Energy Regions in Transition

Report on the European energy expert tour to China (January 2018)

Renewables Grid Initiative

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1 Introduction

'Energy Regions in Transition' (ERIT) is a wide-reaching and systematic regular exchange of energy-related best practices and experiences between different regions of the world. Up until this point, activities have focussed on Europe and the United States of America learning from each other. However, the Renewables Grid Initiative's (RGI) recent trip to China in January of 2018 represents a new chapter, in terms of expanding the ERIT exchange to Asia. Since we strongly believe that this mutual exchange is a fundamental contribution to improving the reliability of the electricity system, to reduce costs and limit environmental impacts, RGI has put a lot of effort into making this exchange a regular and sustainable one.

The below report breaks down the most important points of what was discussed during the trip to China. It summarises the meetings in chronological order focussing on the input from the speakers on the Chinese side. For reasons of readability the report is mostly written in present tense and in an indicative mode. However, the information and opinions given are solely based on the presentations given by the respective speakers and do not necessarily represent RGI's opinions. If numbers differ from section to section this is due to different values stated by different presenters.

2 Day one: introductory sessions and global perspective

2.1 Introduction to Chinese politics

The tour began with a visit to the ABB China office. Zhang Jinquan, head of ABB China's power grids division, welcomed the group and Mats Harborn, the President of the European Chamber of Commerce in China, shared his personal views on Chinese politics. Mr. Harborn started his speech by explaining some key terms:

Socialism within China	Socialism is nowadays mostly used to legitimise the power position of the communist party. It is argued that to get to communism, one has to go through a capitalist phase which includes looking at interests of the middle class.
Rejuvenation of China	China is striving to recover its appropriate position, which is in line with close to 20 per cent of the world population being Chinese. Clearly, this is very successful as China now contributes 15 per cent of the global GDP, has the largest home market, and the highest and most stringent needs on technological development.
Xiaokang	A term which describes the Chinese idea of becoming a moderately prosperous society with a functional middle-class.
A beautiful China	Five years ago, president Xi Jinping started to introduce the idea of making China more liveable again as a reaction to the recent development of blind growth at any price,

	resulting in a deteriorated environment and highly unpleasant cities.
Anti-corruption	China has seen 5 years of a determined anti-corruption campaign.
The new normal	A paradigm shift introduced by President Xi in 2014 that sees China moving away from a planned economy, towards a structure in which the market plays a more decisive role in resource allocation (which involves a focus on quality over quantity, and more inclusive growth).
A new world order	There is a clear understanding that China should have a say in shaping the new world order. While a few years ago, this still sounded as if the world had to be Chinese, this has now softened, and China describes itself as part of new world order.
One Belt One Road Initiative	A 900 billion US dollar 'Chinese Marshall Plan', aiming to connect China with the Middle and East Asia, Africa and Central Europe to which China intends to contribute 150 billion. The 'global grid initiative for communication, telecommunication and energy distribution' is also part of this initiative.
Asia Infrastructure Investment Bank	While the establishment of this Bank is not directly related to the above, it reflects China's recognition of big infrastructure needs in Asia and the will to make its own financial contributions.
China Manufacturing 2025	China wants to improve its value chain. More research and development, distribution and brands are on its list of objectives in order to become a leading world manufacturer.
A vision for the common prosperity of mankind	China wants to become a global vision-leader, for example by supporting the Paris Agreement and therefore establishing itself as a specialist in the area of energy.

During the 2017, 90th party congress, the President positioned himself once more as the leading ideologist for the Republic of China. His thoughts on socialism with Chinese characteristics for a new era encompasses the following elements: ensuring prosperity; reducing inequality; promoting Chinese socialism; furthering reform; improving the rule of law; building a strong, world-class military that respects the Party's command and that can fight, win and maintain excellent conduct; fostering international relations, and placing the Party at the centre of Chinese socialism.

To the Western world these elements may appear rather scary and according to Mats Harborn, the United States now see China as the one main competitor with the Western system. However, to survive, China has to develop further, and it is by now evident that the development model which was followed until 2012 did not bring

benefits to society as a whole. China consequently needs a more coordinated and strategic approach with regard to its development. It needs to rebuild the country in a more coherent structure and control its military which until 2012 was corrupt and challenging the former president.

The question at hand from Mr. Harborn's perspective is therefore whether we view these ambitions as a threat or whether we should try to continue to influence China by further integration. His personal view favours the latter and he supports initiatives to support China on the development of standards and policies as this shapes to a large extent how society functions.

In this context, two fundamental principles have already been declared in 2013:

a) the market should play a decisive role in resource allocation

b) development should be people-centred

This implies that the enforcement of rule of law is key to secure that all market participants can compete on a level playing field and that the role of government is being redefined.

From the perspective of Mr. Harborn, the Western world needs to accept the new world order in which China is a permanent player. At the same time, China's debt level has now exceeded 300 per cent of its gross domestic product (GDP), and international rating institutes downrated China for the first time in 40 years, which means that the government now has to choose where to put money.

2.2 Introduction to China's energy power strategy

ChengYan Yue, Vice President in charge of the smart grid at ABB China, briefed all the participants on the topic of renewable power and smart grid developments in China. She explained that the Chinese energy transformation can be described with four target words: clean, low carbon, secure, efficient.

Two main factors are driving the current transformation:

a) on the generation side, the replacement of traditional fossils by renewables (RES)

b) on the consumption side, the replacement of coal and oil by electricity

In 2016, the total installed power capacity for China was 1,645 gigawatt (GW), of which coal is responsible for 64 per cent, hydro for 20 per cent, wind for 9 per cent, solar for 5 per cent and nuclear for 2 per cent. By the end of 2016, 148 additional GW of wind and 77 additional GW of solar had been installed.

Recent estimates for 2020 suggest that installed power capacity will grow to 2,000GW, of which coal is responsible for 61 per cent, hydro for 19 per cent, wind for 11 per cent, solar for 6 per cent, and nuclear for 3 per cent. The target for 2020/2030 is to add another 220-250GW/450GW of wind and about 110GW/350GW for solar. These are ambitious targets requiring fast growth.

By 2020, the share of electricity in primary energy consumption shall reach 27 per cent from currently 25.5 per cent. This 1.5 per cent increase translates into ±450 terawatt hours (TWh). These shall come from:

a) Heating: so far 20 per cent of coal firing is in distributed coal firing for heating, the objective is to significantly reduce this figure

b) Electric vehicle (EV) charging: the 2020 target is to have 12,000 charging stations, constructing 4.5 million charging poles on the road to meet demand of 5 million EVs. The status in April 2017 is 171,000 public charging poles.

c) Shore to ship: Supply the power needs of ships with shore-based electricity. In 2017, an according policy and pilot project were set up, with the ambition to provide electricity for 493 berths by 2020, this would mean a 50% coverage.

For grid infrastructure, these ambitions mean that a meshed grid is required to support the future electricity system. Approximately 3,000 kilometres (km) of bridging grid infrastructure will need to be built, in order to bring electricity from the main RES production areas in Northern China to consumption centres in Central and Southern China. Large-scale concentrated wind and solar farms have been set up during the past years. As a result, congestion of long distance transmission lines has become an issue, requiring remediation measures.

A diverse list of measures has been developed to tackle this challenge, including:

- the construction of new power lines, including ultra-high voltage (UHV) lines, high voltage direct current (HVDC) grids, hybrid HVDC grids, ultra-high voltage alternating current (UHVAC) lines, flexible alternating current transmission systems (FACTS) and multi-channel solutions
- the development of distributed RES and networks
- the development of integrated energy systems at both the micro-grid and regional level
- increasing usage of storage systems
- grid digitalisation

- demand side management and the deregulation of power markets

The latest round of power market reforms started in March 2015 reset the rules so that in addition to existing grid organisations, additional companies may register on retail market and distribution level. As a result, by July 2017, roughly 5,000 additional/new (retail and distribution) companies had registered.

A large number of pilot projects have been set up to test for the subsequent roll out of differing elements of the above, including:

- 195 pilot projects dealing with an incremental distribution network
- 23 energy pilots which combine power, cooling, heating and gas
- 55 pilots on the energy internet: how to be smart and make it more efficient
- 28 microgrid demonstration projects

Integrated energy systems consisting of distributed energy resources and multiple loads of electricity, cooling and heating are being tested. They have a local control system ensuring real-time balance between generation and demand and are operating as a single autonomous grid, either grid connected or off-grid. There are two types of these:

- microgrid solutions (e.g. for industry parks, running at up to 35 kilovolt (kV), with 20MW and below)
- regional grids (e.g. in developing zones for up to 220kV and tens of MW).

