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REVIEW ON THE CHALLENGES IN CHINA'S ENERGY TRANSITION FROM FOSSIL FUELS TO RENEWABLE ENERGY

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ABSTRACT

Juha Köykkä: Review on the challenges in China's energy transition from fossil fuels to renewable energy
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This thesis looks into the challenges China is facing in its energy transition from fossil fuels to renewable energy. The challenges are analyzed from technical, market, and policy viewpoints in order to form a general view of the transition and factors affecting it. This thesis reviews existing literature on the subject and combines major findings from different studies and papers together. Lastly this thesis summarizes policy proposals for further integration of renewable energy into the Chinese power system.

China is the worlds' leading energy producer and consumer. China also leads in electricity produced and consumed and in renewable energy produced. Between 2010 and the first half of 2019 China has invested more in renewable energy than any other country in the world. There are good reasons for China to heavily invest in renewable energy. Coal-burning poses a serious public health problem for Chinese citizens and China has the world's largest greenhouse gas emissions, so phasing out coal-fired power in favor of renewable energy would benefit both Chinese people and the global climate. Renewable energy and electrification also provide China a possibility to reduce its dependency of oil imports and to gain self-sufficiency in energy sector.

Chinese energy sector has been built on its vast coal resources and coal-fired power still dominates the generation mix. Due to this the power system and electricity market have been very inflexible. The tariffs for electricity have been heavily government regulated as has been the planning of electricity production. This system hasn't allowed for a widespread integration of renewable energy, as renewable energy is inherently an energy source, whose output varies in time. Therefore, increasing flexibility of both the power system infrastructure and the electricity market is needed in order to integrate further renewable energy production into the Chinese power system.

There have been reforms aiming to reduce government regulation on the electricity market and to increase the flexibility of the power system. Transmission and distribution tariff reform unbundled transmission and distribution prices from the electricity tariffs and there have been efforts to promote direct trading of electricity between the producers and the consumers. One key object of the reforms is to establish electricity trading with the renewable energy resources rich northern and southwestern provinces and the coastal and central provinces, where the biggest load centers are located. New UHV transmission lines have been constructed to connect different regions, but trading between regions is still hindered by conflicts of interests between the local provincial governments.

The scattered renewable energy legislation that lacks practicability is one culprit behind these conflicts. In the future, the central government needs to upgrade the legislation and implement concrete measures to ensure that local governments and energy enterprises work towards the national objective of renewable energy integration. At the same time government needs to develop open regional wholesale and retail markets for electricity, also real time spot markets. To increase flexibility of the power system infrastructure, ancillary services and demand response markets are needed. Lastly, central government needs to gradually phase out feed-in tariffs for wind power and solar photovoltaics (PV), in order to avoid over-capacity construction and to ensure the long-term profitability of new energy companies.

Keywords: China, renewable energy, wind power, solar PV, energy transition, electricity market, power system, energy policy

TIIVISTELMÄ

Juha Köykkä: Analyysi haasteista, joita Kiina kohtaa siirtyessään fossiilisista polttoaineista uusiutuviin energianlähteisiin
Kandidaatinytö
Tampereen yliopisto
Sähkötekniikka
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Tämä kandidaatintyö analysoi haasteita, joita Kiina kohtaa siirtyessään fossiilisista polttoaineista uusiutuviin energialähteisiin. Kokonaiskuvan muodostamiseksi näitä haasteita tarkastellaan teknisestä, taloudellisesta ja poliittisesta näkökulmasta. Tämä työ kerää yhteen olemassa olevan kirjallisuuden havaintoja. Lopuksi työssä esitetään toimenpide-ehdotuksia uusiutuvien energianlähteiden integroimiseksi Kiinan sähkövoimajärjestelmään.

Kiinan on maailman johtava energian tuottaja ja kuluttaja. Kiina johtaa myös sähkön tuotannossa ja kulutuksessa sekä uusiutuvan energian tuotannossa. Vuodesta 2010 vuoden 2019 puoleenväliin mennessä Kiina on investoinut uusiutuvaan energiaan selvästi enemmän kuin mikään muu maa maailmassa. Kiinalla on myös perusteita investoida uusiutuvaan, sillä pienhiukkaspäästöt ovat Kiinassa vakava terveysongelma. Tämän lisäksi Kiina on maailman suurin kasvihuonepäästöjen aiheuttaja. Uusiutuvan energian lisääminen on siis tärkeää sekä kiinalaisten kansanterveydelle, että ilmastolle. Lisäksi sähköistyminen ja uusiutuvan energian käyttöönotto mahdollistavat Kiinalle siirtymisen tuontiöljyriippuvaisuudesta kohti energiaomavaraisuutta.

Kiinan energiasektori on rakentunut pitkälti suurten hiilivarantojen varaan ja hiilivoima hallitsee energiantuotantoa. Tästä syystä kiinan energiajärjestelmässä ei ole juuri joustavuutta. Se on ollut myös vahvasti keskusjohtoisesti säännelty. Koska uusiutuvan energian tuotanto vaihtelee sääoloista riippuen, uusituvan energian integroiminen sähkövoimajärjestelmään vaatii siltä joustavuutta. Joustavuuden lisääminen energiajärjestelmässä onkin edellytys uusiutuvan energian käytön lisäämiselle Kiinassa.

Kiinassa on käyty läpi reformeja, joiden tarkoituksena on vähentää keskushallinnon sääntelyä, vapauttaa sähkömarkkinoita ja lisätä sähkövoimajärjestelmän joustavuutta. Siirto- ja jakelumaksut on irrotettu sähkön hinnoista ja on kannustettu suoraan sähkökauppaan tuottajien ja kuluttajien välillä. Koska Kiinan merkittävimmät uusiutuvan energian resurssit sijaitsevat pohjoisessa ja luoteessa ja kulutuskeskukset rannikoilla ja maan keskiosissa, yksi tärkeä tavoite on mahdollistaa sähkökauppa näiden välillä. Tätä on tuettu rakentamalla uusia korkeajännitelinjoja näiden alueiden välillä. Kaupankäyntiä kuitenkin häiritsevät provinssien taloudelliset eturistiriidat.

Yksi syy näihin haasteisiin on Kiinan hajanainen ja ylätasoinen energialainsäädäntö. Tulevaisuudessa keskushallinnon tulee selkeyttää ja yhtenäistää lainsäädäntöä sekä tarkentaa paikallishallinoille ja energiayhtiöille kohdennettuja velvoitteita. Tämä on välttämätöntä, jotta kansalliset tavoitteet uusiutuvan energian integroinnista saadaan jalkautettua käytäntöön. Samaan aikaan keskushallinnon on kuitenkin myös vähennettävä sääntelyä sähkön hinnoittelussa ja tuotannon suunnittelussa sekä luotava tukku- ja kuluttajamarkkinat sähköenergialle. Myös reaaliaikaiset spot-markkinat tarvitaan tukemaan markkinoiden joustavuutta. Lisäksi tarvitaan markkinat kysyntäjoustolle ja liitännäispalveluille, kuten säätövoimalle ja loistehon kompensoinnille. Viimeisenä, keskushallinnon on vähitellen luovuttava syöttötariffeista, jotta vältetään yli-investointeja ja varmistetaan uusien sähköntuotantoyhtiöiden toiminnan kestävyys ja kannattavuus pitkällä tähtäimellä.

Avainsanat: Uusiutuva energia, tuulivoima, aurinkovoima, Kiina, energiapolitiikka, sähkövoimajärjestelmä, sähkömarkkinat, energiajärjestelmän muutos

Tämän työn alkuperäisyystarkastus on tehty Turnitin -palvelua käyttäen.

FOREWORD

This bachelor's thesis was written as part of my degree of BSc (Tech) in electrical engineering. As I will spend the spring of 2020 as an exchange student in China, I chose the subject of this thesis so that I could learn more about the country, its economy, and its history in the field of electrical engineering. The writing process of this thesis took a bit longer than I anticipated, but I'm content with the results and I got valuable insight into the politics of China. I'm beginning to understand some of the mechanisms that shape industries in China and how those are related to my own field of study and possible future occupation.

