity price and equalized nationally. So, private and company both are satisfied with this paying method.

4.3.2 What is the Significant Idea of German 100,000 Rooftop Programme and its Financial Support Solution, Feed-in Tariff

The progress till now of German 100,000 rooftop has been proved effective. This programme's success also erected a cornerstone for Germany's PV market development and settled Germany as the leading country in European PV application. In 2004, the new PV installation amounted to 410 MW in European 25 countries, whilst Germany took account for 88.5 %, reached 363 MWp, which is quite impressive. In addition, this figure of new installation in Germany in 2004 exceeded Japan's 280 MWp and hinted Germany will be the largest PV market temporarily. (EPIA, 2005).

[19] the figure comes from the accumulation of 2003 subtracts accumulation of 1998, 415-67=348 MWp, See Figure 4.3.1

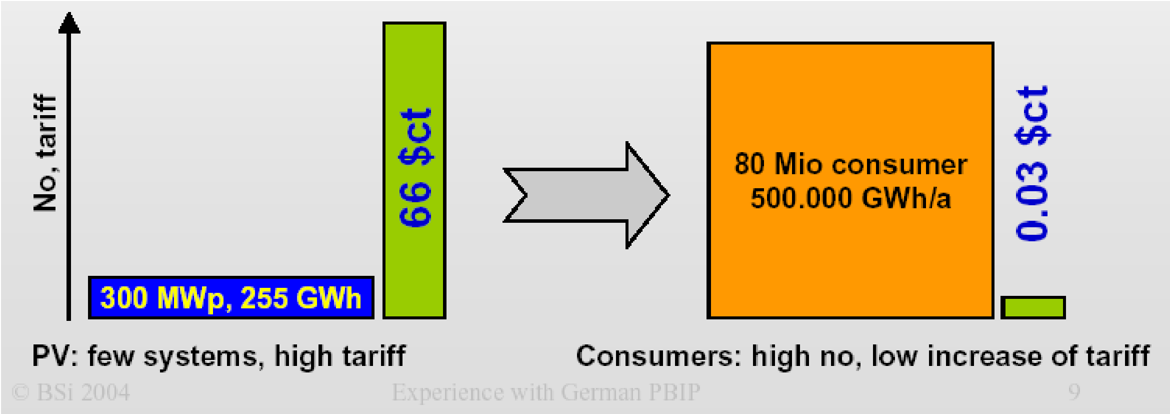

Figure 4.3.2 The Demonstration of FiT Theory (Source: Experience with German PBIP, presentation by Stryi-Hipp, Gerhard, 2004)

Figure 4.3.2 illustrates the theory of how FiT is realized. For 300 MWp installed capacity, the annual production of PV electricity is 255GWh. These electricity is quite expensive, about 66$ct per kWh. But when this amount of electricity was put into the pool of the whole country, averaged by 80 million consumers and 500,000 GWh annual consumption, the additional charge per electricity is only 0.03 $ct/kWh. Thus the PV installers, the clean electricity producers can get subsidized with a high price according to their generation in household. This scheme is beneficial to every stakeholders. That's a multi-wins scenario.

The PV Installer (investors): get subsidized and guarantee for recovery of investment

The Government: reduction of GHGs emission and added job opportunity

The Utility: the benefit of peak-shaving, less investment on building new plants

Consumer (non-installers): Cleaner air and reduction of fossil fuel consuming

PV Industry: Increased production of PV cell and module, enlarged scale, exporting

4.3.3 What Can We Learn from German 100,000 Rooftop Programme

1. The 100,000 Rooftop Programme fostered a PV market in Germany

Just before the 100,000 Rooftop Programme in the 1998, there was only 0.003% PV in national whole electrical capacity in Germany. In the year 2003, when the programme is finished, the installed capacity reached 415 MWp(cumulative). The expansion of market brought down the PV system price more than 20% lower from 1999 to 2004. The applicants for new installation are increasing even some favourable policy has been cancelled. In 2004, the whole year saw 363 MWp new installations. The PV market showed a sustainable way of development.

2. The PV industry accumulated relative experiences

Before the 100,000 rooftop programme, there was a 1000 rooftop programme in Germany started in 1992. As a pilot project, the former one gave some experiences to latter and set the base of later triumph. In light of a tracing record performed by IEA to 177 early installed PV systems, there were significant reductions of annual yield compared with later years' 58 new systems. The reason is the failure of the former batch of inverters caused output lower. After enhancement of this defect, the average performance reached stable higher level, in 0.8 performance ratios(PR).(Nordmann, T et. al. 2004, p. 2) This kind of experience can only acquire from practical test.

3 A Perfect Scheme Design

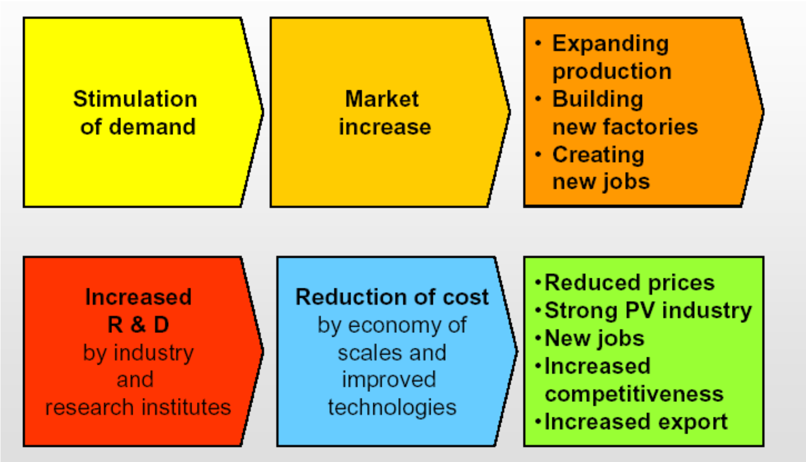

Figure 4.3.3 Market Entrance Strategy (Source: Experience with German PBIP[20], presentation by Stryi-Hipp, Gerhard, 2004)

Stryi-Hipp gave a quite thorough summary of German 100,000 Rooftop Programme. As Figure 4.3.3 shows, the scheme demonstrates a positive feed-back loop. First, Stimulation of Demand by spread the PV system. In the beginning of 1990s, there was a similar 1000 rooftop programme. This programme could be deemed as the prelude of PBIP. "From 1990 to 1995, 2250 PV systems were installed and connected to grid with an average capacity 2.6 kWp per roof."(EPIA, 2004, p. 23) The following PBIP from 1999 to 2003 testified the anticipation. When the market increased gradually, the economical and social benefit began to appear, such as: augmentation of production, new built factories and new borne job opportunities. This gave industry confidence to invest on R&D and added put-in of research institutes. The increase of R&D brought further reduction of cost, enlarged production scale and improved technologies pulled down price again. The buy-down effect appeared. The social and national benefits are more obvious: Reduced price, strong PV industry, more new jobs, increased competitiveness as well as increased export. This scheme is influential and edificatory to other countries which want to exploit their own PV and other renewable energy market.

[20] PBIP: Performance-based Incentive Programme, Stryi Hipp

5. A Pilot Scheme of BIPV in Beijing, China

Looking back through these years of photovoltaic development in the world, the various programmes promoted by several countries' governments played main roles in fostering PV market, enhancing R&D and drag down the price. As early as 1970s, Japan had begun doing research on PV technology and initiated Sunshine Project in 1974. In 1993 the Japanese government launched New Sunshine Project again aiming for the introduction of "New Energy". (Waldau, A.J, 2004, p11) Till 2004, the accumulated installed capacity reached 1100 MWp in 38000 systems. The goal in 2010 of 4.8 GWp in capacity is very likely to be met. (Waldau, A.J, 2004, p13). Germany is the leading country in PV installation and photovoltaic production in Europe, thanks to its 100,000 Rooftop Programme started in 1999. The Rooftop Programme is so successful that it did not stop when the programme was declared finished in 2002. The PV market kept on increasing in the following years. In 2004, the PV cumulative installed capacity met 720 MWp, increased 305 MWp than 2003. Gross electricity generated by PV system reached 550 GWh. Behind the successful numbers is the government strong support and successive policy. From 1989 to 2001, the investment on renewable R&D is 1.5 billion Euros, thereinto 500 million Euros were spent on PV's research. (Langniss O, 2005, presentation in Lund) Summarizing these countries' experience, the government's push is the main impetus of renewable energy development. At the early phase of electricity generated by renewable energy, the price is the apprehensive point and bottle neck for application. The governmental role is to stipulate mandatory policy and incentive scheme, leading the renewables merge into traditional energy system and take traditional energy share gradually. Therefore in China, such similar incentive mechanism should be established as soon as possible for the renewables development may take 10 or more years to form considerable scale. For BIPV's development, we suppose there is a rooftop programme aiming to install 100,000 PV systems with average 5 kWp per unit. Comparing with other cities, we choose Beijing as the pilot place.

5.1 Why Choose Beijing

Beijing is the capital of China, the second largest city behind Shanghai. Located in north-west of Huabei Plain, Beijing is endowed bountiful solar insolation during the year. Boasted 16800 sq km and 12 million people, Beijing is a fast growing, dynamic metropolis combining historical heritage and modern civilization[21]. From the aspects of solar insolation resource, family income level and dwelling house area, Beijing is suitable to develop BIPV system. Hence I choose Beijing as the pilot site for 100,000 rooftop programme.

5.1.1 The Solar Insolation Resource of Beijing and Comparison with 3 other Cities in China

In geography, Beijing locates in 39.55N (latitude) and 116.25E (longitude), belongs to warm continental climate. Annual rainfall averages nearly 700 mm. The average temperature throughout the whole year is 7.78 C. The average temperatures from the hottest month of July to coldest month of January ranging from 23.5 C to -10 C(monthly average, see Table 5.1-5). Generally speaking, Beijing belongs to distinctive four-seasonal weather. From the data acquired in NASA website, annual average insolation amount is 4.31 kWh/m2/day. I picked 4 cities in China from the highest solar insolation in Lhasa, Tibet to the lowest in Chengdu, Si

[21] http://www.moveandstay.com/beijing/guide_introduction.asp?city_id=3

Chuan province. Beijing's insolation level is representative because it is the middle level but a little above average. (See Table 5.1-1 to Table 5.1-4) The solar insolation quantity accepted per year is suitable for developing PV electricity.

Monthly Averaged Insolation Incident On A Horizontal Surface (kWh/m²/day) Beijing													
Lat 39.55 Lon 116.25	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
10-year Average	2.69	3.47	4.29	5.50	6.15	6.27	5.42	4.97	4.40	3.56	2.75	2.37	4.31

Table 5.1-1 Data source: NASA

Monthly Averaged Insolation Incident On A Horizontal Surface (kWh/m²/day) Lhasa													
Lat 28.45 Lon 91.5	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
10-year Average	4.00	4.58	5.22	5.55	6.23	5.88	4.80	4.55	4.67	4.95	4.34	3.78	4.87

Table 5.1-2 Data source: NASA

Monthly Averaged Insolation Incident On A Horizontal Surface (kWh/m²/day) Taibei (or Taipei)(25.05, 121.5)													
Lat 25.05 Lon 121.5	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
10-year Average	2.10	2.35	2.80	3.70	4.49	5.64	7.12	6.41	4.92	3.67	2.93	2.47	4.05

Table 5.1-3 Data source: NASA

Monthly Averaged Insolation Incident On A Horizontal Surface (kWh/m2/day) Chengdu, Si Chuan													
Lat 30.67 Lon 104.06	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
10-year Average	2.40	2.57	3.07	4.05	4.44	4.43	4.34	4.18	3.02	2.46	2.39	2.15	3.29

Table 5.1-4 Data source: NASA

Monthly Averaged Air Temperature At 10 m Above The Surface Of The Earth (° C)													
Lat 39.55 Lon 116.25	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
10-year Average	-10.7	-6.72	1.46	9.99	17.8	22.0	23.5	21.8	16.1	8.23	-1.71	-8.33	7.78

Beijing Monthly Temperature

Table 5.1-5 Data source: NASA

One thing should be noted is that the solar insolation does not depend on latitude. There are many factors that will take effect, e.g. sunshine days per year, temperature, altitude above the sea, pollution extent of local atmosphere. For example Taibei has a lower latitude than Beijing, but is has misty weather and semi-tropical climate, which affects the acceptance of sunshine. The solar resource in Beijing is also better than Germany, such as in Berlin(L/N 52.52/13.33) the annual insolation is 2.74 kWh/m2/day. From Figure 5.1-1 to Figure 5.1-4, the contract is conspicuous, if we take 3 kwh/m2/day as the basic threshold. In addition to solar insolation, the temperature is another factor which may affect the PV output. Too high temperature will lower the efficiency of PV panel. The standard temperature for PV cell measuring condition is 25 °C, the peak power will decrease 0.4% with every °C increase.(Luo Yunjun et. al.2005, p289) From Table 5.1-5, Beijing's average temperature is 7.78 °C. And the over-heat of components can be avoided by engineering installation. To sum up, among the four Chinese cities aforementioned, Beijing seems the perfect situs to carry out a pilot scheme.

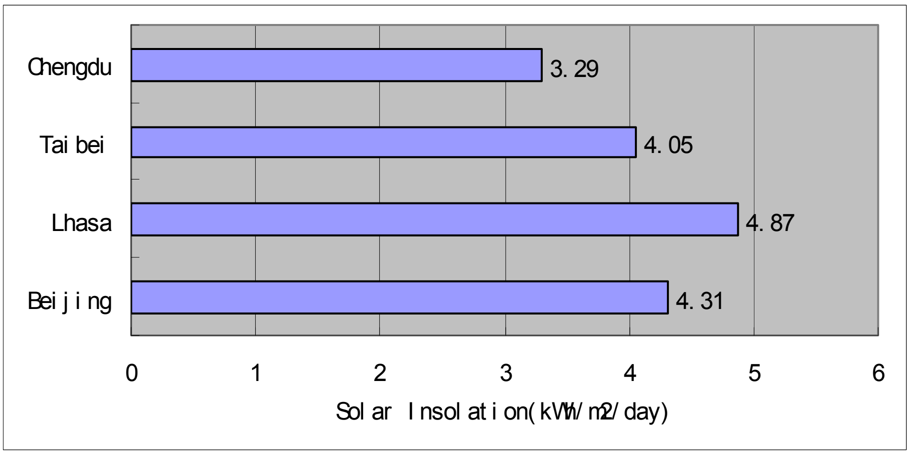

Figure 5.1.1 The Comparison of Solar Insolation in Four Representative Cities in China

5.1.2 The Income Level Analysis of Beijing

Beijing is the city of political, cultural, and northern economical centre of China. Most of international embassies locate at here. Over 80 universities and 115 research agencies find their sites here and every year there will be 99600 graduates and 29500 postgraduates coming out of campus.(Beijing Statistics Bureau 2004 Economics and Social Communique). This provide the city high quality labour resources. The Zhong Guan Chun high technical industry garden concentrates most of Chinese IT companies and world famous IT corporations' branches or sub-companies. It is also called Chinese Silicon Valley. Also thousands of world known brands opened their deputy office in thousands of towers in Beijing commercial districts. These special advantages endow this city a colony of high income and the average income level also ranks top 3 in China. See Table 5.1.2. The Chinese City Family Income (Dec,2004)

The City Family Income Basic Status (Dec, 2004)					
City	No. of Family Investigated	Average Family Size	Average Working member	Average Monthly Income/person (RMB)	Average Monthly Sum for Consuming /person (RMB)
Beijing	2000	2.94	1.54	1455.22	1306.76
Tianjin	1500	2.94	1.47	1596.60	1522.65
Shanghai	1000	3.03	1.51	1537.41	1368.05
Guangdong	1600	3.27	1.73	1228.48	1091.44

Table 5.1.2 The City Family Income Basic Status in China(Excerpted from National Statistics Bureau website)

The high level income families prone to get bank loan supports and are in favour of penetration of BIPV programme.

