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The role of China in world's renewable energy market

By

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Abstract

As China faces harsh challenges by the increased energy demand and global warming caused by the use of fossil fuels, many targets being set by the Chinese government to increase the share of renewable energy in the energy structure and push for the construction of wind, solar and hydro energy power plants. This study examines the significant rise of China's renewable energy industry by analyzing the historical decisions that made China adopt the renewable energy model, its technological contributions to the global industry, the economic data of this transition and further investigates the development of the top three renewable energy sources China is using, solar energy, wind energy and hydro energy. China has surfaced as the world's largest carbon emitter by a large edge, and many of its cities are facing high levels of air pollution. Wind, solar and hydro are the main power sources that Chinese government turned into to help decarbonize its electricity system and alleviate increasingly critical air pollution problems. In short order China has bolstered its international standing as a renewable energy powerhouse. The first chapter analyzes the historical transition of China, from a highly coal dominated energy market to a clean, emission - free renewable pioneer. Development in Renewable energy is needed to replace China's coal dominated energy mix. Providing economic data second chapter aims to explain how this energy transition is going to help the economy of China in general, apart from just protecting the environment, by becoming a large renewable development center and a haven for foreign investors of renewable energy technologies. Third chapter analyzes in detail the three main renewable energy power sources China adopted over the years in order to minimize the coal dominated energy mixture. This chapter also provides short, mid and long term developments of the main renewable energy sources.

Chapter 1. Introduction

This dissertation aims to empirically examine the progress and challenges in China's renewable energy sector. Chapter 2 examines the historical decisions China has taken in incubating a renewable, coal-free, model that can make significant contributions to global emissions reduction goals. The use of coal has dominated energy consumption in China for decades. Admittedly the need to change this is twofold: environmental protection and allaying anthropogenic climate change. Chapter 3 evaluates the development of the renewable energy industry that promotes the overall adjustment of the country's macroeconomic structure by analyzing economic data. Providing these economic data we are trying to explain how this energy transition is going to help the economy of China in general, apart from just protecting the environment, by becoming a large renewable development center and a haven for foreign investors of renewable energy technologies. Chapter 4 analyzes China's solar, wind and hydro energy industry, detailing the technological and non-technological factors that contributed to industry's success. Solar, Hydro and Wind power are the main sources China is using to diversify its energy mixture. This chapter also provides short, mid and long term developments of the main renewable energy sources. Chapter 5 concludes the dissertation with a summary of findings and implications.

Fossil fuels have powered hyper growth of the Chinese economy and are the chief source of the country's air pollution and carbon emissions. Rapid increase in economic activity has led to a seemingly insatiable demand for energy, most of which is derived from coal. By one estimate, China's consumption accounts for close to half of the world's total coal use (EIA, 2016). Emissions from coal consumption have increased 5% annually between 2000 and 2012 (Liu, et al. 2015). China became the world's largest emitter of greenhouse gases by the mid-2000s due to the country's significant use of its abundant domestic supplies of coal. China is now responsible for nearly 30% of global carbon emissions (Olivier, et al. 2016). Its annual emissions have more than doubled since the early 2000s. The short- and long-term environmental consequences of the rapid expansion of Chinese energy-intensive economy have been the subject of both domestic and international attention.

Aware of the heavy toll that economic growth has exacted on the country's environment, Chinese leaders have turned to alternative sources of power. Rich hydropower resources and low marginal cost made hydroelectric generators an obvious candidate. However, constructions of massive dams failed to satiate the country's ever-growing demand for energy. At the same time fewer and fewer hydropower resources are left unexploited. After initial forays into building non-hydro renewable energy projects, the government decided that wind energy would play a central role in meeting the country's energy needs (Zhi, et al. 2014). The decision to embrace wind energy made sense given the country's abundance in wind sources, particularly in the northern regions. Besides, the economic argument was on wind energy's side, when solar energy was viewed as a niche technology that only high-income countries could afford.

With the passage of the 2005 Renewable Energy Law, the central government's grasp of wind energy set in motion the greatest construction increase in the history of the global industry. China went from having virtually no wind power to installing more wind turbines than any other countries in the world in less than a decade. In 2001 the cumulative capacity of China's wind turbine fleet was only around 400 MW by 2010 its capacity had expanded by more than 100- fold, to 44.7 GW (CWEA, 2016). China surpassed the United States as the country with the most installed wind capacity that year (GWEC 2012). By 2016 China's wind energy installed capacity dwarfed that of the United States, reaching more than 168 GW (AWEA & CWEA, 2016) During this time period, China successfully – and at times controversially – incubated a competitive domestic industry through various support policies and mechanisms. Playing only a marginal role not so long ago, domestic firms seized most of the Chinese wind turbine market from foreign producers and are now self-sufficient in most parts of the supply chain. In contrast to the wind energy industry, China's solar PV industry grew up primarily on foreign demand and relied on the private sector in its early days (Gallagher 2014, Zhang & Gallagher 2016, Zhi et al. 2014). By 2010, Chinese PV cell production made up of more than half of the global production (CRES 2010).

As financial conditions of the major solar power producers in China worsened, the Chinese central government began to put in place much more aggressive policies to promote the deployment of solar energy. In addition to putting in place a generous FIT regime, the government also established an installation target for solar PV. As a result, in 2015 China installed 16.5 GW of solar PV, bringing the country's total to 43 GW, stripping Germany of its global leader status. Hoping to take advantage of economies of scale, Chinese PV producers integrated up and down the supply chain and increased their production capacity. In short order Chinese firms dominated the global silicon PV industry. Today of every ten solar panels installed in the world, seven were manufactured by Chinese producers (CPIA 2016a). Recent developments demonstrate China's commitment to clean energy development and its intention to bolster its international image as a climate leader.

Nevertheless, China's renewable energy undertakings are far from being an unmitigated success. The same policies that buoyed domestic firms also resulted in severe overcapacity problems, both in the production of power equipment and in the generation of electricity. Both wind and solar industries have experienced painful periods of consolidation that led to a number of high-profile bankruptcies. Overcapacity also besets the electricity generation sector. The large amount of renewable capacity coming online coupled with business-as-usual expansion of coal- fired power plants resulted in reduced utilization rates across all energy supplies. Rampant curtailment of wind and solar energy owing to political and infrastructural obstacles continues to dog the industry, calling into question the efficiency of China's energy policies (Lâm 2017).

The contribution of the thesis is to provide not only a significant amount of renewable energy potential, but also to identify the geographical distribution of wind, solar and hydro future in China as well as the historical agreements that led China to focus on renewable energy and their economic impact.

Chapter 2. History of China's Renewables

2.1 Introduction

Chinese government made up some polices and planning in renewable energy which were suit for Chinese society conditions based in successful experiments from governments of other countries that made some specific programs and aims about the renewable energy, and then, under these frameworks advantageous policies came out. Furthermore, comities who either invest or just make use of renewable energy will be encouraged by market economic instruments. This chapter will analyze the critical decisions China's government took in order to lead the country in the renewable energy market.

2.2 Timeline

The Chinese government was driven to support the substantial increase in renewable energy sources due to the increased demand for energy and the environmental impact of greenhouse gas emissions. In the process renewable energy sources would substitute for fossil fuel consumption. Chinese government managed to accommodate the increased demand for energy and reduce carbon emissions at the same time. The widespread use of sources of renewable energy can assist in reducing global warming in environmental terms while at the same time help reach energy needs in economic terms (Yue & Wang, 2006).

As Table 1 states the development of China's engagement in global energy governance from the pre-80's period up until 2000. Development trends in region and countries also impact possibilities and actions in other countries this is why the energy shift China is undertaken should not be seen in isolation but rather in a global picture. (Zhongying, 2017).

Table 1: Development of China's engagement in global energy governance

Period	Level of engagement	Milestone events
Pre-1980s	No engagement	Began exporting oil, without communication with international energy entities.
1980s	Start of engagement	Acquired membership in the WEC in 1983. Joined IAEA in 1984.
1990s	More active engagement	Together with Hong Kong, China and Chinese Taipei, joined the APEC Energy Working Group in 1991. Signed UNFCCC treaty in 1992. Established co-operation relationship with IEA in 1996.
Since 2000	More influential engagement	Became a founding member of JODI in 2001. Established co-operation relationship with Energy Charter in 2001. Became a founding member of IEF in 2002. Established co-operation relationship with OPEC in 2005. Became a founding member of SCO Energy Club in 2007. Became a founding member of IFNEC in 2010. Involved in in-depth energy discussions under the G20 process since the early 2010s. Joined IRENA in 2014.

Source: Zhu, (2016), pp. 13

The increasing energy demand and the following economic growth in China was first introduced at the start of the opening and reform period since '78 . By mid '80s it became clear that in order to be able to keep up with this demand the energy sector needed thorough market reforms. In '86 the supply shortage reached 17% of annual power consumption. (Zhang, 2004; cit. in Cherni and Kentish, 2007) This gave a push to a first series of market reforms based on models for liberalization. Independent power producers (IPPs), which most of them were joint-ventures designed to reign in foreign investments, were allowed to enter the Chinese energy market by the policy makers.

In 1983, China acquired membership in the World Energy Council (WEC) and established a national WEC committee in 1983 as a first step to engaging in global energy governance. Unfamiliar with international rules and worried its own interests would be compromised, it took cautious steps in engaging with international energy entities, with the objective of exploring the outside world and learning how to abide by international rules (Zhu, 2016).

In 1996, the State Development Planning Commission associated State Science and Technology and the State Economy and Trade Commission made *The Outline of New Energy and Renewable Energy Development in China of 2010*. The Law of Renewable Energy in People's Republic of China has been become effective since January 2006. China's government first introduced policies of pricing electricity, taxes and resorted to investment to help the development of renewable energy. Furthermore, the government established a special fund for the development of renewable energy plus a system of subsidies that could achieve a rational pricing of electricity that is made of renewable energy sources (Zhu, 2016).

In 1997, a big financial crisis took place in China. In reacting to that the Chinese government installed a pool system that led to abandoning the long-term power purchasing agreements (PPAs) (Su *et al.*, 2010) This measure lead to large-scale retreat of foreign capital from the Chinese energy sector due to the reduced foreign investor confidence. Nevertheless, the intentions were to decrease prices by breaking the chains between state purchasers and state owned enterprises (Zhu, 2016).

Additional reforms during the '90s finally led to the current system of private ownership and government. This system is built around a predominant state planning, with a dispersed generation and grid system assisting, with private, dual or government ownership. Even today, reforms focusing on the establishment of competitive energy markets, still taking place, unbundling of generation and distribution.

In August 2004, the State Council updated and accelerated the investment mechanisms of China's electricity sector. The new process also known as 'check and approve process' altered the responsibility taken for assessment of profitability, a fast process in which authority, decision making and operating risk became responsibilities of the investor, in addition to the slow government regulated three step process (Zhu, 2004; cit. in Cherni and Kentish, 2004).

In January 2006, *The Law of Renewable Energy* in People's Republic of China has become effective. Chinese government set up a special system for renewable energy development, a support system which can make the renewable energy's pricing of electricity allocated and some policies of tax, pricing of electricity, investment and finally to subsidy the development of renewable energy (Zhu, 2016).

In June 2007, the *China's national program to address climate change* has been published. According to that, the top quota are biomass and developing wind energy in reaction to climate changes and greenhouse gases' reduction (Zhu, 2016).

In September 2007, Chinese government announced *the medium-and Long-term Program for Renewable Energy Development*, setting the goal of increasing renewable energy consumption to 10% by 2010 and 15% by 2020 of the total energy consumption (Zhu, 2016).

In December 2007, the government of China published the white paper of China's Energy Conditions and Policies. That paper accelerate the plan to develop energy diversification. In the national energy diversification strategy the development of renewable energy would be pivotal. The Chinese President Hu Jin-tao pointed it out in the report of 17th People's Congress that "*China should develop clean energy and renewable energy, protect land and water resource, build a reasonable and scientific system of utilizing energy resource, enhance the efficiency of using power resource, strengthen the ability of reacting the climate change and make contributions to protect the global climate*" (Zhu, 2016).

In 2009, China was the first to outstrip the United States by becoming the country with the most investments in renewable energy according to the annual report stated by the United Nations Environment Program (Zhu, 2016).

In January 2010, the National Energy Commission (NEC), headed by current Chinese Premier Wen Jiabao, was created by the State Council. This commission would be responsible for reviewing energy security and major energy issues, coordinating domestic energy development and international cooperation but most importantly preparing a national energy development plan (Zhu, 2016).

In 2012, Chinese government has published a book called *China's Energy Policy.* In this book the Chinese government called for international attempts in the following three respects.

First, enhanced dialogue and exchange. Enhancing communication among energy consuming, transiting and exporting countries is the base of international energy co-operation. The international community should further seal its ties, bilateral and multilateral, by increasing dialogue and exchange in the area of sufficient use of energy, environmental protection ,energy conservation, energy policy and energy management, while also promoting emergency response mechanisms and monitoring for the world energy market, and further deepen co-operation in co-ordination, exchange, and information personnel training (Zhu, 2016).

Second is carrying out effective energy co-operation. Promoting the principles of, common development, mutual benefit and reciprocity, the different countries should, improve and enrich co-operative methods, diversify supply channels, increase the international energy supply and ensure mutually beneficial co-operation in international energy resource exploration. They should co-operate to minimize volatility in the prices of big energy commodities, maintain the normal order of the energy market and secure the energy needs of various countries. In behalf of sustainable development, the developed countries should transfer and provide highly efficient and clean energy technology to underdeveloped and developing countries, and promote together ecological development globally making sure that intellectual property rights are kept protected. The international community should aim to increase energy services, promote sustainable development and eliminate energy poverty while helping the least-developed countries. (Zhu, 2016).

Third is working together to manage energy security. A rational and fair energy management mechanism in international level is essential for a strong worldwide energy market. The international community should work collectively to keep stability in oil exporting and producing countries (Middle East) and avoid geopolitical conflicts that will most likely affect the world's energy supply and assure the security of international energy transport routes. The foreign countries involved should establish major international energy discussions through consultation and dialogue. The use of armed and forced dispute should be avoided and energy issues should not be politicized (Zhu, 2016).

In 2014, China took a leading role in drafting the G20 Principles on Energy Collaboration. (Zhu, 2016). And in January of 2014 China became an official member, confirming its high renewable ambitions. China is now one of the top financial contributors to the International Renewable Energy Agency (IRENA).

In June 2014, Chinese President Xi Jinping announced a sweeping energy revolution in China, focused on the four areas of production, demand, incorporating international energy co-operation,institutional governance and technology —the "Four Revolutions and One Co-operation" vision (Liu, et al. 2018). He called for "strengthening international co-operation comprehensively and realising energy security under open conditions" (Xi, 2014a). Even though international co-operation had long been considered important in Chinese energy policy, this is the first time a Chinese president had recognised it officially, paving the way for China's deeper and wider engagement in global energy governance (Zhu, 2016).

In 2015, with 43 GW of total installed capacity China became the world's largest producer of photovoltaic power for the first time. (Zhu, 2016).