I want to give special thanks to Nelli, Teemu and Riku, who were also doing their bachelor's theses during the summer and gave me essential motivation and support during this process! Also, thanks for the short but warm enough Finnish summer for being a lovely time to sit and write at a lakeshore and to the City of Tampere for providing so well-tended outdoor areas in very accessible locations, but still with uncompromising views onto the beautiful Finnish lake nature.

In Tampere, 19.12.2019

Juha Köykkä

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ABBREVIATIONS AND NOTES

AGC	automatic generation control
CHP	combined heat and power
CREO 2018	China Renewable Energy Outlook 2018
DR	demand response
EU	European Union
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
IRENA	International Renewable Energy Agency
NBSC	National Bureau of Statistics of China
NDRC	National Development and Reform Commission
NEA	National Energy Administration
OECD	Organization for Economic Co-operation and Development
PV	Photovoltaics
REL	Renewable Energy Law
T&D	transmission and distribution
UHV	ultra-high voltage
UN	United Nations
US	United States

1. INTRODUCTION

China is the world's biggest energy producer and consumer and also the world's biggest electricity consumer and producer [1][2][5]. According to International Energy Agency (IEA) world's total electricity production reached 25 721 TWh in 2017 and according to National Bureau of Statistics of China (NBSC), China's electricity production reached 6495 TWh, which is approximately 25 % of the total world electricity production [2][3].

China's electricity production still relies heavily on coal-fired power. According to National Bureau of Statistics of China (NBSC), the output of thermal power electricity in year 2017 was 4663 TWh. The output of nuclear power electricity in 2017 was 248 TWh and combined output from hydro, wind and solar power was 1602 TWh. Hydro power output amounted for 1190 TWh and wind and solar 295 TWh and 118 TWh, respectively [3][4]. So, in 2017 roughly 72 % of the electricity produced in China came from thermal power, 26 % from renewable sources and 4 % from nuclear power. China still relies heavily on fossil fuels for its electricity production, although it has made significant investments in renewable energy sources in the 2010's. China is the world's leading investor in renewable energy and with a great margin. As seen in Figure 1., from 2010 to first half of 2019 China has invested 758 $BN in renewable energy, which is more than double the amount second biggest investor United States has invested. [6]

There are also significant reasons for China to invest heavily in renewable energy sources. China's metropolitan areas have been plagued by serious air pollution problems for decades. In 2016 Tsinghua University and the Health Effects Institute conducted a study that identified coal combustion to be the largest singular source of air-pollution related health effects. In 2013, it was linked to 366 000 premature deaths in China [6]. The research program Global Burden of Disease also approximated that in 2013 overall exposure to fine particulate air pollution was linked to total of 916,000 premature deaths in China [7]. In the light of these findings, it's clear that substituting coal power with renewable energy would also have significant public health benefits.

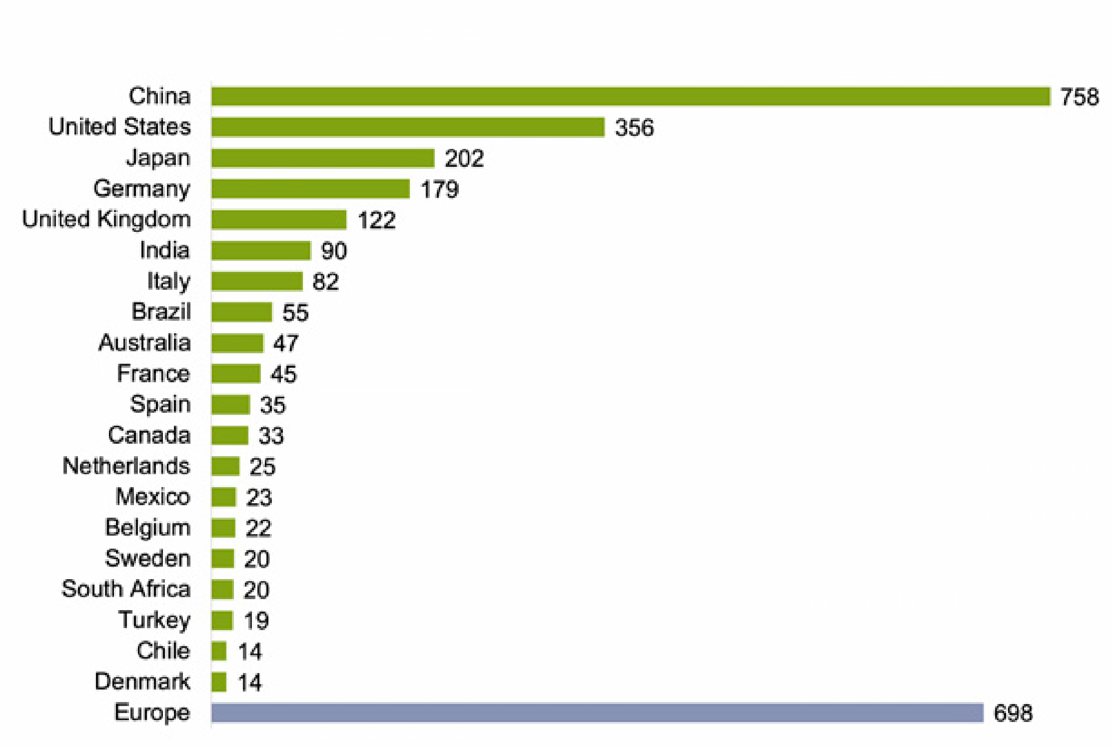

Figure 1. *Global investment in renewable energy capacity in $BN, from year 2010 to year 2019 1H [6].*

In 2016 China signed the Paris Agreement, the global United Nations (UN) led agreement to cut down greenhouse-gas-emissions. The Paris Agreement aims to prevent the global average temperature from rising over 2°C above the pre-industrial levels and attempts to limit the increase to 1,5°C. In 2018 the Intergovernmental Panel on Climate Change (IPCC) published a report that presented a great deal of scientific evidence for limiting the temperature rise to a maximum of 1,5°C. Among these findings was the risk of irreversible changes and loss of vital ecosystems, if global average temperature rises over 1,5°C from the pre-industrial levels. [8] Currently the world is on a course that would lead to increase of at least 3°C by the end of the century, states UN Environment Programme Emissions Gap Report 2018 [9]. As energy sector accounts for two thirds of global emissions, the IPCC 2018 report states, that most pathways to low-carbon economy require rapid development of renewable energy and a doubling of energy efficiency [8]. This idea is also seconded by a 2018 analysis published by International Renewable Energy Agency (IRENA). According to the analysis, the most cost-efficient method to reach the 90% reduction of energy related emissions required in order to meet the Paris Agreement target, is the implementation of renewable energy and improving energy efficiency. [10]

China also stands to gain a lot from the energy transformation in the form of energy security and global influence. Currently China is heavily dependent on oil imports, that have been growing steadily. In the long-term electrification and significant investment in renewable energy would allow China to become self-sufficient in energy production. [6] As the leading investor in renewable energy and the leading producer, exporter and installer of renewable energy technology, China is in a very good position to become the world's renewable energy superpower. [12]

In the 2016 Paris agreement China has agreed to peak its CO_2 emissions by 2030 or earlier and to increase the share of non-fossil energy sources in the total primary energy supply to around 20% by 2030 [13]. It is estimated that China will also hit these targets if it succeeds in the implementation of its current policies and plans [14]. Still, the targets should be upgraded to be much more ambitious in order for them to be consistent with the 2°C limit, let alone with the 1,5°C limit [15].