5.1.3 The Real Estate Investment Analysis of Beijing

With the continuous process of rural area to urbanization, the urban expansion speed in Beijing is gearing up too. From January to November in 2004, the total investment in real estate in Beijing is RMB 115.13 billion, increased 20.8% comparing with the same period in 2003. The new dwelling area developed ranks No 2 just behind Guang Dong province of the whole country.

Table 5.1.3 Jan to Nov,2004 Real Estate Development Status

Main Indicator	2004,Jan-Nov	Last year	Increase (%)
Real Estate Develop investment□RMB Billion□	115.13	95.28	20.8
Dwelling Building investment□RMB Billion□	62.23	51.66	20.4
New Commercial Building Area with Last Year's Unfinished□million sq m□	88.34	81.52	8.4
New Dwelling Space under construction with Last Year's Unfinished□million sq m□	60.68	57.99	4.6
New Commercial Building Area in 2004 □Million sq m□	23.62	27.37	-13.7
New Dwelling Space under construction □Million sq m□	17.51	20.19	-13.3
Finished Commercial Building□Million sq m□	16.11	12.77	26.2
Finished Dwelling Space□Million sq m□	12.04	10.49	14.8
Commercial Building Sold□Million sq m□	14.55	10.99	32.4
Dwelling House Sold□Million sq m□	13.31	10.38	28.2
Commercial Building Sold□RMB billion□	73.51	53.68	36.9
Dwelling House Sold□RMB billion□	61.93	47.03	31.7

Data Source Chinese National Statistics Bureau,

Another tendency in 2004 of Beijing is the dwelling house sales mainly focus on 81 m2 to 160 m2 per house, accounted for 63.5% of the whole sale. The house type of 81 m2 to 120 m2 in area accounted for 55.6% in whole sale from Jan to Nov 2004. The average price of commercial dwelling house is RMB 5052 per m2, nearly twice of the national average price. (2004 Real Estate Analysis Report, p32) In light of the 10th "Five-year Plan", the dwelling area per capita is 22 m2. And typical Chinese family member is 3 to 5 people. The mainstream of house selling should be 66 to 110 m2. The Beijing 2004 house sale data indicated the people's consuming concept on house is quite advanced. This phenomenon can be attributed to the comparatively high income level of Beijing people. It also shows a great potential to develop rooftop PV systems in Beijing.

5.1.4 The Poll of Willingness to Pay (WTP) for Green Electricity

The 1999 Consumer Association in China made a WTP poll for green electricity. This investigation issued 3,200,000 questionnaires to Chinese consumer. The result indicated 92% of investigators are willing to pay for green electricity. As the limitation of data, I can't get more detail about this poll. But the result is quite encouraging. In 2001, the South-north Institute for Sustainable Development made another pool on green electricity in Beijing, but this time the objectives are enterprises, companies and entities in Beijing as business consumers. The scope included 339 business units. The result also showed positive attitude to accept green electricity. See Table 5.1.5 the result. These results indicate Beijing has a good consumer support basis for renewable energy.

Table 5.1.4 The Structure of Investigation Objective (Table modified from the Green Electricity Poll by South-north Institute for Sustainable Development, 2001)

	Foreign Company	Joint Venture	Domestic Company	Total
Number	143	114	82	339
Proportion	42.2%	33.6%	24.2%	100%

Table 5.1.5 Impact of premium on willingness to purchase (Source: South-north Institute for Sustainable Development, 2001)

	At 5% higher	At 10% higher	At 15% higher
Percentage of respondents willing to purchase some renewable energy	38.6%	29.8%	16.8%
Willing to purchase less than 10%	15.3%	13.0%	6.5%
Willing to purchase 11%-25%	8.6%	6.2%	6.2%
Willing to purchase 26%-50%	5.3%	4.1%	2.1%
Willing to purchase more than 50%	9.1%	6.5%	2.1%

5.2 The Calculation Model Adopted

5.2.1 The PV Model Adopted

As Beijing locates in the northern hemisphere, the available roof or facade area should face south. "Today's commercial thin-film models need 20-30 m2 for a kW and crystalline models need 8-15 m2."(Sick, F & Erge T (1996), p154) Considering the current market status, crystalline PV panel dominate over 80% share, we will adopt crystalline products as the first choice for this programme. A 5 kW system will need 40-75 m2 roof area. As the technology of PV developed so fast, today the 5 kW system need only 35 m2 if a mono-silicon cell system is adopted. (PV3 software[22], see Appendix 7)

The utility has covered all over the Beijing district even suburb mountain areas. The PV system will be grid-connected. This pattern is also advantageous for buy-back of electricity and help the owners recover investment under utility's buy-back pricing policy. From a global perspective, the grid connected pattern is the developing trend. As Dr. W Hoffmann said, the world PV growth since 1998 was about 40% p.a., whilst stand alone PV systems grew with a modest 18% p.a. What astonishing is the grid connected PV system increase in 63% rate p.a. since 1998. (See Figure 5.2.1) Nowadays the grid connected system has taken account for 78% of installed PV market.

[22] about PV3 software's introduction, see Chapter 5.3

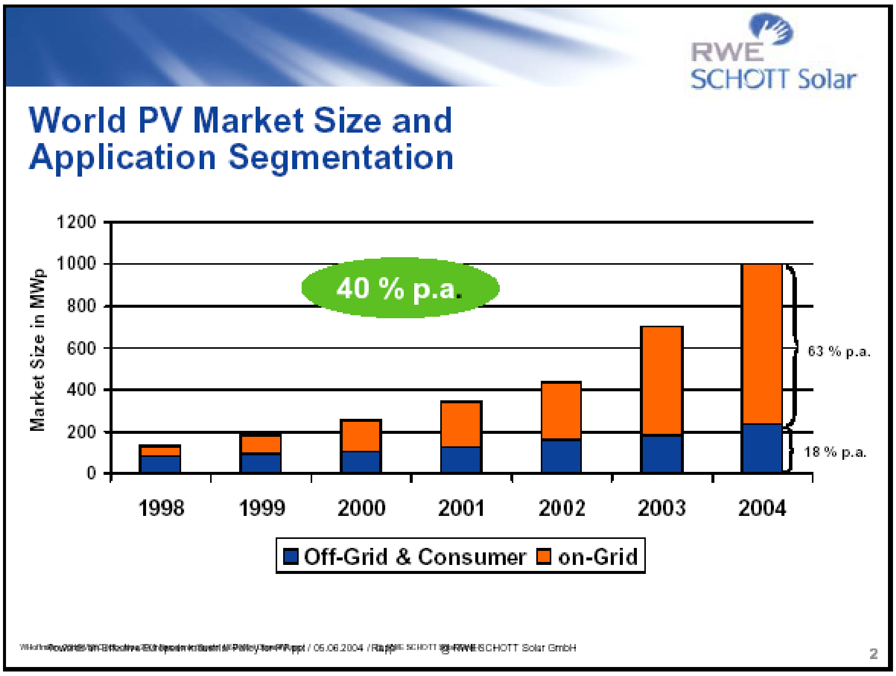

Figure : 5.2.1 World PV Market Size and Application Segmentation(W. Hoffmann, 2005)

5.2.2 The Load Analysis

For household the everyday load must be identified in case of overload for PV system or too big exceeding financial ability for investment. The latter will lead to too long to payback. When sizing the capacity of the PV system, we will also take into account of the future load to fulfil, for Chinese family are getting more and more wealthy and the electricity consumption will rise gradually in the near future.

Table 5.2.2 lists out most commonly used end-use in Chinese household.

Table 5.2.2 Household Electric Appliances (Source: Chinese Utility Company in Linyi, Shang Dong)

	Low (Watts)	High(Watts)
Air Conditioner	950	3000
Refrigerator	100	260
Clothes Washer/with dryer	400	4400
Television	68	200
Electric Pot	550	900
Microwave Oven	750	900
Drinking Water Machine	315	700
Bath Heater	1060	1060
Kitchen Fan	100	400
VCD CD DVD Player	35	57
Amplifier	100	200
Electric Fan(desktop)	56	72
Venting Fan	30	30
Electric Fan(ceiling hanging)	800	1200
Iron	1000	1500

	Low (Watts)	**High(Watts)**
Oil Heater	2000	3000
Electric Bath Heater	1200	2000
Coffee Pot	800	800
Pressure pump	90	180
incandescent	15	300
Energy saving lamp	25	100
fluorescent	40	40
Sanitary Closet	600	600
Food Shredder	230	230
Electric Thermos	800	1200
PC/Laptop	70	100
Fax	50	50
Projector TV	200	300
Sum	12 kW	23.8 kW

Table 5.2.3 Beijing City Inhabitant Durable Electrical Devices Ownership Statistics (per 100 families)

Device	**2003**	**2002-2003 Year-on-year increase (%)**
Air Conditioner	119.3	112.0
Electrical Bath Heater	85.4	102.3
Colour TV	147.0	99.1
Refrigerator	100.4	98.8
Washing Machine	99.3	100.7
Personal Computer	68.3	123.1
Microwave Oven	79.2	108.3
Kitchen Venting Fan	81.3	103.6
Electrical Cooking Pot	107.8	109.9

Source: Beijing Statistics Year Book 2004

In fact a family can't use so many electric equipments simultaneously. Table 5.2.2 just list the most daily use devices and their reference power. Table 5.2.3 indicates the air conditioner, colour TV, electrical cooking pot and refrigerator's penetration are over 100%, that means, some families may own more than one such devices. According to "China Energy Databook", the annual electricity consumption in 2002 is 440 kWh per capita in Beijing. The average load in household of current Beijing inhabitants is 1320 kWh to 2200 kWh(3-5 people) per family per year, the peak hour need maybe 4-4.5 kWp for use of air conditioner. But not all the family electrical devices work simultaneously, some devices may work in standby while others working fully. As sensitivity prediction, the range of working power needed should between 2 kWp and 3 kWp. We choose of 5 kWp system as the model for application is based on the consideration of peak demand.

The other reason to pick a 5 kWp system lies in that there is little difference between the final budget of a 5 kWp system and a 3 kWp system(See appendix 9 and 10), a 5kWp BIPV budget is estimated about 206513 RMB and a 3kWp BIPV costs about 189987 RMB. The initial investment is only 16526 RMB on saving comparing a 5 kWp system, whereas the output of a

3 kWp system is 40% less than a 5 kWp system. That's a significant factor. Taking into account cost-benefit effect, a 5 kWp system will generate more electricity and gain more under a favourable recovery policy, which will shorten the payback time of the primary investment. If we break down the initial investment of BIPV, the reason of so little difference of the two system lies in that the design, the BOS, the engineering spending and other cost take account for a big proportion, and they are almost the same spending of the two systems. The main difference is the PV cell cost, a 3kWp system will spend 17 thousand RMB on PV cell whilst a 5 kWp system 29 thousand RMB. But put it in the whole investment, the difference accounts for only s small proportion as 9%, but it will bring extra 40% output. The investment of the extra 2 kWp is more economical in a 5 kWp system. So, under this context, a 5kWp system model is recommended.

5.2.3 The Daily Load Management and PV Peak-shaving

5.3 The PV System Production Calculation

If we suppose S stands for the solar radiation on the PV array, P_{PV} stands for the system power, η_{PV} stands for PV cell efficiency, A_{PV} stands for PV cell area, then we can get the formula for A_{PV} as:

$$A_{PV} = P_{PV} / \eta_{PV}$$

To get the PV system's production, we suppose E_{PV} stands for output, then

$$E_{PV} = S * A_{PV} * \eta_{PV} = S * P_{PV}$$

But in reality, we should consider the effective parameters such as dust, module temperature, circuit loss etc. These factors attribute to K_{PV} approximately 0.9, and after the PC cell is assembled into systems, there are also system converting loss, we suppose it is η_{BOS}, mainly comes from converter loss, usually equals 0.75. Thus we get the output formula:

$$E_{PV} = \eta_{BOS} K_{PV} P_{PV} S \qquad \textbf{(formula 1)}$$

This calculation method is adopted by F Sick & Thomas Erge in their book of *Photovoltaics in Buildings, a Design Handbook for Architects and Engineers*[23]. In real PV design, the situation might be more complex for we must think about the system's installation angles, with or without axis, the solar insolation level of local area, the average temperature, climate condition etc. These conditions vary from place to place. For coarse estimation, we can use **formula 1** to get primary outcome. To get more accurate result, we must resort to special computer software. PV3 is one of these software and used frequently by engineers. It is provided by a Canadian website named RETscreen. What's more benevolent, this software is free of charge and can be downloaded freely. When using it, the computer should be connected with internet so you can choose suitable PV products from their online database and get meteorologic data from

[23] See Page 163

American NASA website. With the help of this software, we saved a lots work of complex calculation.

An interesting thing is through **formula 1** we can find that the PV cell efficiency is not important for PV's output. There is no efficiency coefficient in it. For a certain system, what really matters to the output is the power of that system. No matter what kind of material you choose, e.g. mono-silicon, poly-crystalline or thin-film. But the PV cell's efficiency affects the system cost. For lower efficient cell need more area to produce the same amount of electricity, which means the more spending on hardware. The cost can be embodied by the same kind of material or different kind of material. For instance, thin-film is cheaper than crystalline cell, but the low efficiency of thin-film make the system need more cell modules which offset the advantage of price. According to the living condition in Beijing, the apartment buildings dominate the dwelling type. Villa only takes a small part. We must take into consideration of the limited rooftop area which is different from western countries. That is why we put crystalline PV cell in priority for it takes less rooftop space. From the economical point of view, to enhance the photovoltaic efficiency is to lower the system cost. Other factors that will affect electricity production are solar insolation intensity, angle to the sun, dust, pollution extent locally, and circuit efficiency. All these factors decide the final output of the system.

5.4 The Production Estimation of this Scheme Implemented in Beijing

With the aid of PV3 software, we can get some useful reference outcome.

Table 5.4 Preconditions of BIPV Scheme

PV model	**Product Type**	**Efficiency**
Mono-silicon	BP Solar/BP 590F	14.3%
Miscellaneous Loss	PV Array Power	PV Array Area
5%	5 kW	35 M2
PV temperature Coefficient	Inverter Size	Average Inverter Efficiency
-0.40% / ^{o}C	72 kW	90%

Thus a 5 kW PV system in Beijing rooftop can produce electricity 6.425 MWh per year. (See appendix 7 for the running result of the PV3 software.)

If we suppose the 100,000 Rooftop Programme to finish in 3 years, then, when it comes to the end, there would be 500 MWp in installation capacity. The annul PV electricity produced by this programme would be 642.5 GWh per year.

Another thing I would like point out is the solar insolation data got from NASA website. This is the most important data related with the performance of PV system. As we can see from comparison in Chapter 5.1, the solar insolation data is 10 years average data. The PV3 software employed data is less than the 10 years average data, as I believe it is current data. There is 0.61 kW/m2/day difference. To my understanding, this is caused by the degradation of air condition in Beijing area, for the pollution is worse than 10 years ago. The penetration ability of solar energy through atmosphere was reduced. Another difference of data in application is the data we get from NASA is insolation of flat surface. When the PV system is being installed, there is a tilt angle of PV panel to flat. This method will gain the solar insolation level for PV receiving. As PV3 software indicated, the gaining would be 0.52 kW/m2/day for tilted installation. (See appendix 8 Solar insolation data employed for calculation)

6. Benefit of BIPV in China

BIPV as a clean method in electricity production, and will generate electricity without CO_2 emission and other damage to our environment after the payback period of CO_2 emission by fossil fuel consumed during its manufacture. The payback period varies according to different place in the world and local electricity generation structure. The detail is explained in Chapter 6.2. The benefit of BIPV can be divided as avoidance of GHG emission, avoidance of coal burning thus reduces externality cost by coal incineration, economical value of electricity by BIPV and other benefits.