In 2016, storage capacities in China were 24GW for pumped hydro and 23MW for chemical energy. They are applied to support distributed energy generation and integration (including RES integration) and to provide ancillary services.

The 2020 forecast estimated a total accumulated installed energy storage capacity of 44GW, with pumped storage accounting for 40GW, 2GW for chemical energy storage and 1.8GW for molten salt heat storage.

2.3 Frontier technologies and market trends in China

Liu Quianjin, Chief Technical Officer at ABB China, explained how much China has achieved with regards to technological innovation in the last years. The country scores high on a global innovation ranking, in part due to developments such as its high-speed rail network (which is still expanding) and bicycle sharing initiatives as a means to replace cars on the road. Additionally, China contributed to/or lead the development of self-driving trucks and facial recognition payment systems (2017 Massachusetts Institute of Technology Breakthrough Technologies list[1]), among others.

[1] See https://www.technologyreview.com/lists/technologies/2017/

With regards to grids, the integration of RES brings a set of new challenges. In 2017, 10 per cent of wind was curtailed. This is due to the fact that over 80 per cent of wind and solar resources are in the Northern regions of the country, while two thirds of the load is located in Central and Eastern regions (thereby the integration of renewable electricity takes place anywhere from 800 to 3000km away from the load centres). Voltage and frequency stability and sub-synchronous oscillations are amongst the challenges that have to be dealt with. As of today, grid codes have to be refreshed every three to five years because of the speed of the RES integration and incidents (for example, a high-speed train passing by a windfarm causing its disconnection from the grid and leading to a necessity to re-design both converter and connections to prevent this in the future). New grid codes now require that generation can behave as conventional power plants.

Recent innovations in voltage sourced converter (VSC) HVDCs allow for increased power, lower losses and higher flexibility to support alternating current (AC) grids. Generally, two broad trends can be observed. One is the development of new technology for a higher voltage level (such as the 1,200kV AC circuit breaker). The expectation here is that the direct current (DC) grid is not far away and is needed as a complementation to the existing AC network. However, a DC circuit breaker to get over point-to-point connections only is still missing.

2.4 Northeast Asia Supergrid Initiative

Our first day ended with a visit to the Global Energy Interconnection Development and Cooperation Organization (GEIDCO) offices. Founded in March 2016 upon the initiative of the State Grid Corporation of China (SGCC), GEIDCO's goal is to 'promote the establishment of a GEI system, to meet the global demand for electricity in a clean and green way, to implement the United Nations "Sustainable Energy for All" and climate change initiatives, and to serve the sustainable development of humanity'[2]. GEIDCO has its permanent office in Beijing with

[2] Source: https://www.renewable-ei.org/en/asg/about/

representatives around the world and as of January 2018, 365 members in 15 countries.

According to studies, 85 per cent of clean energy resources are concentrated in an 'energy belt' which stretches from Africa via West Asia to Central Russia whereas load centres are mainly located in East and South Asia, Europe and the USA. China itself is a showcase for the need of large-distance high voltage interconnection and has developed UHV grids to bridge both West to East and North to South. For future development, GEIDCO envisages three stages. Until 2025, the focus will be on Chinese domestic interconnection. From 2025 to 2035, the focus will shift to intracontinental connection and from 2035 to 2050, the intention is to create the 'real' GEI (meaning intercontinental interconnections). So far, an MoU (Memorandum of Understanding) was signed within the Northeast Asia Supergrid Initiative with the intention is to connect China, Korea, Japan, Russia and Mongolia. In May 2016, a technical working group initiated a pre-feasibility study for 2GW of transport capacity via a 500kV LCC or VSC connection, connecting China and Korea (366km) and Korea with Japan (460km or 770km depending on the landing point). The pre-feasibility study concluded that the project is technically feasible and the idea shall therefore be pursued further.

The RGI delegation agreed that the idea of the Global Energy Interconnection is very interesting. However, European experts also pointed out some potential challenges related to governance, environmental and social consequences of such a new system. They also pointed out that building grids in Europe is strongly driven by the existence of a power market which gives signals on where investment in an interconnector is reasonable. GEIDCO responded explaining that their approach is a different one, starting with a long-term vision and an overarching design to develop a plan for implementation. GEIDCO also stated that in this approach grids are developed first and opening the market happens second. GEIDCO also underlined their devotion to promote this vision for the sake of common prosperity and to prevent global warming.

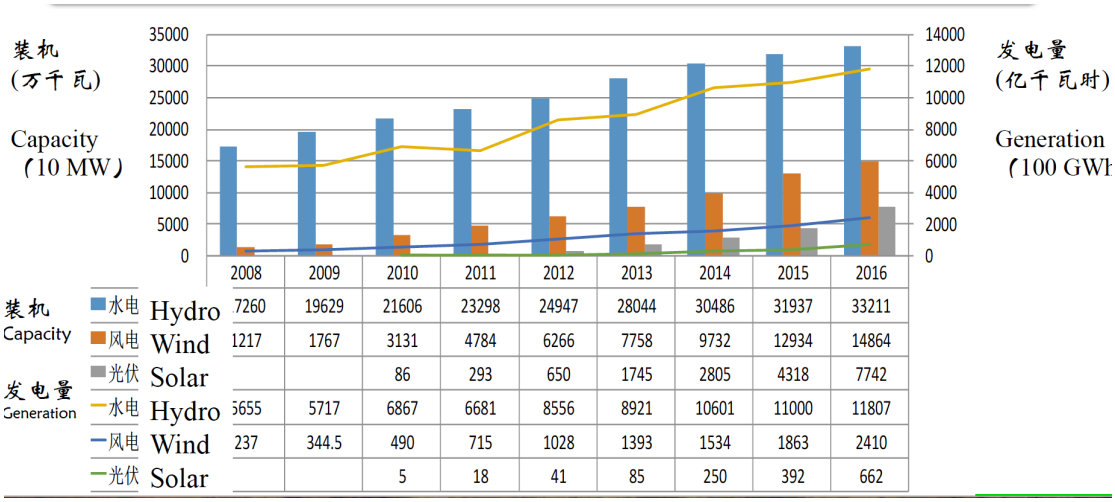
3 Day two: renewable energy integration and generation

3.1 Renewable energy in China: vision, integration challenges and implications for the market and grid development

Zhao Yongqiang from the Energy Research Institute of the National Development and Reform Commission (NDRC) started the briefing on the vision and challenges surrounding RES by saying that they have grown substantially in China over the last

15 years thanks to government support. In 2007, mid and long-term plans for RES development were issued; and in 2015 a 'State Council Guidance on Power Reform' and further rules for RES development were published. As of today, RES benefit from subsidies and a feed-in-tariff, and their integration is compulsory.

Installed capacities for hydro, wind and photovoltaic (PV) in China are (as of today) the highest of any country and in 2017, the share of renewable electricity generation amounted to 26,5 per cent. In 2016, 14 per cent of primary energy consumption came from non-fossil energy, 5 per cent above the corresponding 2010 value.



		2008	2009	2010	2011	2012	2013	2014	2015	2016
装机 Capacity	水电 Hydro	7260	19629	21606	23298	24947	28044	30486	31937	33211
	风电 Wind	1217	1767	3131	4784	6266	7758	9732	12934	14864
	光伏 Solar			86	293	650	1745	2805	4318	7742
发电量 Generation	水电 Hydro	5655	5717	6867	6681	8556	8921	10601	11000	11807
	风电 Wind	237	344.5	490	715	1028	1393	1534	1863	2410
	光伏 Solar			5	18	41	85	250	392	662

Figure 1: Development of hydro, wind and solar capacity and generation between 2008 and 2016; Source: NDRC

By the end of 2017, installed wind capacity reached 163GW, producing 306TWh of electricity (>5 per cent of primary energy consumption) and installed PV reached 130GW, contributing 118,2TWh or close to 2 per cent. In comparison to 2011, wind increased by 115GW installed capacity, solar by 110GW.

By the end of 2016, the government released its strategy for the future energy revolution. It encompasses that by 2030 carbon dioxide (CO2) emissions shall peak. The non-fossil energy objective for 2030 is 20 per cent, with RES contributing 50 per cent to power generation (the target for 2050 is approximately 80 per cent).