Also in 2015 the country joined the IEA, it also took an active part in the restructuring and reform of the IEF and the Energy Charter and suggested discussions to conduct efforts to meet the global power demand with green and clean alternatives through the establishment of a global energy interconnection (Zhu, 2016).

In May 2015, China became an Observer to the Energy Charter Conference when it signed the International Energy Charter political declaration in The Hague, Netherlands, Observer countries progress towards accession to the ECT by aligning their legal and regulatory frameworks with the provisions of the Energy Charter Treaty (ECT) and the Protocol on Energy Efficiency and Related Environmental Aspects (PEEREA). When Observer countries accede to the ECT they typically ratify the PEEREA at the same time (Zhu, 2016).

The PEEREA is a political agreement and its focus is on practical implementation of political commitment to improve energy efficiency consistent with sustainable development through efficient energy markets and market-orientated price formation, effective policies and measures as well as through cooperation with other Contracting Parties to the Protocol (EYIEL 2012)

In 2015 also, the United Nations Climate Change Conference took place in Paris. As stated in the United Nations Conference For Climate Change coal has dominated energy consumption in China for decades and that had to change to reduce anthropogenic climate change and protect the environment. To fulfil the Intended National Determined Contribution (INDC) for the post 2020 period developing renewable energy was necessary. Both developing and developed countries have promised to reducing their greenhouse gas emissions by increasing the use of renewable energy. China already submitted its Intended Nationally Determined Contribution (INDC) to the United Nations Framework Convention on Climate Change for the post-2020 period. This mitigation plan requires the attainment of five objectives by 2030. The share of non-fossil fuels had to increase to account for 20% of primary energy consumption at least and the peak in carbon emission would have to be reached by 2030 or earlier. China's forest stock volume had to increase by 4.5 billion cubic meters, which would amount to an increase of about 32.8% in terms of 2005 levels; carbon dioxide emission had to lower per unit of GDP to 35-40% of 2005 levels, which would be achieved around 2030 and regulations to reduce greenhouse gas emissions (GHG) had to be introduced (Zhu, 2016)

In 2016, as chair of the G20 and its Energy Sustainability Working Group (ESWG), China is promoting a more efficient and effective global energy governance system through enhanced energy dialogue under the G20 framework (Zhu, 2016).

In 2017, the International Energy Charter- China Electricity Council Joint Research Centre was established in Beijing. Additionally in 2017 the Chinese government released its Energy Revolution Strategy in four parts. Transition in energy supply with a focus on renewable energies and clean coal, energy consumption transformation to monitor unreasonable energy consumption and top primary energy growth with coal in particular, energy system revolution with institutional arrangement and energy technology revolution to stimulate (Zhongying, 2017).

2.3 Five-Year Plans

China's five-year plans are a series of strategic development initiatives that provide guidelines for development over five-year periods as Table 2 shows. Studying the five-year energy sector plans offers insight into the social and economic changes in China. Global energy governance first appears in the 12th Five-Year Energy Plan (plan for year 2010-15). In three Five-Year plans coal and oil have been endorsed as the main fuels for China's development. The coal power plants have been spoiled with access to cheap money, favorable dispatch rules, strongly supported by local governments and promoted by strong state-owned companies. The industry has been allowed to grow coal consumption without awareness for the environment, and additionally to that, the sector of transportation has made the oil consumption rise to a level, where two-third of the consumption is being imported. This energy system build-up is responsible for severe pollution of soil, water and air, but has also enabled a rapid economic growth. China has become increasingly dependable on imported fuels while the energy system is defined by low energy efficiency and cost-efficiency has not been the primary focus in the energy sector. Renewable energy has in fact been promoted, but only support or add-on to the existing system. The result has been relative high contribution levels to improve for the additional risk factors for renewable energy projects and high condensation of solar and wind power due to the lack of integrating into the power system (Zhongying, 2017). According to the 12th national five-year plan, China has set a target of 20% by 2020 as the share of renewable energy in the energy structure (Zhu, 2016).

Table 2: International energy co-operation in China's five year energy plans

Document	Global energy governance cited	References to international energy co-operation
10th Five-Year Energy Sector Plan	No	• Support and encourage Chinese enterprises to develop overseas oil and gas bases to ensure energy supply security. • Offer supportive policies to overseas oil exploration and development, such as cancellation of or preferential access to import quotas and licenses for domestic processing and utilisation of equity oil produced overseas, and establishment of overseas oil exploration and development funds and credit support.
11th Five-Year Energy Sector Plan	No	• Expand opening up. • Strengthen international energy co-operation in accordance with the principles of equality, mutual benefit and win-win co-operation.
12th Five-Year Energy Sector Plan	Yes	• Improve supporting systems for international co-operation. • Encourage domestic insurance agencies to participate in businesses such as insurance for Chinese equity oil and offshore personal and property insurance. • Participate actively and steadily in trade in the international energy futures market, and reasonably avoid market risks. • Engage actively in global energy governance, make full use of international multilateral and bilateral energy co-operation mechanisms, enhance communication and dialogue in the fields of energy security, energy conservation, CO_2 emissions mitigation, climate change, clean energy development, etc. • Promote the establishment of a fair and reasonable new order of global energy, and collectively safeguard energy security.
13th Five-Year Energy Sector Plan draft	Yes	• Expand international energy co-operation. • Make important bilateral and multilateral mechanisms as platforms, so as to promote international co-operation in the energy field. • Promote concrete energy co-operation in the frameworks of the "Silk Road economic belt" and "21st Century Marine Silk Road," extend co-operation projects, expand areas of co-operation, and promote development in industries such as equipment manufacturing, infrastructure construction and services. • Consolidate and improve four oil and gas import channels—from the northwest, northeast, southwest and offshore—and actively promote construction of related energy channels along the Bangladesh-China-India-Myanmar (BCIM) economic corridors and China-Pakistan Economic Corridor. • Actively participate in international energy governance and rule-making, push forward to build a just and equitable global energy governance mechanism, and enhance the country's voice in the international energy sector.

Source: Zhu, (2016), pp. 10

The 13th Five-Year plan changed this development orbit. As Table 3 states, the plan introduces visionary targets for the future development of the energy system. Approved and planned coal power projects were delayed or even stopped ,the encouraging conditions for coal power plants have been abated for new plants, more focus has been put on the development of electric cars as a promising solution for the increasing oil-dependency in the transport sector and lastly efforts to better integrate renewable energy were launched (IEA, 2018). China launched an innovation plan, China 2025, with focus on new technologies and on quality instead of quantity, including emerging industries such as electric vehicles and updated renewable energy technologies, which should form the main pillar of the Chinese economy in the future.

Table 3: The 13th Five Year Plan for key energy sub-plans

Sub-plans	Main objectives	Key measures
The 13th FYP for **Renewable Energy** Development	• Active and steady development of hydropower. • Coordinate and promote the development of wind power • Promote the diversification of solar power. • Accelerate the development of biomass energy and use of geothermal energy.	• Establish a goal-oriented management system for the development and use of renewable energy. • Implement renewable energy power generation in full purchase • Establish a renewable energy .green certification trading mechanism • Strengthen the regulation of renewable energy.
The 13th FYP for **Wind Power** Development	• Solve the problem of wind power consumption • Enhance the level of development and use of wind power in the eastern and southern regions • Improve the wind power industry management system • Establish the market competition mechanism	• Improve the annual development programme management mechanism • The implementation of a full protection of the acquisition system • Strengthen the operation of consumer regulation supervision • Innovative Price and Subsidy Mechanism
The 13th FYP for **Hydropower** Development	• Large-scale base construction, small and medium-sized river basin development, pumped storage construction • Ecological environmental Protection, integrated river basin management • Hydropower technology and equipment development	• Strict infrastructure management procedures • Implement corporate responsibility to ensure the safety of production and operations • Strengthen government regulation • Strengthen tracking analysis and project evaluation
The 13th FYP for **Solar Energy** Development	• Optimize the layout of photovoltaic power plants • Promote the industrialization of solar thermal power • Based on local conditions to promote solar heating • Demonstration of new energy micro-grid application • Speeding up technological innovation and industrial upgrading	• Improve the planning lead and project configuration management • Establishment of solar energy monitoring and evaluation system • Improve solar power market mechanisms and support supplementary power grid construction • Strengthen the solar energy industry standard system • Innovative Investment and Financing Models and Financial Services

Source: Yan, (2018), Pp. 129

2.4 Conclusions

China's 12th Five-Yea plan marked the initiation of the transition towards the adoption of clean, renewable energy. The Plan intended to materialize the primary objectives of energy security and protection of the environment. It also set a target to reduce energy intensity of GDP by 16% and increase the proportion of energy generated by sources other than fossil fuel in the TPEC (total primary energy consumption) to 11.4 %. Following that, it was during the National Climate Change Conference which was hosted in Paris in 2015, in which China stated that coal had dominated energy consumption in the country for decades and admitted openly that this had to change in order to protect the environment and to reduce anthropogenic climate change. This was the first time China took a step towards changing the energy mix of the country that up until this point was mostly based on fossil fuels and harming the environment. Lastly the 13th Five-Year plan set the ground for the major changes China is willing to take in order to reach the optimal amount of CO2 emissions as stated in Table 2 and Table 3 above.

Chapter 3. Economic Data

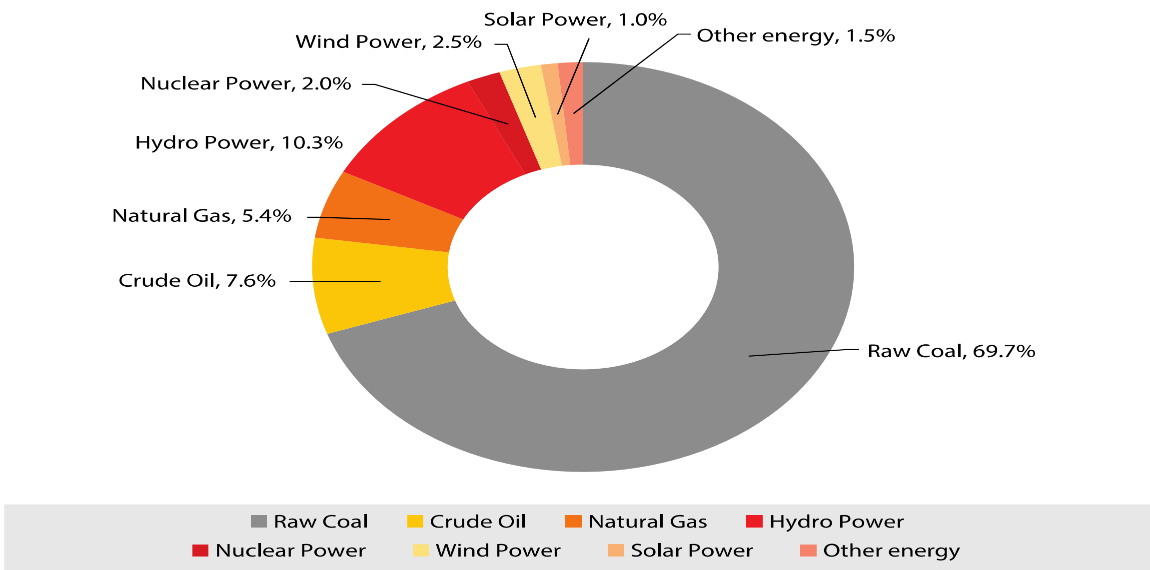
3.1 Introduction

This chapter will analyze the economic progress of China and the impact of the development of renewable sources of energy in China's economy and society. Taking onboard the increasing pressure of economic activity on the environment coupled by the shortage of fossil generated energy, China faces the need to prepare for and plan the adoption of renewable energy. Coordinated actions that involve the economic, political and technological aspects of the plan need to be implemented so that generation of said energy in plants and commercialization of renewable energy accelerate for it to become one critical part of social energy supply.

3.2 Economic View of China's Energy Production and Consumption

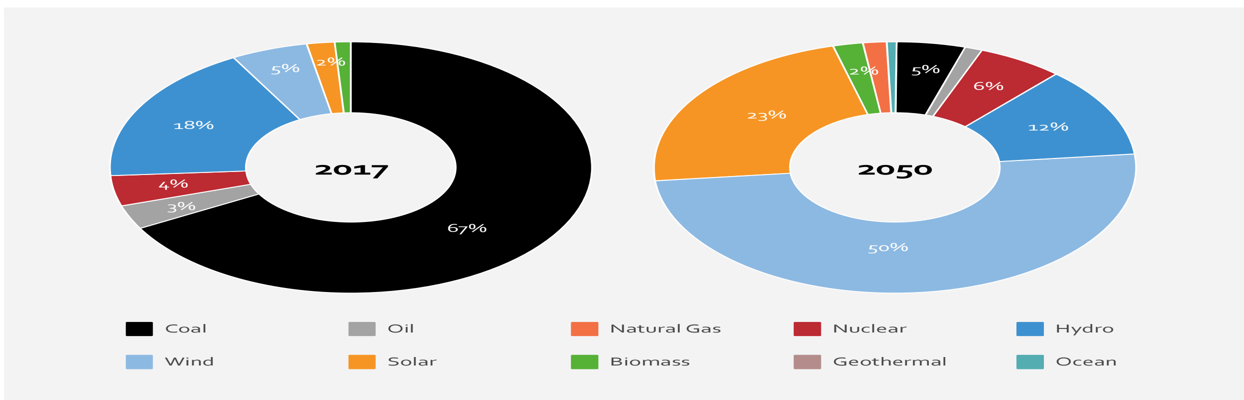
As Figure 1 and Figure 2 shows, China is still dominating by coal as a main energy source. The development of renewable energy in China should not only give guidance according to circumstances and improve the occasion, but additionally to catch the moment and explore the way to go.

Figure 1: Primary energy production and composition in China, 2017



Source: Yan, (2018)

Figure 2: China's power generation mix in 2017 and 2050



Source: IEA, (2018)

Modern developed economies rely heavily on easy access to energy that is both affordable and reliable. The improvement of Chinese energy security have informed the policies that have been adopted in two directions: the increased use of domestic energy sources and the diversification of imported energy. Electricity as an energy carrier is adjustable and could be generated from nuclear, renewable energy sources or fossils. This diversification of the electricity portfolio allows China to supply security regardless of the increasing dependence in importing of energy resources.

China emitted a total of 9023.1 Mt CO_2 and accounted for 28% of world emissions in 2013, a figure that ranked China as the world largest emissions source. Table 4 shows the energy related CO2 emissions from fuel combustion by regions. China holds the first place among U.S, India and Europe in total CO2 emissions. Power and heat production accounted for almost fifty percent of China's emissions. The submitted INDC implies that Chinese CO_2 emissions are expected to reach their peak by 2030. Thus, the Chinese electricity sector must accelerate the transition towards the implementation of the low carbon energy system.