China has strong reasons to invest greatly in renewable energy sources, but when comparing the capacity installed and energy produced, it becomes apparent that heavy investment in new capacity hasn't increased the share of renewable energy sources in the electricity production mix in accordance to the new capacity built. There has been both significant curtailment of wind and solar power electricity [16] and the capacity factors for wind and solar power plants are low [17]. Whether trying to improve air quality or combat climate change, China needs to be able to substitute fossil-based power sources with clean sources. Regardless of China's heavy investment in renewable energy, it still also builds more coal fired power [18] and has problems in increasing the share of clean energy sources in its energy mix to a level that would be consistent with the 1,5°C limit for global warming. This thesis looks into the challenges China is facing in its energy transition from technical, market and policy viewpoints and seeks to form a general view of these challenges. To conclude this thesis also summarizes some policy proposals presented in the existing literature.

2. TECHNICAL CHALLENGES CHINA FACES IN ELECTRIC POWER SYSTEM TRANSITION

China is the world’s third or fourth largest country depending on how the area is measured [27][28], so the distances between different regions are long. The geography of China is also very varied, including deserts and mountain ranges. Due to its long coastline, China has plentiful wind power resources. Onshore potential is estimated to range from 800G W to 3.4 TW and offshore potential from 297 GW to 1007 GW. China has a stationary solar power capacity that is estimated at 4,7 TW to 39,3 TW and distributed solar capacity at about 200G W. The solar power resources are most abundant in the sparsely populated north and northwest provinces of Inner Mongolia, Xianjiang and Gansu. The richest wind resources are also located in the northern and coastal regions and hydro resources in the southwest regions. In contrast, most of the population lives in the central and southeastern coastal provinces. This poses a technological challenge for the electric power system as the power grids in the northern regions are relatively poorly developed and the demand centers are located far away in the southern coast. [5] This together with the fact that the output of solar photovoltaics (PV) and wind power resources varies in time challenges the current power system infrastructure in China that is built for a coal-fired power dominated generation mix [16][29].

2.1 Inflexible power system

Renewable energy integration requires flexibility from the electric power system, as meteorological and geographical factors affect the output of renewable energy power. Therefore, complex planning and operation scheduling are required in the implementation of renewable energy, in order to respond rapidly to changes in supply and demand. This chapter analyses different approaches to increasing the power system flexibility and the challenges encountered in their implementation. This chapter also points out factors affecting the curtailment of renewable energy and the inefficiency of wind power in China.

2.1.1 Transmission systems

Well-planned investment in high-voltage transmission systems is one of the most critical steps in preparing for higher levels of renewable energy penetration [19]. This combined with greater grid interconnection could reduce grid congestion and allow the demand centers to use the renewable resources and reduce renewable energy curtailment during regional valley load periods. As the electricity resources and demand in China are located unevenly, Chinese power system is based on transmission of western electricity to eastern regions and supply of northern and southern electricity, which is shown in Figure 2. Nationwide electricity interconnection is very important for the Chinese power system and in 2017 the construction of six main regional grid frameworks was completed. [29] Still, the development of power grids has mainly concentrated on large-capacity and long-distance Ultra High Voltage (UHV) transmission projects, which has resulted in low utilization of the existing inter-provincial and inter-regional 500 kV and 750 kV transmission lines. This has resulted in low transmission line resource allocation efficiency. In 2016 the ratio of combined electricity consumption to transmission line circuit length in China was 9,55 million kWh per km, which is barely 80% of European Union and U.S. utilization and far from the 22,91 million kWh per km utilization of Japan. There have also been problems with the new UHV power transmission projects, as they were rushed before technology was fully mature and this has led to reliability problems and lower transmission capacities. Yet one factor contributing to low utilization rates for power grids is the use of a planned scheduling system which lacks flexible electric power exchange across provinces and regions. Unlike in countries with high renewable energy penetration such as Denmark or Germany, the operational model of China is unable to perform real-time adjustments based on the changing characteristics of the receiving and sending sides of the transmission channels. [29]

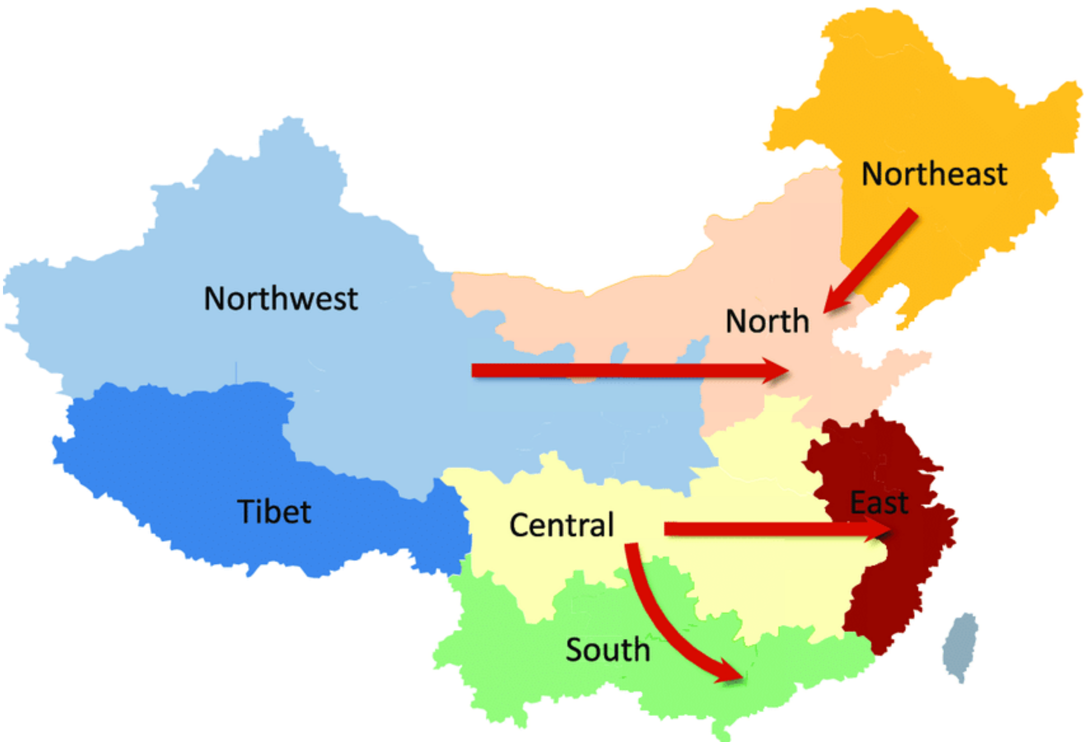

Figure 2. *The regional power grid division and the national power flow pattern in China [30].*

2.1.2 Ancillary services

As the output of renewable energy power varies in time, measures to increase the power system flexibility are required when a high amount of renewable energy production is connected to the power system. These measures are referred as ancillary services, that can be provided by network users such as generators or customers or by various system assets. In China ancillary services are categorized into basic ancillary services, such as frequency regulation, reactive power and basic peak regulation and paid ancillary services, such as automatic generation control (AGC), standing and spinning reserve, paid reactive and peak power regulation and black start capability. These services allow system operators to maintain the power quality as well as the stability and integrity of the transmission or distribution system. Electricity generation units are required to provide the basic ancillary services, depending on the features of the generation units, and they are not compensated. [16] In history only coal-power plants used to provide ancillary services in China and the costs of these services were pooled among thermal generators, which gave little incentive for flexible operation or integration of renewable energy sources [29]. Also, although now the services categorized as paid ancillary services are compensated, the payments are so low, that they barely cover the costs of the ancillary services. [16] China lack’s standardized mechanisms to increase the supply of the paid ancillary services and this poses a difficulty for renewable energy integration. A solution for this problem could be establishing ancillary service markets that have been piloted in the northern and southern regions since 2017. These markets cater to regional challenges in different provinces. In the northern Gansu and Qinhai provinces capacity reserve markets have been set up as they suffer from curtailment of wind and solar power. At the same time in southern Guangdong province the market began with frequency regulation services as the province had an enduring shortfall in that capacity. The results from these provincial pilots are promising, but more work is needed to ensure the ancillary service markets have transparent and persistent rules that allow cost-effective investments and wide participation. [29]

2.1.3 Demand response

Yet another way to increase power system flexibility is to control the power demand. This is called demand side response (DR) and it means that the electricity users adjust their usage intelligently to balance the energy production and demand. This could for example mean that factories delay some energy intensive processes in order to make room for the demand by households in the cities, that consume more energy in the evenings.