The key drivers of this energy transformation are:

a) the source efficiency of end-use energy sector

b) electrification as a means to increase energy efficiency and reduce fossil fuels

c) promotion of RES through innovation incentives and scale development

d) carbon trading to trigger a broader development of RES

e) usage of the electricity market as a major tool to implement a cost-effective energy transformation

Both PV and wind will primarily be developed in the North of China, while the main consumption takes place in the East and South. As a consequence, power

transmission will be of fundamental importance. It will therefore be particularly important to connect Inner Mongolia also because of its storage potential via pumped hydro storage.

Over the last five to six years, power curtailment especially of wind, PV and hydro has been quite pronounced in China, to a point that it arouses international attention. One of the ambitions is therefore to shift RES development from the North to South to benefit from an increase in complementarity, and additionally to support the development of a distributed PV system (which has already spread quickly from industrial scale to roof top solutions in residential and commercial areas).

PV shall be the new major player, combined with batteries. Projections also forecast that there will be approximately 80 million electric vehicles in China in about 30 years. Additionally, a significant amount of coal fired power plants shall be converted into flexible resources. Planning and operation of the power system therefore need to be transformed fundamentally, so that planning of generation, consumption and transport all prioritise flexibility.

In this context, China is currently following the so-called 'Document No. 9' to allow for independent pricing, and to support mid and long-term construction of the power-market. The 'Document No.9' is intended to be a guiding document which will result in a relatively independent trading system. There is a necessity to establish a retail market which allows different players to participate on a level playing field. Establishing this market is the responsibility of both the central and provincial governments who are crucial players in the energy system. The two however have differing understandings of the implementation of the document showcasing the necessity for a closer collaboration in the future.

A preliminary roadmap foresees that several power spot markets shall be established at a cross-provincial level, with a national market established by 2030 and the subsequent phase out of a significant number of fossil power plants. Given this, incentives and policies need to be reviewed and reformed. The process of understanding markets as they have been set up in the US and in Europe is ongoing, as is therefore the decision on what is the best approach to take for China.

3.2 Promoting the development of high RES penetration

The next session was a presentation by State Grid Corporation of China (SGCC), China's grid operator, on promoting renewables based electricity in China. SGCC is responsible for the largest scale of RES integration worldwide. China has seen a significant growth of renewables capacity in the last seven years. In 2017, installed wind capacity was up by 10 per cent in comparison to the previous year and PV saw an increase of 70 per cent. In 19 of China's provinces, renewables are now the second largest electricity source and in ten provinces RES account for more than 20 per cent of installed energy.

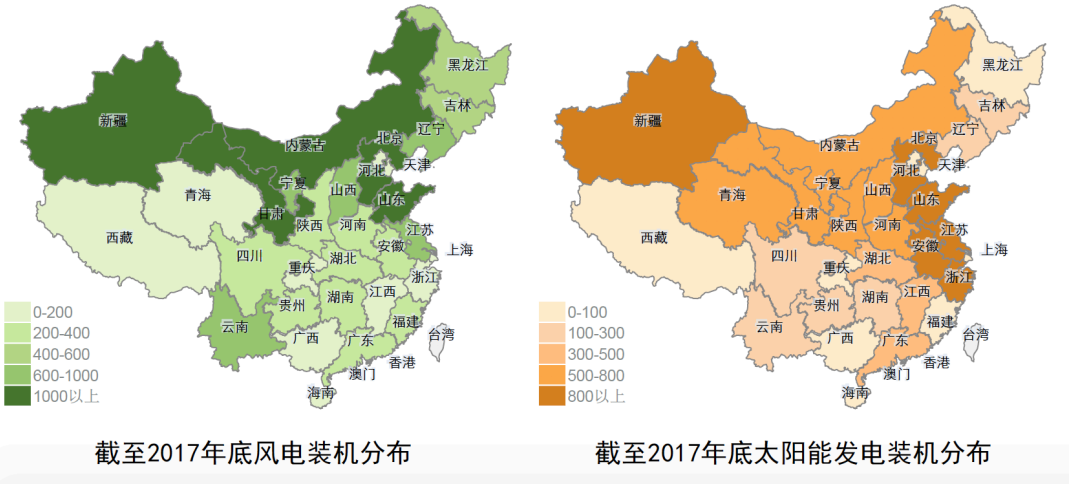


Figure 2: Wind power distribution at the end of 2017 in million kilowatts (left), solar distribution at the end of 2017, also in million kilowatts (right); Source SGCC

In 2017, both wind and solar saw a significant increase in generation capacity, with wind growing by approximately 25 per cent and solar by approximately 75 per cent. Both contributed to power generation in 2017 at 4.8 per cent and 1.8 per cent respectively.

From 17 to 23 June in 2017, the SGCC initiated a full-scale clean energy supply test for seven consecutive days in Qinghai Province. In these seven days, Qinghai Province used 1.18 billion kilowatt hours of electricity, of which hydropower accounted for 72 per cent and new energy accounted for 28 per cent.

Encouragingly however, curtailment of wind and PV was not significant in 2017 and the government is now focusing on a transfer of installed capacity from Central to East China. As of 2017, 80 per cent of the new installed capacity was located in the South of China, with distributed PV experiencing an exponential growth with the new integration of 740.000 households.

Despite such successes, China faces a variety of challenges:

a) The lack of flexibility of thermal capacity. Thermal power provides for 60 per cent of the electricity in North China and is especially in winter a major player. This capacity is not suitable to contribute to peak shifting.

b) It remains difficult to shift power at large scale because there is not enough transport capacity across regions and provinces.

c) The economic growth in China has stabilised compared to previous years (with the annual GDP growth rate hovering between six and eight per cent for approximately the last five years). Consequently, the growth of power demand is slowing down. This has negative impacts on the distribution and reception of RES.

d) Energy market mechanisms are not comprehensively established yet and therefore the market is not the predominant player across China. Some regions still work with very rigid power consumption plans. This often results

in the underusage of transport capacities and administrative barriers across provinces in the integration of RES.

SGCC proposes solutions to these challenges (and works closely with the government on these challenges), including to promote more links between transmission, distribution and consumption, as well as market solutions and the according policy support.

A number of measures have been taken to help the promotion of RES:

a) Specific analyses have been run, targeting technology and market mechanisms (with eleven specific case studies carried out to contribute to this). Furthermore, workshops and seminars have been organised to involve experts, academia and others. Learning from international counterparts is an important element of this and a delegation has been sent to Germany to learn from best practices in the international community.

b) Control over newly installed power is an increasing priority. China is working with a 'street-light' system, which indicates priority areas in order to better manage the integration of RES.

c) Grid transmission capacity improvements are of high importance, with substantial amounts being invested in R&D (research and development), and the development of new transmission capacity.

d) To increase the flexibility of generation, a cooperation with the government is ongoing about retrofitting thermal power facilities. This includes an evaluation of the minimum operating hours which are necessary for the thermal capacities.

e) There is a continuous optimisation of the way the grid is being operated, trying to decrease power generation which happens outside the market. This included the introduction of new mechanisms on how to share regional grids.

f) RES power is increasingly being traded via the market. SGCC also encourages cross-provincial spot market trading.

Thanks to all these efforts a lot of positive results have been achieved. However, challenges remain. Given the large number of new energy developments, it will be difficult to keep track/control and thereby ensure these developments remain aligned with the overall strategy. SGCC is also aware that the targets for refurbishment of thermal capacity are challenging and the plan to have a nationally integrated market within the next five years is very ambitious.

3.3 Enhancing thermal power flexibility in China: drivers and experiences

This agenda point was filled by EPPEI (Electric Power Planning & Engineering Institute), who shared their thoughts on how fast development of RES in China (31 per cent annual growth rate for wind, 158 per cent for solar between 2010 and 2016, see figure 3 below) has led to challenges with respect to system integration. In this context, the lack of flexibility in the power system has become one of the main causes for curtailment of RES in China.

