The Social, Policy and Economy Factor in the solar power market potential identification model with the case study for China

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Declarations

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Abstract

This study is inspired by a previous research of market potential identification for small scale solar power generator by David Sanchez. Sanchez et al's model includes 5 factors' analysis: Solar Irradiation (DNI), Demand, Grid, Social-Policy and Risk. Among these 5 factors, the Social-Policy factor includes the analysis of the policy of renewable energy and economy variation in EU countries as well as the energy import rate for 22 candidate countries. The potential problems for this Social-Policy factor model are: 1. This model overlooks the regional diversity on policy and economy situation in big countries, such as China. 2. This model analyses the policies for renewable energy in EU countries, however, it lacks specific policy information for solar power 3. The energy import rate cannot reflect the whole picture of other energies' interference, especially in a country with sufficient local energy resources.

Therefore, the aim of this study is to modify the model for Social-Political factor in Market Potentials Identification study and prove the market potential regional variety with this factor. This study also uses China as a case study in modifying the Social-Policy factor in the solar market potential identification study from Sánchez et al. and then identify the factor of social, economy and policy in different province in China. Factor 'social, economy and policy' (F_s) includes 4 sub-factors: Energy Mix Factor, Economic Factor (GDP &GDP growth rate), Policy factor (Local policy in solar power) and Solar increase trend factor. Through this study, it will be proved that there is difference for the market potential for China in each province. As a result, for big countries like China, the regional analysis needs to be applied on market potential identification.

Nomenclature

F_s :Social, policy and economy factor of solar energy market potential

f_i: Energy Mix factor

f'_i: Energy Mix factor calculated with energy percentage

f_{i1}: market interference from coal

f'_{i1}: market interference from coal with percentage in energy mix

f_{i2}: market interference from hydro power

f'_{i2}: market interference from hydro power with percentage in energy mix

f_{i3}: market interference from wind power

f'_{i3}: market interference from wind power with percentage in energy mix

f_{i4}: market interference from natural gas

f'_{i4}: market interference from natural gas with percentage in energy mix

f_{i5}: market interference of nuclear

f'_{i5}: market interference of nuclear with percentage in energy mix

a_1: proportion of coal

a_2: proportion of hydro power

a_3: proportion of wind power

a_4: proportion of natural gas

a_5: proportion of nuclear

f_r: Solar energy target by government

f_g: Economic wealth

f_p: Regulatory for solar power policy.

w: predicted GDP for Chinese provinces in 2020

DNI: Direct Normal Irradiance

IMP: Index Market Potential

F_I: Solar irradiation factor

F_D: Demand factor

F_G: Grid Accessibility factor

F_P: Energy policy and social facto

F_F: Risk factor

ω_I: factor weigh of Irradiance in IMP

ω_D: factor weigh of Demand in IMP

ω_D: factor weigh of Grid in IMP

ω_P: factor weigh of Policy in IMP

ω_F: factor weigh of Risk in IMP

g: GDP growth rate of candidate countries with farm-arrangement grid

G: GDP of candidate countries with stand-alone systems

R: fraction of renewable energy in a country

$F_{D,farm-arrangement}$: farm arrangement demand factor

$F_{D,stand-alone}$: stand-alone system demand factor

Chapter 1. Introduction

Solar systems produce clean energy with nearly zero carbon emission to the environment and it is one of many options for clean energies. Increase the application of solar energy is a sustainable solution for people's future.

David Sanchez create a model for solar power market potential identification, which helps promote solar energy in different countries more effectively. The solar market potential identification model identifies the country market potential of solar system with factors of Direct Normal Irradiation (DNI), energy demand, power grid, social-policy, and risk analysis. More importantly, it provides a method that is able to transfer the analysed information into numerical data and present the results by non-dimensional figures.

Based on the model, this study will take and modify the social-policy factor to discover the impact from social, political and local economy on the market potential of solar power in different provinces in China. The reason for choosing to modify this factor is that

1. The old model only discusses the influence from energy import rate to the local energy market. However, it does not discuss the interference from other local energies to solar power.
2. The model only discussed the policy influence for renewable energy. However, discussing the detail policy on solar power would make the result more accurate.
3. The candidates in old model are countries, and the old model analyses the average value for each country as a whole, which neglects the regional diversity in big countries.

The aim of this study is to demonstrate the significance of the regional variety and explore the social, policy and economy factors for each province in China to reveal that there are regional diversities in different provinces and the market potential could vary within wide ranges. Specifically, the regional diversity will be presented with parameters aiming at identifying the regional diversity of China and giving an in-depth solution for the social, policy and economy market potential factor for solar system.

Chapter 1 will introduce the background of solar energy in China. Chapter 2 will review solar technologies and illustrate the market potential model. Chapter 3 and Chapter 4 will demonstrate the social, political and economy sub-factor analysis for the market potential of solar power in different provinces in China.

1.1 Solar resource in China

The solar resources in China varies among different regions and around 2/3 of the whole country area has up to 2200 hours annual solar radiation, which are suitable for solar energy power generation [1]. Tibet, Qinghai, north Gansu, east Xinjiang and mid-west Inner Mongolia has the highest level of annual solar radiation (6700-8379MJ/m^2), which are suitable for big scale solar power generation; Xinjiang, middle and east Inner Mongolia, west of Heilongjiang, Jilin and Liaoning, west Hebei, north Ningxia, middle Gansu and south Sichuan comes after, annual solar radiation ranges around 5400-6700MJ/m^2, which also provide good quality of solar generation resources[2]. Table 1.1 presents the solar power potential in different Chinese regions.

Fig 1.1 Map of China [3]

Potential for solar power system installation	Region
Areas with premium solar resources	Tibet
Areas suitable for large scale solar power plant	Qinghai, north Gansu, east Xinjiang, mid-west Inner Mongolia
Areas second suitable for large scale solar power plant	Xinjiang, middle and east Inner Mongolia, west of Heilongjiang, Jilin and Liaoning, west Hebei, north Ningxia, middle Gansu, south Sichuan
Areas for small scale solar power plant	east and west part of Northeast China, Huabei Flatland, Huangtu Highland, southeast Qingzang Highland, Yunnan, north Xinjiang, Leizhou Island, Hainan

Table 2.1 Summary of solar power potential in different Chinese regions [2]

1.3 Energy Mix in China

Currently, the main energy in China is coal. However, since 2010, hydro, gas, nuclear, bioenergy and renewable energy grow significantly [4]. In 2016, the

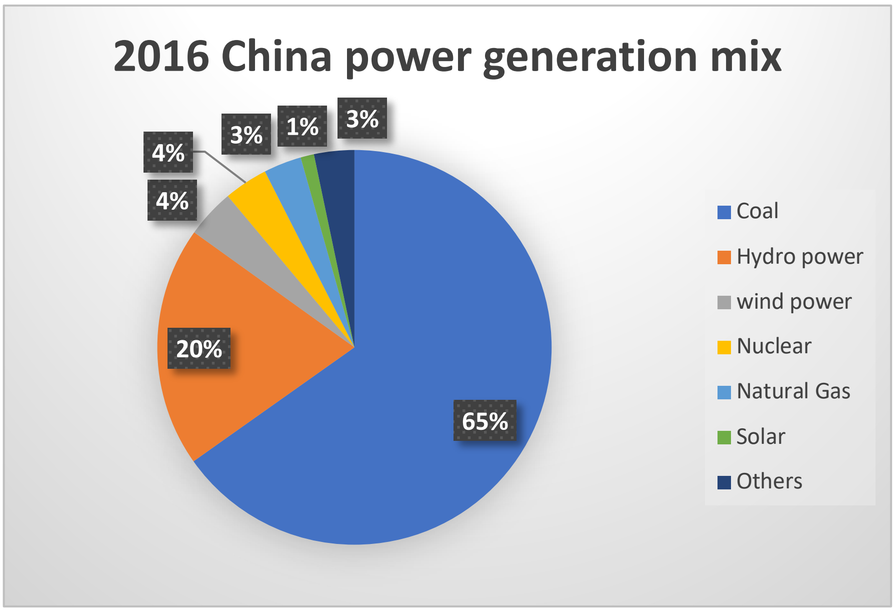

Fig 1.2 2016 China power generation mix [5]

whole installed electricity capacity in China was 1073 GW, among which coal accounts for 65%, followed by hydropower accounts for 20%; solar power only accounts for 1.1% in the installed capacity [5]. This energy mix is shown in Fig 1.2.

Stanley Research expect solar power to reach 70 GW by 2017 and 110 GW by 2020 and in the latest adjustments to the 12th five-year-plan, the government of China has targeted solar PV new installation of 35 GW by the end of 2015 [6].

In 2014, solar PV module prices declined by 53%, which drove down the cost of capital investment in solar PV projects by 50% [6], which indicates that the price for electricity from solar system might drop in the future. Currently, the coal power tariff is at a low level due to the low cost of coal [6]. However, while coal cost remains low in 2014-15, it is expected that the environmental protection costs and emission requirements will lead to higher costs. For example, in June 2014, the Chinese Government released requirements for further improvements in desulfurization, denaturation, and dust removal at coal power plants, which increase coal power cost [6].

1.4 Environmental Issues in China

China, as the largest developing economic community, is now facing serious environmental problems and has large amounts of carbon emissions. The economic growth in China is heavily dependent on natural resources [7], which leaves a big burden on its environment. In 2015, the air quality has deteriorated drastically in Beijing, the capital of China, and the nearby province Hebei. The main reasons for the air pollution are the increases of natural gas usage on residential commercial buildings, renewable and nuclear power generation facilities, and the scrapping of older and heavily polluting vehicles [8]. The pollution increases the dust and sulphur dioxide in the air, which negatively affects the average life span of people and threatens the health of new-born infants [9].

In China, air pollution is causing serious environmental pollution and health problems, that raises attention for government. During recent years, PM2.5 is becoming a serious air problem in some areas in China. Originally, this problem occurred at Beijing, Tianjin and Hebei provinces and gradually it spread to the east China and middle part of China. Department for Environment, Food and Rural Affairs defines Particulate Matter (PM) as a term used to describe the mixture of solid particles and liquid droplets in the air. PM 2.5 means the mass per cubic metre of air of particles with a size (diameter) generally less than 2.5 micrometres (µm). PM2.5 is also known as fine particulate matter (2.5 micrometres is one 400th of a millimetre). Particles come in a wide range of sizes. Particles less than or equal to 10 micrometres in diameter are so small that they can get into the lungs, potentially causing serious health problems [10]. It will require long-term work to reduce the PM2.5 and Chinese government is putting efforts to reduce the PM 2.5 air pollution and carbon emission. One of the solution that government suggested for industrial and manufacture institutions is replacing traditional energy source with clean energy. Therefore, the government policy that supports the renewable energy can be an important factor to the development of renewable energy, especially solar power energy in this study, in Chapter 3 and Chapter 4, the detail of the policy factor for solar power will be discussed.

The background demonstrates that although in the energy market, coal dominates the energy mix in China, the government has already taken action to promote clean energy and decrease the proportion of coal fired energy in the energy mix in China. Thus, there is good long-term potential for solar power energy in China. The aim of this research is to explore some of the factors that could influence the market potential and identifying the regional difference in the market potential of solar power in China. In Chapter 2, the literature review will introduce the solar technologies and the models to market potential factors and in the following Chapter 3 and 4 will illustrate the detail research models.

Chapter 2. Literature Review

In this chapter, Section 2.1 illustrates the characteristics of different solar technologies. Section 2.2 demonstrates the potential market identification model and other previous studies.

2.1 Solar Power Technology Review

This section presents a review of different solar technologies and compares the performance of different technologies of solar thermal and solar photovoltaic in performance and economic sense. International Renewable Energy Agency (IRENA) illustrated the comparison of the features and break down costs for Concentrated Solar Power (CSP) [11] and solar photovoltaic [12]. The details of the performance and cost of each technology is presented in Table 2.1.2 and Table 2.1.2.

Fig 2.1.1 shows the brief structure of the solar technologies reviewed in this section.