6.1 The Reduction of GHG Emission

6.1.1 The Coefficient of CO_2 Emission Incurred from Coal-burning

Among all the fuels to produce electricity, coal is the biggest contributor of CO_2 emission. As I had mentioned before, 75 % of China's electricity generation is coming from coal-fuelled plant. This context is very rare in the world. Therefore, every kWh of electricity produced in China has more CO_2 emission comparing with other countries.

According to Chinese PV Industry Report 2004(Shi Lishan et. al.), the CO_2 discharging is 1430g/kWh. This data is deducted by 390g standard coal per kWh electricity. See Table 6.1-3. But this data is quite dubious. Even though China's electricity production is higher than other countries in CO_2 emission, but can't be so high. Because this figure is worked out through chemical reaction formula. In reality this outcome can be fulfilled unless in very extreme condition，such as no impurity in coal and 100% complete incineration. In light of ExernE UK report, the average composition of coal in UK's coal LCA analysis is as shown in Table 5.1-1. The pure carbon inside coal is only 60%. In China, the coal's carbon content varies greatly, from lignite(c.a. 50%) to hard coal(anthracite) (80%), for calculation convenient, we take carbon content of 70% as standard coal. By this emendation, the effective data from Chinese PV Industry Report 2004(Shi Lishan et. al.) should be 390*70%=273g/kWh. The coal derived CO_2 coefficient is 1001 g/kWh.

Table 6.1-1 The Composition of Coal (source: ExternE UK report)

Composition of coal	
Water	12%
Ashes	15%
Carbon	60%
Oxygen	6%
Sulphur	1.6%
Hydrogen	3.9%
Chlorine	0.2%
Nitrogen	1.3%

In the book of Solar Application Technology, the current Chinese carbon emission data in electricity production were given(Luo Yunjun et. al. 2005, p7) as coal 275 g/kWh, oil 204 g/kWh, natural gas 181 g/kWh, PV 55 g/kWh, wind 20 g/kWh, geothermal 11 g/kWh, nuclear 8 g/kWh, hydro 6 g/kWh etc. When these data are transformed into CO_2, they should be:

Table 6.1-2 Chinese Carbon Dioxide Emission of Electric Power Production

Fuel for electricity	CO_2 emission g / kWh
Coal	1008
Oil	748
Natural gas	664
PV	201
Wind power	73
Geothermal	40
Nuclear	29
Hydro	22

Table 6.1-3 the calculation model based on a 1W PV cell unit

The CO_2 Emission Level in Electricity Production in China (Shi Lishan, et. al. 2004)	
The consumption of standard coal g/ kWh	390
The CO_2 Emission kg/ kWh	1.4 3
The PV generation kWh/ year	1.5
Subtraction of CO_2 equivalent / Wh PV system annully	2.145 kg 1.4*1.5=2.145 kg/ Wh annually

The CO_2 emission coefficient in electricity production in UK is 654 g/kWh (Talor D and Bruhns H, 2001, p. 6 Table1). In Germany, this figure is 781 g/kWh for coal and 1015 g/kWh for lignite. (ExternE German report, table 2. http://externe.jrc.es/f8b8file2.htm). In the US, according to US Department of Energy, the air emission of major pollutants by using the Best Available Control Technology (BACT) for coal is 1930 lbs/MWh CO_2. (Leitner A, 2002, p32) This figure transits to g/kWh is 875 g/kWh.

The CO_2 Emission Level in Coal-fuelled Electricity Production Comparison g/ kWh	
China	1008
UK	654
Germany	781 (Coal)
	1015 (Lignite)
US	875

Table 6.1-4 The CO_2 Emission Level in Coal-fuelled Electricity Production Comparison

6.1.2 The Coefficient of CO_2e of Methane(CH4) Emission

The methane (CH4) is not produced during combustion of coal, but is released during coal mining. Therefore, to reduce coal consumption in electricity generation will contribute to the reduction of methane release during mining. It is estimated by China Coalbed Methane Clearinghouse in 2004, the coal mining methane (CMM) discharge was about 10 billion m^3. As the intensity of CH4 is 0.717g /litre, or 0.717 kg/m^3 , and the GHG potent of methane is 23 times of CO_2 (Miller, G2005, p. 464)[24], that means the methane releasing weight equals 0.165 billion tons of CO_2 equivalent. Suppose 60% coal was used to produce electricity(Huang Shch,2003, p15), 75% electricity is generated by coal-fuelled plants, and in 2004 electricity generation is 2187 billion kWh (China Statistics Bureau), and electricity incurred CCM releasing will be (0.165*60%)*1000/(2187*75%)=0.06 kg/kWh CO_2e.

6.1.3 The Total Reduction of GHG Emission in CO_2e

To put the result of 6.1.1 and 6.1.2 together, the coefficient of GHG emission in coal-fuelled plants, taking account the CMM emission during mining, should be 1.008+0.060=1.068 kg/kWh.

With the coefficient, the PV derived CO_2e abatement annually from 100,000 Rooftop Programme in Beijing can be calculated. As in Chapter 5 counted, the annul PV electricity produced by this programme would be 642.5 GWh per year. As China's 2004 electricity structure, the electricity can be split as Table 5.1-6

Table 6.1-5 2004 China's Electricity Production Structure （Lu Jianping et. al. 2005）

2004 Electricity	Generation(TWh)	Percent%
Coal-fired Generation	1807.3	82.6%
Hydro Power	328	15%
Nuclear Power	50.1	2.3%
Other	1.6	0.1%
Total	**2187**	**100%**

Table 6.1-6 CO2 Emission Avoided per year of Rooftop Programme in Beijing

Structure	Percent	PV Electricity production /year(G Wh)	CO_2e coefficient (kg/kWh)	CO_2e emission avoided (Mkg CO_2)	CO_2e emission avoided (ton CO_2)
Coal	83.00%	533.3	1.068	569.54	569541
Nuclear	2%	12.8	0.029	0.37	370
Hydro	15%	96.4	0.022	2.12	2120
Total	100%	642.5		572.03	572030

[24] According to IPCC and UNEP's estimation, the CH4 as global warming potential is 21 times of CO2 in 100 years.

On all accounts, the assumed rooftop programme aiming to 100,000 installations in Beijing will produce 642.5 GWh electricity annually. This part of clean energy will reduce 570 kiloton of CO_2e emission comparing with the traditional scenario of electricity production in China.

We must notice that the above calculation does not take into account the consumption of traditional energy during PV module production. That procedure will consume fossil fuel and emit CO_2. The amount of CO_2 emission will be recouped in 3 or 4 year. Only after that, the PV module can be the real "zero emission" generator in electricity production. The follow chapter 6.3 will describe this in detail.

6.2 Atmospheric Pollution Avoidance Derived from BIPV Project

6.2.1 The SO_2 Avoidance Due to BIPV Electricity

According to statistics data coming from China's State Environmental Protection Bureau, the SO_2 emission in 1990 in China is 14.95 million tons. This figure reached 23.7 million tons in 1995 and exceeded the US's SO_2 emission. In 2000, the SO_2emission decreased to 19.95 million tons under the strengthened regulation on coal mining and coal-fuelled plants. But this figure is still the highest in the world. China has become one of the three areas plagued by acid rain. If the trend of burning high sulphur-contained coal continues, it is anticipated the SO_2 emission will triple in next decade. See figure 6.2.1

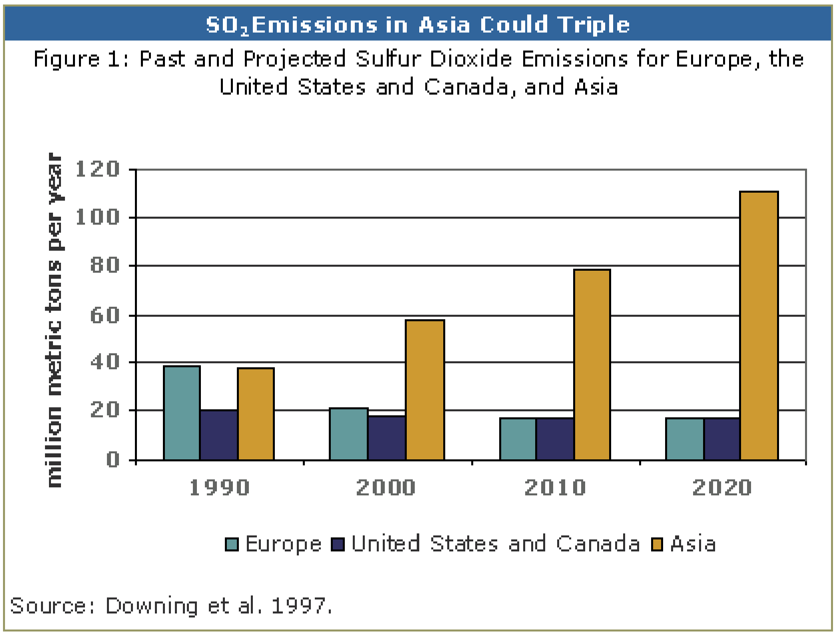

Figure 6.2.1 SO_2 Emission in Asia Could Triple (World Resource 1998-1999)

According to Chinese Electric Power Year Book 2001, the coal-fuelled electricity generated is 1107.94 G kWh in 2000. As I lack the direct SO_2 emission data per kWh in China, the data can be estimated roughly by current data. Since the SO_2 emission by coal-fuelled power plant is 8.9 million ton in 2000(Huang Shengchu et. al. 2003, p. 30), we can get the result of SO_2 per kWh as: $8.9*10^{12}/1107.94*10^{9}=8.03$ g/kWh. Comparing with Germany, the data ranges from 0.288-0.411 g/ kWh. (German Data source: ExternE, http://externe.jrc.es/f8b8file2.htm). The contrast shows how serious the SO_2 emission is in China.

Thus, if we adopt the BIPV system in Beijing, the annual avoidance of SO_2 emission would be:

$642.5*10^6*8.03=5159.28*10^6$ g= 5.2 kiloton

6.2.2 The NOx Avoidance Due to BIPV Electricity

For a long term people only paid attention on SO_2 emission as acidification reason. Actually the NOx affection should not be overlooked. The monitoring data indicates, the nitrous factor in China's acid rain area is increasing.

NOx mainly refers to NO and NO2. About 50% NOx originated by human activities is coming from coal combustion in power plants and industry. According to Huang's report, in 2000 the NOx emission achieved 10.15 million ton in coal combustion. This figure takes account on 65% of the whole country NOx emission. As we know, the adverse impact of NOx is multifold, including irritative effect to human respiration system and damage to agriculture. NOx is also responsible for secondary pollutants. NO is colourless, whilst NO_2 is yellowish-brown gas with choking odour.(Miller, G 2005, p 439) "NO_2 is also the cause of brownish haze that hangs over many cities during the afternoons of sunny days." (Miller, G 2005, p 439) when expose under sun's UV radiation and VOC, the NOx takes a complex series of chemical reaction and produces about 100 primary and secondary pollutants.

VOCs+NOx+heat+sunlight → ground level ozone(O_3)+other photochemical oxidants+aldehydes+other secondary air pollutants

(Miller, G 2005, p. 439)

The electricity generation in 2000 is 1107.9 billion kWh from coal-fuelled plants. (China Electrical Power Year Book 2001). Suppose 60% coal is supplied for electricity production (Huang Shch, 2003, p. 15), the coefficient of NOx/kWh should be 10.15*60%/1107.9=0.0055 kg NOx/ kWh. Thus, the BIPV's yearly production can avoid NOx emission as:

$642.5*10^6*0.0055$ =3.5 kiloton per year.

6.2.3 The TSP Avoidance Due to BIPV Electricity

The dust discharged by coal combustion is close related to the total TSP amount. According to Huang Shengchu's report, in 1995, the coal combustion derived dust reached 14.8 million tons during that year, taking account for 86% of total dust emission nationally. With the enforcement of dedusting / scrubber installation in plants, the dust discharging comes down yearly. However, proportion of coal combustion derived dust still takes account for 70% in the whole emission. See Figure 6.2.3. From the 2001 data, we can get the coefficient of dust and coal consumption.

c = 10.59/1239=0.0085

The BIPV programme can produce about 642.5 GWh electricity per year, which can save 0.25 million [25]ton of coal consumption. Thus, the dust avoided will be:

250000*0.0085=2125 ton /year

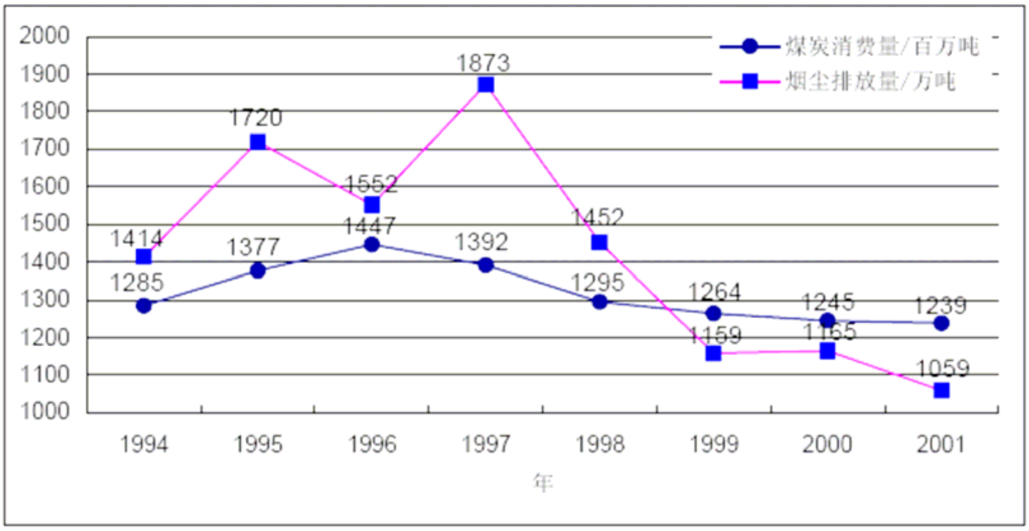

Figure 6.2.3 1994-2001 Dust Emission and Coal Consumption Trend (Square: Dust emission in 10,000 ton, Dot: Coal Consumption million ton)

Source: Chinese Coal Information Research Inst. (Huang Shengchu 2003, p. 29)

6.3 Energy Payback Time (EPBT) of Photovoltaic

Energy Payback Time (EPBT) refers to the time that is necessary for PV module to generate the amount of electricity consumed to produce them. Because this part of energy usually is generated by fossil fuels in most countries, when considering the amount of CO_2 reduction during the life cycle of PV system, we must subtract the CO_2 emission caused by PV module production process. In most people's impression, the EPBT period might be very long, till 10 years or so. Nevertheless, according to recent year's research, with the advancement of PV R&D and expansion of PV manufacture, the EPBT has been shortened significantly.