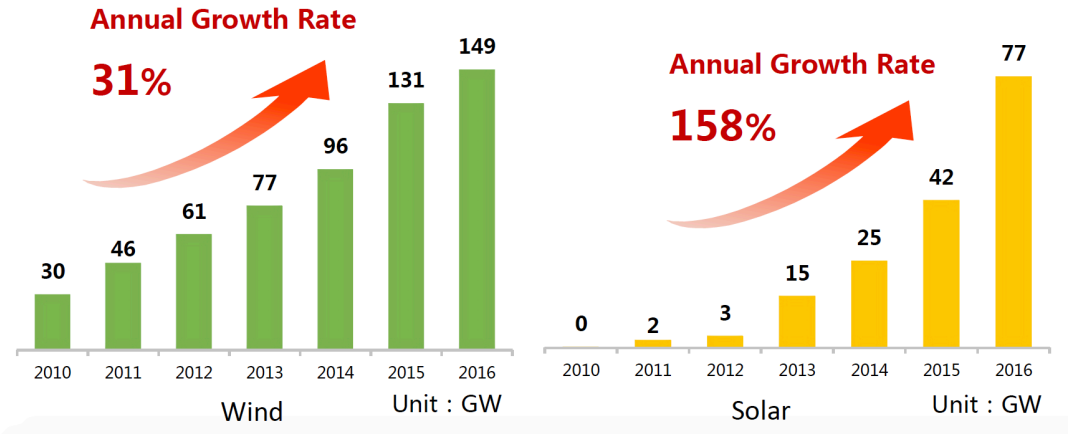


Figure 3: Annual growth rate of wind and solar in China between 2010 and 2016; Source: EPPEI

The reduction of thermal power generation is currently not an option, therefore the main ambition is to tap into flexibility potentials with regard to generation, grid and demand aspects to tackle integration problems of RES.

On the generation side, while new gas turbines and new pumped hydro are being considered, the main focus is on retrofitting thermal power plants to increase their flexibility. The reason for this is that the retrofitting costs are comparatively low and the existing capacity is huge. Until 2020, thermal power will provide two thirds of all power generation in China's North. As part of a five year political plan, the scale of power generation that needs to be retrofitted to keep curtailment below five per cent while achieving RES targets was assessed. The assessment concluded that 133GW combined heat and power (CHP) and 86GW power-only plants need retrofitting. This represents more than 20 per cent of currently installed power plants.

Market mechanisms need to be developed to support this power market reform. Since 2016, pilot markets for down-regulating ancillary service markets have been established with the intention to incentivise power producers to retrofit their units. Within this scheme, units which surpass a certain threshold have to pay compensation to facilities which remain below the threshold. While in 2015, half of the payments still came from inflexible thermal units, in the first half of 2017 these accounted for only 30 per cent, reflecting the increasing number of thermal units being retrofitted.

An ongoing debate is whether such a market leads to a sustainable solution or whether it simply has the effect of money moving from one pocket to the other. As a

result, there are many promoters of spot markets providing real-time pricing signals to prompt the flexibility of the system. Currently, eight provinces have been selected for spot market pilots and EPPEI is leading a taskforce on the research of spot market rules and supporting systems.

3.4 The development of distributed energy in China

The presentation on the development of distributed energy was given by Mr. Jincheng Yang of Trinasolar. Trinasolar supports a market-oriented approach to integrate RES which allows for an active role of consumers. Their subsidiary company – Chinasolar – in 2017 generated a revenue of 35 billion Yuan, it employs over 15,000 people and is present in over 70 countries.

As prices for PV panels have decreased dramatically over the last years, organisations such as Chinasolar have evolved. Typically, they started with researching, producing and selling individual PV products. Over time, many of these organisations have begun designing, constructing and operating residential, commercial and utility scale PV power stations, and are becoming providers for integrated solutions such as smart micro-grid systems.

As mentioned above, RES power generation has developed extremely fast in China over the last years and there has been substantial government support since 2011. However, growth of distributed solar was initially very slow even though different subsidies were available. It only picked up in 2016. For the whole of 2017, positive estimates now calculate that 34GW of the new solar capacity was distributed, and distributed generation is now making up for the majority of solar development.

Integrating this capacity growth comes with some challenges, however. The current system is one of fixed prices and subsidies with the ambition to encourage market

players to generate power. For major established incumbants, this can become a huge burden if not regulated well, and it should be noted that the latest developments have not been positively received by all players. It is evident that for the future, the relationship between the grid and its users has to be re-organised. In China, both the grids and (most) generators are state-owned enterprises. With the integration of market-oriented trading, a whole new market, separate from the existing setting is being established to allow for more efficient responses to the customers.

Difficulties which need to be sorted include:

a) Cost constraints: Renewable energy power generation costs are generally higher than coal power generation costs. Subsidies for PV are however decreasing, and further decreases are predicted. The expectation is economic viability without subsidies.

b) Application bottleneck: There are intermittent, stochastic and low energy density bottlenecks in renewable energy mainly based on solar energy and wind energy.

c) Consumptive problem: The growth of consumptive ability is too slow in areas with substantial development of wind and solar power. Interprovincial trading remains difficult, while the installed capacity increased considerably, resulting in large scale curtailment.

d) Market barriers for the trading mechanism: the real-time market is still in the pilot stage. There is currently no mandatory renewable energy market security policy and no stable market demand.

Four suggestions have been made to further move towards marketised trading:

a) Establishing target driven and a mandatory market share system: This refers to solving problems from top level design, laying the policy foundation for the long-term development of renewable energy, for example by establishing a renewable energy quota index.

b) Establishing a national renewable energy green certificate trading mechanism to further improve the subsidy mechanism of renewable energy power.

c) Establishing a multi-channel industrial development mechanism that speeds up the development of distributed renewable energy (such as residential rooftop photovoltaics), effectively solving the problem of consumption.

d) Promoting smart energy solutions - maximise local consumption of distributed energy, through the combination of energy system technology with ICT (information and communication technology), and building an intelligent energy platform. Establish smart micro grids, smart energy consumption and other technical means and promote smart energy solutions to interact with the public energy grid.

The next step will be to make the whole system more economically viable. Further pilot cases will serve to test the commercial model and how it can work together with the existing model.

4 Day three: high penetration of RES and smart city development

4.1 Wind power market development in China

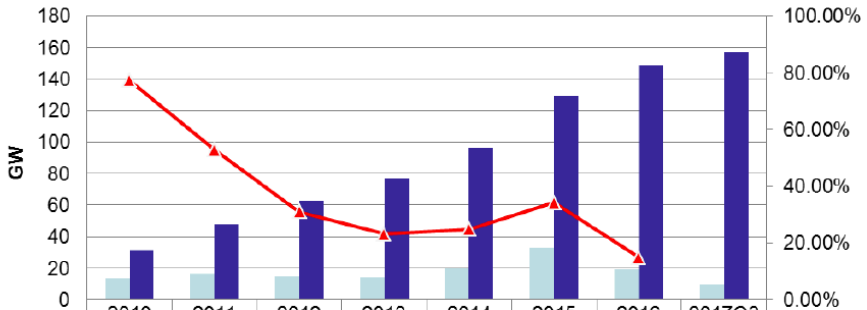
Yu Guiyong, Director of Industry Research at the Chinese Wind Energy Association (CWEA), explained that the association was founded 1991 to catch up with Western communities. He underlined that today, the wind sector has the strong support of the highest leaders of the Chinese government in the ambition to counter climate change and to deal with issues of environmental protection which are rooted in the current energy mix.

As of today, more than 70 per cent of the Chinese energy mix comes from coal, which leads to big problems with air pollution. Moreover, China is on the way to becoming a relatively developed country, which will lead to increased energy consumption. Therefore, there is a need for fast change. The new administration follows a vision of green development, but there are many challenges in translating this idea into practice.

First steps of green power development in China, similar to the EU, started in the mid 80s. After 2005, China issued a renewables law, which has led to faster and larger scale development. Today, a lot of equipment is produced in China.

China has deployed both onshore and offshore wind, both in the plains and near shore; in addition, there are intertidal windfarms. Product lines are becoming more and more diversified to adapt to the very wide range and sometimes very complicated geo conditions. There are also first projects in Northern China which convert wind energy into hydrogen to then provide fuel for the heating system, but distribution issues still need to be solved.