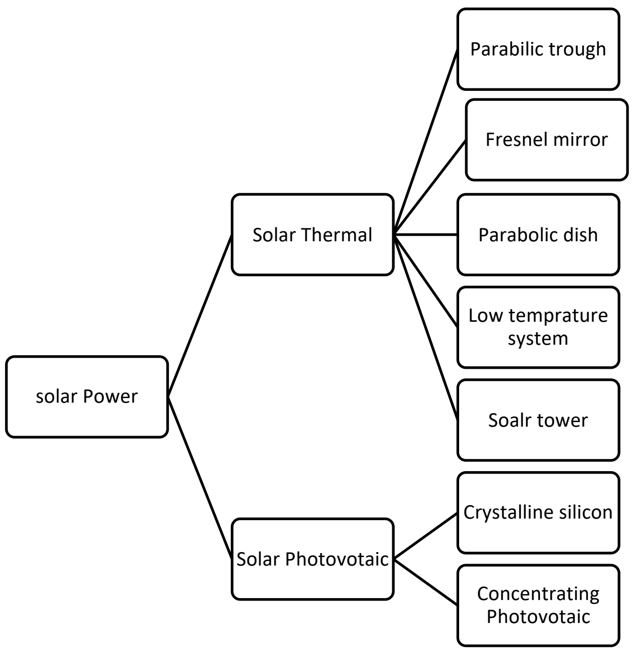

Fig 2.1.1 Solar Power System

2.1.1 Solar Thermal Systems

Solar thermal electricity generation is known as Concentrated Solar Power (CSP). It concentrates sunlight to raise a working fluid temperature to a sufficient level to enable utilisation in an engine to convert the heat to mechanical power and hence generate electricity. For example, the engines (steam engines, gas turbines or Stirling engines) phase change from solid to fluid or fluid to gas via the energy of sun heat, normally those materials can be water, salt, air nitrogen or helium. This system solves the problem of sun heat storage. There are several elements to a solar thermal system, concentrator, receiver and engine and the low-temperature system consists of solar ponds, and solar updraft tower devices.

The basic technology of the low temperature system is having water flowing through the zigzag pipes and the water is heated gradually. The channels are covered with a layer of heat absorber and a layer of glass to let the heat get through and keep the heat inside. This kind of system normally used on the rooftop for water heating. It is with relatively low cost and the temperature is low, average can reach 40-90 degree Celsius [13]. In China, this technology is widely used but the accuracy of temperature for water storage system are expected to be improved.

Fig 2.1.2 Parabolic Trough [14]

The parabolic-trough collectors and Fresnel mirror system are called line focus system. This form of system is rotating the parabola-shaped mirrors to track the sun. The average temperature that the line focus can reach is 250 degrees. The receiver efficiency of parabolic trough system is comparatively lower than solar tower and parabolic dish but the technology is simpler and the cost is also lower [13].

The parabolic-trough collectors are more commonly used in industrial, institutional and commercial area. It can reach higher heat as it can trace the attitude angle of the sun and have sunlight from each angle focused on a pipe.

Fig 2.1.3 Fresnel mirror [15]

The Fresnel mirror system works with a raised linear collector heated by steerable strips of flat mirrors. It is cheaper but the temperature raising ability is limited compared to the parabolic through.

The parabolic dish concentrator and solar tower are point focus systems. A point focus system shows higher temperature efficiency than a line focus system, which can reach the temperature of 500 degrees from the sunlight. However, this system is also more expensive and more technically demanding [13].

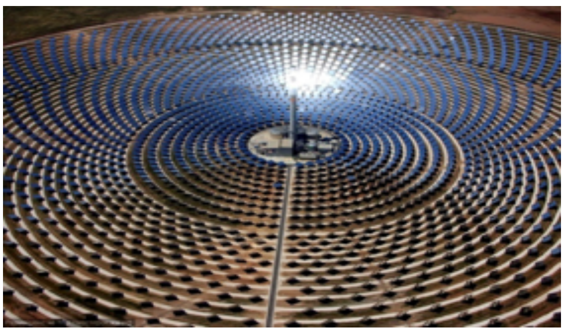

Fig 2.1.4 Solar Tower [16]

Fig 2.1.5 Solar Dish [17]

The parabolic dish concentrator works with a Stirling engine at the focus of the mirror dish. A parabolic dish that collects and concentrates the sun into a heat source to run the engine and produce power drives this Stirling engine [18].

Solar Towers are comprised of many reflecting mirrors and a central receiver. There are tracking or non-tracking solar collectors in the solar thermal system. The azimuth angles of non-tracking collectors are fixed, One-Axis Tracking Rotation or Two-Axis Tracking Rotation are able to track the sunlight. Similarly, tracking collectors have two types: One-Axis Tracking Concentrating Collector and Two-Axis Tracking Concentrating Collector [19].

The solar tower system is still in very limited use in China. However, it has a large improvement potential in the future. The northeast area in China has a large desert land for solar tower systems, more importantly, those areas are expose to more sunlight as the height of the land and the latitude reaches the best angle for solar heat. For solar thermal system, it helps the receiver to reach higher heat so that the receiver can get higher converting efficiency.

Overall, CSP system has its advantages: it converts the solar insolation energy into thermal energy, cost and technical complexity of energy storage of CSP is considerably lower. With storage, power production can be shifted according to demand. Therefore, there is less dependent on the time period and daily weather conditions. In addition, CSP uses the same turbine system to generate electricity just as the conventional fuel powered plant. Therefore, it is also a feasible choice to couple CSP with fossil fuel to form a hybrid CSP plant, or work as supplemental steam generating source to a fuel fired plant.

A summary of solar thermal technologies is shown Table 2.1.1, which illustrates the main advantages and disadvantages of each solar thermal system, as well as the information of system efficiency, storage and installation cost. There is a lack of data of land use, which will need to be discovered in the further study and identify the impact on final market potential.

	Parabolic Trough	**Solar Tower**	**Linear Fresnel**	**Dish-Stirling concentrator**
Main Application	Electricity generation especially steam generation	Power network Electricity generation	Electricity generation especially steam generation	Building or residential hot water supply
Advantage	Lower cost	High temperature reached	Lower cost	Low cost
Disadvantage	Rely on the angle of the sun when the sun is high	High cost	Rely on the angle of the sun when the sun is high	Low temperature reached
Maturity of technology	Commercially proven	Pilot commercial projects	Pilot projects	Demonstration projects
Technology development risk	Low	Medium	Medium	Medium
Operating temperature(°C)	350-550	250-565	390	550-750
Plant peak efficiency (%)	14-20	23-35	18	30
Annual solar-to electricity efficiency (net) (%)	11-16	7-20	13	12-25
Receiver/absorber	Absorber attached to collector, moves with collector, complex design	External surface or cavity receiver, fixed	Fixed absorber, no evacuation secondary reflector	Absorber attached to collector, moves with collector
Storage system	Indirect two-tank molten salt at 380°C or Direct two-tank molten salt at 550°C	Direct two-tank molten salt at 550°C	Short-term pressurised steam storage (<10 min)	No storage for Stirling dish, chemical storage under development
Hybridisation	Yes and direct	Yes	Yes, direct (steam boiler)	Not planned

Grid stability		Medium to high	High	Medium	Low
Maximum slope of solar field (%)		<1-2	<2-4	<4	10% or more
Water requirement (m^3/MWh)		3 (wet cooling) 0.3 (dry cooling)	2-3(wet cooling) 0.25(dry cooling)	3 (wet cooling) 0.2 (dry cooling)	0.05-0.1 (mirror washing)
Application type		On-grid	On-grid	On-grid	On-grid/Off-grid
Suitability for air cooling		Low to good	Good	Low	Best
Storage with molten salt		Commercially available	Commercially available	Possible, but not proven	Possible, but not proven
Installed Cost (2010 USD/KW)	Without storage	4600	-	-	-
	With storage	7100-9800 (6 hours)	6300-7500 (6-7.5hours)	-	-
			9000-10500 (12-15 hours)		

Table 2.1.1 Comparison of different solar thermal technologies [11]

2.1.2 Solar Photovoltaic

This study mainly discusses three types of two types of PV: Crystalline Silicon (c-Si), and Concentrator Photovoltaic (CPV). There are other types of solar PV on the market such as Polycrystalline Silicon (pc-Si), Amorphous Silicon (a-Si) and Copper Indium Gallium Selenide (CIGS), since the market share is too low and the solar efficiency and cell life span are less than half of Crystalline Silicon (c-Si), this study eliminates the discussion of these solar PV.

The Crystalline Silicon is the first-generation PV and it is the most commercialised and widely used solar PV. The cell is covered with glass on the top and the bottom, the life span is 25-30 years[20][21]. This technology relies on silicon. The core technology to extract silicon determines the supply and the price of c-Si. The cell works with P-N junction which is comprised of two layers of dissimilar semiconducting materials of positive (P) type semiconductor and negative (N) type semiconductor. Silicon is a common material for PV cells. When the sunlight gets on the PV cell, electrons move from one side to the other side so that a voltage is triggered with the current from the electrons' movement. This technology is currently dominant in the solar market for its maturity of production.

Concentrating Photovoltaics (CPV) is the third generation PV. Although there is a low production on the market, the solar cell is able to reach high efficiency (25%-30%) and it has potentially to reach a higher efficiency of more than 40% or higher [12]. The limitation is that it requires direct sunlight rather than diffuse light, so it has to be used at clear and sunny locations. In some cases, tracking equipment and cooling systems are required. After all, this type of PV requires less photovoltaic material to capture the same sunlight as non-concentrating PV and make use of the high-efficiency but due to smaller space requirements, its expensive multi-junction cells are not economically viable so far. The optical system comprises standard materials and be manufactured in proven processes,which is less dependent on the current silicon supply chain.

In Table 2.1.2, there is a summary on the features of the advantages and disadvantages of c-Si and CPV, as well as information on the cost and performance values. Among the data, there is no information about storage of solar PV, the reason is that there is merely storage system practically applied on PV systems due to the high cost (the possible storage for solar PV is batteries).

Fig 2.1.5 Solar Panel [22]

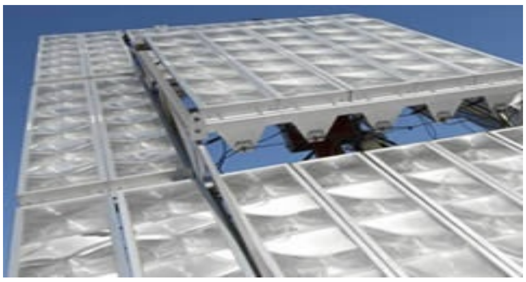

Fig 2.1.6 Concentrating Photovoltaics(CPV)
[23]

	Crystalline silicon (c-Si)	Concentrated PV (CSP)
Main Application	Industrial Power generation, building power generation	-
Advantage	High maturity of industry production.	High accuracy for high concentration, Less PV material required
Disadvantage	High initial investment, Limited material life span which requires high maintenance cost	High Cost, cooling system required, small scale of production
Best research solar cell efficiency at AM 1.5* (%)	24.7	43.5
Confirmed solar cell efficiency at AM 1.5(%)	20-24	36-41
Commercial PV Module efficiency at AM 1.5(%)	15-19	25-30
Confirmed PV Module efficiency (%)	23	25
Current PV module cost (USD/W)	<1.4	-
Market share in 2010 (%)	87	-
Maximum PV module output power (W)	320	120
PV module size (m^2)	2.0	-
Area needed per KW(m^2)	7	-
State commercialisation	Mature with large scale production	Just commercialised. Small scale production

Table 2.1.2 Typical Cost and Performance Values For Solar PV Systems. *AM 1.5: 25˚C, light intensity 1000W/m^2, Air mass 1.5 [12]

2.2 Models for market potential identification and sites matching

This part illustrates the methodologies of market potential analysis by analysing factors that influence the solar energy market. In 2.2.1 there is an explanation of potential market identification methodology, which provides a useful factor analysis models for the following case study in China. In 2.2.2 there is a review of other studies with similar research basis that introduces the methodology background.

2.2.1 Potential market Identification

Sánchez et al. performed research for the potential market for parabolic dish and micro gas turbine engines, but the models for each factor are suitable for all the solar technology market analysis [24]. The model estimates the solar power system market potential in 22 countries and ranks the market potentials from high to low to identify which countries has the better potential for solar energy investments. In Sánchez et al.'s methodology the data applied for each country are using the average data values across the whole country, i.e there is no regional study in this methodology. However, it is only depending on the data source and data analysis. If apply the model to regions within a big country with regional data, the regional market potential can be found out.

This section reviews Sánchez et al.'s methodology as the background and an explanation of the model modification and regional study based on this methodology will be presented in Chapter 3.

This model analyses 22 candidate countries by combining the 5 following factors to calculate the index market potential (IMP): solar irradiation DNI, energy demand, power grid, energy policy with local GDP and financial risk. IMP indicates the market potential level in different countries. The IMP value for each country ranges from 0 to 1. The values in this model of the factors are non- dimensional. The 5 factors are solar irradiation factor (F_I), demand factor (F_D), grid factor (F_G), energy policy factor (F_P) and financial risk factor (F_F). These 5 factors also range from 0 to 1. When the factor value is closer to 1, the factor has more positive impact on high market potential of the country and vice versus.