According to China Renewable Energy Outlook 2018 (CREO 2018), the local governments in China are encouraged to enforce economic, administrative and technical measures to orderly manage power consumption. The order of the measures taken is: first, shifting peak load of power consumption to other periods; second, peak avoidance through interruptible loads; third, power restriction; and finally, power rationing [29]. In 2011 and 2012 The National Development and Reform Commission of China (NDRC) has launched a demand side management pilot where cities attempted to cut the peak demand for electricity in commercial buildings and industrial facilities and improve the efficiency of power consumption. According to CREO 2018 [29], the load aggregators (individual energy users banded together in order to participate in the grid dispatching of DR) gained more prominent roles and functions during the implementation of these DR programs. Still, the programs also highlighted several problems for DR in China. Demand side response requires accurate measurement and data transmission systems and therefore large investments to installation and maintenance of online metering equipment and data transmission equipment is needed. As many DR events are not automatic, the response speed in China is slow, the peak shaving capacity poor and the magnitude uncertain. China needs to provide transparent information about local generation and load and expand the extent of involvement from large customers to small and medium - sized customers also. There are also market measures to be taken. The most important is the implementation of a complete and competitive power market with wholesale and retail markets and dynamic price signals. A transparent and open market is needed in order to allow companies and DR aggregators to assess their individual potential of delivering flexible loads. Other needed market measures are to increase the compensation of DR to reflect its full system value and to enhance stakeholder involvement and to spread knowledge about the DR functionalities. [29] The implementation of a full-fledged power market is discussed in greater detail in the chapter 3, as it is a very crucial step for China to take on its path to a higher penetration of renewable energy.

2.2 The curtailment of solar PV and wind power

Bulk of China's solar PV and wind power resources are located in the "Three North's" Region of China, consisting of North China, Northeast China and Northwest China. These regions are far away from the load centers, so problems have emerged when the output of renewable energy sources combined with electricity produced by thermal power has surpassed the local electricity demand in these regions. Large scale curtailment of wind power began in 2009 and spread to other regions in the year 2010. [17] This means that some of the energy produced has been abandoned as it hasn't been possible to integrate all the energy produced to the grid. As evident in the Figure 3 the nationwide wind curtailment rate peaked at 17% in 2016 and nationwide solar PV curtailment rate peaked at 11% in 2015. This means 50 TWh and 5 TWh of energy lost respectively during those years.

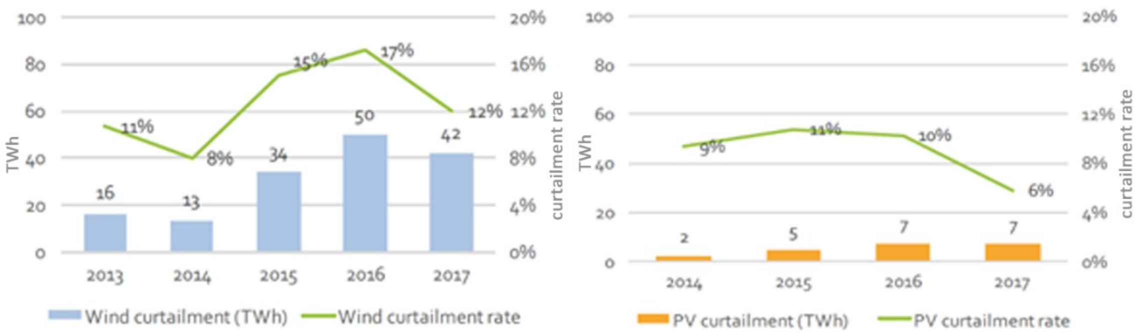

Figure 3. *Wind and solar PV curtailment situations in China from 2013 to 2017 [29].*

Zhang et al. identified the main factors for renewable energy curtailment to be the geographical distance between renewable energy resources and the load centers, the inflexible and coal-fired power dominated generation mix, the misalignment of transmission capacity and the renewable energy resources, the lack of energy storage as well as slowing growth of power demand [16]. Li et al. also point out that there is a large amount of combined heat and power (CHP) production in the Northeast China and therefore in the winter when heating is needed, the CHP units are used extensively, and renewable energy units are squeezed out. Also the lack of sufficient peak-valley regulation capacity and barriers to electricity trading between regions contributed to the curtailment. [20] Since 2017 the government has also taken measures to ease the curtailment of renewable energy. Restrictions for adding wind and solar projects in provinces with high curtailment rates have been set up and as discussed earlier, investments to UHV transmission lines have been made. Clean heating is also promoted and there has been an increase in trading of electricity between provinces and regions [29]. Still, some curtailment remains and despite the importance of the physical and technological factors, Zhang et al. argue, that the root causes for China's renewable energy curtailment are in China's unique electricity sector regime governed by planned economy institutions. This has led to inflexibility in operation, generation, demand and pricing essential in the integration of renewable energy [16]. Kahrl and Wang also point out China's approach to dispatch as an important reason for severe renewable energy curtailment [21]. These factors will be discussed in the chapter 3, along with other institutional and market-related challenges China is facing in energy system transition.

2.3 Low capacity factors of wind power

Despite China being the globally leading investor in renewable energy and having the largest installed capacity of renewable energy power in the world, the actual energy output from renewable energy sources doesn't seem to be as high as it should be according to the amount of installed capacity. When looking at wind power generation statistics from the years 2014-2016 in Figure 4, it is shown, that the European Union (EU) actually generated more energy than China with less installed capacity. According to Huenteler et al., in 2016 the EU generated 36% more electricity per unit of installed wind capacity than China and the United States (US) generated 93% more [17]. The efficiency of power generation can be measured with the capacity factor that is the ratio of realized energy generation to potential generation if a facility operated constantly at its full nameplate capacity. The capacity factor of Chinese wind power generation in 2016 was approximately 16,5% as the capacity factors for EU ad US were 22,5% and 32,0% respectively. Not only is the capacity factor lower than those of the other leading wind power generators, it is also lower than what have been used when estimating the potential for future Chinese wind generation as the range of assumed capacity factors range from 22,8% to 31.8%. [17]

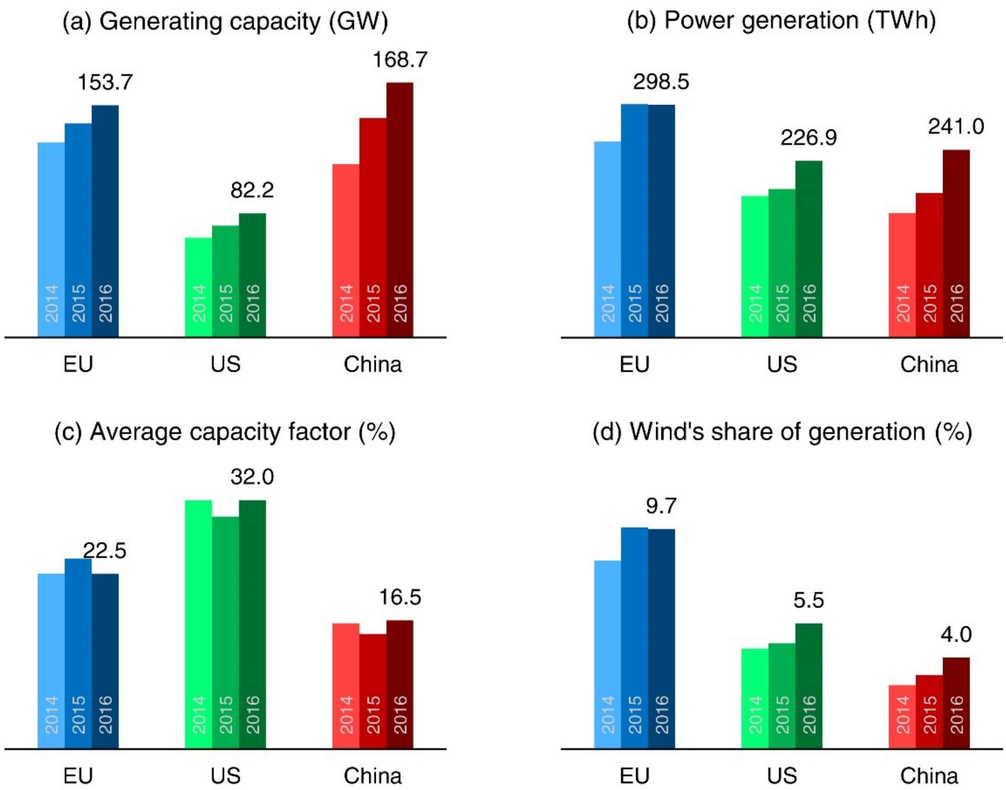

Figure 4. *Key wind sector statistics in the European Union, United States and China in 2014–2016: (a) generating capacity, (b) power generation, (c) average capacity factors (without the installation-date correction) and (d) wind's share of total power generation [17].*