In 2017, the wind market added roughly a capacity of 18-20GW to the 149GW of 2016. It was at 157GW at the end of the third quarter of 2017:



Source: NEA

	2010	2011	2012	2013	2014	2015	2016	2017Q3
new installed grid-intergrated capacity	13.64	16.53	14.83	14.49	19.81	32.97	19.3	9.7
total installed grid-intergrated capacity	31.31	47.84	62.66	77.16	96.37	129.34	148.64	157.2
annual rate of growth	77.19%	52.79%	30.98%	23.14%	24.90%	34.21%	14.92%	

Figure 4: installed grid-integrated capacity of wind power in China; Source: CWEA

The share of wind capacity over total power capacity increases steadily and is currently at nine per cent. In 2016, from this 241,000 MWh of power were generated, or four per cent of total electricity. This means wind was the third largest power supplier:

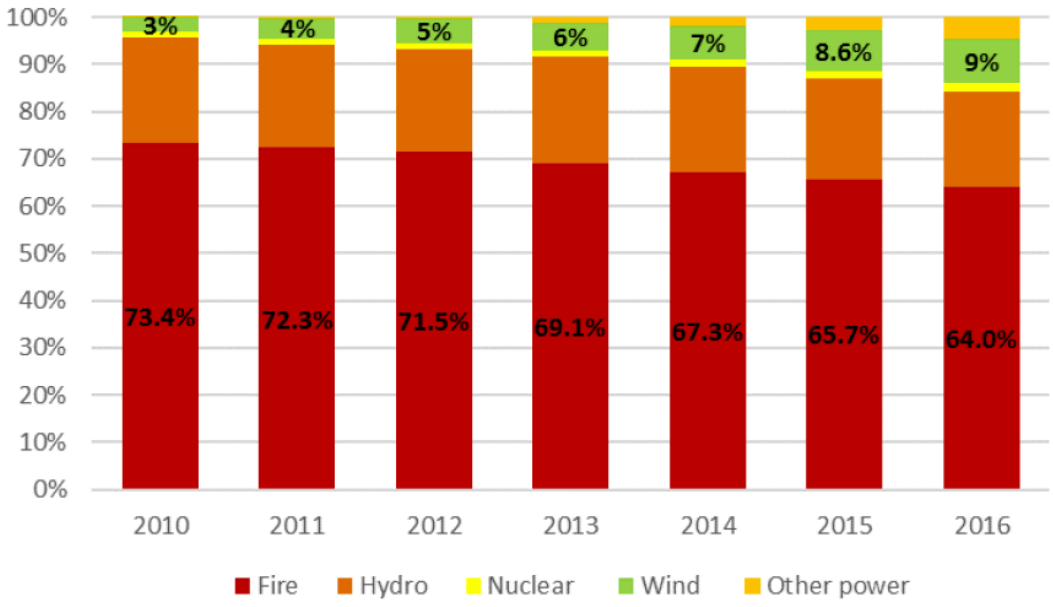


Figure 5: Chinese wind power market growth year by year; Source: CWEA

Offshore wind has developed very fast lately (plus 592MW from 2015 to 2016 which is an increase of 64 per cent; installed capacity at the end of 2016 was 1.627MW). While there is no big problem of integrating this generation, a complicated geographical situation needs to be dealt with. In 2017 wind power was exported to more than 30 countries, including Australia, South Africa and Pakistan.

Seven of the top 15 wind suppliers are Chinese companies. Technology improves very fast: for example, the power per unit, the length of turbine and the height of wheel are all increasing while the hub is expanding and efficiency has improved. Latest wind turbine models run at 6.7MW, the diameter of the turbine is 171 metres.

Due to different geo conditions, China has also developed wind turbines that can be used in very low temperature, are resistant to sand, and work with slow wind speed as there are many regions in China which do not have an abundance of wind.

While the Chinese wind market is the biggest in the world, it faces a range of unique problems:

a) **Wind curtailment:** emerged in 2010 and became a serious issue in 2016 when some companies faced curtailment of up to 50 per cent. Since then, a part of the problem could be tackled by changing the managing system. Curtailment is not a technical problem, but an issue of striking the right balance between a variety of different interests in the process of reforming the power system as a whole. In 2017, the Chinese president tackled this problem, which led to changes in utilisation hours. The newly introduced system implied that if wind curtailment exceeded 20 per cent and solar five

per cent, no new product can be set up in the respective region. As a consequence, new installed capacity has declined in the North, and new development has moved to the centre. 60 per cent of new capacity will be set up in the Central and Eastern parts of China.

b) **RES subsidies:** by 2020, the shortfall of subsidies will reach 300 billion Renminbi (39.7 billion Euro). Since this is a huge amount, changes to subsidy schemes are needed.

c) **Grid parity**: by 2020, China wants to reach grid parity for wind power since China is facing issues of high prices and European countries have shown that this can help to reduce them. A lot of thinking is going into establishing a market-based transaction system to replace a system of centralised and long-term generation and transmission planning, but uncertainty about how this could work remains high.

d) **Ultra-high networks**: a network of ultra-high voltage lines has been built, but is not fully used to transmit renewables power. There is a tendency to go towards developing wind much more as a distributed resource in different parts of the country.

e) Target of integrating **210GW wind power by 2020**, which is necessary to fulfil the 2030 carbon reduction obligations.

Yu Guiyong does not think that a reduction of subsidies will affect the ability of large-scale deployment. Investor confidence will be affected to some extent, but as the Chinese government is very determined about its targets, he does not foresee renewables development to slow down.

4.2 China's clean energy investment

At Bloomberg New Energy Finance, Senior Analyst Zhou Yi Yi briefed the delegation on the following:

Investment trends

In 2017, the global total investment in clean energy was at 333 billion US dollar, which is an increase of three per cent versus 2016. Historically, 2017 was the second highest investment year with 2015 being the highest at 360 billion US dollar. While a three per cent increase might appear rather moderate, the huge drop of the costs for wind power needs to be considered, which means that the number of installed turbines has increased much more.

Over 50 per cent of the 2017 investment in PV and wind - the two technologies with the highest investments - come from China. This means that Chinese investment reached a historical high, while clean energy investment figures in Europe are shrinking and have become rather flat in the US.

Challenges

A comparison of wind curtailment rates between different countries shows that the wasted energy in China is massive:

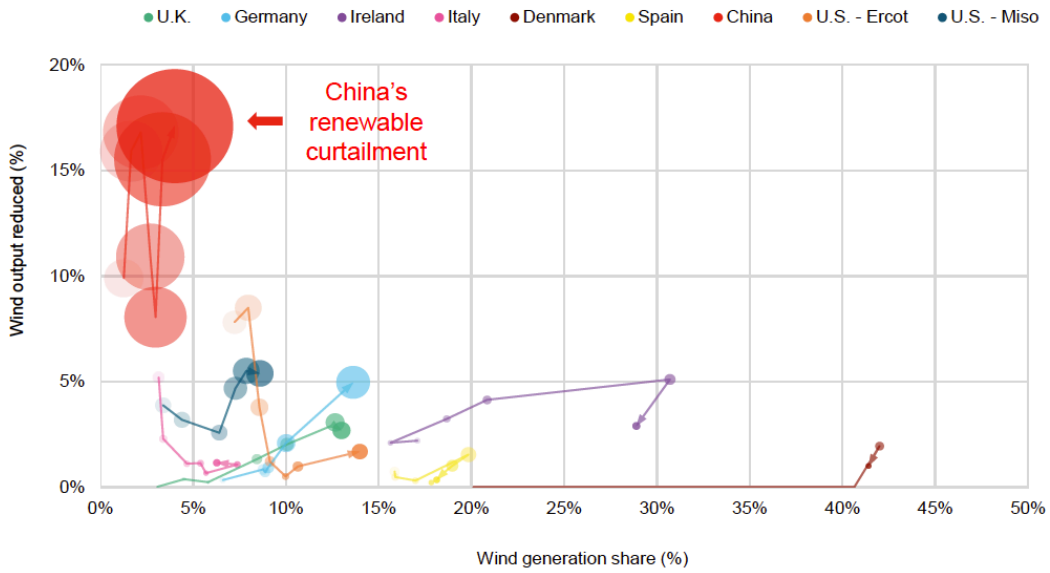


Figure 6: China is seeing significant renewable curtailment; Source: Bloomberg New Energy Finance

Chinese wind developers do not receive any compensation for curtailed power, which means that they have to cover for their own losses. Since curtailment differs from region to region and is highest in the Northwest, a big part of the solution lies in a different location for new investments.

Around 400 billion Renminbi (53 billion Euro) have been invested in ultra-high voltage transmission lines. By the end of 2014, 14 lines had been built. Two more lines are currently under construction. By 2019, the capacity will add up to 100GW. Transmission capacity is therefore no longer the problem – provided it is being utilised properly.

While over many years, energy demand has increased substantially, since 2015, the increase was only about 0.5 per cent. Meanwhile, installed capacity has increased a lot. As a consequence, there is now an over-supply of installed capacity of 35 per cent across the entire country. This means that curtailment will remain a serious problem and the new ultra-high voltage grid capacities will not be fully used.

The system for dispatching power is a further problem. While in many countries, power is dispatched following the rules of a liberalised market and the margin costs for wind and solar, China is still using a pre-allocation mechanism combined with direct participation in the market. This means that there is a pre-allocated ratio that secures usage of electricity from thermal power plants. In addition, when wind and solar are traded in the market, the bidding prices are lower than the feed-in tariff, meaning that wind and PV are not fully traded. The transfer from this pre-allocated to a more liberalised market is ongoing.