Fig 2.2.1 shows a summary for the methodology identifying each factor for the index market potential (IMP). In the following chapter 3 and Chapter 4, there will be a detailed identification of the social, policy and economy diversity within Chinese provinces and demonstration of model modification for social, political and economy factor. The purpose for the review is to explain the difference of each factor for IMP and illustrate complete background for the model modification in the next chapters.

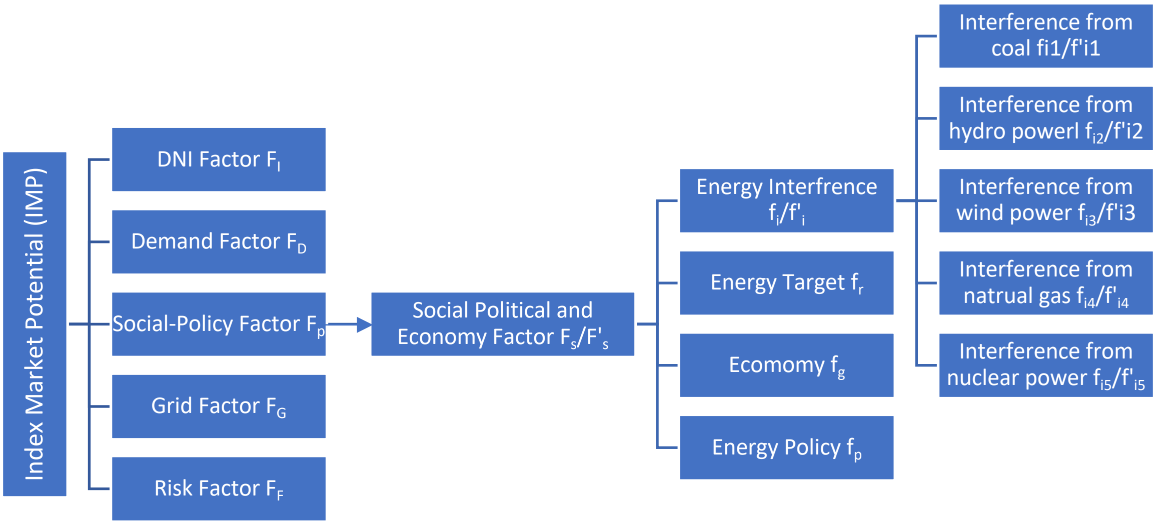

Fig 2.2.1 Market Potential Model Structure and its further modification in this study

(1) Solar irradiation factor F_I

The irradiation factor F_I is determined by the annual average value of DNI in the candidate countries. When DNI is below 1000kWh/m^2, the technology struggles to trigger the electricity generation from thermal energy and it is not economical either. Thus, the factor value F_I = 0, which means the average solar irradiation of the country does not make it competitive for the market potential of solar power. When DNI is beyond 2000kWh/m^2 the local DNI is sufficient for this technology to generate electricity. Where the factor F_I=1 means the solar irradiation factor is strongly competitive for the market potential of the country.

The thresholds 1000kWh/m^2 and 2000kWh/m^2 are defined by references specified to the Parabolic Dish system. These factor thresholds are chosen by size of collector, efficiency of power conversion units (including available DNI, concentration factor and design of the receiver) and peak temperature achievable at the receiver. For different solar technologies, the thresholds would vary.

(2) Demand factor F_D

F_D is the factor measuring how the energy demand of the country affects the market potential of solar energy. It is assessed by the annual electricity consumption and the fraction of population that have no access to electricity. F_D is defined separately for large scale systems (farm-arrangement) with power grids and small countries without power grid (stand-alone systems).

For those countries with isolated power supply system (stand-alone), when the proportion of people who have no access to the electricity and the annual electricity consumption is lower than the 10th country of the top ten countries' consumption, the energy consumption and the population in the country do not show a good potential for the parabolic dish system and the demand factor ranges between 0 to 1. When the country has competitive consumption potential for parabolic dish system, the demand factor value is 1.

In this model, the demand factor for farm-arrangement system countries only consider the annual consumption compare with the 10th annual consumption among all the candidate countries. For stand-alone system, Sánchez et al. introduces the proportion of people who have no access to the electricity. The idea is to consider the combined impact of electricity consumption and the lack of electricity supply.

(3) Risk factor F_F

For the risk analysis, Sánchez et al. use the model from the organization Euler Hermes which calculates the country grade and country risk level. This risk analysis model is used for the national level risk analysis, the database from Euler Hermes for this model is based on the information of each candidate country.

(4) Grid Accessibility F_G

The grid accessibility factor stands for the quality of the transmission and power distribution of the country, which reflects the market potential of the country in terms of the power grid in the country. In stand-alone system, there is no need transmission grid for power supply as the electricity production centre directly accesses the consuming centre, so they consider the grid factor high and the grid accessibility factor F_G is 1. For countries with grid connection (farm-arrangement), Sánchez et al. assume the value of factor F_G is high when the country is with high proportion of electricity access, high solar irradiation (DNI) and high demand i.e. high population density. In [38], Labordena and Lilliestama conducted a similar but more in depth research on the transmission for solar power from desert area with low energy consumption to urban areas with high energy. This research compares the cases in China and U.S. as they have geographical similarity of solar energy and population density distribution. To estimate the possibility of transmitting solar power via HVDC system, this paper identifies the solar energy potential of the desert generation sites. Then it optimises the plant siting, design and operation of the power plant to meet the actual hourly demand for the transmission and identify the optimal transmission routes for minimizing the costs of economic, social and environmental. This paper shows the potential of solar power long distance transmission breakthrough in China and shows the possibility for the location choosing in desert area, it also shows a good comparison with the case of U.S. solar transmission.

The study from the grid factor hints that there is big diversity for electricity generation and even energy resource imbalances in countries with wide areas. China, has over 30 provinces and it is reasonable to assume that there can be variation among all the provinces in China. In the next chapters, the analysis will be conducted with this assumption to analyse the social, policy and economy differences and its impact on solar market potential. The methodology is based on the following factor F_p. The original factor F_p in Sánchez et al.'s model is reviewed in the following session. In Chapter 3, further detail of the factor modification will be explained.

(5) Energy policy and social factor F_p

In Chapter 3 and Chapter 4, the identification of social, policy and economy market potential factor is based on the analysis of factor F_P and the model used is the modified version of factor F_P. Therefore, in this session, there is a detailed review of the model of factor F_P with discussion of modification in case study of China.

Factor F_p is determined by five sub-factors:

- f_i(Electricity import rate of the country),
- f_r (Fraction of renewable energies in the electricity mix),
- f_g(Macroeconomic wealth – GDP growth rate),
- f_G(Microeconomic wealth – per capita GDP),
- f_p(Regulatory framework and renewable energy policy).

The value of these five factors vary from 0 to 1. When the value is closer to 1, the sub-factor has greater impact and vice versus. F_P is defined as equation (2.2.8) with the five sub-factors. The GDP factor $f_G$and the GDP growth rate factor $f_g$will be combined as one economy factor f_g in Chapter 4, as in China, there are big power grids across the provinces, stand-alone system does not apply in the country, as well as other big countries connected with big power grids. However, the economic factor will still include the GDP data in the analysis.

$$F_p = \begin{cases} \dfrac{f_i + f_r + f_g + f_p}{4}, & \text{Farm-Arrangement} \\ \dfrac{f_i + f_r + f_G + f_p}{4}, & \text{Stand- Alone} \end{cases} \tag{2.2.8}$$

(i) f_i is the electricity import rate of each country. If the electricity of the country is highly dependent on importing energy from outside the country, the value of f_i is tend towards 1, which indicates a higher potential for greater demand for the solar system. If the country has low import rate of electricity, the value of f_i tends towards 0, which shows a lower potential for the need of additional energy system.

The basis to use this sub-factor is to consider how the competitiveness of solar power will be affected by other energy in the country. However, in China, the import electricity has less interference for the potential of solar energy compared with the traditional energy e.g. coal fire, hydro power, natural gas. In chapter 1, there is information on the energy mix of China in recent years. To explore this information in more depth for different provinces, a more accurate factor for China will be crated to measure the competitiveness and potential of solar power among other energies. It is assumed that, identifying regional energy mix instead of considering the energy import rate would contribute a better result for this research on China.

Thus, the improvement will be made for this sub factor f_i is to evaluate the influence of other energy in the local regions to identify the factor.

(ii) Factor f_r -- renewable energy fraction in electricity is measuring the potential for renewable energy growth according to policy targets to renewable energies, which reflects the potential of solar power market trend. Sanchez et al. determines this factor with the 20-20-20 Climate Energy package.

Let R the fraction of renewable energy in a country (without hydro power).

- When R<20%, f_r =1,
- When 20%<R<40%, f_r decreases down to a residual value 0.25 (0.25 is the value set a bit higher than 20%),
- When R>40%, f_r= 0.25.

The variation is presented as equation (2.2.9). The threshold 20% refers to the aim of 20-20-20 Climate Energy package:'Raising the share of EU energy consumption produced from renewable resources to 20%'. The threshold 40% is twice the goal of the aim 20% which is expected in good proportion of the usage of renewable energy.

$$f_r = \begin{cases} 1, & R<20\%, \\ 1.75 - 3.75R, & 20\%<R<40\% \\ 0.25, & R>40\% \end{cases} \tag{2.2.9}$$

The value of f_r is determined with the 20-20-20 Climate Energy package in Sánchez et al.'s methodology. It presents the idea to identify the factor for how solar energy market potential varies with the renewable energy policy target. After all, the renewable energies in each province in China is developing by different amount and speed, the investment from government for different renewable energy also varies in different areas according to the local resources. Therefore, for China, this model is useful but there is further improvement that can be made on it, such as to exploring the exact goal for governments in each region to install solar power specifically and how much expenditure is planned to invest in solar energy industry so that makes the policy target threshold value more related to solar power and obtains a more suitable result for China.

(iii) In equation (2.2.10), the sub-factor of wealth in countries with farm-arrangement systems and stand-alone systems are determined respectively by f_g(competitiveness of GDP growth rate) and f_G (competitiveness of country GDP).

f_g is the factor of how the GDP growth rate impacts on the solar power market potential in countries with large scale power grids (farm-arrangement). The thresholds for the GDP growth rates for candidate countries are 0% and 3%, which are determined by EU27 commission in 2012 and 2014. The value of f_g can be given by equation (2.2.10).

g represents the country GDP growth rate.

- When g is greater than 3%, the wealth level in the country can support solar power technology in the country and factor f_g=1.
- When g is less than 0%, the country does not had suitable wealth environment for solar energy and f_g=0.
- When <0%g<3%, f_g increase from 0 to 1.

$$f_g = \begin{cases} 1, & g \geq 3\%, \\ \dfrac{g}{0.03}, & 0\% < g < 3\%, \\ 0\,, & g < 0\%, \end{cases} \tag{2.2.10}$$

For countries with stand-alone systems, the value of factor f_G (the competitiveness of its GDP value) is given in equation (2.2.11). In the equation, 5360.7USD/year is the transition value (GDP of Algeria) of the first and second quarter of the GDP among all candidate countries in the database of World Bank in 2013. G is the GDP value of the country. Similar to equation (2.2.10),

- when G≥ 5360.7 USD/year, f_G=1, which means that the wealth level in the country has opportunities for solar power.
- when 0<G<5360.7USD/year, the value of f_G linearly varies from 0 towards to 1.

$$f_G = \begin{cases} 1, & G \geq 5360.7\, USD/year, \\ \dfrac{G}{5360.7}, & 0 < G < 5360.7\, USD/year, \end{cases} \tag{2.2.11}$$

The regional wealth is an important factor to measure the market potential for solar power energy. To use this model to analyse China, an improvement to combine the regional GDP, GDP growth rate and government subsidies in each province to get the wealth factor for each region would contribute a more accurate result for China.

(iv) f_p indicates whether or not the renewable energy policy is in place in a country or not.

- If the renewable energy policy is in place in the countries, f_p=1 which means there is a big market potential for solar energy;
- If the renewable energy policy is not in place in the countries, f_p=0, which means the market potential for solar energy is weak.

This sub-factor is a simple measurement for the impact of the implementation of renewable policy on solar energy. This sub-factor can be directly applied to analyses the market potential in China among different regions. To make this factor more accurate on this model, the further studies analyse how much effort that government contributes into solar energy i.e. identifying the target for solar energy infrastructure plan from government.