Huenteler et al. developed a framework for analyzing data from nearly all wind farms in China and the US in order to quantify the effect of following six drivers in the performance of each country's wind sector: grid-connection delays, installation-date correction, site selection, turbine choice, operational efficiency and curtailment. The installation date correction takes into account that newly commissioned capacity is not available to generate for the entire year and operational efficiency captures unobserved factors, such as losses from the electrical efficiency of the wind farm. The Figure 5 shows the breakdown of the capacity factors for wind power generation in China from 2006 to 2013. [17]

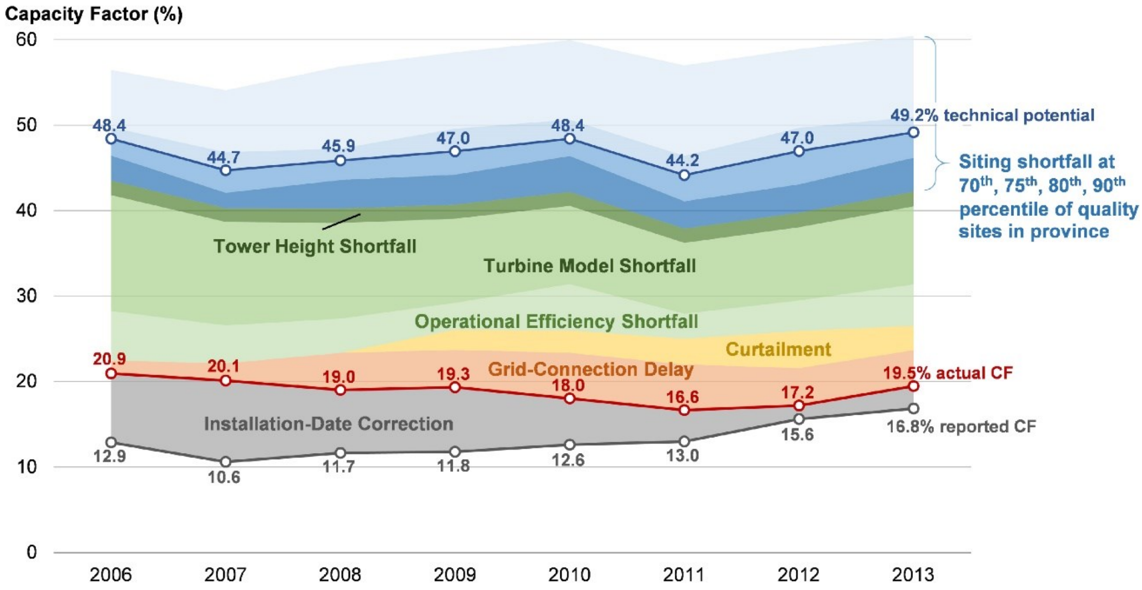

Figure 5. *The shortfall in average capacity factors in the cumulative installed wind power base in China from 2006 to 2013 attributed to seven factors: siting shortfall, tower height shortfall, turbine model shortfall, operational efficiency shortfall, curtailment, grid-connection delay, installation-date correction. [17].*

When taking into account the installation date correction, the capacity factor of Chinese wind power generation for the period of 2006-2013 is 18,2%. It is shown that the corrected capacity factors actually decreased from 20,9% to 19,5% during 2006-2013. Huenteler et al. suspect, that the average wind farm performance in China did not measurably improve between 2006 and 2013, despite significant government and industry efforts. Huenteler et al. found out that instead of wind farm operation, factors related to project design were the biggest contributors to the shortfall of the generation of the Chinese wind farms. In 2013 project design gaps accounted for 17,8 percentage points of the total capacity factor shortfall that was 29,7 percentage points from the technical potential of 49,2%. 9,1 percentage points of this is attributed to turbine model choice, 6,9 percentage points to non-optimal selection of sites and 1,7 percentage points to tower height design. Grid related factors curtailment and grid connection delays accounted for

4,2 and 2,8 percentage points. Other operational inefficiencies accounted for a 4,8 percentage point shortfall. [17] As seen in Figure 5, the relative changes to each of these factors remain quite small over time. Huenteler et al. point out that in 2013 the US produced 60,7% of their technical potential and China produced 39,6%. In both countries the largest cumulative contributor is the selection of turbine model. Also siting had a prominent effect in both countries, though the effect was greater in China. The biggest difference between the countries came from the grid connection delays and curtailment, that clearly had more impact in China. [17]

According to Huenteler et al. there are two contributors to the underperformance of Chinese wind power sector. First, policy efforts by the Chinese government to grow the wind sector have focused primarily on creating incentives to install new wind turbines rather than to incentivize the actual generation. This may have led to project design decisions that have partially neglected turbine model selection, site selection and hub height. Second, the curtailment and grid connection delays impede the performance and it is important to take efforts to improve the grid integration and grid management, which is where the Chinese government's focus has recently been. Together these findings suggest that on top of reducing curtailment and improving grid connection, there is also a need to address the incentives and constrains affecting farm siting and technology choices. This is especially important in order to prevent locking further inefficiencies in the sector for years in the form of wind power units that cannot achieve their technical potential. [17] As siting choices for the wind farms are driven by trade-offs between land availability and prices, wind resource quality, proximity to electric grid and service roads and the level of available feed-in-tariffs, there are many economic factors affecting them. Therefore, the incentives for wind power construction should take these factors in to account instead of encouraging to prioritize capacity development over actual generation. Also increasing access to multi-year wind measurements and requiring these assessments could reduce the amount of wind power units built in places where the wind resources are actually insufficient. The incentives and economic factors affecting wind power are looked into in greater detail in the next chapter.

3. CHINESE ELECTRICITY MARKET AND ITS EFFECTS ON RENEWABLE ENERGY INTEGRATION

This chapter forms an overall picture of China's electricity market and the ongoing reforms and analyzes their effects on renewable energy integration. In order to tackle the technical challenges China faces in its energy transformation many market-based and institutional measures need to be taken, as has become evident in the previous chapter. Trading electricity differs from trading other commodities in several ways: it's not commercially viable to store it extensively, so it must be consumed immediately it is generated. In other words, its supply must exactly meet the demand across the grid at any given time. On top of the energy-related commodities, as generation output, also power related commodities like ancillary services are traded in wholesale electricity markets. Energy can be traded in forward markets or in spot markets. [16]

Before 2002 the Chinese electricity utility was a vertically integrated state monopoly system as is common in transitional economies. In order to introduce competition into the power sector it was broken into five generating companies and two grid companies. The goal was to establish a competitive electricity wholesale market and to regulate grid tariffs, but these reforms were later halted before the market could be established. In 2015 new reforms were launched: the business models of grid companies were restructured and business was opened to non-grid companies. The idea was to separate retail segment from the natural monopoly networks and allow electricity tariffs to be determined by the market. [20] As evident in the Central Committee of the Communist Party of China's Document #9 "Opinions on Further Deepening the Power System Reform" that was issued in 2015, China's long-term objective is to form mechanisms for market-based pricing of energy and to build a market system of effective competition. [22]