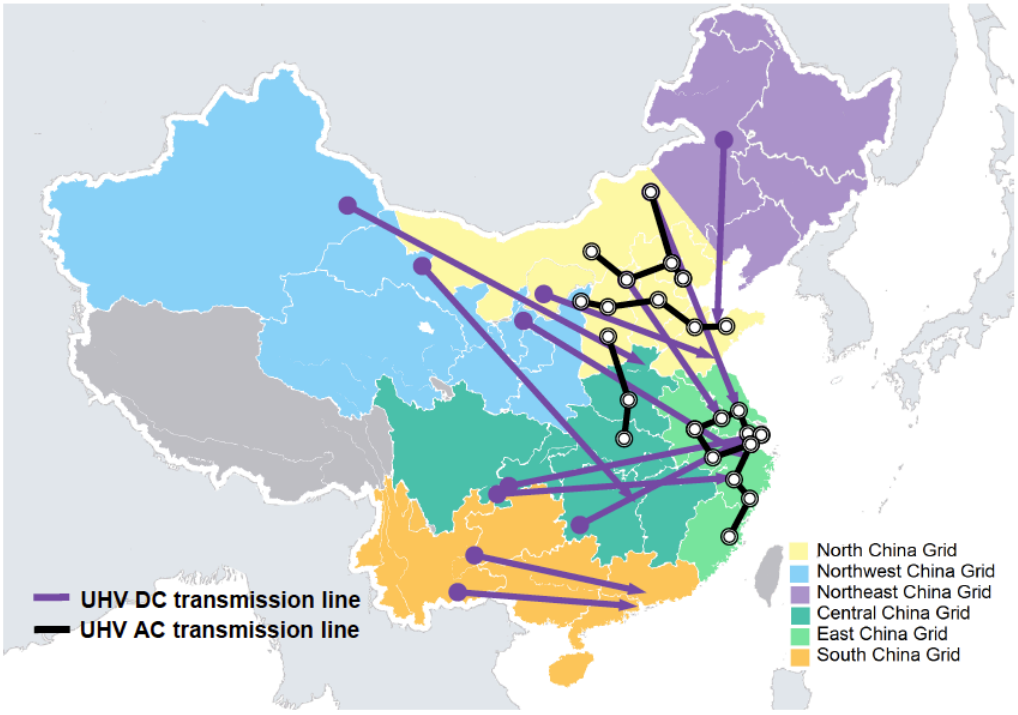


Figure 7: China's commissioned UHV transmission; Source: Bloomberg New Energy Finance

The energy mix itself is another cause for curtailment: China is rich on coal resources, but coal and thermal generation lack flexibility, so they are not suitable to regulate peaks. So far, no ancillary services market has been established and utilities are not interested in taking part in peak regulation. This lack of flexibility is not only an issue in the North where generation capacities are located, but also in the South where over-generation, the lack of a fully established power market and the lack of flexibility of the power system impact renewables consumption.

4.3 The role of storage in China

YU Zhenhua, Chairman of the China Energy Storage Alliance (CNESA) talked about the role of storage in China. Its role for the integration of wind and solar, in providing ancillary services, for the energy internet, and for multi-energy systems will increase with the further development of RES in the coming years.

The following developments can currently be observed:

a) Expansion of scales of projects, an increasing focus on technology roadmaps and the broadening of applications to new fields (such as ancillary services)

b) The development focuses on profitable and replicable popularisation models

c) Parallel promotion of market development and the creation of market and price mechanisms which provide market opportunities for storage

d) Domestic and international financial investments for technological research and project financing

e) Beginnings of standardisation for energy storage technology and projects

Chinese storage technologies focus on compressed air, lithium-ion batteries and supercapacitors. The speed of the cost reduction is significant: for example, in 2013 a subsidies programme for electric vehicles was initiated, which led to a price drop by 50 per cent within three years.

Pilot projects play an important role, but their focus has shifted in recent years: the first ones were established in 2011 and aimed at learning about technology; after 2013, matters of commercial exploration played an increasing role. Commercial projects include energy storage participating in frequency regulation, in large-scale peak shaving, and in PV and energy storage solutions as part of distributed power systems.

Both global and Chinese storage is still dominated by pumped hydro (97 and 99 per cent respectively). However, the growth of electrochemical storage is significant, albeit from a low level: an increase of 50 per cent between 2000 and 2016 globally, and of 72 per cent in China. China's total operational energy storage capacity reached 24.3GW by the end of 2016.

A set of policies drives the development of China's energy storage industry: policies which confirm electrical storage identity, support technological development, to implement regional pilot programmes and promote multi-dimensional pilot projects. The 13th Five-Year Plan of the Chinese government focused on initial commercialisation to promote energy storage technology and industry development, while the 14th Five-Year Plan sets a focus on large-scale development.

Significant growth is foreseen in all different technologies. Pumped hydro is predicted to grow to 40GW by 2020; compressed airs from 1000 to 15,000MW, molten salt from 1000MW to 1.8GW and electrochemical storage from 0.24 to 2.02GW.

4.4 Grid-interactive mode and value in energy storage of EV

Dr. Liu Jian of the Energy Research Institute National Development and Reform Commission (ERI) gave a presentation about electric vehicles (EVs) and their storage potential.

The size of the Chinese electric vehicle market is four times that of the US. It takes up 55 per cent of the global market, making China the global market leader. While the EV industry has been developing very fast, the electricity mix remains a problem, as most electricity comes from coal. This means that EVs are actually contributing to pollution and the development of clean vehicles needs to go hand in hand with the development of clean energy.

EVs have good credentials for energy storage as they can be a new type of load which is much more flexible than traditional load. They can be charged flexibly and used as distributed storage facilities.

China has no distinct roadmap about when fossil fuel-based vehicles shall be phased out, but some predictions can be made. To phase out by 2030, 50 per cent of the market should be EVs in 2024, to phase out by 2040, 50 per cent market penetration would be needed by 2028 and to phase out by 2050, 50 per cent need to be achieved by 2032. This means that there will be 500 million EVs driving on Chinese roads latest by 2050.

EV charging can be used as a demand side response facility or a static energy storage system. With 500 million EVs, energy storage capacity will amount to 5,0000 GWh (incl. pumped hydro potential).

While the theoretical potential for energy storage is massive, it is evident that regulations need to be set to influence the parking and charging behaviour and thereby reduce morning and evening peaks. Done well, EVs can serve as peak load shaving capacities to avoid charging ‘rush-hours’ in the evening and shift this load late into the night. This would help to reduce the output of thermal power plants and could also contribute to reducing the curtailment problem.

The introduction of time-of-use tariffs will play an important role in establishing EVs. Other policies will have to come on top that to allow that the frequency of charging becomes more flexible and better responses to supply and demand are possible.

5 Day four: site visit and State Grid Cooperation of China

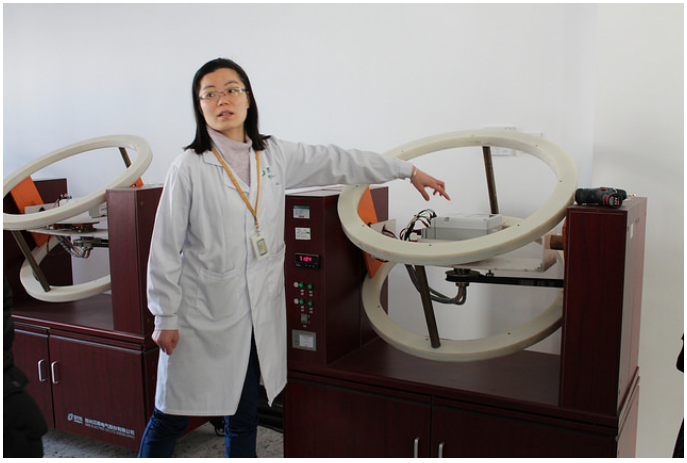
The fourth day of the tour was spent at the China Electric Power Research Institute (CEPRI) where the delegation visited several units:

At the **State Grid Centre of Metrology**, the process of testing metering devices and terminals was presented. Tests include the environmental performance (e.g. behaviour in humid conditions, fire resistance), communication performance (reliability of communication), and the installation and calibration of devices. Overall, the tests take about three to six months and include 7,000 metering devices per year. Within the area covered by SGCC, more than 450 million metres have been deployed which equals a coverage of over 99 per cent.

Digital-analogue-hybrid simulation laboratory

SGCC envisages to operate 31 HVDC lines by 2020. This simulation laboratory helps to better understand how AC and DC will influence each other in the future system. The current maximum size of a system is 12GW. A 3,000km and 11,000kV DC line is currently under construction. The strongest AC lines will likely amount to about half of this size. The simulation laboratory investigates completely independently of the control centre.