Table 4: Energy related CO2 emissions from fuel combustion by regions

	Total CO_2 emissions (Mt CO_2)	**Growth Rate** (%)
	2018	**2017-2018**
United States	4 888	3.1%
China	9 481	2.5%
India	2 299	4.8%
Europe	3 956	-1.3%
Rest of world	11 249	1.1%
World	33 143	1.7%

Source: IEA, (2018), Global Energy And CO2 Status Report 2018

Countries outside the Organization for Economic Cooperation and Development appear to have the biggest growth in energy consumption, where energy demand is guided by long-term economic growth. In the reference case, energy use in non-OECD nations is set to increase by 85%, in comparison to 18% in OECD economies (EIA, 2011). China, with its economic growth of more than 7% in 2013, continues to face an abrupt increase in energy consumption: since 2009, energy consumption in China tops that in the United States (Word Energy Council, 2013) making China the largest energy consumer in the world (Bogaert, 2010).

According to China's National Bureau of Statistics , the energy-structure amount of petroleum, coal and natural gas, over the first energy report are 68.7%, 21.4% and 9.9% in 2009. In recent years, renewable energy, new energy, and clean energy has developed swiftly in China. Notwithstanding, the energy structure which is currently being optimized.

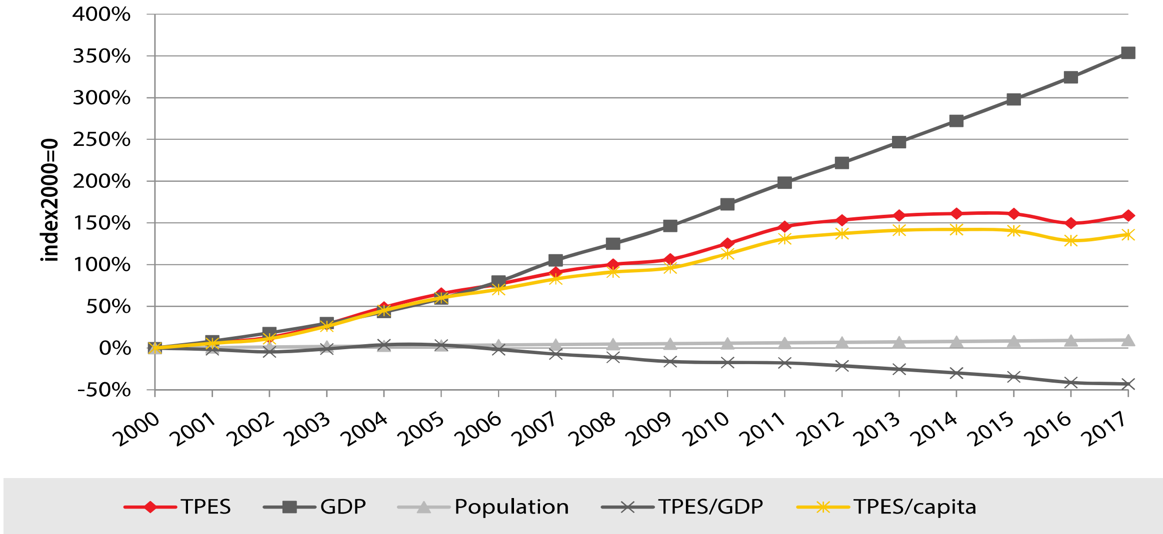
In order for China to achieve carbon intensity targets the increased energy efficiency is critical. Energy conservation and efficiency are China's top energy priorities. China passed the Energy Conservation Law in 2008, to improve energy efficiency throughout the Chinese economy. The NDRC, in 2010 enforced management regulations focused on the demand side, that require services to achieve electricity savings of 0.3% per year, and reduce top demand by 0.3% as well. Unbalanced deployment of renewable energy that threatens the decarbonizing China's electricity system is a challenge that carbon mitigation and energy conservation will both face. Considering the characteristics of China's energy resource properties, the current power generation is producing huge emissions by giving priority to coal mixture, this is the main problems of emissions reduction and energy conservation. In China's Energy Development Strategy Action Plan (2014–2020), the percentage of coal consumption in the energy mix is topped to 62% (Bogaert, 2010).

Technological and economic globalization has created a hyper-connected global economy with huge benefits. Today's global economy is characterized by increasing exposure and integration of markets, and flows between nations of capital, labor and trade intensified by technological advancements. All countries, including China, benefit from an atmosphere that improves conditions for investment and energy trade and facilitates energy technology and innovation. In the past decade, China has been usually depicted as a big "buyer" due to the trade and the foreign direct investment (FDI) in the mining and energy sectors. Many times ignoring China's role as a potential "seller" of energy, in the forms of energy infrastructure construction, energy equipment manufacturing, and associated energy services. China is already moving to make use of its manufacturing experience with expectations of reestablishing itself as a leader in the clean energy technologies of the future: solar, wind, hydro, smart grid technology and more energy-efficient appliances. The more that China interacts with the world in the energy sector, the better it appreciates the benefits of global rules that protect investments and trade. In the past decade, China has often been viewed as a huge energy consumer and importer. In the coming decade its role as an energy production capacity producer and exporter, in particular in the renewables sector, must not be neglected. The creation of stable and predictable conditions for an open and free global energy market among consumer, producer and transit countries with orderly competition and efficient supervision is in alignment with the country's economic interests (Zhu, 2016).

3.3 Economic Context

China is the largest developing country in the world by its population size and geography as Figure 3 shows. In recent years, China's economic development has made very rapid progress. From 2013 to 2017, China's GDP increased from CNY 54 trillion to CNY 82.7 trillion, with an average annual growth rate of 7.1%, with its share of the world economy increasing from 11.4% to around 15% and contributing more than 30% to world economic growth. From 2011 to 2016, the annual growth rate of GDP showed a downward trend. The slowdown reflects China's transition from resource-intensive economic and industrial growth to a 'New Normal' of slower but higher quality growth that is more stable and orientated towards sustainable development. China's supply-side structural reforms for the energy sector play an important role in achieving this 'New Normal' by accelerating the optimization of the country's economic structure through strategies that will improve the efficiency and quality of the supply system, transforming or upgrading traditional industries, actively supporting emerging industries and, promoting the development of advanced manufacturing through implementation of the 'Made in China 2025' strategy (Yan, 2018).

Figure 3: TPES, population, GDP and major energy efficiency indicators China 2000-2017

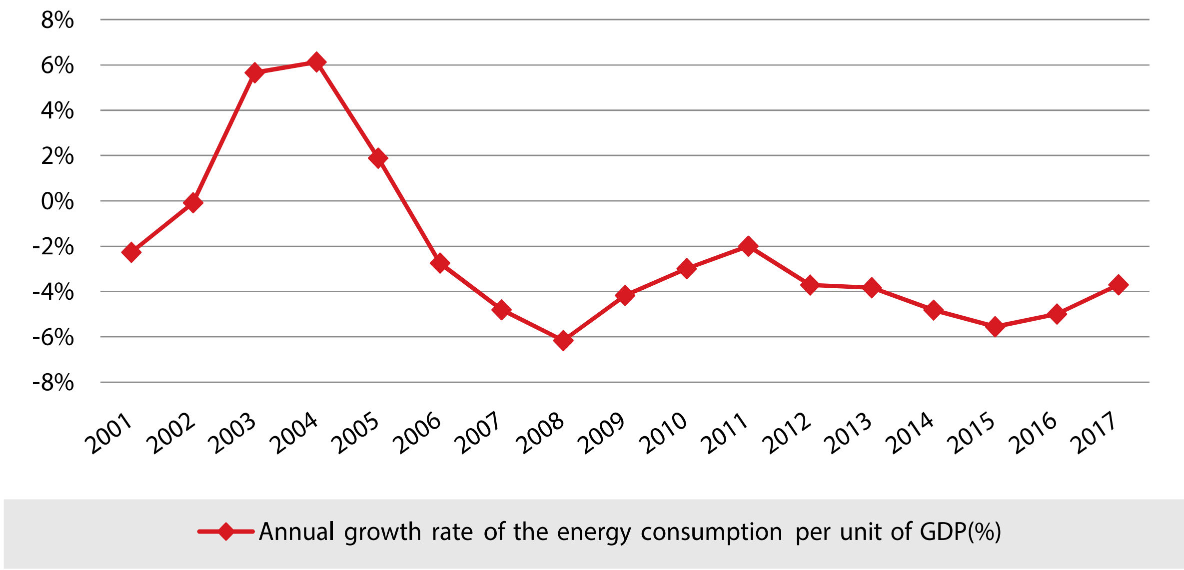


Source: Yan, (2018)

China implements a proactive financial policy and a cautious monetary policy, involving drastic reductions of taxes and fees and adjustments in distribution of fiscal expenditure in order to ensure basic livelihoods and key projects. The fiscal deficit rate has been kept below 3% by strengthening government debt management. In 2017, the Government of China viewed that the main objectives and tasks of its social and economic development were fully completed and performance was higher than expected.As we can see in Figure 4, China's annual growth rate in energy consumption per unit of GDP grew by 6.9%, the income of residents increased by 7.3%, the financial revenue increased by 7.4%, the import and export increased by 14.2%

and the actual use of foreign capital was USD 136.3 billion, which was the highest level ever recorded in China. This was the result of a series of major policy effects in the past years and China's pursuit of economic development with increasing coordination of economic objectives focused on growth, quality, structure and efficiency (Yan, 2018).

Figure 4: China's annual growth rate in energy consumption per unit of GDP, 2001-2017

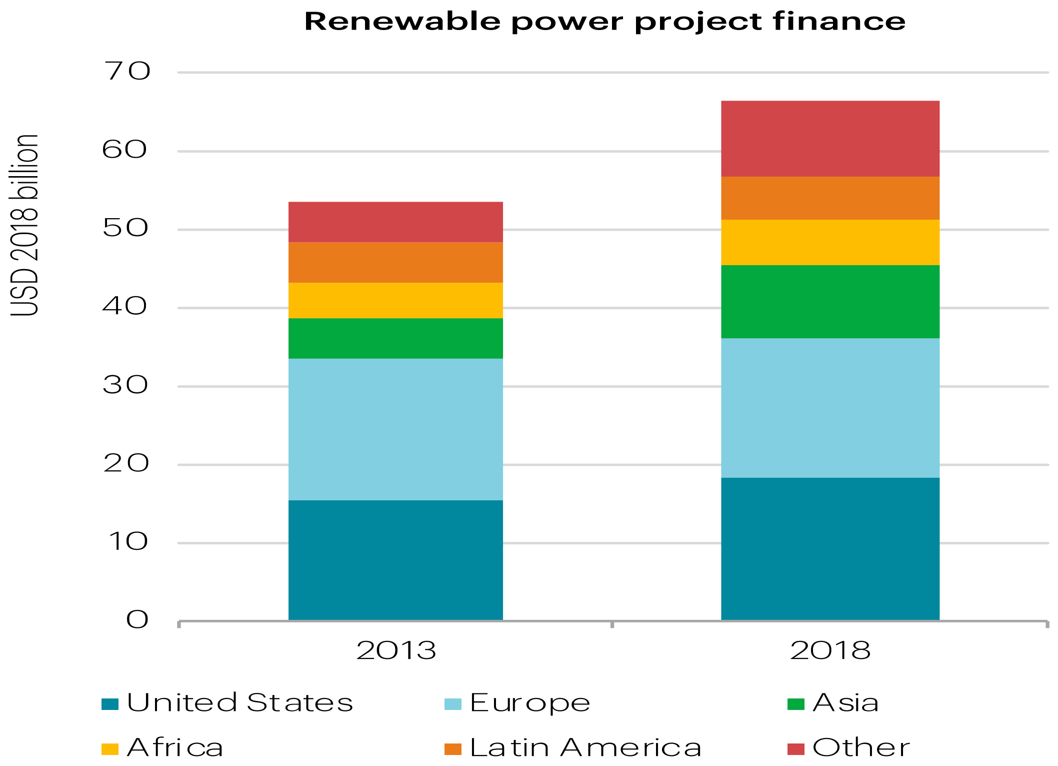


Source: Yan, (2018)

3.4 Investment Context

Since 1978, China has been opening up its economy to the rest of the world. In recent years its commitment to facilitating international collaboration and overseas investment has strengthened, with considerable activity in the energy sector. As Figure 5 shows Asia had a big increase in renewable power project finance in 2018 compared to 2013. Foreign investors can invest in China through three main forms of entities, Chinese-foreign contractual joint ventures, Chinese-foreign equity joint ventures and Wholly foreign-owned enterprises. China has considerably improved its private investment environment and enhanced the comfort of doing business for foreign investors, including measures to improve its intellectual property rights system and to liberalize capital flows (Yan, 2018).

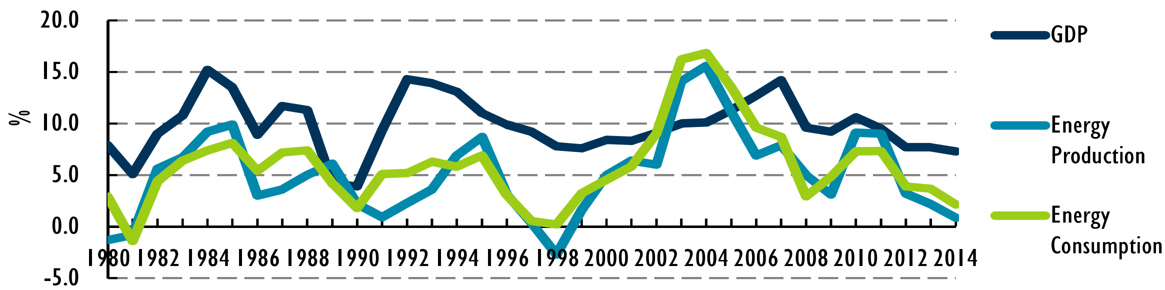
Figure 5: Global power sector investment by project finance for renewable power



Source: IEA, (2019), Pp. 133

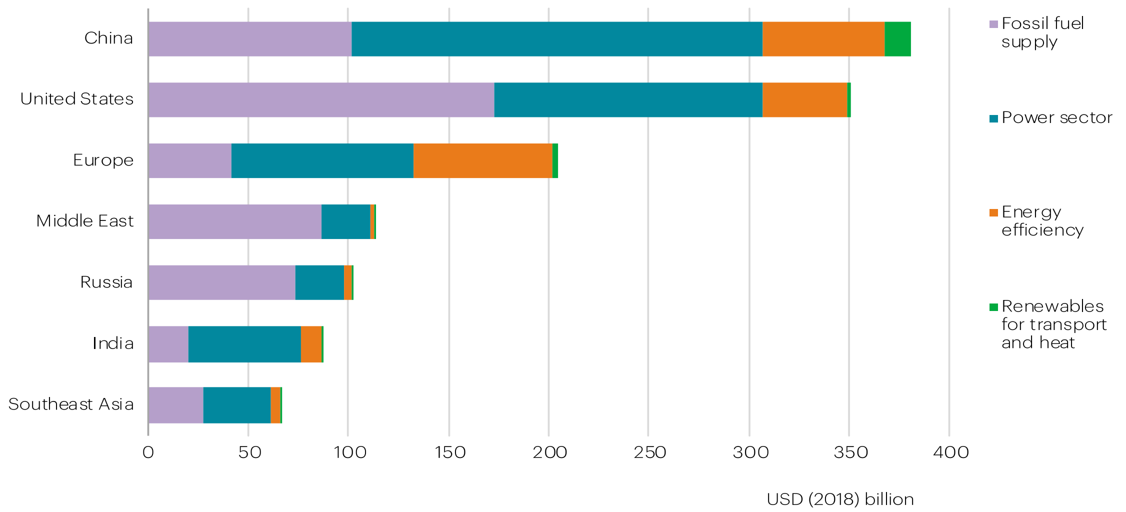
According to the World Investment Report 2018 of the International Energy Agency (IEA), and Figure 6, China is the largest destination of energy investment, taking over one-fifth of the global total. China's energy investment is progressively propelled by networks, energy efficiency, and low-carbon electricity supply. Figure 7 and Figure 8 shows the energy investment by sector in selected markets in 2018 compared to 201. Power sector is first, followed by fossil fuel supply and energy efficiency.