(6) Index market potential (IMP)

With the 5 factor results for the 22 candidate countries, Sánchez et al. define the weighs for each factor as they could have different level of impact in the IMP. To obtain the result of index market potential (IMP) for each country, Sánchez et al. put weights ω_I, ω_D, ω_G, ω_P, ω_F on the factor of F_I, F_D, F_G , F_P and F_F representatively in overall IMP, demonstrated as equation (2.1.12). All the weighs range from 0 to 1. $\omega_I + \omega_D + \omega_G + \omega_P + \omega_F = 1$

$$IMP = \omega_I F_I + \omega_D F_D + \omega_G F_G + \omega_P F_P + \omega_F F_F \qquad (2.2.12)$$

The features for different solar technologies are different, so that the sets of weighs for each solar technology differentiate the IMP for each technology. In the case study in China, the model analysis is only on social policy and economy factor F_s, which is modified from the social factor F_p in Schanchez's model and the factor weighting will not be discussed further in this case study.

In the next section, there is a review of other similar research to compare the differences and advantages of Sánchez et al.'s method with other similar methods that regarding to analyse the solar power prospect in China.

2.2.2 Other Site Selection Research reviews

This section reviews other related research on site selection, that shares the same basis of exploring the proper site for solar energy or for other uses. This review analyses the similarities and differences of these studies with Sánchez et al.'s study in 2.2.1 and compares the advantages and disadvantages of them.

Wang et al. presented the idea of choosing the solar power plant location by using the information from GIS to estimate the electricity generation potential as solar irradiation determines the quality of the solar energy usage in certain locations [25]. Based on solar irradiation distribution, the model for choosing the solar power plant locations can be built, which involves using land information including the landscape, area of usable land, water supply, transportation, local residence and power grid. This information indicates that the location of solar power station influences the power capacity, the cost of construction and land use. So the electricity price determines whether it is balanced in economical profit and the environmental benefits that the solar power plant can make. Wang et al. showed importance of solar irradiation and showed a model for the location selection, which is influenced by space factors and suggests the factors to be considered and the interrelationship for investing or building a solar power station. However, this paper does not show a methodology or tool for quantitative analysis of how those factors affect each other with specific parameters.

Aydin et al. analyse the optimal sites for hybrid renewable power on grid system with wind turbine and solar PV in Turkey [26]. This study first discussed environmental objectives and economic feasibility objectives for wind power and solar power, then integrate the performance indexes on economic objectives to wind energy and solar energy respectively and performance index on environment objectives to solar energy and wind energy respectively. Combing the site selection for wind turbines and solar power plant, the study can get the site selection plan for the hybrid system. The main objective on the methodology is combing two suitable results together consisting of solar power and wind power by its calculation and stimulation model. The similarity for this research and Sánchez et al.'s research is that they both process different factors by turning the regional information into the non-dimensional values varying from 0 to 1 to identify the suitability for solar power and wind power on a site. However, the factors counted in this methodology are mainly environmental and geographical factors as the research purpose is for site selection. The data processing on each factor is similar. The advantage of Sánchez et al.'s methodology on China is that it involves better regional information on the capability of electricity demand and supply by identifying grid factor, demand factor and social policy factor. These factors are processed in different models, such as policy and DNI factor are identified with different types of information source of numerical and non-numerical, that provides a better diversity of processing different factor data.

Sener et al. established a method of site selection of landfill in Ankara with GIS and multi-criteria decision analysis [27]. The basis for this study is similar to Sánchez et al.'s study as it relates to detecting the suitable site with the local conditions for its application purpose. These two studies both choose multi-factors and combine the factors (layers) with different weights. In Sener et al.'s study, all the information for the analysed factors are taken from GIS and the data is put into good unity, the main process is to identify the weights for different layers with multi-criteria decision analysis. In this research Sener et al. use 16 map layers of local geographical information including: topography, settlements, roads, railways, airport, wetlands, infrastructures, slope, geology, land use, floodplains, aquifers and surface water. They discussed the top 4 candidate sites of the landfill use with two multi-criteria decision analysis methods: simple additive weighing method (SAW) and analytic hierarchy method (AHP). Although there are some similarities on the research basis with Sener et al., Sánchez et al.'s study still shows the advantages of the diversity for the regional factor processing (DNI, demand, grid, social policy and risk), which is more suitable for analysing the solar power market prospect in China rather than solely identify the geographical information.

Kengpol et al. presented a research on solar power plant site selection to avoid flooding with Fuzzy Analytic Hierarchy Process (Fuzzy AHP) and the Technique for Order Preference by

Similarity to Ideal Solution (TOPSIS) model [28]. The Fuzzy AHP is employed to determine the weights of qualitative and quantitative criteria that can affect the selection process. The difference between fussy AHP with classical AHP is that it can be used for dealing with uncertain criteria in decision-making cases, such as environment and policy, which do not have precise numerical values [29]. TOPSIS is also a decision-making method used to rank different sites to based on certain criteria. This study gives an algorithm for site selection. Choudhary and Shankarhad present a similar research in [30] that combine Fuzzy-AHP, TOPSIS and a 'social, technical, economic, environmental, and political (STEEP) consideration' to build the model for the solar thermal plant site selection [27]. This research emphasises the differences of different decision-making methodology and how the algorithms applied into solar thermal site selection. These provides a reference for choosing the decision making model. Similarly, Uyan presents a study for solar PV site selection with analytic hierarchy process (AHP) in city of Konya in Turkey with five criteria: distance from residential areas, land use, distance from roads, land slope, distance from transmission lines [31]. This study presented the solar irradiation distribution information on Konya but this paper does not consider it as a main factor that affects the site selection.

To conclude, the research on site choosing are on similar process:

(1) Identify factors,

(2) Process the factor data,

(3) Weight different factors,

(4) Obtain the result of the suitability or potential of the candidate sites.

Overall, the other studies illustrate the decision making mathematical models for the solar power plant site selection. It again reveals the importance of the role of decision making models on different factors when identifying the potential to build a solar energy sites. However, it can be seen that most similar methodology for solar station site selection are more focused on the geographical situation rather than the social policy and economy situation for the candidate region.

Sánchez et al.'s method for identifying the market potential for parabolic dish and micro gas turbine and the model is able to process the data into comparable numerical results. Thus, the advantage of Sánchez et al.'s method is being significant for the study on the prospect of solar power in China because the market potential for solar power in China is not just about the suitability of building solar power plant or installing solar panels, but it is also related to the balance of regional energy supply and demand, economy development and political support from government. On the other hand, due to the discussion on each factor in 2.2.1, there are still modification needed to ensure the whole model is suitable for analyse the market potential for China.

Chapter 3. Methodology

3.1. Objectives

This study aims to explore a more social, political and economy details for the market potential of local provinces in China by modifying and applying part of the potential market identification methodology. The aim to the results is presenting the social, policy and economy factor F_s for each Chinese province and demonstrating the correspondent conclusions to the results. This study is based on part of the solar market potential identification study from Sánchez et al., aiming at presenting an accurate distribution on social and political condition in each province of China and illustrating how the social energy development, local economy and energy policies impact solar market potential in regions shown as parameters with non-dimensional values.

3.2 Case study: China

The sub-factor is modified from the market potential study (Sanchez et al., 2016) in literature review, that identified the sub-factors of electricity import rate, the renewable energy target, the economic wealth level and the policy. The following paragraphs explain the reasons for the necessary sub-factor modifications adapting to the market of China.

(1) The basis to use electricity import rate as sub-factor is to compare how the competitiveness of solar power will be affected by other imported energy in the country. However, in China, the imported electricity has less interference for the potential of solar energy compared with the local traditional energy e.g. coal fire, hydro power, natural gas. A more effective way to evaluate this factor for China would be to compare the competitiveness and potential of solar power with the country's energy mix. Therefore, identifying regional energy mix, instead of considering the energy import rate would contribute to a more accurate result for this research of China.

(2) The renewable energy target reflects the potential for renewable energy growth by looking at policy targets to renewable energies, which indicates the potential of solar power market trend. Sánchez et al. introduces the 20-20-20 Climate Energy package as the basis to determine the value of this sub-factor. The idea also suggests that solar energy market potential follows the renewable energy policy target, which is 20% reduction of greenhouse gas, 20% EU energy from renewable energy and 20% improvement for energy efficiency in 2020. This data source is based on renewable energy plans, however, it neglects the competition from other renewable energies, such as wind power and hydro power. Thus, changing the data source into solar energy plan will make the result more accurate. Therefore, to evaluate this sub-factor for China, the data on government's energy development plan will be focusing on solar power plan specifically.

(3) The Economic Factor shows the impact of local wealth level on the solar power market potential in countries. For farm-arrangement system, Sánchez et al. evaluate the thresholds with the GDP growth rates for candidate countries based on the GDP growth rate 0% and 3% from EU27 commission in 2012 and 2014. In the case study of China, the analysis will combine the GDP and its growth in recent years and identify the economy competitiveness for each province.

(4) The Policy Factor indicates whether or not the renewable energy policy is in place in a country. The value sub-factor is straightforward: 1 (policy in place) or 0 (policy not in place) and it easily adapts to the provinces in China. Therefore, the following methodology carries over the formula for policy sub-factor f_p =1 (big market potential).

This study is mainly modifying the social-policy factor of the market potential identification from Sánchez et al's model in order to improve and adapt the market to each province in China. The main data in this study is from the 13th Five-Year Plan government documents [32] and China Statistical Year Book[33]. The specific tasks include:

1. Explore the details of energy mix in China, identifying the interference from other energies in each province in China and create the formula that replaces f_i with energy mix in various regions in China.

2. Re-formulate f_r by searching and obtaining information and data of government goals on developing solar energy and related policies for each province in China.

3. Understand the wealth background of each province. Estimate the wealth level with GDP and GDP growth rate which indicate to the potential for installing solar energy to calculate the wealth sub-factor f_g for each province.

4. Identify the current local installation for solar power system and define policy factor f_p in the modified model.

5. Integrate the data information for each province of Energy mix, government goals, local wealth level and current local installation to generate a new social and political factor F_s for China and demonstrate result.

3.3 Methodology Explanation

With the review of solar market potential estimation. This section presents the methodology to calculate social and political factor F_s . The social, policy and economy factor F_s includes four sub-factors:

- Energy Mix Factor f_i,
- the Economic Factor f_g
- Policy factor f_p
- Solar increase trend f_r.

$$Fs = \frac{f_i + f_g + f_p + f_r}{4} \tag{3.3.1}$$

Energy Mix factor f_i

f_i is calculated by the local resources interference from coal, hydro power, wind and natural gas in each province in China. The data applied is the installation capacity or production of each resource: coal, hydro power, wind, natural gas and nuclear, which are the top 5 energies among the energy mix in China and they were selected as the interferences. The results will be presented as distribution curves for the energy production or capacity in each province ranking from low to high. The fractions that the capacity of each resource takes in each province are represented by variables: a_1 (Coal), a_2 (Hydro Power), a_3 (Wind Power), a_4(natural Gas) and a_5 (Nuclear). $0 \le a_i \le 1$. The sub factors for the local resource interference of the chosen five resources are f_{i1}, f_{i2} , f_{i3}, f_{i4}, f_{i5}.

Energy	Coal Fire	Gas Fire	Nuclear	Hydro Power	Wind Power	Solar
Percentage In energy mix	65%	3.1%	3.5%	19.2%	4%	1.1%

Table 3.3.1 Chinese Energy Mix

$$f_i = \frac{f_{i1} + f_{i2} + f_{i3} + f_{i4} + f_{i5}}{5} \qquad (3.3.2)$$

In order to make the value more uniformed, the data is processed into the proportion among the country's total. This does not affect the shape and the rankings on each curve, which are shown in chapter 4. If a_i represents the value of each point on the curves, a_i indicates the proportion value:

- $0 < a_i < 1$, a_i is non-dimensional.
- when a_i is greater than the turning point value, the production or installed capacity of this resource takes overwhelming advantage in the province and the sub-factor would be 0 (low market potential for solar power).
- While a_i is between 0 and the turning point value, the sub-factors vary linearly with formulas 3.3.3, 3.3.4, 3.3.5, 3.3.6 and 3.3.7.

- If $a_i = 0$, the province has barely no production for this interference energy and the market potential sub factor for that resource would be 1 (high market potential for solar power).