In 2017 only 27% of total electricity consumed in China was traded through market, so though China's power system is transitioning to a market system, it is still heavily regulated. [20]. According to CREO 2018 the government still generally sets the power generation schedules, consumption plans and electricity retail tariffs. China also lacks wholesale electricity trading and retail competition is still a work in progress. As Market trading between power generators and users is limited and market-based pricing remains unestablished, new capacity is being built by traditional power generators to meet the growing load. This hinders the utilization of renewable energy and it's recognized that without an effective modern electricity market system it is hard to drive the transformation to a higher integration of renewable energy and to a more optimized power structure. [29]

3.1 Notable features of the Chinese power system

One notable feature of the current power system in China is the equal shares dispatch system. It means that economic planning agencies inside provincial governments, that follow a “fair dispatch” principle, guide the dispatch of generators. The provincial governments make annual forecasts for total electricity demand next year and allocate the demand to generators within the province. The demand can also be allocated to imports from outside the province. The demand is allocated so that all generators in the same class of generation technology get equal annual utilization hours. The idea behind this principle is to guarantee that all investors have a fair chance for recovering their costs. The feed-in tariffs for these quotas vary by generation technology and are set by the provincial governments. Most thermal power plants are compensated on a per-kWh basis and therefore they are determined to reach their annual allocation of hours. They also resist reductions in their operating hours that result from renewable energy generation. Under the equal shares dispatch pricing model, investments in flexible resources such as gas-fired power plants are discouraged, which hurts peak regulating capacity that would be needed to support the integration of renewable energy generation. The Renewable Energy law that has been in effect since 2006 requires renewable energy to be fully purchased by the grid and to be given priority dispatch, but despite the legislation, renewable energy sources have not received full priority. [20]

Another important characteristic of the Chinese power system is the highly regulated electricity tariff. The benchmark wholesale tariffs for generating plants are set by the government. Each province creates its own Catalogue of end-user tariffs, where the tariff varies between different categories of end-users. These Catalogues are approved by the NDRC. The tariffs for wind and solar power consist of two parts, one is the benchmark wholesale tariff for coal-fired power units, which is paid by the grid company, and one is the renewable energy subsidy granted by the central government. [20]

3.2 Dispatch practices and the curtailment of renewable energy power

According to Zhang et al., economies which have electricity markets usually optimize dispatch based on a ‘merit order approach’, where available electrical generation is ranked on the basis of ascending order of price together with amount of energy that will be generated. This means that electricity with lowest net costs is dispatched, which minimizes overall electricity system costs to consumers. In turn, in China the equal shares dispatch system explained earlier is used and the dispatch is guided by economic planning agencies within provincial governments. [16] Kahrl and Wang argue that the current electricity pricing mechanisms in China create conflicts between coal units and renewable energy units. This stems from the system where coal units receive energy-only benchmark price and renewable energy units receive the benchmark price combined with a feed-in tariff. Coal units need to operate a planned number of full load hours to recover their fixed costs while wind generators want to generate whenever possible in order to earn the feed-in tariff. This has led to financial conflicts between coal and renewable energy units and there have been no competitive or environmental criteria to identify which units to dispatch and which units to curtail. [21] The Renewable Energy Law of China requires a priority dispatch for renewable energy, but the current dispatch practices neglect this and the marginal costs and environmental advantages of renewable energy. According to CREO 2018, moving from a fixed tariff structure to a power market where prices are set by supply and demand could already bring a lot of resource flexibility potential that wasn’t incentivized before. Also, the dispatch shouldn’t in general be affected by administrative rules or bilateral power purchasing contracts. Instead it should be neutral to the underlying technology and contracts and efficiently choose the lowest-cost resources. [29]

3.3 Electricity market reforms and inter-regional electricity trading

One key challenge for China is to reform its highly regulated electricity tariff system. The deregulation of pricing could allow for a more efficient usage of different resources in the power system and could promote cross-regional energy trading. According to Zhang et al. the deregulation of electricity pricing can be divided into three components that are the transmission and distribution (T&D) tariff reform, the retreat of planning and the direct trading of electricity [16]. CREO 2018 states the T&D price reforms have already been implemented across China in 2017. The goal of these reforms was to change the grid companies’ business model so that their revenue would come from providing T&D services and not from selling electricity. In this new system government regulators estimate the T&D costs and these combined with a reasonable margin for profit serve as the basis for the T&D prices. [29] Direct trading of electricity means that the electricity users and generators negotiate prices directly together without a grid company in the middle, which allows market-based pricing. The direct trading of electricity was originally introduced in

2002, but it was ceased in 2009 when some provincial governments had begun to use it to give power tariffs to energy intensive industries. Zhang et al. point out that there is a risk of local governments interfering in the direct trading of electricity and determining which end users' generators should sell to or force renewable energy generators to lower their prices. [16] Nevertheless, direct trading of electricity between producers and consumers is an important step towards competitive wholesale and retail electricity markets. According to CREO 2018, China has also begun to replace the previous system of planned power plant operating hours with a system that emphases energy security, energy integration, energy supply-demand balance and emission reduction. The plan is to cut down guaranteed generation hours gradually by every year by allowing coal-fired power plants to get only 80% of the previous year's guaranteed hours. Also, newly built coal-fired power plants don't get any guaranteed generation hours and will be dispatched only according to direct purchase contracts. This enforces bilateral trading between generators and retailers and is also a step towards wholesale markets. [29]

One of the objectives stated in the Central Committee of the Communist Party of China's Document #9 issued in 2015 is to further develop inter-provincial and inter-regional power trading mechanisms [22]. As the renewable energy resources are unevenly divided between geographical regions in China, there is a need for both inter-regional transmission capacity and inter-regional and inter-provincial power markets. Efforts to increase transmission capacity have been made and although some technological challenges, as the lack of flexible transmission line scheduling system remain, the real barriers to inter-provincial trade lie elsewhere. CREO 2018 points out, that China's power grid development requires establishing of an unified regional power market, marketization of cross-provincial and regional electricity trading and promotion of resource optimization in broader areas. It also points out that the barriers to inter-provincial trading appear to be worsening and names the interest conflicts between provinces as the culprit. The provinces selling electricity tend to use the low-cost electricity by themselves and sell high-priced electricity. On the other hand, the provinces on the receiving end tend to perceive that competition brought by electricity imports could worsen the financial position of their local power generation enterprises. [29] Zhang et al. also argue that one reason for provincial governments to prefer intra-provincial electricity trading over inter-provincial electricity trading is the fact that the intra-provincial trading generates more taxes for provincial governments. Another reason addressed is that the potential for national electricity supply has surpassed the national demand and therefore importing electricity from another province could cut the revenue of local coal-fired power plants. The third reason mentioned is the cost of cross-provincial energy transmissions. Due to high transmission prices and high losses for the inter-provincial electricity flows, the imported electricity may cost as much or more than the local on-grid tariffs for thermal power. [16] There is also a conflict of interests between the central government, that promotes renewable energy purchase guarantees and inter-provincial electricity trading and the provincial governments, who protect local enterprises. This has some roots in legislation and its enforcement, and this will be looked into in a greater detail in the chapter 4.