Figure 6: Growth of gross domestic product (GDP), energy production and consumption (%)



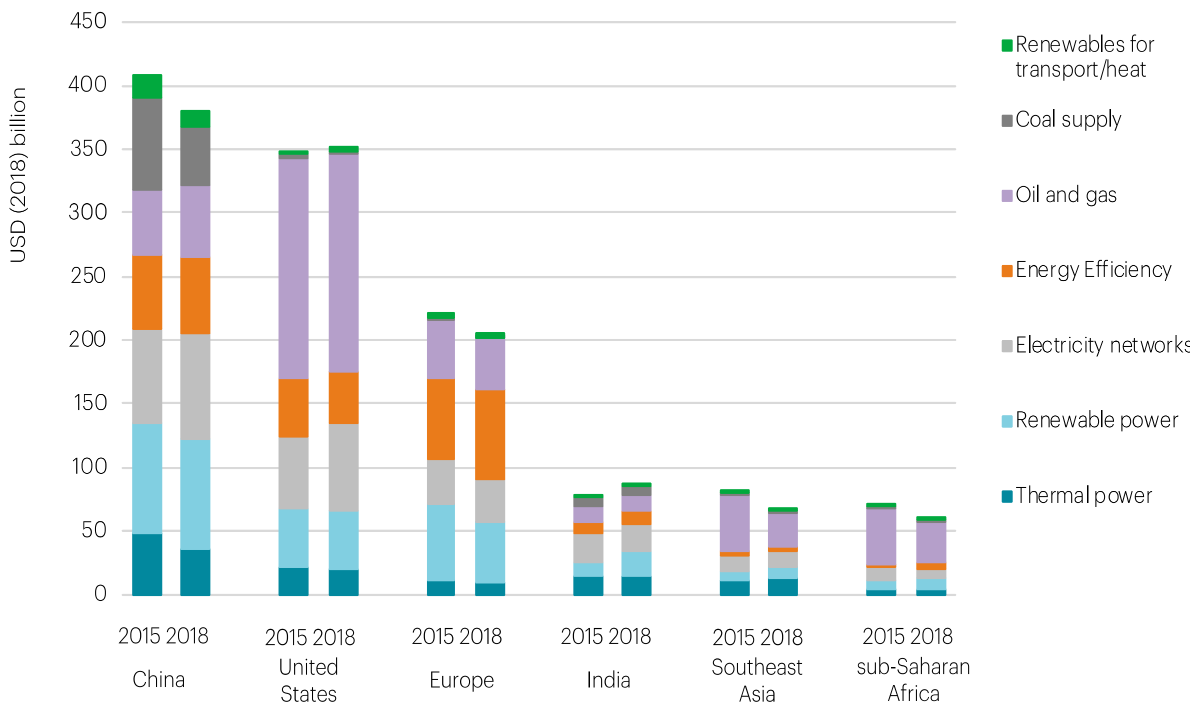
Source: Zhu, (2016)

Figure 7: Energy investment by sector in selected markets in 2018



Source: IEA, (2019), Pp. 19

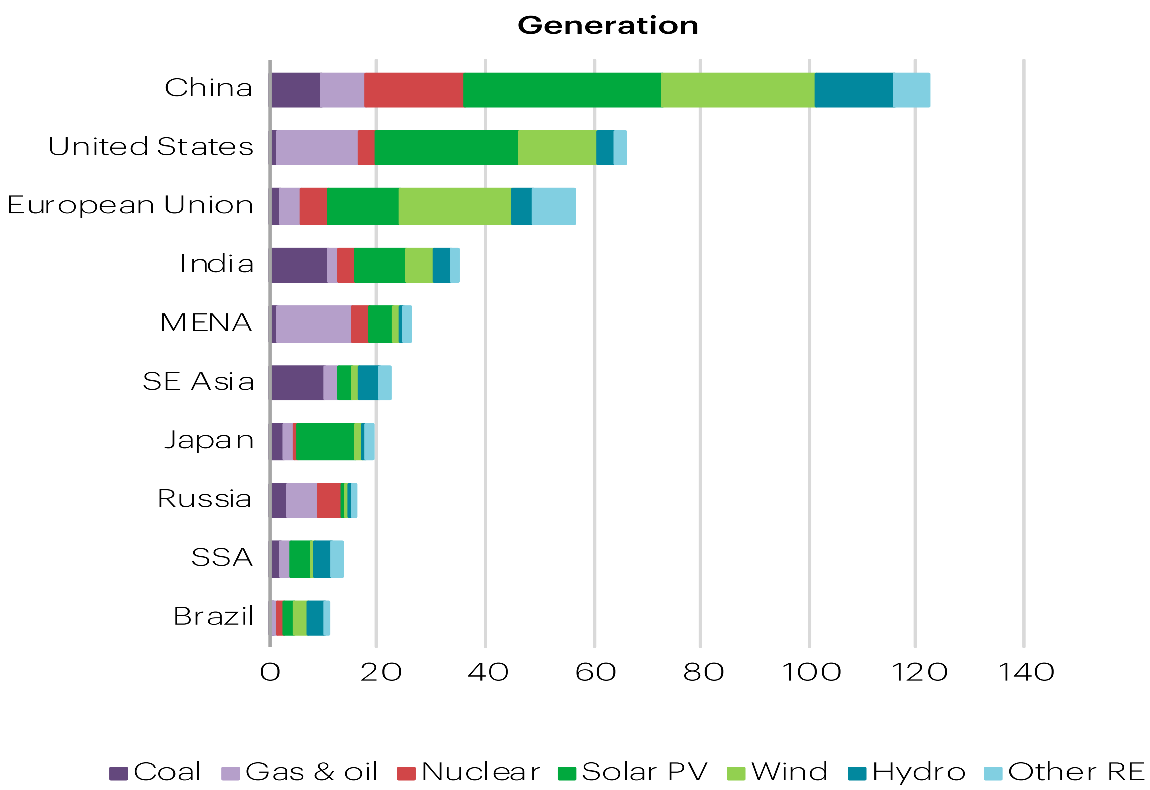
Figure 8: Energy investments by sector in selected markets, 2015 and 2018



Source: IEA, (2019), Pp. 20

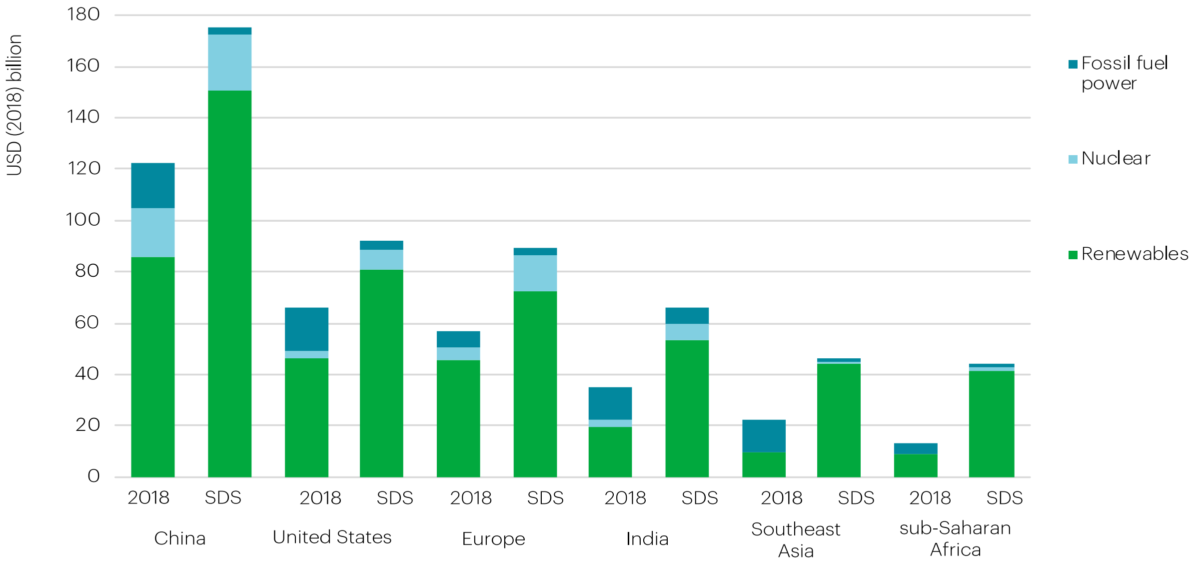
China's Outward Foreign Direct Investment (OFDI) has been significantly increasing while driven by Government policy. China's OFDI is focused on upgrading of power grids as well as the construction of cross-border electricity transmission as China has a strong ambition to create a network of energy infrastructure with South Caucasus, Central Asia, Europe, Middle East, Africa and Latin America. Since October 2016, foreign investment has shifted from the ‘approval system’ to the ‘negative list management system’. China grants foreign investors national treatment in the pre- establishment phase under its Pre-Establishment National Treatment (PENT) supplemented by a Negative List policy. This means that all foreign investors activities that are not listed on the negative list (i.e restrictive or prohibited), will be handled treatment no less favorable than that to domestic investors. The 2018 edition of the Special Management Measures for Foreign Investment Access (Negative List) greatly eased market access, and open measures were launched for 22 areas. For example, since 28th July 2018, the construction and operation of power grid and gas stations, usually controlled by the Chinese party, have been removed from the list, as were restrictions on the ratio of foreign-invested shares in the manufacture of new energy vehicles (Yan, 2018). Figure 9 shows the massive energy generation out of Solar PV and wind compared to U.S and other regions and Figure 10 shows the power generation investment by region compared with annual investment needed in the period 2025-2030.

Figure 9: Power sector investment by major countries and regions, 2018



Source: IEA, (2019), Pp. 58

Figure 10: Power generation investment by region compared with annual investment needed. (2025-2030)



Source: IEA (2019), Pp. 64

3.5 Renewable Energy Subsidies

The ultimate goal of the Law on Renewable Energy is to ensure that renewable energy is eventually independent of subsidies and able to participate competitively in energy markets. Currently, China continues to support its renewable energy sector as it is still growing, technologies continue to evolve and costs continue to decline. However, China intends to phase out subsidies. Tariffs for renewable energy power generation are determined by the Government according to the situation in different regions and the characteristics of different types of renewable energy power generation. The cost in purchasing renewable energy is higher than for conventional energy sources. The renewable energy electricity tariffs paid to generators are based on the coal-fired electricity tariff plus the renewable energy subsidies. The additional cost of renewable energy, covered by subsidies, is levied as a renewable energy surcharge on retail electricity tariffs. The Renewable Energy Development Fund has been established to promote the utilization and development of renewable energy by collecting and disbursing funds to support renewable energy generators. The main source of the Fund is public financial budget for Government and levies through the renewable energy surcharge. Since the renewable energy surcharge was implemented in 2006, it has undergone several adjustments from its starting point at CNY 0.001/kWh to the current rate of CNY 0.019/kWh. The surcharge rate is consistently increasing despite the cost reduction being achieved by the industry each year, reflecting the rapid development and expansion of the renewable energy sector in China and the associated accumulating subsidies needed to support it. The Government focuses on improving the policy support and phasing out subsidies and the issue of, insufficient funds. Another issue that needs to be addressed relates to the lag in the Government's payment of subsidies to investors due to lengthy approval and payment processes involving several institutions. It is also recognized that energy efficiency plays a key role in keeping energy bills affordable as retail prices rise (Yan, 2018).

3.6 Belt and road initiative

The Belt and Road Initiative was first conferred by Chinese President Xi Jinping in his keynote address at Kazakhstan's Nazarbayev University in the fall of 2013. The initiative's priorities include: facilitating connectivity, unimpeded trade, people-to-people relations, policy co-ordination and financial integration. On 8 November 2014, President Xi declared that China would contribute USD 40 billion to its new Silk Road Fund, designed to enhance transport and trade links in Asia. China's vision on the initiative was addressed and in depth analyzed in March 2015 at the 2015 Boao Forum for Asia (Zhu, 2016).

The Belt and Road will run through Europe, Asia, and Africa, connecting the European with the East Asian economies. The initiative aims to rebuild and revive maritime and overland trade routes, encouraging growth and co-operation. The initiative is expected to benefit China and all the nations along the inland and maritime links through efficient resource-sharing and regional integration of infrastructure. Chinese investment in these countries, in particular in central Asian countries, is growing rapidly. The Belt and Road Initiative would enable Chinese companies and products to gain wider market shares and access, as better connected transportation infrastructure for trade and outward investment creates a more integrated market (Zhu, 2016).

In 2013, China launched its Belt and Road Initiative (BRI), which for the energy sector focuses at strengthening inter-regional cooperation in energy resource exploitation, developing new energy technology, accelerating the interconnectivity of energy infrastructure, encouraging energy infrastructure projects and facilitating energy project financing. To support the BRI, China has set up the Silk Road Fund and has established 11 free trade pilot zones. The establishment of the Asian Infrastructure Investment Bank (AIIB) was also driven by China (Zhu, 2016).

3.7 Silk Road Fund (SRF)

China set up the SRF in 2014 to directly support its Belt and Road Initiative. The SRF invests in a wide range of sectors within the framework of the One Belt One Road Initiative, including energy resources, infrastructure, financial cooperation and industrial capacity cooperation. It is jointly funded by the China Foreign Exchange Reserve (CFER), the China Investment Corporation (CIC), the China Export-Import Bank (CEIB), and the China Development Bank (CDB) (Yan, 2018).

The first phase of the SRF involved USD 10 billion capital foreign exchange reserves contributed USD 6.5 billion through its investment platform, and CIC, CEIB and CDB also invested USD 1.5 billion, USD 1.5 billion and USD 500 million respectively. In May 2017, China's President Xi Jinping announced at the opening ceremony of the Belt and Road International Cooperation Summit that China will support the Belt and Road Initiative by increasing the capital of the SRF by CNY 100 billion in order to strengthen its ability to provide multi-currency and sustainable financial support for Belt and Road projects (Yan, 2018).

3.8 Conclusions

China is expected to grow in years to come as a result of having invested heavily in renewable technologies and having built up the capacity to exploit the opportunities that arise from renewable technologies. By contrasts, states that have resisted to adapt to the transition to renewable energy and have continued to rely heavily on fossil fuel exports, may face risks and lose influence. China may face the chance to achieve energy independence which promotes security and is at the same time development enhancing. Nevertheless, the precise scope and pace of energy transformation may not be easily predicted, yet it is expected that the process will have a profound impact on companies and communities. This transition may reveal significant opportunities and benefits. Energy security and independence for China are likely to promote job creation, enhance equity and sustainability and improve water and food security. Economic and industrial growth is expected to be reached with the high energy intensity, that is energy consumption per unit of GDP, that can be supplied domestically. Electricity is flexible and may be generated from a portfolio of sources that include fossil, nuclear as well as renewable sources of energy. The diversified portfolio of electricity generation enhances supply security in China regardless of the increasing import dependence of energy resources.