In the formulas below,

- $a_1$is the turning point value of coal fire production proportion among the whole production in China (Guizhou, the highest 4th province with coal production). $a_1 = 0.045$.
- a_2 is the turning point value of hydropower capacity proportion among the whole capacity in China (Guangxi, the highest 6th province with hydropower capacity installed). $a_2 = 0.068$
- $a_3$is the turning point value of wind power installed proportion among the whole capacity in China (Heilongjiang, the highest 6th wind power installed capacity). $a_3 = 0.056$
- a_4 is the turning point value of natural gas proportion among the whole supply in China (Guangzhou, the highest 4th natural gas supply). $a_4 = 0.209$
- a_5 is the turning point value of nuclear proportion among all the provinces (Liaoning, the highest 4th nuclear proportion) . $a_5 = 0.122$

Coal:

$$f_{i1} = \begin{cases} 1, & a_1 = 0 \\ 1 - \dfrac{a_1}{0.045}, & 0 < a_1 < 0.045 \\ 0, & a_1 \geq 0.045 \end{cases} \tag{3.3.3}$$

Hydropower:

$$f_{i2} = \begin{cases} 1, & a_2 = 0 \\ 1 - \dfrac{a_2}{0.068}, & 0 < a_2 < 0.068 \\ 0, & a_2 \geq 0.068 \end{cases} \tag{3.3.4}$$

Wind:

$$f_{i3} = \begin{cases} 1, & a_3 = 0 \\ 1 - \dfrac{a_3}{0.056}, & 0 < a_3 < 0.056 \\ 0, & a_3 \geq 0.056 \end{cases} \tag{3.3.5}$$

Natural Gas:

$$f_{i4} = \begin{cases} 1, & a_4 = 0 \\ 1 - \dfrac{a_4}{0.048}, & 0 < a_4 < 0.048 \\ 0, & a_4 \geq 0.048 \end{cases} \tag{3.3.6}$$

Nuclear

$$f_{i5} = \begin{cases} 1, & a_5 = 0 \\ 1 - \frac{a_5}{0.122}, & 0 < a_1 < 0.122 \\ 0, & a_1 \geq 0.122 \end{cases} \quad (3.3.7)$$

Energy target factor $\boldsymbol{f_r}$

Factor f_r measures the potential for renewable energy growth according to policy targets to renewable energies, which reflects the potential of solar power market trend. In the modified formula, the threshold for calculating Factor f_r is based on the 'Thirteens Five Year Plan' which illustrates the national development plan from 2016 to 2020. This information indicates the potential for building the solar power plant with the government support in each province in China. The upcoming installation capacity of solar power plant in each province will be based on the government plan. Factor f_r is defined by the solar power installation increase trend and speed. The Factor is calculated with the predicted increase speed and the value is non-dimensional, $1 \geq f_r \geq 0$. The detailed solar power installation capacity in each province is presented in next chapter.

Policy factor $\boldsymbol{f_p}$

f_p is the measurement for the impact of the implementation of renewable policy on solar energy, i.e. f_p indicates whether government has a plan to contribute in solar energy in each province in China.

- If the province has no solar energy development plan or from government or has restrictions for solar energy, f_p=0 (little market potential).
- If the province has the solar energy installation plan from government, f_p=1 (big market potential).

Economic Factor $\boldsymbol{f_g}$

The economic factor is identified by using GDP data as the base level adding the GDP growth for each region to predict the energy purchasing power in the future in different regions. The wealth factor is predicted with the GDP in 2016 increasing yearly until 2020 using the average increase rate from 2014 to 2016. The predicted GDP value for 2020 is calculated with the average increase rate of 2014, 2015 and 2016 and assume the GDP is increasing from 2016 to 2020 at the same rate. f_g varies linearly with formula (3.3.8).

f_g= 0 if the provinces rank in the bottom six provinces for the predicted GDP.

f_g= 1 if the provinces rank in the top six for the predicted GDP.

4542.4 (billion RMB) is the predicted GDP in 2020 for Hubei which is the sixth province from the top and 1347.5(billion RMB) is the predicted GDP in 2020 for Xinjiang which is the sixth province from the bottom.

$$f_g = \begin{cases} 1, & w \geq 4542.4 \\ \frac{w}{4542.4}, & 4542.4 > w > 1347.5 \\ 0, & w < 1347.5 \end{cases} \tag{3.3.8}$$

Chapter 4. Discussion and Results

The objective of this chapter is to illustrate the approach of the analysis model among solar market potential analysis and make conclusion for the social and political factor analysis in China with the model modification. As China is a country with wide area, various landscape and different level of society development, the advantage of this analysis is that it involves the data from the energy market in different regions in China and the government policies for each region so that we can get the precise result for each province of factor F_S rather than just for the whole country of China.

The social, political and economy analysis indicates a big variation for factor F_S to the solar system market potential in each province with the impact from local energy mix, economy and policies. This factor analysis excludes the solar irradiation, energy demand, power grid and risk analysis. Even though F_S does not represent the Index Market Potential (IMP), it reveals there is a big diversity of the market potential impacted by factor F_S in each province within a big country.

4.1 Discussion for $\boldsymbol{f_i}$

The analysis for f_i is based on the production or installed electricity generation capacity for the top five energies among the energy mix: coal, hydro power, wind power, natural gas and nuclear. By ranking the energies' capacity or production from low to high for each province, the distribution can be shown as discrete increase curves for each energy, presented from Table 4.1.1 to Table 4.1.5. On each curve, it can be seen that the energy distributions mildly increase among most of the provinces and soar up in the last 4^{th} or 6^{th} provinces along the rankings. The turning point for the distribution soaring can be set as the threshold of the sub-factors corresponding to each energy. Among the statistics, the local proportion of coal and natural gas are calculated with the local production amount, while the local proportion of hydro power, nuclear and wind power are calculated with the installation capacities. The reason for this is that coal and natural gas are taken from natural resources and the resource intensity in the region can better reflect the competitiveness of these two energy sources. Whilst, making use of hydro power, wind power and nuclear energy more dependent upon equipments, thus, the local proportion of these three energies are calculated with the data of their regional installed capacities.