CREO 2018 also reviews the Chinese government's plans to establish a national spot power market as the power market reforms progress. The outlook points out that this is essential as without a spot power market coal power remains cheaper than the government-set tariffs for renewable energy. In the current situation, provincial governments and grid companies are enticed to uphold within-province generation, which combined with transmission system operation practices hinders inter-provincial purchasing of renewable energy. In order for a spot market system to work, an ancillary service market, flexible and reliable power system infrastructure and T&D reform are needed. These conditions are met in some pilot provinces but creating inter-regional spot markets will still need time and resources. [29]

3.4 Ancillary services markets and demand response

Ancillary services and demand response capacity play a crucial role in power system flexibility as they help in balancing of supply and demand and maintaining power quality. However, the power system of China has traditionally been built for steadily producing thermal power plants and the need for ancillary services has been low, as have been the incentives to build ancillary services or demand response capacity. With the increasing integration of renewable energy however, the requirements for power system flexibility are higher and this calls for new ways to incentivize ancillary services and demand response. The ancillary services are categorized into basic ancillary services and paid ancillary services. Producing basic ancillary services has been mandatory for the power generation units and paid ancillary services have been compensated with tariffs that just cover the expenses of creating ancillary service capacity. One way to incentivize ancillary service production would be the establishment of an ancillary services market and Li et al. argue, that it would be simpler than building a mature power market, as it allows market participants to face lower risks and less physical constraints from the power system and it involves smaller cash flows. They argue that well-designed traded items in the ancillary service market could effectively increase the optimization of the power system and the integration of renewable energy. As an example, they use the deep peak regulation trading in Northeast China, where ancillary service market successfully motivated

CHP units to reduce their minimum output. They point out though, that ancillary service markets cannot be well implemented, if dispatch agencies don't have incentives to support this, as more trading items of ancillary services increase their workload and reduce opportunities for rent-seeking activities. [20] Also CREO 2018 argues, that instead of developing ancillary service compensation mechanisms China should develop ancillary services markets. Ancillary service markets are said to be fundamental in distributing various grid services from a centralized system based on thermal power to new market participants. As of 2017, government established ancillary service market pilots have been running in the Three Norths region and southern China. According to CREO 2018 the results have been positive, but more work is needed to ensure the ancillary service markets have transparent and persistent rules that allow cost-effective investments and wide participation. [29]

As discussed in the chapter 3, also building demand response capacity could improve the power system flexibility. CREO 2018 asserts that the successful implementation of DR depends on the full implementation of ongoing power market reforms in China and setting up wholesale and retail markets for electricity, also in the form of spot markets. It's argued, that unbundling grid operation and retail sales could help to avoid conflicts of interests that currently stand in the way of transmitting wholesale price signals to retail users. The open sharing of information is especially important as DR is a complex system and the stakeholders, like grid companies, industrial customers and aggregators need to understand the DR framework and how they can take part in it and profit from it. [29]

3.5 The effect of subsidies and green certificates on renewable energy integration.

Energy subsidies are a way to incentivize desired forms of energy production and to keep the prices of certain energy sources competitive with the market levels. This can be achieved in direct or indirect ways, such as guaranteed tariffs or taxation of other energy sources. Green certificates on the other hand are tradable commodities that prove that certain amount of electricity has been produced into the grid with renewable energy sources. The idea is that by purchasing a green certificate an energy consumer can claim that a certain amount of energy consumed by the certificate owner was from renewable sources. Both renewable energy subsidies and green certificates are used in China, but their effects on the power system are quite different.

A 2017 study by Nicolini and Tavoni on subsidy policies of the five largest European countries found out that subsidies positively affected installed capacity and that feed-in tariffs are more effective than tradable green certificates [23]. However, as pointed out in chapter 2, a high amount of installed capacity does not necessarily lead to an equally high output of energy into the grid. Also, China has problems in paying subsidies to renewable energy producers, as the funds for subsidies are collected as taxes from power plants, but many of those refuse to pay the tax. This has led to a great deficit on subsidy funds. As there are no specific penalties for not paying the tax in the Renewable Energy Law, Liu estimated in 2018, that the subsidy gap for renewable energy could possibly break through 200 billion Yuan in 2020 [25].

Zhu and Liao studied the effects of China's government subsidies from 2010 to 2016 on the profitability of new energy companies. The conclusions were that the subsidies actually had a negative impact on the profitability of the companies. Rent-seeking activities were identified as one major cause of this effect. These activities show as investments in nonproductive activities and exploitation of the subsidies in a way that has adverse effects on the profitability of companies. Overcapacity was identified as another factor that damages the performance of new companies as local governments can easily induce over-investment in order to stimulate local growth. Lastly, information asymmetries between the government and the companies were pointed out, as without punishment mechanisms large number of subsidy frauds may be committed. In order to constrain these practices, Zhu and Liao call for screening mechanisms to increase the companies' cost of sending false signals. They also call for different subsidy mechanisms to prevent over-investing and to ensure that subsidies are targeted and accurate. Lastly, they suggest that supply-side side subsidy policies should be combined with demand side subsidy policies in order to expand new energy markets and to improve the competitiveness of new energy products and companies [24].

Some of these propositions are already being put into practice: according to CREO 2018, China aims to shift from fixed feed-in tariffs to more flexible, market oriented, approaches. One method is to set renewable energy obligations for each province, based on current renewable energy development, potential, and local electricity demand. Also auctions for onshore wind and solar PV are proposed. For technologies that haven't yet reached similar scale, relatively fixed tariffs are proposed in order promote the development of such resources as biomass and ocean energy. In order to phase out subsidies entirely, a host of market measures are named. Many of them are part of the ongoing market reform, such as cross-provincial trading and spot market participation. Also reforming tax structures, like carbon and land taxes, to reflect the external costs of energy sources is proposed. [29]

National Energy Administration of China (NEA) is also shifting the focus from capacity-based targets to improving planning and integration of renewable energy. As there has been heavy wind and solar PV curtailment in the Northwestern provinces, NEA has issued investment alerts for both wind and solar in these areas, in order to prevent further construction of over-capacity. In the areas that are marked red on the left side of the Figure 6, unapproved wind power projects should be suspended, and construction of approved projects deferred. In the orange areas no wind construction quotas were given in 2018, except for special projects. On the right side that is the solar PV side, in the red areas only units connected to UHV lines receive subsidy quotas and in the yellow areas, subsidy quotas are reduced by 50%. With these measures China aims to shift the focus of renewable energy construction to distributed generation in low-curtailment provinces. [29]

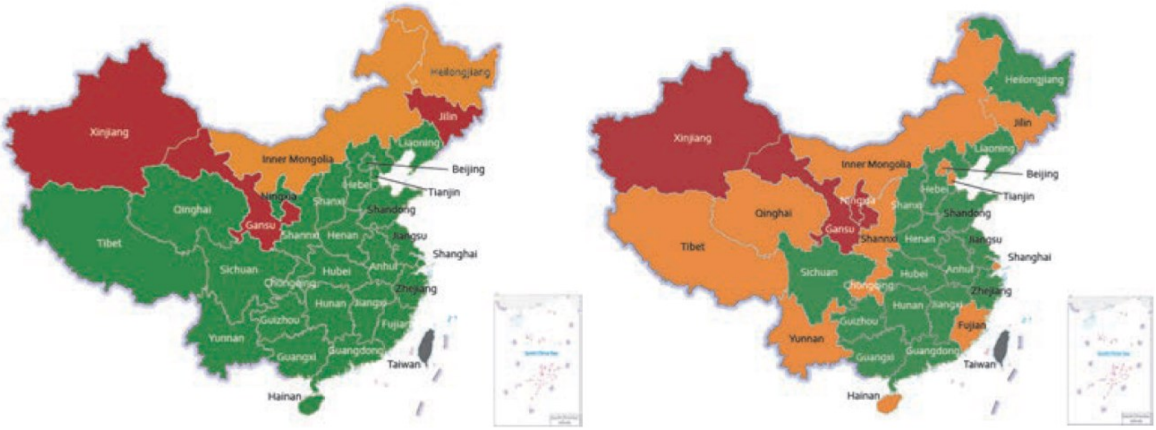

Figure 6. *(left) Investment alarms for wind power in 2018. In the red areas unapproved wind power projects should be suspended, and construction of approved projects deferred. In the orange areas no wind construction quotas were given in 2018, except for special projects; (right) Market environment assessment results for solar power in 2017. In the red areas, only units connected to UHV lines receive subsidy quotas and in the yellow areas, subsidy quotas are reduced by 50 %. [29]*

In China, the green certificate is an electronic certificate that the government can issue to grid connected non-hydropower renewable energy producers. Each certificate equals 1 MWh of electricity produced and the price of the certificate is negotiated between the buyer and the producer. The price should not be lower than the subsidy level for the same amount of power output. [16] In 2018, the Renewable Energy Engineering Institute launched a market for voluntary green certificates. The object behind this was to reduce subsidy payments, raise public awareness of sustainable development and to develop experience for running a certificate market [29]. According to Zhang et al. the green certificate system could also allow wind and solar PV producers to receive revenue in more timely fashion, as government subsidy payments have been experiencing substantial delays [14]. The policy did not achieve its goals, as only 0,13% of wind certificates and only 0,008% of solar PV certificates were sold in a timespan of nearly a year [29]. Zhang et al. argue that the effective implementation of the green certificate system could be difficult, as it's inherently a market-based system and the electricity market is not yet properly developed [16].