Chapter 4. Renewables

4.1 Introduction

As China faces harsh challenges by the high demand for energy, as well as environmental problems caused by the use of fossil fuels including global warming, the Chinese government is setting numerous targets to increase the share of renewable energy in the energy structure and incentivize the establishment of wind, solar, hydro and other renewable energy power plants. This chapter examines the significant rise of China’s renewable energy industry by analyzing the three main renewable energy sources, their technological distribution across the country as long as their development and the future potential they have in becoming reliable and help China, the world’s largest carbon emitter by a large edge, decarbonize its electricity system and alleviate increasingly critical air pollution problems

4.2 Solar Energy

China is the world's largest market for both solar thermal energy and photovoltaics. Furthermore, China has been the world's leading installer of solar photovoltaics (PV) since 2013. In 2015, China became the world's largest producer of photovoltaic power, surpassing Germany. In 2017 China was the first country to achieve 100 GW of cumulative installed PV capacity, and it had 174 GW of cumulative installed solar capacity by the end of 2018. As of

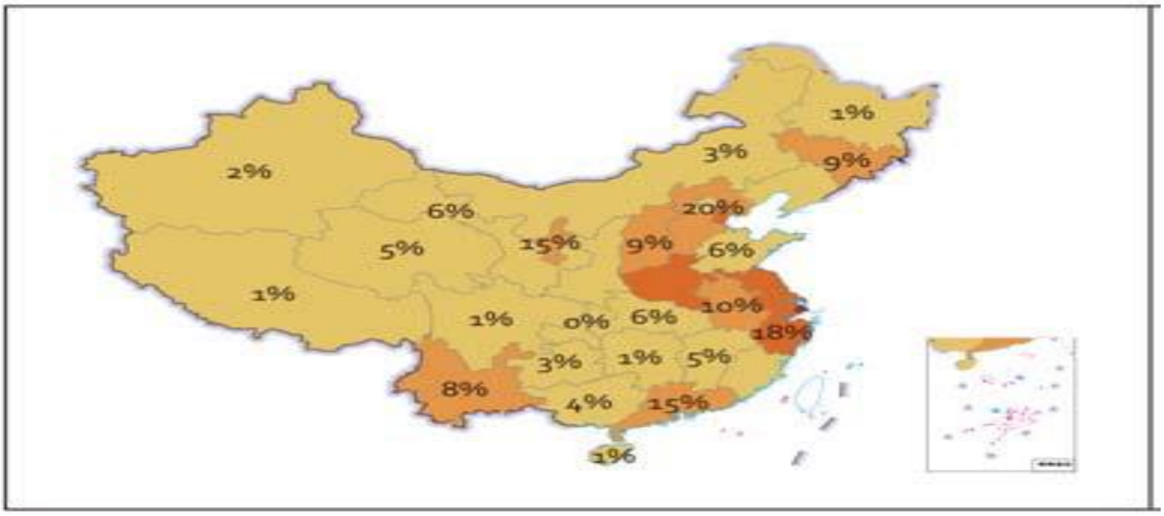
May 2018, China holds the record for the largest operational solar project at Tengger (1,547-MW). As the average capacity factor of solar power plants is relatively low (17% on average) the contribution to the total electric energy production remains modes. In 2017, out of the 6,412 TWh electricity that produced in China, 118.2 TWh was generated by solar power, equal to 1.84% of total electricity production, a significant amount of energy. Reaching 1,300 GW of solar capacity is the goal for 2050. If this target is to be achieved, it would be the source with the largest installed capacity in China.

One of the most important power generation technologies in renewables, solar PV, has attracted continuous investments spending into development and research. All the different types of solar PV technologies meant for power generation are expected to develop rapidly in the near future. Power generation from solar PV is already being applied at a large magnitude in China. In 2010 a new feed-in tariff was made known. Projects received 1.15 yuan ($0.18) per kWh when completed before September 30, 2012. Since then, solar power deployment enormously eclipsed initial government plans. (Zhongying, 2017)

Since 2010, the Chinese solar PV production system experienced serious shocks. In 2010, institutional alterations in the German market resulted in an abrupt recession in the global demand, followed by anti-subsidy countervailing duties and anti-dumping duties on Chinese PV products imposed in both EU and USA. Manufacturers in Chinese solar PV sector, who were already running on their full capacity, experienced difficult situation in 2011 and 2012 with enormous financial loses that led to bankruptcy of some important actors, such as SunTech Power in 2013 being defaulted on $541 million of convertible bonds (Shubbak, 2018). A set of policies were introduced by the Chinese government in order to try and rescue the PV industry with its large assets and and labor market, but mainly to arouse the domestic market. Therefore, since 2011 the annual installed capacity of solar PV in China has accomplished a remarkable growth. This growth was happened due to the construction of many PV plants around the country. In May 2011, the National People's Congress (NPC) adjusted the solar target again, setting as a minimum PV target for 2015 5 GW of capacity, with a capacity of 20–30 GW as a target by 2020. Eventually, China exceeded 77GW as of the end of 2016 in cumulative installed capacity of solar PV, at an annual growth of 34 GW. China has become the world leader in terms of both cumulative and new installations. Solar PV power generation is playing a significant place in the country’s energy development and transformation and has grew into one of the pivotal new technologies in China. A phenomenon known as “solar curtailment", has been getting worse due to the lack of compatibility between supply and power load in addition to the shortage of a mechanism that will balance the cross-regional electricity consumption, the fast-expanding scale of solar PV power generation use and finally the large-scale deployment of solar PV application mostly in the northwest region. Distributed solar PV has grown in recent years, where is nearby load centers where there is no need for long-distance transmission, especially east and central regions which have an approximately large power demand. Distributed solar PV power generation, holds impressive future development capability, even though they still responsible for a market share of about 13% of total installed solar PV capacity. The market development target of concentration photovoltaics will be the reduction of its power generation costs but at the same time the improving of system reliability. Technological cost for the power generation with solar PV power is likely to drop, taking the following factors into consideration: Uses of low-cost materials, improved module conversion efficiency in different types of photovoltaic technologies associated with the module cost decline, upgraded performance ratio of solar PV power generation systems is associated with the reduction in levelized cost of electricity (LCOE), reduction in material consumption and extended lifetime of power generation modules (Zhongying, 2017).

In the short-term , solar PV market will develop greatly as we see in Figure 11. China is already close in overcoming the capacity target set to 105 GW by 2020 of solar PV power installations, as also stated in the 13th FYP. Considering China's framework and present policy documents, along with the power grid construction status condensation of solar PV power will be basically solved increasing flexibility by 2020 despite the fact that conventional solar PV and power systems are to possess certain regulating abilities. Diminishing solar PV generation costs will assist the realization of grid unity. (Zhongying, 2017).

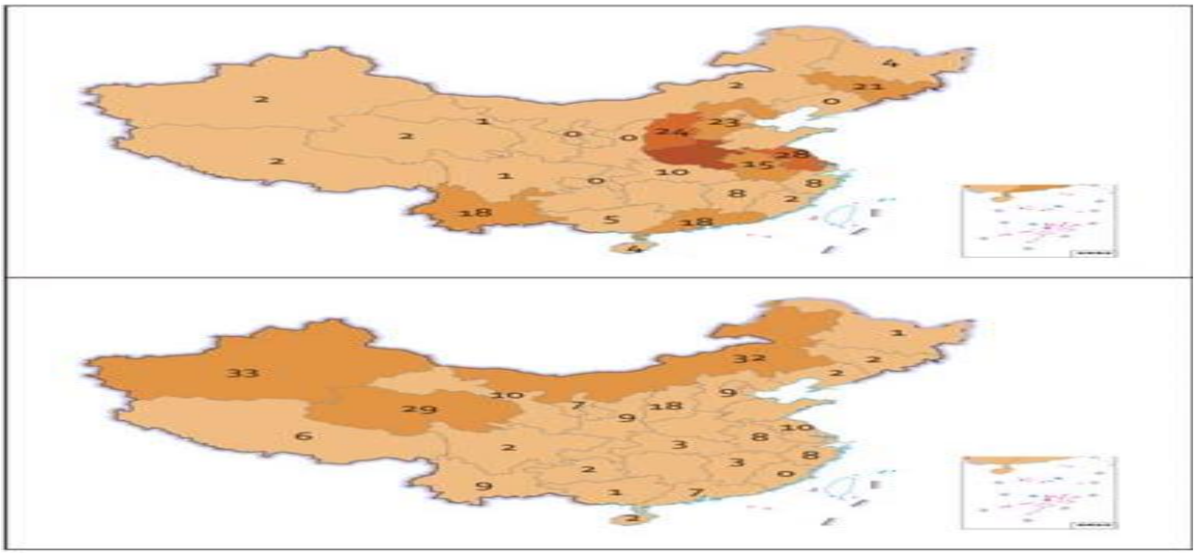
Figure 11: Solar PV power generation development in 2020



Source: Zhongying, (2017)

As for the medium- term, the period between 2020 and 2030 will be a decisive period for the energy development of China. The installation capacity of solar PV is expected to reach 470 GW. By scaling up the supply chain along with the increased integration capability of CSP generation (Concentrated Solar Power), CSP generation costs will deteriorate fast. This combined with the advantage thermal power generation gives in smoothing the power supply together witg the power system reform, will make CSP play a significant role in the future supply structure. By 2030, distributed solar PV power generation will face broad development, with increased market competitiveness and diminishing costs. In the eastern, south, and central regions, utilization of distributed rooftop solar PV systems and large-scale development will appear in zones with economic development and industrial parks. Applications of distributed solar PV applications in places such as greenhouses, water surfaces and railways will also take place. (Figure 12) The market growth in the northwestern regions will slow down afflicted by power load factors and solar PV power transmission. In China's northeastern regions and middle-eastern, utility scale solar PV power plants will expand fast, something that will demonstrate how to deploy advanced PV technology and reconstruct abandoned coal mining sites. In terms of market distribution, there is going to be a shift of solar PV power generation from the central and northern regions to the eastern, southern, and middle regions (Zhongying, 2017).

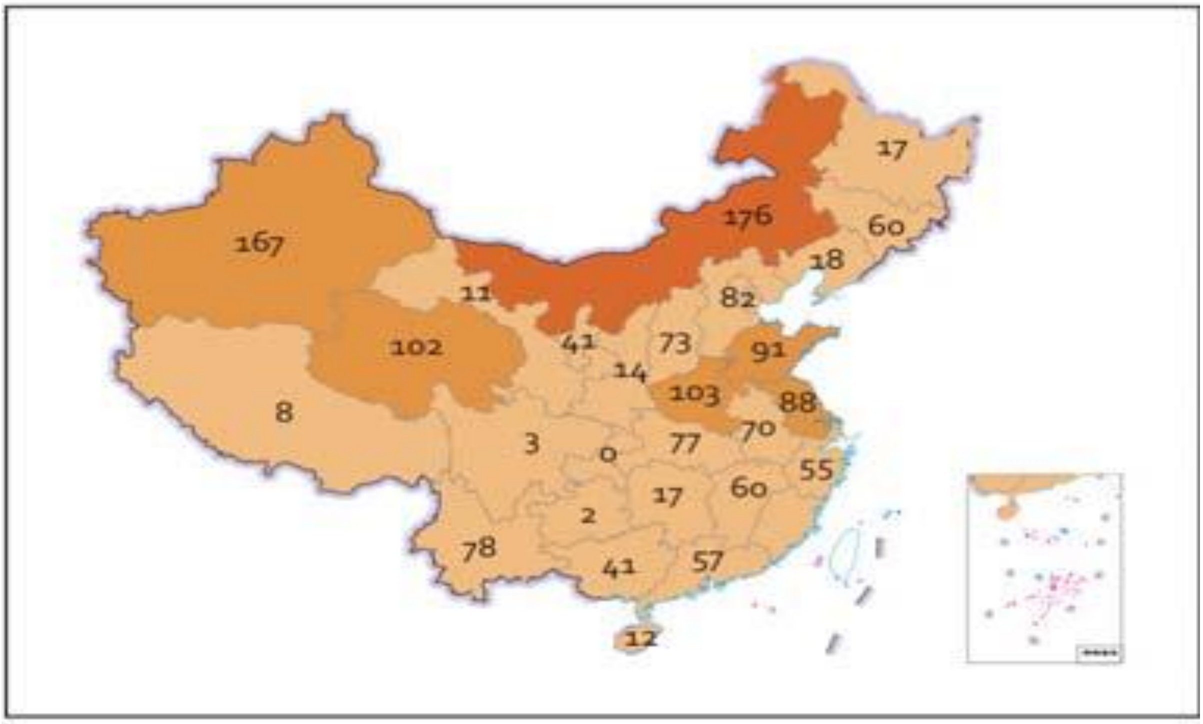
Figure 12: Distributed (top) and utility scale (bottom) solar PV installation capacity by regions in 2030



Source: Zhongying, (2017)

Long-term, after 2030, high-penetration and high-proportion solar PV system and power transmission, along with power grid system technologies, will be capable of supportin solar PV power generation. Additionally, efficiency in Solar PV cells will be greatly enhanced. Different surfaces to install solar PV such as the surface of water and roadways, are exploited at a large magnitude along with, solar PV technologies, energy storage and smart grid (Figure 13).After 2030, market growth in CSP generation will be stimulated, resulting from evident competitiveness in efficiency, electricity cost per unit and operating hours. In order to considerably reduce emissions even more, intense efforts will be made to accelerate the development of solar power generation. In the long-term policy framework will be farther improved excluding all the factors restraining the consumption and transmission of solar energy (Zhongying, 2017).

Figure 13: Installed solar power capacity in 2050



Source: Zhongying, (2017)

4.3 Hydro energy

Hydropower is a renewable energy source using water as input that is economically achievable, applicable in large-scale development and technologically mature. Taking advantage of hydropower resources is of great magnitude to optimize the energy mix, reduce emissions, promote regional coordinated development and safeguard national energy security. Sufficient resources of water make China's abilities in both exploitation and reserves, top of world (Table 5). However, China was introduced to the modern hydroelectric late. The first ever hydroelectric power station was built in Yunnan region with a 472 kilowatt capacity until 1912. The hydroelectric in China grew robustly after having been through developed and researched for many years. By 2009, an increase of 0.74% was achieved compared with that in 2008 reaching197 million kilowatt in hydroelectric power capacity. The hydroelectric system in China has been already caught up with advanced world level and is perplexingly built. Hydro grew one third of the 10-year average growth of 9.2% with a percentage of 3.2% (Xinyu, 2011). Hydro power brings a reliable power production in addition to the limitations energy sources have in siting possibilities and potential (Zhongying, 2017).