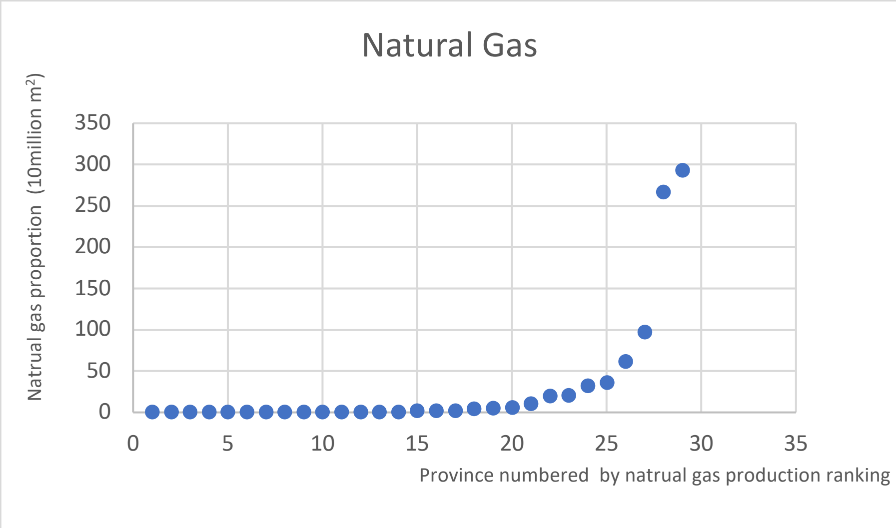

Fig 4.1.1 Curves for natural gas distribution in each province

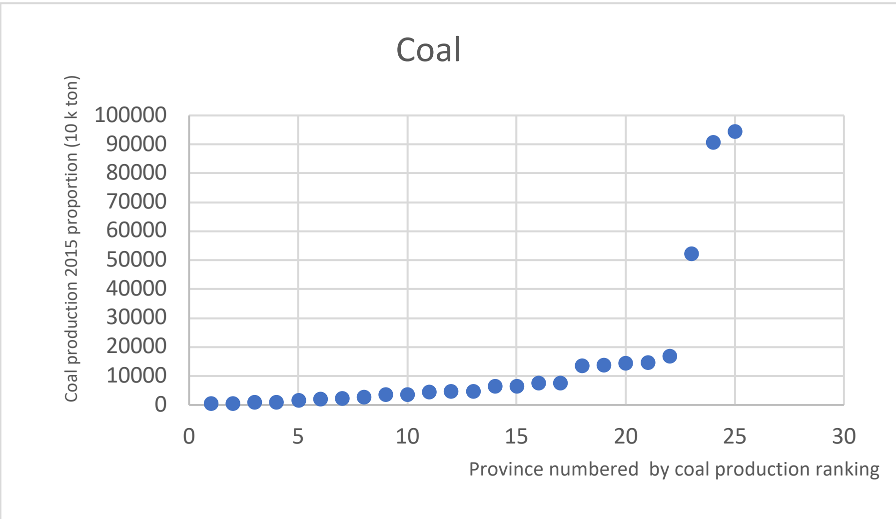

Fig 4.1.2 Curves for coal production distribution in each province

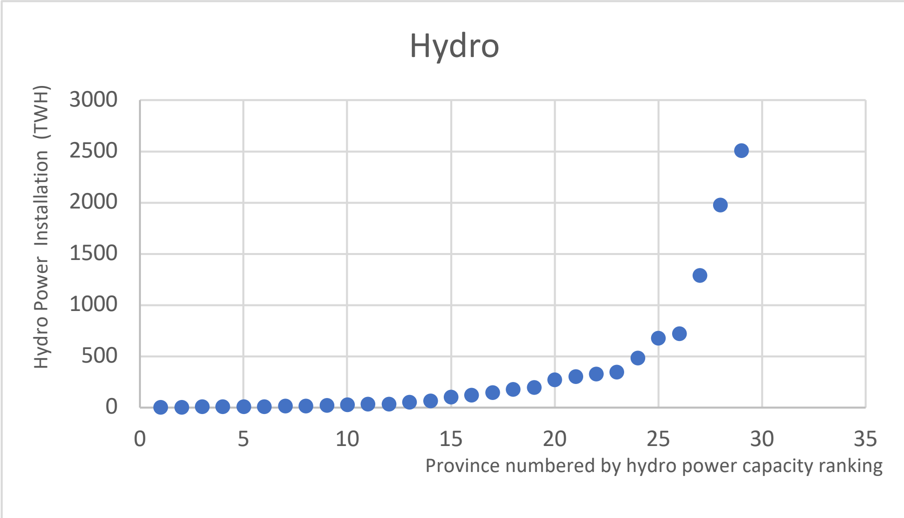

Fig 4.1.3 Curves for hydro power capacity distribution in each province

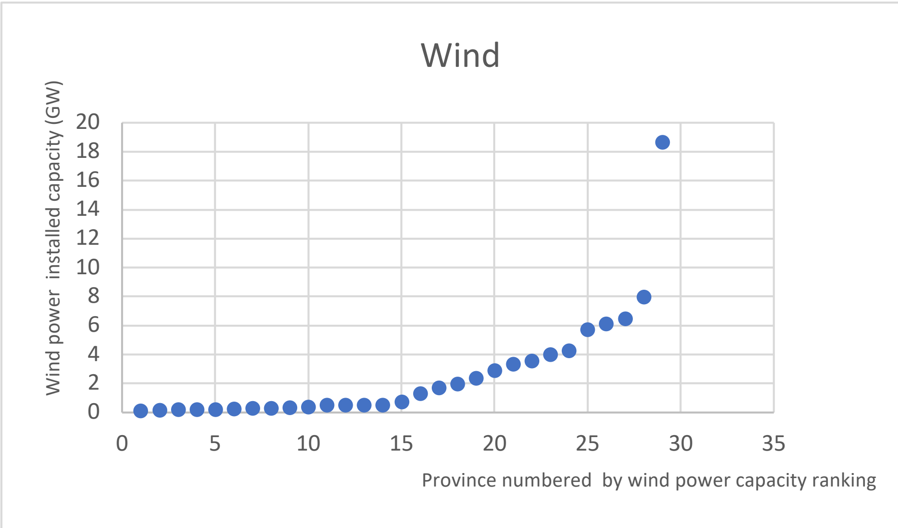

Fig 4.1.4 Curves for wind power capacity distribution in each province

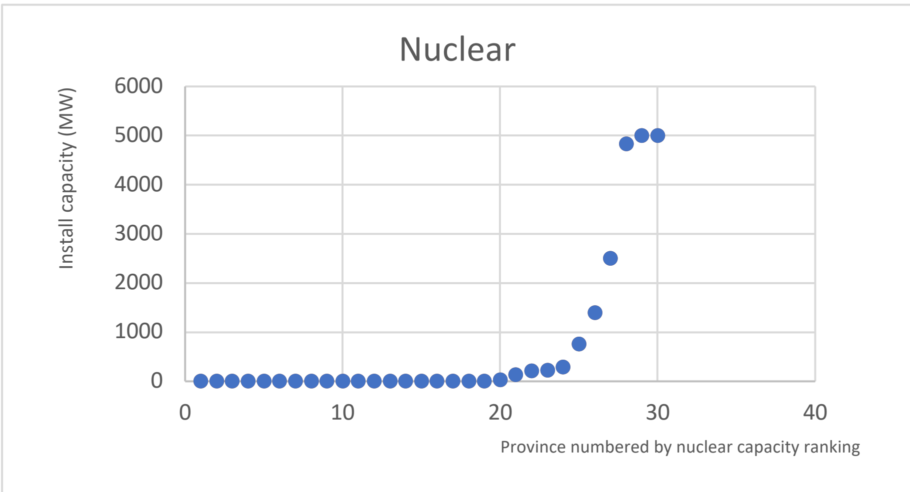

Fig 4.1.5 Curves for nuclear power capacity distribution in each province

province Number	Province	Natural Gas Production (100m m2)	Province Number	Province	Coal production (10k ton)	Province Number	Province	Hydro Capacity (Twh)
1	Inner Mongolia	0	1	Guangxi	402.4	1	Hebei	4.3
2	Ningxia	0	2	Beijing	450.1	2	Hainan	4.9
3	Shanxi	0	3	Hubei	758.4	3	Beijing	6.5
4	Yunnan	0	4	Qinghai	804.8	4	Shandong	7.1
5	Fujian	0	5	Fujian	1531.8	5	Liaoning	8.8
6	Guizhou	0	6	Jiangsu	1918.9	6	Jiangsu	11.1
7	Anhui	0	7	Jiangxi	2090.2	7	Heilongjiang	15.1
8	Zhejiang	0	8	Jilin	2622.5	8	Ningxia	15.5
9	Jiangxi	0	9	Hunan	3464.6	9	Inner Mongolia	22.8
10	Hunan	0	10	Chongqing	3477.6	10	Shanxi	27.7
11	Beijing	0	11	Gansu	4390.3	11	Anhui	30.9
12	Gansu	0.084	12	Yunnan	4590.1	12	Xizang	32.1
13	Guangxi	0.163	13	Liaoning	4635.4	13	Jilin	54.8
14	Jiangsu	0.372	14	Heilongjiang	6321.9	14	Jiangxi	62.7
15	Hubei	1.4	15	Sichuan	6355.5	15	Henan	103.3
16	Shanghai	1.9	16	Hebei	7437.1	16	Shaanxi	120.3
17	Hainan	1.9	17	Ningxia	7443.5	17	Zhejiang	146.5
18	Henan	4.2	18	Anhui	13404.2	18	Xinjiang	174.9
19	Shandong	4.6	19	Henan	13547.8	19	Chongqin	195.1
20	Liaoning	5.8	20	Shandong	14216.7	20	Gansu	271
21	Hebei	10.4	21	Xinjiang	14643.3	21	Guangdong	305.6
22	Jilin	19.4	22	Guizhou	16763	22	Fujian	330.5
23	Tianjin	20.5	23	Shaanxi	52224.2	23	Qinhai	344.2
24	Chongqing	32	24	Inner Mongolia	90580.3	24	Hunan	485.3
25	Heilongjiang	35.6	25	Shanxi	94410.3	25	Guangxi	678
26	Qinghai	61.4	26	Guangdong	n/a	26	Guizhou	723.7
27	Guangdong	96.6	27	Zhejiang	n/a	27	Hubei	1290
28	Sichuan	266.2	28	Shanghai	n/a	28	Yunnan	1978.9
29	Xinjiang	293	29	Hainan	n/a	29	Sichuan	2508.4
30	Shaanxi	415.9	30	Tianjin	n/a	30	Tianjin	N/A
						31	Shanghai	N/A

Table 4.1.1 Data to the number labeled for provinces in Fig 4.1.1 to Fig4.1.3

province number	Province	Wind power capacity (GW)	province number	Province	Nuclear capacity (MW)
1	Sichuan	0.07	1	Jilin	0
2	Chongqing	0.1	2	Heilongjiang	0
3	Beijing	0.15	3	Guizhou	0
4	Qinghai	0.18	4	Sichuan	0
5	Hubei	0.19	5	Henan	0
6	Guangxi	0.2	6	Inner Mongolia	0
7	Hunan	0.24	7	Hubei	0
8	Tianjin	0.27	8	Shanxi	0
9	Jiangxi	0.28	9	Tianjin	0
10	Hainan	0.3	10	Shaanxi	0
11	Shanghai	0.35	11	Ningxia	0
12	Zhejiang	0.48	12	Hebei	0
13	Anhui	0.49	13	Anhui	0
14	Henan	0.49	14	Qinhai	0
15	Guizhou	0.5	15	Xizang	0
16	Shaanxi	0.7	16	Gansu	0
17	Fujian	1.29	17	Xinjiang	0
18	Guangdong	1.69	18	Shanghai	0
19	Yunnan	1.96	19	Chongqin	0
20	Jiangsu	2.37	20	Yunnan	0
21	Shanxi	2.9	21	Beijing	25
22	Xinjiang	3.3	22	Hainan	130
23	Ningxia	3.56	23	Jiangsu	212
24	Jilin	3.99	24	Guangxi	216
25	Heilongjiang	4.26	25	Shandong	290
26	Shandong	5.69	26	Fujian	756
27	Liaoning	6.11	27	Guangdong	1392
28	Gansu	6.47	28	Liaoning	2500
29	Hebei	7.97	29	Zhejiang	4832
30	Inner Mongolia	18.62	30	Hunan	5000

Table 4.1.2 Data to the number labeled for provinces in the Fig 4.1.4 to Fig 4.1.5

The provincial results for f_i shown in Table 4.1.3, it can be found that most of the values of f_i in each are above 0.5. This result is probably caused by the even weight of each energy calculated or it does not count the grid transported electricity supply. One of the concern is that there is no comparison of the energy proportion on each energy in each province. For instance, the interference parameter shows the same value of wind power and nuclear power for Fujian province (f_{i3} =0.7 f_{i5} =0.7). However, seen from the electricity production from the same year (2015), wind power produced 1.29 GW while nuclear only produced 756MW in Fujian province. One of the possible way to adjust the result of $f_i$is to weight the value of f_{i1},

f_{i2}, f_{i3}, f_{i4} and f_{i5} with the energy mix percentage presented in chapter 3 and the result as follow in Table 4.1.4.

Province	f_{i1}	f_{i2}	f_{i3}	f_{i4}	f_{i5}	f_i
Fujian	0.90	0.51	0.70	1	0.70	0.76
Guangxi	0.97	0	0.95	1	0.91	0.77
Jilin	0.84	0.92	0.06	0.83	1	0.73
Heilongjiang	0.62	0.98	0	0.48	1	0.61
Hunan	0.79	0.28	0.94	1	0	0.60
Guizhou	0	0	0.88	1	1	0.58
Jiangxi	0.87	0.91	0.93	1	0	0.74
Sichuan	0.62	0	0.98	0	1	0.52
Liaoning	0.72	0.99	0	0.92	0	0.53
Henan	0.19	0.85	0.88	0.97	1	0.78
Guangdong	1	0.55	0.60	0	0.44	0.52
Inner Mongolia	0	0.97	0	1	1	0.59
Hubei	0.95	0	0.95	0.99	1	0.78
Shanxi	0	0.96	0.32	1	1	0.65
Tianjin	1	1	0.94	0.68	1	0.92
Shaanxi	0	0.82	0.83	0	1	0.53
Ningxia	0.55	0.98	0.16	1	1	0.74
Beijing	0.97	0.99	0.96	1	0.99	0.98
Hebei	0.56	0.99	0	0.90	1	0.69
Zhejiang	1	0.78	0.89	1	0	0.73
Anhui	0.20	0.95	0.88	1	1	0.81
Qinhai	0.95	0.49	0.96	0.42	1	0.76
Jiangsu	0.88	0.98	0.44	1	0.91	0.84
Xizang	n/a	0.95	n/a	n/a	1	n/a
Gansu	0.74	0.60	0	1	1	0.67
Xinjiang	0.13	0.74	0.22	0	1	0.42
Shanghai	1	1	0.92	0.98	1	0.98
Shandong	0.15	0.99	0	0.93	0.88	0.59
Hainan	1	0.99	0.93	0.97	0.95	0.97
Chongqin	0.79	0.71	0.98	0.67	1	0.83
Yunnan	0.73	0	0.54	1	1	0.65

*Table 8*Table 4.1.3 Result data for energy mix factors $\mathrm{f_i}$

$$\begin{cases} f'_{i1} = f_{i1}\times 0.65 \\ f'_{i2} = f_{i2}\times 0.192 \\ f'_{i3} = f_{i3}\times 0.04 \\ f'_{i4} = f_{i4}\times 0.031 \\ f'_{i5} = f_{i5}\times 0.035 \\ f'_{i} = f_{i1}\times 0.65 + f_{i2}\times 0.192 + f_{i3}\times 0.04 + f_{i4}\times 0.031 + f_{i5}\times 0.035 \end{cases} \tag{4.1.1}$$

Province	f'_{i1}	f'_{i2}	f'_{i3}	f'_{i4}	f'_{i5}	f'_{i}
Jiangsu	0.57	0.19	0.02	0.03	0.03	0.84
Hebei	0.36	0.19	0	0.03	0.03	0.61
Zhejiang	0.65	0.15	0.03	0.03	0	0.87
Shandong	0.10	0.19	0	0.03	0.03	0.35
Henan	0.12	0.16	0.03	0.03	0.03	0.39
Guangdong	0.65	0.10	0.02	0	0.01	0.79
Hubei	0.62	0	0.04	0.03	0.03	0.72
Inner Mongolia	0	0.18	0	0.03	0.03	0.25
Anhui	0.13	0.18	0.03	0.03	0.03	0.41
Shanxi	0	0.18	0.01	0.03	0.03	0.26
Hunan	0.51	0.05	0.04	0.03	0	0.64
Heilongjiang	0.40	0.19	0	0.01	0.03	0.64
Sichuan	0.40	0	0.04	0	0.03	0.48
Guangxi	0.63	0	0.04	0.03	0.03	0.73
Jiangxi	0.57	0.17	0.04	0.03	0	0.81
Shaanxi	0	0.16	0.03	0	0.03	0.23
Yunnan	0.47	0	0.02	0.03	0.03	0.56
Chongqin	0.51	0.14	0.04	0.02	0.03	0.75
Jilin	0.55	0.18	0	0.02	0.03	0.79
Liaoning	0.47	0.19	0	0.03	0	0.68
Guizhou	0	0	0.03	0.03	0.03	0.1
Qinhai	0.62	0.09	0.04	0.01	0.03	0.80
Beijing	0.63	0.19	0.04	0.03	0.03	0.93
Shanghai	0.65	0.19	0.04	0.03	0.03	0.94
Fujian	0.59	0.10	0.03	0.03	0.02	0.77
Tianjin	0.65	0.19	0.04	0.02	0.03	0.93
Hainan	0.65	0.19	0.04	0.03	0.03	0.94
Ningxia	0.36	0.19	0.01	0.03	0.03	0.62
Xinjiang	0.08	0.14	0.01	0	0.03	0.27
Gansu	0.48	0.11	0	0.03	0.03	0.66

Table 4.1.4 Energy mix factors calculated by weighting each energy proportions

In Table 4.1.4, the result f_i' shows wider range of value variation than f_i . The advantage is that it adapts the energy fraction to the energy market mix so that shows the variation of energy interference according to the amount supplied. The only problem will be that it weakens the impact for each energy and it does not reflect the effects from other renewable energy such as nuclear and hydropower as much. When choosing a site for solar system, the results of the final factor Fs calculated with f_i or F's calculated with f_i' can be compared and both are worth taken into consideration.

4.2 Discussion for f_r

The factor f_r energy target is calculated with the latest growth speed of solar system installation target according to government's 13th Five-Year Plan. The analysis compared the solar system installed capacity from 2012 to 2016 and planned installation capacity from 2017 to 2020, shown in Table 4.2.1. The value of f_r is defined by the average 5 year's increase speed up to 2020 (2016 to 2020), which can be presented on graphic curves and seen in Fig 4.2.1. Apparently, the solar power increase trend led by the government clearly indicates the potential for solar system in the region. Even though in the further future, the solar capacity can be full in regions and the increase speed becomes slower and slower. The curve for the recent years of solar power capacity increase is still increasing, thus, the value of factor f_r can effectively represent the solar market potential in terms of the government target.