Super-computer centre



This centre was built in December 2016 and is described as most advanced in modelling power systems worldwide. All software is developed by the centre itself. It provides support for the SGCC dispatching centre by calculating suitable operation modes. The centre operates with a closed network only for SGCC, but can be sold to other countries (e.g. REN in Portugal works with it as well). 810 servers are able to run more than 900 trillion calculations and parallel computing of millions of tasks are possible as the servers are connected via a fibre network that allows to process 1GB/second.

Numerical weather prediction centre

This centre was founded in 2006 and has been growing in parallel to the increased deployment of wind and PV. It looks into

- meteorology forecasts to improve prediction of RES generation and their implications for the grid
- meteorological and natural disasters (e.g. risk to transmission lines from thunder, heavy rain or floods)
- the manifold fundamental processes of the grid which are impacted by meteorology (e.g. load temperature relation)

The centre receives its input data from sea, satellites, radars and surface-based sensors. Forecasts are being run four times a day. It provides information to 23 regional centres which do forecasts for up to three days ahead.

SGCC UHV DC&AC test yard, Changping

The Changping test base is one of four test facilities that SGCC has established to conduct research on hundreds of different items related to the deployment of ultra high-voltage DC and AC. It comprises a variety of different test sites, including:

- UHV DC test line section – an UHV DC ±1200kV double circuit line of 1080 metres of length, mainly used to examine the electromagnetic environment of EHV/UHV DC transmission lines
- Corona cage – sized 70m*22m*13m, used to perform corona tests of various bundle conductors of ±800kv monopolar or bipolar transmission lines.
- Outdoor test site – sized 180*90m, including a 7.2MV outdoor impulse voltage generator, a ±1600kV DC voltage generator, a gantry sized 50*60m and two tension anchor towers.
- Pollution and environment laboratory – a metallic canned chamber of 20m diameter and 25m height to perform DC 1100kV and AC 1000kV pollution, ice covering and rain spray tests of long string insulators etc.
- Insulator laboratory focusing on electrical and mechanical property tests of insulators and bushings of various materials and types used in the UHV DC transmission projects.

6 Day five: NGO perspective and smart systems

6.1 A visit to greenpeace China

The morning of the final day in China was spent at greenpeace China, where the delegation talked to a number of representatives.

Since greenpeace is not allowed to raise funds in China, the Beijing office is maintained by the offices in Taiwan, HongKong and South Korea. The focus of their work has just been restructured to fit into the context of a global vision for climate

change counteraction and the ambition to stay within 1,5° of global warming. Their focus areas are:

a) Counterresistance: dealing with resistance that is trying to slow down the pace of the energy transition

b) Accelaration of change: supporting the introduction of new players that commit to climate targets, new business models which play a disruptive role

c) Quality of life: responding to the desire of a large and emerging middle class that wishes to have a high quality of life, increase their awareness and willingness to engage

d) Global assertiveness of China: building upon China's wish to take a larger role in environmental protection and the climate arena

6.1.1 Coal in China and what is behind it

Coal continues to be the biggest energy source in China, but is in decline since 2011. The 2020 target for coal is to contribute less than 58 per cent (compared to 70 per cent in 2011), RES more than 15 per cent. Figures of 2017 assume that these targets will be surpassed. Absolute coal consumption peaked in 2013. The decrease since then is driven by 1) successfully delinking coal and consumption/growth; 2) introduction of energy efficiency measures; 3) economic restructuring (growing importance of the service sector) and 4) the Chinese energy transition.

In 2016, China started to tackle overcapacity in coal mining. During the next three to five years, 500 million tons of coals shall be phased out and 500 million tons shall be consolidated. Furthermore, for the next three years, no new permits for coal mines shall be granted. By the end of 2016, coal-fired power plants (CFPP) with a capacity of **940GW**were operating in China, **310GW** were under construction or in planning.

Over 120 GW were either cancelled or shelved in a series of policies aiming at tackling coal power overcapacity in 2016. CFPP will be capped below **1100GW** in 2020.

A war on air pollution, which coal is a major contributor to, is going on ever since 2012, meters stopped measuring because the pollution values had grown too high. This let to the development of an air pollution prevention control plan in 2013, targeting major economic regions. The introduced measures include substituting coal with gas or RES for heating or electricity, raising standards for industry and ordering coal-fired plants need to reach an ultra-low emission standard. The Eastern areas of the country need to finalise the implementation of the measures before 2018, the whole of China by 2020. This switch is supported via subsidies and educational plans on how to save energy. Implementation problems include the shut-down of many small factories and households being cut of from proper power supply.

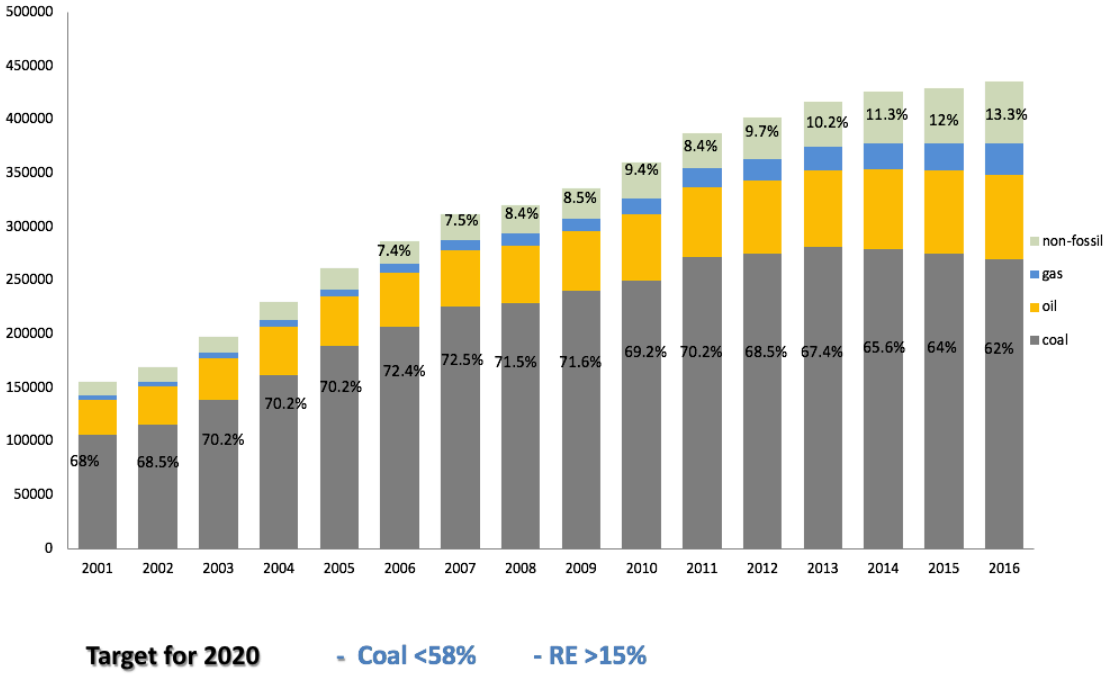
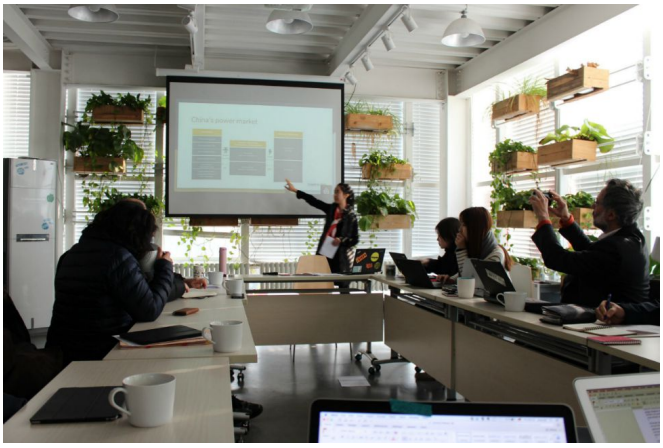


Figure 8: China's energy structure 2001-2016; Source: greenpeace

6.1.2 Booming renewables – current situation and discursive dynamics

The development of renewables in China is going fast, but not fast enough – while there is a large amount of new installation, RES provide for a small proportion of generation with a high curtailment rate. In 2017, 15.03 GW of wind were newly installed, this leads to an accumulative installation 164 GW (an increase of 10.33 per cent). Generation amounts to 305.7 TWh, an increase by 26.3 per cent. New installations increasingly take place in the central East and South (50 per cent) to optimise allocation capacity and lower prices in some regions of the country.