Table 5: Growth of hydropower in China since 1990

Year	Installed capacity (GW)	Share (%)	Energy generation (TWh)	Share (%)
1990	36.0	326.1	126.7	20.4
1995	52.2	24.0	186.8	18.6
2000	79.3	24.9	243.1	17.8
2002	84.6	24.0	271.0	16.5
2003	94.9	24.2	281.3	14.8
2004	108.3	24.6	328,0	15.0
2005	116.5	22.9	395.2	16.0
2006	128.6	20.7	416.7	14.7
2007	145.3	20.4	486.7	14.9
2010*	194,0	23,1	640.2**	n.a.
2020*	300,0	n.a.	990,0**	n.a.

*Target numbers in 11^{th} Five Year Plan

Source: Huang and Yan, (2009).

The development of hydropower is slowing because of the increasing investment cost and the environmental impacts. China lead the global rank in installed hydropower capacity and the number of dams built but also in terms of construction know-how and dam design. In 2016 the fast development of the hydropower industry in China continued . Total hydropower capacity and recently installed capacity nationwide rose to approximately 305 and 10 GW, with the recent one responsible for 25 percent of the total installed hydropower capacity in the world. With a total installed capacity of 15.7 GW. Additionally, 11 new hydropower projects took approval and began constructions in the same year.

Apart from steady development. China's hydropower, established new characteristics throughout 2016. As China's economic growth stabilized and entered a "new normal" phase, in the electric power market important changes are taking place. While social electricity demand and consumption decreases, installed thermal power capacity continuous to grow vigorously, leading to periodic occurrences of wind, solar and hydro power decrease and worsen the imbalance of electricity between supply and demand. A transition of development focus is starting to be faced while hydropower operation and construction scale starts to decline in China. Perplexing climatic and geographical conditions are moving hydropower construction projects towards the southwest region. This lead to important cost increases that worsened the economic efficiency of hydropower and raised engineering safety requirements, not to mention, the increasing technical difficulties attributed to complicated geological structure and high altitude that had to be overcome. The above mentioned factors resulted in a challenge for risk and safety aspects of construction work. China still holds huge development potential, despite the fact that hydropower development has spread to become increasingly significant over the years, making hydropower responsible for the production of 40% of China's total electricity. In 2016, China released the 13th FYP for hydropower development, suggesting an expansion of 60 GW in pumped storage and hydropower capacity during the period 2016-2020. Additionally, the 13th FYP states that should be under construction 60 GW of pumped storage hydro and 60 GW of conventional hydropower making the total installed capacity of hydropower reach 340 GW by 2020. Hydropower takes up to a 50% share of non-fossil energy consumption due to the capability of hydropower stations generating 1250TWh of electricity per year. The plan suggests that, the capacity of the "West-East Power Transmission Project" has to be repeatedly upgraded up to the point it reaches the level of 100 GW in 2020 and eventually making the installed hydropower capacity of China reach 380 GW by 2025 raising the annual hydropower production in 1400TWh (Zhongying, 2017). In comparison to other countries China has a future potential in terms of economically and technically feasible hydropower resources. There are 3,880 rivers in China, based on a water resources examination survey of 2015, with a hydropower resource potential of 10 MW in mainland China able of generating 6082.9 TWh of electricity per year, while their average power being 694.4 GW (Zhongying, 2017).

According to prior studies the national pumped storage economic development capacity is 137GW. Most of the resources are distributed in South and North region of China, accounting for 40% of the total amount. Furthermore, China's hydropower resources are unevenly distributed in terms of geography. Hydropower resources are scarce in the eastern and central parts of China but sufficient in the west. The southwestern region has the most hydropower resources in China. (Zhongying, 2017).

The southwest region is where hydropower resources are the most sufficient in China judging from geographical distribution. The region's that are vital for the hydropower resources is responsible for 70.6% of the country total. In contrast, South and East - Central China account for hardly 8.6% and 4% even though their economically development is much higher. Sichuan and Tibet have the most sufficient resources of hydropower by region, with their average power potentials being 201 and 144 GW (Zhongying, 2017).

Based on distribution of installed capacity scale, of all the technically viable hydropower resources in China, small-sized ones are accounting for 12%, middle-sized ones are accounting for 16%, and large-sized hydropower stations are accounting for 72% of the total. The amount of technically feasible hydropower resources are basically in lineup with those of hydropower stations of various types (Zhongying, 2017).

China will most likely comply to the limits of ecological protection and assure development targets based on hydropower are met. The main aspects stirring hydropower development have changed from technical and economic to involuntary displacement and protection of the environment. This takes place especially over the recent years when the effects of displacement of people and hydropower development on ecological environment are drawing increasing public attention. Agreements have become more difficult despite the raised coverage standards for people displaced from new hydropower projects, as a result of lack of sufficient attention to increased expectation towards agreement and personal interests. Moreover, people have helped the environmental requirements raise even higher on hydropower development, along with remarkable levels of environmental awareness. The 'recipe' of success in China's low-carbon and clean power development is hydropower and will continue as the low-carbon and clean technology with the largest share in China's power mix right before 2030. To understand energy development targets and transformation, hydropower in China's low-carbon and clean power generation structure must exceed 50% as a share by 2020, and conventional hydropower capacity must reach 340 – 360 GW. The large-scale bases construction should continue to expedite before 2030 by mainly developing rivers with concentrated and robust hydropower resources. China's focus on hydropower development will be drift to the main stream of the Yarlung Zangbo River located in southern Tibet by 2030. In 2050, installed hydropower capacity is expected to reach 520 GW. The following aspects includes the Strategic positioning of China's hydropower development (Zhongying, 2017).

Hydropower holds the first place as the renewable energy source with the biggest advantage in utilization, scale development and most mature technologies. China is the nation with the biggest hydropower resource capability in the world, with the development of society and economy, the challenges China is now facing, such as irrational energy mix, energy resource shortage, GHG emissions reduction and environmental pollution, will escalate. Further development of hydropower resources, may assist optimizing China's energy mix and mitigate energy supply shortages (Zhongying, 2017).

China's west region shows that despite being lacking development, has a plethora of hydropower resources. Hydropower resources of the 12 western regions and municipalities account for approximately 79.3% of China's total. Today,the total exploited hydropower capacity of the west region is responsible for hardly 10% of its technically feasible potential. Therefore, the west region has broad prospects for hydropower development and holds huge potential (Zhongying, 2017).

Finally, hydropower projects contain even more broad benefits in utilization, aside power generation, including irrigation, flood prevention, shipping, water supply, ice prevention and tourism (Zhongying, 2017).

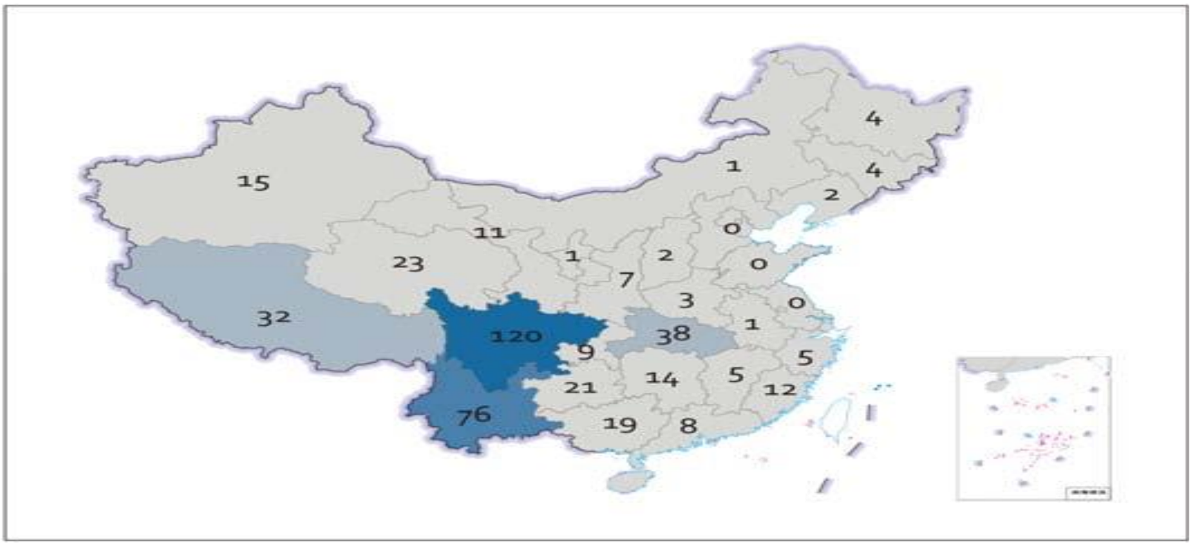
Some development thoughts are properly proceeding with agreements for displaced people, conserving the ecological environment, and minimizing farmland floods being the essential necessities, placing equal attention on social and economic benefits and focusing on social benefits being the principle. As by geographical distribution hydropower development surplus and level resource distribution characteristics, China can be divided into tthree zones: first is the optimal development zone, in which the region's development level is below 50%, the hydropower resources mainly distributed in main river streams and there are overall good conditions for development. This zone mainly refers to four regions, i.e. Sichuan, Qinghai, Tibet and Yunnan (Table 6). Second is the key development zone, referring to Chinese regions for future hydropower development. The development scale of key development zones for 2020, 2030 and 2050 will account for 54%, 63% and 68%, respectively (Figure 14), of then total national installed capacity. Last, deep development zone, is referring to a region exceeding 80% of the development level and having minimum development potential. (Zhongying, 2017).

Table 6: Hydropower development distribution in Sichuan, Yunnan, and Tibet (GW)

	Technically feasible resources	2020 capacity	2030 capacity	2050 capacity
Sichuan	146.9	78.6	120.0	120.0
Yunnan	117.3	64.9	75.7	101.9
Tibet	151.5	7.1	31.6	99.9
Total	**415.7**	**150.7**	**227.4**	**259.8**

Source: Zhongying, (2017), pp. 336

Figure 14: China's hydropower development distribution in 2030 (GW)



Source: Zhongying, (2017), pp. 336

China's total installed conventional hydropower capacity is expected to reach 341 GW by 2020 (Table 7). Basically, hydropower resources are fully used in this region, covering Liaoning up to Guangdong where hydropower resource development turns into deep exploitation, total development scale of the central region reaches 80 GW, accounting for 23% of the national total. The Tibet Autonomous Region sees a somehow low development and use level and so has the condition for large-scale development (Zhongying, 2017).

Table 7: Short term development of hydropower

	2020
Total installed hydropower capacity (GW)	341
Development and utilization rate (%)	49%

Source: Zhongying, (2017), pp. 338

Installed conventional hydropower capacity is expected to reach 434 GW By 2030 in the mid-term (Table 8). The development level is expected to reach 62%. In total, 90 GW of hydropower capacity will be installed during 2021-2030. This mainly includes 41.4 GW in Sichuan, 24.5 GW in Tibet and 10.8 GW in Yunnan (Zhongying, 2017).

Table 8: Medium term development of hydropower

	2030
Total installed hydropower capacity (GW)	434
Development and utilization rate (%)	62%

Source: Zhongying, (2017), pp. 338

Long-term, after 2030, the main focus of China's hydropower development will be moving into the main stream of the Yarlung Zangbo River located in southern Tibet. Installed conventional hydropower capacity is expected to reach 529 GW by 2050 (Table 9). The development level is expected to reach 76% (Zhongying, 2017).

Table 9: Long term development of hydropower

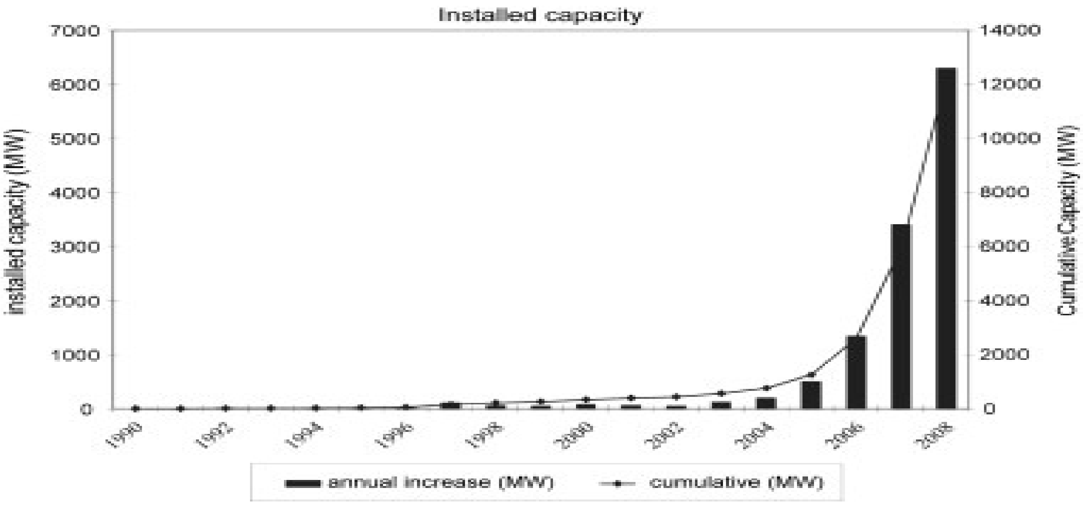
	2050
Total installed hydropower capacity (GW)	5.29
Development and utilization rate (%)	76%

Source: Zhongying, (2017), pp. 339

4.4 Wind energy

Wind is a seasonal energy source, which cannot be dispatched nor make electricity on demand. It also gives variable power, which varies over shorter time scales but is consistent from year to year. Consequently, it must be used together with other storage or electric power sources to give a reliable supply. As the percentage of wind power in a region increases, more traditional power sources are needed to back it up (such as fossil fuel power), and the grid may need to be enhanced. China has the largest wind resources in the world and three-quarters of this natural resource is located at sea as well as high annual installed and cumulative wind power capacity (Figure 15).

Figure 15: Annualy installed and cumulative wind power capacity 1990-2008



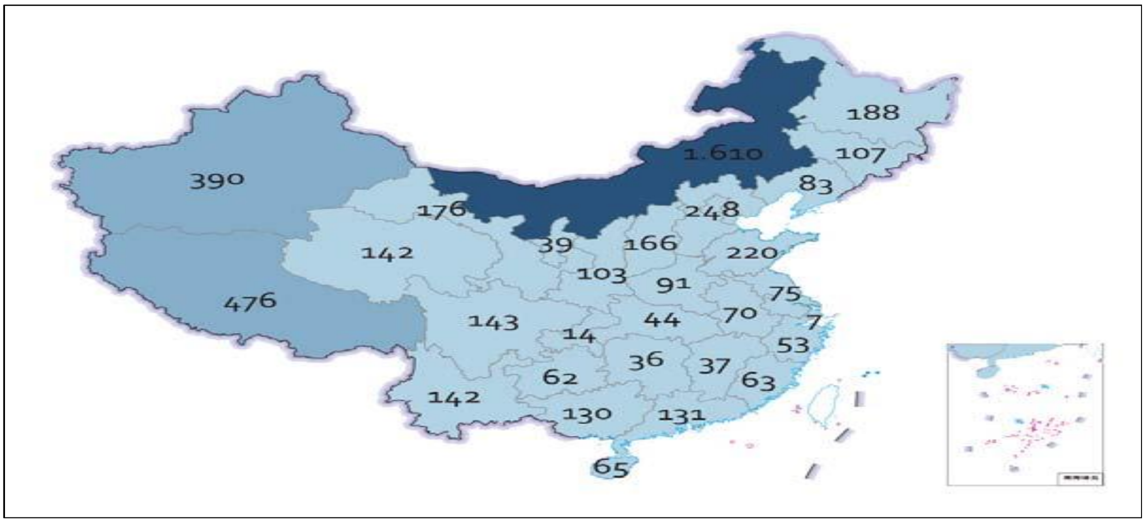
Source: Kautto & Jäger-Waldau, (2009)

China set a target of having 210 GW of wind power capacity by 2020 while at the same time encourages foreign companies, notably from the United States, to invest in Chinese wind power generation. However, the use of wind energy in China has not always got the best results considering the solid construction of wind power capacity in the country (Zhongying, 2017).