Provinces in China	2012 installed solar systems (GW)	2014 installed solar systems (GW)	2015 installed solar systems (GW)	2016 installed solar systems (GW)	2017 installed solar systems (GW)	2018 installed solar systems (GW)	2019 installed solar systems (GW)	2020 Solar plant planned installation (GW)	f_r
Fujian	0.094	0.094	0.15	0.27	0.42	0.57	0.72	0.9	0.15
Guangxi	0.074	0.074	0.12	0.18	0.68	0.98	1.28	1.58	0.325
Jilin	0.011	0.025	0.07	0.56	1.06	1.46	1.76	2.06	0.208
Heilongjiang	0.061	0.02	0.02	0.17	0.97	1.77	2.57	3.37	0.67
Hunan	0.265	0.051	0.29	0.3	0.8	1.3	1.6	1.9	0.17
Guizhou	0.00056	0.005	0.03	0.46	0.76	1.06	1.36	1.66	0.25
Jiangxi	0.107	0.13	0.43	2.28	2.78	3.08	3.38	3.68	0.25
Sichuan	0.01	0.35	0.36	0.96	1.46	1.96	2.26	2.56	0.17
Liaoning	0.097	0.12	0.16	0.52	1.02	1.42	1.72	2.02	0.208
Henan	0.223	0.356	0.41	2.84	3.74	4.24	4.74	5.24	0.417
Guangdong	0.275	0.32	0.63	1.56	2.06	2.86	3.66	4.46	0.67
Inner Mongolia	0.381	2.84	4.98	6.37	7.37	8.37	9.37	10.37	0.83
Hubei	0.118	0.118	0.49	1.87	2.37	2.87	3.17	3.47	0.208
Shanxi	0.043	0.43	1.13	2.97	3.77	4.77	5.77	6.77	0.83
Tianjin	0.055	0.03	0.12	0.6				0.8	0.042
Shaanxi	0.152	0.52	1.17	3.34	4.14	4.94	5.74	6.54	0.67
Ningxia	0.565	2.17	3.09	5.26					0
Beijing	0.136	0.06	0.16	0.24					0.192
Hebei	0.209	1.23	2.39	4.43	5.43	6.63	7.83	9.02	1
Zhejiang	0.264	0.66	1.64	3.38	4.38	5.38	6.38	7.38	0.83
Anhui	0.166	0.26	1.21	3.45	4.25	4.85	5.35	5.85	0.375
Qinhai	2.13	4.13	5.64	6.82	7.62	8.12	8.62	9.12	0.292
Jiangsu	0.87	1.72	4.22	5.46	6.66	7.66	8.66	9.66	0.83
Xizang	0.142	0.15	0.17	0.33					0.139
Gansu	0.44	5.17	6.1	6.86					0
Xinjiang	0.27	2.71	4.06	8.62					0
Shanghai	0.151	0.03	0.21	0.35					0.083
Shandong	0.347	1.14	1.33	4.55	5.05	6.05	7.05	8.05	0.83
Hainan	0.161	0.23	0.24	0.34					0.2
Chongqin	0	0	0	0.005					0
Yunnan	0.044	0.33	0.65	2.08	2.58	3.08	3.58	4.08	0.417

Table 4.2.1 Energy target factor f_r with government target statistics

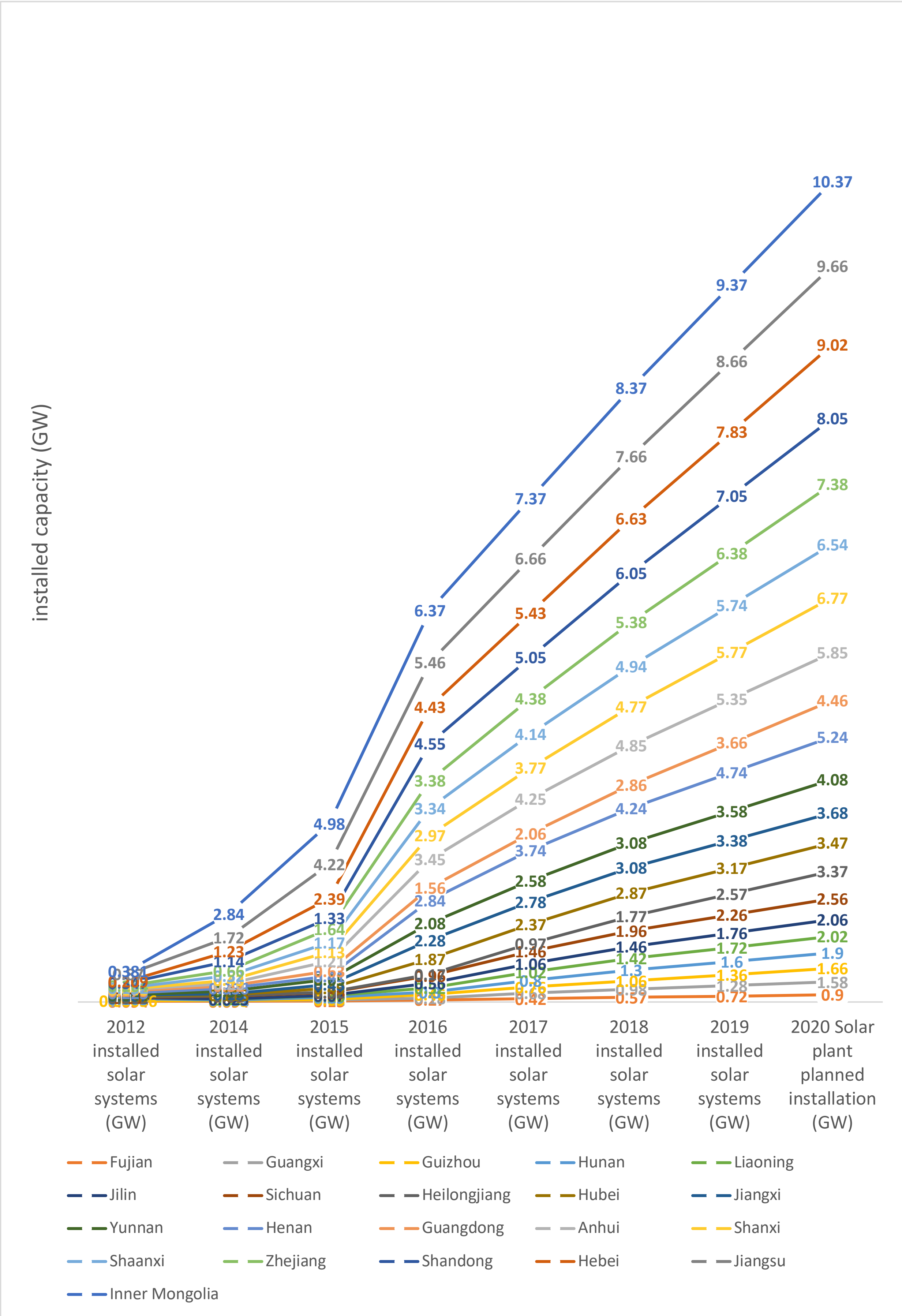

Fig 4.2.1 Solar energy installation with government targets over years

With the data and graphic curve in Table 4.2.1 and Fig 4.2.1, the increase trend is defined by the most recent stable increase speed since 2016. For some provinces with increase speed variation, the estimate speed is combined with the two most recent speed towards to 2020. Table 4.2.1 presents the solar capacity installation target for 22 provinces, based on the information of the government 13th Five-Year-Plan. The data for rest provinces are based on annual energy data sheet.

With the statistics of the solar installation target and the graphic trends, f_r can be predicted for each province. This prediction is only based on the existing data and all the values are assumed with the current trends. For instance, in Hunan province, solar installation increases by the rate of 50 GW/year for 2016-2018 and increases by the rate of 30 GW/Year for 2018-2020. Thus, the predicted increase rate will be between 30-50 GW/Year and the mid-point 40 GW/Year is taken.

However, in Qinhai province, the solar power increase during 2016-2017 is 80GW/Year, but the increase speed drop to 50GW/Year for 2017-2020, the predicted installation increase in the next five years (2020-2025) is 50GW/Year as the speed is stable for 3 years' time.

Among all the provinces, Beijing, Tianjin, Shanghai, Fujian, Xizang and Hainan are not given a certain target in the plan and the solar installation will be according to the local infrastructure condition. Thus, the increase speed would be calculated by (2020 target – 2016 installed capacity)/4. For Gansu, Xinjiang and Ningxia area, since there is a severe electricity restriction to solar energy for its local electricity overloading, the government currently has no plans on solar system installation Thus, the install speed is expected to be 0 up to 2025. As mentioned at the beginning of this section, f_r reflects the predicted solar energy installation increase speed and in order to make this factor non-dimensional, the values of f_r in each province are divided by the top speed (Heibei: 120 GW /year).

The result well represents the regional variation of f_r in each province. And it identifies the future increase of solar system in different regions and it reflects where the government targets are for developing solar energy. However, since the result is processed by analysing the existing data, the limitation for this is that this result could vary in the next five or ten years and it requires further adjustment over times depending on the future national Five-Year Plans.

4.3 Discussion for f_p

The policy factor f_p reflects whether there is a strong policy support from the energy plan with government, which directly influences the stability development potential for solar power in the province. This factor is also based on governments most recent Five-Year Plan. And simply represents whether or not there is government support for the particular region to develop solar energy or not. Due to the power overload in Gansu, Xinjiang and Ningxia province of the solar and wind power are restricted at the moment, government is not planning to increase the solar system capacity in these three provinces. Thus, f_p=0 for these three regions (little market potential). Due to the limitation of land use in Beijing, Tianjin, Shanghai, Fujian, Xizang and Hainan, government is not setting certain target for solar power installation for these six provinces and f_p=0 for these six areas. For the rest of the provinces, government set plans to increase the solar power capacity and f_p=1 (big market potential). The limit is that the even for government, the balance of electricity supply is hard to predict in long run. The policy for each province may change or remain in the next 5 years or 10 years would only depend on the effect from the macro-control of the county authority, especially for those province with power overload. Thus, the result accuracy from the policy impact could be weaken overtime by the future policy variation.

4.4 Discussion for f_g

For the economy factor f_g, the analysis compares the GDP and GDP growth rate from 2014 to 2016 and calculate the predicted GDP in 2020 with the average GDP growth rate from 2014-2016. The main purpose of this calculation is combining the GDP and GDP growth rate and use non-dimensional numbers to represent the wealth level in different regions. This factor will indicate whether the region has the economy advantage to develop solar systems.

Thus, the result for f_g in Table 4.4.1 is presenting the wealth level for each province and contribute a measurement for the overall factor F_s.

Province	2014GDP (billion RMB)	2014gdp Growth (%)	2015GDP (billion RMB)	2015gdp Growth (%)	2016GDP (billion RMB)	2016gdp Growth (%)	2020 GDP prediction	f_g
Guangdong	6781	7.8	7281.2	8	7951.205	7.5	10724	1
Jiangsu	6508.8	8.7	7011.6	8.5	7608.6	7.8	10479.8	1
Shandong	5942.6	8.7	6300.2	8	6700.8	7.6	9150.1	1
Zhejiang	4017.3	7.6	4288.6	8	4648.4	7.5	6254.1	1
Henan	3493.8	8.9	3701	8.3	4016	8.1	5551.9	1
Sichuan	2853.6	8.5	3010.3	7.9	3268	7.7	4451.6	0.98
Hubei	2737.9	9.7	2955	8.9	3229.8	8.1	4542.4	1
Hebei	2942.1	6.5	2980.6	6.8	3182.8	6.8	4125.4	0.91
Hunan	2703.7	9.5	2904.7	8.6	3124.4	7.9	4356.6	0.96
Fujian	2405.5	9.9	2598	9	2851.9	8.4	4040.5	0.89
Shanghai	2356.8	7	2496.5	6.9	2746.6	6.8	3586.8	0.79
Beijing	2133	7.3	2296.9	6.9	2489.9	6.7	3259.7	0.72
Anhui	2084.9	9.2	2200.5	8.7	2411.7	8.7	3387.7	0.74
Liaoning	2862.6	5.8	2870	3	2203.8	-2.5	2394.8	0.53
Shaanxi	1769	9.7	1817.2	8	1916.5	7.6	2649.5	0.58
Inner Mongolia	1777	7.8	1803.3	7.7	1863.2	7.2	2494.4	0.55
Jiangxi	1571.4	9.7	1672.4	9.1	1836.4	9	2617.7	0.58
Guangxi	1567.3	8.5	1680.3	8.1	1824.5	7.3	2479.1	0.54
Tianjin	1572.7	10	1653.8	8.1	1788.5	9	2527.7	0.55
Chongqing	1426.2	10.9	1572	11	1755.8	10.7	2652.6	0.58
Heilongjiang	1503.9	5.6	1508.4	5.7	1538.6	6.1	1927.8	0.42
Jilin	1380.3	6.5	1427.4	6.5	1488.6	6.9	1924.6	0.42
Yunnan	1281.4	8.1	1371.8	8.7	1487	8.7	2060.8	0.45
Shanxi	1276.1	4.9	1280.2	3.1	1292.8	4.5	1522.1	0.33
Guizhou	922.6	10.8	1050.2	10.7	1173.4	10.5	1760.0	0.39
Xinjiang	927.3	10	932.5	8.8	961.7	7.6	1347.6	0.30
Gansu	683.7	8.9	679	8.1	715.2	7.6	980.2	0
Hainan	350.1	8.5	370.3	7.8	404.4	7.5	548.8	0
Ningxia	275.2	8	291.2	8	315	8.1	429.1	0
Qinhai	230.3	9.2	241.7	8.2	257.2	8	356.0	0
Xizang	92.1	10.8	102.6	11	115	10	172.1	0

Table 4.4.1 Economy factor f_r with economy statistics

The results for f_g presents the wealth level of each province, which potentially indicates the demand for local utility of solar energy. Similar to other sub-factors, the value of f_g is based on the past years GDP and the average GDP increase rates and the prediction for the future economy level in each province uses the average increase rate from the past years economy level, which might cause inaccuracies in the prediction with future economy fluctuation, which requires minor adjustments over years.