"Two parameters determine the energy payback time for a PV module -- how it is produced and how it is used."(Karl E. Knapp & Teresa L. Jester, 2000, p. 1) The amount of energy consumed on production is fixed as long as the PV panel is off the streamline. But how it is used could be very different with the different scenarios, such as the installation, tilt angle, fixed or rotating paddle, location, climate etc. the payback time might varies with these conditions. The EPBT can be calculated by the formula:

EPBT=Specific Energy/ Energy Generation Rate=E/E

(Karl E. Knapp & Teresa L. Jester, 2000, p1)

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[25] This figure comes from calculation in Chapter 6.4.2

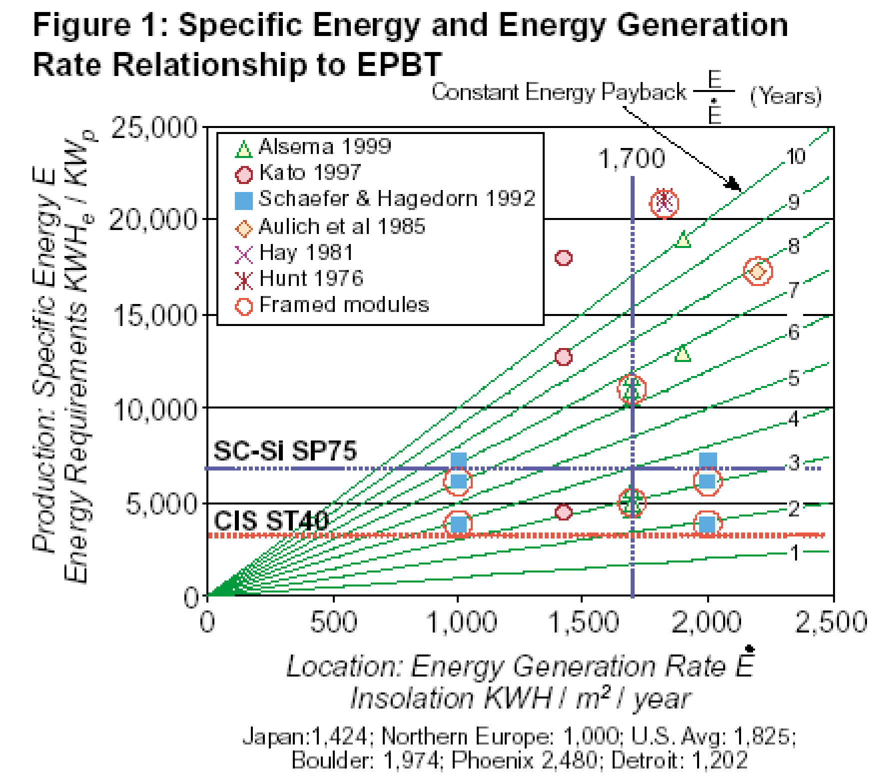

Figure 6.3 Specific Energy and Energy Generation Rate Relationship to EPBT (Source: Karl E. Knapp & Teresa L. Jester, 2000)

Figure 6.3 is the research outcome by Knapp and Jester. They took two PV products, one is Sigle-Crystalline Silicon(SC-SI) SP75, another is thin file copper indium diselenide (CIS) ST40. These two products stand for current two mainstream categories of PV products. As their conclusion, under the solar insolation of 1700 kWh/m2/year, the SC-SI EPBT is 2.9 year. For 1700 kWh/m2/year insolation is equivalent to 4.66 kWh/m2/day (1700/365). We predict the single silicon products may have EPBT time of 2.9*4.66/4.31=3.13 year in Beijing in pursuance of Beijing's solar insolation condition. Generally PV has a life span of 25-30 years. So after EPBT time, the PV system becomes net energy producer.

6.4 Social Economic Benefit Analysis

6.4.1 Peak-shaving Function during Daytime

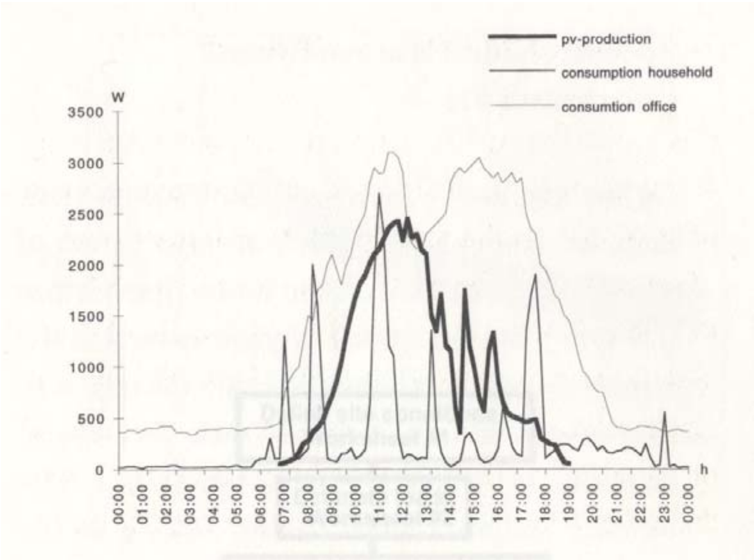

Figure 6.4.1 Daily Load Profile of a 5-person Household and an Office with 10 Work Places Compared to the Energy Production of a 3 kW system in Partly Overcast Conditions (Sick, F & Erge T(1996), p159)

The PV's output is in proportion with solar irradiation intensity. As shown in Figure 6.4.1, the electricity generation will get peak around noon time. The PV's output profile has a big part overlapped with household and office load profile. Therefore, PV system has evident peak-shaving function, particularly in hot summer noon. As the result of PV's peak-shaving function, the peak load demand get cut down obviously. Since the data gap in China, I can't find 24-hour daytime graphics to depict the grid load condition. The figure 6.4.1-2 is the data from California, America for reference.

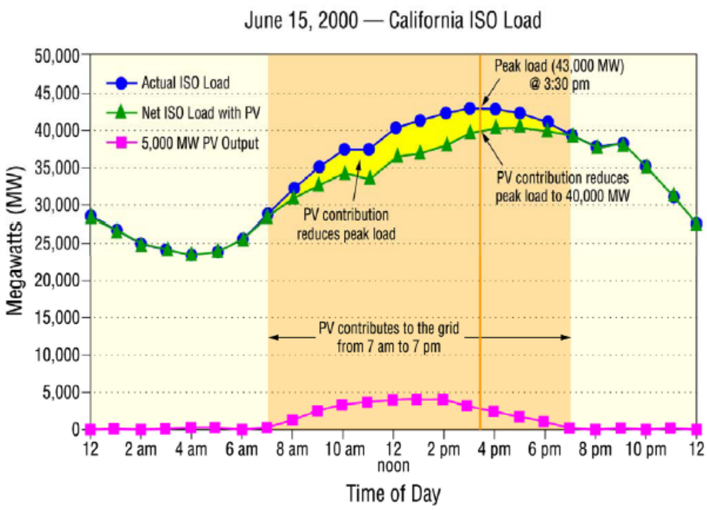

Figure 6.4.1-2 PV's Peak-shaving Contribution in CA, US. (Source: First Solar, 2005)[26]

[26] ISO, Independent System Operator

6.4.2 Economic Benefit Analysis

As the primary result we have got, the 100,000 BIPV project will realize 5kW*100000 =500 MW capacity. According to China's investment on coal-fired plant, the basic standard is RMB 8000 / kWp. If the 500 MWp capacity will realize by coal-fuelled plant, the investment is 4 billion. According to PV3's calculation, a 5kWp PV system will cost RMB 206,513. To realize 500 MWp in PV system, the cost would be RMB 20.7 billion approximately. It is over 5 times of the coal investment. The high cost of PV system is still the bottleneck against its penetration.

According to current China's coal-fuelled plant production level, it will need 390g Standard coal to produce one kWh electricity. The annual production of this PV project will be 642.5GWh. the saving on coal will be

$642.5*10^6*0.39$kg=0.25 million ton.

As the current market price 350 RMB / T, add 3% price increase rate per year, in 20 years, the avoidance of coal usage will be

$0.25*10^6*350*(1+1.03+1.03^2\ldots+1.03^{19})$ =2.32 billion RMB

In fact, to compare PV electricity's cost with bulk electricity delivery is not impartial as PV electricity's peak-shaving character. The delivery of electricity during peak hour values times of bulk supply by utility. For example, in the time of hot wave attacking, the utility supply is most stressed and vulnerable in big cities like Beijing and shanghai. The inhabitants suffer from power failure time to time when temperature exceeds 37 centigrade. Many of them would afford times of plat price to avoid this. So the PV delivery during this time values higher which shortens the gap of price with traditional electricity. Another reason appreciate PV's peak-shaving function is the high cost for utility to meet the peak load demand with their transmission and distribution (T&D) system. The peak delivery can release the pressure of T&D, enhancing system's robustness, avoiding expensive new investment on capacity escalation and transmission ability enlargement. This feature of peak-shaving should not be doubted, see Figure 6.4.1-2 in Chapter 6.4.1.

The more environmental-benign character of PV is its free emission of GHGs and other hazardous gases during operation. Take into account coal's externality cost, which will be discussed in Chapter 6.4.4, the value of PV can make balance with traditional energy. That is a "panorama" view of PV's value, which includes its peak-shaving value and external-cost avoidance.

In a nutshell, PV electricity is not cost competitive to coal-fuelled electricity in current market mechanism (market failure), but its value in peak time context and environmental-friendly character exceeds its cost. That's where its attractiveness lies. That's why policy-makers should interfere and make PV favourable policies and economical incentives to redress this bias in market.

6.4.3 Estimation of PV Electricity Cost

According to PV3's calculation, the investment is 206,500 RMB per 5kWp system, suppose there are 50% bank loans, and the interest rate is 6%, instalment term is 10 years. Exclude inflation influence, 10 years bank interest should be 34,072 RMB. If we assume the 20 years period the system works perfectly, the total output should be 6245*20=128,500 kWh electricity.

Thus the electricity cost of PV system would be (206500+34072)/128500=1.87 RMB/kWh

Normally the current market price of electricity is 0.44 RMB/kWh. The BIPV electricity cost is 4.25 times of market price electricity.

How to offset the gap?

Refer to Germany's experience, we can adopt green price policy. The approach is: calculate the sum of PV electricity cost and the gap need to be compensated. The gap is covered by the national electricity charge. In fact the extra pay per family bill is very small, about 12 Euro per family in Germany in 2003. (EPIA(2004), p. 36). In 2004, the additional pay per family is around 1.10-1.47 Euros per month in Germany. These extra charge accumulated is quite considerable of the whole country. But this part of gaining can't be the profit of utility company, it is used for purchasing the high cost electricity from household producers (BIPV) and other renewable energy producers. Therefore everybody contribute a little, say, 1 cent in electricity bill for every kWh, but solute the problem of subsidy for PV electricity. According to statistics, in 2004, the FiT subsidy to PV electricity is 204 million[27] Euro in Germany (Source: VDN, 9, Feb, 2005). The consumers are glad to install PV systems, because they will get profit from "selling" surplus electricity to company. Obviously 5 kWh PV system is big enough to cover most household need and future increase capacity. The government should act as a good mover for the propaganda work, to explain to citizens the enhancement in electricity charge and the virtues of BIPV system. The utility company doesn't lose anything, but they are responsible to provide grid connection service. That is one of the key parts of this project's success.

[27] this figure includes FiT to small PV plant and BIPV end-users, the figure of 2003 is 144 million Euros

6.4.4 Externality Cost Avoidance by BIPV

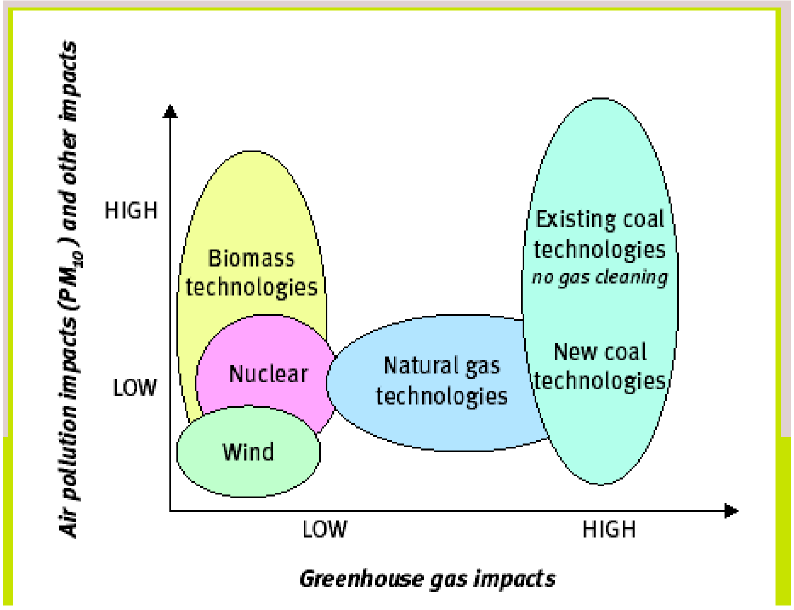

Figure 6.4.4 Impact of different fuels for Electricity production (Source Busquin P 2003, p. 12)

Among all the fuels to produce electricity, coal is the most pollutant one. The new coal burning technologies alleviate this situation, but don't eradicate the essential roots to pollution. Unfortunately, Chinese coal-fired plant are still in the phase of low efficiency and high pollution in production. As shown in figure 6.4.4 the Chinese power plants should be in the high-high area(high GHG impact and high air pollution impact). Due to long term relying on coal-fired mode, which has shaped most people's mindset, the research on externality of coal in electricity production was overlooked. The relative data on externality of coal-fired electricity production is scarce in China.

In 2003, consigned by World Wildlife Fund (WWF), correspondent to WWF's global campaign of "Power Switch", which aims to decrease the global GHGs emission in electricity production and decelerate the global warming process, an investigation on Chinese coal utilization and the impact from coal-burning was implemented by Clean Energy and Environment Centre of Chinese Coal Information Institute in Beijing. This topic finally produced the report of "*The Research on Environmental Impact of Chinese Coal Exploration and Utilization*" (Huang Shengchu, et. al. 2003). This report might be the most thorough research on coal's impact in China and calculation of coal-fuelled externality till now.

For calculation of external cost stemming from coal-burning, they adopted the following model:

Externality = (the whole loss caused by coal-burning in electricity generation)÷

(the coal-fuelled electricity)

The whole loss caused by coal-burning in electricity generation include:

The following Table 6.4.4 summarized the estimation of Huang's research on economic loss by coal-fuelled plant in China.

Damages & Impacts Caused by Coal-burning from Power Plants in China(RMB Billion)	
Damages from Acid Rain and Fee Spent on SO_2 Prevention	50 ca
Damages to People's Health(SO_2 and TSP[28])	60 ca
Impact from CO_2 and other GHGs	Not available
Impact to Ecosystem(mainly damage to water resource & pollution caused by tailing of coal-burning)	44 ca
Investment on Prevention of Coal-fuelled Plant Pollution	44.4 ca
Total Cost	**198 ca**

Table 6.4.4 Damages & Impacts by Coal-burning from Power Plants in 2001 in China(Source: Huang, et. al. 2003)

Thus, as the electricity generated in 2001 is 1081 billion kWh, the externality of coal-fuelled electricity would be 0.18 RMB/kWh. (Huang et.al. 2003, p50). This result is quite lower than other countries for many losses didn't included in consideration. The limitations are: the GHGs effect didn't include into calculation; the impact to ecosystem didn't include species degradation; the calculation of damage to human health adopted 1995's data. All these factors caused the externality value tending to lower deflection. However, this report did an attempt in externality estimation. Even its accuracy need further rectification, it initiated a start of research on this field in China.