By the end of 2016, out of 148.6 GW of installed grid-connected wind power capacity that China's cumulative reached, 1.5 GW was offshore wind power (Rao, 2019). China has become the fastest growing and the world's largest market for wind power. Data from the Global Wind Energy Council show that the compound annual growth rate (CAGA) for global cumulative installed wind capacity was 22% during 2011-2016. Amid the same period CAGA in China reached 50%. China installed 19.3 GW additional wind capacity in 2016, accounting for 43% of global additional capacity, making China a global leader in freshly installed wind capacity.

In 2016 as well, China's wind power production reached 241 TWh, accounting for 4% of national power production (Figure 16). The extensive growth in wind power has made some issues in the Chinese power system come into the surface such as hardware and software issues, incompatibility of supply and power load, lack of cross-regional and local power consumption balance mechanisms and inadequate grid flexibility. Issues like these make wind reduction a significant challenge that is not yet effectively addressed. As of now, more projects have been delayed or suspended in regions with severe wind reduction. In contrast, fresh installed capacity has been on the rise close to power load centers in the eastern and middle regions, which have low speed of wind (Zhongying, 2017).

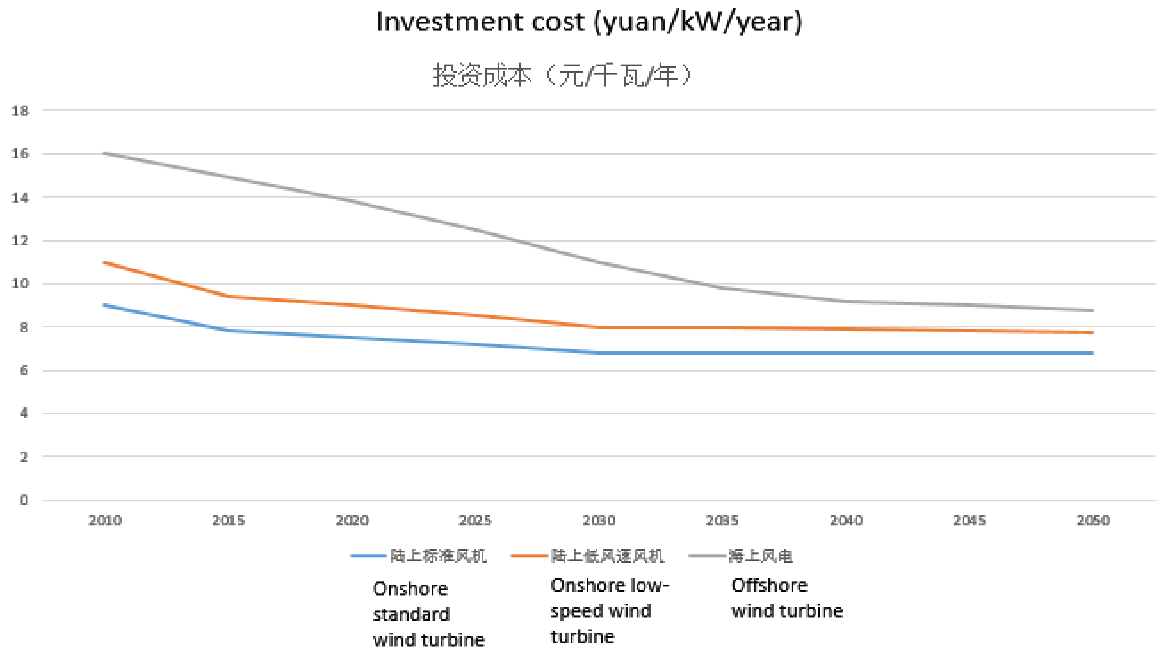
Figure 16: China's resource potential of wind power (GW)



Source: Zhongying, (2017)

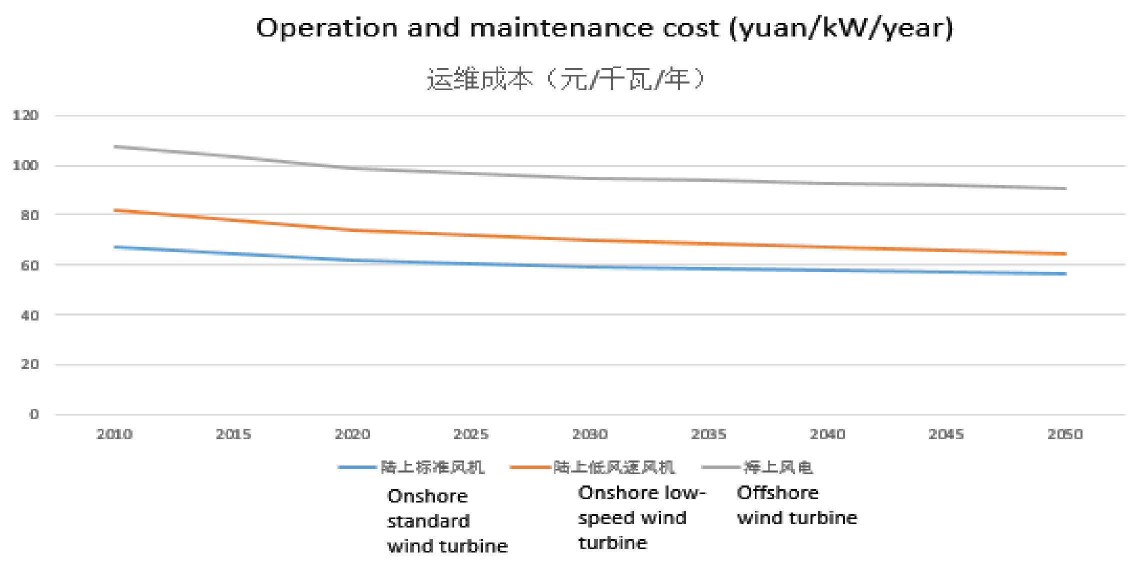
Wind power cost assumptions are divided by type of turbine and region, low wind speed onshore turbines, standard onshore turbines, and offshore turbines. The current slow growth in offshore wind power development is taken into consideration as long as the cost reduction rates, which are lower-than-expected. It is presumed that an average investment cost for onshore standard wind turbines will decrease by 12.8% to 6.8 yuan/w by 2030 compared to the 2015 levels. This is happening, while investment costs for low wind speed turbines fall 15% to 8.02 yuan/w and offshore wind power investments costs is presumed to drop by 26% to 11 yuan/w. The operation and maintenance costs for all wind turbines are presumed to be reduced over time. For standard turbines costs go down 8% from 2015 levels to 59.3 yuan/w by 2030, for low wind speed turbines costs compared to 2015 are reduced to 70 yuan/w by 2030, meaning a drop of 10% and management and offshore wind power operation costs are expected to fall to 94.8 yuan/w by 2030, a drop of 8% compared to 2015 (Figure 17). From 2030 to 2050 management and operation costs are presumed to decline slightly (Figure 18) (Zhongying, 2017).

Figure 17: Assumed wind power investment development



Source: Zhongying, (2017)

Figure 18: Assumed operational and maintenance cost development for wind power



Source: Zhongying, (2017)

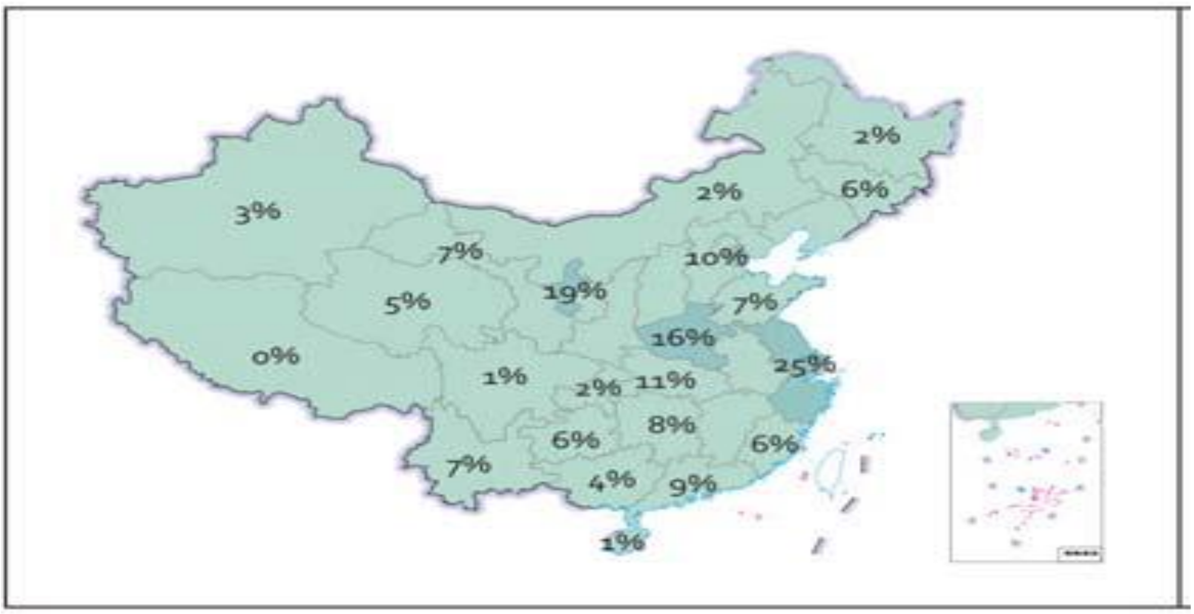
Regulation, a power market that is well-functioning, and supporting infrastructure will grant China to successfully and efficiently develop its wind power industry. Major efforts will be conducted towards onshore wind farms and to a minor extent on some offshore wind turbines. Under the premise that grid connection and wind reduction issues in the three northern regions are successfully solved, by 2020, installed wind power capacity will reach 5 GW for offshore wind and 544 GW for onshore wind turbines. During the period 2020-2030, wind power will face fast increase, thanks to increased power system flexibility and extensive power transmission capacity development, along with technological breakthroughs, successful power system reform and cost declines. By 2030, offshore wind power capacity is expected to reach 34 GW and onshore 1.257 GW. Wind power becomes pivotal in meeting China's power demand, bolstering the economic and social development and improving the energy mix. Most promising is the production from onshore low speed wind power, while offshore wind power plays a progressively important role in realizing the high-share renewable energy development goals (Zhongying, 2017).

By the end of 2020, according to the 13th FYP for wind power short-term development, installed and cumulative grid-connected wind power capacity must reach 210 GW, of which 5 GW is offshore wind power capacity. China's annual wind power production must reach 420 billion kWh, responsible for 6% of total power production.(Zhongying, 2017).

China's wind power distribution will be continuously optimized during the 13th FYP period, stimulating development of onshore wind energy resources in the eastern, central, and southern regions. Added installed and grid-connected onshore wind power capacity in the eastern, central, and southern regions China will reach 42 GW, and by 2020 cumulative installed and grid-connected capacity will reach at least 70 GW. Regions with severe wind reduction issues will focus on solving these issues during this period. For regions where wind power takes up a small share of their electricity production in total, but without wind reduction issues, the priority of China is to expand the local wind power consumption and wind power development. After successfully solving the wind reduction issue in the three northern regions, 35 GW of grid-connected and installed wind power capacity will be added by 2020, bringing the cumulative grid-connected capacity amount to 135 GW. During the 13th FYP wind power consumption will be advanced, equal to 40 GW of transmission capacity in the northern regions. The projected wind power development to 2020 follows the adjusted targets for the 13th FYP period, which are considerably higher than the targets declared in the 13th FYP. This means that the 210 GW target is overachieved generating 420 TWh in total. By 2020, 259 GW wind power capacity is installed generating 619 TWh, 9% of national power generation. In order to achieve the policy targets for 2020, China must efficiently make use of wind power resources in the eastern and central parts of China, where there is a low speed of wind, so a potential wind farm development will become central (Zhongying, 2017).

In the short term, some changes will take place focusing on the deployment of onshore wind power resource. Deployment happened previously concentrated more on large-scale wind power farms in the three northern regions. Now the focus will be into a development model on low speed wind farms in the eastern and central parts of China. The highest resource utilization rate will take place in the economically developed eastern coastal provinces, and will have a range of 16-25% by 2020 (Figure 19).Also during this time, all other Chinese regions wind power resources will be developed and utilized. (Zhongying, 2017).