4. RENEWABLE ENERGY LEGISLATION

In the 2010's China has become the global leader in both investments in renewable energy and in renewable energy produced. China's renewable energy laws and policies have been in an essential role in this transition and they have helped to speed up the deployment of renewable energy. Nonetheless, As Liu points out, there are still limitations in the current framework of renewable energy law and policy in China, that hinder the further development of renewable energy. The current framework has been a driving force in starting renewable energy projects. Still, the laws and policies in China aren't yet adequate to integrate renewable energy into the existing national energy system. [25]

4.1 Scattered legislation and conflicts of interest between the central government and the provincial governments

The backbone of Chinese renewable energy legislation is the Renewable Energy Law (REL) issued in 2005 and revised in 2009. It's the only law in China that specifically regulates renewable energy. It for example states that all renewable power generated must be purchased by the power grids. This is clearly not the case in practice, which serves as an example of the major weakness of the REL: it stipulates many important principles, but it lacks practical measures to implement these principles and to sanction entities that don't abide by these principles. Due to the rather vague legislation concerning the development and utilization of renewable energy, many specific operations rely on policy documents. This causes confusion between law and policy and makes the system complex. Also adding to the complexity, many renewable energy related issues are also regulated by laws and policies under completely different administrative branches. These can be central level, local level, general, and specialized laws. This means that the regulations of a given issue can be scattered in various rules. To exemplify this, generally renewable energies would be under the management of NEA, but for example geothermal energy is actually governed by the Ministry of Land and Resources. [25] This kind of institutional separation can become an obstacle for renewable energy projects, as approval needs to be gained from multiple government agencies. Sometimes this can also lead to conflicting regulations between agencies.

Liu argues that the biggest obstacle for China's energy industry reform are industry monopolies and regional market monopolies. As traditional energy-related industries are important taxpayers provincially, the provincial governments may protect them with provincial policies and legislation. This can make it hard for renewable energy to break through. This also affects inter-provincial trade, as is evident in the eastern and southern China, where governments are reluctant to accept the electricity transmitted from northern regions with abundant renewable energy, even though new UHV transmission lines have been built between the regions. [25] According to Lin and Purra, the standard best-practice model for electricity markets would be one where electricity transmission is separated from generation and funded by transmission fees. Before the T&D tariff reform, China however deviated from this by having a wholesale price on electricity, that included both generation and transmission. It's argued that this pricing decision has shaped sectoral interests and posed difficulties for marketization and regulation, as the only cost-effective means for transmission companies to grow has been trading generated electricity. [26] Since the T&D tariff reform has taken place, government regulators set the transmission prices and T&D is unbundled from wholesale and retail of electricity [29]. According to Lin and Purra, one problem still persisting is the lack of clear distinction between transmission and distribution networks. In Organization for Economic Cooperation and Development (OECD) countries the small-scale generators are allowed to sell electricity over local distribution networks and the distribution fees are set by the local regulators. In China, no explicit distribution charges exist, only a regulated retail tariff to final consumers that is controlled by the NDRC. Lin and Purra argue that the ambiguous distinction of authority of control over transmission and distribution networks diffuses the regulatory boundaries between the national, provincial and regional levels and hinders the creation of competitive generation market and retail competition. [26]

4.2 The role of the central government in renewable energy integration

Liu states that to eliminate the monopoly in the energy market, China should differentiate the functions of the government and the market and strengthen the basic role of the latter. Liu also argues that market-driven mechanisms are essential for renewable energy development and that an open and competitive modern market system needs to be established in order to optimize the allocation of resources. [25] Lin and Purra however point out that although the Chinese central government has relinquished its vertical command and control, it hasn't yet taken on new responsibilities in regulating and supervising horizontal, contractual relationships. Lin and Purra argue that as China's transitional electricity sector is under growing pressure to support the country's fast expanding economy, inflexible, inefficient and even collusive institutional structures hinder the planned power sector reforms. [26] Also Zhang et al. call for more stronger top-level design and supervision from the central government in order to develop government regulation of market actors and to enforce coordination over the reforms led by local governments. Presently local governments tend to view electricity market reform as a way to cut electricity retail tariffs and boost the local economy, while the central government's objective is to optimize resource deployment and enhance renewable energy development. According to Zhang et al., the central government should require local governments to implement the reform in alignment with the principles set by the central government. If local governments develop their own reform strategies, the national market will become fragmented. [16] Also Liu states, that the China's State Council should formulate specific implementation rules for renewable energy legislation. Provincial governments should improve supervision and management systems and impose local laws and regulations that take into account both the regional status of renewable energy and the central government objectives. According to Liu the legal responsibilities for power grid operators and other energy industry enterprises should be clearly stipulated and there should be measures to punish those failing to meet these responsibilities. This would increase the practicability of the REL and reduce loopholes in its implementation. [25] This could also reduce the subsidy deficit caused by power generating units not paying taxes and could limit the practice of exploiting subsidies with so called "face" projects that are quickly constructed and then demolished, with no intention of producing energy.

Liu suggests China to improve its renewable energy legal system as the REL currently regulating renewable energy doesn't meet practical needs. Instead, current scattered laws should be formulated into a basic law for all energy related issues, the Energy Law. This law should be used as a base for systematically integrating or cleaning up the various administrative rules, departmental regulations and local regulations. The legislation should also be constantly upgraded and policies that have been proven in practice should be gradually established as laws or regulations to enhance their authority and binding force. [25]

5. CONCLUSIONS AND POLICY PROPOSALS

China has made significant efforts in order to deploy considerable amounts of renewable energy capacity and reform its energy sector and the legislation concerning energy production. Due to these efforts, China has become the global leader in renewable energy, both in investments and in capacity installed. As technological and economic developments are highly interdependent, the further integration of renewable energy requires investments both into the power system infrastructure and into creating mechanisms and platforms for open electricity markets. In the heart of the energy transition is the central government and its ability to enforce its policies down to the local governments. Currently the legislation concerning renewable energy is scattered and lacks practicability. The legislation needs to assign concrete responsibilities to local governments and energy industry enterprises, and it needs screening mechanisms to spot exploitations and rent-seeking.

The unbundling of transmission and distribution and electricity trading is a good step towards separate T&D companies, power generators and energy retailers. Similarly, it would be important to unbundle ancillary services from the electricity tariffs and create separate markets for ancillary services and demand response. This, together with open generation planning, would help to incentivize investments into flexible T&D networks and electricity markets. The ongoing pilot projects in select provinces should be scaled to regional and national level, in order to have real impact on the power system. As power system flexibility increases and market platforms develop, also spot markets should be established, in order to adapt to the varying output of renewable energy. This is essential for the optimal utilization of resources. Inter-provincial and inter-regional electricity trading is becoming physically possible thanks to investments in UHV transmission capacity, but some of the local governments still protect their own energy production and are reluctant towards importing electricity. To solve the provincial differences, central government needs to make sure that the local legislation and regulations follow the national objectives of renewable energy integration.

In order to ensure the sustainability of the renewable energy industry, the government needs to gradually phase out the feed-in tariffs as subsidies contribute to over-investment and low profitability of new energy companies. Measures against over-investment have been taken in provinces with a high curtailment rates, which is a good opportunity to shift focus to promoting distributed generation and the improvement of distribution networks in other provinces.

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