It is an obvious deficit that Huang's report didn't count on CO_2 emission impact. For estimation, an alternative method is taken for this thesis. As we all know, today's CO_2 trading price in international market is 5-7 Euros(50-70 RMB, according 2005 July Exchange Rate) per ton of CO_2. From the data we have mastered we can deduct the estimated value of CO_2 impact per kWh coal-fuelled electricity. The CO_2 emission parameter is 1.068 kg/kWh, times the CO_2 price, the CO_2 impact value would be 0.05-0.075 RMB/kWh. This price is only for reference. For the trading price is the lowest in market. Some brokers will sell the CO_2 credits purchased from developing countries to industrialized countries whose implementation of GHG reduction will be more expensive or hard to fulfil. For various energy production structures, different countries differ greatly on CO_2 reduction cost.

Therefore, to summarize current research result, the externality cost will be

0.18+0.075=0.255 RMB/ kWh

The externality cost avoidance from such rooftop programme will be:

$642.5 * 10^6 * 0.255 =$ 163 million RMB/year

6.5 Sensitivity Analysis and Horizontal Comparison

The cost of PV electricity we got in Chapter 6.4.3 was based on 20 years life span assumption. Actually today's PV system's design life is 25-30 years. If we average the cost to 25 years or longer, the cost of electricity would be lower. The detailed estimation can refer to Table 6.5.1

[28] TSP, Total Suspended Particles

The other influential factor is interest of loan. Zero interest rate will shorten recovery time one year or so. The loan is supposed as 10 years term, half of the investment, 10 instalments, with 6% annul interest rate. Exclude inflation interference, the accumulating interest in 10 years would be 34 kilo RMB. (See Table 6.5.2) From table 6.5.1, we can see the scenarios with or without interest how the influence will be to the PV electricity as well as to the recovery time. Therefore, zero interest can be used as an financial incentive when making the BIPV incentive policy.

Table 6.5.1 PV Electricity Comparison in Different Situations

System Life Span	20 years	25 years	30 years
PV Electr icity Cost(RMB/kWh)	1.87	1.5	1.25
PV Electricity Cost(RMB/kWh) (Zero interest bank loan)	1.60	1.28	1.07

Table 6.5.2 The Calculation of Interest Incurred by 10 Years Loan

Year	1	2	3	4	5	Sum
Credit Amount	103250	92925	82600	72275	61950	
Interest Rate	6%	6%	6%	6%	6%	
Interest	6195	5575.5	4956	4336.5	3717	
Year	6	7	8	9	10	
Credit Amount	51625	41300	30975	20650	10325	
Interest Rate	6%	6%	6%	6%	6%	
Interest	3097.5	2478	1858.5	1239	619.5	34072

Nevertheless, the data from other countries is useful to refer when we make a horizontal comparison. Refer to European data, the externality is around 5-8 Euro cents / kWh. (See Appendix 3.) In UN's report, the externality should be 0.53 RMB in China.(This data has not been verified yet). Because incineration technology and lack of cleaning devices in stacks, this figure should be higher. Considering the other benefit such as GHG reduction and savings on electricity transportation, the electricity from BIPV is competitive after including externality cost and contribution to T&D system due to its peak-shaving characteristic. Comparing with coal-fired electricity, the PV electricity mode should locate at low-low area in Figure 6.4.4, which means low GHG impact and low air pollution impact, for PV will be net zero emission after EPBT.

6.6 Final Price Comparison of PV Electricity and Coal-fuelled Electricity

System Life Span	20 year	25 year	30 year
PV electricity cost(RMB/kWh)	1.87	1.5	1.25
	With externality	Without externality	
Coal-fuelled electricity cost(RMB/kWh)	0.70[29]	0.44	

Table 6.6 Final Price Comparison of PV Electricity and Coal-fuelled Electricity

6.7 Other Benefits

6.7.1 Savings on Building Materials

If a solar system is integral part of a building, the money spent on decorative materials such as marbles on facade and tiles on the roof can be invested in PV modules. The PV module will function as building envelope and energy producer. As the proportion of BIPV and BAPV are not certain in the virtual 100,000 rooftop programme, it is hard to give a quantitative number of savings on building material. But some construction material price can get according to current construction material market. These material include: Floating glass, marbles and other decoration materials etc. What we can speak definitely is the higher integration of PV and building in BIPV design, the more building material we can save in construction. Some building material are even close to PV module price, thus make the PV module more rewarding for investors or house owners.

6.7.2 Reducing Heat Island Effect

Heat Island Effect(HIE) always appears in urban area in summertime. The ambient temperature in hot summer days in urban could be 10 degree higher than countryside. The reason causing this phenomenon is the buildings, pavements and other infrastructure covering the natural land. To keep desired temperature indoors, the air conditioners consume more energy and release more heat to environment which deteriorates this condition. The vitreous facades on high buildings reflect to each other also contribute to the heat accumulation.

The PV panels installed on facade and rooftop can absorb most the sunlight cast on them. This counter effect cools the buildings and at the same time, ameliorates the interior HVAC[30] condition and reduces the requirement for air conditioners.

6.7.3 Efficient Pattern of Distributed Electricity Generation

BIPV is distributed around the cities, close to electricity consumer, these part of electricity produced avoid transporting loss, so it is the efficient way of electricity transportation. In a long time, people deemed transporting loss in grid a must consumption, which takes for about 6% to 10%. The distributed BIPV provide a new idea to avoid this problem instead of superconductor which is still in lab testing phase.

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[29] this externality include Huang's calculation of 0.18 RMB/kWh (Huang, et. Al., 2003, p. 50) and estimation of CO2 price 0.07 RMB/kWh (figure from Chapter 6.4.4 last paragraph)

[30] =Heating, Ventilating and Air Conditioning

Chinese State Power Information Network published the loss rate during electricity transfer in lines. The year of 2001 loss of transfer is 7.55%, 2000 loss is 7.81%. As the annually electricity generation is very high in China, 1438.8 TWh in 2001 and 1368.4 TWh in 2000. The loss in lines would be very astonishing. PV systems avoid most of this loss because the electricity produced by PV is consumed on site. To build a basic conception, the 100,000 Rooftop programme can avoid transfer loss of 642.5 GWh * 7.55%=48.5 GWh per year.

7. Framing the Financial Support Basis for BIPV

The 2002 "Song Dian Dao Xiang" Project is the biggest action recently. The project is mainly aiming to solute North-western counties electricity issue. The financial support came from government appropriation, so this is not real market or commercial meaning action. To lead BIPV develop in commercialized approach, a delicate and sensitive financial scheme is necessary. That should include, initial fund for pilot project, loan for private purchasing, favourable tax for PV industry, pricing system for multilateral profit and subsidy for renewable energy production.

In respect of current energy market, PV electricity as the clean, environmental sound energy is still uncompetitive to electricity generated by fossil fuels. Partly due to the externality cost of fossil fuel is not embodied in price, and partly due to traditional energy domain still gets allowance from government which exacerbate the price distortion. Anyhow, the experience proved that at the initial phase, government should take proactive measures to make a level competition arena for renewable energies with traditional energies.

Another reason calls for government to make favourable policies to renewable energy is the demand by investors on renewable energy. To secure the investment's safety, the investors need stable, durable and predictable policy framework to guarantee their profit. On the contrary, a 15-20 year stable policy will enforce investors' confidence and attract more investments to renewable. A wise political policy-maker should not overlook this avenue to utilize the new source of financial channel.

7.1 Favourable Tax Rate

The custom should differentiate the importing tariff of PV modules. For importing of finished PV products, the tariff should be higher than raw material and semi-conducts. (Lishan, Shi et. al. 2004, p48) For finished products exporting, the enterprises can enjoy tax-return favour.

For PV use sun light to produce electricity, there is no fuel cost to be deducted from revenues for tax purposes. Thus PV revenues as the income to residentials should be exempted from Value-added Tax (VAT).

Income Tax rate in China is 33%. If the residential revenue derived from FiT policy falls into this scope, the pay-back time would be prolonged extraordinarily. Considering the contribution of clean energy to our environment of BIPV, it is highly recommend exempting this tax.

To stimulate the sales and application of national products, the PV system using national products can get refund. To encourage the national products' market share, the retailers who deal with national PV products can also enjoy favourable tax rate at the end of yearly turnover.

7.2 Ad Hoc Fund

These funds should used for supporting of PV new technology research, labs and subsidy for low interest loan for BIPV system. The sources should be: the carbon tax from coal-burning plants, the green price levied from national scope electricity, the special aids from international agencies.

7.3 Bank Credit Loan

This part is the toughest to deal with. With the risk control systems are getting reinforced by national banks, the planning economy mode is phasing out of banking administration. The national banks are in their own role in determination of issuing loans. The governmental influence or interference are reduced nearly to zero. Considering the uncertainty of BIPV programme, it is hard for personal applicants get loans from commercial banks. Even though, the government still perform an important role except making favourable policy to BIPV's development. The positive action could be: the government appropriates some subsidy or initial fund and consign commercial banks in these funds management.

7.4 FiT Financial System

The aforementioned 3 aspects are all important for the pilot project to take off. However, to ensure the project develop in healthy, sustainable way, a delicately designed pricing system is necessary and crucial. On this point, Germany did well and had a lot of experience valuable for other countries. The most typical and triumphal financial support should be FiT policy.

To pick Germany as the research objective is due to China and Germany have somewhat similar characteristics in energy structure. For instance, both countries have heavy reliance on coal as fuel for electricity production. Germany has 24% coal and 27% lignite.(J Schleich et. al.2002, p. 151) both countries have big share of energy production in regional area. Germany accounts for 20% energy demand of EU ((J Schleich et. al.2002, p. 148). The 2004 electricity production reached 2187 TWh, ranked second in the world, almost two times of Japan's production. (China.org news) The China's energy scale has the capacity to affect the district or even asia-pacific energy market.

7.4.1 Essence of FiT Policy

First, the FiT is paid in light of the production of BIPV. i.e. it is a performance based incentive. The more electricity produced, the more the BIPV's owner will get paid. That will encourage owners pay more attention on the BIPV's output and always keep it in efficient condition. Thus avoid the drawback of device left unused which once appeared before. In 1999, when German 100,000 rooftop programme was first initiated, the government provided very attractive soft loans. The loans are 0% interest over 10 years and the instalment repaid in 8 times from years 3 to 10. the last instalment would be cancelled if the BIPV system is still working at that time. Nevertheless, the response was slow. The first year installation were only 9 MWp, half of the aim expected. (Hon Grant, et. al. p2)Comparing with FiT, soft loans are less effective at first phase of sales promotion. What attractive point of BIPV is the long-term, foreseeable repaying commitment. So at the second year of 100,000 programme, the 0% interest loans were cancelled.

Second, FiT is in favour of technology progress and price decline. Usually the FiT is degressive in 5% rate annually. This measure aims for stimulation of technological progress. As different companies will compete on the market, this will ensure the lowest price is favourable for new PV installation. This mechanism will form a pressure to PV manufactures to reduce cost and adopt new technology or increase input to R&D. The rate of 5% is also coordinate with the experience of these years price- going trend.

Third, FiT doesn't add burden to fiscal budget. This is the unique character of FiT. For FiT is coming from people and used for people, it is separate from government fiscal budget. "Unlike investment subsidies, tax rebates etc. does not create burdens on the state budget and as such will gain political acceptance more easily."(European PV Association's Position Paper 2005, p8) The independence position of FiT can avoid financial shortage when the budget is cutting for deficit. The electricity consumers are the steady source for FiT supply.

The green price system must accept monitoring under some special agencies, such as Green Peace in Netherlands act in this role. In China, it should be acted by the third party such as auditing bureau or accountant company. The auditing result should publish periodically for transparency.

7.4.2 How to Scheme the FiT Rate

Refer to the PV electricity cost calculated in Chapter 6.4.3, the PV electricity is 1.87 RMB/kWh. The assumed payback time is 20 years. If the FiT would take this standard as purchasing price for utility, obviously it is not by a fraction of attractive to investors on PV system. Thus, the FiT should be big enough to ensure the magnetic power for investment.

The PV electricity cost in China has no difference from Germany. At the same time, the Chinese family income level is much lower than German family. The actual value of 200kilo RMB in Chinese family and 20kilo Euro in German family is quite different, even though they have the same value in currency. When stipulating the FiT policy, it is necessary for policymakers notice this point and make the FiT level not less than German standard. That is to say, no less than 0.5 Euro/kWh at the first year.

The second key point should be the amount of electricity generated effective for FiT. As the model is on-grid, which means the electricity is fed into grid immediately. In theory, all the electricity counted by the feed-in metre should be compensated by the FiT. The consumption of consumer will be counted by another metre. The BIPV installers still pay their electrical bill as their bills show in flat price. But the PV electricity is recorded and they will get paid from utility for FiT monthly or seasonally.

Suppose the programme of 100,000 rooftop is finished, the annual production of electricity will be around 642.5 million kWh. The annual FiT subsidy will be $642.5*10^6*5=3.2$ billion RMB. The 2003 electricity consumption in Beijing is 47 billion kWh (Chinese National Statistics Bureau). Suppose annual increase is 6%, in 2006 the electricity consumption would be 55.64 billion kWh. The FiT incurred electricity increase would be 0.058 RMB/kWh. According to electricity consumption per family data in Chapter 5.2.2, the range of consumption is 1320-2200 kWh per family per year. Thus the extra expense on green price for BIPV's FiT would be 76-128 RMB per family per year. According to data of Beijing average income statistics in Chapter 5.1.2, we get the income per family per year as:

2.94*1455.22*12=51kilo RMB.

The extra expense on FiT takes account for 0.0015%-0.0025% in annual income per family. This figure would be affordable (acceptable) for most families.

Due to a 5% yearly decrease rate, the payback time of BIPV investment under the FiT policy could be traced in Table 7.4.2:

The initial investment will be recovered on the 8th year.

or considering interest factor

the total investment in addition to interest will be recovered on the 9th year.

Table 7.4.2 The predicted annual income under degressive FiT policy

Year	FiT Rate(RMB/kWh)	Recovery(RMB)
1	5.00	32125
2	4.75	30519
3	4.51	28993
4	4.29	27543
5	4.07	26166
6	3.87	24858
7	3.68	23615
8	3.49	22434
9	3.32	21312
10	3.15	20247
11	2.99	19234
12	2.84	18273
13	2.70	17359
14	2.57	16491
15	2.44	15667
16	2.32	14883
17	2.20	14139
18	2.09	13432
19	1.99	12761
20	1.89	12122
Sum	64.15	412173

In summary, the BIPV could be recovered in 8-9 years and after that, the consumer can enjoy the subsidy for 11-12 years, with annual income of 12kilo RMB to 20kilo RMB.

As the FiT policy is 20 years long. On the 20th year, the FiT rate is 1.89 RMB/kWh, still higher than the first year price of PV electricity cost. It is absolutely certain to predict the PV electricity would be much cheaper then. To ensure the confidence of investors, the utility will purchase the PV electricity at least the same level of flat price after 20 years when the FiT policy ends. Namely, after 20 years, the BIPV installer can continue enjoy nearly free electricity consumption. The PV output can offset most of the yearly electricity consuming. What's more, if the electricity consuming is less than production, they can continue earn money from utility. See Figure 7.4.2 Three phases of BIPV benefit to residentials.