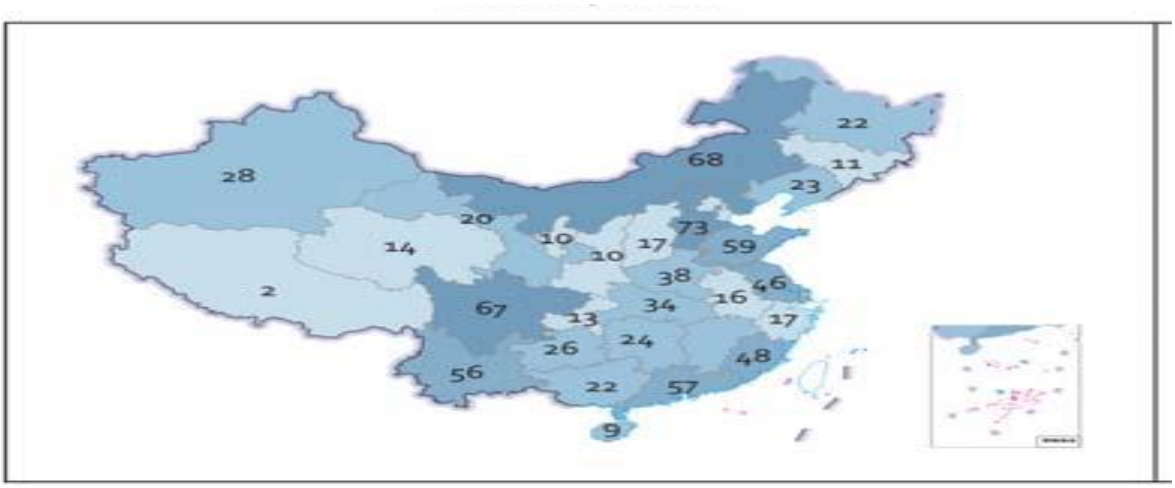
Figure 19: Utilization of wind energy resources in 2020



Source: Zhongying, (2017)

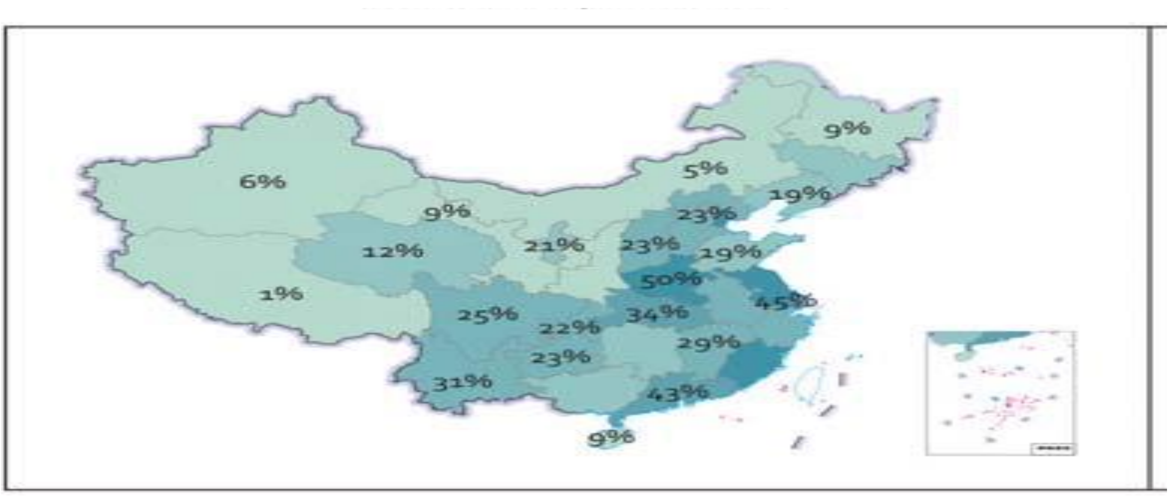
In mid-term development, by 2030, wind power capacity will mostly be distributed in Inner Mongolia while cumulative installed wind power capacity in Inner Mongolia is expected to reach 181 GW, making it the largest wind power base. The eastern and central regions of China will face a fast increase in the portion of installed wind power capacity. In the mid-term 70 GW will be added annually in the eastern and central regions and by 2030, 34 GW offshore wind capacity will be installed in the eastern region (Figure 20). Regional distribution of new capacity is getting more even and previous major deployment in the northwest region is being reduced. The southwest development of wind power will make use of the sufficient hydropower to balance power production. Wind resource development in the eastern and central parts of China is enhanced by 2030 (Figure 21). Development concentration in some regions may reach 70% or above (Zhongying, 2017).

Figure 20: Wind power development situation in 2030



Source: Zhongying, (2017)

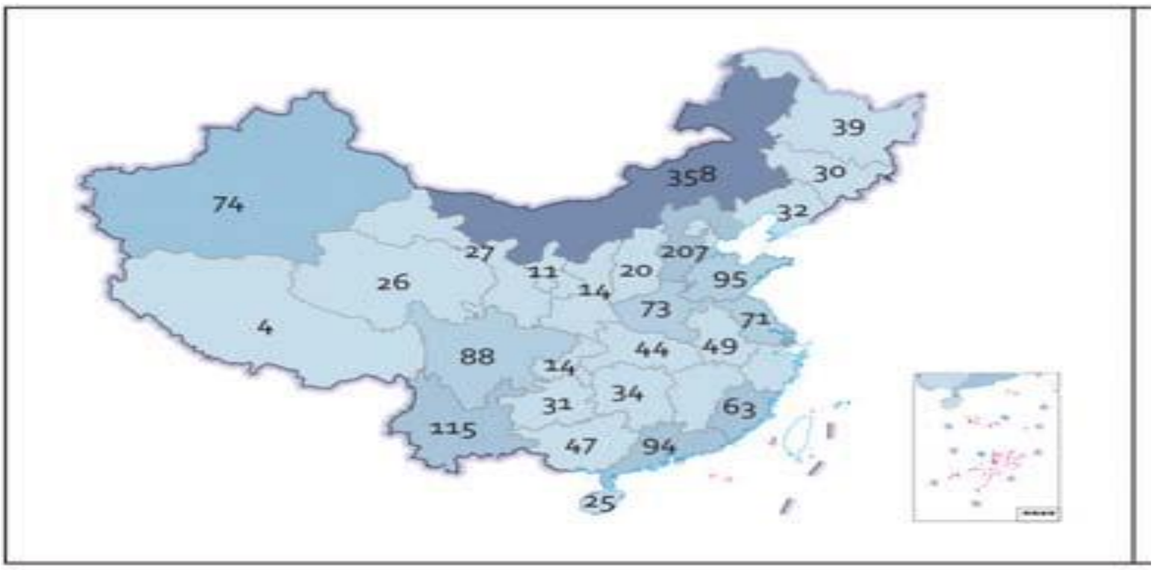
Figure 21: Wind energy resource development situation in 2030



Source: Zhongying, (2017)

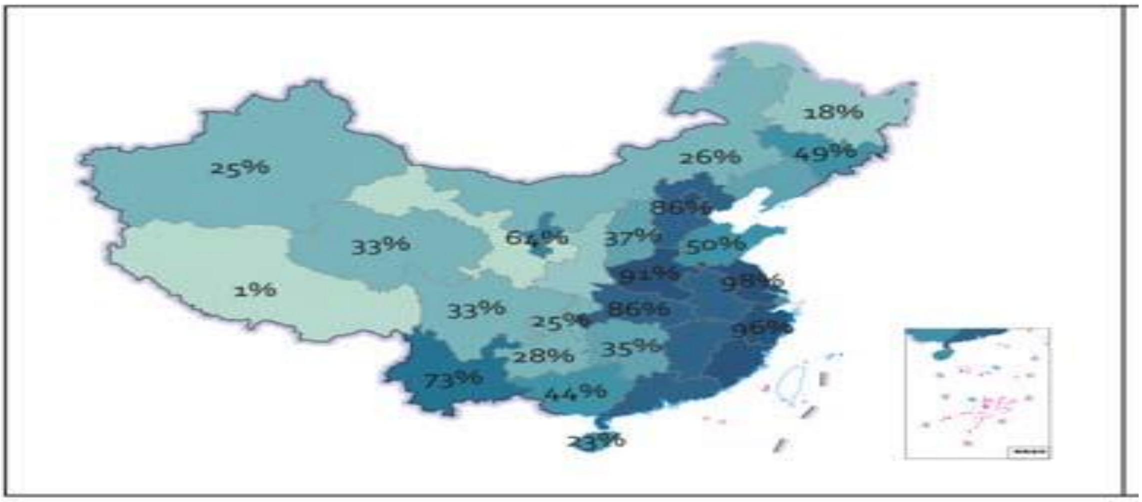
Long-term, by 2050 total installed wind power capacity accounting for 38% of total installed generation capacity and wind power production will be able to meet 42.7% of total electricity production. Installed wind power capacity will account for 41% of total installed power generation capacity by 2040. Wind power production will be able to cover 46% of total electricity production. By 2050, production of wind power will still cover 46% of total electricity production while the installed wind power capacity is expected to reach 39% of total installed generation capacity (Figure 22, Figure 23). Wind energy resources in the eastern and central parts of China are fully utilized, while wind energy resources in other middle- to low-wind speed regions, high attitude areas and plateau are also utilized at a large scale. Wind power is the power source with the largest installed capacity in the eastern and central parts of China and it occupies the most important position in the power system, development of relevant industries, i.e. marine planning, offshore wind power technology and construction capacity, are mutually connected. China must promote technological progress, increase the support for offshore wind power development while reducing the cost and do a fine work with the pre-planning assessments in order to realize this, (Zhongying, 2017).

Figure 22: Wind power distribution for 2050



Source: Zhongying, (2017)

Figure 23: Wind energy resource development situation in 2050



Source: Zhongying, (2017)

4.5 Conclusions

In the future, China's energy structure must become cleaner and greener or more environmentally friendly. This has to involve a gradual transition to the replacement of fossil fuels with clean energy. In the process significant benefits and opportunities will be generated. By strengthening the country's energy independence and security, it leads to several advantages in the economy including sustainable rates of economic growth that lead to job creation and prosperity. Additionally, water and food security is improved and environmental sustainability and equity is enhanced. States, such as China, that have invested heavily in renewable technologies and set up their capacity to exploit the opportunities inherent in the adoption of said technologies, may increase their influence in the global economy. The precise scope and pace of the transformation into clean, renewable technologies may be hard to predict, yet it is almost certain to have a profound impact on countries, communities and companies. To attain a sustainable future, China may need to plan changes that include upgrading and changing its infrastructure, which is mostly the case for the power and refining sectors and strengthening its environmental regulations so that it could address China's chronic environmental conditions. Notwithstanding the aim for transition, fossil fuels are likely to remain China's dominant primary source of energy, since other sources of energy cannot meet the huge demand for energy in China.

China is making large investments in developing renewable energy, totaling USD 102.9 billion in 2015, or 36% of global investment in renewables. The fact that hydropower units can run for 50–100 years and lacks fuel costs make hydropower one of the low-cost power technologies. At the end of 2013, total installed capacity of hydropower was 280 GW, accounting for 22.3 % of China's total power capacity.

Solar-power is critical in China's transition into renewable energy. China is the producer of 63% of the world's solar photovoltaics (PV) and as of June 2015 has came up as the world's largest manufacturer. The solar-power sector, with China at its center, has grown intensively over the past years. It has achieved the status of a global industry, one with geopolitical value, significant employment creation and economic interests, all of which the industry's partisans around the world will fight to protect and expand. Yet, solar energy generation will have to grow many times larger if it is going to contribute meaningfully to combating climate change. Still, China has an even more-compelling reason to invest in this growing industry and that is its economic self-interest.

As for wind power China has the largest wind resources in the world while the three-quarters of this natural resource is located at sea. China aims to have 210 GW of wind power capacity by 2020. Investment in a wind power plant will have risk. Generally, the first investment of wind power is expensive, and involves a certain degree of risk which comes down to financial risk, at most. But an investment with the high risk it may entail could lead into great profits. Compared with another resource, wind power has distinct advantages such as the lowest price for clear and renewable energy. Additionally, wind generated power resolves the complexities of the emitted carbon dioxide problem and fuel cost

5. Conclusions

Renewable energy sources became an important component of the world energy consumption portfolio due to the ongoing concerns about climate change. The replacement of fossil fuels in two sectors, the power generation industry and the transportation sector, with renewable energy technologies could reduce CO2 emissions. Conventional energy production involves irreversible and negative areas that make it important to promote and develop the demand for renewable energy alongside the development of renewable energy supply technologies. Renewable energy sources that are used in power generation should be increased so as to minimize the cost per unit of energy generation. Consumption of energy depends on factors that include population, energy prices, level of economic development attained, technology and weather.

Investing in renewable energy is a priority for the Chinese government mostly because it allows the country to deal with problems such as water and air pollution, as well as reduce risks inherent in socio-economic instability. Air pollution is a major concern for China's government and the major reason why Chinese government promotes renewable energy is to reduce ai-pollution.

The international community should acknowledge positively China's leadership in the renewable energy sector, for two other reasons besides China's domestic considerations.

The first reason refers to ecology: China's declared ecological objectives of developing renewable energy are broadly supported for the decisive area, deployment investments and technology will bring and these objectives are rather undisputed. This is because the need of reduction greenhouse gas emissions in order to reduce the negative effects of climate change is an area that has attracted global consent to a large extent. The international community's expressed its decision to commit itself to dealing with the challenge of climate change in the decision to sign the Paris Agreement in 2015. China, is the world's leader in greenhouse gases emissions, and this fact makes the country's transition to renewable electricity consumption and production important to its international engagement to as possible eliminate carbon dioxide emissions by 2030.

The second reason refers to strategy: increasing the country's capacity of renewable sources for electricity consumption in its energy mixture, can assist China reduce pressure in the geopolitics scene by making the country less and less dependent on regions that may be unstable for energy security. An energy market that relies on fossil fuels consequently depends on securing gas and oil transportation routes from and to fossil fuel-rich countries, which in different ways requires protection by military forces. China has constructed its first overseas naval base in Djibouti recently and this was largely to secure oil transit choke points. In contrast, the availability of sunlight and wind as resources for renewable energy exceeds the availability of fossil fuels and is much more fairly distributed across foreign countries.

Global geopolitics will be benefited by China's leadership in renewable energy growth in two ways. Firstly, as China's share of renewable energy produced domestically in its energy mix increases, it will have less excuses in broadening its military presence justified on arguments of energy security. Secondly, renewable energy usage inspires globally as an area from China's development in this sector. More countries will, hence, receive the ability to become producers of energy and thus be less reliant on regions that are unsuited for conventional fossil fuels, such as Russia. This does not necessarily show that it would eliminate geopolitical worries as a result of a renewable-led world electricity market. Neither would it withdraw questions on property rights for technologies, including questions about capacity, energy storage and grid connectivity or issues of who is in control of the power lines, while the availability of raw materials with the purpose of constructing renewable equipment will still be viable. Yet, China's leading role in the development of renewable technology should be supported and seen by the foreign countries in the wider context of reducing the effects of energy security concerns and climate change. There are legitimate risks to take into consideration when investing in China, risks that involve the loss of financial control, the appropriation of intellectual property without fair compensation, as well as national security.

What is more certain is that incentives have changed and foreign companies are more and more willing to invest in China due to the technological advances in the renewable energy sector. This change may proceed in two ways: first one is that foreign countries that do not associate with China for the development of renewable technology for solar, hydro or wind energy could be left behind technologically. China has been shortening the gap with western countries in terms of developing crucial components for solar panels the last recent years. The strategic benefits of cooperating with the Chinese in development and research while they keep improving in becoming one of the world's leading developers of renewable technology, as well as investing in China might exceed the risks and costs of potential technology piracies.

China is also changing the essence of foreign investments who want to enter the sector by advancing in renewable energy. The country currently depends mainly on corporate bonds and bank loans for funding renewable energy projects, something that does not always provides promising results. These traditional methods of financing are more reachable to state-owned enterprises (SOE), and put a significant disadvantage to the private companies due to their capital efficiency in contrast to their public counterparts. Therefore, more capital but also the need to access to more financing instruments is what the private Chinese companies seek.

China needs financing alternatives, such as taking advantage of direct leasing ,crowd-funding and pension funds already applied profitably by renewable energy companies in the West. This is why China has been pursuing to draw foreign financiers through bilateral platforms such as the U.S.-China Renewable Energy Partnership, to apply these renewable energy investment techniques in their own country. The evolution of China's foreign investment and renewable technology poses a significant opportunity for the country because by cooperating with foreign investors, having more revolutionary financing methods to lead the industry, they can achieve in this increasingly complicated market.

The gap that is left open by U.S. government's withdrawal from the Paris Climate Change agreement, arouses further political and economic support from the international community for China to lead in the sector. Alternatively, by speeding up the world's transition to clean energy the European Union is already creating a partnership with China to carry out the Agreement. As renewable energy distribution continues to increase across the globe, the adjustment of China's incentives and capabilities to invest in the sector gives the country a crucial role for the sector's future.

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