Solar installation and generation has developed very positively as well. From zero in 2010, there are now about 130GW of installed solar capacity which contribute 118TWh of electricity.

In 2017 wind curtailment declined by 7.8 TWh compared to 2016. The curtailment rate fell by 5.2 per cent compared to 2016. Several regions – especially in the northeast have witnessed a much better situation while others still face a severe situation with above 20 per cent of curtailment

The solar curtailment rate in 2017 also dropped by 4.3 per cent, but Xinjiang and Gansu provinces are still above 20 per cent. There are signs of new curtailment in central regions.

Reasons for the decrease in curtailment are an increase of the electricity demand in 2017 and stricter regulations which reduced investment in the affected regions. The situation is envisaged to improve even more, thanks to better quota systems and the introduction of green certificates, cross-regional dispatch and trade, the implementation of a power market and the intention to use more coal power for peak load operation.

greenpeace China observes that many policies and technologies to strengthen RES are already there but need to be implemented better.

6.1.3 Corporate RES procurement 101

Globally, it is it is corporate power purchase agreements, that drive the demand for renewables. However, compared to others, China's power sector and market are very weak and dominated by a small number of generators and two transmission system operators (State Grid China Corporation and China Southern Power Grid (CSG)) and their local subsidiaries.

The Chinese government is now trying to liberalise the power market and to make it more efficient. The most recent idea is to decouple transmission and distribution system operators from retail, allowing private companies to enter distribution and generation. In 2015, 14 per cent of wind and 30 per cent of solar capacity were installed by private enterprises. Going into distribution means the incremental distribution, so the new investors build new infrastructure. SGCC is not obliged to give up parts of their distribution grid.

China has a feed-in-tariff (FIT) for renewables. Because of the fast development, there is a subsidy delay of a couple of months up to three years and the subsidy gap is calculated to be 100bn Yuan. As for the wholesale price, there is a pre-set catalogue price for RES determined by the government. The FIT comes on top of this and is paid into a fund. It is part of the electricity bill. Generally, electricity in China is cheap for households, so an ongoing discussion is which other sources of revenues could be taken for this fund, so as not to further increase the electricity price.

In addition, there is an interprovincial spot market for incremental RES which relies fully on governmental planning. This includes rules for mid- and long-term transactions. However, the market is small and dominated by thermal power.

There are also first pilots for distributed power markets, meaning that if you have a distributed solar plant, you can sell directly to your neighbours needing less money from the fund.

6.1.4 Green financing

The Chinese financial system is dominated by bank loans. 2013 was the worst year for Beijing with regards to air pollution. To deal with this and get hold of money to

fund the energy transition a volume of 290bn dollars in green bonds was issued and purchased to a large extend by the private sector. In 2014/2015, there was a collaboration with the UK government to put green finance standards at the highest level. A legislative process from 2013 to 2015 determined standards of green bonds, which sectors could issue them, and how verification, reporting and auditing should function.

In 2016, 40 per cent of the global total volume in green bonds was issued in China, in 2017 this had decreased to 30 per cent. Green finance today also covers green insurances and green credits. The divestment movement which is becoming increasingly more common in the Western world has not arrived in China yet, but there are first indications that this may change.

Standards of green bonds are more and more harmonised with international standards, reducing the phenomenon of greenwashing that also comes hand in hand with green bonds. Nonetheless, more work needs to be done to increase the quality and consistency of this. Fiscal incentives to issue green bonds are not very high, but there is a strong reputational driver behind this and the market increasingly requests green bonds.

6.2 Expert roundtable on electricity market reform in China

This roundtable discussion was joined by representatives of the German Corporation for International Cooperation and the Electric Power Planning & Engineering Institute (EPPEI). It took place at EPPEI's office.

EPPEI was funded in 1954 and is since then in charge of power planning and policy planning. It provides consultancy services both to the Chinese government and

power companies. The institute's Deputy Director of Power System Planning and Research, Mr. Han Xiaoqi, provided a brief introduction to China's electricity market and the new power market reform.

Aside from consumption, numbers, the generation mix and the FIT, Han presented the six regional grids that have been established in China which are mainly interconnected through HVDC lines.

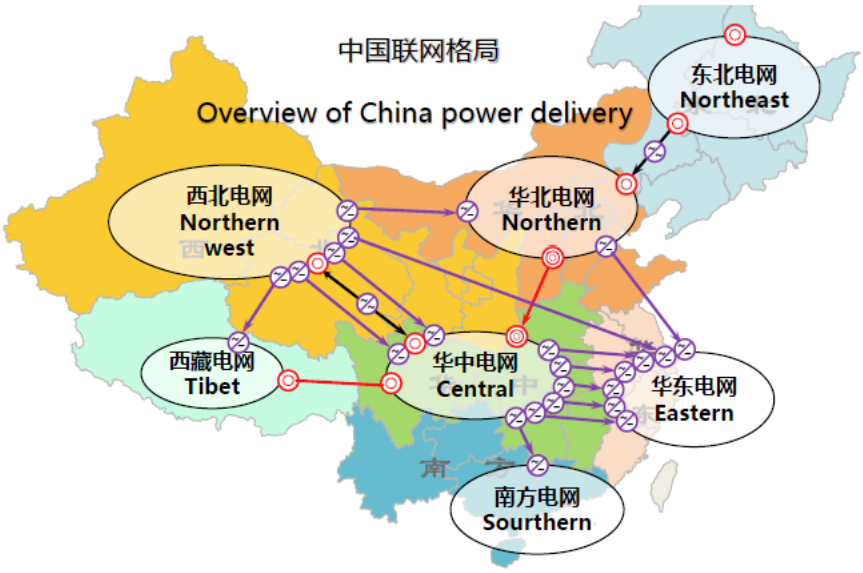


Figure 9: Power transmission in China is operated via six main regional grids

Since 2000, two rounds of institutional reforms have taken place, including the unbundling of vertically integrated industry in 2003. A new round of institutional reforms focuses on the establishment of spot markets. Eight provinces are formulating spot market rules.

Production: Five power generation corporates were established to encourage competition and to initiate a market-based reform of power generation that allows for private investments.

Planning and design: Two engineering corporates were established, focusing on planning, designing, construction and manufacturing.

As mentioned above, two grid companies (State Grid China Cooperation and China Southern Power Grid) remain responsible for **transmission, distribution, retail** and **system operation**. In addition, there is an independent 'Inner Mongolia' grid company.

Grid companies are currently the single buyer and seller in the market. They purchase at benchmark-prices which are approved by the government, consumers buy electricity according to catalogue prices which are also approved by the government.

Further reforms took place in 2014. Production is being further deregulated and liberalised. Transmission and distribution are separated from retail, while retail itself is also being deregulated and liberalised. Additional plans focused on the

establishment of power exchanges which are relatively independent from both grid companies and system operation. At the same time, monitoring, planning, efficiency and reliability should be further strengthened.

As of now, 35 power exchanges have been established, nine of these are joint stock companies. Furthermore, transmission and distribution tariffs/fees have been calculated and approved in each province. Simultaneously, calculation of grid fees for cross-province trading is ongoing. These fees are calculated based on a postage stamp method so that consumers are charged based on the voltage level they connect to. In 2017, the volume of electricity traded on the market was about 1600TWH. This is 25 per cent of the total electricity consumption (up from 19 per cent in 2016). More than 2600 retailing companies have formally registered in the new power exchanges.

7 List of abbreviations

AC	alternating current
CEPRI	China Electric Power Research Institute
CNESA	China Energy Storage Alliance
CHP	combined heat and power
CO2	carbon dioxide
CSG	China Southern Power Grid
CWEA	Chinese Wind Energy Association
DC	direct current
EPPEI	Electric Power Planning & Engineering Institute
ERI	Energy Research Institute National Development and Reform Commission
ERIT	'Energy Regions in Transition'
EV	electric vehicles
FACTS	flexible alternating current transmission systems
FIT	feed-in-tariff
GDP	gross domestic product
GEIDCO	Global Energy Interconnection Development and Cooperation Organization
GW	gigawatt
HVDC	high voltage direct current
km	kilometres
kV	kilovolt
PV	photovoltaic
R&D	research and development
RES	renewable energy sources
RGI	Renewables Grid Initiative
SGCC	State Grid Corporation of China
TWh	terawatt hours
UHV	ultra-high voltage
UHVAC	ultra-high voltage alternating current
VSC	voltage sourced converter