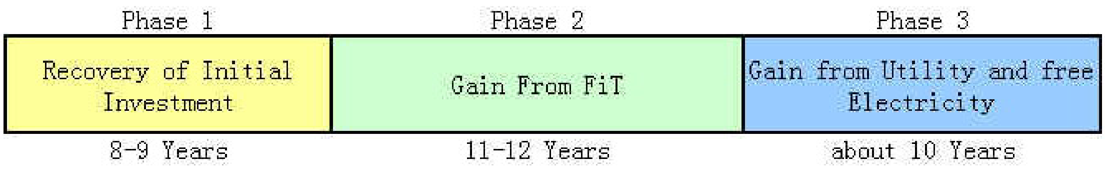

Figure 7.4.2 Three Phases of BIPV benefit to residentials

7.4.3 The Drawbacks Should Be Shunted in FiT Implementation

1. The Scope of FiT in This Pilot Scheme

As the calculation indicated, the executive scope of FiT in Beijing city will be enough to cover the financial subsidy raised by FiT. But that situation is limited for pilot scheme. When the BIPV scale develops larger, the surcharge on electricity would be too high to bear for inhabitants. The high electricity price also weakens local industry's competence against other provinces. If the scope of FiT surcharge expand to other province, they will feel unfair for they can't enjoy the benefit of BIPV while contribute to the system. So when the BIPV develops to some extent, the FiT scope should also expand to adjacent provinces, or take the pattern of combination. Otherwise the subsidy source will be difficult to collect.

The other possibility is to penetrate FiT in light of Grid Companies' administrative scope. After 2002 reform of Chinese National Power Assets, there were 5 grid companies established under the supervision of National Grid Corporation. See Figure 7.4.3. Beijing belongs to Huabei Grid Company with other provinces such as Inner Mongolia, Hebei, ShanXi, Shandong and Tianjing City. The distribution area can be seen in Figure 7.4.4. In 2004, the annual electricity turn over is 357.1 billion kWh.(Source: Chinese State Power Information Network http://www.sp.com.cn) If the FiT policy is put in Huabei Grid Company scope, the possibility of operation is enforced. If the surcharge of FiT is shared in this scope, the adding part will be more acceptable per family.(ca 0.009 RMB/kWh)

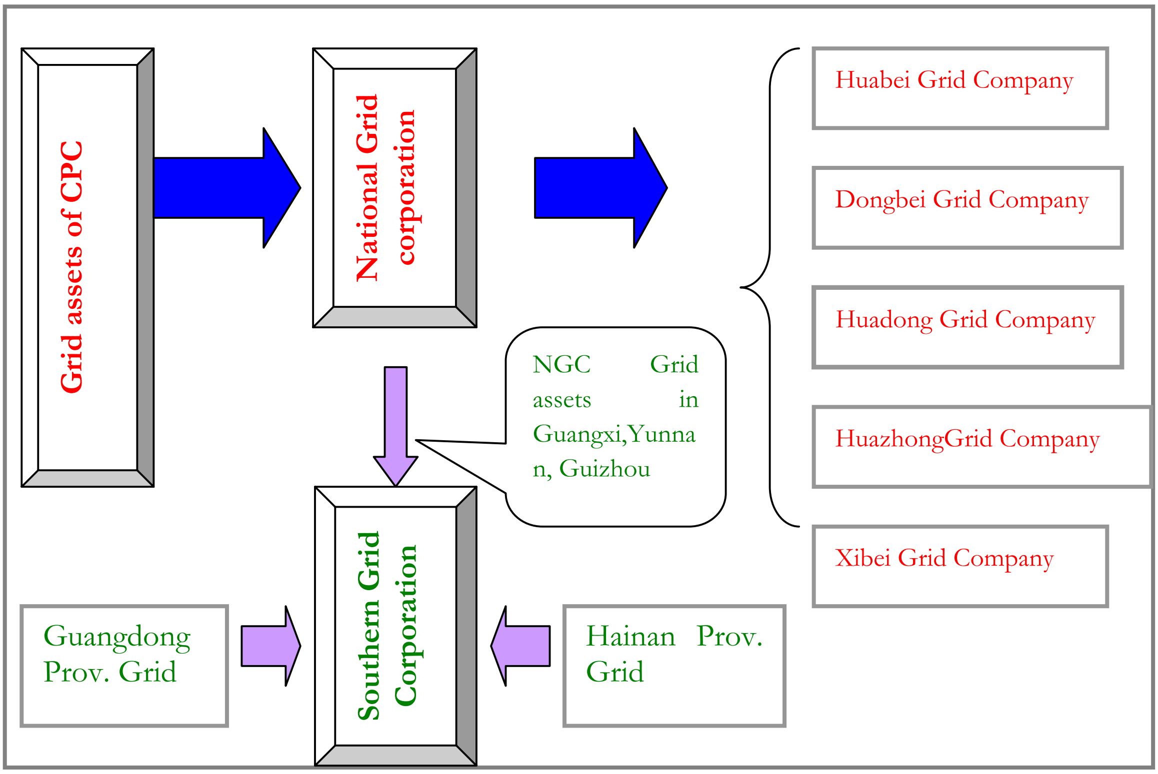

Figure 7.4.3 The National Grid Structure (Source: http://www.china5e.com/focus/reform/dianligaige.htm) (Bo Xie,iiiee,2004, p11)

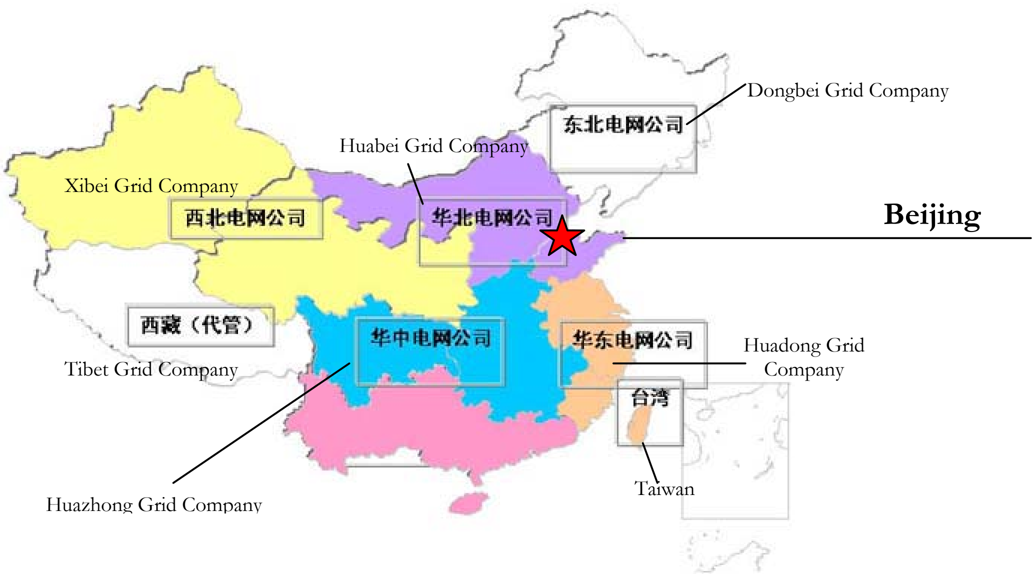

Figure 7.4.4 The Grid Companies after Chinese Electrical Power Reform in 2002.[31] *(Source:* http://www.china5e.com/focus/reform/dianligaige.htm*) (Bo Xie, iiiee,2004, p12)*

[31] Source: Bo Xie,iiiee, 2004, p12

2. The Term of FiT should be fixed to 20 years

As the other countries experience, the FiT policy must keep a stable period to strengthen investors confidence. A swagging policy will damage the pillar of trust and finally lead to project failure. With the inflation rate, the rate of FiT should also adjust slightly on the 5% annual decrease proportion. The term of FiT for recovery should be confirmed on binding contract.

3. The subsidy to fossil fuel consuming plant should be cancelled gradually

As FiT aims for redressing of distorted energy price of fossil fuelled plants, the subsidy to fossil fuel consuming is irrational and will offset the effect of FiT. Considering the reality of China's energy context, the cancellation should be conducted step by step to avoid big shock to industry. But cancellation of fossil fuel subsidy should be scheduled on time table and make buffer time for companies to be ready.

7.4.4 How to Implement FiT

Once the CREL enter into force, who will be the deputy to pay investors for their renewable electricity is a practical issue. The utility company will be a suitable representative entity responsible for this issue. One reason is in terms of current Chinese electricity charging system, the utility company is the collector of electricity consuming. The other reason is the utility is also responsible for the maintenance and metering of consumption. As supplementary regulation of CREL, the responsibility and obligation should be clarified of both stakeholders (customer and utility).

Responsibility:

i The utility company should issue certificate to BIPV consumers stating that if the renewable energy system is eligible for grid-connection, electricity feed-in and transmission.

ii The statement in written of the amount of electricity generated during the charging period (per month or per year)

iii The utility company should notify in 5 working days the applicants if the incentive payment will be issued or denied with reasons.

Obligation:

i The consumer or BIPV installer has the obligation to keep and reserve the original receipt and records of incentive payment for 5 years.

iii When there is error in payment, exceeding the correct payment. The consumer should agree the deduction of redressing amount in the future months. On the other condition, the utility is obliged to pay additional payment if the amount of incentive paid is less than correct number.

7.5 Utilize CDM mechanism to implement BIPV programme

7.5.1 What is CDM

Clean Development Mechanism(CDM) is one of three mechanism of Kyoto Protocol Implementation. To learn CDM well, we must start from the coming of Kyoto Protocol. In 1997 the third conference of UNFCCC, the member states met in Kyoto, Japan to negotiate the limit of GHG emissions. The conference published Kyoto Protocol featured in two: (1) legally binding Annex I countries to collectively reduce GHGs emission by more than 5% from 1990 level by 2008 to 2012; (2) a set of mechanism to help countries achieve their commitments at the lowest cost. The 3 mechanisms are: Joint Implementation(JI), Clean Development Mechanism(CDM) and Emission Trading(ET). These mechanisms, especially CDM, aimed to help developed countries(in Annex I) to meet their mandated emission deductions in cost-effective way. The communal idea of these mechanisms are on the basis of that the reduction cost may vary greatly from region to region while the effect of GHG reduction is the same globally. The main idea of CDM is: the developed countries invest in developing countries for some GHGs reduction projects. Such investment allow developed countries earn Certified Emission Reductions(CERs) and get their reduction mission correspondingly. JI and ET are mainly fulfilled inside Annex I countries.

7.5.2 CDM and CO2 Reduction in China

China as a developing country doesn't have the reduction mission according to Kyoto Protocol. But as the second biggest GHGs emission country, China will actively cooperate with other countries in GHGs emission reduction and decrease GHG emission voluntarily. CDM is a flexible mechanism and an avenue to channel financial support for developing countries in enhancing clean production technology and ameliorate environment. Thus it could be regarded as a win-win solution.

Today with the appearance of specialized company which is dealing with CERs, the CDM is more flexible in implementation. As the CO2 etc GHGs are valued with specific prices in international market, the CO2 reduction amount can be certified by agencies and approved by Executive Board(EB) of Kyoto Protocol. The CERs can be traded as commodity. The BIPV project such as the one conceived in Beijing will produce considerable CO2 emission. It is qualified for CDM project and can apply for CDM certificate in order to get CDM financial support. According to current international CO2 trading price, one ton of CO2 will cost 5-7 Euros. The annul CO2 reduction by Beijing 100,000 Rooftop Programme could produce business value of 2.9 to 4[32] million Euro per year. This fund could be part of subsidies to residential PV users.

[32] 570 kilotons (figure from Table 6.1-6) of CO2e per year times the CO2 price 5-7 Euros/ton

7.6 Establish Differentiated Electricity Price System ASAP

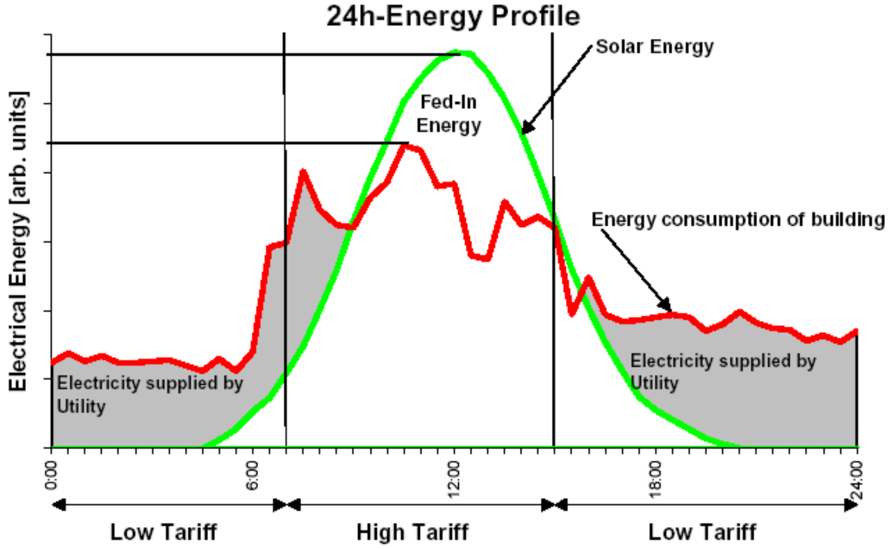

Figure 7.6.1 Varied Tariff of Electricity during a Day(Hoffmann, W, 2004, presentation)

The current electricity price for Chinese residentials is still uniform standard. That means, the consumed number in household metre times a fixed price are the final charge of electricity. The uniform price system has many shortcomings. The biggest one is this system is no helpful for peak-shaving. The peak hour and bulk hour adopting the same charging level goes against building scientific power consuming habits for consumers, such as to arrange rational electricity consuming time, to avoid concentrating in peak hour and lessen the grid pressure. As Figure 7.6.1 shows, if electricity is charged according to different hours during a day, some shrewd consumers will actively remove heavy electricity consuming time-table to non-peak hour to save money. The moving peak hour effect will be very obvious thus release the grid pressure in peak hour.

To adopt a differentiated electricity pricing system is helpful to shorten the gap of PV electricity and conventional fossil-fuelled electricity. For PV electricity out-put diagram is quite consistent with electricity demand curve, the peak hour demand in the day is quite overlapping with the peak output of PV, so the BIPV can incarnate itself more valuable. The differentiated pricing system can also drive people on energy-saving. Therefore, it is imperative to enact this reasonable pricing system ASAP.

8. Other Recommendations for Policy-makers to Push BIPV Application

8.1.1 Set Definite Roadmap under the Framework of CREL

CREL as the support in law for renewables not only include solar energy, but the other renewable energies. Therefore for a directive document to PV industry, it is still a vacancy need to fill up. The PV roadmap is such a profile document in detail set the short-term(3-5 years) middle-term(10 years) and long-term(20 years or more) target for PV industry and market expansion as well as supportive policies, financially and politically. To ensure the China PV development in solid basis and stable policy protection, it is necessary to set up such a roadmap as the bridge for political will and industry confidence, and guarantee the investors' profits. This profile is also helpful to create a thriving PV market.

The roadmap of PV should include:

- Where we are, the current status of PV industry and application, as well as the technical level we have got for PV efficiency;

- Where we will go, the three phases (short-middle-long) of development goal, in capacity and capability of production. The technical standard and goal for PV efficiency we will reach should also be included. The market capacity and scale as the result of promotion effort should be anticipated;

- The political support, including supporting policy, request to utility and guarantee to private investors. The policy should be fixed to 20 years long. The government should initiate a rooftop photovoltaic programme ASAP, the scale can range from 100,000 to 150,000 residential systems;

- The financial support, including FiT policy, tax favours, special funds for R&D etc.

In summary, roadmap of PV is a profile indicating the industry and market development. It is developed under the framework of CREL, and should not conflict with it. It works as the guidance for PV industry, reference for investor consultants, technical developers, and memo for politicians. Even though it does not have the power of law, it functions as the supplement file to key stakeholders.