4.5 Overall Results

Combining factors f_i, f_r, f_p and f_g with Formula 3.3.1 in Methodology, the social, policy and economy potential for each province can be identified by factor F_s in Table 4.5.1. Additionally, according to the discussion for sub-factor f'_i in session 4.1, the correspondent factor F'_s is also calculated, shown in Table 4.5.2.

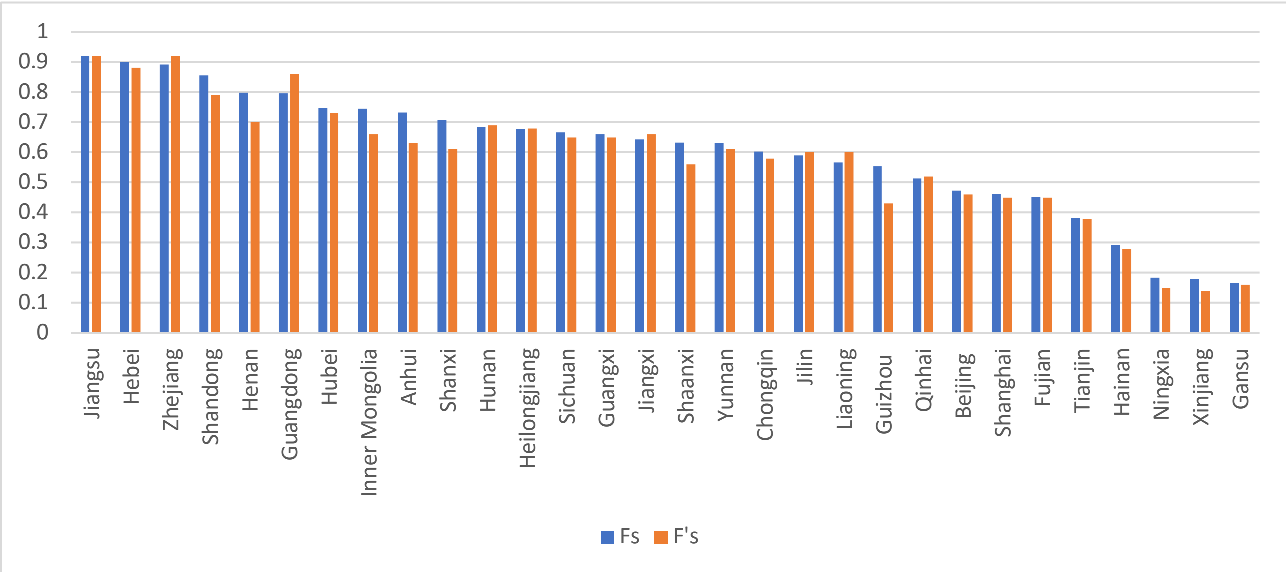

Fig 4.5.1 Result comparison of F_s and F'_s

Province	f_i	f_r	f_p	f_g	**F_s**
Jiangsu	0.84	0.83	1	1	0.92
Hebei	0.69	1	1	0.92	0.90
Zhejiang	0.73	0.83	1	1	0.90
Shandong	0.59	0.83	1	1	0.86
Henan	0.78	0.42	1	1	0.80
Guangdong	0.52	0.67	1	1	0.80
Hubei	0.78	0.21	1	1	0.75
Inner Mongolia	0.59	0.83	1	0.55	0.74
Anhui	0.81	0.37	1	0.74	0.73
Shanxi	0.65	0.83	1	0.33	0.71
Hunan	0.60	0.17	1	0.96	0.68
Heilongjiang	0.61	0.67	1	0.42	0.68
Sichuan	0.52	0.17	1	0.98	0.67
Guangxi	0.77	0.32	1	0.54	0.66
Jiangxi	0.74	0.25	1	0.58	0.64
Shaanxi	0.53	0.67	1	0.33	0.63
Yunnan	0.65	0.42	1	0.45	0.63
Chongqin	0.83	0	1	0.58	0.60
Jilin	0.73	0.21	1	0.42	0.59
Liaoning	0.53	0.21	1	0.53	0.56
Guizhou	0.58	0.25	1	0.39	0.55
Qinhai	0.76	0.29	1	0	0.51
Beijing	0.98	0.19	0	0.72	0.47
Shanghai	0.98	0.08	0	0.79	0.46
Fujian	0.76	0.15	0	0.89	0.45
Tianjin	0.92	0.04	0	0.56	0.38
Hainan	0.97	0.2	0	0	0.29
Ningxia	0.74	0	0	0	0.18
Xinjiang	0.42	0	0	0.30	0.18
Gansu	0.67	0	0	0	0.167
Xizang	n/a	0.14	0	0	n/a

Table 4.5.1 Results for F_s

Province	f_i'	F's
Zhejiang	0.87	0.92
Jiangsu	0.84	0.92
Hebei	0.61	0.88
Guangdong	0.79	0.86
Shandong	0.34	0.79
Hubei	0.72	0.73
Henan	0.39	0.70
Hunan	0.64	0.69
Heilongjiang	0.64	0.68
Jiangxi	0.81	0.66
Inner Mongolia	0.25	0.66
Sichuan	0.48	0.66
Guangxi	0.73	0.65
Anhui	0.41	0.63
Shanxi	0.26	0.61
Yunnan	0.56	0.61
Liaoning	0.69	0.60
Jilin	0.79	0.60
Chongqin	0.75	0.58
Shaanxi	0.23	0.56
Qinhai	0.80	0.52
Beijing	0.93	0.46
Shanghai	0.94	0.45
Fujian	0.77	0.45
Guizhou	0.10	0.43
Tianjin	0.93	0.38
Hainan	0.94	0.28
Gansu	0.66	0.16
Ningxia	0.62	0.15
Xinjiang	0.27	0.14

Table 4.5.2 Results for F's calculated with $\mathrm{f_i}'$

According to the overall result of F_S and F'_S, there is a big variation of the social, economy and political impact for solar energy market potential over different provinces in China (F_S varies from 0.92 to 0.17 and F'_S varies from 0.92 to 0.14), which shows that when considering the solar system development or investment in China, comparing the regional situation is important. The local energy mix could interfere introducing new renewable energy. The government target and policy towards solar system will support or resist the development of the local solar energy market. The local economy also affects the solar market as the installation investment and maintenance cost is high for solar PV system and solar thermal systems. Therefore, this result is meaningful for the market potential identification.

Compare the Result for F_s and F'_s with the government plan for solar in Table 4.2.1. It can be found that the biggest 5 solar power capacities are planned to be built in Inner Mongolia, Hebei, Shandong, Qinghai, Jiangsu. However, within those, only Jiangsu, Hebei and Shandong are in the top 5 provinces for market potential with social political and economy factor. Although government plans to build the biggest capacity of solar power plant in Inner Mongolia in their 13^{th}-five-year plan, the market potential under the factor F_s and F'_s do not show a high competitiveness of the solar market potential for this province. Therefore, it is highly likely that the solar power market potential is not solely determined by F_s and F'_s. The other market potential factors (DNI, demand, grid and risk) also have significant impact to the local market potential, which would affect government's development plans of solar energy. Combining F_s or F'_s with the DNI local factor, local population factor, grid factor and risk factor, there would be a more in depth solar market potential analysis and solar investment solution.

Additionally, as the result only stands for the market potential under social, policy and economy factor, the accuracy is hard to verify at this stage, because the market performance will only reflect back to the overall market potential with other solar market factors. Therefore, to verify this model, the other market potential factors need to be taken into account.

Apart from the case study of China, this model can also be applied in other big countries such as America, which only need different sets data of the local energy mix, energy policy and economy level in different regions. This model can improve the regional accuracy of market potential in big countries.

As advantages,

a. This model is able to present a more accurate and detailed results for solar power market potential with social, policy and economy factor.

b. This model can be applied in other big countries and provide a better regional strategy for solar power investment.

However, as disadvantages,

a. This model relies on the existing annual data, and the published government policy, which means the results will needs to be updated overtime when there are new annual data or policy released.
b. This model is hard to be verify as it does not directly reflect the market performance.
c. This result does not represent the overall regional market potential, the market potential index needs to combine DNI, demand, grid, social-policy and risks.

The results also reveal that:

(1) According to the government target, the solar installation increase speed for Chinese provinces is generally decreasing and it can be predicted that in the future, the renewable energy installation capacity covers most of the spare demands and there will be limit development space for solar power after several decades.
(2) The results demonstrate that Jiangsu, Zhejiang and Hebei are the top three provinces for solar system installation with the advantage of social, policy and economy condition. There are some result differences in Table 4.5.1 and Table 4.5.2 but the top three provinces remain on top. Apart from that, Guangdong, Shandong, Hubei and Henan are all in the top ten provinces in Table 5.5 and Table 5.6 and these four provinces also have high level social, political and economic advantage for solar system utility.
(3) The data for Tibet is partly incomplete, due to the low demand and low regional population intensity the energy usage, especially renewable energy capacity is barely low. On one hand, the energy competition is low. On the other hand, the resources is insufficient. Thus, to develop solar energy systems in Tibet requires more support of social, policy and economy from governments.

Chapter 5. Conclusion

This study is mainly focused on market potential of solar energy in China with the impact of social, political and economy factors. The purpose of this study is to contribute a feasible model to identify the most suitable areas to install solar system with social, political and economy support, so that it makes the best balance and benefit for the use of solar power in Chinese market.

Main Conclusions

1) The analysis methodology provides a feasible way to combine the social, political and economy statistic and information to analyse the solar power adaptability in each province in China.

2) The analysis results reveal the variation of solar market potential in each province in China under the sub-factors of energy mix, energy target, policy and local economy, which indicates that it is necessary to identify the regional differences when considering investing in solar systems.

3) This methodology is only used for predicting the social, policy and economy factor F_s, which contributes but does not represents the overall market potential. Comparing the result Fs and F's, there are some difference between the list of high market potential regions and the list of regions with big solar capacity installation in government's plan. Thus, the impact from other factors (DNI, demand, grid and risk) are also significant to the market potential.

4) This result is hard to verify at this stage as the social, policy and economy factor does not reflect the market performance directly.

5) This method can be applied for similar analysis in other big countries.

6) Undeniably, the prediction is based on the existing energy data, and with the energy market and policy variations in China in the future, the accuracy of this thesis results

itself will be weakened and it will need further data to adjust the model. The adjustment will depend on the future Five-Year-Plans from governments, future policies and economy growth in each province. Even though changes caused by future market or policy variation, the methodology is still available to calculate new prediction to adapt the market.

Further Information Required

1) The solar system installation targets are not set for some provinces such as Beijing and Shanghai - one of the reason could be the limitation of the land resources or interruption from other infrastructural projects. Although in this model, the reason does not have much impact on the result, it could still provide useful information for the future prediction for solar market in the regions.

2) As discussed above, although the solar system installation will slow down in the future years, it does not mean that the need for new solar system is reduced. It worth noting that the solar system life spam needs to be taken into consideration. The impact from the lifespan ranges would possibly make a difference in the demand potential for solar energy, which need more research and more information to explore the possible influence.

3) Electricity overload problem in provinces such as Xinjiang and Gansu also bring limitation for the final prediction as government does not reveal how many years will renewable energy will be limited in these regions. To predict the development trend for renewable energies in these regions might require a more information on their restructuring the power grid and electricity supply system.

4) For investment wise, Zhejiang, Jiangsu, Hebei, Guangdong, Shandong, Hubei and Henan has the best social, political and economy support for solar energy development. However, this study is only part of the market potential analysis, which does not cover the factor of solar irradiation, power demand, power grid and risk

analysis. Thus, this result only reveals one side of advantage but does not properly guarantee the benefit and return of the investment.

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