8.1.2 Synergy of Energy Department and Construction Department

It is very important for cooperation between these two departments. When stipulate the energy consumption standard, it is impossible to skip the participation of Construction department, in particular for BIPV standard, for BIPV is so close related with building design.

The mandatory policy of "Energy Certificate" should be promoted to all the newly built buildings. The Energy Certificate is the document looks like the list of building energy consumption in different seasons. The BIPV's function such as energy saving and reduction of GHGs emission could be one of the items. This measure is corresponding to energy saving law. The BIPV's advantages will be underlined for the penetration of this policy.

The code for architecture design, construction and BIPV's criteria should incarnate this idea of partnership. The penalty to violators should be regulated. This will promote the synergy of different departments and avoid buck-passing phenomenon.

8.1.3 Capacity Building for BIPV

"Capacity building can be defined as the development of an organization's or individual's core knowledge, skills and capabilities in order to build and enhance the organization's effectiveness and sustainability. Capacity building can also include the creation of an enabling environment with appropriate policy and legal frameworks, institutional development and human resources development and strengthening of managerial systems." (IEA, PVPS Task 9, 2003, p. 1) In the capacity building for BIPV in urban scenario, there are several areas or stakeholders concerned.

- Government departments (Environmental, Energy, Architectural, Financial ministries etc) In China, there is a special department belongs to State Department, NDRC. This entity has several functions, comprising making energy policy and stipulating price. It also has the power of Energy ministry, for there is still no energy ministry in Chinese central government now.

- Utility companies. Now in China utility companies refer to 5 electrical power company and their sub-branches in provinces.

- Financial community (Banks, insurance companies)

- PV manufacturers and distributors (PV industry, PV panel dealers)

- End-users

I put government department at first place because the capacity building of government department is crucial for the BIPV's successful. It comprises the policy-making, renewable energy grid price, building codes, PV industry codes and designing codes. Also a financial support scheme is decided by policy-makers. So this sector concentrates almost all the key elements for BIPV's programme. Capacity building is a conception concerned with ideaistic realm, it is abstract in concept but must implement in concrete action. The opportunity of when to initiate capacity building is also very important.

Suggestions on capacity building: the imperative task now is to disseminate a know-how education of BIPV covering wide ranges, such as the stakeholder above mentioned. To communicate the political will with all levels of people, especially the vested interest group leaders of utility is particularly important. Second, continue consummate the relative codes in different fields e.g. building and engineering. Third, the preparation of various level of experts or consultant should be initiated. In architectural design field, to nurture a batch of designers with double background of building-design and electronic-engineering is necessary.

The awareness of public must be nurtured by environmental education. This is a strenuous job which government is responsible. Even though green electricity poll shows encouraging support to renewables, to establish the real environmental consciousness is not a several-day's work. There is a Chinese saying, "3-foot thickness of ice is not formed over one night's chill", while English says "Rome is not built in one day". The capacity building in environmental education is a challenging work. So it is must be recognized thoroughly that capacity building is a long procedure and must be well organized with priority sequence.

8.1.4 Phasing out Subsidy to Coal Production and Coal-fuelled Plants

This suggestion is not only aiming to BIPV, but to all renewable energies.

For a long time, the coal mining receives subsidy from national finance every year. The coal subsidies are composed by three parts. First, from 1995, the central finance department keep the reserve of 1 billion RMB to coal mining per year as the compensation to red in balance. Second, after 1994 tax reform, the VAT levied to coal mining increased from 3% to 13%. The coal mining companies are overburdened by this policy. Then the central government decided refund the VAT levied above 3%. Namely, 10% VAT will be refunded to companies. Consequently a fix number of 1.7 billion RMB per year of this refund was stipulated by financial department. Third, in 1998, all the coal companies belonging to central financial department were devolved to provincial management. Inexplicably, the subsidy to coal companies of red in balance added another 10 billion RMB. Therefore, the annual subsidy to coal mining reached 3.7 billion RMB every year.

Second, the coal as fuel for power plants enjoys restricted protecting price for a long time. The coal marketing price can be seen in table 8.1.4. To keep a low electricity price, the coal as feedstock to power plants adopts a coal-electricity combining price. The coal price is floating with electricity price., but always below the market price. e.g. the average price for plants is 163 RMB/ton in 2004. This resulted in the average 20% lower of coal price as feedstock for power plants. In fact this is a morph(transformed) subsidy to coal-fuelled plants.

Table 8.1.4 Average Coal Price in 2000-2004 Market

Year	Average Market Coal Price (RMB/ton)
2000	140
2001	151
2002	168
2003	174
2004	206

(Source: Chinese Coal Information Research Institute, 2005)

These subsidies not only adds burden of financial budget, but make the renewable energy in more adverse position to compete with traditional energy. That's why the irrational subsidy to coal mining should be phased out gradually. The renewables will get a fairer environment for competing.

9. The Conclusion

The new trend of world wide to develop BIPV accelerates the PV industry's booming and stable declining rate of module price. As an energy consuming and importing country, under the shadow of impending energy shortage menace, China can not miss this opportunity again. The CREL is a good start to support renewable energy's exploitation in China. For CREL is too general on prescription of renewable energy, on practice there is quite a distance from the law to operational implement. Since the relative policy-makers are also working on the implementing clauses, one aim of this paper is focusing on how to do in operation.

Comparing with other renewable energies, PV has its unique priority:

1. The solar resource and climate condition in most parts of China is suitable for PV harnessing.

2. The BIPV techniques have matured and have many successful application examples in other countries.

3. Clean, quiet, no adverse emission during working, long longevity (30 years) and low maintenance cost

Gaps awaited for further endeavours are:

1. PV module Price still need further decrease to add its competitive ability.

2. Continue to consummate of relative law for implementation

3. Stipulate more incentives to motivate all stakeholders to take part in

4. The research area is comparatively weak, the raw material such as crystalline ingot and wafer relying on importing seriously.

Even there is the dispute about the BIPV market as "chicken and egg", which should be first, many countries such as Japan, Germany and US have turned their PV plan into application in niche market. Only spent 15 years, the PV market in Germany has developed to a sustainable way. While we are looking at these countries achievements with admiring eyes, the more important thing is doing something concrete in our country. Anyhow, a PV market needs to be fostered by the whole society's power.

Figure 9.1 shows the surrounding factors to consider as prerequisites to start a 100,000 rooftop solar scheme. Such a scheme will bring environmental, economical, social and other invisible benefit annually in 3 decades. As my calculation, the annual CO2e emission reduction will be 570 kilotons, SO2 emission reduction will be 5.2 kilotons per year, NOx emission reduction will be 3.5 kilotons and dust emission reduction will be 2.1 kilotons per year, in addition with other benefits, with conservative estimation, annual externality benefit will be 163 million RMB[33]. For each BIPV installers, 200 kilo RMB investment will be recovered in 8-9 years, after that, with a stable annual income of 10 kilo-20 kilo RMB from FiT for the rest

[33] 642.5 GWh (data from appendix 7) multiplies externality cost 0.18 RMB/kWh (Huang, et. al. 2003, p. 50) and CO2 impact cost 0.075 RMB/kWh (Chapter 6.4.4 last paragraph)

11-12 years, and then, nearly free electricity bill and surplus gain from utility till the end-life of BIPV(usually another 10 years). For the implementation of FiT system, the utility company is responsible for certificate of consumers' eligibility and issuing the incentive payment. The consumer (BIPV installer) also should cooperate with utility company for record preserving and aftermath proof-checking. As the benefit is therefore foreseen, the private household should be interested in and ensured the safety of investment. The 100,000 Rooftop Programme can produce 642.5 GWh electricity annually, saving 0.25 million tons coal per year, possibly 48.5 MkWh avoidance of electricity transmitting loss, as well as avoiding 163 million RMB of externality cost for society every year. The peak-shaving function by BIPV also contributes to release grid burden during peak hours. The social-economic benefit is significant. BIPV as the clean energy producer stands for environmental-friendly image of a city. This value is hard to evaluate monetarily.

Figure: 9.1 The Sun Diagram of Prerequisites and Benefits of a 100,000 Rooftop Solar Programme

Uncertainties always exist during my research on this topic. The obvious ones are predictions to externality and social benefit such as job-creation. This is unavoidable because till now what we are talking is still a market in virtual or conceiving. Everything will be testified by practice. What I can do is to minimize the bias and attend the most circumspection to what will happen in the future.

To summarize other countries experience, the political-will always plays as a key role in initiating the PV market, such as Japanese New Sunny Plan and German 100,000 rooftop Programme. The successful examples show that this principle is especially useful for penetration of renewable energy. During the process of diversification of energy mix, the role of government is indispensable. As the externality cost of coal is not internalized at current society, the benefits of renewable energy are hard to manifest themselves in electricity pricing system. Thus position them at disadvantageous status with conventional electricity. That's why policy-makers should take proactive measures to convert this situation and provide a level arena for renewables. Phase-out of the unreasonable subsidy to fossil-fuelled plants should be put in agenda too simultaneously with the encouragement of renewables.

Amongst all the economical incentives, the German FiT is the most distinctive and prevailing. The figures of German PV market verified this point. This stereotype provides the solution for other countries which is ambitious to develop renewables but baffled by the imbalance of price system. The German pattern is also upheld by EPIA as their position article published this year. (See *European PV Association's Position Paper On a Feed-in Tariff for Photovoltaic solar Electricity(2005))*. This will also be an indicative document to many European countries. Beijing Scenario adopts German 10,000 rooftop Programme as a model, tries to verify the feasibility if such a pilot scheme will be implemented in Beijing. The final analysis is encouraging, especially under the framework of FiT, the carrot is big enough and fulfils all stakeholders interests.

Even though, as all aspects of BIPV are ready, whether the government will initiate the BIPV market is still pending. But I believe, with the increasingly demand for cleaner energy and reorganization of unsustainable way of fossil fuel consuming, and not least, for national energy security in the future, it is almost certain the Chinese government will not let along this channel of clean energy production and keep the free resource untapped.

(the End)

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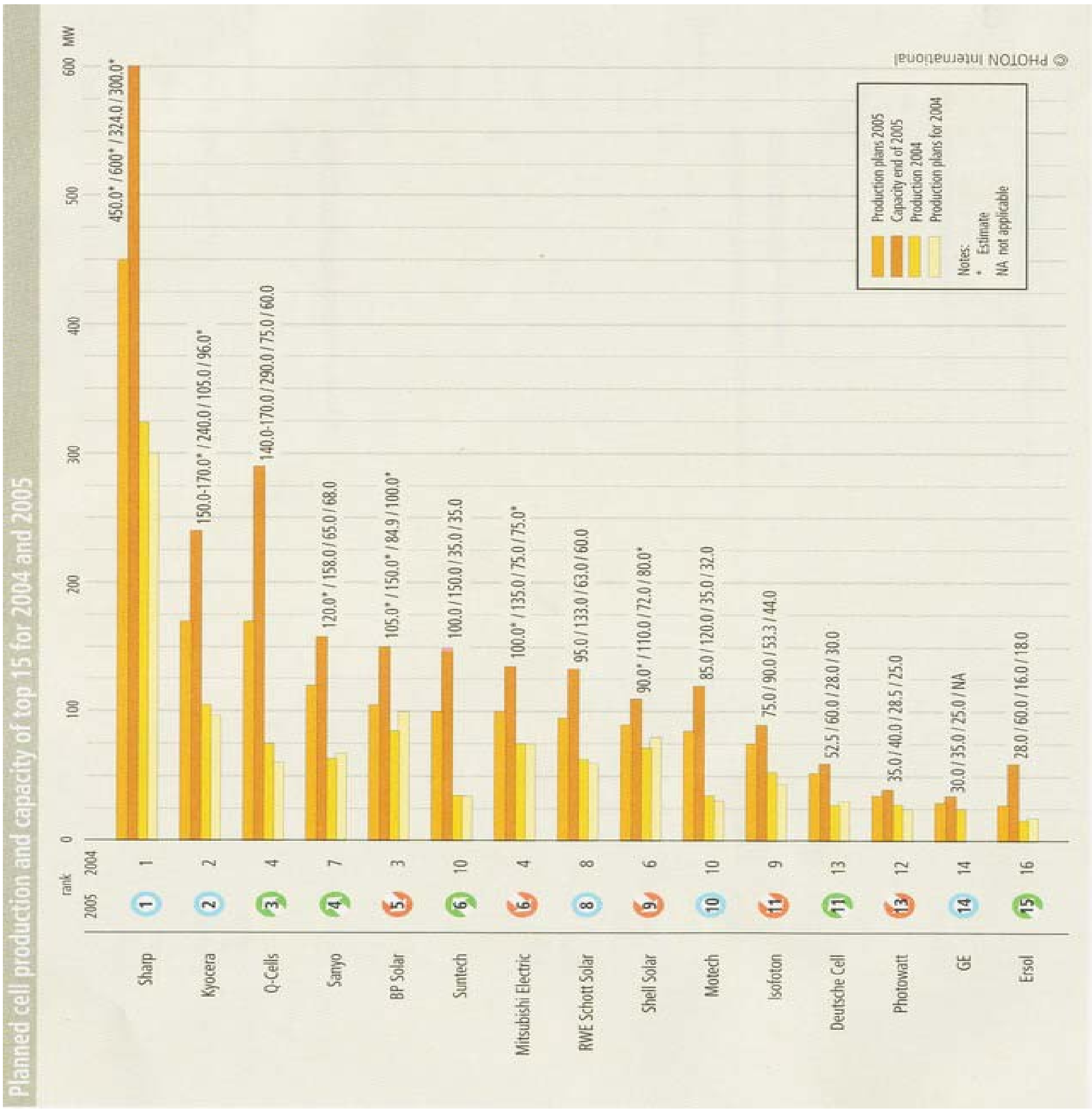
Appendixes

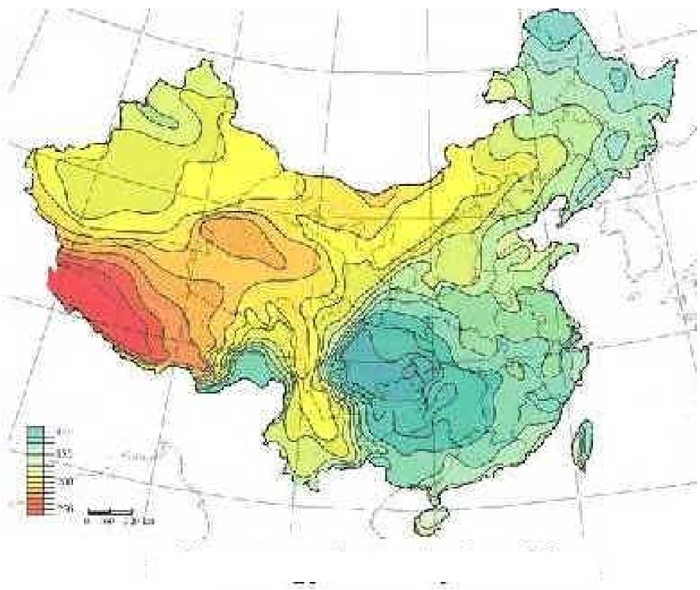
Appendix 1 Planned cell Production and Capacity of Top 15 for 2004 and 2005 (Source, Photon International Magazine, March, 2005)



Appendix 2: The Solar Resources Distribution in China

Colour	Radiation Level	Radiation Amount /year□ MJ/ m²□	Radiation/ Day □KWh/m²□
Red	Best	≥ 6680	≥ 5.1
Orange	Good	5850□6680	4.5 – 5.1
Yellow	Normal	5000□5850	3.8 – 4.5
Light Blue	Weak	4200□5000	3.2 – 3.8
Blue	Poor	< 4200	< 3.2

Source: Shi Lishan, et. al. 2004, p6



Appendix 3 Externality Cost for Electricity Production in the EU for Existing Technologies

Source: (Busquin P, 2003)

EXTERNAL COST FIGURES FOR ELECTRICITY PRODUCTION IN THE EU FOR EXISTING TECHNOLOGIES[1] (IN € CENT PER KWH*)

Country	Coal & lignite	Peat	Oil	Gas	Nuclear	Biomass	Hydro	PV	Wind
AT				1-3		2-3	0.1		
BE	4-15			1-2	0.5				
DE	3-6		5-8	1-2	0.2	3		0.6	0.05
DK	4-7			2-3		1			0.1
ES	5-8			1-2		3-5**			0.2
FI	2-4	2-5				1			
FR	7-10		8-11	2-4	0.3	1	1		
GR	5-8		3-5	1		0-0.8	1		0.25
IE	6-8	3-4							
IT			3-6	2-3			0.3		
NL	3-4			1-2	0.7	0.5			
NO				1-2		0.2	0.2		0-0.25
PT	4-7			1-2		1-2	0.03		
SE	2-4					0.3	0-0.7		
UK	4-7		3-5	1-2	0.25	1			0.15

* *sub-total of quantifiable externalities (such as global warming, public health, occupational health, material damage)*
** *biomass co-fired with lignites*

Appendix 4 The Thermal Unit and Conversion Factors (Source: Trittin J (2004), p40)

Kilo	k	10^3
Mega	M	10^6
Giga	G	10^9
Tera	T	10^{12}
Peta	P	10^{15}
Exa	E	10^{18}

Prefixes and symbols

Terawatt hour:	1 TWh = 1 billion kWh
Gigawatt hour:	1 GWh = 1 million kWh
Megawatt hour:	1 MWh = 1,000 kWh

Units for energy and capacity

Joule	J	for energy, work, heat quantity
Watt	W	for capacity, energy flow, heat flow
1 Joule (J) = 1 Newton metre (Nm) = 1 Watt second (Ws)		

Conversion factors

		kJ	kcal	kWh
1 kilojoule	kJ	1	0.2388	0.000278
1 kilocalorie	kcal	4.1868	1	0.001163
1 kilowatt hour	kWh	3,600	860	1
1 kg coal equivalent	kg ce	29.308	7.000	8,14
1 kg oil equivalent	kg oe	41,868	10,000	11.63

Appendix 5 Glaciers in the High Asia for varying periods

Table11 Advancing or retreating of glaciers in the High Asia for varying periods (After Yao Tandong et al., 2004)

Period	Total statistical glaciers	Retreating glaciers /%	Advancing glaciers /%	Stationary glaciers /%
1950-1970	116	53.44	30.17	16.37
1970-1980	224	44.2	26.3	29.5
1980-1990	612	90	10	0
1990 to Present	612	95	5	0

Source: Shen Yongping(2004), *A Overview of Glaciers, Retreating Glaciers and Their Impact in the Tibet Plateau,* WWF programme, Chinese Academy of Sciences(CAS), Apr, 2004

Appendix 6 Data Source: China's National Energy Strategy and Reform Background Report, p3, (Nov, 2003)

Table 1: Relationship between Economic Growth and Energy Consumption during Different Periods in China

Year	1980~1985	1986~1990	1991~1995	1996~2000	2002/2000
GDP growth rate	10.7%	7.9%	12.0%	8.3%	7.7%
Growth rate of energy consumption	4.9%	5.2%	5.9%	-0.1%	6.6%
Elasticity coefficient of energy consumption	0.46	0.66	0.49	-0.02	0.85

Appendix 7

RETScreen® Energy Model - Photovoltaic Project — *Training & Support*

Site Conditions		Estimate	Notes/Range
Project name		BIPV	See Online Manual
Project location		Beijing, China	
Nearest location for weather data	-	Beijing	Complete SR&SL sheet
Latitude of project location	°N	39.9	-90.0 to 90.0
Annual solar radiation (tilted surface)	MWh/m²	1.53	
Annual average temperature	°C	11.8	-20.0 to 30.0

System Characteristics		Estimate	Notes/Range
Application type	-	**On-grid**	
Grid type	-	Central-grid	
PV energy absorption rate	%	100.0%	
PV Array			
PV module type	-	mono-Si	
PV module manufacturer / model #		BP Solar/ BP 590F	See Product Database
Nominal PV module efficiency	%	14.3%	4.0% to 15.0%
NOCT	°C	45	40 to 55
PV temperature coefficient	% / °C	0.40%	0.10% to 0.50%
Miscellaneous PV array losses	%	5.0%	0.0% to 20.0%
Nominal PV array power	kWp	**5.04**	
PV array area	m²	35.2	
Power Conditioning			
Average inverter efficiency	%	90%	80% to 95%
Suggested inverter (DC to AC) capacity	kW (AC)	4.5	
Inverter capacity	kW (AC)	72.0	
Miscellaneous power conditioning losses	%	0%	0% to 10%

Annual Energy Production (12.00 months analysed)		Estimate	Notes/Range
Specific yield	kWh/m²	182.3	
Overall PV system efficiency	%	11.9%	
PV system capacity factor	%	14.6%	
Renewable energy collected	MWh	7.139	
Renewable energy delivered	MWh	**6.425**	
	kWh	6,425	
Excess RE available	MWh	**0.000**	
			Complete Cost Analysis sheet

Version 3.1 NRCan/CETC - Varennes

Appendix 8

RETScreen® Solar Resource and System Load Calculation - Photovoltaic Project

Site Latitude and PV Array Orientation		Estimate	Notes/Range
Nearest location for weather data		Beijing	See Weather Database
Latitude of project location	°N	39.9	-90.0 to 90.0
PV array tracking mode	-	Fixed	
Slope of PV array	°	30.0	0.0 to 90.0
Azimuth of PV array	°	0.0	0.0 to 180.0

Monthly Inputs

Month	Fraction of month used (0 - 1)	Monthly average daily radiation on horizontal surface (kWh/m²/d)	Monthly average temperature (°C)	Monthly average daily radiation in plane of PV array (kWh/m²/d)	Monthly solar fraction (%)
January	1.00	2.08	-4.3	3.33	-
February	1.00	2.89	-1.9	3.98	-
March	1.00	3.72	5.1	4.36	-
April	1.00	5.00	13.6	5.27	-
May	1.00	5.44	20.0	5.28	-
June	1.00	5.47	24.2	5.14	-
July	1.00	4.22	25.9	4.03	-
August	1.00	4.22	24.6	4.24	-
September	1.00	3.92	19.6	4.36	-
October	1.00	3.19	12.7	4.08	-
November	1.00	2.22	4.3	3.33	-
December	1.00	1.81	-2.2	2.97	-

		Annual	Season of use
Solar radiation (horizontal)	MWh/m²	1.34	1.34
Solar radiation (tilted surface)	MWh/m²	1.53	1.53
Average temperature	°C	11.8	11.8

Load Characteristics		Estimate
Application type	-	On-grid

Return to Energy Model sheet

Version 3.1

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Appendix 9. A 5kWp BIPV System Cost Analysis

RETScreen® Cost Analysis - Photovoltaic Project

Type of analysis: Feasibility | Currency: China | Cost references: None

Initial Costs (Credits)	Unit	Quantity	Unit Cost	Amount	Relative Costs	Quantity Range	Unit Cost Range
Feasibility Study							
Site investigation	p-h	8	CNY 65	CNY 520		-	-
Preliminary design	p-h	20	CNY 65	CNY 1,300		-	-
Report preparation	p-h	10	CNY 65	CNY 650		-	-
Travel and accommodation	p-trip	1	CNY 1,200	CNY 1,200		-	-
Other - Feasibility study	Cost	1	CNY 10,000	CNY 10,000		-	-
Credit - Base case system	Credit	1	CNY 3,000	CNY (3,000)		-	-
Sub-total :				**CNY 10,670**	5.2%		
Development							
Permits and approvals	p-h	4	CNY 65	CNY 260		-	-
Project management	p-h	50	CNY 85	CNY 4,250		-	-
Travel and accommodation	p-trip	1	CNY 2,000	CNY 2,000		-	-
Other - Development	Cost	1	CNY 15,000	CNY 15,000		-	-
Credit - Base case system	Credit	1	CNY 5,000	CNY (5,000)		-	-
Sub-total :				**CNY 16,510**	8.0%		
Engineering							
PV system design	p-h	15	CNY 65	CNY 975		-	-
Structural design	p-h	20	CNY 65	CNY 1,300		-	-
Electrical design	p-h	32	CNY 65	CNY 2,080		-	-
Tenders and contracting	p-h	11	CNY 65	CNY 715		-	-
Construction supervision	p-h	15	CNY 65	CNY 975		-	-
Other - Engineering	Cost	1	CNY 55,000	CNY 55,000		-	-
Credit - Base case system	Credit	1	CNY 4,000	CNY (4,000)		-	-
Sub-total :				**CNY 57,045**	27.6%		
Energy Equipment							
PV module(s)	kWp	5.04	CNY 5,750	CNY 28,980		-	-
Transportation	project	0	CNY -	CNY -		-	-
Other - Energy equipment	Cost	0	CNY -	CNY -		-	-
Credit - Energy equipment	Credit	0	CNY -	CNY -		-	-
Sub-total :				**CNY 28,980**	14.0%		
Balance of Equipment							
Module support structure	m^2	35.2	CNY 100	CNY 3,524		-	-
Inverter	kW AC	72.0	CNY 1,000	CNY 72,000		-	-
Other electrical equipment	kWp	5.04	CNY -	CNY -		-	-
System installation	kWp	5.04	CNY 1,500	CNY 7,560		-	-
Transportation	project	0	CNY -	CNY -		-	-
Other - Balance of equipment	Cost	0	CNY -	CNY -		-	-
Credit - Balance of equipment	Credit	0	CNY -	CNY -		-	-
Sub-total :				**CNY 83,084**	40.2%		
Miscellaneous							
Training	p-h	6	CNY 65	CNY 390		-	-
Contingencies	%	5%	CNY 196,679	CNY 9,834		-	-
Sub-total :				**CNY 10,224**	5.0%		
Initial Costs - Total				**CNY 206,513**	100.0%		

Annual Costs (Credits)	Unit	Quantity	Unit Cost	Amount	Relative Costs	Quantity Range	Unit Cost Range
O&M							
Property taxes/Insurance	project	0	CNY -	CNY -		-	-
O&M labour	p-h	16	CNY 55	CNY 880		-	-
Other - O&M	Cost	0	CNY -	CNY -		-	-
Credit - O&M	Credit	0	CNY -	CNY -		-	-
Contingencies	%	0%	CNY 880	CNY -		-	-
Sub-total :				**CNY 880**	100.0%		
Annual Costs - Total				CNY 880	100.0%		

Periodic Costs (Credits)		Period	Unit Cost	Amount		Interval Range	Unit Cost Range
Inverter Repair/Replacement	Cost	12 yr	CNY 50,000	**CNY 50,000**		-	-
			CNY -	**CNY** -		-	-
			CNY -	**CNY** -		-	-
End of project life		-	CNY -	**CNY** -		Go to GHG Analysis sheet	

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Appendix 10. A 3kWp BIPV System Cost Analysis as Comparison with Appendix 9

RETScreen® Cost Analysis - Photovoltaic Project

Type of analysis: Feasibility | Currency: China | Cost references: None

Initial Costs (Credits)	Unit	Quantity	Unit Cost	Amount	Relative Costs	Quantity Range	Unit Cost Range
Feasibility Study							
Site investigation	p-h	8	CNY 65	CNY 520		-	-
Preliminary design	p-h	20	CNY 65	CNY 1,300		-	-
Report preparation	p-h	10	CNY 65	CNY 650		-	-
Travel and accommodation	p-trip	1	CNY 1,200	CNY 1,200		-	-
Other - Feasibility study	Cost	1	CNY 10,000	CNY 10,000		-	-
Credit - Base case system	Credit	1	CNY 3,000	CNY (3,000)		-	-
Sub-total :				**CNY 10,670**	5.6%		
Development							
Permits and approvals	p-h	4	CNY 65	CNY 260		-	-
Project management	p-h	50	CNY 85	CNY 4,250		-	-
Travel and accommodation	p-trip	1	CNY 2,000	CNY 2,000		-	-
Other - Development	Cost	1	CNY 15,000	CNY 15,000		-	-
Credit - Base case system	Credit	1	CNY 5,000	CNY (5,000)		-	-
Sub-total :				**CNY 16,510**	8.7%		
Engineering							
PV system design	p-h	15	CNY 65	CNY 975		-	-
Structural design	p-h	20	CNY 65	CNY 1,300		-	-
Electrical design	p-h	32	CNY 65	CNY 2,080		-	-
Tenders and contracting	p-h	11	CNY 65	CNY 715		-	-
Construction supervision	p-h	15	CNY 65	CNY 975		-	-
Other - Engineering	Cost	1	CNY 55,000	CNY 55,000		-	-
Credit - Base case system	Credit	1	CNY 4,000	CNY (4,000)		-	-
Sub-total :				**CNY 57,045**	30.0%		
Energy Equipment							
PV module(s)	kWp	3.06	CNY 5,750	CNY 17,595		-	-
Transportation	project	0	CNY -	CNY -		-	-
Other - Energy equipment	Cost	0	CNY -	CNY -		-	-
Credit - Energy equipment	Credit	0	CNY -	CNY -		-	-
Sub-total :				**CNY 17,595**	9.3%		
Balance of Equipment							
Module support structure	m^2	21.4	CNY 100	CNY 2,140		-	-
Inverter	kW AC	72.0	CNY 1,000	CNY 72,000		-	-
Other electrical equipment	kWp	3.06	CNY -	CNY -		-	-
System installation	kWp	3.06	CNY 1,500	CNY 4,590		-	-
Transportation	project	0	CNY -	CNY -		-	-
Other - Balance of equipment	Cost	0	CNY -	CNY -		-	-
Credit - Balance of equipment	Credit	0	CNY -	CNY -		-	-
Sub-total :				**CNY 78,730**	41.4%		
Miscellaneous							
Training	p-h	6	CNY 65	CNY 390		-	-
Contingencies	%	5%	CNY 180,940	CNY 9,047		-	-
Sub-total :				**CNY 9,437**	5.0%		
Initial Costs - Total				**CNY 189,987**	100.0%		

Annual Costs (Credits)	Unit	Quantity	Unit Cost	Amount	Relative Costs	Quantity Range	Unit Cost Range
O&M							
Property taxes/Insurance	project	0	CNY -	CNY -		-	-
O&M labour	p-h	16	CNY 55	CNY 880		-	-
Other - O&M	Cost	0	CNY -	CNY -		-	-
Credit - O&M	Credit	0	CNY -	CNY -		-	-
Contingencies	%	0%	CNY 880	CNY -		-	-
Sub-total :				**CNY 880**	100.0%		
Annual Costs - Total				CNY 880	100.0%		

Periodic Costs (Credits)		Period	Unit Cost	Amount		Interval Range	Unit Cost Range
Inverter Repair/Replacement	Cost	12 yr	CNY 50,000	**CNY 50,000**		-	-
			CNY -	**CNY** -		-	-
			CNY -	**CNY** -		-	-
End of project life		-	CNY -	**CNY** -			Go to GHG Analysis sheet

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